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Bank Market Power and the Risk Channel of Monetary Policy[☆]

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Abstract

This paper investigates the risk channel of monetary policy through banks' lending standards. We modify the classic costly state verification (CSV) problem by introducing a risk-neutral monopolistic bank, which maximizes profits subject to borrower participation. While the bank can diversify idiosyncratic default risk, it bears the aggregate risk. We show that, in partial equilibrium, the bank prefers a higher leverage ratio of borrowers, when the profitability of lending increases, e.g. after a monetary expansion. This risk channel persists when we embed our contract in a standard New Keynesian DSGE model. Using a factor-augmented vector autoregression (FAVAR) approach, we find that the model-implied impulse responses to a monetary policy shock replicate their empirical counterparts.

Keywords: Costly state verification, Credit supply, Lending standards, Monetary policy, Risk channel

JEL classification: D53, E44, E52

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1. Introduction

One of the narrative explanations of the credit boom preceding the recent financial crisis and the Great Recession is that financial intermediaries took excessive risks because monetary policy rates had been "too low for too long" (compare Taylor, 2007). On the one hand, loose monetary policy lowers the wholesale funding costs of banks and other financial intermediaries, incentivizing higher leverage and thus risk on the liability side of their balance sheets. On the other hand, low policy interest rates might also induce banks to lower their lending standards, i.e. to grant more *and* riskier loans. While risk taking on the liability side has received a lot of attention in the recent macroeconomic literature (see, e.g., Gertler and Karadi, 2011; Gertler et al., 2012), much fewer studies have so far addressed the aggregate implications of a risk channel of monetary policy on the asset side. The present paper aims at closing this gap by focusing on the *ex-ante* risk attitude of banks. We develop a general equilibrium model, where the financial intermediary determines lending standards by choosing how much to lend against a given amount of borrower collateral. Testing our theoretical predictions empirically, we find robust evidence for an asset-side risk channel of monetary policy in the U.S. banking sector, consistent with the model.

In this paper, we provide a microeconomic foundation for banks' decision to lower their "lending standards" in response to a monetary expansion. To this end, we reformulate the costly state verification (CSV) contract in Townsend (1979) and Gale and Hellwig (1985) in order to allow for a nontrivial role of financial intermediaries. The CSV contract provides a natural starting point, given that its parties determine both the *quantity* of credit (via the amount lent) and the *quality* of credit (via the borrower's ex-ante implied default risk). However, in conventional implementations of the contract in models of the financial accelerator, such as Bernanke et al. (1999), financial intermediaries are passive and do not bear any risk.

We depart from these assumptions and introduce a monopolistic bank that chooses its lending standards. The resulting contract is incentive-compatible, robust to ex-post renegotiations, and resembles a standard debt contract (compare Gale and Hellwig, 1985). It also implies a unique partial equilibrium solution and the well-known positive relationship between the expected external finance premium (EFP) and the borrower's leverage ratio. Following an exogenous increase in the expected EFP, e.g. due to a monetary expansion, the monopolistic bank finds it profitable to lend more against a given amount of borrower collateral. The reason is that it benefits from the increase in borrower leverage through a larger share in total profits, while it can price in the higher default probability of the borrower through the rate of return on non-defaulting loans, thus increasing its net interest margin.

In order to quantify the effects of our partial equilibrium mechanism in response to a monetary expansion and over the business cycle, we embed our modified and the classic version of the optimal debt contract in an otherwise standard New Keynesian dynamic stochastic general equilibrium (DSGE) model. In contrast to Bernanke et al. (1999) and most of the existing literature, our model implies an *increase* in bank lending relative to borrower collateral and thus a higher leverage ratio of borrowers in response to an expansionary monetary policy shock. Over the business cycle, both models can replicate the dynamic cross-correlations of key variables with output qualitatively and quantitatively, while our model also replicates the unconditional moments of bank-related balance sheet variables that are either missing or constant in standard models of the financial accelerator.

Prior research based on microeconomic bank-level data (Jiménez et al., 2014; Ioannidou et al., 2015) has shown that lower overnight interest rates might induce banks to commit larger loan volumes with fewer collateral requirement to ex-ante riskier firms. Similarly, Paligorova and Santos (2017) use bank-loan data and find compelling evidence in favor of the risk-taking channel of monetary policy in the U.S. For macroeconomic time series, the results in the literature are rather ambiguous (see, e.g., Buch et al., 2014). The use of aggregated data in this context is complicated by the limited availability of suitable measures of banks' risk appetite and a comparatively short sample period. On the one hand, econometric models with an excessive number of parameters are thus prone to overfitting. On the other hand, small-scale VAR models might contain *insufficient information* to identify the structural shocks of interest (compare Forni and Gambetti, 2014). To address these issues, we adopt the factor-augmented vector autoregression (FAVAR) approach proposed by Bernanke et al. (2005), which allows us to parsimoniously extract information from a large set of macroeconomic time series, thereby mitigating both the concern of overfitting and the concern of informational sufficiency.

To capture the credit-risk attitude of banks, we use the quantified qualitative measures from the Federal Reserve's Senior Loan Officer Opinion Survey on Bank Lending Practices (SLOOS)[1], which reflect changes in lending standards of large domestic as well as U.S. branches and agencies of foreign banks at a quarterly frequency, starting in 1991Q1. In contrast to the prior empirical literature, we consider 19 different measures of lending standards, such as the net percentage of banks *increasing collateral requirements* or *tightening*

[1]These data are publicly available at https://www.federalreserve.gov/data/sloos/sloos.htm.

loan covenants for various categories of loans, borrowers and banks, in order to capture the comovement in the underlying time series. Based on Bernanke et al.'s (2005) one-step Bayesian estimation approach by Gibbs sampling with recursive identification of monetary policy shocks, we find that all 19 SLOOS measures of lending standards decrease in response to a monetary expansion. This loosening of lending standards is accompanied by an increase in loan riskiness[2], the net interest margin and bank profits from the so-called Call Reports that is qualitatively and quantitatively in line with our theoretical predictions.

Our empirical findings are qualitatively robust to variations in the FAVAR specification and alternative identification strategies. In light of recent evidence that U.S. monetary policy became more forward-looking during our sample period, we include variables from the Fed's Greenbook in the FAVAR observation equation. Among further robustness checks, we adopt the high-frequency identification approach in Barakchian and Crowe (2013), which does not rely on a VAR specification.

We finally find that our results carry over to alternative measures of financial intermediaries' risk appetite. In particular, we show that Bassett et al.'s (2014) measure of the supply component of bank lending standards decreases, while the net percentage of domestic banks easing lending standards due to *higher risk tolerance* increases in response to a monetary expansion. Moreover, two market-based measures of lending standards – Gilchrist and Zakrajšek's (2012) "excess bond premium" and the Chicago Fed's National Financial Conditions credit subindex – decrease significantly after an expansionary monetary policy shock.

The remainder of our paper is organized as follows. Section 2 derives the optimal financial contract and discusses the risk channel in partial equilibrium. In Section 3, we embed this contract in a quantitative New Keynesian DSGE model. Section 4 sketches our econometric approach and presents new empirical evidence of an asset-side risk channel of monetary policy in the U.S. banking sector. Section 5 concludes.

2. The Optimal Debt Contract in Partial Equilibrium

In this section, we show that it can be optimal for a lender to increase the amount of credit per unit of borrower collateral in response to expansionary monetary policy, even if this raises the default probability of a given borrower and the default rate across borrowers. In other words, the lender lowers its credit standards. To this end, we draw on a problem of the type analyzed in Townsend (1979) and Gale and Hellwig (1985), and embedded in a New Keynesian DSGE model by Bernanke et al. (1999). The CSV contract accounts for

[2]Loan riskiness is measured as an average risk score from the Terms of Business Lending Survey of the Federal Reserve.

both dimensions of a credit expansion: (i) the quantity of credit, i.e. the amount lent, and (ii) the quality of credit, i.e. the expected default threshold of the borrower that a bank is willing to tolerate. It provides thus a micro-foundation for banks' optimal decision on lending standards during a credit expansion.

In contrast to Bernanke et al. (1999) and most recent contributions, we formulate the optimal financial contract from the lender's perspective.[3] In particular, we assume that a risk-neutral bank decides how much to lend against a given amount of borrower collateral. Accordingly, the bank determines the entrepreneur's total capital expenditure and expected default threshold. Note that introducing an active financial intermediary is a prerequisite for analyzing the effect of monetary policy on bank lending standards. In our model, the latter are endogenously determined through the bank's constrained profit-maximization problem.

We further assume that market power in the credit market is in the hands of the bank, which makes a "take-it-or-leave-it" loan offer to borrowers, similar to that in Valencia (2014). In order for a firm to accept this offer, it must be at least as well off with as without the loan. While representing one of many conceivable profit-sharing agreements, this can be motivated by the prevalence of relationship lending between banks and small or medium-sized enterprises.[4] In what follows, we specify the details of the optimal loan contract in partial equilibrium. Assuming that each entrepreneur borrows from at most one bank, the latter can enter a contract with one entrepreneur independently of its relations with others, and we can consider a representative bank-entrepreneur pairing (compare Gale and Hellwig, 1985).

2.1. The Contracting Problem

Suppose that, at time t, entrepreneur i purchases capital $Q_t K_t^i$ for use at $t+1$, where K_t^i is the quantity of capital purchased and Q_t is the price of one unit of capital in period t. The gross return per unit of capital expenditure by entrepreneur i, $\omega_{t+1}^i R_{t+1}^k$, depends on the ex-post aggregate return on capital, R_{t+1}^k, and an idiosyncratic component, ω_{t+1}^i. Following Bernanke et al. (1999), the random variable $\omega_{t+1}^i \in [0, \infty)$ is i.i.d. across entrepreneurs i and time t, with a continuous and differentiable cumulative distribution function $F(\omega)$ and an expected value of unity.

[3]Recall that, in Bernanke et al. (1999), there is no active role for the so-called "financial intermediary", which merely diversifies away the idiosyncratic productivity risks of entrepreneurs and institutionalizes the participation constraint of a risk-averse depositor, along which the firm moves when making its optimal capital and borrowing decision.

[4]For example, Petersen and Rajan (1995) use a simple dynamic setting to show that the value of lending relationships decreases in the degree of competition in credit markets. The reason is that a monopolist lender can postpone interest payments in order to extract future rents from the borrowing firm, effectively "subsidizing the firm when young or distressed and extracting rents later" (Petersen and Rajan, 1995, p.408). A similar argument applies for the monopolist bank in our model, which can fully diversify the idiosyncratic productivity risks by lending to the entire cross section of firms.

Entrepreneur i finances capital purchases at the end of period t using accumulated net worth, N_t^i, as well as the borrowed amount B_t^i, so that the entrepreneur's balance sheet is given by

$$Q_t K_t^i = N_t^i + B_t^i. \tag{1}$$

Abstracting from alternative investment opportunities of entrepreneurs, the maximum equity participation (MEP) condition in Gale and Hellwig (1985) is trivially satisfied.[5] As in Valencia (2014), entrepreneur i borrows the amount B_t^i from a monopolistic bank, that is endowed with end-of-period-t net worth or bank capital N_t^b and raises deposits D_t from households. Defining *aggregate* lending to borrowers as $B_t \equiv \int_0^1 B_t^i di$, the bank's aggregate balance sheet identity in period t is given by

$$B_t \equiv N_t^b + D_t. \tag{2}$$

The need for borrower collateral arises from the presence of a state-verification cost paid by the lender in order to observe entrepreneur i's realization of ω_{t+1}^i, which is private information. We assume that this cost corresponds to a fixed proportion $\mu \in (0, 1]$ of the entrepreneur's total return on capital in period $t+1$, $\omega_{t+1}^i R_{t+1}^k Q_t K_t^i$, so that initially uninformed agents may become informed by paying a fee which depends on the invested amount and the state (compare Townsend, 1979).

Both the borrower and the lender are *risk-neutral* and care about expected returns only, whereas depositors are *risk-averse*. Accordingly, the bank promises to pay the risk-free gross rate of return R_t^n on deposits in each aggregate state of the world, as characterized by the realization of R_{t+1}^k.

Let Z_t^i denote the gross non-default rate of return on the period-t loan to entrepreneur i. Given R_{t+1}^k, $Q_t K_t^i$, and N_t^i, the financial contract defines a relationship between Z_t^i and an ex-post cutoff value

$$\bar{\omega}_{t+1}^i \equiv \frac{Z_t^i B_t^i}{R_{t+1}^k Q_t K_t^i}, \tag{3}$$

such that the borrower pays the lender the fixed amount $\bar{\omega}_{t+1}^i R_{t+1}^k Q_t K_t^i$ and keeps the residual $\left(\omega_{t+1}^i - \bar{\omega}_{t+1}^i\right) \cdot R_{t+1}^k Q_t K_t^i$ if $\omega_{t+1}^i \geq \bar{\omega}_{t+1}^i$. If $\omega_{t+1}^i < \bar{\omega}_{t+1}^i$, the lender monitors the borrower, incurs the CSV cost, and extracts the remainder $(1-\mu)\,\omega_{t+1}^i R_{t+1}^k Q_t K_t^i$, while the entrepreneur defaults and receives nothing.

In contrast to Bernanke et al. (1999), we assume that the lender determines the amount of credit to entrepreneur i, B_t^i, for a given amount of borrower collateral, N_t^i. Yet, the entrepreneur will only accept the

[5] Proposition 2 in Gale and Hellwig (1985) states that any optimal contract is weakly dominated by a contract with MEP, where the firm puts all of its own liquid assets – here N_t^i – on the table.

bank's loan offer if the corresponding expected return is at least as large as in "financial autarky", without the bank loan:

$$E_t\left\{\int_{\bar{\omega}^i_{t+1}}^{\infty}\left(\omega-\bar{\omega}^i_{t+1}\right)R^k_{t+1}Q_tK^i_t dF(\omega)\right\}\geq E_t\left\{\int_0^{\infty}\omega R^k_{t+1}N^i_t dF(\omega)\right\}=E_tR^k_{t+1}N^i_t, \tag{4}$$

where the last equality uses the assumption that $\int_0^{\infty}\omega dF(\omega)=E(\omega)=1$. Hence, the bank must promise the borrower an expected return no smaller than the expected return from investing her own net worth, N^i_t, which implies that investment opportunities are continuous and do *not* have a minimum size.

The bank's expected gross return on a loan to entrepreneur i can be written as

$$E_t\left\{\bar{\omega}^i_{t+1}\left[1-F\left(\bar{\omega}^i_{t+1}\right)\right]+(1-\mu)\int_0^{\bar{\omega}^i_{t+1}}\omega dF(\omega)\right\}R^k_{t+1}Q_tK^i_t.$$

Given that the bank pays the risk-free rate of return, R^n_t, on deposits, while we assume that no costs accrue on its own net worth, N^b_t, the bank's aggregate funding costs equal $R^n_tD_t=R^n_t\left(B_t-N^b_t\right)=R^n_t\left(Q_tK_t-N_t-N^b_t\right)$. Suppose that the bank assigns $N^{b,i}_t$ of its total net worth, N^b_t, to the loan to entrepreneur i.[6] Then the bank's constrained profit maximization problem for a loan to entrepreneur i is given by

$$\begin{aligned}\max_{K^i_t,\bar{\omega}^i_{t+1}}\quad & E_t\left\{\bar{\omega}^i_{t+1}\left[1-F\left(\bar{\omega}^i_{t+1}\right)\right]+(1-\mu)\int_0^{\bar{\omega}^i_{t+1}}\omega dF(\omega)\right\}R^k_{t+1}Q_tK^i_t-R^n_t\left(Q_tK^i_t-N^i_t-N^{b,i}_t\right), \qquad (5)\\ \text{s. t.}\quad & E_t\left\{\int_{\bar{\omega}^i_{t+1}}^{\infty}\left(\omega-\bar{\omega}^i_{t+1}\right)R^k_{t+1}Q_tK^i_t dF(\omega)\right\}\geq E_tR^k_{t+1}N^i_t.\end{aligned}$$

2.2. The Contract without Aggregate Risk

As a starting point, consider the case when the aggregate return on capital, R^k_{t+1}, is known in advance. As a consequence, the only risk immanent in the loan contract between the bank and entrepreneur i arises from the idiosyncratic productivity realization, ω^i_{t+1}.

Given that the non-default repayment on the loan to entrepreneur i, $Z^i_tB^i_t$, is constant across all unobserved ω-states and the CSV cost is a fixed proportion μ of the entrepreneur's total return, the financial contract is *incentive-compatible* according to Proposition 1 in Gale and Hellwig (1985). The contract without aggregate risk further resembles a *standard debt contract* (SDC), since (i) it involves a fixed repayment to the lender as long as the borrower is solvent, (ii) the borrower's inability to repay is a necessary and

[6] We only consider cases where aggregate shocks are small enough, so that the bank never defaults. As a consequence, the assignment of bank capital to a particular loan i is without loss of generality and mainly for notational consistency.

sufficient condition for bankruptcy, and (iii) if the borrower defaults, the bank recovers as much as it can.[7] Hence, the optimal contract between the bank and each entrepreneur is a SDC with MEP, as in Bernanke et al. (1999). Moreover, the optimal contract is robust to ex-post renegotiations, if μ represents a *pure verification cost* rather than a bankruptcy cost. In the latter case, it would be optimal to renegotiate the terms of the loan ex post in order to avoid default, whereas, in the former case, incentive compatibility requires monitoring the borrower whenever he or she cannot repay.[8]

For notational convenience, let

$$\Gamma\left(\bar{\omega}_t^i\right) \equiv \bar{\omega}_t^i\left[1 - F\left(\bar{\omega}_t^i\right)\right] + \int_0^{\bar{\omega}_t^i} \omega dF(\omega) \qquad \text{and} \qquad \mu G\left(\bar{\omega}_t^i\right) = \mu \int_0^{\bar{\omega}_t^i} \omega dF(\omega)$$

denote the expected share of total profits and the expected CSV costs accruing to the lender in period t, where $0 < \Gamma\left(\bar{\omega}_t^i\right) < 1$ by definition, and note that

$$\Gamma'\left(\bar{\omega}_t^i\right) = 1 - F\left(\bar{\omega}_t^i\right) > 0, \qquad \Gamma''\left(\bar{\omega}_t^i\right) = -f\left(\bar{\omega}_t^i\right) < 0, \qquad \mu G'\left(\bar{\omega}_t^i\right) \equiv \mu\bar{\omega}_t^i f\left(\bar{\omega}_t^i\right) > 0.$$

We can then write the expected share of total profits net of monitoring costs received by the lender and the expected share of total profits going to the borrower as $\Gamma\left(\bar{\omega}_t^i\right) - \mu G\left(\bar{\omega}_t^i\right)$ and $1 - \Gamma\left(\bar{\omega}_t^i\right)$, respectively.

Defining the expected *external finance premium* (EFP), $s_t \equiv R_{t+1}^k / R_t^n$, the entrepreneur's capital/net worth ratio, $k_t^i \equiv Q_t K_t^i / N_t^i$, as well as $n_t^i \equiv N_t^{b,i} / N_t^i$ and using the above notation, the bank's constrained profit maximization problem in (5) can equivalently be written as

$$\max_{k_t^i, \bar{\omega}_{t+1}^i} \quad \left[\Gamma(\bar{\omega}_{t+1}^i) - \mu G(\bar{\omega}_{t+1}^i)\right] s_t k_t^i - (k_t^i - 1 - n_t^i) \qquad \text{s. t.} \qquad \left[1 - \Gamma(\bar{\omega}_{t+1}^i)\right] s_t k_t^i = s_t, \tag{6}$$

where we have omitted the expectations operator, since R_{t+1}^k and thus s_t are assumed to be known in advance.

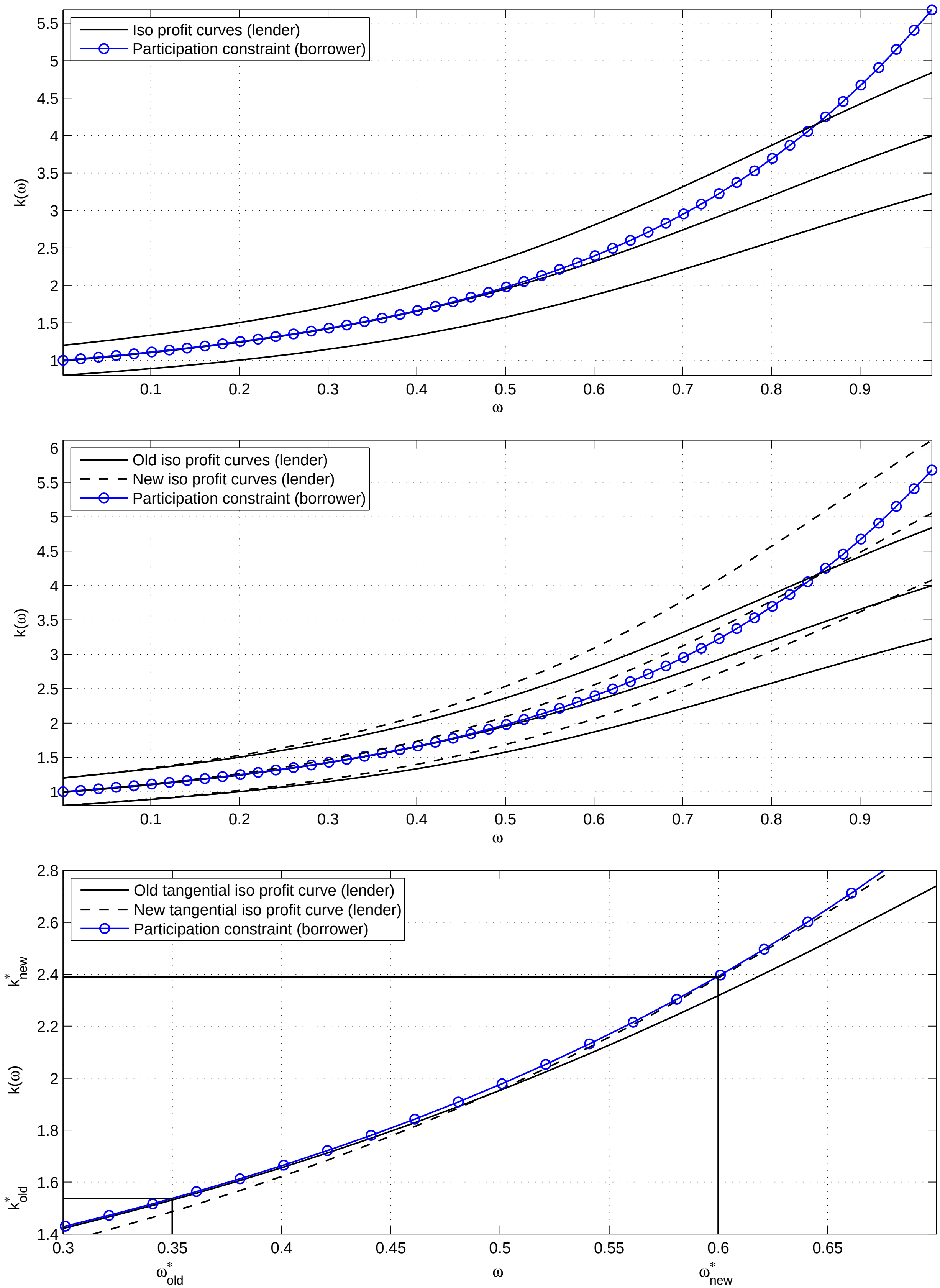
The corresponding first-order conditions with respect to k_t^i, $\bar{\omega}_{t+1}^i$, and the Lagrange multiplier λ_t^i are

$$\begin{aligned}
k_t^i : \quad & \left[\Gamma(\bar{\omega}_{t+1}^i) - \mu G(\bar{\omega}_{t+1}^i)\right] s_t - 1 + \lambda_t^i \left[1 - \Gamma(\bar{\omega}_{t+1}^i)\right] s_t = 0, \\
\bar{\omega}_{t+1}^i : \quad & \left[\Gamma'(\bar{\omega}_{t+1}^i) - \mu G'(\bar{\omega}_{t+1}^i)\right] s_t k_t^i - \lambda_t^i \Gamma'(\bar{\omega}_{t+1}^i) s_t k_t^i = 0, \\
\lambda_t^i : \quad & \left[1 - \Gamma(\bar{\omega}_{t+1}^i)\right] s_t k_t^i - s_t = 0.
\end{aligned}$$

[7] Proposition 3 in Gale and Hellwig (1985) states that any contract is weakly dominated by a SDC with the above three features.

[8] The central assumption is that the bank incurs the CSV cost in order to verify the entrepreneur's idiosyncratic realization of ω *before* agreeing to renegotiate, because the borrower cannot truthfully report default without the risk of being monitored (compare Covas and Den Haan, 2012).

Figure 1: Illustration of the Optimal CSV Contract without Aggregate Risk and the Effects of Expansionary Monetary Policy.



Proposition 1. *The optimal contract implies a positive relationship, $k_t^i = \psi(s_t)$ with $\psi'(s_t) > 0$, between the expected EFP, $s_t \equiv R_{t+1}^k / R_t^n$, and the optimal capital/net worth ratio, $k_t^i \equiv Q_t K_t^i / N_t^i$.*

Proof. See Appendix A.1. □

Accordingly, an exogenous increase in the expected EFP, for example due to a reduction in the risk-free rate, R_t^n, induces the bank to lend more against a given amount of borrower net worth and thus collateral.

2.3. The Risk Channel

The mechanism driving our partial equilibrium result is illustrated in Figure 1, where time subscripts and index superscripts are suppressed for notational convenience. Note that the lender's iso-profit curves (IPCs) and the borrower's participation constraint (PC) can be plotted in $(k, \bar{\omega})$-space and that the constrained profit maximum of the bank is determined by the tangential point between the PC and the (lowest) IPC.[9] The corresponding expressions for the borrower's PC and the lender's IPC are

$$k_{PC} \geq \frac{1}{1 - \Gamma(\bar{\omega})} \tag{7}$$

and

$$k_{IPC} = \frac{\pi^b - 1 - n}{[\Gamma(\bar{\omega}) - \mu G(\bar{\omega})]\, s - 1}, \tag{8}$$

where π^b denotes an arbitrary level of bank profits.

From (7), the PC is not affected by the EFP, s. In the absence of aggregate risk, the borrower's expected share of total profits, $1 - \Gamma(\bar{\omega})$, must be no smaller than her "skin in the game", $1/k \equiv N/QK$. For any given $\bar{\omega}$ and thus an expected share of total profits, the borrower's PC determines a minimum value of the lender's "skin in the game", k, below which the entrepreneur does not accept the offered loan contract. The bank's IPC in (8) accounts for expected monitoring and funding costs. By choosing the tangential point between the borrower's PC and its lowest IPC in $(k, \bar{\omega})$-space, the bank *minimizes* its "skin in the game" for a given expected share of total profits, $\Gamma(\bar{\omega})$. Note that, for $QK = N$, the borrower is fully self-financed, never defaults ($\bar{\omega} = 0$), and retains all the profits ($1 - \Gamma(0) = 1$).

The first panel of Figure 1 illustrates the tangential point between the borrower's PC and the lender's IPC for the calibration in Bernanke et al. (1999). Now consider the effects of a monetary expansion, i.e.

[9] Online Appendix A.1 proves that the optimal contract yields a *unique interior* solution.

a decrease in R^n and thus an increase in $s \equiv R^k/R^n$, where R^k is known in advance. While the borrower's PC remains unaffected, the lender's IPCs are tilted upwards, as shown in the second panel. Although the borrower would accept any point above its PC on the new IPC, this is no longer optimal from the lender's perspective. The bank can move to a lower IPC and thus to a higher level of profits, as indicated in the third panel. In doing so, however, it must satisfy the borrower's PC, as in the new optimal contract $(k^*_{new}, \omega^*_{new})$, where both the bank's expected profit share, $\Gamma(\bar{\omega})$, and its "skin in the game", k, have increased.

The previous discussion illustrates a crucial feature of the optimal debt contract. For a profit-maximizing bank, it is optimal to respond to an increase in the EFP (e.g. due to a monetary expansion) by lending more against a given amount of collateral, thus increasing the entrepreneur's leverage ratio. In partial equilibrium, a similar qualitative result arises from the optimal debt contract in Bernanke et al. (1999), yet for a different reason. In particular, financial intermediaries make zero profits and the *lender's PC* just equates the expected return on the loan net of monitoring costs to the risk-free rate. A monetary expansion loosens the PC and induces the entrepreneur to raise more external funds against a given amount of collateral, while the expected return to the lender *decreases*. The expansion of credit is therefore driven by a shift in demand due to the increased creditworthiness of borrowers.

In contrast, the increase in the borrower's leverage ratio in Figure 1 represents the optimal response of the bank. In our model, a monetary expansion lowers the interest rate on deposits and thus the funding cost of the lender in (5), while it does *not* affect the *borrower's PC* in (4). Ceteris paribus, the profitability of the marginal loan increases, whereas the demand for credit is unchanged. Since entrepreneurs' net worth is predetermined, the increase in lending leads to an increase in borrower leverage. From (3), the higher leverage ratio implies a higher default threshold, $\bar{\omega}$, and a higher default probability of the loan. This corresponds to the risk-taking channel of monetary policy described, for example, in Adrian and Shin (2011) and Borio and Zhu (2012). By affecting the rates of return on both sides of the bank's balance sheet, a monetary expansion raises the profitability of financial intermediaries, thus shifting the supply of credit. While moving along the borrower's PC, the bank must compensate the entrepreneur for a lower share of total profits by increasing its own "skin in the game".

2.4. The Contract with Aggregate Risk

In the dynamic model, the aggregate return on capital is *ex ante* uncertain. As a consequence, the default threshold characterizing a loan contract between the bank and entrepreneur i, $\bar{\omega}^i_{t+1}$, generally depends on the ex-post realization of R^k_{t+1}. Bernanke et al. (1999) circumvent this complication by presuming that, given the risk aversion of depositors, the lender's participation constraint must be satisfied *ex post* and the entrepreneur bears any aggregate risk. Similarly, we assume that the borrower's PC must be satisfied ex post and that the bank absorbs any aggregate risk. This assumption is only viable, if the bank's capital buffer, N^b_t, is sufficient to shield depositors from any fluctuations in R^k_{t+1}, so that the bank never defaults.[10]

In order to understand the implications of our assumption, recall the PC in equation (7). Given that the borrower's capital expenditure, $Q_t K^i_t$, and net worth, N^i_t, are predetermined in period $t+1$, the ex-post share of total profits, $1 - \Gamma\left(\bar{\omega}^i_{t+1}\right)$, and the corresponding default threshold, $\bar{\omega}^i_{t+1}$, can *not* be made contingent on the aggregate state of the economy. From the definition of the cutoff in (3), the non-default rate of return, Z^i_t, must then be state-contingent in order to offset unexpected realizations of R^k_{t+1}.

In contrast to Bernanke et al. (1999), where both $\bar{\omega}^i_{t+1}$ and Z^i_t are state-contingent and *countercyclical* (in the sense that a higher than expected realization of R^k_{t+1} lowers the default threshold and the non-default rate of return required by the lender), here $\bar{\omega}^i_{t+1}$ is predetermined and *acyclical*, while Z^i_t is *procyclical*. Higher than expected realizations of R^k_{t+1} raise Z^i_t, whereas the borrower's and the lender's expected profit shares are determined by their "skin in the game", i.e. by the relative shares of N^i_t and B^i_t in $Q_t K^i_t$. Although neither of the ex-post versions seems fully consistent with the common perception that the non-default rate of return on bank credit is predetermined and thus acyclical, the procyclicality of Z^i_t in our contract can be interpreted as the bank having a stake in the firm in terms of either equity or a long-term lending relationship. Hence, it is in the bank's interest that borrowers default only due to idiosyncratic risk, which can be diversified away, rather than due to aggregate risk. While a formal proof is beyond the scope of the current paper, Appendix A.3 provides a simple heuristical argument for the optimality of this risk-sharing agreement.

The ex-post version of our financial contract is *incentive-compatible* and resembles a *standard debt contract*, if and only if R^k_{t+1} is observed by both parties without incurring a cost (compare Gale and Hellwig, 1985).[11] Otherwise, the non-default rate of return on the loan, Z^i_t, can *not* be made contingent on the state of the economy, whereas entrepreneurs generally have no incentive to misreport a true observed state.

[10] In other words, we assume that the fluctuations in the bank's net return on lending, $\int_0^1 \left[\Gamma\left(\bar{\omega}^i_{t+1}\right) - \mu G\left(\bar{\omega}^i_{t+1}\right)\right] R^k_{t+1} Q_t K^i_t di$, are small enough to be absorbed without the bank defaulting.

[11] One could argue that, by holding a perfectly diversified loan portfolio, the bank can deduce the ex-post realization of R^k_{t+1}, unless entrepreneurs misreport their returns in an unobserved state in a systematic way across i. However, we already know that entrepreneurs have no incentive to lie, if Z^i_t is independent of ω^i_{t+1}. Note that a similar argument must implicitly hold in Bernanke et al. (1999) for optimality.

Proposition 2. *Even in the case with aggregate risk, the optimal contract between the bank and entrepreneur i implies a positive relationship, $k_t^i = \psi(s_t)$ with $\psi'(s_t) > 0$, between the expected EFP, $s_t \equiv E_t\left\{R_{t+1}^k\right\}/R_t^n$, and the optimal capital/net worth ratio, $k_t^i \equiv Q_t K_t^i / N_t^i$.*

Proof. See Appendix A.2. □

3. The General Equilibrium Model

While the previous section illustrates that a monetary expansion might induce a profit-maximizing bank to lower its lending standards, the partial equilibrium analysis is confined to variables specified in the contract. In what follows, we embed both our optimal debt contract and the contract in Bernanke et al. (1999) in an otherwise standard New Keynesian DSGE model in order to be able to quantify their implications for a variety of macroeconomic variables, in response to a monetary policy shock and over the business cycle.

The general equilibrium model comprises eight types of economic agents: A representative household, perfectly competitive capital goods and intermediate goods producers, a continuum of monopolistically competitive labor unions and retailers, respectively, a monetary authority, a continuum of entrepreneurs, and a monopolistic bank. Since we borrow the former six from the existing literature, only entrepreneurs and the bank are discussed here in detail.

3.1. The Model Environment

The representative household supplies homogeneous labor to monopolistically competitive labor unions, consumes, and saves in terms of risk-free bank deposits. The representative capital goods producer buys the non-depreciated capital stock from entrepreneurs, makes an investment decision subject to adjustment costs, and sells the new capital stock to entrepreneurs within the same period without incurring any capital gains or losses. The representative intermediate goods producer rents capital from entrepreneurs, hires labor from labor unions, and sells intermediate output to retailers in a competitive wholesale market. Retailers (unions) diversify the homogeneous intermediate good (labor input of households) without incurring any costs and are thus able to set the price on final output (wage) above their marginal cost, i.e. the price of the intermediate good.[12] Monetary policy follows a standard Taylor (1993) rule. Since the optimization problems of these

[12]Monopolistically competitive labor unions and retailers are introduced in order to allow for nominal wage and price rigidities without unnecessarily complicating the production and investment decisions of firms (compare Bernanke et al., 1999).

agents are standard in the literature, we defer a detailed discussion to Appendix B, focusing instead on the optimal behavior of competitive entrepreneurs and the monopolistic bank in general equilibrium.

3.1.1. Entrepreneurs

At the end of period t, entrepreneurs use their accumulated net worth, N_t, to purchase productive capital, K_t, from capital goods producers at a price Q_t in terms of the numeraire. To finance the difference between their net worth and their total capital expenditures, entrepreneurs must borrow an amount $B_t = Q_t K_t - N_t$ in real terms from banks, where variables without an index superscript denote economy-wide aggregates.

The aggregate real rate of return per unit of capital in period t depends on the real rental rate on utilized capital, $r_t^k u_t$, the capital gain on the non-depreciated capital stock, $(1-\delta)K_{t-1}$, between $t-1$ and t, and the capital utilization cost $a(u_t)$:

$$R_t^k = \frac{r_t^k u_t + (1-\delta)Q_t - a(u_t)}{Q_{t-1}}. \tag{9}$$

A continuum of risk-neutral entrepreneurs, indexed $i \in [0,1]$, is hit by an idiosyncratic disturbance ω_t^i in period t. As a result, the ex-post rate of return of entrepreneur i per unit of capital equals $\omega_t^i R_t^k$. Following Bernanke et al. (1999), we assume that ω_t^i is i.i.d. across time t and across entrepreneurs i, with a continuous and differentiable cumulative distribution function $F(\omega)$ over a non-negative support, where $E\left\{\omega_t^i\right\} = 1\ \forall t$ and the corresponding *hazard rate* $h(\omega) \equiv f(\omega)/[1-F(\omega)]$ satisfies $\partial\omega h(\omega)/\partial\omega > 0$.

In contrast to Bernanke et al. (1999) and variations thereof, entrepreneurs can operate even in *financial autarky* by purchasing $Q_t K_t = N_t$ in period t. In order for an entrepreneur to accept a loan offer, its terms, i.e. the amount B_t and the nominal non-default rate of return, Z_t, must be such that the entrepreneur expects to be no worse off than in financial autarky. Assuming constant returns to scale (CRS), the distribution of net worth, N_t^i, across entrepreneurs is irrelevant. As a consequence, the aggregate version of the participation constraint in equation (4) can be written as

$$E_t\left\{\int_{\bar{\omega}_{t+1}}^{\infty} \omega R_{t+1}^k Q_t K_t - \frac{Z_t}{\pi_{t+1}} dF(\omega)\right\} \geq E_t\left\{R_{t+1}^k\right\} N_t, \tag{10}$$

where the expectation is over R_{t+1}^k, and $\bar{\omega}_{t+1}$ denotes the *expected* default threshold in period $t+1$, defined by $E_t\left\{\bar{\omega}_{t+1} R_{t+1}^k\right\} Q_t K_t \equiv E_t\left\{Z_t/\pi_{t+1}\right\} B_t$.

Using the definition of $\bar{\omega}_{t+1}$ to substitute out $E_t\left\{Z_t/\pi_{t+1}\right\}$ and expressing the aggregate profit share of entrepreneurs in period t as $1-\Gamma(\bar{\omega}_t)$, equation (B.4) can equivalently be written as

$$E_t\left\{[1-\Gamma(\bar{\omega}_{t+1})]\,R^k_{t+1}\right\}Q_tK_t \geq E_t\left\{R^k_{t+1}\right\}N_t. \tag{11}$$

Note that the ex-post realized value of $\Gamma(\bar{\omega}_{t+1})$ generally depends on the realization of R^k_{t+1} through $\bar{\omega}_{t+1}$. Similar to Bernanke et al. (1999), we assume that this constraint must be satisfied *ex post*. Implicit in this is the assumption that R^k_{t+1} is observed by both parties without incurring a cost, and that the non-default repayment, Z_t, can thus be made contingent on the *aggregate* state of the economy.

In order to avoid that entrepreneurial net worth grows without bound, we assume that an exogenous fraction $(1-\gamma^e)$ of the entrepreneurs' share of total realized profits is consumed each period.[13] As a result, entrepreneurial net worth at the end of period t evolves according to

$$N_t = \gamma^e\,[1-\Gamma(\bar{\omega}_t)]\,R^k_tQ_{t-1}K_{t-1}. \tag{12}$$

To sum up, the entrepreneurs' equilibrium conditions comprise the real rate of return per unit of capital in (B.3), the ex-post participation constraint in (B.5), the evolution of entrepreneurial net worth in (B.6), and the real amount borrowed, $B_t = Q_tK_t - N_t$. Moreover, the definition of the expected default threshold, $E_t\bar{\omega}_{t+1}$, determines the expected non-default repayment per unit borrowed by the entrepreneurs, $E_t\{Z_t/\pi_{t+1}\}$.

3.1.2. The Bank

For tractability, we assume a single *monopolistic* financial intermediary, which collects deposits from households and provides loans to entrepreneurs. In period t, this bank is endowed with net worth or bank capital N^b_t. Abstracting from bank reserves or other types of bank assets, its balance sheet identity in real terms is given by equation (2). The CSV problem in Townsend (1979) implies that, if entrepreneur i defaults due to $\omega^i_tR^k_tQ_{t-1}K^i_{t-1} < \left(Z^i_{t-1}/\pi_t\right)B^i_{t-1}$, the bank incurs a proportional cost $\mu\omega^i_tR^k_tQ_{t-1}K^i_{t-1}$ and recovers the remaining return on capital, $(1-\mu)\omega^i_tR^k_tQ_{t-1}K^i_{t-1}$.

In period t, the risk-neutral bank observes entrepreneurs' net worth, N^i_t, and makes a take-it-or-leave-it offer to each entrepreneur i. As a consequence, it holds a perfectly diversified loan portfolio between period t and period $t+1$. Although the bank can thus diversify away any idiosyncratic risk arising from the possible default of entrepreneur i, it is subject to aggregate risk through fluctuations in the ex-post rate of return on capital, R^k_{t+1}, and the aggregate default threshold, $\bar{\omega}_{t+1}$. In order to be able to pay the risk-free nominal

[13] In the literature, it is common to assume that an exogenous fraction of entrepreneurs "dies" each period and consumes its net worth upon exit. The dynamic implications of either assumption are identical.

rate of return R_t^n on deposits *in each state of the world*, the bank must have sufficient net worth to protect depositors from unexpected fluctuations in R_{t+1}^k.

Now consider the bank's problem of making a take-it-or-leave-it offer to entrepreneur i with net worth N_t^i in period t. The contract offered by the bank specifies the real amount of the loan, B_t^i, and the nominal gross rate of return in case of repayment, Z_t^i. Given that N_t^i is predetermined at the end of period t, the bank's choice of B_t^i also determines the entrepreneur's total capital expenditure, $Q_t K_t^i = B_t^i + N_t^i$. Given $Q_t K_t^i$ and N_t^i, the bank's choice of Z_t^i further implies an expected default threshold, $E_t \bar{\omega}_{t+1}$, from equation (3). We can thus rewrite the bank's constrained profit-maximization problem for a loan to entrepreneur i as

$$\max_{K_t^i, \bar{\omega}_{t+1}^i} \quad E_t \left\{ \left[\Gamma\left(\bar{\omega}_{t+1}^i\right) - \mu G\left(\bar{\omega}_{t+1}^i\right) \right] R_{t+1}^k Q_t K_t^i - \frac{R_t^n}{\pi_{t+1}} \left(Q_t K_t^i - N_t^i - N_t^{b,i} \right) \right\}, \tag{13}$$

where $\Gamma\left(\bar{\omega}_t^i\right) \equiv \int_0^{\bar{\omega}_t^i} \omega dF(\omega) + \bar{\omega}_t^i \left[1 - F\left(\bar{\omega}_t^i\right)\right]$, $\mu G\left(\bar{\omega}_t^i\right) \equiv \mu \int_0^{\bar{\omega}_t^i} \omega dF(\omega)$, and $N_t^{b,i}$ denotes the share of total bank net worth assigned to the loan to entrepreneur i, subject to the participation constraint in (4).

The corresponding first-order conditions with respect to $\left\{K_t^i, E_t \bar{\omega}_{t+1}^i, \lambda_t^{b,i}\right\}$, where $\lambda_t^{b,i}$ denotes the ex-post value of the Lagrange multiplier on the participation constraint, are given by

$$K_t^i: \quad E_t \left\{ \left[\Gamma(\bar{\omega}_{t+1}^i) - \mu G(\bar{\omega}_{t+1}^i) + \lambda_t^{b,i} \left(1 - \Gamma(\bar{\omega}_{t+1}^i)\right) \right] R_{t+1}^k \right\} = E_t \left\{ \frac{R_t^n}{\pi_{t+1}} \right\}, \tag{14}$$

$$E_t \bar{\omega}_{t+1}^i: \quad E_t \left\{ \left[\Gamma'(\bar{\omega}_{t+1}^i) - \mu G'(\bar{\omega}_{t+1}^i) \right] R_{t+1}^k \right\} = E_t \left\{ \lambda_t^{b,i} \Gamma'(\bar{\omega}_{t+1}^i) R_{t+1}^k \right\}, \tag{15}$$

$$\lambda_t^{b,i}: \quad \left[1 - \Gamma(\bar{\omega}_{t+1}^i)\right] R_{t+1}^k Q_t K_t^i = R_{t+1}^k N_t^i. \tag{16}$$

In Proposition 2, we show that the optimal debt contract between entrepreneur i and the bank implies a positive relationship between the expected EFP, $s_t \equiv E_t \left\{R_{t+1}^k \pi_{t+1} / R_t^n\right\}$, and the optimal capital/net worth ratio, $k_t^i \equiv Q_t K_t^i / N_t^i$. Note that (B.9) equates the expected marginal return of an additional unit of capital to the bank and the entrepreneur to the expected marginal cost of an additional unit of bank deposits in real terms. Assuming that the participation constraint is satisfied ex post, this implies a positive relationship between $E_t \left\{R_{t+1}^k \pi_{t+1}\right\} / R_t^n$ and $E_t \left\{\bar{\omega}_{t+1}^i\right\}$. Moreover, (B.11) equates the entrepreneur's expected payoff *with* and *without* the bank loan and implies a positive relationship between $E_t \left\{\bar{\omega}_{t+1}^i\right\}$ and $Q_t K_t^i / N_t^i$.[14] Together,

[14]This becomes evident, when we use the ex-post assumption that R_{t+1}^k and $\bar{\omega}_{t+1}$ are uncorrelated and rewrite (B.11) as

$$\left[1 - \Gamma(\bar{\omega}_{t+1}^i)\right] \geq \frac{N_t^i}{Q_t K_t^i} \equiv \frac{1}{k_t^i},$$

these two conditions determine the positive ex-ante relationship between the expected EFP in period $t+1$ and the leverage ratio chosen by the bank in period t, while the first-order condition with respect to $E_t\left\{\bar{\omega}^i_{t+1}\right\}$ pins down the ex-post value of the Lagrange multiplier, $\lambda^{b,i}_t$.

Given N^i_t, $Q_tK^i_t$, and $E_t\left\{R^k_{t+1}\right\}$, the definition of the expected default threshold, $E_t\left\{\bar{\omega}^i_{t+1}\right\}$, implies an expected non-default real rate of return on the loan to entrepreneur i, $E_t\left\{Z^i_t/\pi_{t+1}\right\}$, while the same equation evaluated ex post determines the actual non-default repayment conditional on N^i_t, $Q_tK^i_t$, $E_t\left\{\bar{\omega}^i_{t+1}\right\}$, and the realization of R^k_{t+1}. By the law of large numbers, $\Gamma\left(\bar{\omega}^i_t\right)-\mu G\left(\bar{\omega}^i_t\right)$ denotes the bank's *expected* share of total period-t profits (net of monitoring costs) from a loan to entrepreneur i as well as the bank's *realized* profit share from its diversified loan portfolio of all entrepreneurs. Accordingly, we can rewrite the bank's aggregate expected profits in period $t+1$ as

$$E_tV^b_{t+1}=E_t\left\{\left[\Gamma\left(\bar{\omega}_{t+1}\right)-\mu G\left(\bar{\omega}_{t+1}\right)\right]R^k_{t+1}Q_tK_t-\frac{R^n_t}{\pi_{t+1}}\left(Q_tK_t-N_t-N^b_t\right)\right\}, \tag{17}$$

where the expectation is over all possible realizations of R^k_{t+1} and π_{t+1}, while V^b_{t+1} is free of idiosyncratic risk. The entrepreneurs' participation constraint in (B.5) implies that $\bar{\omega}_{t+1}$ and thus $\left[\Gamma\left(\bar{\omega}_{t+1}\right)-\mu G\left(\bar{\omega}_{t+1}\right)\right]$ are predetermined in period $t+1$. To keep the problem tractable, we assume that aggregate risk is small relative to the bank's net worth, N^b_t, so that bank default never occurs in equilibrium.

In order to avoid that its net worth grows without bound, we assume that an exogenous fraction $(1-\gamma^b)$ of the bank's share of total realized profits is consumed each period.[15] As a result, bank net worth at the end of period t evolves according to

$$N^b_t=\gamma^bV^b_t. \tag{18}$$

3.2. Calibration and Steady State

Our New Keynesian DSGE model is parsimoniously parameterized and standard in many dimensions. For this reason, we follow the existing literature in calibrating most of the parameter values. We set the coefficient of constant relative risk aversion, σ, equal to 2 and the Frisch elasticity of labor supply to $\eta=3$. We assume habit formation in consumption with a coefficient h of 0.65. The relative weight of labor in the

i.e., entrepreneur i's expected return on capital with the loan relative to financial autarky must be no smaller than the entrepreneur's "skin in the game". Since $\left[1-\Gamma(\bar{\omega}^i_{t+1})\right]$ is strictly decreasing in $E_t\left\{\bar{\omega}^i_{t+1}\right\}$, the participation constraint implies a positive relationship between $E_t\left\{\bar{\omega}^i_{t+1}\right\}$ and k^i_t.

[15] Alternatively, one could think of this "consumption" as a distribution of dividends to share holders or bonus payments to bank managers, which are instantaneously consumed.

utility function, χ, is determined by a target value of $1/3$ for steady-state employment. The representative household discounts future utility with a subjective discount factor of $\beta = 0.995$, implying a steady-state real interest rate of 2% per annum. Following Basu (1996) and Chari et al. (2000), we set the elasticity of substitution between different consumption and investment varieties, ϵ_p, equal to 10 and the elasticity of substitution between different labor varieties to ϵ_w=10.

The productive capital stock depreciates at a quarterly rate of $\delta = 2.5\%$. We set the investment adjustment cost coefficient to its estimate based on a model with the same real and nominal rigidities in Christiano et al. (2005), i.e. $\phi = 2.5$. As in Bernanke et al. (1999), the elasticity of output with respect to the previous period capital stock, α, is set to 0.35. The Calvo probability that a monopolistically competitive retailer and union can adjust its price and wage, respectively, in any given period is assumed to be $\theta_p = \theta_w = 0.75$ – a value in the middle of the range of estimates in Christiano et al. (2005).

In line with the estimate in Christensen and Dib (2008), we assume a moderate amount of interest rate inertia in monetary policy, i.e. $\rho = 0.7418$, while the central bank's responsiveness to contemporaneous deviations of inflation and output from their steady state is set to $\phi_\pi = 1.5$ and $\phi_y = 0.5$, respectively. We are primarily interest in the effects of an unexpected monetary expansion. The shock to the Taylor rule, ν_t, is assumed to follow a mean-zero i.i.d. process with an unconditional standard deviation of $\sigma_\nu = 0.0058$, the estimate in Christensen and Dib (2008).

The remaining parameters relate to the optimal debt contract between the bank and the continuum of entrepreneurs. To avoid that either the bank or an entrepreneur grows indefinitely, we assume that 5% and 1.5% of their net worth is consumed each quarter, implying an average survival rate of 5 years and 16 years, respectively.[16] The relative monitoring cost in case of default, μ, is set to 20%, a value at the lower end of the range reported in Carlstrom and Fuerst (1997) and in the middle of the range of estimates reported in Levin et al. (2004). Moreover, we assume that idiosyncratic productivity draws are log-normally distributed with unit mean and a variance of 0.18 and that the default threshold, $\bar{\omega}$, is 0.35 in the steady state. Together, these parameter values imply an annual default rate of entrepreneurs close to 4.75%, an annual non-default interest rate on bank loans of 4.8%, and a leverage ratio of entrepreneurs equal to 1.537, which corresponds to the median value of leverage ratios for U.S. non-financial firms in Levin et al. (2004). Their sample of quoted firms ranges from 1997Q1 to 2003Q3. Table 1 summarizes our benchmark calibration.

[16]Note that, in addition to this exogenous consumption, an endogenous fraction of entrepreneurs defaults in each period due to an insufficient idiosyncratic realization of ω^i. Total exit of firms is thus given by the sum of the *exogenous* consumption and the

Table 1: Benchmark Calibration of Parameter Values.

Household and production sector	Parameter	Value
coefficient of relative risk aversion	σ	2
Frisch elasticity of labor supply	η	3
habit formation in household consumption	h	0.65
relative weight of labor in utility function	χ	5.19
quarterly discount factor of households	β	0.995
elasticity of output with respect to capital	α	0.35
quarterly depreciation rate of physical capital	δ	0.025
coefficient of quadratic investment adjustment costs	ϕ	2.5
elasticity of capital utilization adjustment costs	σ_u	0.4
elasticity of substitution between retailer varieties	ϵ_p	10
Calvo probability of quarterly price adjustments	θ_p	0.75
elasticity of substitution between labor varieties	ϵ_w	10
Calvo probability of quarterly wage adjustments	θ_w	0.75
Optimal financial contract	Parameter	Value
exogenous consumption rate of entrepreneurial net worth	$1-\gamma^e$	0.015
exogenous consumption rate of bank net worth	$1-\gamma^b$	0.05
monitoring costs as a fraction of total return on capital	μ	0.20
variance of idiosyncratic productivity draws	σ^2_ω	0.18
steady-state default threshold of entrepreneurs	$\bar{\omega}$	0.35
Monetary policy	Parameter	Value
interest-rate persistence in monetary policy rule	ρ	0.7418
responsiveness of monetary policy to inflation deviations	ϕ_π	1.5
responsiveness of monetary policy to output deviations	ϕ_y	0.5
standard deviation of unsystematic monetary policy shocks	σ_v	0.0058

This calibration implies an annual capital-output ratio of 1.945, a consumption share of households, entrepreneurs, and bankers of 0.696, 0.078, and 0.025, respectively, and an investment share in output of 0.195 in the steady state. The share of net worth and loans in total capital purchases amounts to 0.651 and 0.350, respectively, and implies an equivalent distribution of gross profits between entrepreneurs and the bank. Monitoring costs amount to less than 0.6% of steady-state output. Bank loans are funded through deposits and bank capital with relative shares of 0.824 and 0.176. The implied leverage ratio of entrepreneurs of 1.537 was explicitly targeted in the calibration.

We assume zero trend inflation in the steady state. Accordingly, all interest rates can be interpreted in real terms. From the benchmark calibration, we obtain an annualized risk-free rate of return on deposits of 2%, an annualized aggregate rate of return on capital of 6.2%, a non-default rate of return on bank loans of 6.8%, and an annualized EFP of 4.2%.

The steady-state default rate of entrepreneurs increases with the default threshold, $\bar{\omega}$, and the exogenous

endogenous default rate.

variance of idiosyncratic productivity realizations, σ_{ω}^2. For our baseline calibration, the annualized default rate equals 4.7%. Note that this default accounts for part of the overall turnover of entrepreneurs in the steady state only. Each period, 1.5% of entrepreneurial and 5% of bank net worth are also consumed exogenously. The steady-state values of selected variables and ratios are summarized in Table 2.

3.3. Dynamic Simulation Results

3.3.1. The Risk Channel of Monetary Policy

Figure 2 plots selected impulse responses to an expansionary monetary policy shock, i.e. an exogenous reduction in the unsystematic component of the Taylor rule, for "Our contract" against the "BGG contract" in Bernanke et al. (1999). The formulation of the optimal debt contract is the only dimension along which the two models differ.[17] All impulse response functions are expressed in term of percentage deviations from the steady state, except for the policy rate, the loan rate, the net interest margin, and the expected EFP, which are expressed in terms of percentage points. Consider first our contract.

In response to a monetary expansion, the policy rate, R_t^n, decreases on impact, albeit not by the full amount of the shock, since the interest rate rule implies a contemporaneous reaction to inflation and output, which are both above their steady-state values. The reduction in the policy rate is passed through to the non-

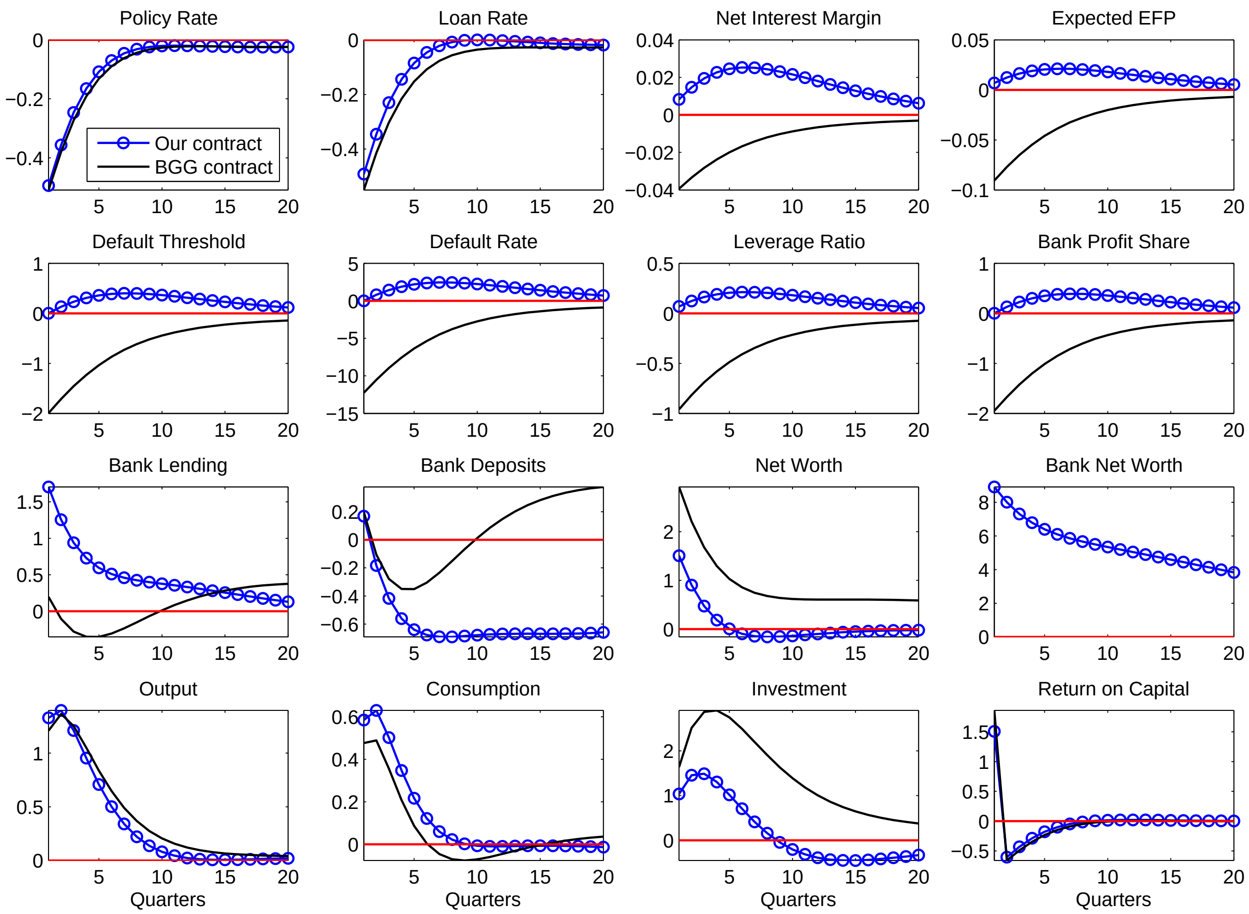
[17] It is important to note that, apart from $N_{ss}^b = V_{ss}^b = 0$, reformulating the debt contract has little effect on the steady-state values.

Table 2: Selected Steady-State Values for Benchmark Parameter Calibration.

Steady-State Variable or Ratio	Computation	Value
capital-output ratio	$K/(4 \cdot Y)$	1.9451
household consumption relative to output	C/Y	0.6963
entrepreneur consumption relative to output	C^e/Y	0.0784
bank consumption relative to output	C^b/Y	0.0251
capital investment relative to output	I/Y	0.1945
employment as a share of time endowment*	H	1/3
gross price markup of retailers*	$\epsilon_p/\left(\epsilon_p - 1\right)$	1.1111
gross wage markup of labor unions	$\epsilon_w/(\epsilon_w - 1)$	1.1111
leverage ratio of entrepreneurs*	QK/N	1.5372
default monitoring costs relative to output	$\mu G(\bar{\omega}) R^k QK/Y$	0.0057
annualized default rate of entrepreneurs*	$4 \cdot F(\bar{\omega})$	4.735%
annualized risk-free policy interest rate*	$4 \cdot (R^n - 1)$	2.010%
annualized interest rate on bank loans*	$4 \cdot (Z - 1)$	6.816%
annualized rate of return on capital	$4 \cdot \left(R^k - 1\right)$	6.195%
annualized external finance premium	$4 \cdot \left(R^k/R^n - 1\right)$	4.164%

Note: Superscript * indicates steady-state values targeted in the benchmark calibration.

Figure 2: Selected Impulse Response Functions to an Expansionary Monetary Policy Shock for Different Optimal Debt Contracts.



Notes: All impulse response functions are expressed in terms of *percentage deviations from steady state*, except for the policy rate, the loan rate, the net interest margin, and the expected EFP, which are expressed in terms of *percentage points*.

default rate of return on loans, Z_t, which also decreases on impact and follows virtually the same pattern. The monetary expansion further implies an unexpected increase in the real rate of return on capital, R_t^k, and thus in the ex-post realized EFP, as conjectured in our partial equilibrium analysis.[18]

Assuming that the entrepreneurs' participation constraint must be satisfied ex post, their share in gross profits, $1-\Gamma(\bar{\omega}_t)$, is predetermined in the period of the shock. Accordingly, neither the default threshold, $\bar{\omega}_t$, nor the default rate, $F(\bar{\omega}_t)$, of entrepreneurs responds on impact. The fact that profits are split according to the predetermined leverage ratio, $Q_{t-1}K_{t-1}/N_{t-1}$, implies that both entrepreneurs and the bank benefit from a monetary expansion. As a result, bank net worth, N_t^b, and entrepreneurial net worth, N_t, increase on impact.

[18]The impulse response function in Figure 2 shows the *ex-ante expected* rather than the *ex-post realized* EFP and does therefore not reflect the unexpected increase in the period of the monetary policy shock.

From $t + 1$ on, the price of capital declines (not shown), implying capital losses to the entrepreneurs, which are correctly anticipated by all economic agents under rational expectations (RE) in the absence of further shocks. Nevertheless, the expected EFP for period $t + 1$ is above its steady-state value by about 0.7 basis points, which induces the bank to grant more loans both in absolute terms and *relative to entrepreneurs' net worth*. As a consequence, the leverage ratio of entrepreneurs increases from the end of period t onwards and peaks after five quarters at 0.21% above its steady-state value of 1.537.

This increase in borrower leverage allows the bank to demand a larger share of gross expected profits realized in period $t + 1$ by raising the non-default rate of return on bank loans relative to the policy rate and thus its net interest margin. Together with the implied default threshold, $\bar{\omega}_{t+1}$, the expected default rate of entrepreneurs, $F(\bar{\omega}_{t+1})$, rises above its steady-state value. The maximum effect is reached after six quarters, when the default threshold is 0.4% above its steady-state value of 0.35, and the default rate of entrepreneurs is about 3 basis points above its steady-state value of 1.18%.

Now recall that the classic formulation of the CSV contract implies that entrepreneur i determines the optimal amount of lending, B_t^i, and thus the leverage ratio for a predetermined amount of net worth, N_t^i, while the "financial intermediary" only corresponds to a participation constraint. Assuming perfect diversification across borrowers and the risk-sharing agreement in Bernanke et al. (1999), the passive financial intermediary must break even in each realized state of the economy. Hence, there is no role for bank capital, $N_t^b = 0 \; \forall t$, and the entire windfall gain from the monetary expansion accrues to the entrepreneurs.

Figure 2 shows that, for the BGG contract, the entrepreneurs' default threshold, default rate, and leverage ratio as well as the expected EFP and net interest margin all *decrease* in response to a monetary expansion. As a result, the partial equilibrium mechanism works in the opposite direction. In contrast with our contract and the popular notion of a *bank lending channel* of monetary policy, the BGG contract furthermore implies an initial contraction rather than an expansion of bank lending.

These crucial differences arise from the assumption in Bernanke et al. (1999) that a competitive financial intermediary merely transforms household deposits into loans to entrepreneurs *one for one*. In contrast, the monopolistic bank in our model retains a share of total profits, accumulates own net worth, and is thus able to expand lending despite an even more pronounced and persistent reduction in deposits. The bank's market power and our assumption about aggregate risk sharing manifest themselves in a weaker pass-through from monetary policy to the loan rate, relative to the BGG contract, and an increase rather than a decrease in the net interest margin, which measures the expected profitability of bank loans.

The more pronounced increase in borrower net worth, N_t, as well as the contraction of aggregate bank lending, B_t, imply the well-known decrease in the leverage ratio of entrepreneurs, $Q_t K_t / N_t = (N_t + B_t) / N_t$, in Bernanke et al. (1999), whereas the introduction of a *risk channel* in this paper facilitates a reduction in deposits and an expansion of bank lending at the same time.

3.3.2. Risk Taking over the Business Cycle

A related question is whether our new mechanism matters for replicating the unconditional moments of certain key variables over the business cycle. For this purpose, we augment our benchmark New Keynesian DSGE model with four additional shock processes to total factor productivity, consumer preferences, and the marginal efficiency of investment, as well as so-called "risk shocks" to the standard deviation of idiosyncratic productivity draws, $\sigma_{\omega,t}$. While our calibration of the former three is based on the Maximum Likelihood estimation results in Christensen and Dib (2008), unanticipated and anticipated risk shocks are calibrated in line with the Bayesian estimation results in Christiano et al. (2014). Table C.1 in the Appendix summarizes the calibration of additional shock processes.

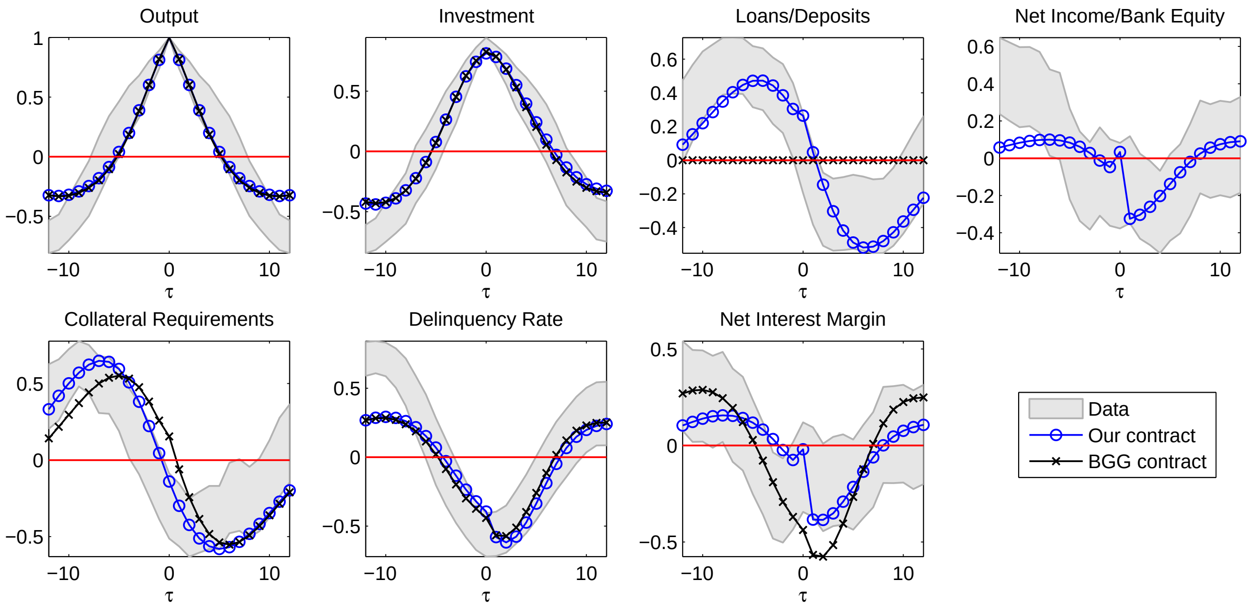
Figure 3 plots the dynamic cross-correlations of selected variables and ratios with output based on the theoretical model with our debt contract and the optimal debt contract in Bernanke et al. (1999), respectively, against their empirical counterparts. To capture the variability at business cycle frequencies, both the data and the simulated time series are HP-filtered with $\lambda = 1,600$ before computing the unconditional moments.

Figure 3 illustrates that both models replicate the empirical cross-correlations of output and, especially, investment reasonably well. Moreover, the simulated default rate of entrepreneurs tracks the correlation of delinquency rates on business loans with output in the data surprisingly well. The importance of introducing a risk channel becomes evident when considering bank-related variables. The model with our contract does substantially better in replicating the empirical cross-correlations of banks' SLOOS collateral requirements and the net interest margin from Call Reports, in particular contemporaneously. The unconditional moments of banks' loan-to-deposit ratio and return on capital can only be assessed in our model in a meaningful way, whereas, in Bernanke et al. (1999), the former is constant at unity, while the latter is not defined at all.

3.3.3. Sensitivity Analysis

An important question is whether the results in Figure 2 are sensitive to our choice of parameters. For this reason, we perform a number of robustness checks within the range of commonly used parameter values. First, our results are qualitatively and quantitatively robust to the absence of habit formation in consumption

Figure 3: Cross-Correlation of Selected Variables at Period t with Output at period $t + \tau$, DSGE Model and Data.



Notes: Simulated time series and data are HP-filtered ($\lambda = 1,600$). In the data, output corresponds to *log(real GDP per capita)*, investment to *log(real investment expenditure per capita)*, loans/deposits to *log(loans and leases in bank credit/demand deposits) at commercial banks*, net income/bank equity to Call Reports *log(net interest income/total equity capital) for commercial banks in the U.S.*, collateral requirements to the *net percentage of domestic banks increasing collateral requirements for large and middle-market firms*, delinquency rate to *delinquency rate on business loans; all commercial banks*, and net interest margin to Call Reports *net interest margin for all U.S. banks*.

($h = 0$) as well as to the presence of price and wage indexation to past inflation by retailers and labor unions, respectively.

Second, the results are qualitatively robust to the introduction of nonzero trend inflation. For example, an annualized steady-state inflation rate of 1% marginally lowers the peak response of the borrowers' leverage ratio, default rate, and other contract variables while increasing their persistence somewhat.

Third, the absence of investment adjustment costs ($\phi = 0$) substantially magnifies the impulse responses of contract variables, such as the expected EFP, and increases therefore the risk channel of monetary policy. With zero adjustment costs, however, the response of investment becomes unreasonably large. In contrast, higher investment adjustment costs, the absence of variable capital utilization ($\sigma_u \rightarrow \infty$), and the absence of wage stickiness ($\xi_w = 0$) attenuate the risk channel quantitatively, albeit not qualitatively.

Fourth, our results are qualitatively robust to alternative specifications of a Taylor-type interest-rate rule, such as a response to past or expected future rather than current inflation (compare Bernanke et al., 1999), a response to past or expected future rather than current output, or a stronger response to deviations of inflation from steady state.[19] The only parameter that matters is the degree of interest-rate inertia in the Taylor rule. Following a monetary expansion, higher inertia implies that the policy rate remains "too low for too long" and magnifies thus the effect of the risk channel (see also Figure C.2 in the Appendix).

4. The Empirical Evidence

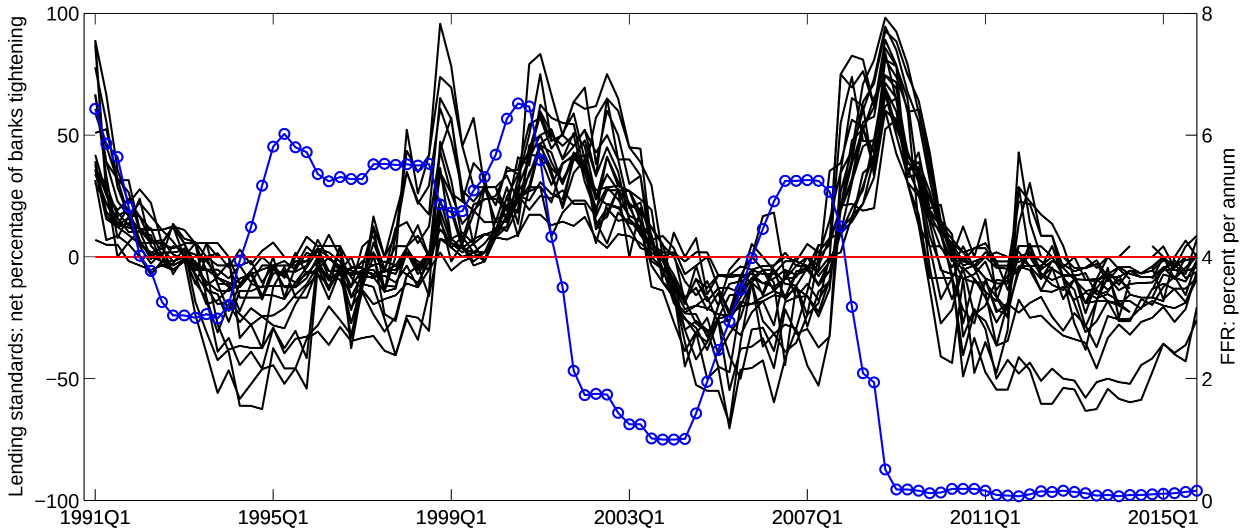
In the existing literature, evidence for a risk-taking channel of monetary policy on the asset side is mostly confined to microeconomic loan-level data (see, e.g., Jiménez et al., 2014; Ioannidou et al., 2015; Paligorova and Santos, 2017). When macroeconomic time series are used, the results are often ambiguous. Maddaloni and Peydró (2011) exploit the cross-sectional variation in economic conditions across euro-area countries to show that corporate banks soften their lending standards in response to low short-term interest rates and that the impact on lending standards is amplified by the duration of relatively low interest rates. Since their identification strategy rests on a common monetary policy stance in the euro area, it is not suitable for the U.S., where they find little evidence for a risk channel of monetary policy. Using a rich panel of banking data with 140 time series in a FAVAR model, Buch et al. (2014) find evidence in favor of asset-side risk taking for small U.S. banks only. Importantly, Buch et al. (2014) use a different measure of asset risk – the *riskiness of new loans* from the Survey of Terms of Business Lending of the U.S. Federal Reserve, which restricts their sample period to 1997Q2-2008Q2.

Instead, we use the quantified qualitative survey measures of bank lending standards from the Federal Reserve's SLOOS, which are available from 1991Q1 onwards. Similar to Buch et al. (2014), we employ a FAVAR model, which allows us to parsimoniously use the information in a large number of macroeconomic time series, thereby reducing the risk of omitted-variable bias (see also Bernanke et al., 2005).[20] We extract the so-called factors from a comprehensive set of real economic activity measures including indicators of production, investment, and employment. In order to be able to detect a risk channel of monetary policy, we augment the macroeconomic and financial time series commonly used in the FAVAR literature by 19 measures of lending standards, such as the net percentage of banks *increasing collateral requirements* or *tightening loan covenants*, for several categories of loans, borrowers, and banks. Figure 4 plots these lending

[19]Note that our results are not affected by a response of monetary policy to the so-called "output gap", i.e. the deviation of actual from potential output, under flexible prices. Due to the neutrality of money, potential output is identical to steady-state output in the absence of nominal rigidities.

[20]In Appendix F.1, we illustrate that the response of SLOOS lending standards to a monetary policy shock is not robust to different choices for the measure of real economic activity in a small-scale VAR model.

Figure 4: SLOOS Lending Standards and the Effective Federal Funds Rate, 1991Q1-2015Q4.



Notes: See Appendix D for a detailed description of lending standard measures.

standards against the effective federal funds rate. Note that the substantial comovement in lending standards over the sample period might be captured well even by a relatively small number of common factors.

4.1. The Econometric Specification

Suppose that the observation equation relating the $N \times 1$ vector of informational time series, X_t, to the $K \times 1$ vector of unobservable factors, F_t, and the $M \times 1$ vector of observable variables, Y_t, with $K + M << N$, is given by

$$X_t = \Lambda^f F_t + \Lambda^y Y_t + e_t, \tag{19}$$

where Λ^f is an $N \times K$ matrix of factor loadings of the unobservable factors, Λ^y is an $N \times M$ matrix of factor loadings of the observable variables, and e_t is an $N \times 1$ vector of error terms following a multivariate normal distribution with mean zero and covariance matrix, R.

Suppose further that the joint dynamics of the unobserved factors in F_t and the observable variables in Y_t can be captured by the transition equation

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + v_t, \tag{20}$$

where $\Phi(L)$ is a lag polynomial of order d and v_t is a $(K + M) \times 1$ vector of error terms following a multivariate normal distribution with mean zero and covariance matrix, Q. The error terms in e_t and v_t are assumed to be contemporaneously uncorrelated.

Estimating the FAVAR model in (19) and (20) requires transforming the data to induce stationarity of the variables.[21] Our baseline sample contains quarterly observations for 1991Q1-2008Q2. While the start is determined by the availability of the SLOOS measures of bank lending standards, we exclude the period after 2008, when U.S. monetary policy was effectively operating through the balance sheet of the Federal Reserve rather than through the Federal Funds rate (compare Figure 4). The predominance of unconventional policy measures would require a different strategy for identifying monetary policy shocks during this period.

Following Bernanke et al. (2005), we identify monetary policy shocks recursively, ordering the Federal Funds rate last in equation (20). In our case, this implies that the unobserved factors do not respond to monetary policy innovations *within the same quarter*, while the idiosyncratic components of the informational time series in X_t are free to respond on impact.[22] One could argue that senior loan officers take into account the current monetary stance when deciding on their lending standards. Hence, it is important to note that the SLOOS is conducted by the Federal Reserve, so that results are available *before* the quarterly meetings of the Federal Open Market Committee (FOMC), in line with our identification scheme.

We estimate the FAVAR model in (19) and (20) by a one-step Bayesian approach, applying multi-move Gibbs sampling to sample jointly from the latent factors and the model parameters. Appendix E provides details on the prior distributions, the Gibbs sampler, and how we monitor the convergence of the latter. In our baseline specification, we set the lag order of the transition equation to two quarters and consider the Federal Funds rate as the only observable variable in (20), i.e. $M = 1$.[23]

To determine the appropriate number of unobservable factors in our FAVAR specification, we consult a number of selection criteria, monitor the joint explanatory power of F_t and Y_t for bank lending standards, and check the robustness of our results by adding more factors. The tests of Onatski (2009) and Alessi et al. (2010) point to three and five factors, respectively. Trying specifications with up to seven factors, we found that our results were not affected qualitatively.[24] In what follows, we therefore refer to the specification with three unobservable factors as the baseline FAVAR model.

[21] The transformation of variables is detailed in Appendix D. Note that the measures of bank lending standards enter the FAVAR model in (standardized) levels, i.e. without first-differencing or detrending, given that they are stationary by construction.

[22] Bernanke et al. (2005) apply the same recursive ordering to a FAVAR model in *monthly* data.

[23] Results for lag orders one and three are very similar. Adding CPI as an observable variable ($M = 2$) does not affect our results.

[24] Table F.1 in the Appendix reports the adjusted R^2 for each of the 19 SLOOS measures with one, three, five, and seven unobservable factors, illustrating that a small number factors is sufficient to capture the common comovement in lending standards. Our results are also consistent with the so-called "scree plot", which plots the eigenvalues of X_t in descending order against the number of principal components. In our case, the scree plot displays a steep negative slope and a kink around the fifth principal component, supporting the results based on the selection criteria and the robustness checks.

4.2. *Results from the Structural FAVAR Model*

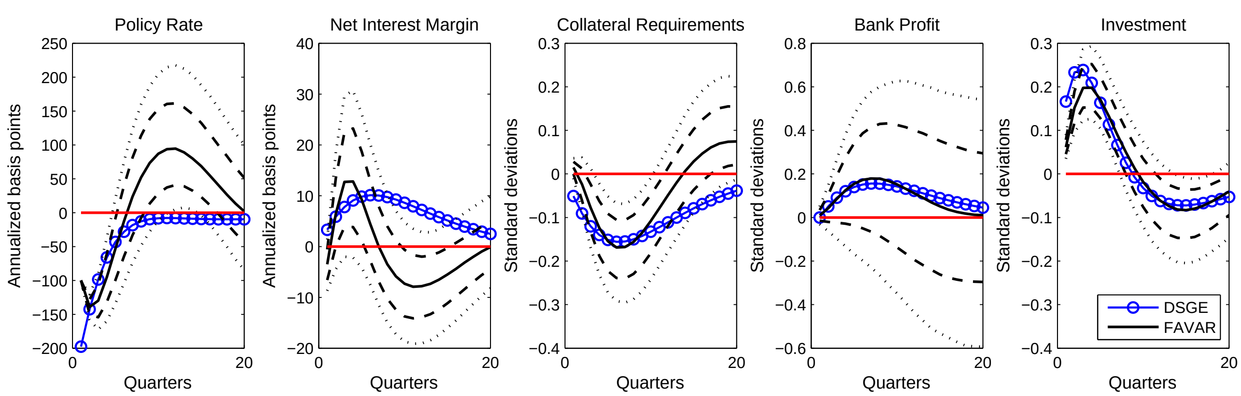
4.2.1. *Impulse Response Functions*

Figure 5 plots the responses of selected variables from the theoretical DSGE model to an expansionary monetary policy shock against their empirical counterparts from the benchmark FAVAR model with $K = 3$ latent factors. In order to facilitate a comparison of the theoretical and empirical impulse response functions, the bank's collateral requirements, bank profits, and investment are expressed in terms of their unconditional standard deviations, while the policy rate and the bank's net interest margin are converted to annualized basis points, both in the DSGE and the FAVAR model. One period on the x-axis corresponds to one quarter.

In the theoretical model, the policy rate converges smoothly to its steady-state value, while the empirical effective federal funds rate displays substantial overshooting about two years after the monetary expansion. Hence, the initial increase in the empirical net interest margin is quickly reversed, turning into a marginally significant decrease, while the response of the theoretical net interest margin remains positive throughout. Despite this discrepancy in the transmission of the shock through interest rates and spreads, our theoretical model is able to replicate the empirical impulse responses of bank lending standards, profits, and investment.

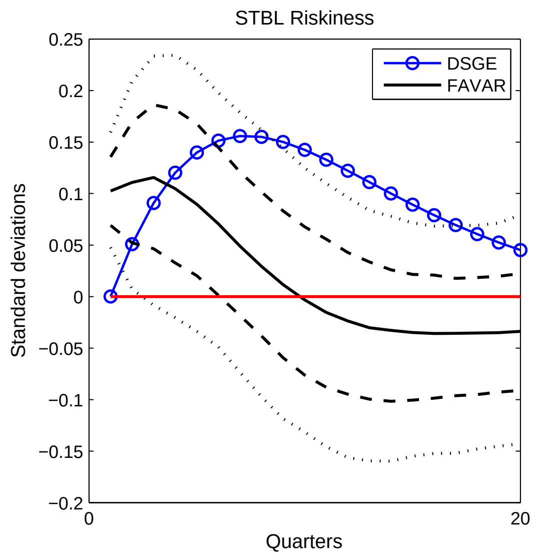
In the DSGE and the FAVAR model, banks significantly lower their collateral requirements in response to an expansionary monetary policy shock, thus raising the demand for productive capital and investment.

Figure 5: Impulse Responses of Selected Variables to an Expansionary Monetary Policy Shock, DSGE Model and FAVAR Model with Three Unobserved Factors.



Notes: In the FAVAR model, the *effective federal funds rate* is used as a measure of the monetary policy rate, the Call Reports *net interest margin for all U.S. banks* as a proxy for the theoretical interest rate spread, the *net percentage of domestic banks increasing collateral requirements for large and middle-market firms* as a measure of bank lending standards, the Call Reports *net income for commercial banks in the U.S.* to measure bank profit, and the *ISM Manufacturing: New Orders Index* as a proxy for investment. See Appendix D for a detailed description of the data. For the FAVAR model, median responses are plotted with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles.

Figure 6: Impulse Responses of Loan Riskiness to an Expansionary Monetary Policy Shock, DSGE Model and FAVAR Model with Three Unobserved Factors.



Notes: The measure of loan riskiness is obtained from the Terms of Business Lending Survey of the Federal Reserve. In particular, we compute weighted average risk score across all participating banks for the sample 1997Q2-2008Q2. For the FAVAR model, median responses are plotted with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles.

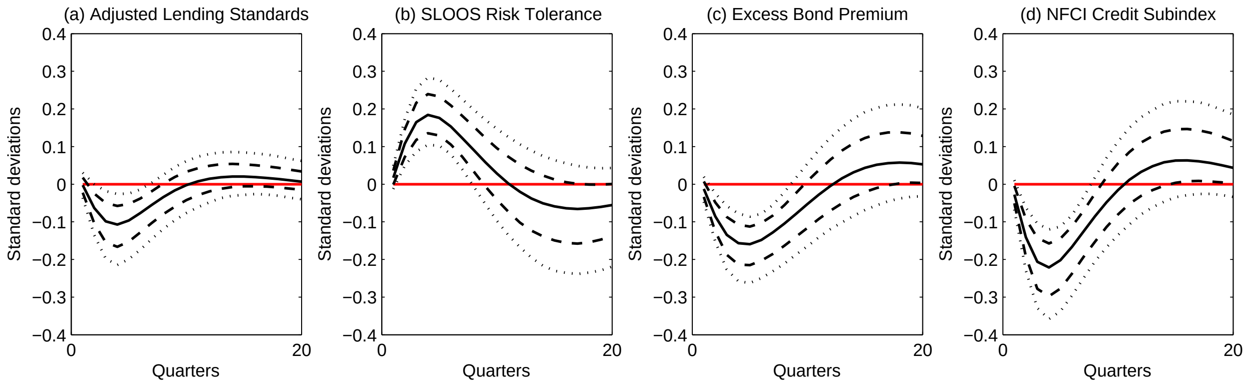
Importantly, the bank's behavior is driven by an increase in profits, which we also find in the FAVAR model, albeit not statistically significant. In the model and the data, loosening of lending standards is accompanied by an increase in loan riskiness (see Figure 6). The empirical measure of loan riskiness is computed based on the Terms of Business Lending Survey of the Federal Reserve. Figure F.3 in the Appendix shows that *all* 19 measures of lending standards decrease in response to an expansionary monetary policy shock, while Figures G.1, G.2, and G.3 illustrate the robustness of this finding for 1, 5, and 7 unobserved factors, respectively.

4.2.2. Alternative Measures of Lending Standards

To address concerns that our result might be driven by loan demand rather than loan supply, we replace the "raw" lending standards in X_t by the alternative measure proposed by Bassett et al. (2014), which adjusts changes in lending standards for macroeconomic and bank-specific factors that might simultaneously affect the demand for bank credit. Panel (a) of Figure G.7 illustrates that, despite a quantitatively smaller decrease, this alternative indicator responds to an exogenous monetary expansion in exactly the same way.[25]

[25]Recall that, in our original FAVAR model, the first factor primarily captures the common comovement in lending standards. While replacing the latter in X_t might therefore affect the impulse response functions even qualitatively, this does *not* seem to be the case. Moreover, Bassett et al. (2014) show that an exogenous disruption in the supply of bank credit leads to a significant *easing* of monetary policy. In this light, the positive conditional comovement that we find between lending standards and the effective Federal

Figure 7: Impulse Responses of Alternative Measures of Lending Standards to an Expansionary Monetary Policy Shock.



Notes: Median responses with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles, based on the FAVAR model with three unobserved factors, where the 19 SLOOS lending standard measures have been replaced by (a) the *credit supply indicator* proposed by Bassett et al. (2014); (b) the *net percentage of domestic banks easing lending standards due to increased risk tolerance*; (c) the *excess bond premium* proposed by Gilchrist and Zakrajšek (2012); (d) the *NFCI credit subindex* published by the Federal Reserve Bank of Chicago. See Appendix D for a detailed description of the data.

The SLOOS also asks senior loan officers for the *reasons* that induced them to adjust lending standards. Among the latter, the category "risk tolerance" allows us to explicitly address the question whether banks' risk appetite played any role when easing lending standards in response to a monetary expansion. Panel (b) of Figure G.7 plots the (negative) impulse response function of the net percentage of domestic banks easing lending standards due to *increased risk tolerance*. The finding of a statistically significant increase supports our interpretation of banks' easing of lending standards as a risk channel of monetary policy.

While the focus of our paper is on lending standards and collateral requirements, in particular, qualitative surveys like the SLOOS can be criticized for being more prone to subjectiveness or intentional misreporting. Hence, we also investigate the impulse responses of two market-based measures of the financial sector's risk attitude: the "excess bond premium" proposed by Gilchrist and Zakrajšek (2012) – a component of the "GZ spread" that captures cyclical changes in the relationship between objective default risk and credit spreads – and the credit subindex of the Chicago Fed's National Financial Conditions Index (NFCI) – a composite measure of credit conditions. Panels (c) and (d) of Figure G.7 illustrate that both the excess bond premium and the NFCI credit component decrease significantly in response to an exogenous monetary expansion, indicating an increase in "the effective risk-bearing capacity of the financial sector" (compare Gilchrist and Zakrajšek, 2012) and thus an expansion in the supply of credit, consistent with the risk-taking channel of

Funds rate is unlikely to be contaminated by reverse causality from bank behavior to monetary policy.

monetary policy.

4.2.3. Robustness of Identifying Strategy

Barakchian and Crowe (2013) provide empirical evidence that U.S. monetary policy post 1988 became more forward-looking, implying that a credible identification of exogenous monetary shocks must account for policy makers' expectations about future economic activity and price dynamics during our sample period. While our benchmark specification of X_t already contains forward-looking variables, such as the S&P 500 or business and consumer survey data, one could argue that the Board of Governors uses additional information when forming its monetary policy decisions. For this reason, we include 13 quarterly time series from the Philadelphia Fed's Greenbook data set, expressed in terms of one-year-ahead expectations of average growth rates, directly in the vector X_t and find that the impulse responses of lending standards to an expansionary monetary policy shock are quantitatively very similar to those presented above and statistically significant at the 10% level for 1, 3, and 5 factors. For 7 factors, our estimates become less precise, while the easing of lending standards remains significant according to the error bands containing 68% of the probability mass.[26]

Moreover, we abandon the FAVAR model altogether in favor of a high-frequency identification approach. Following Barakchian and Crowe (2013), we extract an alternative time series of monetary policy shocks from daily changes in federal funds futures yields for different maturities around FOMC meeting dates.[27] We then regress each variable of interest on $P = 4$ own lags as well as the contemporaneous and $Q = 12$ lagged observations of the quarterly aggregate of this monthly shock series in a distributed lag regression model. Figure G.5 in the Appendix plots the impulse responses of selected variables from the theoretical DSGE model to an expansionary monetary policy shock against their empirical counterparts and illustrates that our findings in Figure 5 are qualitatively robust to the identifying strategy in Barakchian and Crowe (2013). Note also that, based on the high-frequency identification of monetary policy shocks, the increase in bank profits is statistically significant. As in the FAVAR, the loosening of lending standards is accompanied by an increase in loan riskiness (see Figure G.6). The qualitative robustness carries over to all 19 SLOOS lending standards measures and the alternative measures of the financial sector's risk appetite in Figure G.7.

[26]The projections from the Fed's Greenbook are released to the public with a lag of five years and are currently available up to 2010Q4. For more details, see Table D.2 in the Appendix. All results are available from the authors upon request.

[27]The median correlation of the resulting shock series with the shock series based on the last 10,000 draws from the Gibbs sampler for our baseline FAVAR model is 0.273 and highly statistically significant (see also Figure G.4 in the Appendix).

4.2.4. Extended Sample Period

Despite concerns that the effective Federal Funds rate represents an incomplete measure of monetary policy at the zero lower bound (ZLB), we extend our sample period to 2015Q4 as a final robustness check. In Appendix G.3, we reproduce Figures 5, G.7, and F.3 for the extended sample based on the FAVAR model with three unobserved factors and the high-frequency identification approach. When including the ZLB period, our theoretical model continues to replicate the empirical impulse responses of the effective Federal Funds rate, banks' collateral requirements from SLOOS, and investment to a monetary policy shock. For the FAVAR model, the responses of banks' net interest margin and profits are imprecisely estimated and tend toward the opposite direction, whereas the net interest margin's response remains significantly positive for the identifying strategy in Barakchian and Crowe (2013). At the same time, Figures G.10 and G.11 show that all 19 SLOOS lending standards decrease significantly in response to a monetary expansion, while Figures G.12 and G.13 indicate a significant easing of alternative measures of the financial sectors' lending standards, regardless of the chosen identification.[28] It is beyond the scope of this paper to identify monetary policy shocks attributable to the unconventional monetary policy during the zero lower bound period. Kurtzman et al. (2017) study the effect of large-scale asset purchase programs of the Federal Reserve and find loosening of lending standards and higher bank risk-taking measured by loan riskiness, thus corroborating our baseline findings.

5. Concluding Remarks

In this paper, we reformulate the well-known application of Townsend's (1979) CSV contract in Bernanke et al. (1999) from the perspective of a monopolistic bank, which chooses the amount of risky lending against borrower collateral subject to the participation constraint of a continuum of entrepreneurs. We assume that both the bank and entrepreneurs are risk-neutral. While the bank can diversify any idiosyncratic default risk of borrowers, it bears the aggregate risk. In partial equilibrium, the optimal debt contract yields a positive relationship between the expected EFP and the borrower's leverage ratio chosen by the bank. As a result, an exogenous increase in the expected EFP induces the bank to lend more against a given amount of borrower collateral in order to gain a larger "share of the pie". At the same time, entrepreneurs become more

[28]The *credit supply indicator* proposed by Bassett et al. (2014) is only available until 2008Q2. For this reason, we omit it in our robustness checks for the extended sample.

leveraged and thus more likely to default ex post.

We then embed our version of the CSV contract in an otherwise standard New Keynesian DSGE model. In contrast to the prior literature, an expansionary monetary policy shock leads to a hump-shaped increase in the expected EFP and the bank's net interest margin, which measures the profitability of loans. As a result, our model predicts an increase in bank lending relative to borrower collateral, a higher leverage ratio, and thus a higher expected default rate of entrepreneurs, in line with the risk channel of monetary policy (see, e.g., Adrian and Shin, 2011; Borio and Zhu, 2012).

Using a FAVAR model and including measures of bank lending standards from the Federal Reserve's Senior Loan Officer Opinion Survey (SLOOS), we show that our theoretical model replicates the empirical impulse responses of banks' self-reported collateral requirements, their net interest margin and profits as well as investment to a monetary policy shock both qualitatively and quantitatively. U.S. banks significantly lower all 19 lending standards in response to an unexpected reduction in the effective Federal Funds rate. This finding carries over to alternative measures of financial intermediaries' risk appetite and is robust to the high-frequency identification of monetary policy shocks in Barakchian and Crowe (2013).

While our results can be interpreted as robust evidence for an *ex-ante* risk channel of monetary policy (i.e. lower lending standards), we do not show empirical evidence of *ex-post* risk taking (i.e. higher default rates). The reason is that aggregate charge-off and delinquency rates are reported for the *stock* of loans and leases at commercial banks. It is therefore unclear whether a defaulting loan was originated before of after the monetary policy shock occurred. By tracking each loan in the Bolivian credit register from origination to maturity, Ioannidou et al. (2015) show that lower overnight interest rates induce banks to commit larger loan volumes with fewer collateral requirements to ex-ante riskier firms that are more likely to default ex post. A similar analysis based on loan-level data is beyond the scope of this paper and left for future work.

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Appendix A. The Optimal Loan Contract

This appendix provides details on the optimal financial contract, following the logic in Bernanke et al. (1999). Given the different assumptions about the roles of borrowers and lenders, however, we deviate from the latter, where this is necessary.

Appendix A.1. Without Aggregate Risk

In the absence of aggregate risk, the loan contract between the bank and entrepreneur i is only affected by the entrepreneur's idiosyncratic risk ω^i. Consequently, the bank's constrained profit maximization problem can be formulated as in equation (6), where all terms are defined in the main text.

Given the borrower's net worth, the bank chooses the volume of the loan and thus k. For any value of k, the entrepreneur's participation constraint (PC) pins down the default threshold $\bar{\omega}^i$, which splits the expected total profits from the investment project between the borrower and the lender. Given $\bar{\omega}^i$, the non-default rate of return on the loan to entrepreneur i, Z^i_{t+1}, will then be determined by (3).

For notational convenience, we suppress any time subscripts and index superscripts throughout the appendix, while our aim remains to derive the properties of the optimal contract between the bank and entrepreneur i.

Appendix A.1.1. The EFP and Loan Supply

In what follows, we establish a positive relationship, $k = \psi(s)$, $\psi'(s) > 0$, between the *external finance premium* (EFP) $s \equiv R^k/R$ and the bank's optimal choice of the capital/net worth ratio $k \equiv QK/N$. The Lagrangian corresponding to the constrained profit-maximization problem in (6) is given by

$$\mathcal{L} = [\Gamma(\bar{\omega}) - \mu G(\bar{\omega})]\, sk - (k - 1 - n) + \lambda \{[1 - \Gamma(\bar{\omega})]\, sk - s\},$$

where $n \equiv N^b/N$ and λ is the Lagrangian multiplier on the borrower's PC. The corresponding first-order conditions (FOCs) are

$$\begin{aligned} k: &\quad [\Gamma(\bar{\omega}) - \mu G(\bar{\omega})]\, s - 1 + \lambda [1 - \Gamma(\bar{\omega})]\, s = 0, \\ \bar{\omega}: &\quad [\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})]\, sk - \lambda \Gamma'(\bar{\omega})\, sk = 0, \\ \lambda: &\quad [1 - \Gamma(\bar{\omega})]\, sk - s = 0. \end{aligned}$$

Note that the assumptions made about $\Gamma(\bar{\omega})$ and $\mu G(\bar{\omega})$ imply that the bank's expected profit share net of expected default costs satisfies

$$\Gamma(\bar{\omega}) - \mu G(\bar{\omega}) > 0 \quad \text{for} \quad \bar{\omega} \in (0, \infty) \tag{A.1}$$

and

$$\lim_{\bar{\omega}\to 0} \Gamma(\bar{\omega}) - \mu G(\bar{\omega}) = 0, \qquad \lim_{\bar{\omega}\to\infty} \Gamma(\bar{\omega}) - \mu G(\bar{\omega}) = 1 - \mu.$$

In order for the bank's profits to be bounded in the case where the borrower defaults with probability one, we therefore assume that $s < 1/(1-\mu)$ (compare Bernanke et al., 1999).

We further assume that $\bar{\omega}h(\bar{\omega})$ is increasing in $\bar{\omega}$, where $h(\bar{\omega})$ denotes the *hazard rate* $f(\bar{\omega})/[1-F(\bar{\omega})]$.[29] Hence, there exists an $\bar{\omega}^*$ such that

$$\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega}) = [1-F(\bar{\omega})][1-\mu\bar{\omega}h(\bar{\omega})] \gtreqless 0 \quad \text{for} \quad \bar{\omega} \lesseqgtr \bar{\omega}^*,$$

i.e., the bank's expected net profit share reaches a global maximum at $\bar{\omega}^*$. Moreover, the above assumption implies that

$$\Gamma'(\bar{\omega})G''(\bar{\omega}) - \Gamma''(\bar{\omega})G'(\bar{\omega}) = \frac{\partial[\bar{\omega}h(\bar{\omega})]}{\partial\bar{\omega}}[1-F(\bar{\omega})]^2 > 0 \quad \text{for all } \bar{\omega}. \tag{A.2}$$

Consider first the FOC w.r.t. $\bar{\omega}$, which implies that

$$\lambda(\bar{\omega}) = \frac{\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})}{\Gamma'(\bar{\omega})}.$$

Taking the partial derivative w.r.t. $\bar{\omega}$, we obtain

$$\begin{aligned}\lambda'(\bar{\omega}) &= \frac{\Gamma'(\bar{\omega})[\Gamma''(\bar{\omega}) - \mu G''(\bar{\omega})] - \Gamma''(\bar{\omega})[\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega})]}{[\Gamma'(\bar{\omega})]^2}. \\ &= \frac{\mu[\Gamma''(\bar{\omega})G'(\bar{\omega}) - \Gamma'(\bar{\omega})G''(\bar{\omega})]}{[\Gamma'(\bar{\omega})]^2} < 0, \end{aligned} \tag{A.3}$$

because $\Gamma'(\bar{\omega}) = 1 - F(\bar{\omega}) > 0$ and $\Gamma''(\bar{\omega})G'(\bar{\omega}) - \Gamma'(\bar{\omega})G''(\bar{\omega}) < 0$ from (A.2) for all $\bar{\omega}$.
Taking limits,

$$\lim_{\bar{\omega}\to 0} \lambda(\bar{\omega}) = 1, \qquad \lim_{\bar{\omega}\to\bar{\omega}^*} \lambda(\bar{\omega}) = 0.$$

In contrast to Bernanke et al. (1999), $\lambda(\bar{\omega})$ is therefore a decreasing function of the cutoff. This is due to the fact that, while the bank's expected share of total profits is increasing in $\bar{\omega}$, a higher default threshold also implies a higher expected verification cost. At $\bar{\omega}^*$, the increase in the expected verification cost, $\mu G'(\bar{\omega})$, exactly offsets the increase in the bank's expected gross profit share, $\Gamma'(\bar{\omega})$. As a consequence, the shadow value of loosening the borrower's PC converges to zero as $\bar{\omega} \to \bar{\omega}^*$.

From the FOC w.r.t. k, we can furthermore define a function

$$\rho(\bar{\omega}) \equiv \frac{1}{\Gamma(\bar{\omega}) - \mu G(\bar{\omega}) + \lambda[1-\Gamma(\bar{\omega})]} = s.$$

Taking the partial derivative w.r.t. $\bar{\omega}$, we obtain

$$\begin{aligned}\rho'(\bar{\omega}) &= -\rho(\bar{\omega})^2\{\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega}) + \lambda'(\bar{\omega})[1-\Gamma(\bar{\omega})] - \lambda(\bar{\omega})\Gamma'(\bar{\omega})\} \\ &= -\rho(\bar{\omega})^2\{\lambda(\bar{\omega})\Gamma'(\bar{\omega}) + \lambda'(\bar{\omega})[1-\Gamma(\bar{\omega})] - \lambda(\bar{\omega})\Gamma'(\bar{\omega})\} \\ &= \underbrace{-\rho(\bar{\omega})^2}_{<0}\underbrace{\lambda'(\bar{\omega})}_{<0}\underbrace{[1-\Gamma(\bar{\omega})]}_{>0} > 0, \end{aligned} \tag{A.4}$$

[29] Given that we borrow the definitions of $\Gamma(\bar{\omega})$ and $\Gamma(\bar{\omega}) - \mu G(\bar{\omega})$ from Bernanke et al. (1999), our assumption about the hazard rate and its implications are identical to those in their Appendix A.

where the second equality uses the FOC w.r.t. $\bar{\omega}$. In the limit, as $\bar{\omega}$ goes to 0 and $\bar{\omega}^*$, respectively,

$$\lim_{\bar{\omega}\to 0} \rho(\bar{\omega}) = 1 \qquad \text{(due to } \lim_{\bar{\omega}\to 0} \lambda(\bar{\omega}) = 1 \text{ and } \lim_{\bar{\omega}\to 0} G(\bar{\omega}) = 0\text{)},$$

$$\lim_{\bar{\omega}\to \bar{\omega}^*} \rho(\bar{\omega}) = \frac{1}{\Gamma(\bar{\omega}^*) - \mu G(\bar{\omega}^*)} \equiv s^* \qquad \text{(due to } \lim_{\bar{\omega}\to \bar{\omega}^*} \lambda(\bar{\omega}) = 0\text{)}.$$

Accordingly, there is a one-to-one mapping between the optimal cutoff, $\bar{\omega}$, and the premium on external funds, s, as in Bernanke et al. (1999). Inverting the function $s = \rho(\bar{\omega})$, we can therefore express the cutoff as $\bar{\omega} = \bar{\omega}(s)$, where $\bar{\omega}'(s) > 0$ for $s \in (1, s^*)$.

From the FOC w.r.t. λ, i.e. the borrower's PC, we finally define

$$\Psi(\bar{\omega}) = \frac{1}{1 - \Gamma(\bar{\omega})} = k.$$

Taking the partial derivative w.r.t. $\bar{\omega}$, we obtain

$$\Psi'(\bar{\omega}) = -\Psi(\bar{\omega})^2 \left[-\Gamma'(\bar{\omega})\right] = \underbrace{\Psi(\bar{\omega})^2}_{>0} \underbrace{\left[1 - F(\bar{\omega})\right]}_{>0} > 0. \tag{A.5}$$

Hence, the qualitative implications are the same as in Bernanke et al. (1999). Taking limits,

$$\lim_{\bar{\omega}\to 0} \Psi(\bar{\omega}) = 1, \qquad \lim_{\bar{\omega}\to \bar{\omega}^*} \Psi(\bar{\omega}) = \frac{1}{1 - \Gamma(\bar{\omega}^*)} < \infty.$$

Combining $k = \Psi(\bar{\omega})$ and $\bar{\omega} = \bar{\omega}(s)$, where $\Psi'(\bar{\omega}) > 0$ and $\bar{\omega}'(s) > 0$, we can express the capital/net worth ratio, $k = QK/N$, as a function $k = \psi(s)$, where $\psi'(s) > 0$ for $s \in (1, s^*)$.

Appendix A.1.2. Proof of Interior Solution

Bernanke et al. (1999) use a general equilibrium argument to justify their assumption of an interior solution, i.e. an optimal contract with $\bar{\omega} < \bar{\omega}^*$ and $s < s^*$. In particular, they argue that "as s approaches s^* from below, the capital stock becomes unbounded. In equilibrium this will lower the excess return s." (compare Bernanke et al., 1999, p.1384).

Here, we employ an analytical argument instead. Recall that the lender's iso-profit curves (IPC) and the borrower's participation constraint (PC) in $(k, \bar{\omega})$-space can be written as

$$k_{IPC} = \frac{\pi^b - 1 - n}{\left[\Gamma(\bar{\omega}) - \mu G(\bar{\omega})\right] s - 1}, \tag{A.6}$$

$$k_{PC} \geq \frac{1}{1 - \Gamma(\bar{\omega})}, \tag{A.7}$$

where π^b denotes an arbitrary level of bank profits.

Recall further that, in $(k, \bar{\omega})$-space, the optimal contract is determined by the tangential point of the borrower's PC with the lowest IPC of the lender. Consider first the borrower's PC in (A.7). Since $\Gamma'(\bar{\omega}) > 0$, k_{PC} is a strictly increasing function for any $\bar{\omega} \in [0, \infty)$, so that the borrower's PC has a positive slope everywhere in $(k, \bar{\omega})$-space.

Consider next the lender's IPC in (A.6). Taking the partial derivative of k_{IPC} w.r.t. $\bar{\omega}$,

$$\left.\frac{\partial k}{\partial\bar{\omega}}\right|_{IPC} = \left(1-\pi^b+n\right)\frac{\left[\Gamma'(\bar{\omega})-\mu G'(\bar{\omega})\right]s}{\left\{\left[\Gamma(\bar{\omega})-\mu G(\bar{\omega})\right]s-1\right\}^2} \quad \begin{cases} >0 & \text{for} \quad \bar{\omega}\in[0,\bar{\omega}^*) \\ =0 & \text{for} \quad \bar{\omega}=\bar{\omega}^* \\ <0 & \text{for} \quad \bar{\omega}\in(\bar{\omega}^*,\infty) \end{cases} .$$

Accordingly, the lender's IPC has a positive slope in $(k,\bar{\omega})$-space *left of* $\bar{\omega}^*$ and a negative slope *right of* $\bar{\omega}^*$.

Since the optimal contract requires that

$$\left.\frac{\partial k}{\partial\bar{\omega}}\right|_{IPC} = \left.\frac{\partial k}{\partial\bar{\omega}}\right|_{PC},$$

at the tangential point, and we already know that

$$\left.\frac{\partial k}{\partial\bar{\omega}}\right|_{PC} = \frac{\Gamma'(\bar{\omega})}{\left[1-\Gamma(\bar{\omega})\right]^2} > 0 \quad \text{for} \quad \bar{\omega}\in[0,\infty)$$

the optimal default threshold can only lie in $\bar{\omega}\in[0,\bar{\omega}^*)$, which guarantees an *interior solution* to the bank's constrained profit maximization problem.[30]
This completes the proof.

Appendix A.1.3. Proof of Uniqueness

As shown above, the tangential point of the borrower's participation constraint (PC) and the lender's iso-profit curve (IPC) is located on the interval $[0,\bar{\omega}^*)$. Uniqueness requires that there is exactly one such point, i.e., we need to show that there exists only one $\bar{\omega}$ that satisfies both

$$k_{PC} = \frac{1}{1-\Gamma(\bar{\omega})} = \frac{\pi^b-1-n}{\left[\Gamma(\bar{\omega})-\mu G(\bar{\omega})\right]s-1} = k_{IPC} \tag{A.8}$$

and

$$\left.\frac{\partial k}{\partial\bar{\omega}}\right|_{PC} \equiv \frac{\Gamma'(\bar{\omega})}{\left[1-\Gamma(\bar{\omega})\right]^2} = \frac{\left(1-\pi^b+n\right)s\left[\Gamma'(\bar{\omega})-\mu G'(\bar{\omega})\right]}{\left\{\left[\Gamma(\bar{\omega})-\mu G(\bar{\omega})\right]s-1\right\}^2} \equiv \left.\frac{\partial k}{\partial\bar{\omega}}\right|_{IPC}, \tag{A.9}$$

as the levels of k as well as the slopes implied by the PC and the IPC are identical at the point of tangency.

In what follows, we suppress the dependence of $\Gamma(\bar{\omega})$ and $G(\bar{\omega})$ on their argument $\bar{\omega}$ for notational ease. Note that (A.8) and (A.9) can be merged into a single condition that must hold at the tangential point:

$$\frac{\Gamma'-\mu G'}{\Gamma'} = \frac{1-\pi^b+n}{s}. \tag{A.10}$$

Given that $\Gamma' = 1-F \neq 0$ on $[0,\bar{\omega}^*)$, we can rewrite (A.10) as

$$1-\frac{\mu G'}{\Gamma'} = \frac{1-\pi^b+n}{s} \qquad \Leftrightarrow \qquad \frac{G'}{\Gamma'} = \frac{1}{\mu}\left(1-\frac{1-\pi^b+n}{s}\right),$$

the right-hand side of which is constant and thus a horizontal line in $(k,\bar{\omega})$-space.

Partially differentiating the left-hand side with respect to $\bar{\omega}$ yields

[30] Note that our line of argument equally applies to the formulation of the financial contract in Bernanke et al. (1999), likewise guaranteeing an interior solution.

$$\frac{\partial\left(G'/\Gamma'\right)}{\partial\bar{\omega}}=\frac{G''\Gamma'-\Gamma''G'}{\left(\Gamma'\right)^{2}}>0\quad\text{for all }\bar{\omega}\text{ from (A.2).}$$

Given that the left-hand side is monotonically increasing in $\bar{\omega}$, it can cross the horizontal line defined by the right-hand side at *no more than one point* on $[0, \bar{\omega}^{*})$, yielding a unique point of tangency between the borrower's PC and the lender's IPC.[31]
This completes the proof.

Appendix A.2. With Aggregate Risk

In the presence of aggregate risk, the loan contract between the bank and entrepreneur i is affected by the entrepreneur's idiosyncratic risk, ω_{t+1}^{i}, as well as by the ex-post realization of R_{t+1}^{k}. In this appendix, we establish a positive relationship between the entrepreneur's capital/net worth ratio, $k_{t}^{i}\equiv Q_{t}K_{t}^{i}/N_{t}^{i}$, and the *ex-ante expected* external finance premium (EFP), $s_{t}\equiv E_{t}R_{t+1}^{k}/R_{t}^{n}$. Again, we suppress time subscripts and index superscripts for notational convenience.

Following Bernanke et al. (1999), it is convenient to write total profits per unit of capital expenditures as $\tilde{u}\omega R^{k}$, where $\tilde{u}$ denotes an aggregate shock to the gross real rate of return on capital, while ω continues to denote the entrepreneur's idiosyncratic productivity shock, where $E(\tilde{u})=E(\omega)=1$. Using definitions from the main text and Appendix Appendix A.1, we can rewrite the bank's constrained profit maximization problem in equation (6) as

$$\max_{k,\bar{\omega}}\quad E\left\{\left[\Gamma(\bar{\omega})-\mu G(\bar{\omega})\right]\tilde{u}sk-(k-1-n)\right\}\qquad\text{s. t.}\qquad E\left\{\left[1-\Gamma(\bar{\omega})\right]\tilde{u}sk-\tilde{u}s\right\}\geq 0.$$

The corresponding Lagrangian,

$$\mathcal{L}=E\left\{\left[\Gamma(\bar{\omega})-\mu G(\bar{\omega})\right]\tilde{u}sk-(k-1-n)+\lambda\left(\left[1-\Gamma(\bar{\omega})\right]\tilde{u}sk-\tilde{u}s\right)\right\},$$

yields the following first-order conditions (FOCs):

$$\begin{aligned}
k:&\qquad E\left\{\left[\Gamma(\bar{\omega})-\mu G(\bar{\omega})\right]\tilde{u}s-1+\lambda\left[1-\Gamma(\bar{\omega})\right]\tilde{u}s\right\}=0,\\
\bar{\omega}:&\qquad E\left\{\left[\Gamma'(\bar{\omega})-\mu G'(\bar{\omega})\right]\tilde{u}sk-\lambda\Gamma'(\bar{\omega})\tilde{u}sk\right\}=0,\\
\lambda:&\qquad E\left\{\left[1-\Gamma(\bar{\omega})\right]\tilde{u}sk-\tilde{u}s\right\}=0.
\end{aligned}$$

As discussed in the main text, we assume that the borrower's participation constraint (PC) is satisfied *ex post*, i.e. for each realization of $\tilde{u}$. As a consequence, $\bar{\omega}$ and any function thereof, such as $\Gamma(\bar{\omega})$ and $\Gamma'(\bar{\omega})$, for example, is independent of the realization of $\tilde{u}$. Using this assumption, the above FOCs simplify to

$$\begin{aligned}
k:&\qquad E\left\{\left[\Gamma(\bar{\omega})-\mu G(\bar{\omega})\right]\tilde{u}s+\lambda\left[1-\Gamma(\bar{\omega})\right]\tilde{u}s\right\}=1,\\
\bar{\omega}:&\qquad \left[\Gamma'(\bar{\omega})-\mu G'(\bar{\omega})\right]=\lambda\Gamma'(\bar{\omega}),\\
\lambda:&\qquad \left[1-\Gamma(\bar{\omega})\right]k=1.
\end{aligned}$$

[31]Note that G'/Γ' is defined on $\bar{\omega}\in[0,\infty)$ and takes values on $[0,\infty)$. For this reason, the intersection between G'/Γ' and $\left[1-\left(1-\pi^{b}+n\right)/s\right]/\mu$ exists for $\pi^{b}\geqslant 1+n-s$.

Partially differentiating the borrower's ex-post PC w.r.t. k and $\bar{\omega}$, respectively, we obtain

$$\frac{\partial}{\partial k} = 1 - \Gamma(\bar{\omega}) - \Gamma'(\bar{\omega}) k \frac{\partial \bar{\omega}}{\partial k} = 0 \qquad \Rightarrow \qquad \frac{\partial \bar{\omega}}{\partial k} = \frac{1 - \Gamma(\bar{\omega})}{\Gamma'(\bar{\omega}) k} > 0$$

and

$$\frac{\partial}{\partial s} = -\Gamma'(\bar{\omega}) k \frac{\partial \bar{\omega}}{\partial s} = 0 \qquad \Rightarrow \qquad \frac{\partial \bar{\omega}}{\partial s} = 0.$$

Furthermore defining $\Upsilon(\bar{\omega}) \equiv \Gamma(\bar{\omega}) - \mu G(\bar{\omega}) + \lambda [1 - \Gamma(\bar{\omega})]$, total differentiation of the FOC w.r.t. k yields

$$\begin{aligned}
& E\left\{\tilde{u}\Upsilon(\bar{\omega}) + \tilde{u}s\Upsilon'(\bar{\omega})\left(\frac{\partial \bar{\omega}}{\partial s}ds + \frac{\partial \bar{\omega}}{\partial k}dk\right)\right\} = 0 \\
\Leftrightarrow \qquad & E\left\{\tilde{u}s\Upsilon'(\bar{\omega})\frac{\partial \bar{\omega}}{\partial k}\right\} dk = -E\left\{\tilde{u}\Upsilon(\bar{\omega}) + \tilde{u}s\Upsilon'(\bar{\omega})\frac{\partial \bar{\omega}}{\partial s}\right\} ds \\
\Rightarrow \qquad & \frac{dk}{ds} = -\frac{E\left\{\tilde{u}\Upsilon(\bar{\omega}) + \tilde{u}s\Upsilon'(\bar{\omega})\frac{\partial \bar{\omega}}{\partial s}\right\}}{E\left\{\tilde{u}s\Upsilon'(\bar{\omega})\frac{\partial \bar{\omega}}{\partial k}\right\}} = -\frac{E\{\tilde{u}\Upsilon(\bar{\omega})\}}{E\left\{\tilde{u}s\Upsilon'(\bar{\omega})\frac{\partial \bar{\omega}}{\partial k}\right\}} > 0,
\end{aligned}$$

where the final equality makes use of our previous results that $\partial\bar{\omega}/\partial k > 0$, $\partial\bar{\omega}/\partial s = 0$, and

$$\Upsilon'(\bar{\omega}) = \underbrace{\Gamma'(\bar{\omega}) - \mu G'(\bar{\omega}) - \lambda(\bar{\omega})\Gamma'(\bar{\omega})}_{= 0 \text{ from the FOC w.r.t. } \bar{\omega}} + \lambda'(\bar{\omega})[1 - \Gamma(\omega)] = \lambda'(\bar{\omega}) k^{-1} < 0.$$

Similar to Bernanke et al. (1999), the optimal loan contract therefore implies a positive relationship between the borrower's capital/net worth ratio and the ex-ante expected EFP even in the presence of aggregate risk. This completes the proof.

Appendix A.3. Heuristic Argument for our Risk-Sharing Agreement

Suppose that Z_t^i was predetermined and thus acyclical in period $t+1$. Given that B_t^i and $Q_t K_t^i$ are also predetermined in $t+1$, the definition of the default threshold in (3) implies that $\bar{\omega}_{t+1}^i$ is a strictly convex, decreasing function in $R_{t+1}^k \; \forall Z_t^i, R_{t+1}^k > 0$.[32] Accordingly, an unexpected decrease in R_{t+1}^k raises $\bar{\omega}_{t+1}^i$ by more than an equivalent unexpected increase in R_{t+1}^k lowers $\bar{\omega}_{t+1}^i$, i.e., symmetric fluctuations in R_{t+1}^k imply *asymmetric* fluctuations in the default threshold and thus in the default rate of entrepreneurs, even if the idiosyncratic productivity shocks were uniformly distributed. This asymmetry is amplified if ω_{t+1}^i follows a log-normal distribution with $\bar{\omega}_{t+1}^i$ in the left tail of the distribution, as we assume below. Since default imposes a resource cost on the economy in this model, any (unexpected) cyclicality of $\bar{\omega}_{t+1}^i$ over the business cycle is undesirable. Our risk-sharing agreement, where the bank bears the aggregate risk and hence $\bar{\omega}_{t+1}^i$ is acyclical on impact, eliminates the share of the monitoring cost that is due to the asymmetric fluctuations in entrepreneur default.

[32] Recall that Z_t^i and R_{t+1}^k are the *gross* non-default rates of return on a loan to entrepreneur i and per unit of capital, respectively.

Appendix B. The General Equilibrium Model

The general equilibrium model comprises eight types of economic agents: A representative household, a representative capital goods producer, a representative intermediate goods producer, a continuum of monopolistically competitive retailers, a continuum of monopolistically competitive labor unions, a continuum of perfectly competitive entrepreneurs, a monopolistic bank, and a monetary authority.

Appendix B.1. Entrepreneurs

At the end of period t, entrepreneurs use their accumulated net worth, N_t, to purchase productive capital, K_t, from capital goods producers at a price Q_t in terms of the numeraire. To finance the difference between their net worth and total capital expenditures, $Q_t K_t$, entrepreneurs must borrow an amount $B_t = Q_t K_t - N_t$ in real terms from banks, where variables without an index superscript denote economy-wide aggregates.

The entrepreneur decides on the degree of capital utilization u_t and rents part of capital services $u_t K_{t-1}$ to the intermediate goods producers (introduced below). The revenue from selling the capital services is $r_t^k u_t K_{t-1}$ and the cost (in real terms) of adjusting the capital utilization rate is $a(u_t)K_{t-1}$, where we assume $a' > 0$ and $a'' > 0$. The optimization problem of the entrepreneur is given by:

$$\max_{u_t} \quad \left[r_t^k u_t - a(u_t)\right] \omega K_{t-1}$$

In the aggregate optimum, i.e. averaged over all entrepreneurs, it must hold that

$$r_t^k = a'(u_t). \tag{B.1}$$

As in Christiano et al. (2014), we employ the following functional form for the adjustment cost function of the capital utilization rate:

$$a(u_t) = \frac{r_{ss}^k}{\sigma_u} \left[\exp\left\{\sigma_u (u_t - 1)\right\} - 1\right], \tag{B.2}$$

where r_{ss}^k refers to the steady-state rental rate of capital services.

The aggregate real rate of return per unit of capital in period t depends on the real rental rate of capital services, $r_t^k u_t$, and the capital gain of the non-depreciated capital stock, $(1 - \delta)K_{t-1}$, between $t - 1$ and t in real terms, net of capital utilization adjustment costs $a(u_t)$:

$$R_t^k = \frac{r_t^k u_t + (1 - \delta)Q_t - a(u_t)}{Q_{t-1}}. \tag{B.3}$$

A continuum of risk-neutral entrepreneurs, indexed $i \in [0, 1]$, is hit by an idiosyncratic disturbance ω_t^i in period t. As a result, the ex-post rate of return of entrepreneur i per unit of capital equals $\omega_t^i R_t^k$. Following Bernanke et al. (1999), we assume that ω_t^i is i.i.d. across time t and across entrepreneurs i, with a continuous and differentiable cumulative distribution function $F(\omega)$ over a non-negative support, where $E\left\{\omega_t^i\right\} = 1 \; \forall t$ and the corresponding *hazard rate* $h(\omega) \equiv f(\omega) / [1 - F(\omega)]$ satisfies $\partial \omega h(\omega)/\partial \omega > 0$.

In contrast to Bernanke et al. (1999) and variations thereof, we assume that entrepreneurs can operate even in *financial autarky* by purchasing $Q_t K_t = N_t$ in period t. In order for an entrepreneur to accept a loan offer, the terms of the loan, i.e. the amount B_t and the nominal non-default rate of return, Z_t, must be such that the entrepreneur expects to be no worse off than in financial autarky. Assuming constant returns to scale (CRS), the distribution of net worth, N_t^i, across entrepreneurs is irrelevant. As a consequence, the aggregate version of the participation constraint in equation (4) can be written as

$$E_t\left\{\int_{\bar{\omega}_{t+1}}^{\infty} \omega R_{t+1}^k Q_t K_t - \frac{Z_t}{\pi_{t+1}} dF(\omega)\right\} \geq E_t\left\{R_{t+1}^k\right\} N_t, \tag{B.4}$$

where the expectation is over R_{t+1}^k, and $\bar{\omega}_{t+1}$ denotes the *expected* default threshold in period $t+1$, defined by $E_t\left\{\bar{\omega}_{t+1} R_{t+1}^k\right\} Q_t K_t \equiv E_t\left\{Z_t/\pi_{t+1}\right\} B_t$.

Using the definition of $\bar{\omega}_{t+1}$ to substitute out $E_t\left\{Z_t/\pi_{t+1}\right\}$ and expressing the aggregate profit share of entrepreneurs in period t as $1-\Gamma\left(\bar{\omega}_t\right)$, equation (B.4) can equivalently be written as

$$E_t\left\{\left[1-\Gamma\left(\bar{\omega}_{t+1}\right)\right] R_{t+1}^k\right\} Q_t K_t \geq E_t\left\{R_{t+1}^k\right\} N_t. \tag{B.5}$$

Note that the ex-post realized value of $\Gamma\left(\bar{\omega}_{t+1}\right)$ generally depends on the realization of R_{t+1}^k through $\bar{\omega}_{t+1}$. Similar to Bernanke et al. (1999), we assume that this constraint must be satisfied *ex post*. Implicit in this is the assumption that R_{t+1}^k is observed by both parties without incurring a cost, and that the non-default repayment, Z_t, can thus be made contingent on the *aggregate* state of the economy.

In order to avoid that entrepreneurial net worth grows without bound, we assume that an exogenous fraction $(1-\gamma^e)$ of the entrepreneurs' share of total realized profits is consumed in each period.[33] As a result, entrepreneurial net worth at the end of period t evolves according to

$$N_t = \gamma^e\left[1-\Gamma(\bar{\omega}_t)\right] R_t^k Q_{t-1} K_{t-1}. \tag{B.6}$$

To sum up, the entrepreneurs' equilibrium conditions comprise the real rate of return per unit of capital in (B.3), the ex-post participation constraint in (B.5), the evolution of entrepreneurial net worth in (B.6), and the real amount borrowed, $B_t = Q_t K_t - N_t$. Moreover, the definition of the expected default threshold, $E_t \bar{\omega}_{t+1}$, determines the expected non-default repayment per unit borrowed by the entrepreneurs, $E_t\left\{Z_t/\pi_{t+1}\right\}$.

Appendix B.1.1. Risk Shocks

We follow Christiano et al. (2014) to introduce risks shock, $\sigma_{\omega,t}$, into the model, which capture the extent of cross-sectional dispersion in ω. Risk shocks follow an AR(1)-process with autocorrelation coefficient ρ_σ and mean-zero normally distributed disturbances, u_t^σ. To incorporate both unanticipated and anticipated components of risk shocks, we adopt the following representation from Christiano et al. (2014):

$$\log u_t^\sigma = \xi_{0,t} + \xi_{1,t-1} + \cdots + \xi_{p,t-p},$$

[33] In the literature, it is common to assume that an exogenous fraction of entrepreneurs "dies" each period and consumes its net worth upon exit. The dynamic implications of either assumption are identical.

where $p = 8$, $\xi_{0,t}$ denotes the unanticipated component, while $\xi_{j,t}$, $j > 0$, are so-called "news" components. We assume the following correlation structure:

$$\rho_{\xi}^{[i,j]} = \frac{E\xi_{i,t}\xi_{i,t}}{\sqrt{\left(E\xi_{i,t}^2\right)\left(E\xi_{i,t}^2\right)}}, \qquad i, j = 0, \ldots, p, \tag{B.7}$$

where $\rho_{\xi}^{[i,j]} \in [-1, 1]$. For parsimony, the standard deviation of the anticipated component is equal to σ_{σ}, while the standard deviations of all news components are assumed to be identical and equal to σ_{ξ}.

Appendix B.2. The Bank

For tractability, we assume a single *monopolistic* financial intermediary, which collects deposits from households and provides loans to entrepreneurs. In period t, this bank is endowed with net worth or bank capital N_t^b. Abstracting from bank reserves or other types of bank assets, the balance sheet identity in real terms is given by equation (1). The CSV problem in Townsend (1979) implies that, if entrepreneur i defaults due to $\omega_t^i R_t^k Q_{t-1} K_{t-1}^i < (Z_{t-1}^i/\pi_t) B_{t-1}^i$, the bank incurs a proportional cost $\mu\omega_t^i R_t^k Q_{t-1} K_{t-1}^i$ and recovers the remaining return on capital, $(1-\mu)\omega_t^i R_t^k Q_{t-1} K_{t-1}^i$.

In period t, the risk-neutral bank observes entrepreneurs' net worth, N_t^i, and makes a take-it-or-leave-it offer to each entrepreneur i. As a consequence, it holds a perfectly diversified loan portfolio between period t and period $t+1$. Although the bank can thus diversify away any idiosyncratic risk arising from the possible default of entrepreneur i, it is subject to aggregate risk through fluctuations in the ex-post rate of return on capital, R_{t+1}^k, and the aggregate default threshold, $\bar{\omega}_{t+1}$. In order to be able to pay the risk-free nominal rate of return R_t^n on deposits *in each state of the world*, the bank must have sufficient net worth to protect depositors from unexpected fluctuations in R_{t+1}^k.

Now consider the bank's problem of making a take-it-or-leave-it offer to entrepreneur i with net worth N_t^i in period t. The contract offered by the bank specifies the real amount of the loan, B_t^i, and the nominal gross rate of return in case of repayment, Z_t^i. Given that N_t^i is predetermined at the end of period t, the bank's choice of B_t^i also determines the entrepreneur's total capital expenditure, $Q_t K_t^i = B_t^i + N_t^i$. Moreover, given $Q_t K_t^i$ and N_t^i, the bank's choice of Z_t^i implies an expected default threshold $E_t\bar{\omega}_{t+1}$ through $E_t\left\{\bar{\omega}_{t+1} R_{t+1}^k\right\} Q_t K_t \equiv E_t\left\{Z_t/\pi_{t+1}\right\} B_t$. Hence, we can equivalently rewrite the bank's constrained profit-maximization problem for a loan to entrepreneur i as

$$\max_{K_t^i, \bar{\omega}_{t+1}^i} \quad E_t\left\{\left[\Gamma\left(\bar{\omega}_{t+1}^i\right) - \mu G\left(\bar{\omega}_{t+1}^i\right)\right] R_{t+1}^k Q_t K_t^i - \frac{R_t^n}{\pi_{t+1}}\left(Q_t K_t^i - N_t^i - N_t^{b,i}\right)\right\}, \tag{B.8}$$

where $\Gamma\left(\bar{\omega}_t^i\right) \equiv \int_0^{\bar{\omega}_t^i} \omega dF(\omega) + \bar{\omega}_t^i\left[1 - F\left(\bar{\omega}_t^i\right)\right]$, $\mu G\left(\bar{\omega}_t^i\right) \equiv \mu\int_0^{\bar{\omega}_t^i} \omega dF(\omega)$, and $N_t^{b,i}$ denotes the share of total bank net worth assigned to the loan to entrepreneur i, subject to the participation constraint in (4).

The corresponding first-order conditions with respect to $\left\{K_t^i, E_t\bar{\omega}_{t+1}^i, \lambda_t^{b,i}\right\}$, where $\lambda_t^{b,i}$ denotes the ex-post value of the Lagrange multiplier on the participation constraint, are given by

$$K_t^i: \quad E_t\left\{\left[\Gamma(\bar{\omega}_{t+1}^i) - \mu G(\bar{\omega}_{t+1}^i) + \lambda_t^{b,i}\left(1 - \Gamma(\bar{\omega}_{t+1}^i)\right)\right] R_{t+1}^k\right\} = E_t\left\{\frac{R_t^n}{\pi_{t+1}}\right\}, \tag{B.9}$$

$$E_t\bar{\omega}_{t+1}^i: \quad E_t\left\{\left[\Gamma'(\bar{\omega}_{t+1}^i) - \mu G'(\bar{\omega}_{t+1}^i)\right] R_{t+1}^k\right\} = E_t\left\{\lambda_t^{b,i}\Gamma'(\bar{\omega}_{t+1}^i)R_{t+1}^k\right\}, \tag{B.10}$$

$$\lambda_t^{b,i}: \quad \left[1 - \Gamma(\bar{\omega}_{t+1}^i)\right] R_{t+1}^k Q_t K_t^i = R_{t+1}^k N_t^i. \tag{B.11}$$

Following Bernanke et al. (1999), we show in Appendix Appendix A.2 that the optimal debt contract between entrepreneur i and the bank implies a positive relationship between the expected EFP, $s_t \equiv E_t\left\{R_{t+1}^k \pi_{t+1}/R_t^n\right\}$, and the optimal capital/net worth ratio, $k_t^i \equiv Q_t K_t^i / N_t^i$.

Here, instead, we go beyond this "reduced-form" result and utilize the entire structure inherent in the first-order conditions. Note that (B.9) equates the expected marginal return of an additional unit of capital to the bank and the entrepreneur to the expected marginal cost of an additional unit of bank deposits in real terms. Assuming that the participation constraint is satisfied ex post, this implies a positive relationship between $E_t\left\{R_{t+1}^k \pi_{t+1}\right\}/R_t^n$ and $E_t\left\{\bar{\omega}_{t+1}^i\right\}$. Moreover, (B.11) equates the entrepreneur's expected payoff *with* and *without* the bank loan and implies a positive relationship between $E_t\left\{\bar{\omega}_{t+1}^i\right\}$ and $Q_t K_t^i / N_t^i$.[34] Together, these two conditions determine the positive ex-ante relationship between the expected EFP in period $t + 1$ and the leverage ratio chosen by the bank in period t, while the first-order condition with respect to $E_t\left\{\bar{\omega}_{t+1}^i\right\}$ pins down the ex-post value of the Lagrange multiplier, $\lambda_t^{b,i}$.

Given N_t^i, $Q_t K_t^i$, and $E_t\left\{R_{t+1}^k\right\}$, the definition of the expected default threshold, $E_t\left\{\bar{\omega}_{t+1}^i\right\}$, implies an expected non-default real rate of return on the loan to entrepreneur i, $E_t\left\{Z_t^i/\pi_{t+1}\right\}$, while the same equation evaluated ex post determines the actual non-default repayment conditional on N_t^i, $Q_t K_t^i$, $E_t\left\{\bar{\omega}_{t+1}^i\right\}$, and the realization of R_{t+1}^k.

By the law of large numbers, $\Gamma\left(\bar{\omega}_t^i\right) - \mu G\left(\bar{\omega}_t^i\right)$ denotes the bank's *expected* share of total period-t profits (net of monitoring costs) from a loan to entrepreneur i as well as the bank's *realized* profit share from its diversified loan portfolio of all entrepreneurs. Accordingly, we can rewrite the bank's aggregate expected profits in period $t + 1$ as

$$E_t V_{t+1}^b = E_t\left\{\left[\Gamma\left(\bar{\omega}_{t+1}\right) - \mu G\left(\bar{\omega}_{t+1}\right)\right] R_{t+1}^k Q_t K_t - \frac{R_t^n}{\pi_{t+1}}\left(Q_t K_t - N_t - N_t^b\right)\right\}, \tag{B.12}$$

where the expectation is over possible realizations of R_{t+1}^k and π_{t+1}, while V_{t+1}^b is free of idiosyncratic risk. The entrepreneurs' participation constraint in (B.5) implies that $\bar{\omega}_{t+1}$ and thus $\left[\Gamma\left(\bar{\omega}_{t+1}\right) - \mu G\left(\bar{\omega}_{t+1}\right)\right]$ are predetermined in period $t + 1$. In order to keep the problem tractable, we assume that aggregate risk is small

[34] This becomes evident, when we use the ex-post assumption that R_{t+1}^k and $\bar{\omega}_{t+1}$ are uncorrelated and rewrite (B.11) as

$$\left[1 - \Gamma(\bar{\omega}_{t+1}^i)\right] \geq \frac{N_t^i}{Q_t K_t^i} \equiv \frac{1}{k_t^i},$$

i.e., entrepreneur i's expected return on capital with the loan relative to financial autarky must be no smaller than the entrepreneur's "skin in the game". Since $\left[1 - \Gamma(\bar{\omega}_{t+1}^i)\right]$ is strictly decreasing in $E_t\left\{\bar{\omega}_{t+1}^i\right\}$, the participation constraint implies a positive relationship between $E_t\left\{\bar{\omega}_{t+1}^i\right\}$ and k_t^i.

relative to the bank's net worth, N_t^b, so that bank default never occurs in equilibrium.

In order to avoid that its net worth grows without bound, we assume that an exogenous fraction $(1-\gamma^b)$ of the bank's share of total realized profits is consumed each period.[35] As a result, bank net worth at the end of period t evolves according to

$$N_t^b = \gamma^b V_t^b. \tag{B.13}$$

Appendix B.3. Households

The representative household is risk-averse and derives utility from a Dixit-Stiglitz aggregate of imperfectly substitutable consumption goods,

$$C_t = \left[\int_0^1 C_t(j)^{\frac{\epsilon_p-1}{\epsilon_p}} dj\right]^{\frac{\epsilon_p}{\epsilon_p-1}}. \tag{B.14}$$

Households have an infinite planning horizon and discount their future expected utility with the subjective discount factor $\beta < 1$. They can transfer wealth intertemporally by saving in terms of bank deposits, which pay the risk-free nominal return R_t^n between t and $t+1$.[36] We allow for habit formation in consumption. Households supply homogenous labor to the monopolistically competitive labor unions, which differentiate labor at no cost and set nominal wages. The household's constrained optimization problem can be summarized as

$$\max_{C_t,h_t,D_t} \quad E_0 \sum_{t=0}^{\infty} \beta^t e_t \left\{ \frac{\left(C_t/C_{t-1}^h\right)^{1-\sigma}}{1-\sigma} - \chi \frac{h_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right\},$$

$$C_t + D_t + r_t\tilde{a}_t = \frac{\tilde{a}_{t-1}}{\pi_t} + \frac{R_t^n}{\pi_t} D_{t-1} + h_t^d \int_0^1 w_t^m \left(\frac{w_t^m}{w_t}\right)^{-\epsilon_w} dm + \tilde{\Pi}_t, \tag{B.15}$$

where D_t are real deposits, $\tilde{a}_t$ is the real payoff of nominal state-contingent assets, r_t is the stochastic discount factor between period t and $t+1$, $\pi_t = P_t/P_{t-1}$ is the gross inflation rate, and $P_t \equiv \left[\int_0^1 P_t(j)^{1-\epsilon_p} dj\right]^{\frac{1}{1-\epsilon_p}}$ is the corresponding aggregate price index. $\tilde{\Pi}_t$ denotes net lump-sum transfers of profits to the household from the retailers and labor unions, whereas $h_t^d \int_0^1 w_t^m \left(\frac{w_t^m}{w_t}\right)^{-\epsilon_w} dm$ is the real wage income of the household. The parameter h determines the strength of habit formation, while the preference shocks e_t evolves according to

$$\log e_t = \rho_e \log e_{t-1} + \epsilon_t^e, \quad \epsilon_t^e \sim N(0, \sigma_e^2).$$

The first-order conditions with respect to $\{C_t, D_t\}$, where λ_t denotes the Lagrange multiplier of the budget

[35] Alternatively, one could think of this "consumption" as a distribution of dividends to share holders or bonus payments to bank managers, which are instantaneously consumed.

[36] Note that deposits are risk-free, as long as the bank carries sufficient net worth to shield its depositors from fluctuations in the aggregate return on capital. Assuming that the return on deposits is risk-free *in real terms*, i.e. that the bank compensates depositors also for unexpected fluctuations in the rate of inflation, does *not* affect our result qualitatively.

constraint, are

$$C_t: \qquad e_t \left(\frac{C_t}{C_{t-1}^h} \right)^{1-\sigma} C_t^{-1} - \beta h E_t \left[e_{t+1} \left(\frac{C_{t+1}}{C_t^h} \right)^{1-\sigma} C_t^{-1} \right] = \lambda_t,$$

$$D_t: \qquad \lambda_t = \beta E_t \left\{ \lambda_{t+1} \frac{R_t^n}{\pi_{t+1}} \right\}.$$

We discuss the choice of the optimal labor supply below in Subsection Appendix B.7, jointly with the labor unions' choice of the optimal wage rate.

Appendix B.4. Capital Goods Producers

After production in period t has taken place, capital producers purchase the non-depreciated capital stock from entrepreneurs, invest in a Dixit-Stiglitz aggregate of imperfectly substitutable investment goods, $I_t \equiv \left[\int_0^1 I_t(j)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right]^{\frac{\epsilon_p}{\epsilon_p - 1}}$, and sell the new stock of capital to entrepreneurs at the relative price Q_t. We assume that turning final output into productive capital, i.e. gross investment, is costly due to possible disruptions of the production process, replacement of installed capital, or learning. The accumulation of physical capital can then be written as

$$K_t = (1-\delta) K_{t-1} + x_t \left[1 - S\left(\frac{I_t}{I_{t-1}} \right) \right] I_t, \tag{B.16}$$

where $S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\phi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$, $S(1) = S'(1) = 0$, and $S''(1) = \phi$ (compare, e.g., Christiano et al., 2005). We assume that an investment-specific shock, x_t, affects the production of capital goods and that this shock follows an AR(1)-process:

$$\log x_t = \rho_x \log x_{t-1} + \epsilon_t^x, \quad \epsilon_t^x \sim N(0, \sigma_x^2).$$

The profit-maximization problem of the representative capital goods producer, subject to the capital accumulation equation in (B.16), is given by

$$\max_{I_t} \quad \sum_{s=0}^{\infty} \beta^s \left\{ Q_{t+s} [K_{t+s} - (1-\delta) K_{t+s-1}] - I_{t+s} \right\},$$

while the corresponding FOC with respect to investment in period t is given by

$$Q_t x_t \left[1 - \frac{\phi}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \phi \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] + \beta \phi E_t \left[Q_{t+1} x_{t+1} \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right] = 1. \tag{B.17}$$

Appendix B.5. Intermediate Goods Producers

Intermediate goods producers rent the productive capital stock from entrepreneurs and hire labor from households, paying a competitive rental rate on capital services and a wage rate determined in the labor market, respectively. To convert capital and labor into intermediate or wholesale goods, they use the following Cobb-Douglas production function:

$$Y_t = A_t \tilde{K}_t^{\alpha} h_t^{1-\alpha},$$

where A_t denotes a stationary shock to total factor productivity (TFP) that follows the AR(1)-process

$$\log A_t = \rho_a \log A_{t-1} + \epsilon_t^a, \quad \epsilon_t^a \sim N(0, \sigma_a^2).$$

Note that the first input argument of the production function, $\tilde{K}_t$, stands for capital *services*, defined as

$$\tilde{K}_t = u_t K_{t-1}, \tag{B.18}$$

where u_t is the utilization rate of capital in period t chosen by entrepreneurs.

Suppose that the price of the homogeneous wholesale good in terms of the numeraire is $1/X_t$, so that the gross flexible-price markup of retail goods over the wholesale good is X_t. The static optimization problem of the intermediate goods producer can then be summarized as

$$\max_{\tilde{K}_t, h_t} \quad \frac{1}{X_t} A_t \tilde{K}_t^{\alpha} h_t^{1-\alpha} - r_t^k \tilde{K}_t - w_t h_t,$$

which yields the following FOCs:

$$\tilde{K}_t: \qquad X_t r_t^k = \alpha \frac{Y_t}{\tilde{K}_t},$$

$$h_t: \qquad X_t w_t = (1-\alpha) \frac{Y_t}{h_t}.$$

Appendix B.6. Retailers

Monopolistically competitive retailers purchase homogeneous intermediate output, diversify at no cost, and resell to households and capital goods producer for consumption and investment purposes, respectively. We assume staggered price setting à la Calvo (1983), where θ_p denotes the exogenous probability of *not* being able to readjust the price.

A retailer allowed to reset its price in period t chooses the optimal price, P_t^*, in order to maximize the present value of current and expected future profits, subject to the demand function for the respective product variety in period $t+s$, $s = 0, ..., \infty$, $Y_{t+s}(j) = (P_{t,s}/P_{t+s})^{-\epsilon_p} Y_{t+s}$, where $P_{t,s}$ is the price of a retailer that was last allowed to be set in period t.[37] Hence, the profit maximization problem of a retailer in period t is

$$\max_{P_t^*} \quad E_t \left\{ \sum_{s=0}^{\infty} \theta_p^s \Lambda_{t,t+s} \Pi_{t,s} \right\},$$

where $\Lambda_{t,t+s} \equiv \beta^s E_t \left[U'(C_{t+s})/U'(C_t) \cdot P_t/P_{t+s} \right]$ denotes the stochastic discount factor and

$$\Pi_{t,s} \equiv (P_t^* - MC_{t,s}) \left[\frac{P_t^*}{P_{t+s}} \right]^{-\epsilon_p} Y_{t+s},$$

[37]The isoelastic demand schedule for the product of retailer j can be derived from the definitions of aggregate demand $Y_t = \left[\int_0^1 Y_t(j)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right]^{\frac{\epsilon_p}{\epsilon_p - 1}}$ and the aggregate price index $P_t = \left[\int_0^1 P_t(j)^{1-\epsilon_p} dj \right]^{\frac{1}{1-\epsilon_p}}$.

where $MC_{t,s}$ is the retailer's nominal marginal cost in period $t+s$. The corresponding optimality condition is given by

$$E_t \sum_{s=0}^{\infty} \theta_p^s \Lambda_{t,t+s} Y_{t+s} P_{t+s}^{\epsilon_p} \left[P_t^* - \frac{\epsilon_p}{\epsilon_p - 1} MC_{t,s} \right] = 0.$$

In order to arrive at the New Keynesian Phillips curve, we combine the above FOC with the definition of the aggregate price index,

$$P_t = \left\{ \theta_p P_{t-1}^{1-\epsilon_p} + (1-\theta_p) \left(P_t^*\right)^{1-\epsilon_p} \right\}^{1/(1-\epsilon_p)}.$$

Appendix B.7. Wage Setting

We follow Schmitt-Grohé and Uribe (2006) to introduce nominal wage stickiness. Firms hire labor from a continuum of labor markets of measure 1 indexed by $m \in [0,1]$. In each labor market m, wages are set by a monopolistically competitive labor union. The union faces labor demand $(W_t^m/W_t)^{-\epsilon_w} h_t^d$, where W_t^m is the nominal wage charged by the union in market m at time t, $W_t \equiv \left[\int_0^1 (W_t^m)^{1-\epsilon_w} dm \right]^{1/(1-\epsilon_w)}$ is an economy-wide wage index and h_t^d is aggregate labor demand by firms. In each labor market, the union takes W_t and h_t^d as exogenous. The labor supply by the union satisfies $h_t^m = \left(\frac{w_t^m}{w_t}\right)^{-\epsilon_w} h_t^d$, where $w_t^m \equiv W_t^m/P_t$ and $w_t \equiv W_t/P_t$. The resource constraint implies $h_t = h_t^d \int_0^1 h_t^m dm$, which yields

$$h_t = h_t^d \int_0^1 \left(\frac{w_t^m}{w_t} \right)^{-\epsilon_w} dm. \tag{B.19}$$

We assume that households have access to a complete set of nominal state-contingent assets $\tilde{A}_t$. Each period, consumers can purchase $\tilde{A}_{t+1}$ at the nominal cost $E_t r_t \tilde{A}_{t+1}$, where r_t is the stochastic discount factor between t and $t+1$. The variable $\tilde{a}_t \equiv \tilde{A}_t / P_{t-1}$ denotes the real payoff in period t of nominal state-contingent assets purchased in $t-1$.

Nominal wage stickiness is introduced by the assumption that, each period, a fraction $\theta_w \in [0,1)$ of labor unions *cannot* reoptimize the nominal wage. In these labor markets, wages are indexed to past inflation, π_{t-1}. Let $\beta^t w_t / \tilde{\mu}_t$ be the Lagrange multiplier on (B.19) and $\beta^t \lambda_t$ the Lagrange multiplier on the household budget constraint. Then the Lagrangian associated with the household optimization problem is given by

$$\begin{aligned} \mathcal{L} = & E_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ U(C_t, C_{t-1}, h_t) + \lambda_t \left[h_t^d \int_0^1 \left(\frac{w_t^m}{w_t} \right)^{-\epsilon_w} dm - C_t - D_t - r_t \tilde{a}_t + \frac{\tilde{a}_{t-1}}{\pi_t} + \frac{R_t^n}{\pi_t} D_{t-1} \right] \\ & + \frac{\lambda_t w_t}{\tilde{\mu}_t} \left[h_t - h_t^d \int_0^1 \left(\frac{w_t^m}{w_t} \right)^{-\epsilon_w} dm \right] \Bigg\}. \end{aligned}$$

The FOCs with respect to h_t and w_t^m are as follows:

$$-U_h(C_t, C_{t-1}, h_t) = \frac{\lambda_t w_t}{\tilde{\mu}_t} \tag{B.20}$$

and

$$w_t^m = \begin{cases} \tilde{w}_t & \text{if } w_t^m \text{ is set optimally, and} \\ w_{t-1}^m \pi_{t-1}/\pi_t & \text{otherwise.} \end{cases}$$

If labor demand curves and costs of supplying labor are identical across labor markets, the optimally set wage will be the same across markets, as well. To determine $\tilde{w}_t$, we write the part of the Lagrangian relevant for the optimal wage setting,

$$\mathcal{L}^w = E_t \sum_{s=0}^{\infty} (\theta_w \beta)^s \left(\frac{\prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}}{\pi_{t+k}} \right)}{w_{t+s}} \right)^{-\epsilon_w} h_{t+s}^d \left[\tilde{w}_t^{1-\epsilon_w} \prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}}{\pi_{t+k}} \right) - \tilde{w}_t^{-\epsilon_w} \frac{w_{t+s}}{\tilde{\mu}_{t+s}} \right].$$

Then the FOC with respect to $\tilde{w}_t$ is given by

$$E_t \sum_{s=0}^{\infty} (\theta_w \beta)^s \left(\frac{\tilde{w}_t \prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}}{\pi_{t+k}} \right)}{w_{t+s}} \right)^{-\epsilon_w} h_{t+s}^d \left[\frac{\epsilon_w - 1}{\epsilon_w} \tilde{w}_t \prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}}{\pi_{t+k}} \right) - \frac{-U_h(t+s)}{\lambda_{t+s}} \right] = 0. \tag{B.21}$$

Equation (B.21) implies that, when allowed to reoptimize in period t, each union sets the real wage so that its future expected marginal revenues are equal to the average marginal cost of supplying labor. The marginal revenue s periods after the most recent reoptimization equals $\frac{\epsilon_w - 1}{\epsilon_w} \tilde{w}_t \prod_{k=1}^{s} \left(\frac{\pi_{t+k-1}}{\pi_{t+k}} \right)$, where $\frac{\epsilon_w}{\epsilon_w - 1}$ is the markup of wages over the marginal costs of labor that would prevail without wage stickiness. The marginal cost of supplying labor equals the marginal rate of substitution between consumption and leisure, $\frac{-U_h(t+s)}{\lambda_{t+s}}$. Hence, $\tilde{\mu}_t$ denotes the wedge between the disutility of labor and the average real wage in the economy and can be interpreted as the average markup of labor unions.

In order to state (B.21) recursively, define

$$f_t^1 = \left(\frac{\epsilon_w - 1}{\epsilon_w} \right) \tilde{w}_t E_t \sum_{s=0}^{\infty} (\beta \theta_w)^s \lambda_{t+s} \left(\frac{w_{t+s}}{\tilde{w}_t} \right)^{\epsilon_w} h_{t+s}^d \prod_{k=1}^{s} \left(\frac{\pi_{t+k}}{\pi_{t+k-1}} \right)^{\epsilon_w - 1}$$

and

$$f_t^2 = -\tilde{w}_t^{-\epsilon_w} E_t \sum_{s=0}^{\infty} (\beta \theta_w)^s w_{t+s}^{\epsilon_w} h_{t+s}^d U_h(C_{t+s}, C_{t+s-1}, h_{t+s}) \prod_{k=1}^{s} \left(\frac{\pi_{t+k}}{\pi_{t+k-1}} \right)^{\epsilon_w}.$$

Then f_t^1 and f_t^2 can be written recursively as follows:

$$f_t^1 = \left(\frac{\epsilon_w - 1}{\epsilon_w} \right) \tilde{w}_t \lambda_t \left(\frac{w_t}{\tilde{w}_t} \right)^{\epsilon_w} h_t^d + \theta_w \beta E_t \left(\frac{\pi_{t+1}}{\pi_t} \right)^{\epsilon_w - 1} \left(\frac{\tilde{w}_{t+1}}{\tilde{w}_t} \right)^{\epsilon_w - 1} f_{t+1}^1; \tag{B.22}$$

and

$$f_t^2 = -U_h(C_t, C_{t-1}, h_t) \left(\frac{\tilde{w}_t}{w_t} \right)^{-\epsilon_w} h_t^d + \theta_w \beta E_t \left(\frac{\tilde{w}_{t+1} \pi_{t+1}}{\tilde{w}_t \pi_t} \right)^{\epsilon_w} f_{t+1}^2. \tag{B.23}$$

The FOC with respect to $\tilde{w}_t$ can then be written as

$$f_t^1 = f_t^2. \tag{B.24}$$

Aggregation across labor markets implies

$$h_t = (1 - \theta_w) h_t^d \sum_{s=0}^{\infty} \theta_w^s \left(\frac{\tilde{W}_{t-s} \prod_{k=1}^{s} \left(\frac{\pi_{t+k-s-1}}{\pi_{t+k-s}} \right)}{W_t} \right)^{-\epsilon_w}. \tag{B.25}$$

Defining the measure of wage dispersion as

$$\tilde{s}_t \equiv (1-\theta_w)\sum_{s=0}^{\infty}\theta_w^s\left(\frac{\tilde{W}_{t-s}\prod_{k=1}^{s}\left(\frac{\pi_{t+k-s-1}}{\pi_{t+k-s}}\right)}{W_t}\right)^{-\epsilon_w},$$

we can rewrite equation (B.25) as

$$h_t = \tilde{s}_t h_t^d, \tag{B.26}$$

where the evolution of wage dispersion over time is given by

$$\tilde{s}_t = (1-\theta_w)\left(\frac{\tilde{w}_t}{w_t}\right)^{-\epsilon_w} + \theta_w\left(\frac{w_{t-1}}{w_t}\right)^{-\epsilon_w}\left(\frac{\pi_t}{\pi_{t-1}}\right)^{\epsilon_w}\tilde{s}_{t-1}. \tag{B.27}$$

From the definition of the wage index, $W_t \equiv \left[\int_0^1 (W_t^m)^{1-\epsilon_w} dm\right]^{1/(1-\epsilon_w)}$, it follows that the real wage rate, w_t, can be expressed as

$$w_t^{1-\epsilon_w} = (1-\theta_w)\tilde{w}_t^{1-\epsilon_w} + \theta_w w_{t-1}^{1-\epsilon_w}\left(\frac{\pi_{t-1}}{\pi_t}\right)^{1-\epsilon_w}. \tag{B.28}$$

Equations (B.22)-(B.28) describe the equilibrium in the labor market.

Appendix B.8. Monetary Policy and Market Clearing

We assume that the central bank sets the *nominal* interest rate, R_t^n, according to the following standard Taylor rule:

$$\frac{R_t^n}{R_{ss}^n} = \left(\frac{R_{t-1}^n}{R_{ss}^n}\right)^{\rho}\left[\left(\frac{\pi_t}{\pi_{ss}}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_{ss}}\right)^{\phi_y}\right]^{1-\rho} e^{\nu_t}. \tag{B.29}$$

Hence, the central bank reacts to deviations of inflation and output from their respective steady-state values and might smooth interest rates over time with a weight ρ. Unsystematic deviations from the Taylor rule in (B.29) are captured by a mean-zero i.i.d. random variable, ν_t.

The model is closed by the economy-wide resource constraint,

$$Y_t = C_t + C_t^e + C_t^b + I_t + a(u_t)K_{t-1} + \mu G(\bar{\omega}_t)R_t^k Q_{t-1}K_{t-1}, \tag{B.30}$$

where C_t^e and C_t^b denote the real consumption of entrepreneurial and bank net worth, respectively, $a(u_t)K_{t-1}$ denotes the real adjustment costs due to capital utilization, and $\mu G(\bar{\omega}_t)R_t^k Q_{t-1}K_{t-1}$ the aggregate monitoring costs in period t.

Appendix C. Additional Simulation Results

Appendix C.1. Calibration

Table C.1 summarizes the calibration of exogenous shock processes other than monetary policy shocks used for the simulation and computation of theoretical *unconditional* autocorrelations and cross-correlation with output in Figure C.1 and Figure 3 in the main text. The calibration of productivity, preference, and investment-specific shocks is based on the Maximum Likelihood estimation results in Christensen and Dib (2008), while unanticipated and anticipated risk shocks are calibrated in line with the Bayesian estimation results in Christiano et al. (2014).

Table C.1: Calibration of Additional Shock Processes.

Shock process	Parameter	Value
autocorrelation coefficient of total factor productivity	ρ_a	0.7625
standard deviation of total factor productivity shocks	σ_a	0.0096
autocorrelation coefficient of consumer preferences	ρ_e	0.6165
standard deviation of consumer preference shocks	σ_e	0.0073
autocorrelation coefficient of investment efficiency	ρ_x	0.6562
standard deviation of investment efficiency shocks	σ_x	0.0097
autocorrelation coefficient of exogenous process for σ_ω	ρ_σ	0.97
standard deviation of *unanticipated* risk shocks	σ_σ	0.07
correlation coefficient of *anticipated* risk shocks	ρ_ξ	0.39
standard deviation of *anticipated* risk shocks	σ_ξ	0.028

Appendix C.2. Unconditional Autocorrelations

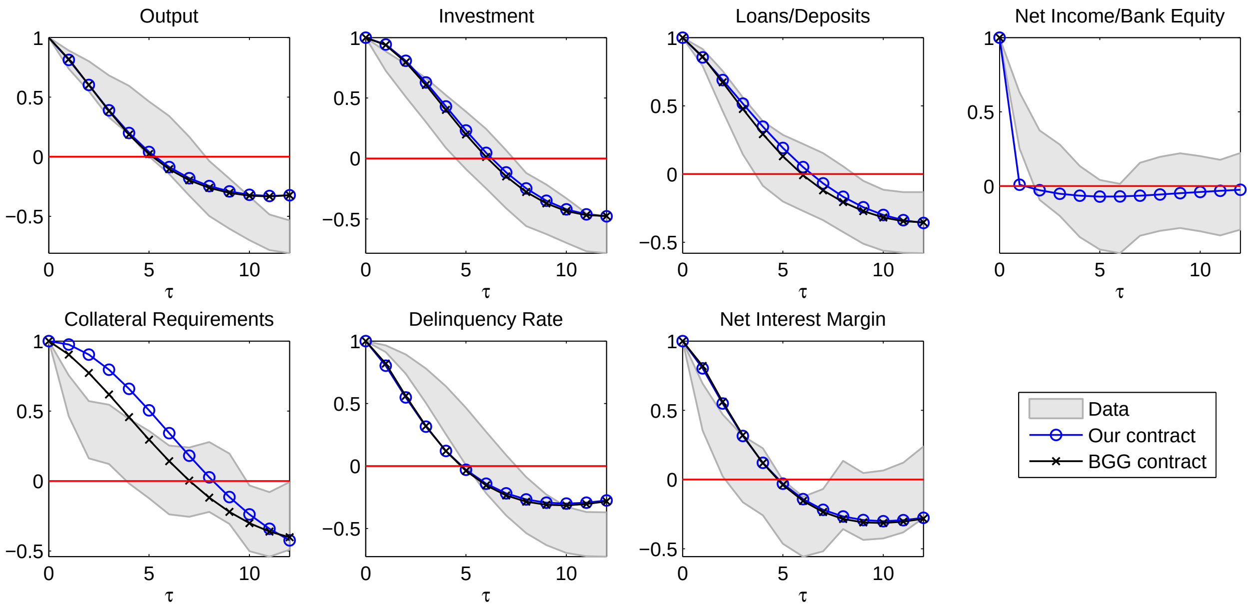
Figure C.1 plots the unconditional autocorrelation coefficients of selected variables and ratios from the benchmark New-Keynesian DSGE model with our optimal debt contract and the optimal debt contract in Bernanke et al. (1999) (BGG) against their empirical counterparts, where both simulated time series and data are HP-filtered before computing second moments. Figure C.1 illustrates that the autocorrelation patterns implied by either of the DSGE models is qualitatively and quantitatively in line with those in the data.

Appendix C.3. "Too Low for Too Long"

Inspired by the motivation in Taylor (2007), we conduct an informal test of the "too-low-for-too-long" hypothesis. According to this hypothesis, a prolonged deviation of monetary policy from what is justified by economic conditions might lead to excessive risk taking in the financial sector. Note that, in our model, a transitory deviation from the Taylor rule becomes more persistent, the higher the degree of interest-rate inertia. In this subsection, we therefore compare the effects of a typical expansionary monetary policy shock for two different values of the Taylor-rule coefficient on the lagged policy rate, ρ, without modifying the other parameters of the model.

Figure C.2 illustrates that higher interest-rate inertia and thus a more persistent reduction in the policy rate, R_t^n, implies an increase in both the peak effect and the persistence of the impulse response functions of the entrepreneurial leverage ratio and default threshold to a monetary easing. Accordingly, the optimal loosening of bank lending standards, measured by the increase in bank lending relative to borrower collateral

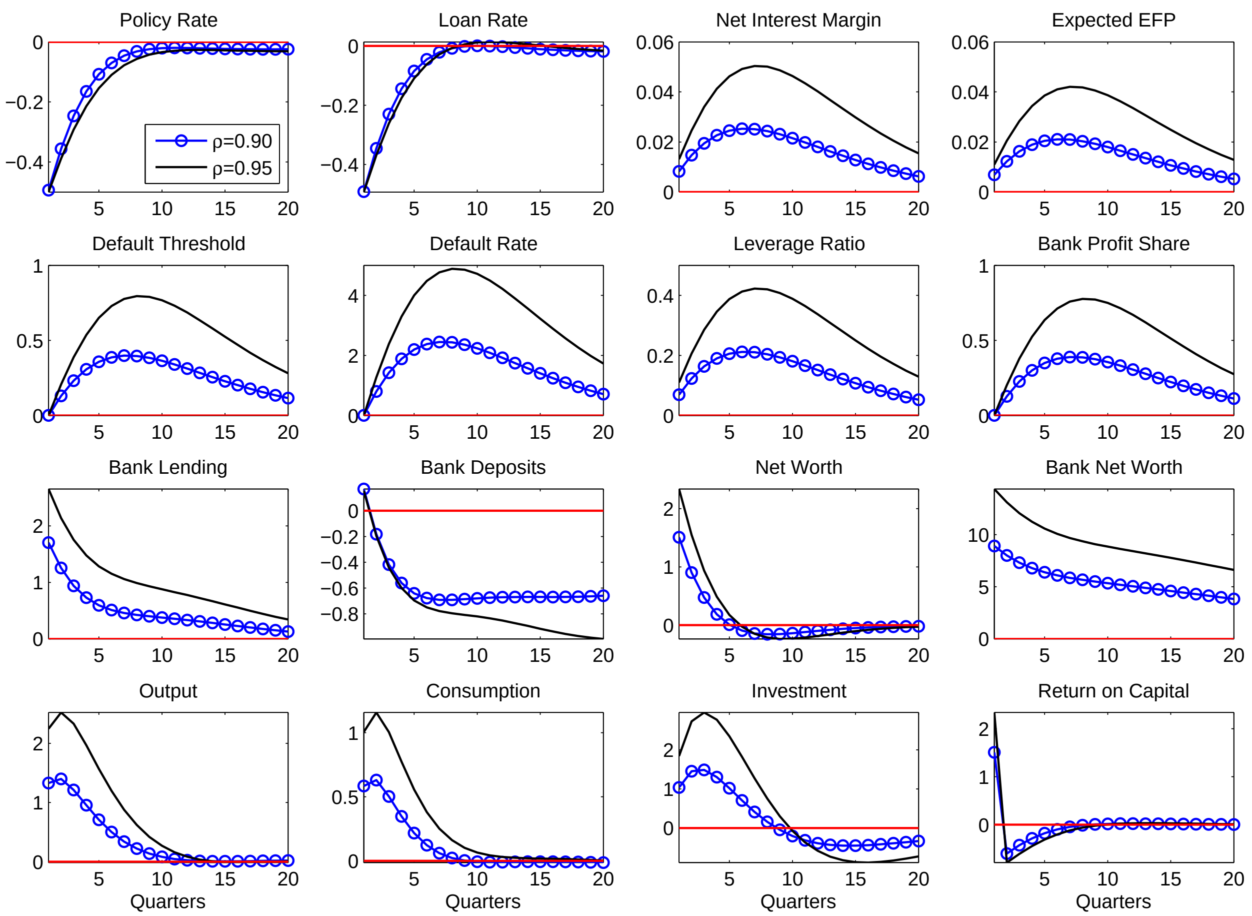
Figure C.1: Serial Correlation of Selected Variables and Ratios between Period t and Period $t - \tau$, DSGE Model and Data.



Notes: Simulated time series and data are HP-filtered ($\lambda = 1,600$). In the data, output corresponds to *log(real GDP per capita)*, investment to *log(real investment expenditure per capita)*, loans/deposits to *log(loans and leases in bank credit/demand deposits) at commercial banks*, net income/bank equity to Call Reports *log(net interest income/total equity capital) for commercial banks in the U.S.*, collateral requirements to the *net percentage of domestic banks increasing collateral requirements for large and middle-market firms*, delinquency rate to *delinquency rate on business loans; all commercial banks*, and net interest margin to Call Reports *net interest margin for all U.S. banks*.

in our model, and the subsequent increase in the default rate of borrowers becomes more pronounced, when the nominal policy rate is more inertial. In the current example, an increase in the Taylor-rule coefficient, ρ, from 0.90 to 0.95 almost doubles the maximum response of the leverage ratio from 3.9 to 7.4 basis points above its steady-state value of 1.537 and postpones the turning point in the leverage ratio (from above to below its steady state) by 1 quarter. The effects on the impulse response functions of output, consumption, and investment are qualitatively the same and of a similar order of magnitude.

Figure C.2: Selected Impulse Response Functions to an Expansionary Monetary Policy Shock of 25 Basis Points for $\rho = 0.90$ and $\rho = 0.95$.



Notes: All impulse response functions are expressed in terms of *percentage deviations from steady state*, except for the policy rate, the loan rate, the net interest margin, and the expected EFP, which are expressed in terms of *percentage points*.

Appendix D. Data

Table D.1: Data and Transformations Used in the Baseline FAVAR Model.

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
1	1	INDPRO	yes	5	Industrial Production Index: Total (2012=100, SA)
2	2	IPBUSEQ	yes	5	Industrial Production: Business Equipment (2012=100, SA)
3	3	IPCONGD	yes	5	Industrial Production: Consumer Goods (2012=100, SA)
4	4	IPDCONGD	yes	5	Industrial Production: Durable Consumer Goods (2012=100, SA)
5	5	IPDMAN	yes	5	Industrial Production: Durable Manufacturing (NAICS) (2012=100, SA)
6	6	IPDMAT	yes	5	Industrial Production: Durable Materials (2012=100, SA)
7	7	IPFINAL	yes	5	Industrial Production: Final Products (Market Group) (2012=100, SA)
8	8	IPMAN	yes	5	Industrial Production: Manufacturing (NAICS) (2012=100, SA)
9	9	IPMAT	yes	5	Industrial Production: Materials (2012=100, SA)
10	10	IPMINE	yes	5	Industrial Production: Mining (2012=100, SA)
11	11	IPNCONGD	yes	5	Industrial Production: Nondurable Consumer Goods (2012=100, SA)
12	12	IPNMAN	yes	5	Industrial Production: Nondurable Manufacturing (NAICS) (2012=100, SA)
13	13	IPNMAT	yes	5	Industrial Production: nondurable Materials (2012=100, SA)
14	14	IPUTIL	yes	5	Industrial Production: Electric and Gas Utilities (2012=100, SA)
15	15	BSCURT02USM160S[38]	yes	1	Business Tendency Surveys for Manufacturing: Rate of Capacity Utilization (% of Capacity), SA
16	16	RPI	yes	5	Real personal income, Billions of 2009 chained USD, SAAR

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[38] Series was discontinued in 2015Q3.

Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
17	17	W875RX1	yes	5	Real personal income excluding current transfer receipts, Billions of 2009 chained USD, SAAR
18	18	GDPC1	yes	5	Real Gross Domestic Product, Billions of 2009 USD chained , SAAR
19	1	CE16OV	yes	5	Civilian Employment (thous., SA)
20	2	DMANEMP	yes	5	All Employees: Durable Goods (thous., SA)
21	3	EMRATIO	yes	4	Employment-Population Ratio (Percent, SA)
22	4	MANEMP	yes	5	All Employees: Manufacturing (thous., SA)
23	5	PAYEMS	yes	5	All Employees: Total Nonfarm (thous., SA)
24	6	SRVPRD	yes	5	All Employees: Service-Providing Industries (thous., SA)
25	7	USCONS	yes	5	All Employees: Construction (thous., SA)
26	8	USGOVT	yes	5	All Employees: Government (thous., SA)
27	9	USINFO	yes	5	All Employees: Information Services (thous., SA)
28	10	USMINE	yes	5	All Employees: Mining and Logging (thous., SA)
29	11	USPRIV	yes	5	All Employees: Total Private Industries (thous., SA)
30	12	AWHNONAG	yes	1	Average Weekly Hours of Production and Nonsupervisory Employees: Total Private (SA)
31	13	CES1000000007	yes	1	Average Weekly Hours of Production and Nonsupervisory Employees: Mining and Logging (SA)
32	14	CES0800000007	yes	1	Average Weekly Hours of Production and Nonsupervisory Employees: Private Service Providing, (SA)
33	15	CES3100000007	yes	1	Average Weekly Hours of Production and Nonsupervisory Employees: Durables (SA)
34	16	CES2000000007	yes	1	Average Weekly Hours of Production and Nonsupervisory Employees: Construction (SA)

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Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
35	17	CES5000000007	yes	1	Average Weekly Hours of Production and Nonsupervisory Employees: Information (SA)
36	18	CES4000000007	yes	1	Average Weekly Hours of Production and Nonsupervisory Employees: Trade, Transportation, Utilities (SA)
37	19	CES6000000007	yes	1	Average Weekly Hours of Production and Nonsupervisory Employees: Professional and Business Services (SA)
38	1	PCECC96	yes	5	Real Personal consumption expenditure, SAAR, chained 2009 BIL USD
39	1	HOUST	no	4	Housing Starts: Total: New Privately Owned Housing Units Started (thsd. of units) SAAR
40	2	HOUSTMW	no	4	Housing Starts: Midwest: New Privately Owned Housing Units Started (thsd. of units) SAAR
41	3	HOUSTNE	no	4	Housing Starts: Northeast: New Privately Owned Housing Units Started (thsd. of units) SAAR
42	4	HOUSTS	no	4	Housing Starts: South: New Privately Owned Housing Units Started (thsd. of units) SAAR
43	5	HOUSTW	no	4	Housing Starts: West: New Privately Owned Housing Units Started (thsd. of units) SAAR
44	6	PERMIT	no	4	New Private Housing Units Authorized by Building Permits, (thsd. of units) SAAR
45	1	S&P 500	no	5	S&P 500 Stock Price Index, NSA, end of period
46	1	EXCAUS	no	5	Canadian Dollars to One U.S. Dollar, NSA
47	2	EXJPUS	no	5	Japanese Yen to One U.S. Dollar, NSA
48	3	EXSZUS	no	5	Swiss Francs to One U.S. Dollar, NSA

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Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
49	4	EXUSUK	no	5	U.S. Dollars to One British Pound, NSA
50	1	AAA	no	1	Moody's Seasoned Aaa Corporate Bond Yield, Percent, NSA
51	2	BAA	no	1	Moody's Seasoned Baa Corporate Bond Yield, Percent, NSA
52	3	FEDFUNDS	no	1	Effective FFR, Percent, NSA
53	4	GS1	no	1	1-Year Treasury Constant Maturity Rate, Percent, NSA
54	5	GS10	no	1	10-Year Treasury Constant Maturity Rate, Percent, NSA
55	6	GS3	no	1	3-Year Treasury Constant Maturity Rate, Percent, NSA
56	7	GS3M	no	1	3-Month Treasury Constant Maturity Rate, Percent, NSA
57	8	GS5	no	1	5-Year Treasury Constant Maturity Rate, Percent, NSA
58	9	AAA_FFR	no	1	Spread: AAA-FFR
59	10	BAA_FFR	no	1	Spread: BAA-FFR
60	11	GS1_FFR	no	1	Spread: GS1-FFR
61	12	GS10_FFR	no	1	Spread: GS10-FFR
62	13	GS3_FFR	no	1	Spread: GS3-FFR
63	14	GS3M_FFR	no	1	Spread: GS3M-FFR
64	15	GS5_FFR	no	1	Spread:GS5-FFR
65	1	BOGNONBR[39]	no	5	Non-Borrowed Reserves of Depository Institutions, Mill USD, SA
66	2	AMBSL	no	5	Monetary Base, Bill USD, SA
67	3	M1	no	5	M1, Bill USD, SA
68	4	M2	no	5	M2, Bill USD, SA
69	5	MZM	no	5	MZM, Bill USD, SA
70	6	TOTLL	no	5	Total Loans and Leases, Bill USD, SA
71	7	REALLN	no	5	Real estate loans, Bill USD, SA
72	8	BUSLOANS	no	5	C&I loans, Bill USD; SA
73	9	CONSUMER	no	5	Consumer loans, Bill USD, SA
74	1	CPIAUCSL	yes	5	Consumer Price Index for All Urban Consumers: All Items, 1982-84=100, SA

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[39] Series was discontinued in May 2013.

Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
75	2	CPIFABSL	yes	5	Consumer Price Index for All Urban Consumers: Food and Beverages, 1982-84=100, SA
76	3	CPILFESL	yes	5	Consumer Price Index for All Urban Consumers: All Items Less Food & Energy, 1982-84=100, SA
77	4	CPIMEDSL	yes	5	Consumer Price Index for All Urban Consumers: Medical Care, 1982-84=100, SA
78	5	DNRGRG3M086SBEA	yes	5	Personal consumption expenditures: Energy goods and services, chain-type index, 2009=100
79	6	DPCXRG3M086SBEA	yes	5	Personal consumption expenditures: Market-based PCE excluding food and energy, chain-type index, 2009=100
80	7	PPICRM	no	5	Producer Price Index: Crude Materials for Further Processing, 1982=100, SA
81	8	PPIFCG	yes	5	Producer Price Index: Finished Consumer Goods, 1982=100, SA
82	9	PPIFGS	yes	5	Producer Price Index: Finished Goods, 1982=100, SA
83	10	PPIIEG	yes	5	Producer Price Index: Intermediate Energy Goods, 1982=100, SA
84	11	PPIITM	yes	5	Producer Price Index: Intermediate Materials: Supplies & Components, 1982=100, SA
85	1	CSCICP02USM661S[40]	no	1	Consumer Opinion Surveys: Confidence Indicators: Composite Indicator, 2005=1.00, SA, end of period
86	1	SUBLPDCILS_N.Q	no	1	Net percentage of domestic banks tightening standards for C&I loans to large and middle-market firms, Percentage

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[40]Series was discontinued in 2013Q2.

Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
87	2	SUBLPDCILTC_N.Q	no	1	Net percentage of domestic banks increasing the cost of credit lines to large and middle-market firms, Percentage
88	3	SUBLPDCILTL_N.Q	no	1	Net percentage of domestic banks tightening loan covenants for large and middle-market firms, Percentage
89	4	SUBLPDCILTM_N.Q	no	1	Net percentage of domestic banks reducing the maximum size of credit lines for large and middle-market firms, Percentage
90	5	SUBLPDCILTQ_N.Q	no	1	Net percentage of domestic banks increasing collateral requirements for large and middle-market firms, Percentage
91	6	SUBLPDCILTS_N.Q	no	1	Net percentage of domestic banks increasing spreads of loan rates over banks' cost of funds to large and middle-market firms, Percentage
92	7	SUBLPDCISS_N.Q	no	1	Net percentage of domestic banks tightening standards for C&I loans to small firms, Percentage
93	8	SUBLPDCISTC_N.Q	no	1	Net percentage of domestic banks increasing the cost of credit lines to small firms, Percentage
94	9	SUBLPDCISTL_N.Q	no	1	Net percentage of domestic banks tightening loan covenants for small firms, Percentage
95	10	SUBLPDCISTM_N.Q	no	1	Net percentage of domestic banks reducing the maximum size credit lines for small firms, Percentage
96	11	SUBLPDCISTQ_N.Q	no	1	Net percentage of domestic banks increasing collateral requirements for small firms, Percentage
97	12	SUBLPDCISTS_N.Q	no	1	Net percentage of domestic banks increasing spreads of loan rates over banks' cost of funds to small firms, Percentage

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Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
98	13	SUBLPDRCS_N.Q	no	1	Net percentage of domestic banks tightening standards for commercial real estate loans, Percentage
99	14	SUBLPFCIS_N.Q	no	1	Net percentage of foreign banks tightening standards for approving C&I loans, Percentage
100	15	SUBLPFCITC_N.Q	no	1	Net percentage of foreign banks increasing costs of credit lines, Percentage
101	16	SUBLPFCITL_N.Q	no	1	Net percentage of foreign banks tightening loan covenants, Percentage
102	17	SUBLPFCITM_N.Q	no	1	Net percentage of foreign banks reducing the maximum size of credit lines, Percentage
103	18	SUBLPFCITQ_N.Q	no	1	Net percentage of foreign banks increasing collateralization requirements, Percentage
104	19	SUBLPFRCS_N.Q	no	1	Net percentage of foreign banks tightening standards for commercial real estate loans, Percentage
105	1	AHETPI	yes	5	Average Hourly Earnings of Production and Nonsupervisory Employees: Total Private, USD per Hour, SA
106	2	CES0600000008	yes	5	Average Hourly Earnings of Production and Nonsupervisory Employees: Goods producing, USD per hour, SA
107	3	CES0800000008	yes	5	Average Hourly Earnings of Production and Nonsupervisory Employees: Private Service Producing, USD per Hour, SA
108	4	CES1000000008	yes	5	Average Hourly Earnings of Production and Nonsupervisory Employees: Mining and Logging, USD per Hour, SA
109	5	CES2000000008	yes	5	Average Hourly Earnings of Production and Nonsupervisory Employees: Construction, USD per Hour, SA

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Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
110	6	CES3000000008	yes	5	Average Hourly Earnings of Production and Nonsupervisory Employees: Manufacturing, USD per Hour, SA
111	1	A015RX1Q020SBEA	no	1	Change in real private inventories: Nonfarm, Billions of 2009 chained USD, SAAR
112	2	B018RX1Q020SBEA	no	1	Change in real private inventories: Farm, Billions of 2009 chained USD, SAAR
113	3	NAPMNOI	no	1	ISM Manufacturing: New Orders Index, SA
114	4	PRFI_d	no	5	Real Gross Private Domestic Residential Investment, Billions of Real Dollars, SA (deflated with the respective implicit deflator)
115	5	PNFI_d	no	5	Real Gross Private Domestic Nonresidential Investment, Billions of Real Dollars, SA (deflated with the respective implicit deflator)
116	1	TFBAIL_MA_NQ	no	1	Charge-off rate on loans; All commercial banks, SA
117	2	STTFBAILB_MA_NQ	no	1	Charge-off rate on business loans; All commercial banks, SA
118	3	STTFBAILC_MA_NQ	no	1	Charge-off rate on consumer loans; All commercial banks, SA
119	4	STTFBAILCC_MA_NQ	no	1	Charge-off rate on credit card loans; All commercial banks, SA
120	5	STTFBAILCO_MA_NQ	no	1	Charge-off rate on other consumer loans; All commercial banks, SA
121	6	STTFBAILF_MA_NQ	no	1	Charge-off rate on loans to finance agricultural production; All commercial banks, SA
122	7	STTFBAILR_MA_NQ	no	1	Charge-off rate on lease financing receivables; All commercial banks, SA
123	8	STTFBAILS_MA_NQ	no	1	Charge-off rate on loans secured by real estate; All commercial banks, SA

Continued on next page

Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
124	9	STTFBAILSF_XDO_MA_NQ	no	1	Charge-off rate on farmland loans, booked in domestic offices; All commercial banks, SA
125	10	STTFBAILSS_XDO_MA_NQ	no	1	Charge-off rate on single family residential mortgages, booked in domestics offices; All commercial banks, SA
126	11	STTFBAILSX_XDO_MA_NQ	no	1	Charge-off rate on commercial real estate loans (excluding farmland), booked in domestic offfices; All commercial banks, SA
127	12	STTFBAIL_XEOP_MA_NQ	no	1	Delinquency rate on loans; All commercial banks, SA
128	13	STTFBAILB_XEOP_MA_NQ	no	1	Delinquency rate on business loans; All commercial banks, SA
129	14	STTFBAILC_XEOP_MA_NQ	no	1	Delinquency rate on consumer loans; All commercial banks, SA
130	15	STTFBAILCC_XEOP_MA_NQ	no	1	Delinquency rate on credit card loans; All commercial banks, SA
131	16	STTFBAILCO_XEOP_MA_NQ	no	1	Delinquency rate on other consumer loans; All commercial banks, SA
132	17	STTFBAILF_XEOP_MA_NQ	no	1	Delinquency rate on loans to finance agricultural production; All commercial banks, SA
133	18	STTFBAILR_XEOP_MA_NQ	no	1	Delinquency rate on lease financing receivables; All commercial banks, SA
134	19	STTFBAILS_XEOP_MA_NQ	no	1	Delinquency rate on loans secured by real estate; All commercial banks, SA
135	20	STTFBAILSF_XEOP_XDO_MA_NQ	no	1	Delinquency rate on farmland loans, booked in domestic offices; All commercial banks, SA
136	21	STTFBAILSS_XEOP_XDO_MA_NQ	no	1	Delinquency rate on single-family residential mortgages, booked in domestic offices; All commercial banks, SA

Continued on next page

Table D.1 – *Continued from previous page*

Overall No.	No. in Block	Series ID[a]	Slow[b]	Transformation[c]	Description
137	22	STTFBAILSX_XEOP_XDO_MA_NQ	no	1	Delinquency rate on commercial real estate loans (excluding farmland), booked in domestic offices; All commercial banks, SA
138	1	BANKPROFIT	no	5	BEA Profits of Other Financial Institutions, Billions of USD, SAAR
139	2	FEDPROFIT	no	5	BEA Profits of Federal Reserve Banks, Billions of USD, SAAR
140	3	CALLNETINCOME	no	5	Net Income for Commercial Banks, Thous. USD, NSA, adjusted for cumulative accounting
141	4	CALLNETINTINCOME	no	5	Net Interest Income for Commercial Banks, Thous. USD, NSA, adjusted for cumulative accounting
142	5	CALLNETMARGIN	no	1	Net Interest Margin for US Banks, Percent, End of Period, NSA

[a] Macroeconomic time series are taken from the FRED database, lending standards measures are taken from the Senior Loan Officer Opinion Survey (SLOOS) of the Federal Reserve.

[b] If yes, a variable is assumed to be slow-moving when estimated with a principal component approach.

[c] Variable transformations codes are as follows: 1 - no transformation, 2 - difference, 4 - logarithm, 5 - log-difference.

Table D.2: Data and Transformations Used in the Robustness Checks.

Series ID	Transformation[a]	Description
GB_RGDPdot	1	Greenbook projections for quarter-on-quarter growth in real GDP, chain weighted (annualized percentage points)
GB_PGDPdot	1	Greenbook projections for quarter-on-quarter growth in price index for GDP, chain weighted (annualized percentage points)
GB_UNEMP	1	Greenbook projections for the unemployment rate, (percentage points)
GB_CPIdot	1	Greenbook projections for quarter-on-quarter headline CPI inflation, (annualized percentage points)
GB_CORECPIdot	1	Greenbook projections for quarter-on-quarter core CPI inflation, (annualized percentage points)
GB_RCONSUMdot	1	Greenbook projections for quarter-on-quarter growth in real personal consumption expenditure, chain weighted (annualized percentage points)
GB_RNRESINVdot	1	Greenbook projections for quarter-on-quarter growth in real business fixed investment, chain weighted (annualized percentage points)
GB_RRESINVdot	1	Greenbook projections for quarter-on-quarter growth in real residential investment, chain weighted (annualized percentage points)
GB_RFEDGOVdot	1	Greenbook projections for quarter-on-quarter growth in real federal government consumption and gross investment, chain weighted (annualized percentage points)
GB_RSLGOVdot	1	Greenbook projections for quarter-on-quarter growth in real estate and local government consumption and gross investment, chain weighted (annualized percentage points)
GB_NGDPdot	1	Greenbook projections for quarter-on-quarter growth in nominal GDP (annualized percentage points)
GB_HOUSING	4	Greenbook projections for housing starts (millions of units)
GB_INDPRODdot	1	Greenbook projections for quarter-on-quarter growth in the industrial production index (annualized percentage points)
ADJLS	1	Supply component of SLOOS lending standards in Bassett et al. (2014) (Net percentage of banks tightening lending standards, adjusted for macroeconomic and bank-specific factors that also affect loan demand)
EBP	1	Excess Bond Premium of Gilchrist and Zakrajšek (2012) (annualized percentage points)
NFCICREDIT	1	Chicago Fed National Financial Conditions Credit Subindex (index)
SLOOSRISKTOL	1	Net percentage of banks loosening lending standards due to an increase in risk tolerance

[a] Variable transformations codes are as follows: 1 - no transformation, 2 - difference, 4 - logarithm, 5 - log-difference.

Appendix E. Bayesian Estimation of the FAVAR Model

In order to jointly estimate equations (19) and (20) using Bayesian methods it is convenient to rewrite the model in state-space form:

$$\begin{bmatrix} X_t \\ Y_t \end{bmatrix} = \begin{bmatrix} \Lambda^f & \Lambda^y \\ 0 & I \end{bmatrix} \begin{bmatrix} F_t \\ Y_t \end{bmatrix} + \begin{bmatrix} e_t \\ 0 \end{bmatrix} \tag{E.1}$$

$$\begin{bmatrix} F_t \\ Y_t \end{bmatrix} = \Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + v_t, \tag{E.2}$$

where Y_t is the $M \times 1$ vector of observables, F_t is the $K \times 1$ vector of unobservable factors, and X_t is the $N \times 1$ vector of informational time series. We restrict the loading coefficient matrices Λ^f of dimension $N \times K$ and Λ^y of dimension $N \times M$ in order to identify the factors uniquely. The vector error terms e_t and v_t are assumed to be normally distributed and uncorrelated, i.e. $e_t \sim N(0, R)$ and $v_t \sim N(0, Q)$, where R is a diagonal matrix.

In one-step Bayesian estimation, all parameters are treated as random variables. The parameter vector θ contains the factor loadings and the variance-covariance matrix of the observation equation in (19) as well as the VAR coefficients and the variance-covariance matrix of the transition equation in (20) , i.e., $\theta = \left(\Lambda^f, \Lambda^y, R, vec(\Phi), Q\right)$. In addition, the unobservable factors are treated as random variables and sampled. The observation and transition equations can be rewritten as

$$\boldsymbol{X}_t = \Lambda \boldsymbol{F}_t + \boldsymbol{e}_t \tag{E.3}$$

$$\boldsymbol{F}_t = \Phi(L) \boldsymbol{F}_{t-1} + \boldsymbol{v}_t, \tag{E.4}$$

where Λ is the loading matrix, $\boldsymbol{X}_t = (X_t', Y_t')$, $\boldsymbol{e}_t = (e_t', 0)$, and $\boldsymbol{F}_t = (F_t', Y_t')$. Let $\tilde{\boldsymbol{X}}_t = (\boldsymbol{X}_1, \boldsymbol{X}_2, \ldots, \boldsymbol{X}_T)$ and $\tilde{\boldsymbol{F}}_t = (\boldsymbol{F}_1, \boldsymbol{F}_2, \ldots, \boldsymbol{F}_T)$ denote the respective histories from time 1 to T. Our goal is to obtain the marginal densities of the parameters and factors, which can be integrated out of the joint posterior density $p\left(\theta, \tilde{\boldsymbol{F}}_T\right)$. Hence, we are interested in the following objects:

$$p\left(\tilde{\boldsymbol{F}}_T\right) = \int p\left(\theta, \tilde{\boldsymbol{F}}_T\right) d\theta, \tag{E.5}$$

$$p(\theta) = \int p\left(\theta, \tilde{\boldsymbol{F}}_T\right) d\tilde{\boldsymbol{F}}_T. \tag{E.6}$$

Appendix E.1. The Gibbs Sampler

We use the multi-move Gibbs sampling approach of Carter and Kohn (1994), which alternately samples from the parameters and the factors as follows:

1. Choose a starting value for the parameter vector θ_0.
2. Draw $\tilde{\boldsymbol{F}}_T^{(1)}$ from the conditional density $p\left(\tilde{\boldsymbol{F}}_T | \tilde{\boldsymbol{X}}_T, \theta_0\right)$.
3. Draw $\theta^{(1)}$ from the conditional density $p\left(\theta | \tilde{\boldsymbol{X}}_T, \tilde{\boldsymbol{F}}_T^{(1)}\right)$.

Repeat steps 2 and 3 until convergence.

Appendix E.2. Choice of Starting Values

An obvious choice for θ_0 is the solution implied by principal component analysis (compare Bernanke et al., 2005), which we use as a baseline in most runs. However, starting the chains (even very long ones) from the same point may not be sufficient to achieve the target distribution, in practice, even if the chain appears to have converged. Therefore, we experimented with "agnostic" starting values, e.g. $vec(\Phi) = 0$, $Q = I$, $\Lambda^f = 0$, Λ^y = OLS of the regression of X on Y and R = fitted residual covariance matrix from the OLS regression of X on Y, without substantial effects on our results. We furthermore ran multiple consecutive chains of 1 million draws each, setting the starting values of the subsequent to the values obtained in the last iteration of the previous chain. Given that the chains were highly autocorrelated for some of the parameters, we applied thinning and kept only every fifth draw.

Appendix E.3. Conditional Densities and Priors

In order to draw from $p\left(\tilde{\boldsymbol{F}}_T|\tilde{\boldsymbol{X}}_T,\theta\right)$, we apply Kalman filtering techniques (see Kim and Nelson, 1999). Due to the memoryless Markov property of $\boldsymbol{F}_t$, the conditional distribution of the history of factors can be expressed as a product of the conditional distributions of factors at date t:

$$p\left(\tilde{\boldsymbol{F}}_T|\tilde{\boldsymbol{X}}_T,\theta\right) = p\left(\boldsymbol{F}_T|\tilde{\boldsymbol{X}}_T,\theta\right)\prod_{t-1}^{T-1} p\left(\boldsymbol{F}_t|\boldsymbol{F}_{t+1},\tilde{\boldsymbol{X}}_t,\theta\right). \tag{E.7}$$

The original model is linear-Gaussian, which implies

$$\boldsymbol{F}_T|\tilde{\boldsymbol{X}}_T,\theta \sim N\left(\boldsymbol{F}_{T|T},\boldsymbol{P}_{T|T}\right) \tag{E.8}$$

$$\boldsymbol{F}_t|\boldsymbol{F}_{t+1},\tilde{\boldsymbol{X}}_t,\theta \sim N\left(\boldsymbol{F}_{t|t,\boldsymbol{F}_{t+1}},\boldsymbol{P}_{t|t,\boldsymbol{F}_{t-1}}\right), \tag{E.9}$$

where

$$\boldsymbol{F}_{T|T} = E\left(\boldsymbol{F}_T|\tilde{\boldsymbol{X}}_T,\theta\right), \tag{E.10}$$

$$\boldsymbol{P}_{T|T} = Cov\left(\boldsymbol{F}_T|\tilde{\boldsymbol{X}}_T,\theta\right), \tag{E.11}$$

$$\boldsymbol{F}_{t|t,\boldsymbol{F}_{t+1}} = E\left(\boldsymbol{F}_t|\boldsymbol{F}_{t+1}\tilde{\boldsymbol{X}}_t,\theta\right) = E\left(\boldsymbol{F}_t|\boldsymbol{F}_{t+1},\boldsymbol{F}_{t|t},\theta\right), \tag{E.12}$$

$$\boldsymbol{P}_{t|t,\boldsymbol{F}_{t-1}} = Cov\left(\boldsymbol{F}_t|\boldsymbol{F}_{t+1}\tilde{\boldsymbol{X}}_t,\theta\right) = Cov\left(\boldsymbol{F}_t|\boldsymbol{F}_{t+1},\boldsymbol{F}_{t|t},\theta\right). \tag{E.13}$$

$\boldsymbol{F}_{t|t}$ and $\boldsymbol{P}_{t|t}$ are calculated by the Kalman filter for $t = 1,\ldots,T$, conditional on θ and the respective data history $\tilde{\boldsymbol{X}}_t$. The Kalman filter starting values are zero for the factors and the identity matrix for the covariance matrix. Further, a Kalman smoother is applied to obtain the updated values of $\boldsymbol{F}_{T-1|T-1,\boldsymbol{F}_T}$ and $\boldsymbol{P}_{T-1|T-1,\boldsymbol{F}_T}$.

The priors on the parameters in Λ and the variance-covariance matrix of the observation equation, R, are as follows. Since R is assumed to be diagonal, estimates of Λ and the diagonal elements R_{ii} of R can be obtained from OLS equation by equation. Conjugate priors are assumed to have the form

$$R_{ii} \sim iG\left(\delta_0/2,\eta_0/2\right) \tag{E.14}$$

$$\Lambda_i|R_{ii} \sim N\left(0,R_{ii}M_0^{-1}\right), \tag{E.15}$$

where, following Bernanke et al. (2005), we set $\delta_0 = 6$, $\eta_0 = 2 \cdot 10^{-3}$ and $M_0 = I$. Given the above priors, it can be shown that the corresponding posterior distributions have the form

$$R_{ii}|\tilde{\boldsymbol{X}}_T, \tilde{\boldsymbol{F}}_T \sim iG(\delta_i/2, \eta/2) \tag{E.16}$$

$$\Lambda_i|R_{ii}, \tilde{\boldsymbol{X}}_T, \tilde{\boldsymbol{F}}_T \sim N\left(\bar{\Lambda}_i, R_{ii}\bar{M}_i^{-1}\right), \tag{E.17}$$

where

$$\delta_i = \delta_0/2 + \hat{e}_i'\hat{e}_i + \hat{\Lambda}_i'\left[M_0^{-1} + \left(\tilde{\boldsymbol{F}}_T'^i\tilde{\boldsymbol{F}}_T^i\right)^{-1}\right]^{-1}\hat{\Lambda}_i, \tag{E.18}$$

$$\eta = \eta_0/2 + T, \tag{E.19}$$

$$\bar{\Lambda}_i = \bar{M}_i^{-1}\left(\tilde{\boldsymbol{F}}_T'^i\tilde{\boldsymbol{F}}_T^i\right)\hat{\Lambda}_i, \tag{E.20}$$

$$\bar{M}_i = M_0 + \tilde{\boldsymbol{F}}_T'^i\tilde{\boldsymbol{F}}_T^i, \tag{E.21}$$

and $\tilde{\boldsymbol{F}}_T^i$ are the regressors of the ith equation.

The priors on the transition (state) equation are as follows. As the transition equation corresponds to a standard VAR, it can be estimated by OLS equation by equation to obtain $vec\left(\hat{\Phi}\right)$ and $\hat{Q}$. We impose a conjugate Normal-Inverse-Wishart prior,

$$Q \sim iW(Q_0, K + M + 2) \tag{E.22}$$

$$vec(\Phi)|Q \sim N(0, Q \otimes \Omega_0), \tag{E.23}$$

where the diagonal elements of Q_0 are set to the residual variances of the corresponding univariate regressions, $\hat{\sigma}_i^2$, as in Kadiyala and Karlsson (1997). The diagonal elements of Ω_0 are set in the spirit of the Minnesota prior, i.e. the prior variance of the coefficient on variable j at lag k in equation i is $\sigma_i^2/k\sigma_j^2$. This prior yields the following conjugate posterior:

$$Q|\tilde{\boldsymbol{X}}_T, \tilde{\boldsymbol{F}}_T \sim iW\left(\bar{Q}, T + K + M + 2\right) \tag{E.24}$$

$$vec(\Phi)|Q, \tilde{\boldsymbol{X}}_T, \tilde{\boldsymbol{F}}_T \sim N\left(vec\left(\bar{\Phi}\right), Q \otimes \bar{\Omega}\right), \tag{E.25}$$

where

$$\bar{Q} = Q_0 + \hat{V}'\hat{V} + \hat{\Phi}'\left[\Omega_0 + \left(\tilde{\boldsymbol{F}}_{T-1}'\tilde{\boldsymbol{F}}_{T-1}\right)^{-1}\right]^{-1}\hat{\Phi} \tag{E.26}$$

$$\bar{\Phi} = \bar{\Omega}\left(\tilde{\boldsymbol{F}}_{T-1}'\tilde{\boldsymbol{F}}_{T-1}\right)\hat{\Phi} \tag{E.27}$$

$$\bar{\Omega} = \left(\Omega_0^{-1} + \tilde{\boldsymbol{F}}_{T-1}'\tilde{\boldsymbol{F}}_{T-1}\right)^{-1} \tag{E.28}$$

and $\hat{V}$ is the matrix of OLS residuals.

Following Bernanke et al. (2005) and Amir Ahmadi and Uhlig (2009), we enforce stationarity by truncating draws of Φ where the largest eigenvalue exceeds 1 in absolute value.

Appendix E.4. Monitoring Convergence

Geman and Geman (1984) show that both joint and marginal distributions will converge to their target distributions at an exponential rate as the number of replications approaches infinity. In practice, however, the Gibbs sampler may converge slowly and requires careful monitoring. We monitor convergence by (i) plotting the coefficients against the number of replications (level shifts and trends should not occur); (ii) comparing the medians and means of the coefficients at different parts of the chain (large differences should not occur); (iii) plotting and comparing the medians of the factors obtained from first and second half of the chain (large and frequent deviations should not occur). The corresponding figures for our baseline model with 3 factors are reported below. It turns out that convergence is quite slow and becomes increasingly difficult to achieve, if we increase the number of unobserved factors.

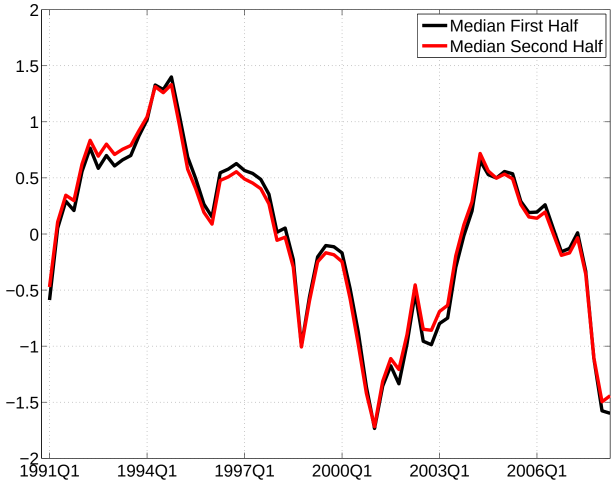
Appendix E.5. Normalization of Unobserved Factors

Due to the fundamental indeterminacy of factor models, the unobserved factors can only be estimated up to a rotation. For this reason, we must impose a set of standard restrictions on the observation equation in order to identify the factors uniquely. Following Bernanke et al. (2005), we eliminate rotations of the form $F_t^* = AF_t + BY_t$. Solving this expression for F_t and plugging the result into the observation equation in (19) yields

$$X_t = \Lambda^f A^{-1} F_t^* + (\Lambda^y + \Lambda^f A^{-1} B) Y_t. \tag{E.29}$$

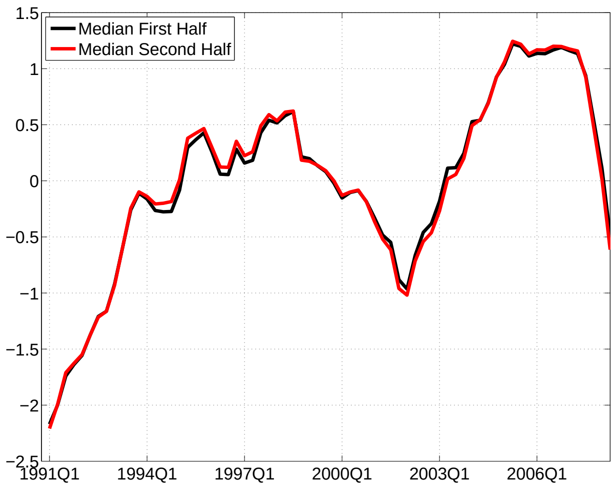
Hence, the unique identification of factors requires that $A^{-1} F_t^* = F_t$ and $\Lambda^f A^{-1} B = \mathbf{0}$. Bernanke et al. (2005) suggest imposing sufficient (overidentifying) restrictions by setting $A = \boldsymbol{I}$ and $B = \mathbf{0}$. Moreover, the one-step estimation approach requires that the first K variables in the vector X_t belong to the set of *slow-moving* variables (compare Table D.1).

Figure E.1: Monitoring of Factor Convergence and Factor Uncertainty for the Baseline FAVAR Model.

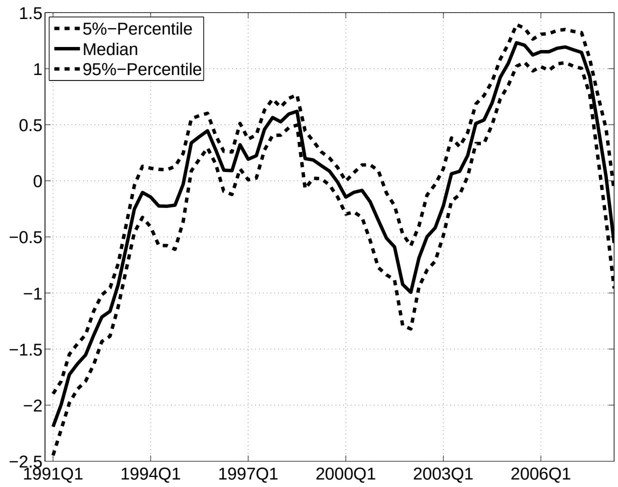


(a) Factor 1: Median of first & second half of draws post burn-in.

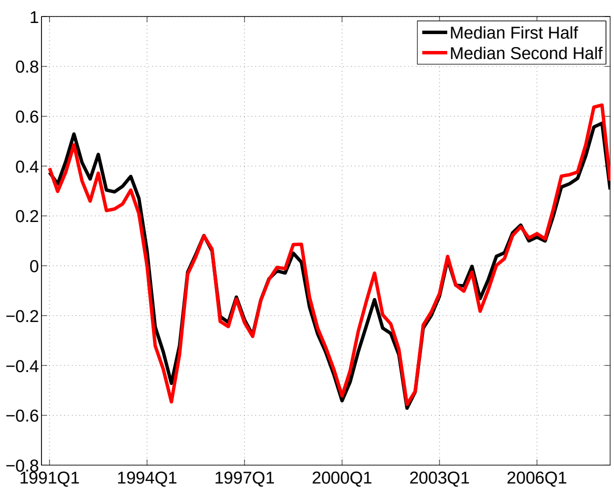
(b) Factor 1: Median of all draws after burn-in & 90% coverage.



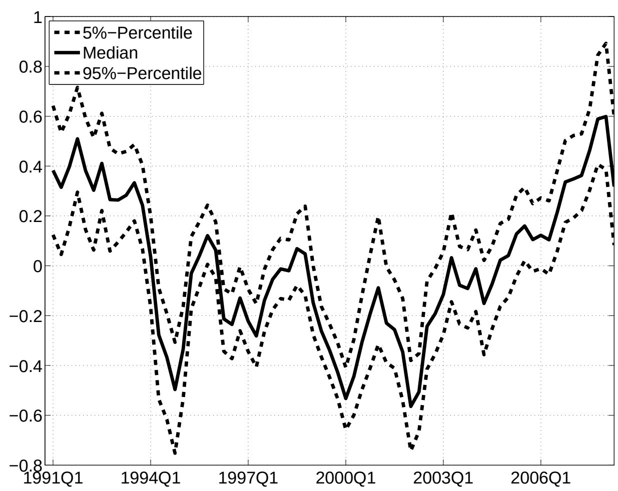
(c) Factor 2: Median of first & second half of draws post burn-in.



(d) Factor 2: Median of all draws after burn-in & 90% coverage.



(e) Factor 3: Median of first & second half of draws post burn-in.



(f) Factor 3: Median of all draws after burn-in & 90% coverage.

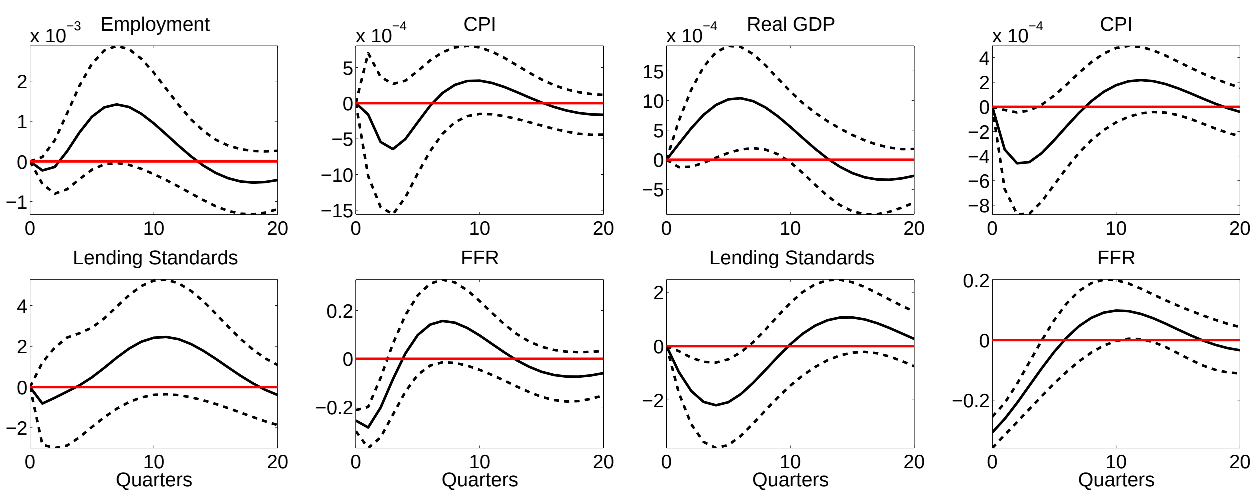
Appendix F. Empirical Evidence

Appendix F.1. Small-Scale VAR Model

In order to corroborate our argument in the main text, consider the following example of a small-scale VAR model of the U.S. economy including four observable variables: real activity (either non-farm employment or real GDP), prices (CPI), banks' risk attitude in lending (the net percentage of domestic banks tightening standards for C&I loans), and a monetary policy instrument (the Federal Funds rate). The VAR model is estimated on quarterly data for 1991Q2-2008Q2 and two lags. As in Angeloni et al. (2013), we detrend the non-stationary variables in logarithms and the stationary variables in levels using the HP-filter (Hodrick and Prescott, 1997) with $\lambda = 1,600$. Monetary policy shocks are identified recursively, ordering the Federal Funds rate last in the VAR. A similar identifying assumption will later be made in the FAVAR analysis.

Figure F.1 plots the impulse response functions to a monetary easing of 25 basis points for *two different* specifications of the VAR model. In the upper panel, we include non-farm employment as a proxy for real economic activity, whereas we include real GDP in the lower panel. Note that all other variables as well as the identifying assumptions are identical across the two specifications. In the upper panel, bank lending standards do not seem to respond significantly, according to the two standard error confidence bands, while the corresponding point estimate suggests a *tightening* of standards with a peak around ten quarters after the expansionary monetary policy shock. In the lower panel, however, where real economic activity is measured by real GDP rather than employment, the impulse response functions suggest a statistically significant *easing* of bank lending standards in response to the same monetary policy shock.

Figure F.1: Impulse Responses to an Expansionary Monetary Policy Shock in a Small VAR.



(a) Using employment as the measure of real economic activity. (b) Using real GDP as the measure of real economic activity.

Notes: Point estimates with two standard error confidence bands.

Appendix F.2. Explanatory Power of Latent Factors

Given that our main interest is in explaining the fluctuations in lending standards, Table F.1 reports the median adjusted R^2 for each of the 19 SLOOS measures based on the FAVAR model with one, three, five, and seven unobservable factors. We find that the first factor exhibits a high correlation with most measures of bank lending standards. The respective adjusted R^2 ranges from .148 for *foreign banks tightening standards for commercial real estate loans* to .882 for *domestic banks increasing the cost of credit lines to large and middle firms*. With very few exceptions, adding further factors improves this tight fit only marginally.

Table F.1: Adjusted R^2 for SLOOS Measures of Lending Standards, 1991Q1-2008Q2.

No.	Lending Standard Description	1 factor	3 factors	5 factors	7 factors
1	domestic banks tightening standards on C&I loans to large and middle firms	0.880	0.890	0.905	0.907
2	domestic banks increasing the costs of credit lines to large and middle firms	0.882	0.867	0.862	0.857
3	domestic banks tightening loan covenants for large and middle firms	0.877	0.909	0.914	0.922
4	domestic banks reducing the maximum size of credit lines to large and middle firms	0.870	0.879	0.885	0.885
5	domestic banks increasing collateral requirements for large and middle firms	0.523	0.603	0.613	0.614
6	domestic banks increasing spreads of loan rates over banks' cost of funds to large and middle firms	0.875	0.849	0.848	0.830
7	domestic banks tightening standards for C&I loans to small firms	0.774	0.804	0.839	0.843
8	domestic banks increasing the cost of credit lines to small firms	0.800	0.800	0.843	0.842
9	domestic banks tightening loan covenants for small firms	0.811	0.826	0.840	0.840
10	domestic banks reducing the maximum size of credit lines to small firms	0.734	0.713	0.747	0.732
11	domestic banks increasing collateral requirements for small firms	0.270	0.362	0.420	0.397
12	domestic banks increasing spreads of loan rates over banks' cost of funds to small firms	0.830	0.844	0.875	0.867
13	domestic banks tightening standards for commercial real estate loans	0.467	0.597	0.718	0.725
14	foreign banks tightening standards for approving C&I loans	0.728	0.784	0.789	0.803
15	foreign banks increasing costs of credit lines	0.719	0.730	0.759	0.780
16	foreign banks tightening loan covenants	0.759	0.784	0.785	0.798
17	foreign banks reducing the maximum size of credit lines	0.584	0.638	0.633	0.682
18	foreign banks increasing collateral requirements	0.430	0.511	0.493	0.503
19	foreign banks tightening standards for commercial real estate loans	0.148	0.204	0.190	0.230

Notes: Median adjusted R^2 based on last 10,000 draws from the Gibbs sampler for the baseline FAVAR model with one, three, five, and seven unobserved factors.

Appendix F.3. Historical Variance Decomposition

We are primarily interested in the response of the 19 measures of bank lending standards to expansionary monetary policy shocks, on average over the sample period. In order to assess the plausibility of our FAVAR specification and the resulting monetary shock series, we consider the historical variance decomposition (HVD) of the standardized changes in lending standards. Figure F.2 plots the cumulative contributions of monetary policy shocks to fluctuations in the Federal Funds rate and lending standards for a single candidate draw from the Gibbs sampler, after discarding a sufficiently long burn-in phase.[41]

Over the second half of the sample, we find that unexpected monetary policy shocks contribute to the reduction in the Federal Funds rate after the dot-com bubble and, to a lesser extent, to the gradual change in the monetary policy stance during the boom preceding the Great Recession.[42] Moreover, the FAVAR model attributes a sizeable share of the initial tightening and subsequent loosening of bank lending standards between 1998 and 2005 to monetary shocks. Note that this HVD pattern is shared by all 19 measures. In line with conventional wisdom, the abrupt tightening of lending standards in 2008 is *not* associated with unexpected monetary policy shocks.

Appendix F.4. Impulse Response Functions of SLOOS Lending Standards

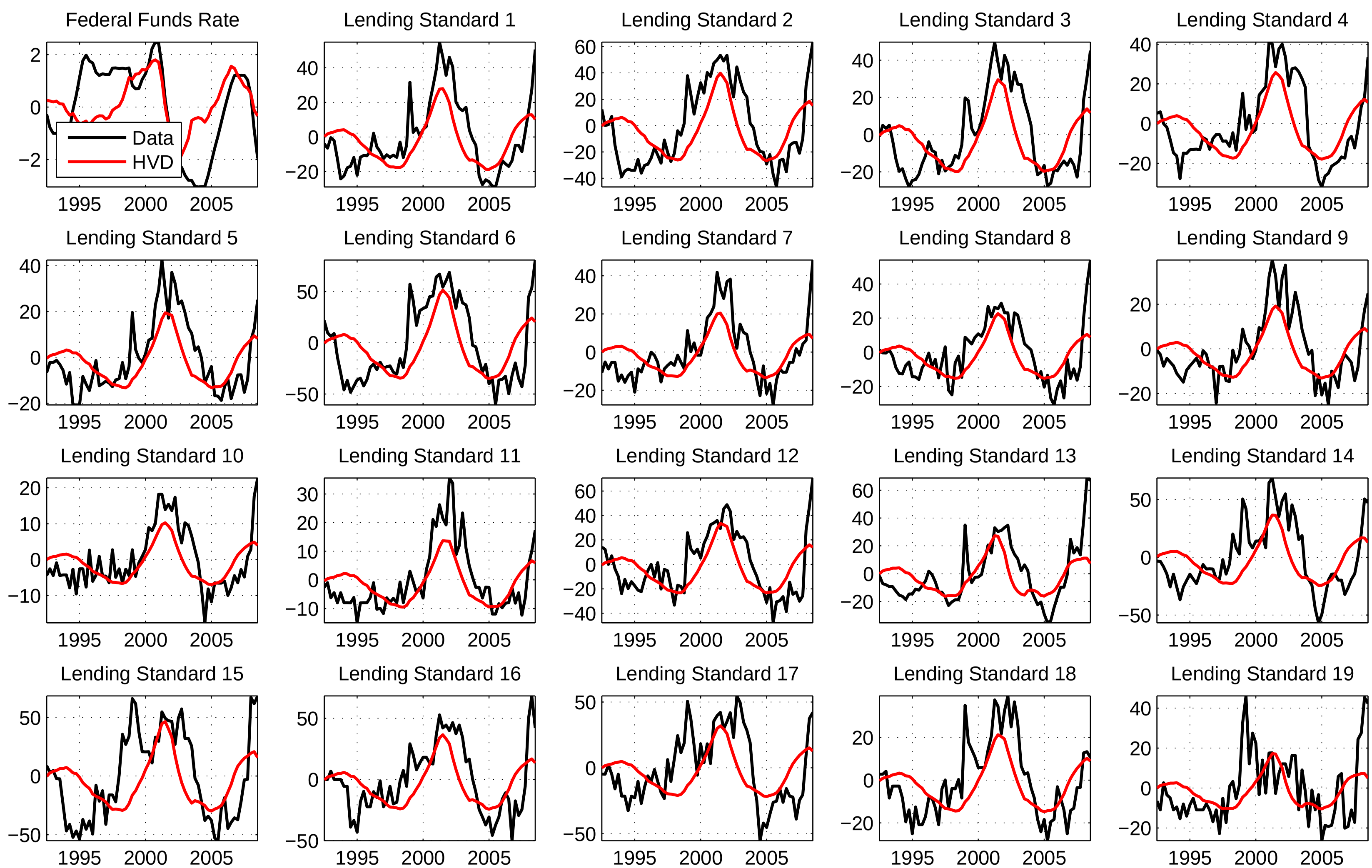
Appendix G. Robustness of Empirical Evidence

Appendix G.1. Number of Latent Factors

[41]The reason for plotting the HVD based on a single model is that *pointwise median* contributions based on all draws imply jumping between different candidates and are thus not interpretable in a sensible way. Nevertheless, the latter results are qualitatively and quantitatively very similar to those in Figure F.2, which can therefore be considered as representative.

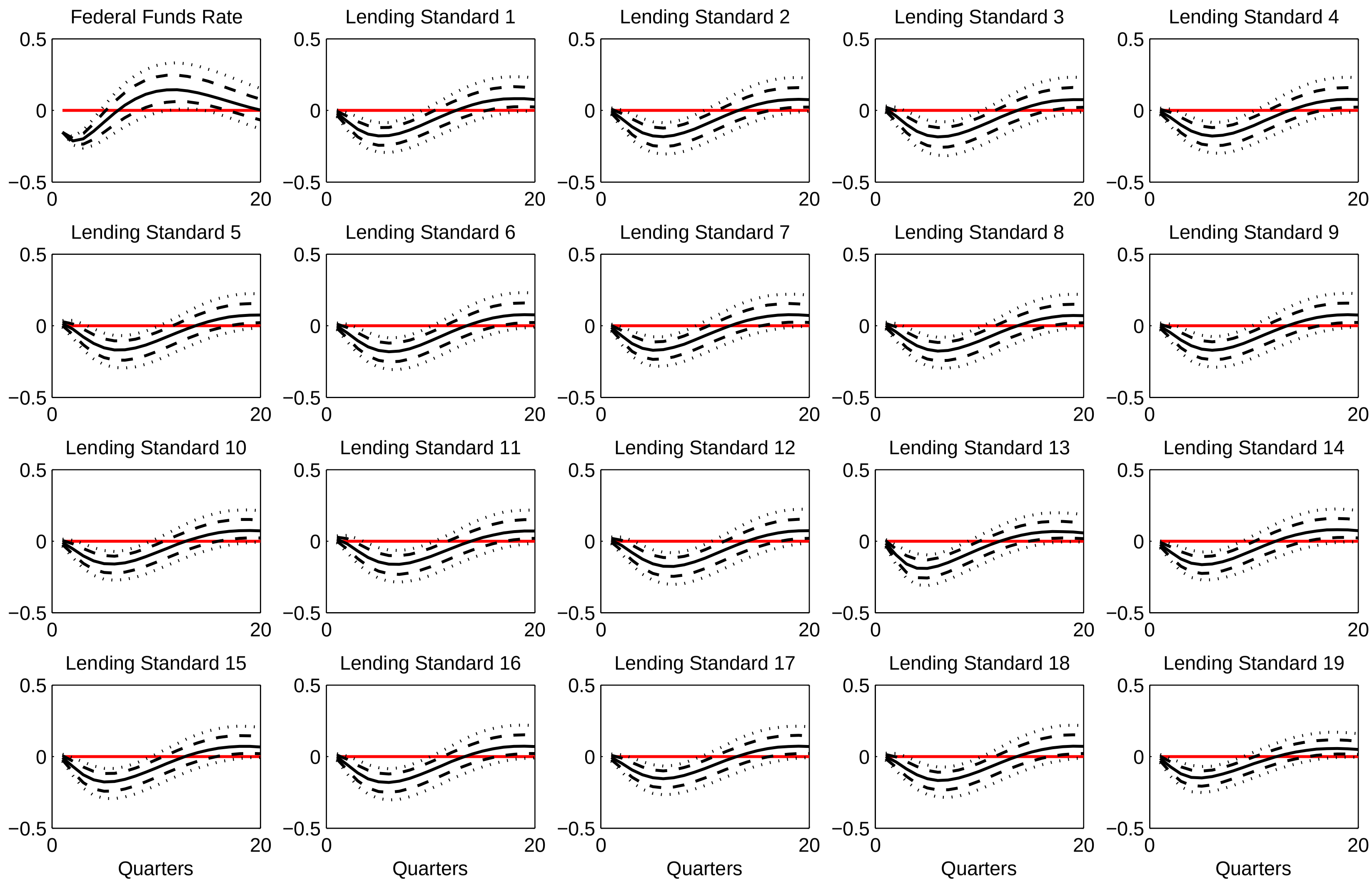
[42]It is well-known that HVD contributions go through a transition phase that can be protracted if the time series in question are serially correlated. Here, the transition phase lasts until roughly 1998 and our discussion therefore focuses on the results thereafter.

Figure F.2: Contribution of Monetary Policy Shocks to Historical Variance Decomposition of FFR and Lending Standards in the FAVAR Model with Three Unobserved Factors for 1991Q1-2008Q2.



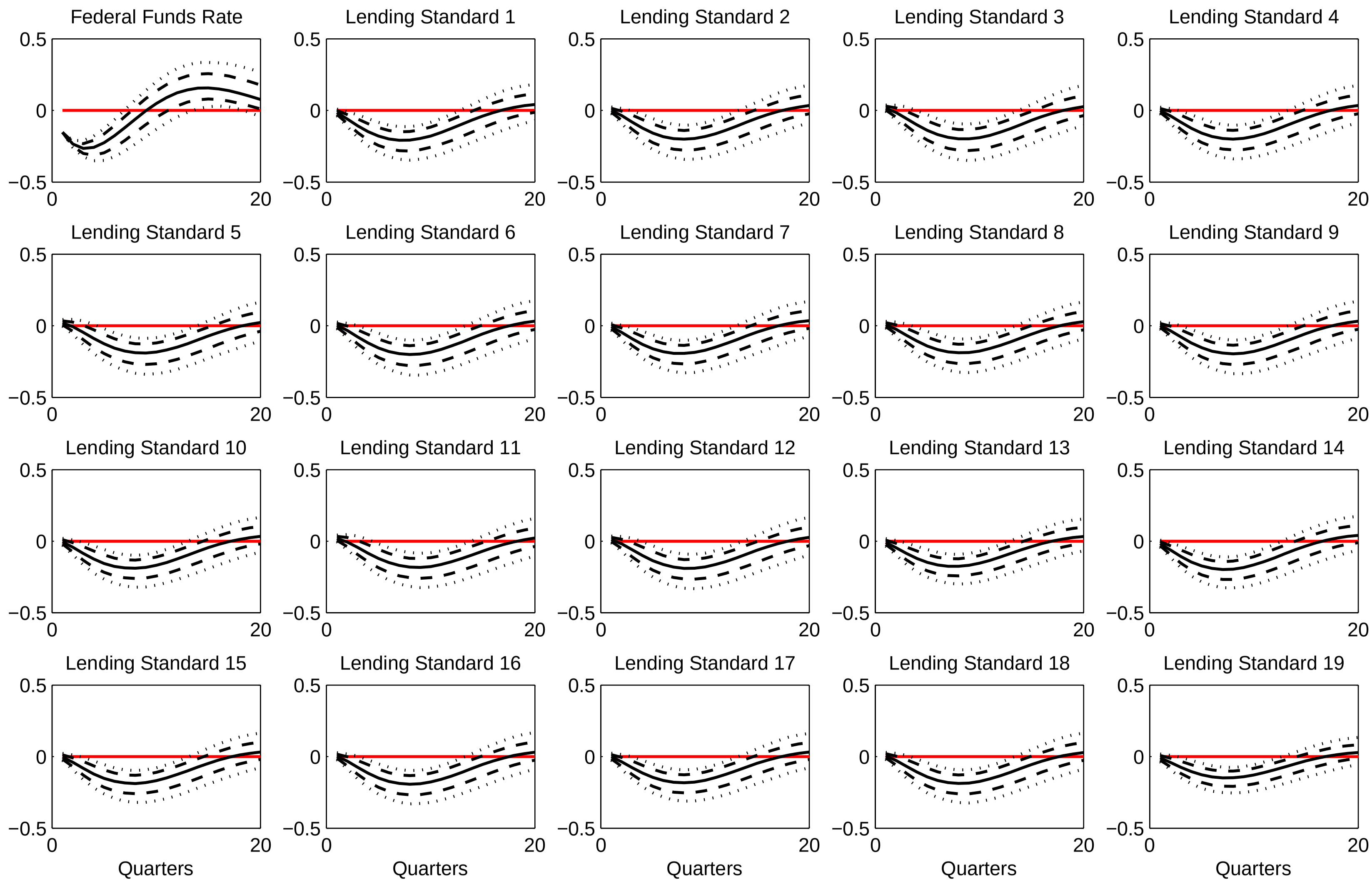
Notes: Point estimates for a single candidate draw from the Gibbs sampler. See Appendix D for a detailed description of lending standard measures.

Figure F.3: Impulse Responses of Lending Standard Measures to a 25bps Expansionary Monetary Policy Shock in the Baseline FAVAR Model with Three Unobserved Factors for 1991Q1-2008Q2.



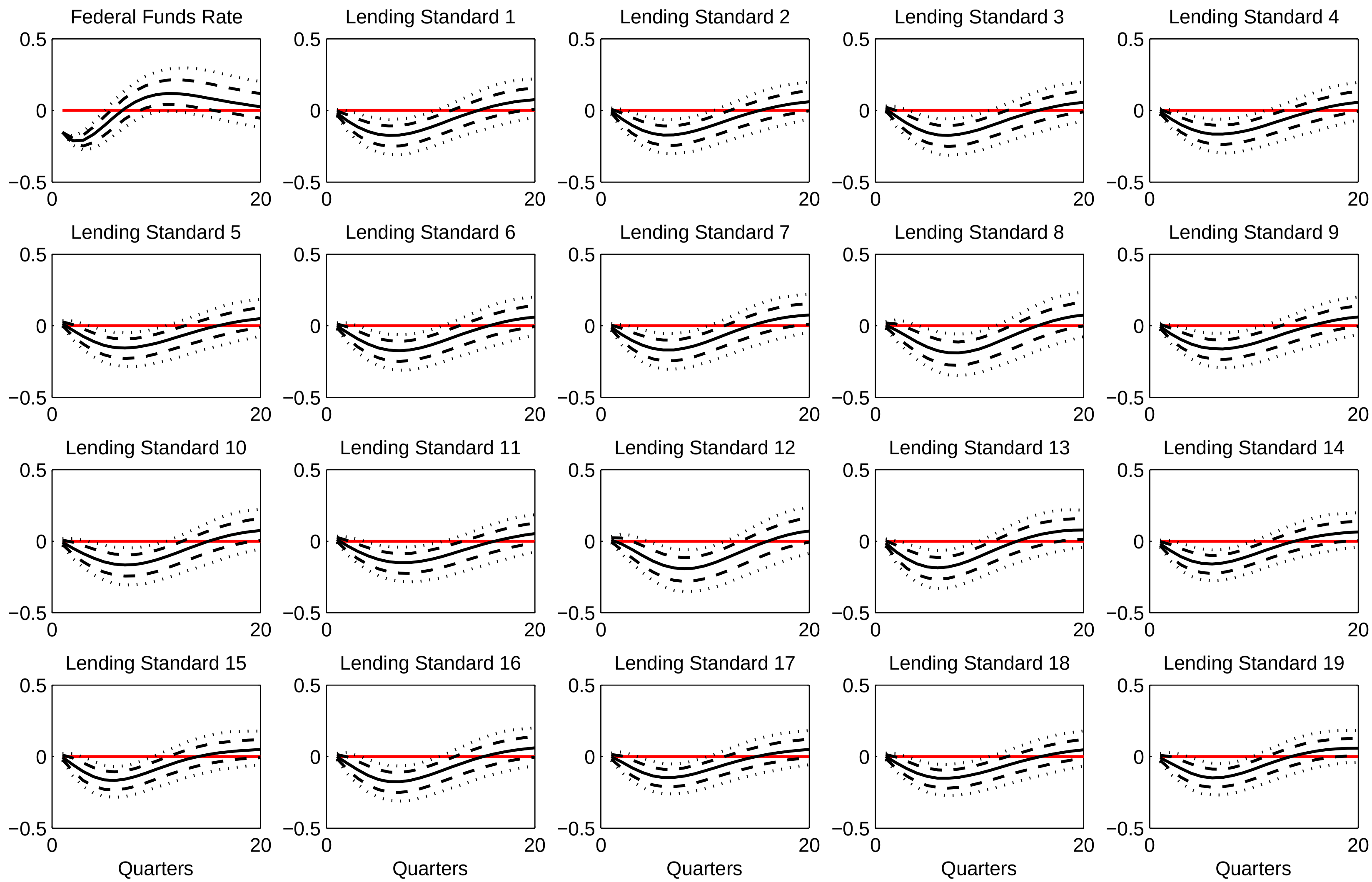
Notes: Median responses with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles. See Appendix D for a detailed description of lending standard measures.

Figure G.1: Impulse Responses of Lending Standard Measures to a 25bps Expansionary Monetary Policy Shock in the FAVAR Model with *One* Unobserved Factor for 1991Q1-2008Q2.



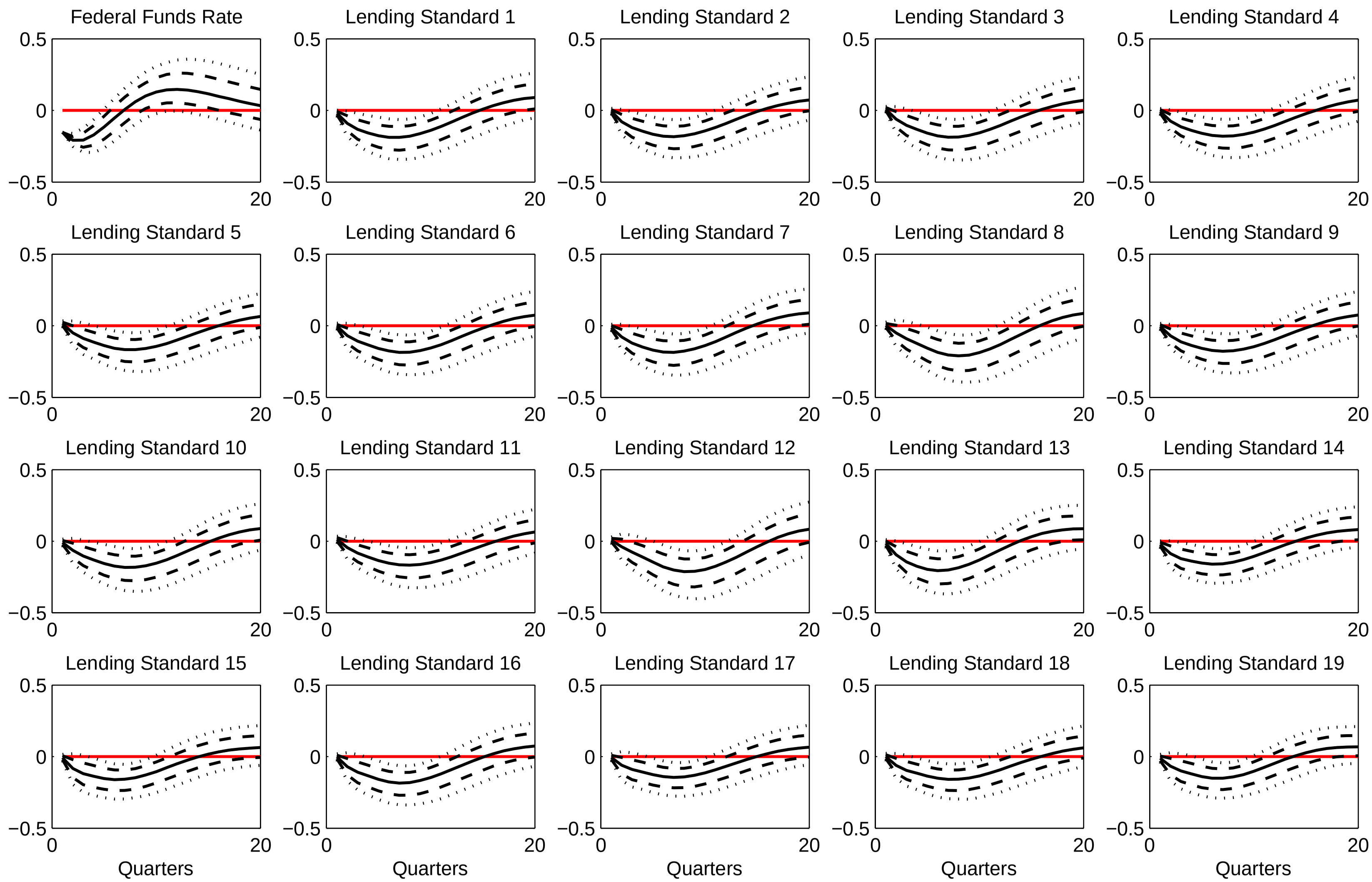
Notes: Median responses with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles. See Appendix D for a detailed description of lending standard measures.

Figure G.2: Impulse Responses of Lending Standard Measures to a 25bps Expansionary Monetary Policy Shock in the FAVAR Model with *Five* Unobserved Factors for 1991Q1-2008Q2.



Notes: Median responses with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles. See Appendix D for a detailed description of lending standards.

Figure G.3: Impulse Responses of Lending Standard Measures to a 25bps Expansionary Monetary Policy Shock in the FAVAR Model with *Seven* Unobserved Factors for 1991Q1-2008Q2.



Notes: Median responses with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles. See Appendix D for a detailed description of lending standards.

Appendix G.2. High-Frequency Identification

Following Barakchian and Crowe (2013), we extract an alternative time series of monetary policy shocks from daily changes in federal funds futures yields for different maturities around FOMC meeting dates. We then regress each variable of interest on $P = 4$ own lags as well as the contemporaneous and $Q = 12$ lagged observations of this exogenous monetary shock series using a distributed lag regression model.

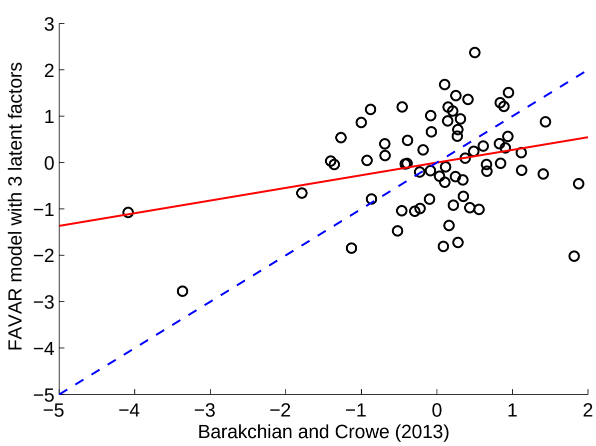
Figure G.4 compares the exogenous shock series based on high-frequency identification and our baseline FAVAR model with three unobserved components. The scatter plot in panel (a) illustrates that the high-frequency monetary policy shocks correlate positively with a representative draw from the Gibbs sampler with median correlation coefficient. The histogram of *all* correlation coefficients for the last 10,000 draws from the Gibbs sampler in panel (b) shows that the correlation between the two shock series is significantly positive for the vast majority of draws.

Figure G.5 plots the responses of selected variables from the theoretical DSGE model to an expansionary monetary policy shock against their empirical counterparts based on high-frequency identification (B&C). As in Figure 5 in the main text, the bank's collateral requirements, bank profits, and investment are expressed in terms of their unconditional standard deviations, while the policy rate and the bank's net interest margin are converted to annualized basis points, both in the DSGE model and in B&C. One period on the x-axis corresponds to one quarter. Figure G.5 documents that the findings described in the main text are robust to discarding the FAVAR model and using an entirely different approach to identifying monetary policy shocks.

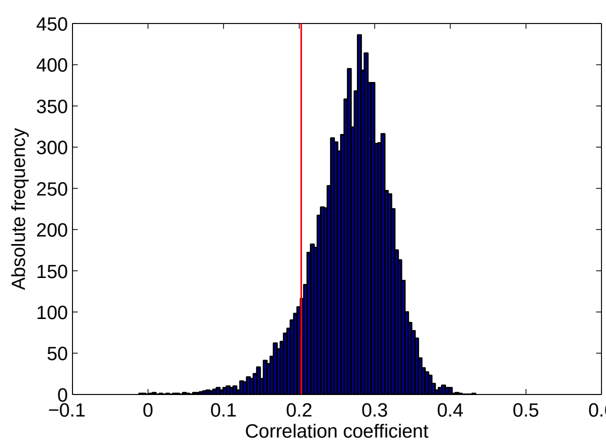
Figure G.7 plots the impulse response functions of alternative measures of lending standards to an expansionary monetary policy shock based on the high-frequency identification in Barakchian and Crowe (2013) and documents that the findings described in the main text are qualitatively robust to discarding the FAVAR model in favor of a different approach to identifying monetary policy shocks.

Finally, Figure G.8 illustrates that *all* 19 SLOOS measures of lending standards decrease in response to an expansionary monetary shock, whether it is identified using the FAVAR or the high-frequency approach.

Figure G.4: Correlation of Monetary Policy Shocks Based on High-Frequency Identification in Barakchian and Crowe (2013) and the Baseline FAVAR Model with Three Unobserved Factors for 1991Q1-2008Q2.

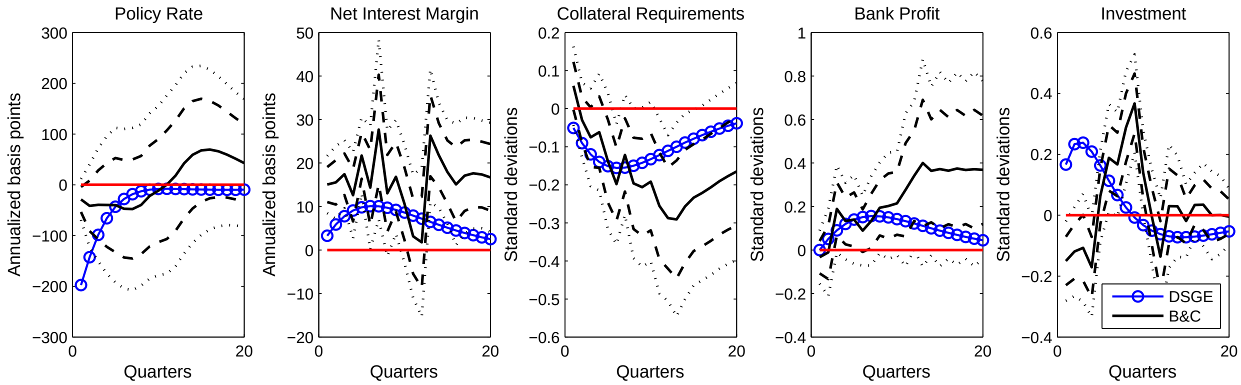


(a) Median scatter plot of standardized monetary policy shocks



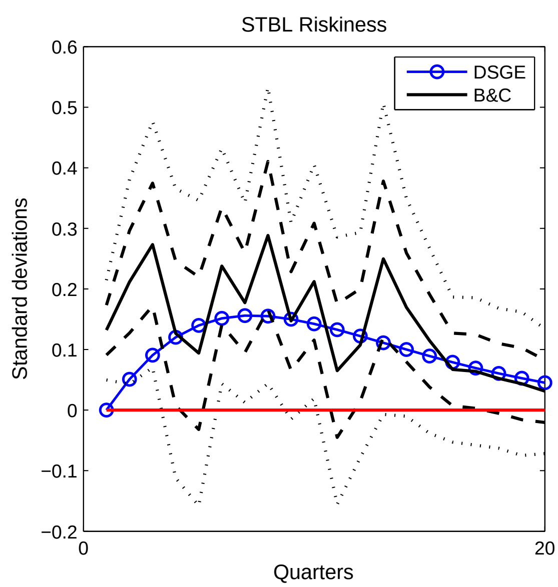
(b) Histogram of correlation coefficients (last 10,000 draws)

Figure G.5: Impulse Responses of Selected Variables to an Expansionary Monetary Policy Shock, DSGE Model and High-Frequency Identification in Barakchian and Crowe (2013) for 1991Q1-2008Q2.



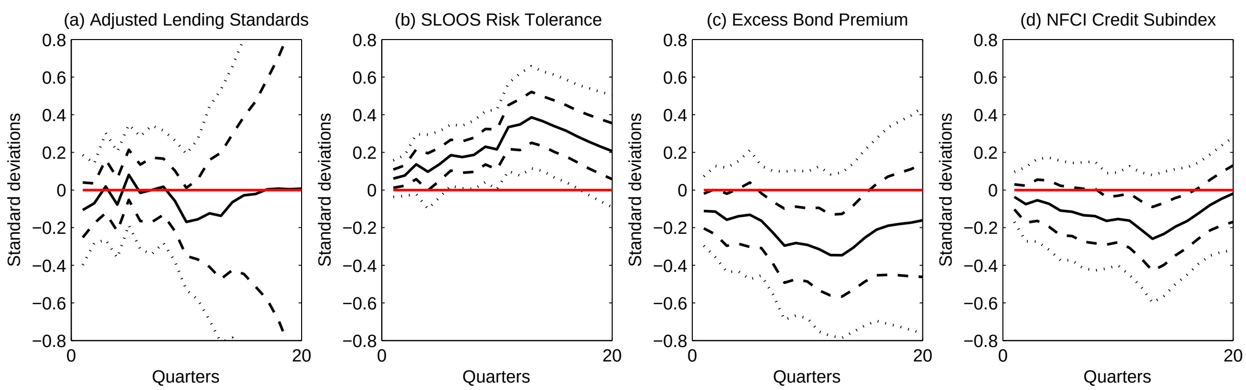
Notes: In the regressions, the *effective federal funds rate* is used as a measure of the monetary policy rate, the Call Reports *net interest margin for all U.S. banks* as a proxy for the theoretical interest rate spread, the *net percentage of domestic banks increasing collateral requirements for large and middle-market firms* as a measure of bank lending standards, the Call Reports *net income for commercial banks in the U.S.* to measure bank profit, and the *ISM Manufacturing: New Orders Index* as a proxy for investment. See Appendix D for a detailed description of the data. For the regression model, point estimates are plotted with pointwise one- and two-standard-error HAC-robust bootstrap confidence intervals.

Figure G.6: Impulse Responses of Loan Riskiness to an Expansionary Monetary Policy Shock, DSGE Model and High-Frequency Identification in Barakchian and Crowe (2013).



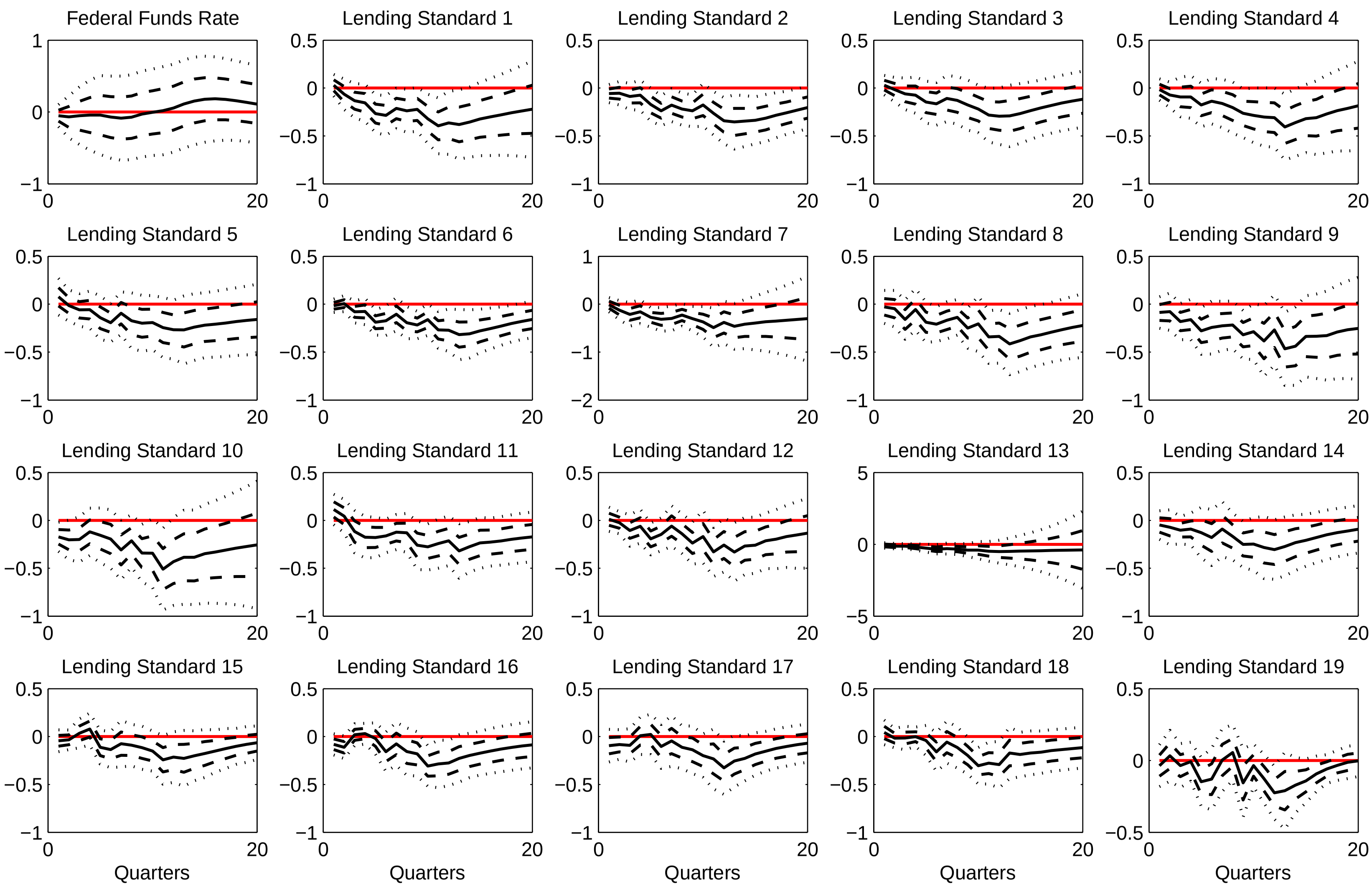
Notes: The measure of loan riskiness is obtained from the Terms of Business Lending Survey of the Federal Reserve. In particular, we compute weighted average risk score across all participating banks for the sample 1997Q2-2008Q2. For the regression model, point estimates are plotted with pointwise one- and two-standard-error HAC-robust bootstrap confidence intervals.

Figure G.7: Impulse Responses of Alternative Measures of Lending Standards to an Expansionary Monetary Policy Shock, High-Frequency Identification in Barakchian and Crowe (2013) for 1991Q1-2008Q2.



Notes: Point estimates with pointwise one- and two-standard-error HAC-robust bootstrap confidence intervals based on distributed lag regressions of (a) the *credit supply indicator* proposed by Bassett et al. (2014); (b) the *net percentage of domestic banks easing lending standards due to increased risk tolerance*; (c) the *excess bond premium* proposed by Gilchrist and Zakrajšek (2012); (d) the *NFCI credit subindex* published by the Federal Reserve Bank of Chicago. See Appendix D for a detailed description of the data.

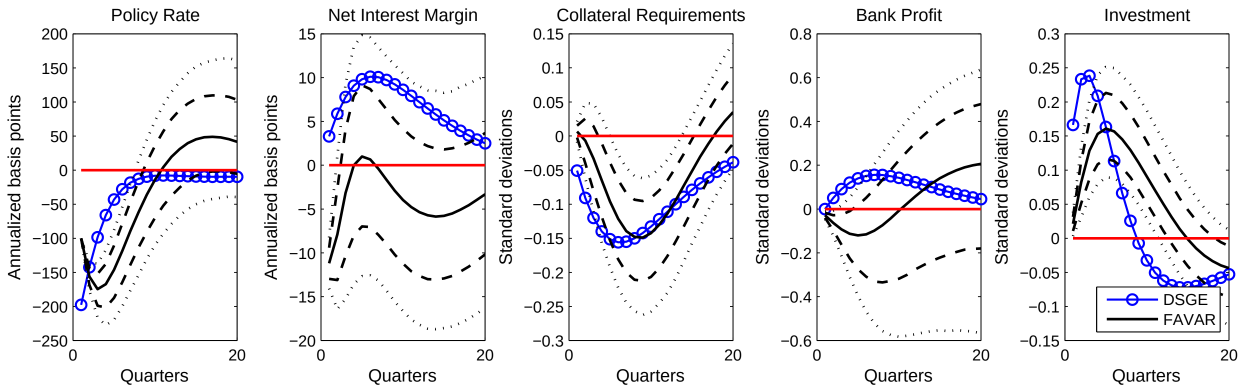
Figure G.8: Impulse Responses of Lending Standard Measures to an Expansionary Monetary Policy Shock, High-Frequency Identification in Barakchian and Crowe (2013) for 1991Q1-2008Q2.



Notes: Point estimates with pointwise one- and two-standard-error HAC-robust bootstrap confidence intervals based on distributed lag regressions of each variable on $P = 4$ own lags as well as contemporaneous and $Q = 12$ lagged observations of the shock series in Barakchian and Crowe (2013). See Appendix D for a detailed description of lending standards.

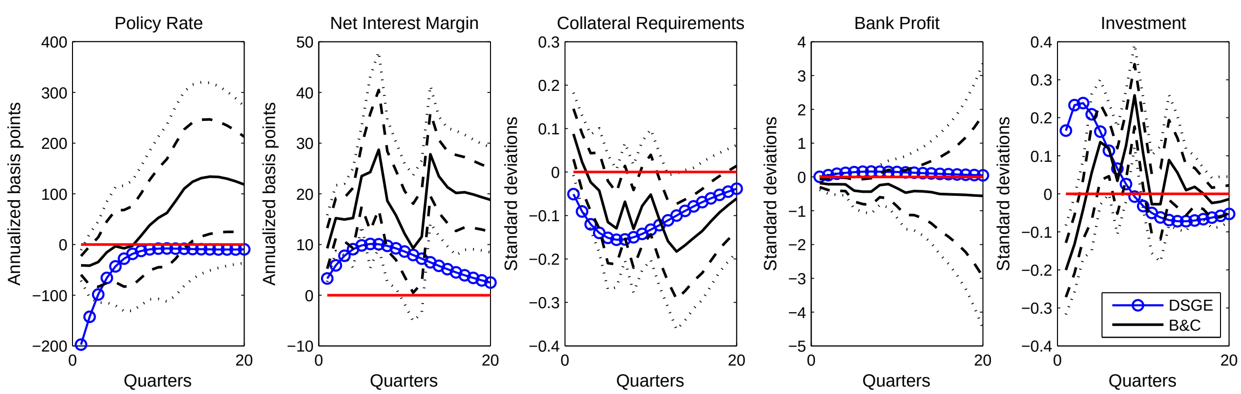
Appendix G.3. Extended Sample Period

Figure G.9: Impulse Responses of Selected Variables to an Expansionary Monetary Policy Shock, DSGE Model and FAVAR Model with Three Unobserved Factors for 1991Q1-2015Q4.



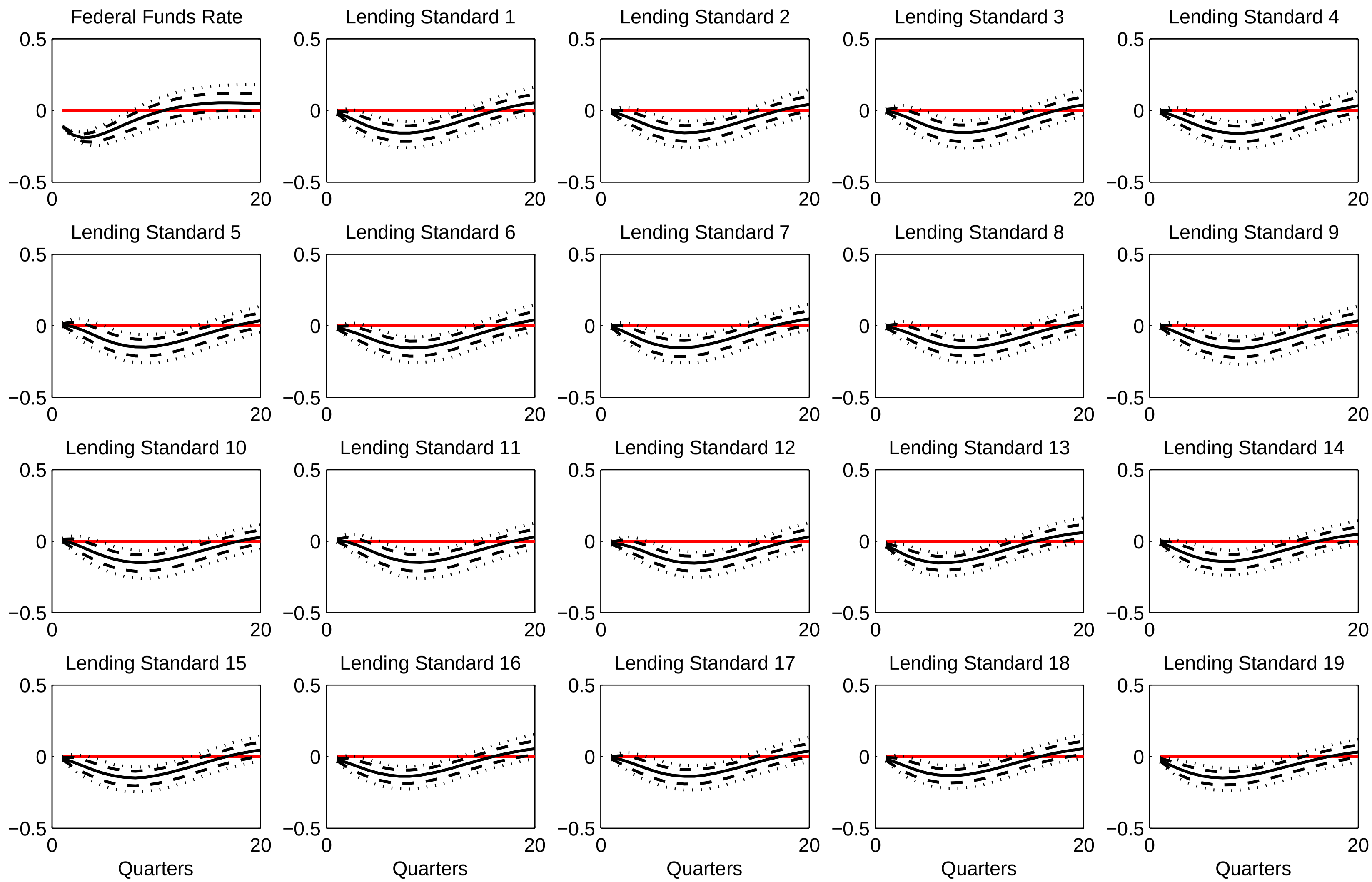
Notes: In the FAVAR model, the *effective federal funds rate* is used as a measure of the monetary policy rate, the Call Reports *net interest margin for all U.S. banks* as a proxy for the theoretical interest rate spread, the *net percentage of domestic banks increasing collateral requirements for large and middle-market firms* as a measure of bank lending standards, the Call Reports *net income for commercial banks in the U.S.* to measure bank profit, and the *ISM Manufacturing: New Orders Index* as a proxy for investment. See Appendix D for a detailed description of the data. For the FAVAR model, median responses are plotted with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles.

Figure G.10: Impulse Responses of Selected Variables to an Expansionary Monetary Policy Shock, DSGE Model and High-Frequency Identification in Barakchian and Crowe (2013) for 1991Q1-2015Q4.



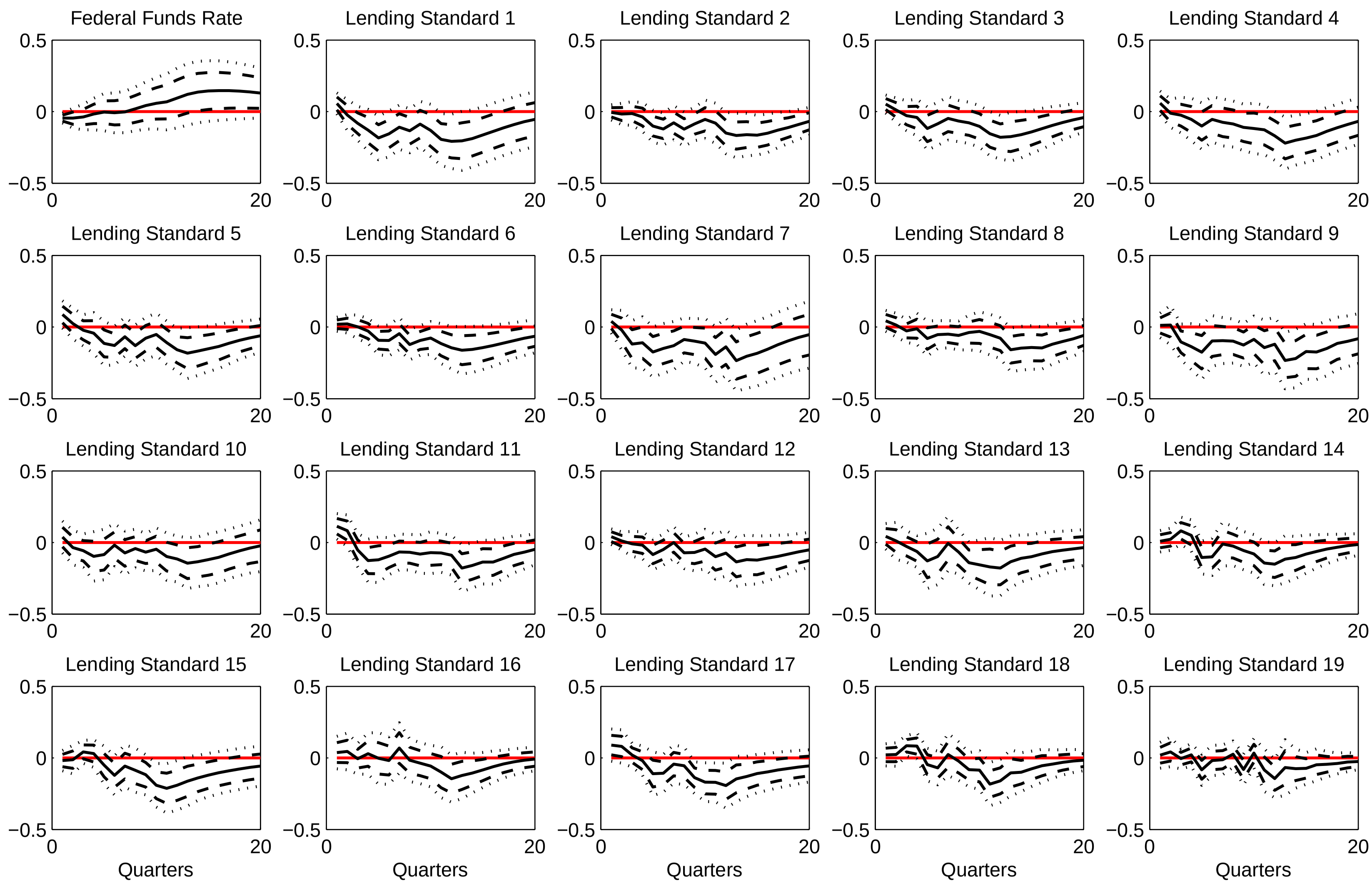
Notes: In the regressions, the *effective federal funds rate* is used as a measure of the monetary policy rate, the Call Reports *net interest margin for all U.S. banks* as a proxy for the theoretical interest rate spread, the *net percentage of domestic banks increasing collateral requirements for large and middle-market firms* as a measure of bank lending standards, the Call Reports *net income for commercial banks in the U.S.* to measure bank profit, and the *ISM Manufacturing: New Orders Index* as a proxy for investment. See Appendix D for a detailed description of the data. For the regression model, point estimates are plotted with pointwise one- and two-standard-error HAC-robust bootstrap confidence intervals.

Figure G.11: Impulse Responses of Lending Standard Measures to a 25bps Expansionary Monetary Policy Shock in the Baseline FAVAR Model with Three Unobserved Factors for 1991Q1-2015Q4.



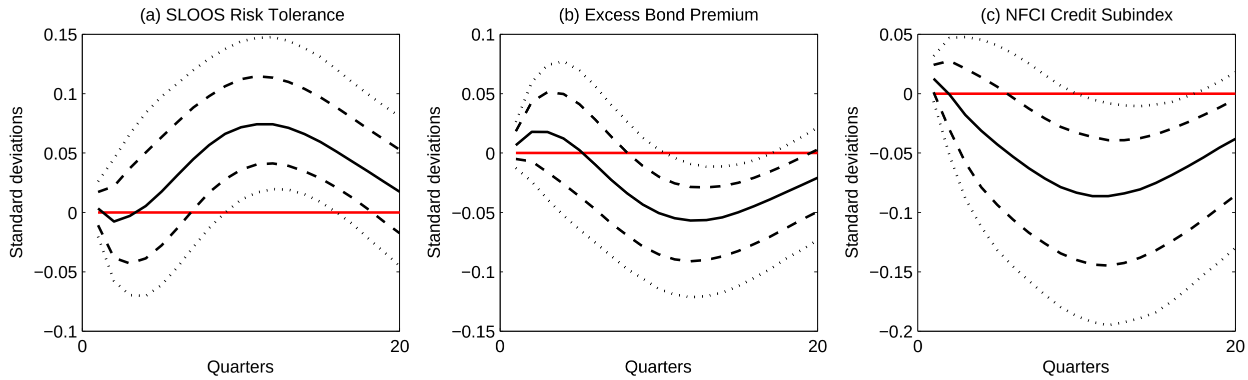
Notes: Median responses with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles. See Appendix D for a detailed description of lending standard measures.

Figure G.12: Impulse Responses of Lending Standard Measures to an Expansionary Monetary Policy Shock, High-Frequency Identification in Barakchian and Crowe (2013) for 1991Q1-2015Q4.



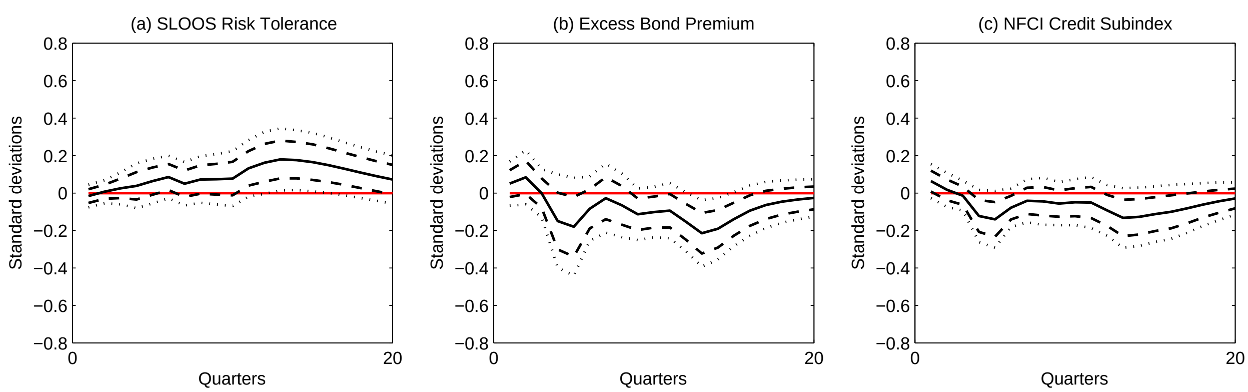
Notes: Point estimates with pointwise one- and two-standard-error HAC-robust bootstrap confidence intervals based on distributed lag regressions of each variable on $P = 4$ own lags as well as contemporaneous and $Q = 12$ lagged observations of the extended shock series. See Appendix D for a detailed description of lending standard measures.

Figure G.13: Impulse Responses of Alternative Measures of Lending Standards to an Expansionary Monetary Policy Shock in the FAVAR Model with Three Unobserved Factors for 1991Q1-2015Q4.



Notes: Median responses with pointwise $16^{th}/84^{th}$ and $5^{th}/95^{th}$ percentiles, based on the FAVAR model with three unobserved factors, where the 19 SLOOS lending standard measures have been replaced by (a) the *net percentage of domestic banks easing lending standards due to increased risk tolerance*; (b) the *excess bond premium* proposed by Gilchrist and Zakrajšek (2012); (c) the *NFCI credit subindex* published by the Federal Reserve Bank of Chicago. See Appendix D for a detailed description of the data.

Figure G.14: Impulse Responses of Alternative Measures of Lending Standards to an Expansionary Monetary Policy Shock, High-Frequency Identification in Barakchian and Crowe (2013) for 1991Q1-2015Q4.



Notes: Point estimates with pointwise one- and two-standard-error HAC-robust bootstrap confidence intervals based on distributed lag regressions of (a) the *net percentage of domestic banks easing lending standards due to increased risk tolerance*; (b) the *excess bond premium* proposed by Gilchrist and Zakrajšek (2012); (c) the *NFCI credit subindex* published by the Federal Reserve Bank of Chicago. See Appendix D for a detailed description of the data.

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