The Macroeconomic Effects of Bank Capital Regulation *

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Abstract

Bank capital regulations aim at reducing risk-taking and increasing the resilience of the financial sector. A key concern, however, is whether higher capital requirements impair banks' ability to lend, with potentially long-lasting negative effects for the economy. We propose a narrative identification strategy to examine the macroeconomic effects of higher bank capital requirements. We exploit the staggered implementation of these policies to account for anticipation effects of changes in capital regulation. We find that higher capital requirements lead to a sizable reduction in bank assets and lending, with substantial negative spillovers to the real economy. These effects are, however, only short-lived and temporary. We do not find evidence for long-run negative effects of higher capital requirements on bank lending and economic activity.

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1 Introduction

Since the 2008-2009 financial crisis, financial regulation in the US has undergone dramatic changes. Among the key elements of the new regulatory regime are enhanced capital requirements, including higher risk-weighted capital ratios and leverage ratio caps. These policy tools aim at reducing risk-taking and increasing the resilience of the banking sector. A key concern is that higher capital requirements impair banks' ability to lend, with long-lasting negative effects for the economy. However, empirical evidence on the dynamic effects of higher capital requirements on the macroeconomy - including its magnitude and duration - is absent. In this paper, we fill this gap.

Identifying the macroeconomic effects of a regulatory increase in bank capital requirements presents a number of challenges. Bank capital and assets are highly endogenous variables such that changes in the bank capital ratio reflect changes in credit demand and supply and many other influences. Furthermore, changes in bank capital requirements do not come as a surprise. In the US, an increase in capital requirements follows a staggered procedure: before becoming effective, the process involves a proposal of the new rules and a request for public comment, followed by a decision on and publication of the final regulatory rule. This final rule specifies the date when the regulation becomes effective. This multi-staged process makes it challenging to identify the effects of higher capital requirements.

Our strategy to identify the effects of bank capital requirements is to focus on historical changes in regulatory policy that affected capital requirements for a large share of US banks simultaneously, in the spirit of Romer and Romer (1989). Based on readings of legal, academic and administrative documents of the time, we identify changes to bank regulation that significantly raised capital requirements for US banks and record the exact timing of the implementation procedures. We document the underlying motives of these regulatory actions: all of the policies were structural in nature and aimed to address long-run features of the banking system. Our narrative analysis shows that these policies were never taken with reference to current or expected changes in macroeconomic and financial conditions.[1] Along the lines of Romer and Romer (2010), we therefore argue that these policy changes are unrelated to the financial and business cycle. In the spirit of the approaches in Fieldhouse et al. (2018) and Ramey and Zubairy (2018), we use these policy changes to identify the causal effects of a tightening in bank capital requirements accounting for the anticipated nature of capital regulation.

To assess the dynamic responses of key macroeconomic and financial variables to these capital requirement tightening events, we use local projections (Jordà 2005). We start by assessing how the aggregate bank balance sheet adjusts to higher capital requirements. Banks can respond to higher capital requirements by either shrinking assets or by increasing the level of bank capital. We show that banks adjust to higher capital requirements by first aggressively reducing the size of their balance sheet, i.e. in the short run banks engage in asset shrinking rather than increasing the level of capital. The maximum drop in bank size is large amounting to 3%. This suggests a reluctance of banks to reduce leverage by issuing new shares and a bias to towards asset shrinking due to asymmetric information and debt overhang (see Admati et al. 2018 and Myers 1977).

Perhaps our most surprising finding is that after around 18 month following the policy announcement banks stop shrinking further. At around the same time, banks start to increase their level of equity capital funding and assets eventually start to increase again. At the end of the adjustment period, banks have increased the level of bank capital by more than 8% while running the same business volume than before the regulation. The capital ratio itself increases permanently by around 50 basis point in the long run.

Banks' decision to adjust to higher capital requirements by first shrinking assets rather than recapitalizing has implications for the propagation of these policies to the real economy. Bank lending drops temporarily by up to 7% and credit spreads increase. These negative credit supply conditions have non-negligible short-run effects on real activity: industrial production and investment drop by around 5%. Also corporate bonds do not substitute for the drop in bank lending suggesting that bank funding is not fully sub-

[1]This reflects that until 2013, bank regulation in the US has never instituted a capital regulation that would explicitly fluctuate with the credit and business cycle (see Elliott et al. 2013)

stitutable (see Diamond 1991). Importantly, however, these effects are temporary only. Bank lending, production and investment all return towards the pre-regulation value, consistent with the dynamic response of bank assets. Hence, our results indicate that the transition to a higher level of bank capitalization involves short-run negative effects on economic activity. At the same time, however, we do not find evidence for any long-run negative consequences of higher capital requirements on the economy.

We then investigate in detail how banks adjust their asset composition, how bank risk evolves and how banks' funding cost respond to higher capital requirements. We show that banks rebalance their asset portfolio after an increase in capital requirements. Specifically, they permanently reduce exposure to the riskiest asset classes. Consistent with this, we find that bank default rates also drop permanently. Maybe even more surprising, we find that realized bank stock volatility as well as bank stocks excess return are permanently lower following higher capital requirements. We interpret these findings as reflecting evidence of a positive risk-return relation after an increase in capital requirements: higher capital requirements reduce risk in the banking sector which leads to a drop in banks' cost of capital.[2]

Our paper is related to a growing literature studying the long run macroeconomic effects of higher bank capital requirements in quantitative macroeconomic models. There is no consensus in this literature on the long-run real effects of higher capital requirements. On the one hand, the idea that equity capital for banks is a more expensive form of financing than deposits has a theoretical foundations in the literature.[3] Quantitative macro models usually capture this effect in reduced form ways by assuming that equity is more costly than debt or by postulating exogenous costs of equity issuance. A common feature of models along these lines is that higher capital requirements increase financial stability, but they permanently reduce the amount of lending and economic activity (see, e.g., Corbae and D'Erasmo 2014, Martinez-Miera and Suarez 2012, Mendicino et al. 2019

[2]This is consistent with Kovner and Van Tassel (2019), who show that the post-crisis regulation reduced systemic risk in banking and lead to a reduction in banks' cost of capital.

[3]These include asymmetric information about banks' conditions, limited market participation and bankruptcy costs, or banks as providers of liquidity (see Allen et al. 2015, DeAngelo and Stulz 2015 and Myers and Majluf 1984).

and Van den Heuvel 2008). On the other hand, some authors have argued that general equilibrium effects can overturn this effect. Admati et al. (2010) argue that higher capital requirements must not have negative long-run effects because they reduce bank risk and thereby their funding costs. In Bahaj and Malherbe (2018) higher capital requirements increase banks' survival probability. This increases the extend to which the marginal loan is subsidies by the deposit insurance. Bank lending increases due to this "Forced Safety Effect". In Begenau (2019) higher capital requirements reduce the aggregate supply of safe and liquid deposit. Because deposits provide liquidity services, this reduces banks' funding costs and generates a positive lending response. Our empirical exercise informs this theoretical literature by providing a robust set of stylized facts on the transmission mechanism and the full transitional dynamics of higher capital requirements to the macroeconomy.

Our paper also relates and contributes to the growing empirical literature investigating the effects of higher capital requirements on bank lending. Existing studies in this literature take a partial-equilibrium perspective exploiting detailed data on the bank or loan level. Aiyar et al. (2014) use UK bank level data to examine the lending effects of bank-specific capital requirements. Based on loan-level data from France, Fraisse et al. (2018) exploit cross-sectional differences in capital requirements due to the use of internal risk models to study examine the effects of capital requirement. Jiménez et al. (2017) use loan-level data from Spain to study the loan supply effects of the introduction and modification of the dynamic loan-loss provisioning regulation in Spain. Gropp et al. (2019) study loan-supply effects of higher capital requirement using the 2011 capital exercise conducted by the European Banking Authority as a quasi-natural experiment. These studies consistently find substantial negative short-run loan supply effects of higher capital requirements.

Our approach complements this literature by taking a general equilibrium perspective. Consistent with the results from these microeconomic studies, we also find a short-run reduction in bank lending. Moreover, we show that these negative lending effects spill over to the real economy generating a temporary contraction. Extending the existing literature, our approach also allows us to assess the medium and long-run effects of higher requirements. To the best of our knowledge, we are the first to show that the negative effects are only temporary and that permanently higher capital requirements are neutral in the long run.

There is a small number of papers that assess the macroeconomic effects of shocks to banks' capital ratio (e.g., Berrospide and Edge 2010, Kanngiesser et al. 2017 and Kok et al. 2016) or the regulatory capital requirement directly (e.g., Meeks 2017 and Noss and Toffano 2016). These studies use small scale Vector Autoregressive Models (VAR) and identify shocks using statistical methods, that is via a Cholesky decomposition or sign restrictions. However, they do not take into account that changes in capital regulation are best thought of as news shocks. With anticipation small scale VARs suffer from non-invertibility because they do not contain sufficient information to recover the 'true' underlying structural disturbances (see e.g., Hansen and Sargent 1991 and Leeper et al. 2013). Put differently, the presence of foresight invalidates the interpretation of VAR residuals as prediction errors, because the condition variables do not span the information set of forward looking agents (see Mertens and Ravn 2013). Our narrative identification approach together with local projections to recover impulse responses does not suffer from these shortcomings (see Owyang et al. 2013 and Ramey and Zubairy 2018). Hence, our approach adopts novel and arguably better identification strategies to recover the dynamic effects of an increase regulatory capital requirements.

The structure of the paper is as follows. In Section 2, we provide a narrative analysis of changes in bank capital regulation in the US. In Section 3, we outline our methodology. Section 4 contains our main results together with robustness analyses. In Section 5, we inspect the transmission mechanism more closely. We also compare effects of the regulation with effects of changes in another financial disturbance, the excess bond premium, see Gilchrist and Zakrajšek (2012). This helps us to better understand the transmission mechanism of capital requirement changes and to verify the validity of our identification approach. We conclude in Section 6.

2 A narrative analysis of changes in aggregate bank capital requirements

Our narrative analysis of changes in bank capital requirements has three objectives: first, to identify events in which regulatory capital requirements were changed for a large share of US banks at once and to classify if the policy change was binding or not; second, to identify the exact dates at which the policy changes were first proposed to the public, finalized and became legally effective; third, to identify the motivation for each change in capital regulation and to determine if these are unrelated to the current financial cycle and the business cycle.

The primary sources for our narrative analysis are official publications of changes in bank capital requirements in the *Federal Register*. Final rules published by the regulators in the *Federal Register* usually include a detailed discussion about the background and the motivation of the policy change. We complement this source with information obtained from the *Federal Reserve Bulletin* and some technical reports published by the FDIC. Finally, we also draw on academic literature from law and economics as changes in capital regulation usually sparked academic work on this event at the time. These academic publications helped us direct the search about the significant regulatory changes in the official outlets. A detailed description of the narrative analysis can be found in Appendix A.

2.1 Identifying significant changes in bank capital regulation

Table 1 presents the key changes we identify in US bank capital requirements. Numerical capital adequacy guidelines were first introduced in Dec. 1981 for the US. Required capital ratios still differed across the three main regulators, the Federal Deposit Insurance Corporation (FDIC), the Federal Reserve System (Fed) and the Office of the Comptroller of the Currency (OCC), but were set in the range between 5% and 6% of capital over unweighted assets. While multinational banks were at first exempt from the requirements, the Fed and the OCC subjected them to similar requirements in Jun. 1983 in the wake of Congressional pressure for higher adequacy ratios. Most multinational banks already fulfilled the requirements of 5% by that time. Therefore we do not account for this change in our baseline CRI (as elucidated by putting the date in gray font in Table 1), but analyze robustness with respect to including the event further below. US Congress demanded stronger and more uniform regulatory capital adequacy ratios in its International Lending and Supervision Act (ILSA) from Nov. 1983. This led to a common set of capital adequacy guidelines by the Fed, OCC and FDIC in Apr. 1985. The common capital requirements were set to 5.5% across all banks. Even though this meant a nominal capital adequacy easing for smaller (community) banks, the overall effect seems to have been a tightening in aggregate bank capital: Baer and McElravey (1993) find a shortfall of bank capital comparable to the one after the introduction of Basel I. We include both the ILSA passing and the regulatory response date into our indicator as the Congress act strengthened the regulators' hand against some court rulings in favor of banks, as well as for consistency with the 1991 legislation (see below).[4]

From the mid-1980s onwards, there were consultations for an international framework of bank capital requirements under the name of Basel Committee on Banking Supervision.[5] The capital requirements of the Basel Accord ("Basel I"), became binding for the US in Dec. 1990. Their main novelty was the introduction of risk weights for different asset classes, and specification of capital ratios of tier 1 and 2 capital to risk-weighted assets of 4% and 8%, respectively (see e.g. Tarullo 2008, p. 55). Several empirical investigations show that Basel I led to significant adjustments on bank capital ratios.[6] Around the same time, there was also renewed legislative pressure for a tougher implementation of capital adequacy rules. After the Savings and Loans (S&L) Crisis had revealed fundamental weaknesses of the US banking system, the US Congress demanded faster

[4] In Feb. 1983, the Fifth Court of Appeal in the case "First National Bank of Bellaire v. Comptroller of the Currency" had nullified a regulatory action by the OCC against the bank, declaring the regulator's capital-adequacy rule "capricious and arbitrary" (see e.g. Posner and Weyl 2013). After ILSA, court decisions generally acknowledged regulators' primacy over setting capital requirements (see Appendix A).XXB: too detailed here?

[5] The committee operated under the name of *Basle* Committee up to 1999, when the mostly German-speaking inhabitants of Basel suggested a change of name (Tarullo 2008, fn. 2, p. 1).

[6] See e.g. Haubrich and Wachtel (1993), Berger and Udell (1994) or Jacques and Nigro (1997).

action against banks with inadequate capitalization. In the FDIC Improvement Act of Dec. 1991, Congress gave very specific instructions how to implement so-called "prompt corrective action" measures against weakly capitalized banks. It also prescribed regulators to implement the new rules within a year, which duly led to regulatory changes becoming effective in Dec. 1992. Aggarwal and Jacques (2001) show that both events led to significant capital ratio build-ups by banks, which is why we include both dates in our indicator.

There were two more large regulatory changes before the global financial crisis. In Jan. 1997, the Market Risk Amendment adapted the Basel risk weights to also take into account market risk, thus affecting capital ratios of all banks. Importantly, banks were allowed to use their internal models to assess these risks. In Apr. 2008, after more long rounds of international negotiations, Basel II became effective in the US. However, for both events it is not clear whether they had a tightening or loosening effect on banks' capital ratios. Gehrig and Iannino (2017), in a study on European banks, argue that in both cases large banks actually lowered their de-facto capital ratios by the use of internal models. We do not include the two events into our baseline indicator, but check for robustness of our main findings in including the Jan. 1997 event. Following Cerutti et al. (2017), we do not include Basel II into the baseline index.

Our baseline sample excludes the reform packages of Basel II.5 and III, which were introduced only after the crisis. The regulatory changes introduced by these packages were manifold, and among others included higher bank capital requirements, which effectively increased bank capitalization (see e.g., Cerutti et al. 2017 and Cohen and Scatigna 2016). Therefore, we also check for robustness using a longer sample and including these two dates.

In our baseline analysis, we use a binary indicator of regulatory capital requirements with ones for the months of CRI changes and zeros otherwise. This ignores that some events may have affected the banking system (and the economy) more than others. As a robustness check, we also (tentatively) weight the events and account for differing numbers of affected banks and increases in capital ratios. Given that quantification in our context is not straightforward and that key results are almost identical to those using our baseline unweighted CRI, the alternative weightings schemes and the results are not presented here. Instead we refer the interested reader to Appendix C.

2.2 Timing

In general, the legal procedure associated with a change in the rules for bank capital requirements is as follows. In all cases except the Congress acts of 1983 and 1991, regulators at some point publish a set of *proposed rules* in the Federal Register, and banks and other stakeholders are invited to send comments. Together with a discussion of received comments on the proposals, the regulators then publish a set of *final rules* of the envisaged changes. The public at this point has a clear idea on which changes to expect. The final rules often include a detailed purpose and a motivation, a background and an overview of the regulation. They also specify a date as of which the rules will become effective. This "effective date" is the date we focus on in our analysis. We do our best to specify comparable dates for the US Congress acts (our second and fifth event), see Appendix D for details. After the effective date, there is usually a phase-in after which the rules fully apply. End of phase-in periods are not considered explicitly here due to the lack of additional information for half of the events.[7]

In columns 2 and 3 of Table 2, we list the dates of proposed and final rules for each of the main policy events. The information in Table 2 shows that changes in bank capital regulation follow a staggered introduction process and are anticipated with substantial leads. These policy events could therefore be interpreted as news shocks about tightenings in capital requirements. If we think of the anticipation horizon as the time between publication of the proposed or final rules and of the effective date, we obtain horizons of $\{6, 8, 9, 57, 9, 5\}$ months for the proposed rule and of $\{6, 7, 1, 23, 4, 3\}$ for the final rule. Basel I with its lengthy international negotiations is an outlier. Without Basel I the

[7] While the Dec. 1981 numerical guidelines and the Dec. 1992 prompt corrective action measures were explicitly introduced without a phase-in, the Apr. 1985 common guidelines and the Basel I reforms had explicit phase-ins of 12 and 24 months (see Federal Register, Vol. 50, No. 53/ Mar. 19, 1985, p. 11139, and Vol. 54, No. 17/ Jan. 27, 1989, p. 4193). ILSA (our second event) did not specify a time until when regulators should take actions. The FDICIA (our fifth event) stated a time window of 12 months.

median anticipation horizons are at 8 months (differences between proposed rules and effective dates) and at 4 months (differences between final rules and effective dates). We have no clear prior whether banks should be expected to act already on the proposed rules, or on the more specific final rules. In our econometric exercise, we will therefore allow for anticipation effects assuming an average anticipation horizon of 6 months. This choice is also supported by a newspaper search of the first mentioning of the new regulations (Appendix D) as well as by an ex-post analysis on when markets first reacts based on bank excess return dynamics (Appendix D). However, we show below that our results are robust to using anticipation horizons of 4, 8 or 10 months.

2.3 Motivation for tighter capital requirements

The motives for the changes in bank capital regulation in our index are virtually always broad, long lasting and structural in nature. Moreover, the policy changes are slowly drafted and subject to lengthy negotiations between bankers, politicians and regulators. As illustrated above, this results in a considerable time lag between the announcement of the new policy rule, the date at which the rule becomes effective, and the date at which the regulations finally become binding for banks after the phase-in. While it is true that some of the policy changes were introduced after periods of financial turbulences, they always addressed the underlying fundamental weakness in the financial system revealed by the turbulence, not the turbulence itself. Our readings of the official documents at the time therefore corroborate the assertion in Elliott et al. (2013) that "as of 2013, supervisors have never instituted a countercyclical capital regime, in which capital requirements would explicitly fluctuate with the credit cycle." (p. 34). We therefore conclude that the policy changes captured by our CRI were not motivated by cyclical consideration but are unrelated to the current business cycle and financial cycle.

To illustrate one example of our readings of the policy statements, we detail the relevant passages for our first event, the introduction of numerical capital-adequacy ratios in Dec. 1981, and Appendix A lists similar relevant quotes for all events in our CRI. We find two quotes particularly telling about the regulators' motivation. For the FDIC, this is a paragraph in the "Statement of Policy on Capital Adequacy" in the Federal Register (Vol. 46, No. 248/Dec. 28, 1981, p. 62693):

> *This policy statement is intended to clearly set forth qualitative criteria to be considered in determining adequacy of bank capital, to inject more objectivity and consistency into the process of determining capital adequacy, to provide nonmember banks with clearly defined goals for use in capital and strategic planning and to address the issue of disparity in capital levels among banks in different size categories by adopting uniform standards regardless of the size of the institution.*

The corresponding announcement published in the Federal Reserve Bulletin conveys a similar point on the motivation (Federal Reserve Bulletin/Vol. 68, No.1/Jan. 1982, p. 33):

> *Objectives of the capital adequacy guidelines program are to address the long-term decline in capital ratios, particularly those of the multinational group; introduce greater uniformity, objectivity, and consistency into the supervisory approach for assessing capital adequacy; provide direction for capital and strategic planning to banks and bank holding companies and for the appraisal of this planning by the agencies; and permit some reduction of existing disparities in capital ratios between banking organizations of different size.*

We also test statistically for exogeneity of the CRI. To do so, we try to predict our CRI events using probit regressions on the following lagged variables from our main analysis below: the bank capital ratio, changes in industrial production and the core PCE deflator, the Federal Funds rate, changes in bank loans and the BAA spread (for details on the series, see Appendix E). We include the variables one at a time to avoid overfitting (Vittinghoff and McCulloch 2007). None of the variables significantly enters the equation (see Table 3), implying that the regulations cannot be forecast using macro and financial data and thus do not appear to react to the state of the business cycle and the financial cycle.[8]

[8] This finding is robust to a battery of different model specifications and variable transformations. We refer to Appendix B for more details.

Finally, in our robustness checks below we include an extensive range of other shock indicators, as well as recession and financial crisis dummies. Results are not affected, which should soothe potential concerns that our regulatory events pick up episodes of financial turmoil.

3 Methodology and data

To assess whether tightenings in bank capital requirement influence the financial system and the real economy, we conduct an impulse response analysis by estimating a series of Jordà (2005) local projection regressions. For this, let y_t denote a variable of interest, x_t a set of control variables and CRI_t the index containing the capital requirement tightenings. For a given monthly outcome variable y_t, we estimate the response to higher capital requirements at horizon h based on

$$\widetilde{y}_{t+h} = c^h + \beta^h(L)\widetilde{x}_{t-1} + \gamma^h(L)CRI_{t-1} + u_{t+h}. \tag{1}$$

When estimating equation (1), we transform all non-stationary variables according to $\widetilde{y}_{t+h} = y_{t+h} - y_{t-1}$ and $\widetilde{x}_t = x_t - x_{t-1}$. Stationary variables enter the regression in levels, that is we set $\widetilde{y}_{t+h} = y_{t+h}$ and $\widetilde{x}^i_t = x^i_t$ for all stationary variables. Each regression contains deterministic regressors c^h which includes a constant, a linear trend and a quadratic trend. For the lag polynomials $\beta^h(L)$ and $\gamma^h(L)$ we choose an order of 2 as in Ramey (2016). Finally, we note that the CRI enters the equation with a lag of one period. We opt for this baseline specification because three of the regulatory changes became effective on the last day of the month, and the other three in the second half of the month (see Table 1). However, our results do not change if we include the CRI contemporaneously. The sequence of parameter estimates $\{\gamma^h_1\}^H_{h=1}$ yields the impulse response of y_t at horizon $h = 1 \dots H$ to a tightening in capital requirements, i.e. to a change in the CRI from 0 (no event) to 1 (a regulatory event).

In equation (1), we assume that changes in capital requirements are unanticipated until they become effective. This assumption stands in stark contrast to the staggered way how regulators communicate and implement tighter capital requirements. In the previous section, we described in detail that changes in capital requirements are anticipated with a substantial lead. To account for the anticipated nature of capital requirements tightenings, we modify the standard local projection regression in equation (1) to allow for endogenous responses k months before the new regulation becomes effective. Along the lines of Mertens and Ravn (2012), for every horizon h we estimate

$$\widetilde{y}_{t+h} = d^h + \delta^h(L)\widetilde{x}_{t-1} + \tau^h(L)CRI_{t-1} + \alpha^h(L)CRI_{t+k} + e_{t+h}. \tag{2}$$

The regression in equation (2) is identical to the specification in equation (1) except that we additionally include k leads of the index of capital requirement changes. The anticipation effects of capital requirement changes are introduced through the lag polynomial $\alpha^h(L)$ of order 6. In the baseline specification, we set the anticipation horizon to $k = 6$ months. This corresponds to the average time period between publication of the new regulation and effective date. Note that these coefficients relate to changes in capital regulation that are part of the information set at date t but not yet implemented. Hence, these terms directly measure announcement effects to changes in bank capital regulation. The impulse response of y_t at horizon $h = 1 \dots H$ to the announcement of an increase in capital requirements are then given by $\{\alpha_1^h\}_{h=1}^H$. The empirical model therefore allows us to trace out the dynamics of y_t from the time when regulatory changes are announced.

We use monthly data from 1979:8 to 2008:8.[9] The beginning of the sample corresponds to Paul Volcker's appointment as chairman of the Federal Reserve, and we end before the Great Recession. These choices help exclude structural instabilities due to major changes in monetary regimes or the global financial crisis. The set of control variables x_t always includes the log level of industrial production, log level of the the core PCE

[9] For all horizons h we define the sample based on the time series of the dependent variable at horizon $h = 0$. That is, for each $h > 0$ we add the required observation beyond (add last date of RHS variables) of the left-hand-side variable such that the number of observations remains constant at T = 349. Specifying the local projection in this way, the vector of explanatory variables is the same across different horizons allowing for better comparability across specifications.

price index, the log level of total bank loans, the federal funds rate, the yield spread of Moody's BAA corporate bond over 10-Year Treasury Bond, and the left-hand-side variable (if not among the previously listed variables). Below we also explore other model specifications and sample periods. Our banking data comes from the Federal Reserves H.8 Assets and Liabilities of Commercial Banks in the United States dataset. These data, to our knowledge, constitute the only monthly source of historical banking and credit data in the United States. The H.8 data is not collected for regulatory purposes, which is why it does not contain measures of regulatory bank capital. In the empirical analysis, we therefore focus on book capital, which we compute as the difference between total assets and total liabilities.[10] Details on data sources, transformations and construction of all variables - including those used in the robustness analysis - can be found in Appendix E.

The local projections model explaining the capital ratio corresponds to the first-stage regression in an instrumental-variable (IV) local projections approach. While the point estimates from the IV local projections are identical to the estimates from the standard local projections up to a scaling (Ramey 2016), the IV setup yields, in addition, information on the relevance of the CRI for bank capitalization, which we can exploit to further understand the relation between our CRI and the bank capital ratio. Based on the regressions for the capital ratio, we compute the Newey and West (1987) robust F-statistic up to 48 horizons after the regulatory changes (see Fieldhouse et al. (2018) for a similar approach). In the model without anticipation effects we find its maximum to be at almost 10 within 38 months after the regulatory changes (dotted line in **??**), suggesting that the CRI is sufficiently relevant for the future capital ratio.[11] In the model with anticipation effects the relevant F-statistic is even larger, exceeding 13 at a forecast horizon of 34 months (solid line in Figure **??**). Overall, while the CRI would lend itself as a strong instrument for the book capital ratio at longer horizons, we prefer to use straightforward

[10] See Adrian and Shin (2014) for a similar approach to compute the capital ratio of security brokers and dealers. We also note that the H.8 contains disaggregated statistics for small, foreign and large banks only from 1985 onwards. Hence, we cannot assess the effects of tighter capital requirements on small and large banks separately. Doing so would require starting our analysis in 1985, in which case we would lose too many events.

[11] F-statistics are much lower when the dates of proposed or final rules are used instead (not shown), never exceeding 7. This supports our focus on the effective dates.

local projections as we do not have the appropriate regulatory bank capital ratio at our disposal for our sample.

In both models, the central identifying assumption is exogeneity of changes in bank capital requirements. This requires that the residuals of equation (1) and equation (2) and the narrative index of capital requirement tightenings are uncorrelated. If the lagged control variables capture all relevant shocks to the dependent variable before time t, then the regression residuals u_{t+h} and e_{t+h} are equivalent to the variables' horizon h forecast error which depends only on unpredictable shocks occurring between period $t+1$ and $t+h$. The identifying restriction then boils down to the assumption of contemporaneous exogeneity, that is, orthogonality between changes in capital requirements and all shocks in month t (see Stock and Watson 2018 and Fieldhouse et al. 2018). If the control set does not fully capture all shocks prior to date t, then the exogeneity requirement is stricter and capital requirement changes must not be correlated with the history of relevant impulses to the left-hand-side variables. Our narrative analysis has shown that capital requirement changes where never imposed based on cyclical motives (see also Elliott et al. 2013). Rather, the index of capital requirements contains only permanent policy changes that were structural in nature. Hence, any correlation between contemporaneous time t shocks with changes in capital requirements is highly unlikely, and including lagged control variables provide additional insurance that potentially confounding effects of any remaining correlations with prior shocks are eliminated (see Fieldhouse et al. 2018, Ramey 2016 and Stock and Watson 2018).

4 Findings

4.1 The macroeconomic effects of higher capital requirement

?? shows how the aggregate banking system adjusts to higher capital requirements in terms of the aggregate capital ratio, the level of bank capital and total assets. **??** shows the broader macroeconomic response to an increase in capital requirements. Each panel shows two sets of impulse responses. The black solid line and the gray shaded areas represent the points estimates and 68% and 90% confidence bands from the model with anticipation effects. The blue solid and dotted lines show point estimates and 90% confidence bands from the model specification without anticipation effects. We compute confidence bands using Newey and West (1987) heteroscedasticity and autocorrelation consistent standard errors.

We discuss first the results from the model allowing for anticipation effects shown by the black and gray shaded areas. The right panel of **??** shows the response of the aggregate capital ratio to the change in regulation. The bank capital ratio hovers around zero during the pre-implementation period and for around 18 month thereafter. After one year into the implementation period the capital ratio starts to increase significantly. The bank capital ratio does not tend to return to its baseline value but remains significantly positive until the end of the projection horizon of four years. Hence, the capital ratio increases permanently after the regulatory tightenings of capital requirements encoded in the CRI. The increase in the capital ratio also comes at a meaningful size. A "representative" CRI tightening in our sample leads to a 30 basis points increase in the aggregate capital ratio. This shows that our index picks up decisive regulatory events given that the capital ratio is at 6.9% on average over the six events.

Banks can adjust to higher capital requirements in various ways: by reducing the size of their balance sheet, by increasing the level of capital, or by a combination of both. Differentiating at which margin banks choose to adjust is crucial for understanding the transmission to the real economy. The middle and right panel of **??** show the responses of the level of bank capital and total assets, respectively.

We find that the response of the level of bank capital matches closely the response of the capital ratio. The level of bank capital increases only around 18 month into the implementation period, but then does so permanently. At the end of the projection horizon banks permanently use around 6% more equity financing relative to the pre-regulation period. Total assets behave very differently: Banks reduce the size of their balance sheet strongly already during the pre-implementation period. Within the first six month from the announcement total assets decline by about 1.5%. They continue to decline during the implementation of the new policy and are lower by around 3% after 2 years. Banks then slowly extend their balance sheet back towards the pre-regulation value. Hence, although higher capital requirements permanently affect the capital ratio and the level of equity financing, they have no long run impact on the size of the banking system. From the figure it seems that the dynamics of the capital ratio (in percentage points) are entirely driven by the dynamics of bank capital (in percent). This is not surprising given that banks are highly levered, with assets being more than 12 times larger than bank capital on average over our sample period.

In **??**, we report impulse responses of industrial production, the federal funds rate, total bank lending to the real economy and the Baa-Aaa spread to higher capital requirement. The behavior of these variables help gauge the broader macroeconomic effects of a tightening of bank capital regulation. Industrial production starts falling around three month after the policy announcement. In continues to decline gradually reaching a maximum decrease of about 3% roughly one year after the implementation of higher capital requirements. Industrial production then starts increasing again and returns to its baseline value.[12] Bank lending to the real economy drops significantly on announcement of the new policy - predating the response of industrial production. Bank lending continues to decline gradually for around one-and-a-half years into the implementation period being lower by about 5%.[13] Bank lending then picks up again and returns to baseline. The BAA spread increases after about 8 months and remains significantly elevated for roughly one year. The rising spread and the declining loan volume suggest that negative credit supply effects indeed dominate after a tightening in capital requirements. Hence, the decline in industrial production seems due to the reduction in bank loan supply.

[12]Monthly GDP (interpolated from quarterly values) declines by a maximum of 1% after announced changes in capital requirements with a similar shape as the impulse response of industrial production.

[13]Loans drop by more than bank assets. Almost half of assets are loans (as in January 2017), whereas the other half consists of treasury and agency securities (15% of assets), other securities (6%), other loans and leases (8%), cash assets (14%) and other assets (8%). We also look at dynamics of the other bank asset categories after anticipated changes in the CRI and find most other categories to fall or not move significantly, but treasury and agency securities to rise. This helps explaining the (percentage) reaction of assets in comparison to the one of loans.

Monetary policy reacts quickly and very aggressively to the drop in bank lending and the reduction in economic activity following falling loan supply. It lowers the federal funds rate by around 250 basis points within the first 18 months after the tightening in capital requirements has been announced. Below, we will examine more formally to what extent monetary policy smooths out negative economic effects of increasing bank capital requirements.

The results from the specification in equation (1) - which ignores the possibility of anticipation effects - are given by the blue lines in **??** and **??**. In general, the results are qualitatively similar to the specification featuring anticipation effects. Still, quantitatively the story told is different. Ignoring anticipation effects, the effects of higher capital requirements are substantially weaker. The impulse responses of total assets and the level of bank capital are barely significant and substantially weaker compared to the model which allows for anticipation effects. Bank loans as well as industrial production decline *before* the regulatory changes become effective, and troughs are reached slightly earlier and are deeper with anticipation effects. In the specification allowing for anticipation effects the reduction in loan supply precedes the decline in industrial production and the federal funds. Ignoring anticipated effects to the policy change obscures this pattern. In general, our results suggests that ignoring anticipation effects leads to different conclusions concerning the nature of the transmission mechanism of higher capital requirements.

Our finding of large, short-run negative loan supply effects due to higher capital requirements confirms results from previous literature based on bank or loan-level data (see e.g., Aiyar et al. 2014; Fraisse et al. 2018; Jiménez et al. 2017; and Gropp et al. 2019). In fact, considering the negative loan supply effects compared to those on relative changes in the bank capital ratio (i.e., changes in the ratio over the level of the ratio), our results are actually very similar in magnitude to the findings from these studies. This is because the average capital ratio over our six events of 6.9% is much smaller than the capital ratio considered in other studies. In Aiyar et al. (2014), for example, banks depart from a capital ratio of about 11%. By contrast, the existing macroeconomic studies document much smaller effects of shocks to bank capital (see Dagher et al. 2016 for an overview).

This illustrates the importance of using properly identified exogenous changes in bank capital regulation to gauge the macroeconomic effects of a tightening in bank capital requirements.[14]

Our findings so far show that banks try to adjust to higher capital requirements by first aggressively reducing the size of their balance sheet. Although policy makers announce the new regulatory environment with a long lead banks do not try to meet the new requirement by using more equity capital financing – for instance, by issuing new shares or retaining earnings. Rather, our results suggests that it might be privately optimal for banks to meet the new regulation by reducing their business volume. Hence, consistent with the *Leverage Ratchet Effect* put forth by Admati et al. (2018), banks seem to be reluctant to reduce leverage by issuing new shares and are biased towards selling assets to meet higher capital requirements. The credit crunch associated with the debt overhang problem Myers (1977) and the *Leverage Ratchet Effect* lead to the contraction in real activity. Importantly, however, we also find this contraction to be only temporary: after some time banks start to use more equity financing and the banking system expands its activity back to pre-regulation values. Hence, mechanisms must be active which lead banks to readjust their business model towards using more equity financing to run the same business volume. We now delve deeper into this question.

4.2 Banking sector funding costs and risk

In **??**, we document the effects of higher bank capital requirements on measures reflecting the funding costs of the banking sector and the overall risk of the banking sector.

The left of panel of **??** shows the impulse response of realized bank stock market volatility to increasing capital requirements. We interpret realized bank stock market volatility as a measure of the overall riskiness of the banking system for which investors require compensation.[15] In the first one-and-a-half years after the announcement of the

[14] In fact, studies using narrative shock measures typically find relatively large economic effects of those shocks (see, e.g., Table 3a in Cloyne and Hürtgen 2016 for the case of monetary policy shocks).

[15] Ideally, we would like to use a measure reflecting *expected* volatility based on the risk-neutral probability measure like the VIX. However, such a measure is not available for our sample period.

new regulatory policy, bank risk does not show a clear pattern to move away from the baseline value. It then drops significantly and remains significantly below baseline until the end of our projection horizon. Hence, higher capital requirements permanently reduces realized risk of the banking system.

In the middle panel of **??**, we show the response of the cumulated change in realized excess returns of bank stocks. We use realized excess return on bank stocks as a (imperfect) measure of expected returns on bank equity, i.e. banks' cost of equity. Consistent with lower aggregate bank risk, banks' cost of equity also drops significantly and remains permanently below its pre-regulation value. Our findings concerning the interplay between bank capital requirements, risk and cost of equity lend support to the theoretical conjectures of Admati et al. (2010), Hanson et al. (2011), and Miles et al. (2013) that higher capital requirement reduce the risk of the banking system and thereby the funding costs of equity.

Overall, the timing and general pattern of the impulse responses to higher capital requirements suggest an intuitive transmission mechanism of the policy change to the macroeconomy: higher capital requirements reduce the riskiness of the banking system which lowers banks' equity funding costs. Banks optimally react to lower cost of equity funding by increasing the share equity capital in their funding mix - most likely until the marginal costs of debt and equity funding are equalized. Once the funding mix has been adjusted according to the relative costs of the different funding sources, banks increase lending growth. At the end of the adjustment to using more equity financing, banks provide the same amount of lending to the economy than in the pre-regulation period.

Intriguingly, however, bank lending and total assets drop substantially faster than bank risk, banks' funding costs or the build-up in equity funding by the banking system. Hence, our results suggest that by selling asset and reducing lending supply banks reduce their balance sheet risk. This in turn seems to lower risk and then the cost of equity financing. A tentative interpretation of these findings is that banks must first shed a significant part of their balance sheet before their cost of capital drops and using more equity capital becomes efficient. At the same time, our results suggest that bank risk, their funding cost and bank capitalization changes permanently. Hence, higher capital requirements seem to lead to permanent shifts in banks asset composition towards less risky asset classes. We dig into this aspect – and its macroeconomic consequences – in the following part.

4.3 Asset allocation and the broader transmission mechanism

We first analyze the effects of higher capital requirements on commercial and industrial (C&I) loans and loans secured by real estate. These two asset classes are the largest loan categories of total bank lending to the economy. Real estate loans are on average riskier and of longer maturity than C&I loans. Shifts in lending from real estate towards C&I loans would indicate less balance sheet risk. Furthermore, the responses of C&I loans and real estate loans might help to uncover which borrowers are most affected by the policy change: Entrepreneurs or households.[16]

We show the impulse responses of C&I loans and real estate loans in the top panel of **??**. The initial responses of both loan categories to the policy announcement is very similar to the response of aggregate bank lending shown above. Both C&I and real estate loans decline on announcement of the new regulatory regime. We thus find significant anticipation effects of changes in capital regulation in all main bank lending categories. Both loan types continue to decline and both bottom-out at around -5% after roughly 18 months into the implementation period. C&I loans then start increasing again and return to their baseline value. The point estimate overshoots its pre-regulation value, which might relate to the overshooting of industrial production. By contrast, the response of real estate loans is very persistent. At the end of our projection horizon loans secured by real estate are still around 4% below the baseline value. These results indicate a persistent shift in banks' asset composition towards safer assets following an increase in capital requirements.

In the lower panel of **??**, we show responses of the C&I loan rate spread, defined as the

[16]The H.8 data do not differentiate between residential and commercial real estate.

bank prime loan rate minus the 2-year Treasury bill rate; and the mortgage rate spread, defined as the 30-year mortgage rate minus the 10-year Treasury constant maturity rate. Unlike the BAA spread, these spreads tend to decline. Both are based on lending to the safest borrowers, so their decline might reflect a portfolio re-balancing of banks towards safer debtors within these asset classes.[17]

In **??**, we document how the differential responses of C&I and real estate lending to higher capital requirements transmit to other key macro variables. The upper panel shows responses of non-residential fixed investment and total personal consumption expenditure. Investment declines for about 18 months reaching -5% and then returns quickly back to the baseline value and even overshoots slightly. Overall, the response of investment is similar to the dynamics of industrial production and C&I loans. Our results thus draw a consistent picture that higher capital requirements have no permanent effects on the production of the economy. Consumption declines by about a maximum of 1%. The point estimate is very persistent and remains below the pre-regulation value until the end of the projection horizon. However, standard errors are wide, making inference difficult.

In the lower panel, we show responses of the house price and the unemployment rate. Consistent with the general temporary downturn, the unemployment rate increases gradually after the policy change, peaking at around 1% two years after the announcement before returning to the pre-regulation value. The house price index drops relatively fast after the policy announcement indicating that house prices are very sensitive to the reduction in bank credit due higher capital requirements. Furthermore, house prices to not fully recover from the initial drop: according to the point estimate, house prices remain below their pre-regulation value. Hence, our result suggest that the persistent reduction in real estate lending due to higher capital requirements translates into a persistent reduction in house prices.

The initial negative response of consumption can be explained by negative wealth and income effects due to lower house prices and higher unemployment. A persistent change

[17] Unfortunately, for our sample we only have the bank prime rate and the 30-year fixed rate mortgage rate to prime borrowers at our disposal.

in asset allocation of banks away from real estate lending, in turn, depresses house prices in the longer run. Negative wealth effects due to lower house prices might explain the persistently negative consumption response after a tightening in capital requirements.

4.4 Robustness analysis

Expanding the set of controls

The crucial identifying restriction underlying our results is the exogeneity of the index of capital requirement changes. If the lagged control variables capture the effects of all past shocks, the identifying assumption boils down to the weaker restriction that CRI_t is unrelated to all contemporaneous shocks. Given the construction of the index of capital requirement changes, any correlation between time t shocks and the policy events itself are highly unlikely. We now explore in detail if the control variables are informationally sufficient to capture any confounding effects of past shocks. That is, we address the concern that the regulatory policy changes are responses to past unspanned shocks, financial crises or stress in the banking sector in general. We do so in various ways:

(a) We expand the set of lagged controls by including one by one variables capturing higher and lower frequency effects of financial crises and banking sector stress. To account for higher frequency consequences of financial shocks, we add the Gilchrist and Zakrajšek (2012) excess bond premium and the TED spread to the baseline model. These variables capture the short run effects via fast moving credit spreads and liquidity squeezes. We capture lower frequency effects of financial shocks by including a S&L crisis dummy variable, a credit-to-GDP gap and the number of monthly bank defaults to the baseline model.[18] In **??**, we show the impulse responses to higher capital requirements from these alternative model setups.

b) We add to our baseline model direct measures of shocks suggested in the literature.

[18] We use the dating of banking crises of Laeven and Valencia (2013) and construct the crisis dummy by setting it to one throughout 1988 and zeros otherwise. In their database, the S&L crisis is the only banking crisis in the US in our baseline sample. For the credit-to-GDP gap we follow the Basel III definition.

To control for monetary policy we add the Romer and Romer (2004) monetary policy shock indicator.[19] To account for fiscal policy we add the exogenous tax changes from Romer and Romer (2010) and the military spending news from Ramey (2011). We include the growth rate of utilization-adjusted total factor productivity from Fernald (2012) to capture technology shocks and the change of the real oil price to account for another exogenous supply shifters. We also include an NBER recession dummy to disentangle the effects of higher capital requirements from ordinary business cycle recessions. We present the results from these exercises in **??**.

c) We increase the number of lags of the control variables to ensure that 2 lags are sufficient to capture all confounding effects of past shocks. The blue dotted line in **??**, shows results when we simultaneously increase the lag length of all the control variables in baseline specification X_t from 2 to 12. Alternatively, we also show the results when increasing the number of lags of CRI_t to 12 given by the red-dashed lines.

In all of these exercises, the point estimates are very similar to - sometimes indistinguishable from - the baseline results. They always lie well within the one standard deviation confidence bands. If capital requirement changes were a direct response to the financial and economic fallout generated by other shocks or financial sector stress in general, including these additional variables would eliminate any effect of the policy changes. Hence, the results from these additional checks gives further confidence that our narrative CRI_t is not contaminated by confounding effects of past shocks. Furthermore, these finding also suggest that a small set key of economic and financial variables contain enough information to control for the effect of any past shocks.

Finally, we note that CRI_t increases the bank capital ratio, the level of bank capital funding, bank risk and bank funding costs *permanently*. At the same time, CRI_t has only *temporary* effects on the broader economy. We want to emphasis here that these results

[19] We use the series updated by Coibion et al. (2017).

are by no way implied by our identification strategy. If CRI_t would capture some sort of temporary recessionary shocks, then there would be no reason for banks to permanently raise their capital ratio.

Anticipation horizon

We test whether our results depend on the anticipation horizon. **??** shows results with anticipation horizons of 4, 8 and 10 months as well as the baseline 6 months. Note that the models which allow for longer anticipation horizons of 8 and 10 months do not exhibit any effects earlier than 6 months before the effective dates. The model with an anticipation horizon of 4 months does not fully capture the negative loan response which we obtain with our baseline model.

One may also argue that time between publication of the final rule and their effective dates differ a lot across events, and that using an average anticipation horizon is not appropriate. We address this issue by forming an index where we shift the ones of the baseline CRI_t forward by the time leads between final rule and effective dates of the individual events. Given the exceptionally long lead between the final rule and the effective date for Basel I, we shift forward the one for this event by the second largest time lead of 7 months. For rough consistency with the baseline model we include 9 lags of the altered index in the local projections. To present results in the same figure, we have shifted impulse response functions left by our average anticipation horizon. Overall, the analysis suggests that an average anticipation horizon of 6 months is a reasonable and robust choice.

Third, our events represent permanent capital regulations, and one may argue that we should therefore rather use the cumulated CRI. When we do so, the effects on loans and production are slightly more short-lived, but results are very similar overall.

Sample period

We check the robustness of our results with respect to the sample period (**??**). We begin in 1983 which broadly marks the beginning of the Great Moderation and at the same time ensures that we keep all events but the first in the CRI. Our key results do not change. Further, we extend our sample to include the global financial crisis and the post-crisis period and end in 2016M12. To account for the zero lower bound and to capture unconventional monetary policy we extent the federal funds rate with the shadow short rate from Krippner (2015) from Nov. 2008 – the announcement date of QE1 – onwards. Results are unchanged. We note that Basel II.5 and Basel III remain excluded from this extended sample given the maximum forecast horizon of 4 years. Hence, we also reduce the maximum forecast horizon to 3 years in order to include Basel II.5 and to 2 years in order to include both Basel II.5 and Basel III. Again, the impulse responses for those horizons closely resemble those of the baseline model.

Stability across policy changes

A potential problem is that the results may derive from particular changes in bank capital regulation rather than being robust across policy changes. High sensitivity to particular policy changes would indicate that the results cannot be viewed as general, but rather derive from features special to particular policy changes such as the economic and financial conditions at the time of introduction.

We examine this issue by individually removing each of the six events one by one. We present the findings in **??**. Overall, we find that the impulse responses from the different setups are very similar in shape and magnitude. This also holds true when we eliminate Basel I - the only international event. Some papers argue that Basel I caused the credit crunch in the early 1990s (see e.g., Bernanke and Lown 1991). The results in **??** show that our findings are not exclusively driven by Basel I but are a general result which also holds for the other policy events.

Another potential issue is that in all but the last two policy events, the Fed was among the regulatory agencies involved in the policy changes. A problem may be that monetary policy reacts differently if the monetary authority is also setting regulatory policy. We investigate this issue by removing simultaneously the last two events in which the FED was not among the regulators. If the Fed acted significantly different after these two events than after the other policy changes, removing the last two policy changes from the analysis would produce different findings. As shown in **??**, it turns out the impulse responses are very similar to the baseline results.

Finally, we exclude the events when Congress passed legislation that finally led to changes in capital requirements (ILSA in Nov. 1983 and FDICIA in Dec. 1992). We also add, one by one, events discussed in Section 2.1 but initially not included in our baseline CRI (Jun. 1983 and Jan. 1997, in gray in Table 1). Again, the impulse responses are very similar in magnitude and shape.

5 Additional analyses

In this section, we first analyze the transmission mechanism in some detail, including the role of monetary policy in cushioning the effects of bank capital regulation on the economy. We then compare the effects of changes in the CRI with those of a change in the EBP, another type of credit supply shock.

5.0.1 The role of monetary policy – a counterfactual experiment

We have seen above that the central bank lowers the monetary policy rate considerably after a capital requirement tightening. This suggests that monetary policy cushions the negative effects of the regulation on lending and the real economy. In order to tentatively quantify these effects we carry out a counterfactual experiment. We assess how selected variables would have reacted had there been no monetary policy response to the regulatory event.[20]

[20]The counterfactual experiment is implemented as follows. We augment out baseline model with contemporaneous and lagged (updated) Romer-Romer monetary policy shocks (Romer and Romer 2004,

In Figure 8, we show the responses of production, the bank capital ratio and the policy interest rate to changes in the CRI from our baseline (black solid lines and shaded areas) together with point estimates of the counterfactual impulse responses (red dashed lines). The first finding is that the monetary policy reaction enables banks to adjust their capital ratio to higher values faster by stabilizing the economy.[21] Second, monetary policy cushions the negative effects on economic activity due to the regulation. It is effective with a delay, both because the monetary policy rate drops most strongly with a delay, and because monetary policy has delayed effects on the economy. However, monetary policy seems to significantly help in preventing longer-lasting negative effects of the regulation. One implication is that the negative effects of capital requirement tightenings might be larger at the zero lower bound of nominal interest rates.

5.1 Comparison with an EBP shock

How do the effects of a regulatory shock compare with those of another, not policy-induced, financial shock affecting the credit supply? One widely used and well-understood financial shock measure that is available on a monthly basis over our sample period is the excess bond premium (a risk premium that reflects systematic deviations in the pricing of US corporate bonds relative to the issuers' expected default risk; henceforth EBP), see Gilchrist and Zakrajšek (2012) and applications, e.g., in Abbate et al. (2016), Furlanetto et al. (2019), and Caldara et al. (2016).

We add the EBP to our baseline model and adopt a specification similar to one for the model used by Gilchrist and Zakrajšek (2012).[22] Figure 9 shows impulse responses to

and Coibion et al. 2017, see Appendix E). Impulse responses to monetary policy shocks are obtained as coefficients of the contemporaneous Romer-Romer measure in local projection regressions. We then feed monetary policy shocks into our baseline model which fully offset the response of the Federal Funds rate to the CRI increase.

[21] This is consistent with the empirical study by Buch et al. (2014), who find an increase in the bank capital ratio after an unexpected monetary policy easing. Expansionary monetary policy shocks increase bank profits by increasing credit demand and reducing loan defaults. Hence bank capital increases by more than bank assets and the bank capital ratio rises.

[22] We include the EBP contemporaneously and with 2 lags. The set of controls are our CRI, the controls from our baseline model and the term spread. Augmenting the number of lags for the EBP or the other explanatory variables from 2 to 6 (mirroring Gilchrist and Zakrajšek 2012 who use 2 lags in their quarterly VAR model) does not alter our key findings. Moreover, we take the EBP to be predetermined

a change in the EBP by 1 percentage point (black line and shaded areas), together with the point estimates for a regulatory shock from our baseline model (blue dotted line).[23]

There are some notable differences between the effects of CRI and EBP changes. An increase in the EBP leads to a decline in the capital ratio as a consequence of the resulting recession. It also has longer-lasting effects on the economy than capital regulation. Reasons for this may be that business loans decline more persistently and the monetary policy rate drops less strongly after the EBP increase. Another difference is that real estate loans and the house price are barely affected by the EBP change. Note that consumption also moves strongly and persistently after the change in the EBP, despite the lack of reactivity of housing loans and the house price. This might be explained by the increase in the unemployment rate, as well as by the decline in stock market wealth. The latter falls more strongly and persistently after the EBP than after the CRI shock. Moreover, lending spread reactions are more front-loaded, which is not surprising given that the EBP has been constructed from corporate bond spreads. Finally, the risk measures temporarily rise after the EBP increase, unlike after the CRI change.[24] This finding is interesting in the light of Adrian (2017) who illustrates that an easing of financial conditions lowers GDP volatility in the short run (over the first 5 quarters) and then increases it (and vice versa for a worsening of financial conditions). Using somewhat different volatility measures, we find this confirmed after the EBP change, but not after a change in our regulatory policy. Hence, the evolution of volatility seems to be dependent on the driver.

Overall, we find some reactions to be very different after the two shocks, e.g. bank leverage or volatility have opposite signs. Results are plausible and suggest that we clearly disentangle our capital regulation shock from this other financial shock.

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with respect to all variables. In their empirical analysis, Gilchrist and Zakrajšek (2012) adopt a recursive scheme to identify shocks to the EBP and order the EBP after slow-moving (macroeconomic) variables and before fast-moving (financial) variables. Our findings with respect to key variables are very similar to Gilchrist and Zakrajšek (2012) and, hence, our approach here can serve as a simple approximation.

[23]Magnitudes are comparable, as the maximum BAA spread reactions are almost identical. Hence, there is no need to normalize one of the shocks.

[24]This latter result is in line with Caldara et al. (2016) who in their baseline identification scheme find that uncertainty temporarily rises after an increase in the EBP.

6 Conclusion

In this paper, we aim to fill a gap in the literature on the macroeconomic effects of regulatory capital requirement policies. So far, inference is drawn mainly from either microeconometric empirical studies largely neglecting dynamic, general equilibrium and anticipation effects, or from structural models depending heavily on the frictions and shocks included as well as the calibration used. We propose a novel indicator of aggregate regulatory capital requirement tightenings for the US from 1979 to 2008. The indicator includes six episodes of exogenous bank capital tightenings. We provide ample evidence that it successfully disentangles regulation-induced from other developments. This evidence is based on narratives, statistical (exogeneity) tests, careful account of controls in our regressions, and the resulting behavior of key variables like the bank capital ratio, lending, or risk, also in comparison to another financial shock.

Using local projections of changes in this capital requirement indicator on various macroeconomic and financial variables, we conclude that aggregate capital requirement tightenings lead to notable, but temporary credit crunches and contractions in economic activity. This result lends support to the assertion of Hanson et al. (2011) and Admati et al. (2010) that higher capital requirements are not associated with substantial medium to long-run costs for the economy. The regulation seems to affect risk and agents' risk perceptions, which helps dampen negative effects on spending. Moreover, an aggressive monetary policy easing after the regulatory events helps the economy to recover quickly from the regulation-induced recession.

What does this imply for policy makers? First, transitory negative effects of capital requirement tightenings on real activity and bank loans, relative to the effects on the bank capital ratio, are found to be larger than those that previous studies report (e.g. Macroeconomic Assessment Group 2010), but in the range of what microeconometric studies find. To assess the side effects of regulation it seems important that policy makers take into account general equilibrium and anticipation effects and carefully identify exogenous financial stability policy changes. Second, monetary policy can support bank capital-based regulation policy by lowering the policy rate in a timely manner. This cushions negative effects of capital requirement tightenings on real activity and loan markets and at the same time helps banks adjust their capital ratios more quickly. We emphasize that this implies by no means that central banks should lower interest rates after and, hence, counteract *countercyclical* bank-capital policies which are intended to curb credit and asset price booms in order to prevent bubbles and subsequent major financial stabilities and which we do not investigate here. Third, our results for monetary policy also imply that at the zero lower bound real effects on capital requirement tightenings may be larger.

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7 Tables and Figures

Table 1: Capital requirement index (CRI)

Date	Event
Dec. 17, 1981	FDIC, Fed and OCC set numerical guidelines for CR
Jun. 20, 1983	Fed and OCC apply CRs to multinational banks
Nov. 30, 1983	International Lending and Supervision Act (ILSA) passed
Apr. 18, 1985	Common CR guidelines by FDCI, Fed and OCC for all banks
Dec. 31, 1990	Basel I effective
Dec. 19, 1991	FDIC Improvement Act passed
Dec. 19, 1992	Prompt Corrective Action effective
Jan. 1, 1997	Market Risk Amendment effective
Apr. 1, 2008	Basel II effective
Jan. 1, 2013	Basel II.5 effective
Jan. 1, 2014	Basel III effective

Notes: CR = capital requirement(s); FDIC = Federal Deposit Insurance Corporation; Fed = Federal Reserve System; OCC = Office of the Comptroller of the Currency. All events constitute aggregate tightenings of capital requirements. Black: events included in the baseline CRI. Gray: events not included in the baseline CRI, but considered in the robustness analysis. An exception is the Basel II event, which is never included because of the maximum horizon we choose for our baseline setup.

Table 2: Dates of proposed rules, final rules and effective dates

Event	Proposed rule	Final rule	Effective date
numerical CRs	Jun. 23, 1981	Jun. 23, 1981	Dec. 17, 1981
ILSA	Mar. 7, 1983	Apr. 21, 1983	Nov. 30, 1983
common CRs	Jul. 20, 1984	Mar. 19, 1985	Apr. 18, 1985
Basel I	Mar. 27, 1986	Jan. 18, 1989	Dec. 31, 1990
FDICIA	Mar. 5, 1991	Aug. 2, 1991	Dec. 19, 1991
PCA	Jul. 7, 1992	Sep. 29, 1992	Dec. 19, 1992

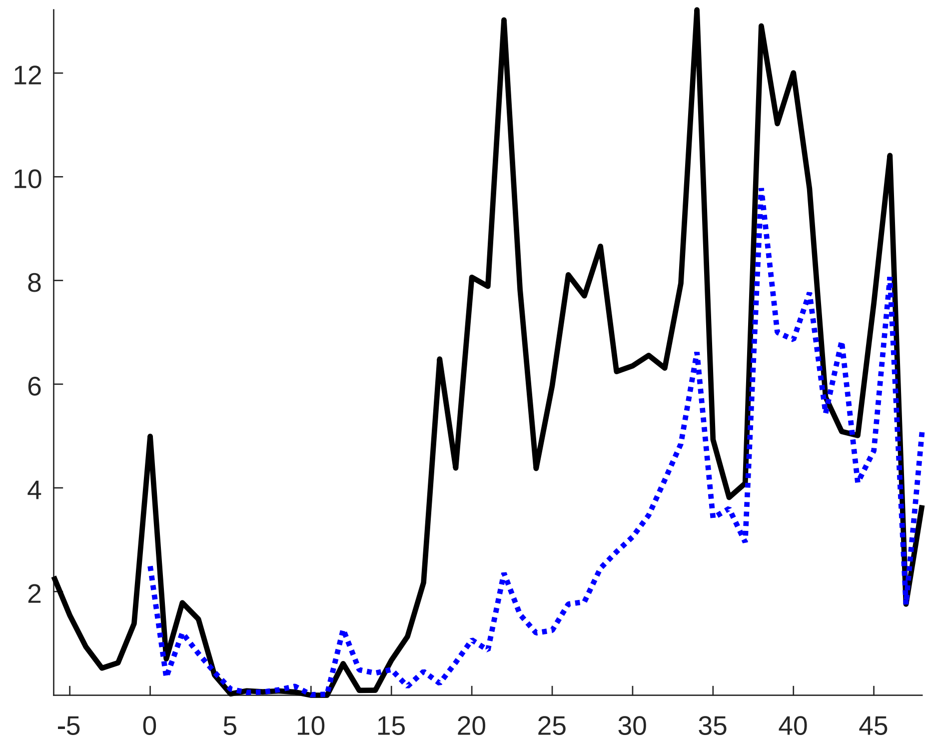
Notes: Dates of the publication of proposed and final rules by the regulators (or comparable for the 1981 event and Congress acts). See text and Table 1 for details.

Table 3: Probit estimation results

Regressors	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bank capital ratio$_{t-1}$	-0.33						-0.48
	(0.30)						(0.53)
Δ_{t-1}log(Industrial production)		-0.43					-0.60
		(0.27)					(0.63)
Δ_{t-1}log(PCE deflator)			0.22				0.37
			(1.62)				(2.46)
FFR$_{t-1}$				0.04			-0.08
				(0.05)			(0.30)
Δ_{t-1}log(Bank loans)					-0.15		0.08
					(0.35)		(1.42)
BAA spread$_{t-1}$						0.08	-0.20
						(0.43)	(1.55)

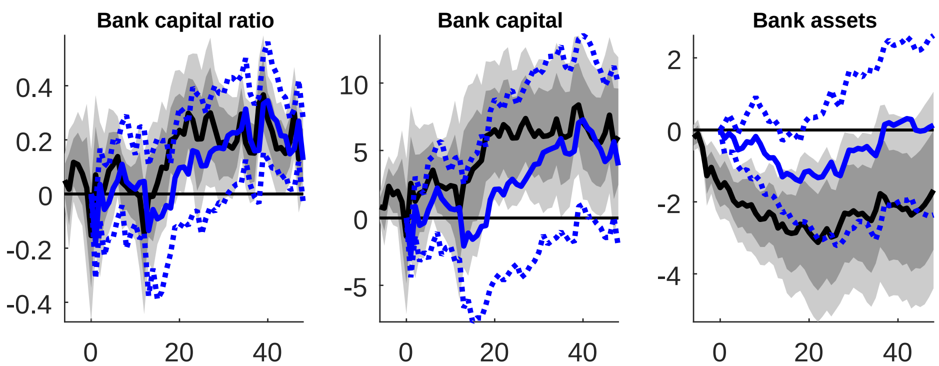
Notes: Dependent variable is CRI$_t$. A constant enters the regression, as well as month-on-month differences in %. Robust standard errors in parentheses. ** $p < 0.01$, * $p < 0.05$.

Figure 1: Relevance of the CRI for the bank capital ratio (F-statistics)



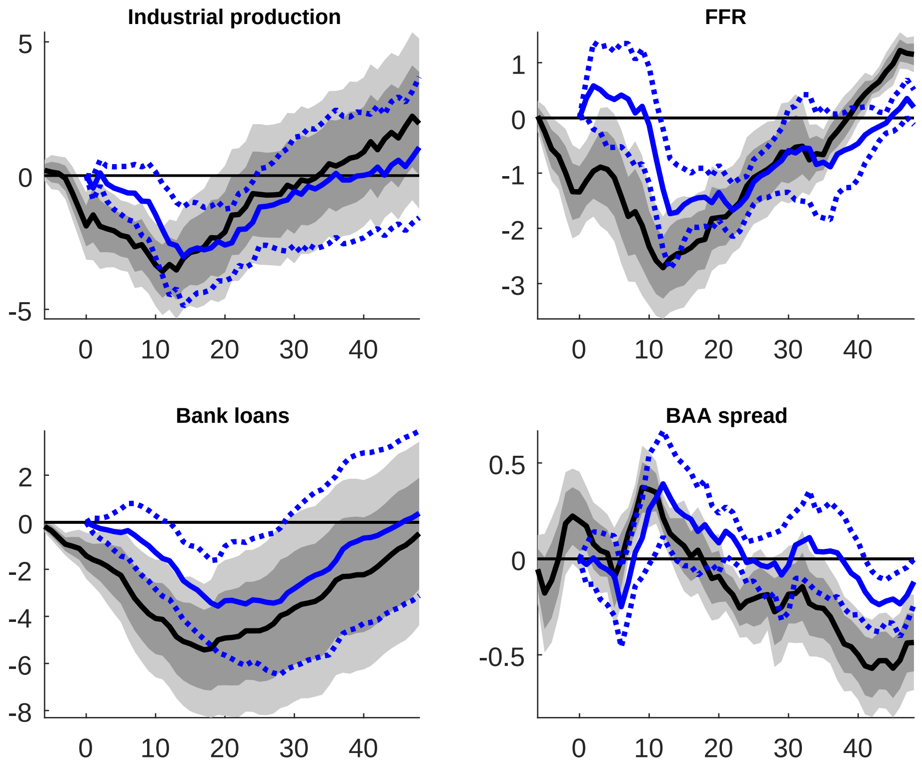
Notes: Newey and West (1987) robust F-statistic. Black solid line: model with anticipation effects, effective dates. Blue dotted: model without anticipation effects, effective dates. X-axis: horizons.

Figure 2: Banks' adjustment to a capital requirement tightening, with and without anticipation effects



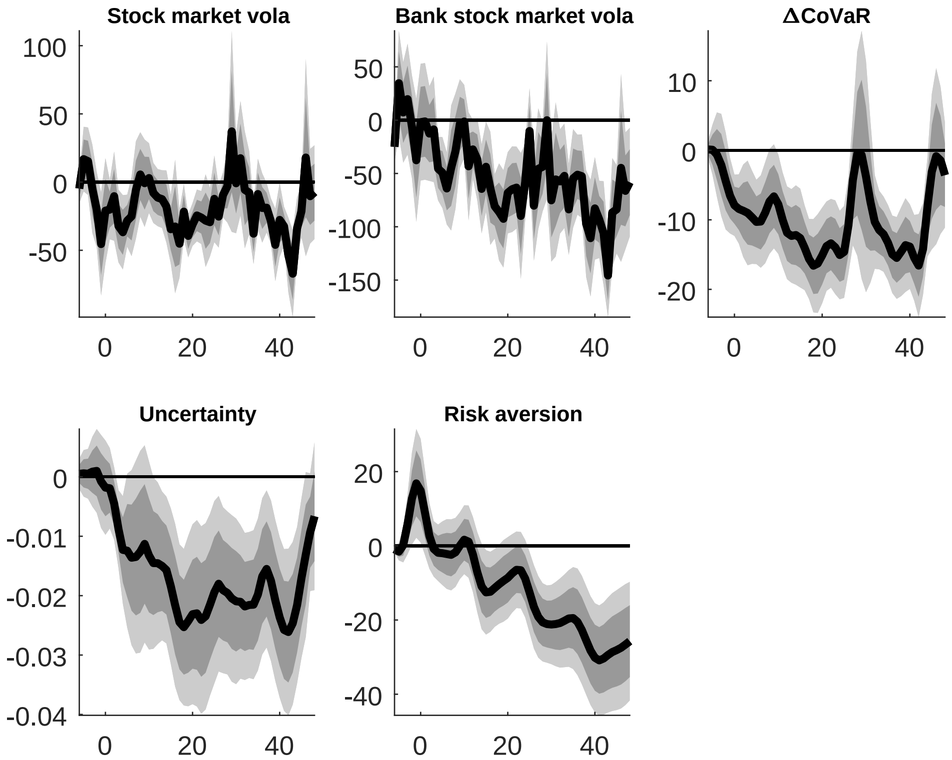
Notes: Bank capital ratio in percentage points, capital and assets in %. Point estimates (black (blue) solid line: with (without) anticipation effects), 68% and 90% confidence bands from the model with anticipation effects (dark and light shaded areas), 90% confidence bands from the model without anticipation effects (blue dotted lines).

Figure 3: Reactions of key variables to a capital requirement tightening, with and without anticipation effects



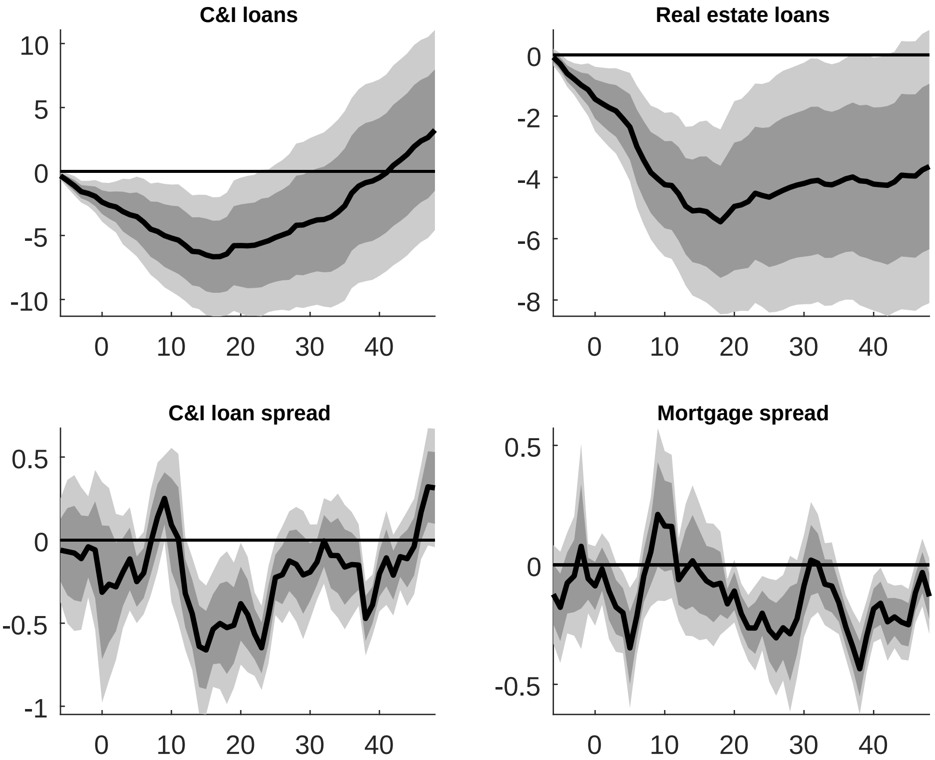
Notes: Federal Funds rate and BAA spread in percentage points, industrial production and loans in %. Point estimates (black (blue) solid line: with (without) anticipation effects), 68% and 90% confidence bands from the model with anticipation effects (dark and light shaded areas), 90% confidence bands from the model without anticipation effects (blue dotted lines).

Figure 4: Transmission to risk



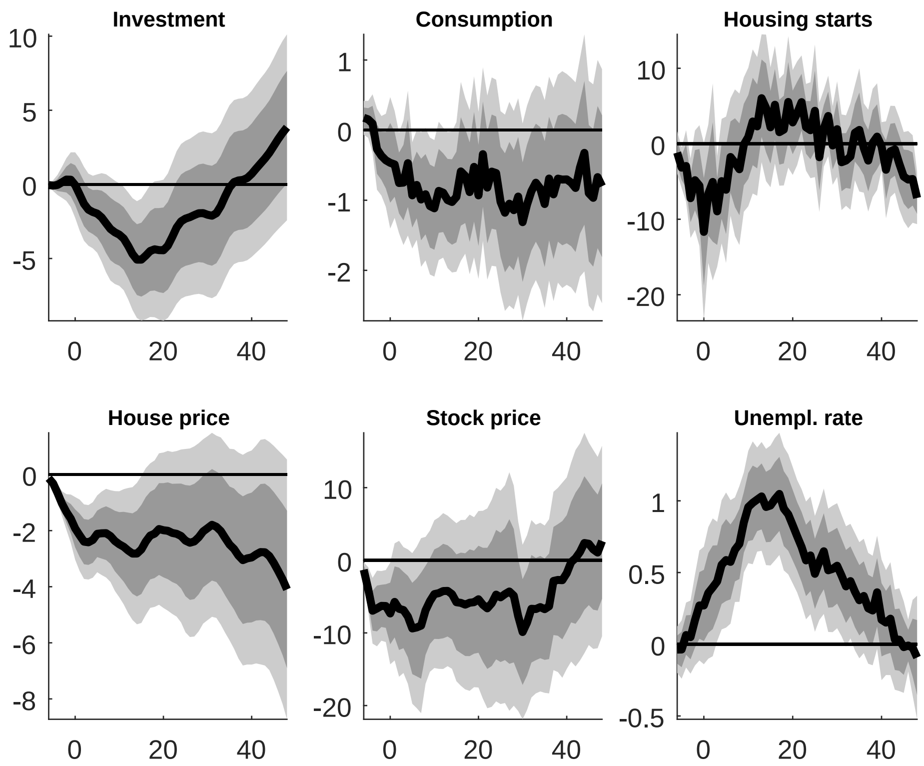
Notes: Stock market volatility measures and ΔCoVaR in %. Risk aversion in percentage points. Uncertainty is the macroeconomic uncertainty measure taken from Sydney Ludvigson's webpage, see Appendix E for details. Point estimates (black solid line), 68% and 90% confidence bands (dark and light shaded areas).

Figure 5: Transmission to loans and spreads



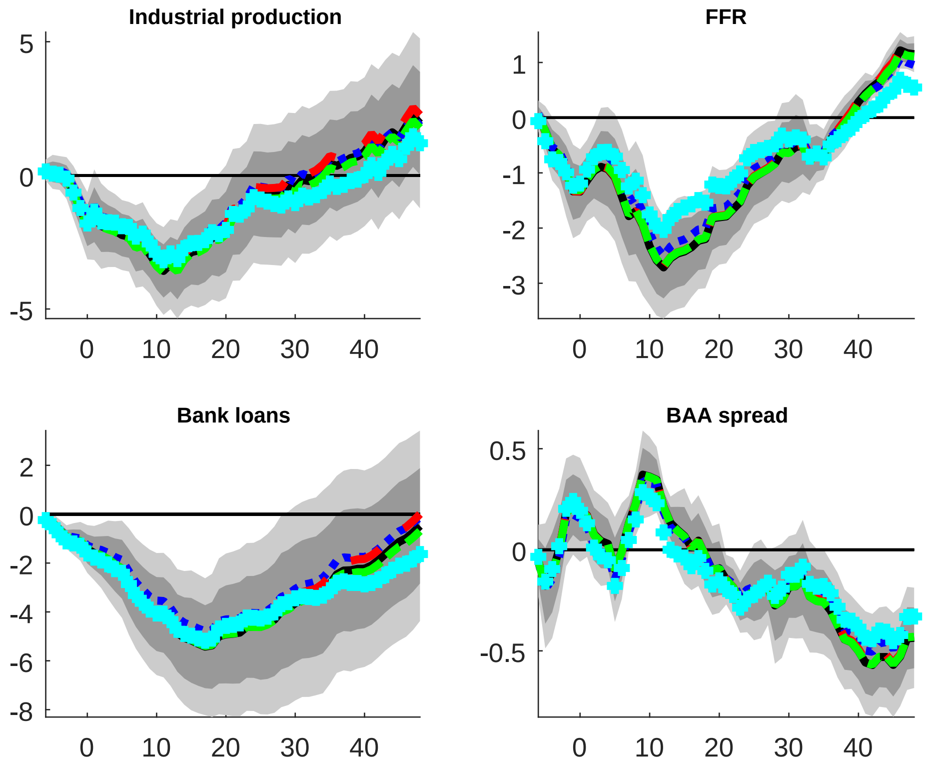
Notes: Loans in %, spreads in percentage points. Point estimates (black solid line), 68% and 90% confidence bands (dark and light shaded areas).

Figure 6: Transmission to non-financial corporations and households



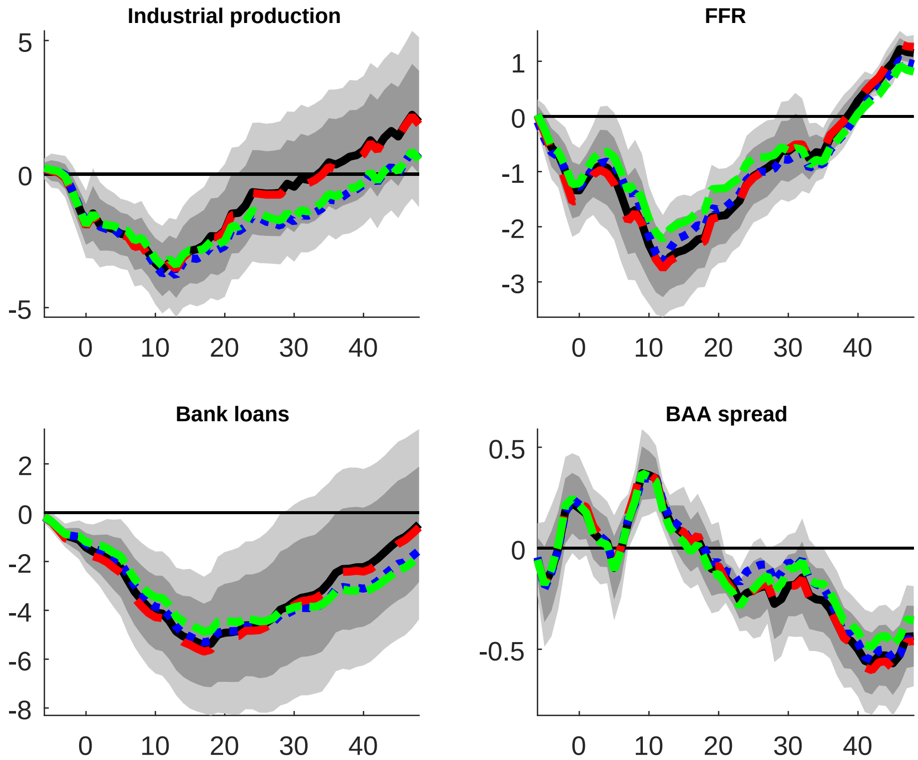
Notes: Unemployment rate in percentage points, other variables in %. Point estimates (black solid line), 68% and 90% confidence bands (dark and light shaded areas).

Figure 7a: Robustness analysis: Additional controls (1/3)



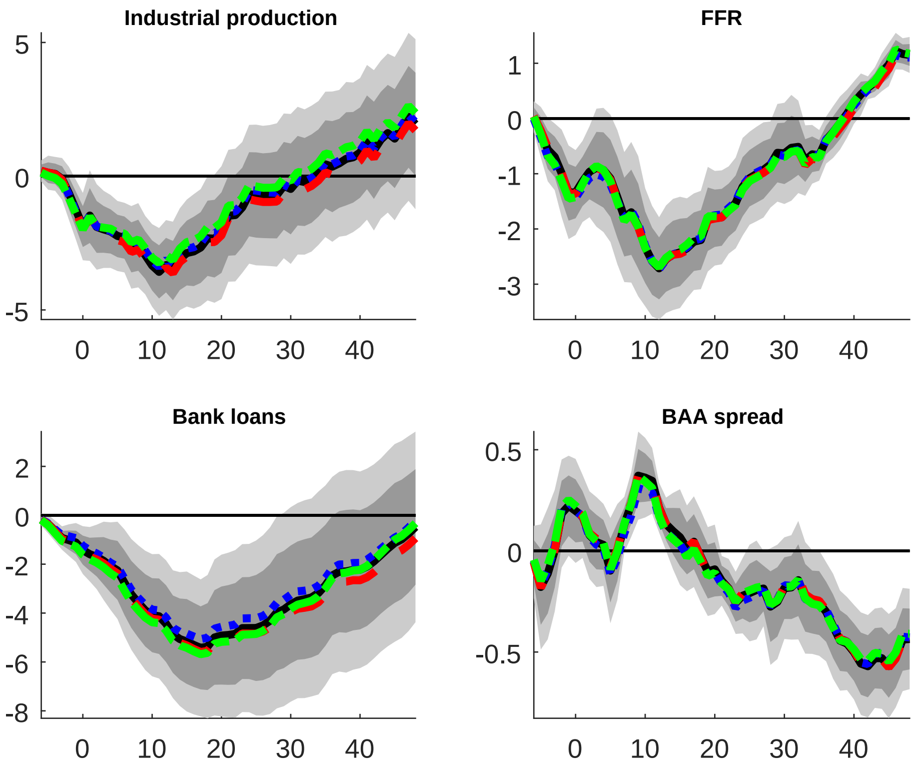
Notes: Black solid line: baseline model (with confidence bands). Blue dotted: add excess bond premium. Red dashed: add Basel credit-to-GDP gap. Green dash-dots: add Savings and Loan crisis dummy. Cyan with crosses: add TED spread.

Figure 7b: Robustness analysis: Additional controls (2/3)



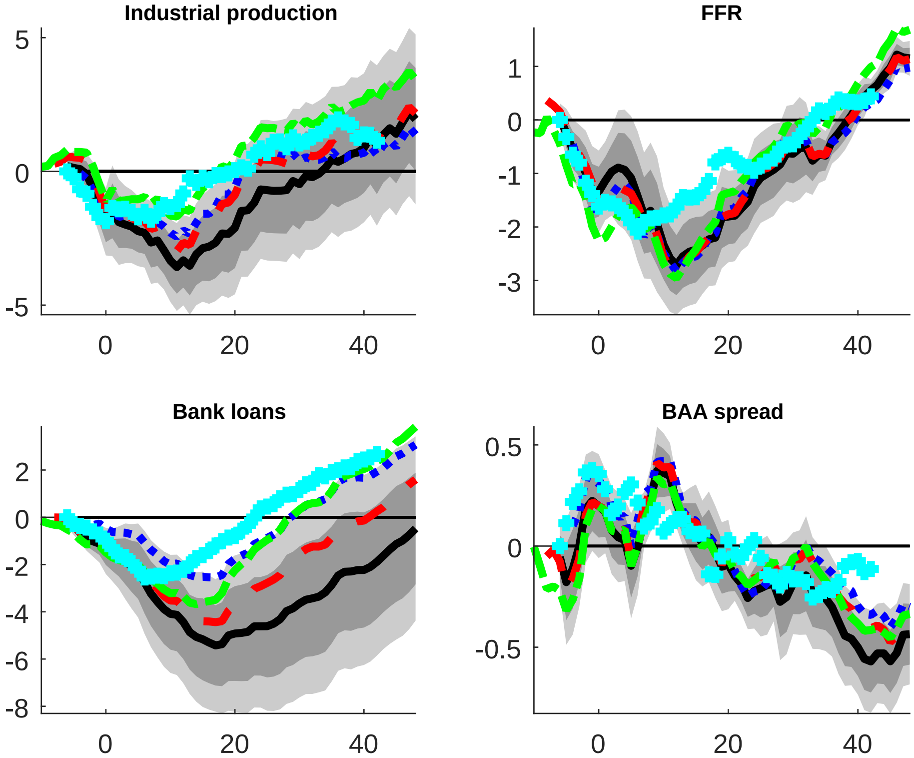
Notes: Black solid line: baseline model (with confidence bands). Blue dotted: add Romer-Romer monetary policy shock measure. Red dashed: add Fernald utilization-adjusted TFP growth. Green dash-dots: add oil price.

Figure 7c: Robustness analysis: Additional controls (3/3)



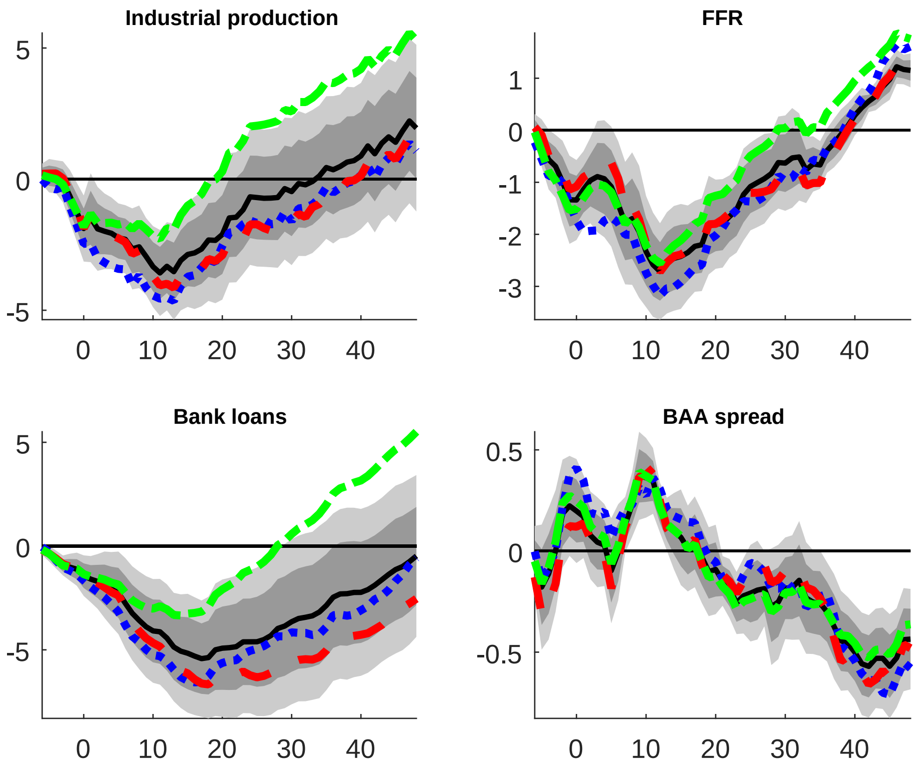
Notes: Black solid line: baseline model (with confidence bands). Blue dotted: add Romer-Romer tax changes. Red dashed: add Ramey military spending news. Green dash-dots: add NBER recession dummy.

Figure 7d: Robustness analysis: Altering anticipation horizons



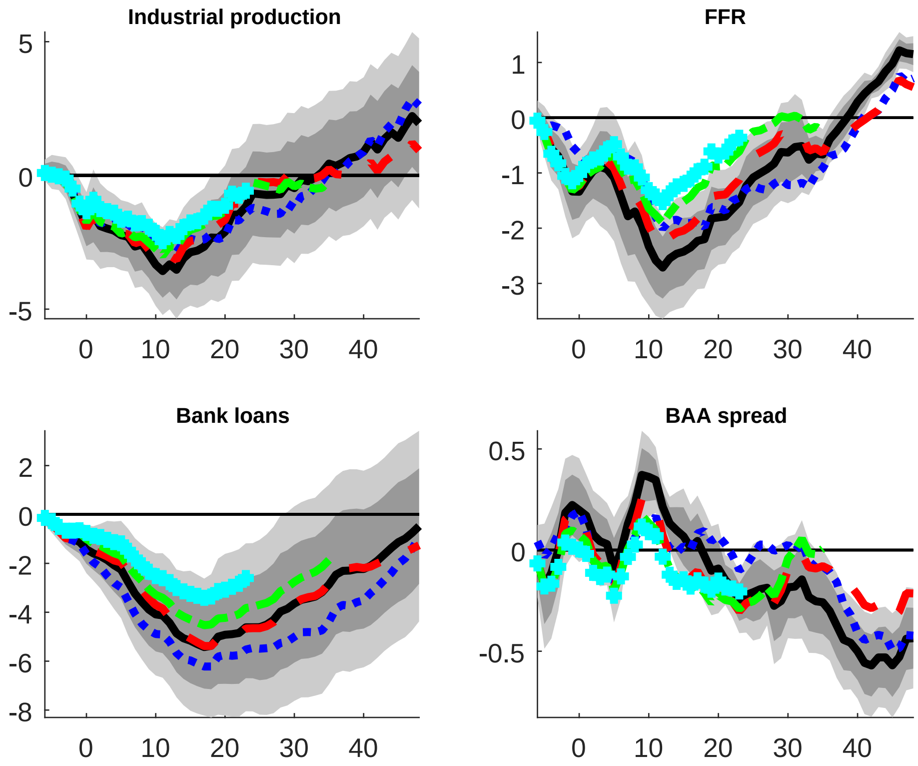
Notes: Black solid line: baseline model with a 6-month average anticipation horizon (with confidence bands). Blue dotted: average anticipation horizon of 4 months. Red dashed: average anticipation horizon of 8 months. Green dash-dots: anticipation horizon of 10 months. Cyan with crosses: individual anticipation horizons

Figure 7e: Robustness analysis: Changing the number of lags and cumulating the CRI



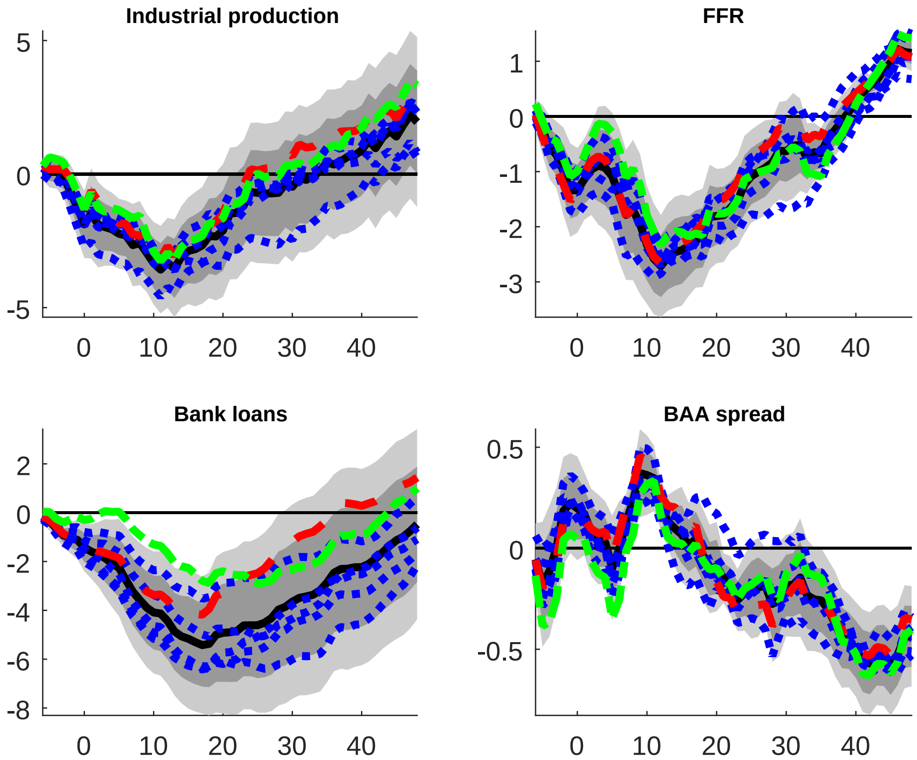
Notes: Black solid line: baseline model (with confidence bands). Blue dotted: 12 lags of controls. Red dashed: 12 lags of CRI. Green dash-dots: cumulated CRI.

Figure 7f: Robustness analysis: Altering the sample period



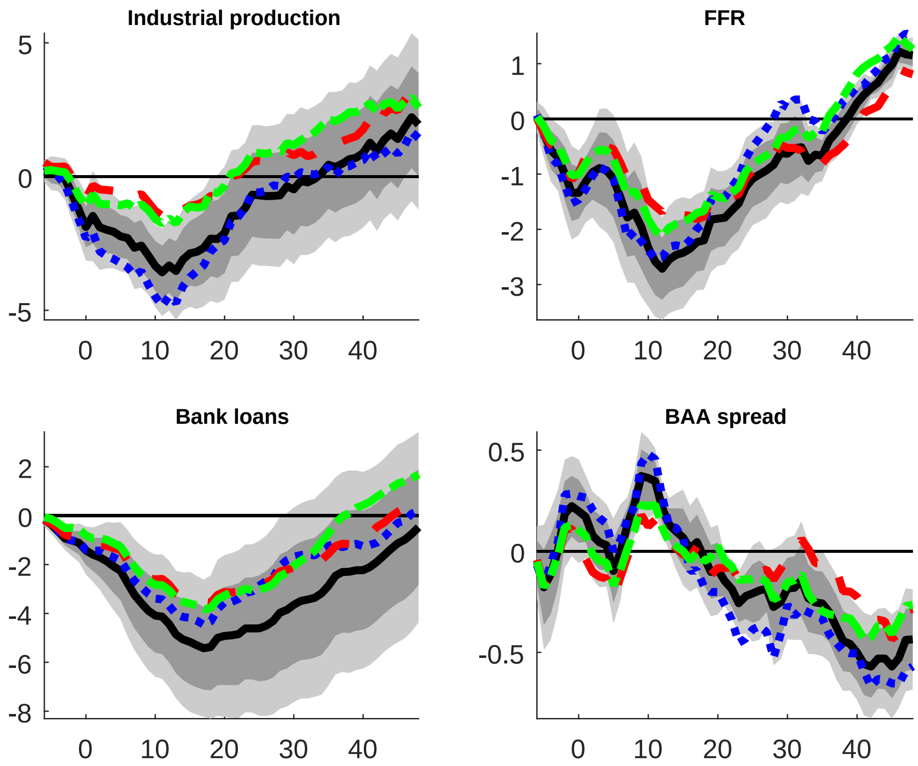
Notes: Black solid line: baseline model (with confidence bands). Blue dotted: 1983-2008. Red dashed: 1979-2016. Green dash-dots: 1979-2016 (incl. Basel II.5, forecast horizon 36 months). Cyan with crosses: 1979-2016 (incl. Basel II.5 and Basel III, forecast horizon 24 months). When we extend the sample to 2016, we link the shadow short rate provided by Leo Krippner to the Federal Funds rate, see text for details.

Figure 7g: Robustness analysis: Changes in the CRI (1/3) - removing individual events



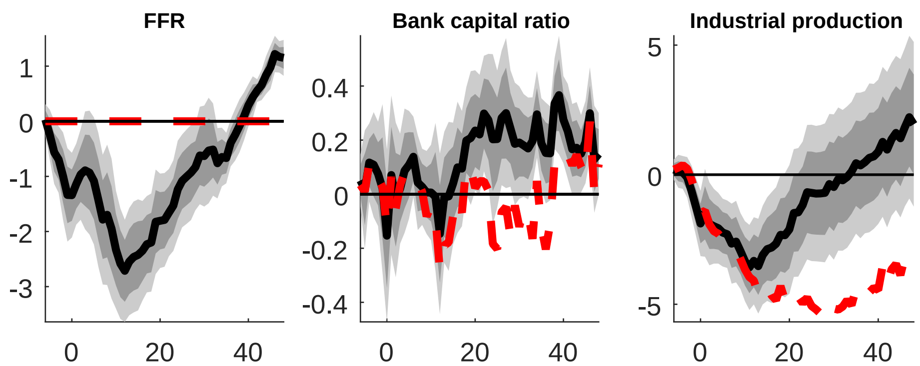
Notes: Black solid line: baseline model (with confidence bands). Red dashed line: remove Basel I (the only international event). Blue dotted: remove other events one by one. Green dash-dots: remove 1991 and 1992 events when the Fed did not act as a regulator.

Figure 7h: Robustness analysis: Changes in the CRI (2/3) - adding capital requirement events



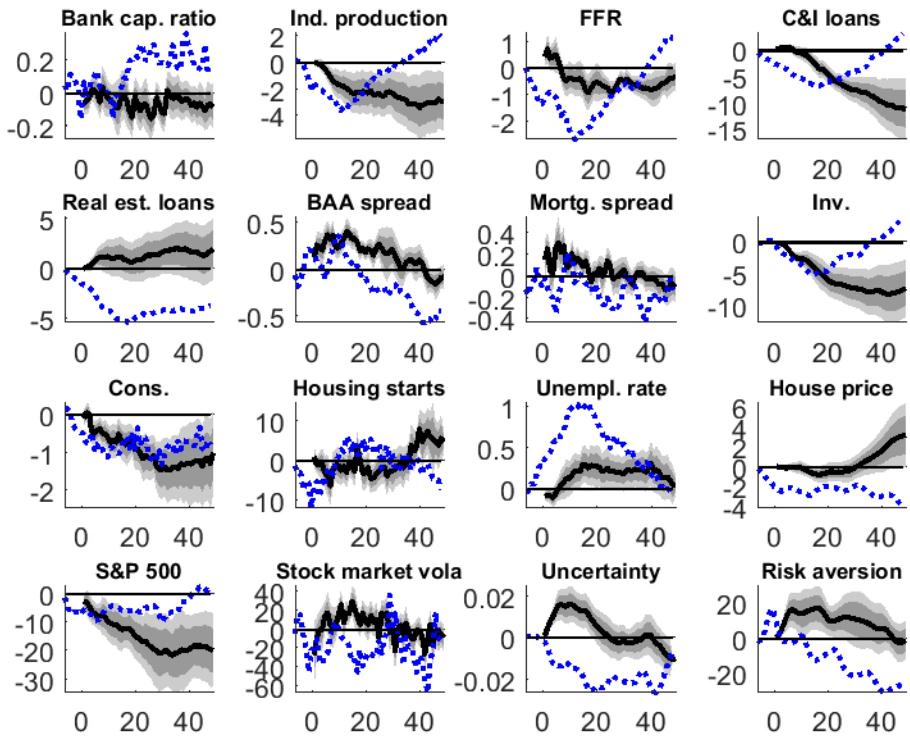
Notes: Black solid line: baseline model (with confidence bands). Blue dotted: only effective dates (no Congress acts). Red dashed: include Jun. 1983 event. Green dash-dots: include Jan. 1997 event.

Figure 8: Role of monetary policy (counterfactual experiment)



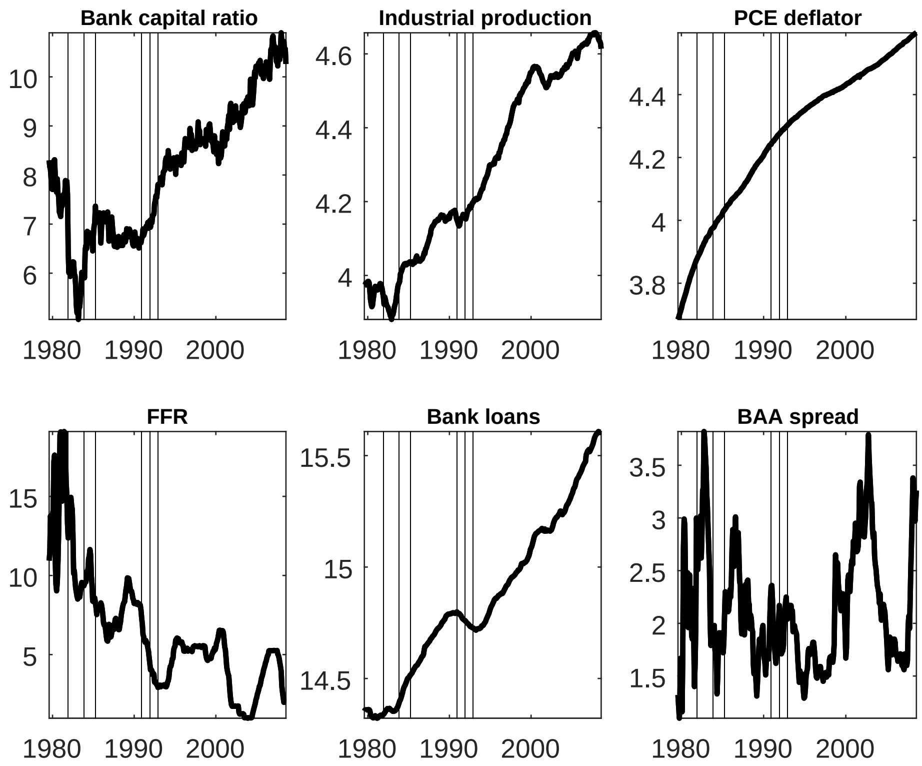
Notes: In percentage points (bank capital ratio, FFR) and % (industrial production). Black solid line with confidence bands: baseline model. Red dashed: point estimates of counterfactual impulse responses (no policy interest rate reaction); see text for details.

Figure 9: Comparison of effects of changes in the excess bond premium to changes in the CRI



Notes: In percentage points (bank capital ratio, FFR, spreads, unemployment rate, risk aversion) and % (all other variables). Black solid line with confidence bands: responses to a 1 percentage point increase in the excess bond premium (EBP). Blue dotted: point estimate of our baseline model.

Figure 10: Key variables and events (Aug. 1978 – Aug. 2008)



Notes: Industrial production, PCE deflator and bank loans in logs, other variables in %. Vertical bars represent our CRI events. See text for details.