# Credit, Risk Appetite, and Monetary Policy Transmission*

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**Abstract**

We show that U.S. economic performance and monetary policy transmission depend on nonfinancial sector credit, and the effects are nonlinear. When credit is below its trend, increases in risk appetite lead to sustained increases in output. In contrast, when credit is above trend, initial expansions are followed by additional excess borrowing and subsequent contractions, suggesting an inter-temporal tradeoff for economic activity. Also, tighter monetary policy is ineffective at slowing the economy when credit is high, consistent with evidence of less transmission of policy changes to distant forward Treasury rates in high-credit periods.

Keywords: Financial stability, financial conditions, credit, asset bubbles, monetary policy

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## 1. Introduction

The recent global financial crisis highlighted the significant damage to economic performance from falling asset prices amid high levels of credit and fragile financial institutions. Empirical studies show that private nonfinancial sector credit and asset prices are early warning indicators of recessions and financial crises (Borio and Lowe (2002), Schularick and Taylor (2012), Drehmann and Juselius (2015)). In addition, studies have found that high credit growth and asset bubbles combined lead to significantly weaker economic recoveries (see Jorda, Schularik and Taylor (2013)). The consequences of financial crises can be severe, with estimates of the cost of the 2007-09 episode in the United States ranging from 40 to 90 percent of a year's GDP, and a 10 percent permanent loss in output in the U.S. following the financial crisis (Atkinson, Luttrell, and Rosenblum (2013), Gourio, Kashyap, and Sim (2016)).

As a result, policymakers have been encouraged to monitor the financial system for the buildup of excess credit or stretched asset valuations – often referred to as macrofinancial "imbalances" – to prevent the system from again becoming vulnerable to shocks, such as a steep drop in asset prices (Adrian, Covitz, and Liang (2015)). When these imbalances are high, the economy is seen as more fragile. Researchers also have been encouraged to add measures of financial imbalances to macroeconomic models, which have traditionally lacked a role for them.

In this paper, we use a threshold VAR model to test the empirical relationships between investor risk appetite, nonfinancial credit, and monetary policy, and the real economy (GDP, unemployment and inflation) for the U.S. economy from 1975 to 2014. Specifically, we test whether shocks to risk appetite lead to subpar economic performance, in the form of lower GDP and a higher unemployment rate. Because much of the post-crisis literature has focused on the proposition that high levels of imbalances leave the economy more vulnerable to negative shocks, we test for nonlinear dynamics by dividing the sample into periods of high and low credit-to-GDP gap, where we follow conventional practice by measuring the credit gap relative to its estimated long-run trend (see Borio and Lowe (2002, 2004); Borio and Drehmann (2009)). We also test for nonlinear effects for monetary policy transmission.

Our aim is to test whether risk appetite and credit aggregates help to explain the dynamics of economic performance in the U.S. We construct a measure of investor risk appetite, dubbed ALLM, which combines measures of asset valuations and non-price terms such as lending standards in four markets: business credit, commercial real estate, household credit (including consumer credit and residential mortgages), and equities. For comparison, we also consider the excess bond premium of Gilchrist and Zakrajsek (2012) as a measure of risk appetite, which has been found to be a useful predictor of macro performance.

We find the following results. First, in a system that includes our risk appetite measure, ALLM, but not the credit-to-GDP gap, higher risk appetite operates as a relaxation of financial conditions and is expansionary. Shocks to ALLM lead to statistically significant increases in real GDP and decreases in unemployment. In contrast, in a system that includes the credit-to-GDP gap but not ALLM, shocks to the credit gap do not have a near-term expansionary effect but lead to a recession with a lag. Because credit growth tends to follow risk appetite with a lag in the data, it is natural to consider risk appetite and credit jointly.

Second, in a system that includes both risk appetite and the credit-to-GDP gap, shocks to risk appetite lead immediately to increases in real GDP and decreases in unemployment. The credit-to-GDP gap reacts with a lag, and it takes about 12 quarters to reach its peak after the initial shock. As the credit gap increases over time, there is a subsequent decrease in real GDP and rise in unemployment. In nonlinear specifications that permit different dynamics depending on the level of the credit gap, the deterioration in performance in the out-years is significantly greater when the credit to GDP gap is high. Thus, credit is an important channel by which shocks to risk appetite affect the economy: faster-than-trend credit growth stimulated by risk appetite is the mechanism driving the economic contraction, but only when the credit gap is already high.

Third, we find that the effectiveness of monetary policy also varies with the credit gap. When the credit gap is low, impulses to monetary policy lead, as expected, to an increase in unemployment, a contraction in GDP, and a decline in credit. However, when the credit gap is high, impulses to monetary policy have no effects on output, unemployment, and credit.

We investigate further why monetary policy is less effective in high credit gap periods. One possible explanation is suggested by the dynamics of risk appetite: when the credit gap is high, an impulse to monetary policy leads to an *increase*, not a decrease, in risk appetite. This easing of financial conditions may work against the contractionary effect of a monetary policy shock in boom periods, perhaps because raising interest rates may not be enough of a deterrent to rising asset prices in those periods. We also redefine the threshold so that the sample is divided in periods when the credit-to-GDP gap is rising or falling, rather than when the gap is high or low. We find that monetary policy is ineffective when the ratio is rising but effective when it is falling, suggesting perhaps that monetary policy is less effective at restraining activity rather than because it cannot stimulate activity after a credit bust. That is, higher interest rates matter less when asset prices are rising and credit is growing.

In addition, following Hanson and Stein (2015), we use high-frequency data to identify monetary policy shocks and decompose the transmission by maturity to Treasury bond yields. They argue that the apparently excessive moves in forward rates at far horizons in reaction to monetary policy shocks can be attributed to a class of investors requiring steady income streams who add (remove) duration by purchasing (selling) longer-maturity Treasuries following a short-term rate cut (increase), leading to a decline (increase) in far forward yields and in the term premium. We test whether the transmission of monetary policy to forward Treasury rates differs significantly between high and low credit gap periods, and find there is less transmission in high credit-gap states. This finding is consistent with investors making fewer adjustments to holdings of Treasury securities to gain additional yield when there are ample credit products to pick up the additional yield in high credit gap states.

We conducted a number of robustness tests. As an alternative to ALLM for risk appetite, we use the excess bond premium (EBP) of Gilchrist and Zakrajsek (2012), which has been found to be a useful predictor of macro performance, and show similar results. We also use alternative measures of excess credit, including a specification with just the (log) level of credit rather than gap to trend.

Overall, our results are consistent with an intuitively appealing story in which an initial impulse to investor risk appetite stimulates economic growth, but also over time stimulates excessive borrowing by households and businesses. The high level of debt then interferes with the normal monetary policy transmission mechanism, and at the same time leaves the economy vulnerable to a negative shock, ultimately precipitating a recession. These results suggest models of economic dynamics and monetary policy in which credit and financial conditions jointly play a role, and with nonlinear effects. Given monetary policy is not effective in a high credit gap state, there are high returns to policymakers from preventing the buildup of excess credit in the first place, which suggests they should pay special attention to investor froth in periods when the credit-to-GDP ratio is increasing rapidly and approaching or exceeding it longer-run trend.

Our results bear on several strands of the literature. We show that the credit gap, and not just risk appetite, matters for real activity and employment in the U.S., adding to the empirical literature on the role of financial variables in business cycles, starting with Bernanke and Gertler (1989). The importance of the credit gap holds whether we use our own constructed risk appetite measure or the EBP. Our results also distinguish between the effects of accommodative financial conditions and a high credit gap as a financial vulnerability, which reacts with a lag to financial conditions, but makes the economy less resilient and increases the likelihood of a recession. These findings suggest some important financial frictions that affect macroeconomic performance, such as borrowing being driven by changes in the supply of credit (see Lopez-Salido, Stein, and Zakrajsek (2015), Mian et al. (2015) and Krishnamurthy and Muir (2016)), or that individuals do not consider the effects on aggregate credit when they make their borrowing decisions (as suggested in a model by Korinek and Simsek (2014)).

Second, this paper is the first to document the joint nonlinear dynamics of risk appetite, credit, and monetary policy transmission, adding to other studies that have identified a role for shocks to certain credit aggregates and asset prices to contribute to business cycle fluctuations. The finding that macroeconomic responses are nonlinear and depend on whether the credit gap is above or below normal adds to a growing line of research arguing that transmission channels may operate differently depending on underlying conditions. Metiu et al. (2014) find a strong asymmetry in the macroeconomic responses to a risk premium shock depending on whether credit conditions are normal or tight. Adrian, Boyarchenko, and Giannone (2016) document that financial conditions are strong forecasters of downside risks to GDP growth.

Third, our results for nonlinear effects for the monetary policy transmission channel based on the credit gap adds to a growing literature on nonlinearities. For example, Hubrich and Tetlow (2012) use a regime switching model to evaluate the relative effectiveness of monetary policy by whether or not the economy is in a financial crisis state.

Finally, our finding that monetary policy is less effective when the credit gap is high, combined with our finding that rapid credit growth is the channel by which shocks to risk appetite can lead to subpar economic outcomes, suggests another reason – the ineffectiveness of monetary policy -- why credit is costly and may lead to more severe recessions. Thus, our results add to the literature on the role of credit for predicting recessions and their severity. For example, Jorda et al. (2013) provide evidence that excess credit creation in the period preceding a recession substantially increases the depth of the subsequent recession, for both normal recessions and financial recessions (those with substantial losses to the banking sector).

The ineffectiveness of monetary policy in a high credit gap state also is relevant for evaluating the use of monetary policy to reduce vulnerabilities and future crises, relative to the use of macroprudential policies. Svensson (2015, 2016) argues that the costs of directing interest rates at financial stability risks (in terms of reduced output today) would almost always significantly exceed the benefits (reduced probability of a future crisis by reducing credit growth). Ajello et al. (2015) find an optimal interest rate policy would respond only by a small amount to the risk of a financial crisis which depends on credit conditions (lagged bank loan growth), based on a calibrated model of the U.S. economy. Our results provide strong support for the use of either monetary or macroprudential policies to avoid entering a high credit gap state, when it would be more prone to a recession. While it may be hard to implement monetary policy because of the long lag between higher risk appetite and credit growth, our results suggest policy makers may want to pay special attention to high risk appetite when credit has been expanding quickly, because it is in those situations that it becomes more likely the economy will move to a high credit gap state.

The remainder of our paper is organized as follows: in section 2 we describe our data, including the construction of our risk appetite measure, and specification; in section 3 we characterize the dynamics of the system with respect to movements of risk appetite and the credit gap. In section 4, we characterize the monetary policy transmission mechanism. Section 5 describes some robustness tests and section 6 concludes.

## 2. Data and Specification

In this section we describe the data, particularly the construction of our measure of risk appetite, ALLM, and the credit-to-GDP gap. Our outcomes of interest are subpar economic performance – contractions in GDP and increases in the unemployment rate – rather than full-blown financial crises. This is because there are relatively few financial crises in the U.S. data since 1975. Of the five U.S. recessions in that period, only the 2007 to 2009 episode has been defined to be a financial crisis in Reinhart and Rogoff (2009). The wave of bank failures that began in 1984 and culminated in 1988-1992 with the failure of almost 1,600 depository institutions associations has also been labelled a crisis (see Laeven and Valencia (2008)), suggesting that perhaps the 1990 recession could also be associated with a financial crisis. Jordà et al. (2013) find that roughly 30 percent of recessions in their sample of 14 advanced economies from 1870 to 2008 involve financial crises.

## 2.1 The credit-to-GDP gap

We follow the literature in defining the credit-to-GDP gap as the difference between the ratio of nonfinancial private sector debt to GDP and an estimate of its trend, designed to be slow-moving. Moreover, this definition of the credit gap is consistent with the Basel III recommendation for evaluating credit excesses for implementing the countercyclical capital buffer.

As shown in figure 1, the credit-to-GDP ratio since 1975 shows two distinct build-ups: the first starts in the early 1980s and ends in the recession of 1990-91; the second starts in the late 1990s and accelerates for a sustained period until the Great Recession. Even after falling significantly from its peak in 2009, the level remains elevated relative to previous decades.

The estimated gap, the ratio less a trend estimated with a HP filter with a smoothing parameter of 400,000, shows a similar pattern over history, with peaks ahead of the recessions of 1990-91 and 2007-09. The gap we report, consistent with the Basel III recommendation, is based on final estimates of credit-to-GDP.[1]

The figure highlights a well-known property of the credit-to-GDP gap: that it tends be high for a significant period after the financial cycle turns, which may have implications for the strength of a recovery. The gap also tends to continue to increase during the recession before turning down, because borrowers may draw upon pre-committed lines of credit that they have with banks, or because GDP, the denominator of the ratio, may fall more quickly than credit in the early stages of a downturn. In our empirical analysis we consider some alternative measures, including the level of credit rather than its gap to a trend.

Another concern with using measures based on credit-to-GDP is the upward trend in the ratio. As an empirical matter, this is dealt with by focusing on the gap with respect to an estimate of the

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[1] Real-time estimates provided an earlier warning than final estimates, and showed the sustained increase starting earlier during the mid-1990s (see Edge and Meisenzahl (2011)).

trend designed to be slow moving. As a theoretical matter, the trend is often ascribed to financial deepening, as credit markets have evolved to make loans more accessible to previously unserved households and businesses.

As shown in the middle panel of figure 1, household credit has nearly doubled since 1975, while the increase in business credit has been more modest, indicating the trend appears to be driven mainly by the growth in household credit. Household credit rose both because of the extensive margin – more households became homeowners – and the intensive margin – existing homeowners took on more debt.[2] On the extensive margin, the homeownership rate also rose, from 64.0 in 1990:Q1 to a peak of 69.2 in 2004:Q4 (since then it has fallen steadily, returning to its 1990 level). In addition, the household and business credit-to-GDP gaps (middle panel of figure 1) highlight the lower frequency of cycles in the household credit gap relative to the business credit gap, as well as the differences in amplitude of changes.

## 2.2 Measures of risk appetite

We constructed an index designed to measure investors' willingness to accept risk, which we call "ALLM". This measure is based on price and non-price measures. Higher asset values relative to historical averages may reflect investor "froth" and greater risk-taking behavior which could lead to a buildup in financial vulnerabilities, which leaves the economy less resilient to adverse shocks. Boom-bust cycles in real estate prices are viewed by many economists as key sources of financial fragility (see, for instance, Cecchetti (2008), Iacoviello (2005), and Jorda, Schularick, and Taylor (2015)). Others have emphasized the information in bond risk premiums and the quality of new bond issuance (Stein (2013b) and Lopez-Salido, Stein, and Zakrajsek (2015)). According to this view, when risk premiums are unusually low there is a greater probability of a subsequent rapid reversal, which may be associated with significant adverse economic effects. Brunnermeier and Sannikov (2014), among others have argued that low volatility may spur risk taking, with the potential for a destabilizing unraveling when volatility eventually spikes.

[2] These increases are due to a combination of public policies, including the tax advantage of mortgage debt and the funding advantage enjoyed by the housing-related government-sponsored enterprises, Fannie Mae and Freddie Mac. The share of mortgage credit funded by Fannie and Freddie grew from 12 percent in 1975 to roughly 60 percent in 2014. (Financial Accounts of the United States, table L.218.) The GSEs faced lower capital charges for funding residential mortgages than did banks, and benefited as well from an implicit backstop by the U.S. government. For a discussion of the capital advantages enjoyed by the GSEs, see Hancock et al. (2006).

We construct our index, ALLM, in the spirit of the methodology described in Aikman et al. (2015). It is the weighted sum of normalized time series related to valuations and lending standards in four sectors: equity markets; business credit; commercial real estate; and household and residential mortgage credit. The overall index is then a weighted average of the standardized index for each of the four sectors (figure 2). The components of each sector are:

(1) Equity markets: stock market volatility (actual before 1989 and the VIX after) and the S&P 500 price-earnings ratio.
(2) Business credit: the BBB-rated corporate bond spread to Treasury, the share of nonfinancial corporate bond issuance that is speculative-grade, and the index of credit availability from the NFIB survey of small businesses.
(3) Commercial real estate: a commercial real estate price index deflated into real terms and commercial real estate debt growth.
(4) Household: the residential price-to-rent ratio and lending standards for consumer installment loans from the Senior Loan Officer Opinion Survey (SLOOS).

To link the existing literature we compare our measure to the excess bond premium measure (EBP) of Gilchrist and Zakrajsek (2012) based on the corporate bond prices. Both measures (the top panel of figure 2) are more volatile than the credit-to-GDP gap and show more cycles. In addition, the contemporaneous correlation of ALLM and the credit-to-GDP gap is low, but the data show that ALLM tends to lead the credit-to-GDP gap, with the strongest correlation at eight quarters ahead (.76). This lead structures suggests that strong risk appetite tends to create the conditions for a period of a high credit gap.

The bottom panel of figure 2 shows the four components. The business credit component of ALLM not surprisingly is quite similar to the EBP, although ALLM recovers somewhat more slowly after the 1990 and 2008-09 recessions because it also includes credit conditions for small businesses, whereas the EBP is based on only publicly-traded corporations. However, ALLM also reflects changes in commercial and residential mortgage credit availability; these real estate markets have cycles distinct from corporate asset markets. As a result, the overall ALLM index is distinctly below the (negative) EBP in the late 1970s to early 1980s, when equity markets fell and household credit was tight, and in the early-to-mid 1990s when commercial real estate and household credit conditions were tight relative to conditions for the business sector.

## 2.3 Sample statistics

Table 1 gives sample statistics for the variables in our system. The table reports statistics for periods when the credit-to-GDP gap and ALLM are above or below their means. For each measure, in periods when it is high or low, the table gives the level and quarterly change in the unemployment rate, real GDP growth, inflation, and the level and quarterly change in the average effective federal funds rate.

When the credit-to-GDP gap is low, real GDP growth and the inflation rate are higher than in periods when it is high. Further, in these low periods, the unemployment rate is falling and the fed funds rate is increasing, suggesting such low periods occur near business cycle peaks. In contrast, periods of when the gap is high are associated with lower economic growth, low but rising unemployment, and loosening monetary policy, suggesting that they occur near business cycle troughs.

This pattern is in contrast with that for ALLM. Periods of low ALLM are associated with worse overall economic performance: the unemployment rate is higher and rising, and real GDP growth is significantly lower. Monetary policy appears to be easing in these periods, with the effective funds rate falling, on average, in such quarters. Put another way, periods of high ALLM are associated with good economic performance -- higher real GDP growth and falling unemployment.

Given our focus on the interaction of the effectiveness of monetary policy with our vulnerability measures, we report in Table 2 the number of quarters in which the effective funds rate rose or fell by 25 basis points or more, conditional on whether the credit-to-GDP gap or risk appetite is high or low. One concern would be if the subsample in a high or low value of a measure contained too few easing or tightening episodes. Overall, for both CY and ALLM, there are a reasonable number of quarters in each of the categories of easing, tightening, or unchanged.[3] For example, when the credit-to-GDP gap is either high or low, the distributions of changes in the federal funds rate across

[3] For the entire sample, the effective funds rate fell 25 basis points or more in 41 quarters; changed less than 25 basis points in absolute value in 70 quarters; and rose 25 basis points or more in 46 quarters.

decreased, unchanged, and increased is roughly equal.

## 2.4 Specification

Our primary goal is to characterize the effect of shocks to ALLM and its effects on credit and economic performance, and to evaluate whether these effects differ depending on whether the credit-to-GDP gap is high or low.

We characterize these effects using threshold vector autoregressions (TVARs) estimated on quarterly U.S. macro data starting in 1975:Q1. We estimate the TVARs using Bayesian techniques, following the estimation strategy proposed by Giannone et al. (2015) that is based on the so-called Minnesota prior, first introduced in Litterman (1979, 1980). This prior is centered on the assumption that each variable follows a random walk, possibly with a drift (for variables such real GDP that are not stationary); this reduces estimation uncertainty and leads to more stable inference and more accurate out-of-sample forecasts. As is standard in this literature, we report the 16th and 84th percentiles of the distribution of the impulse response functions (Uhlig (2005), Giannone et al. (2015)).

Our baseline specifications contain the following variables:

- 100 × logarithm of real Gross Domestic Product (GDP)
- 100 × logarithm of the GDP deflator
- Unemployment rate
- The credit-to-GDP gap
- Risk appetite (ALLM) defined so that higher values indicate increased vulnerability
- Federal funds rate, effective, per annum (FFR).

Following Giannone et al. (2015), real GDP and the GDP deflator enter the models in annualized log levels (i.e., we take logs and multiply by 4), while the rest of the variables are defined in terms of annualized rates, and therefore enter in levels.[4] In all instances we use nine lags of the vector of dependent variables, which allows us to capture the lead-lag relationship between ALLM and the

[4] The impulse response functions are instead displayed in basis points; therefore real GDP and GDP deflator are divided by 4 and multiplied by 100, while the other variables are simply multiplied by 100.

credit gap, which has a maximum correlation at eight quarters.

In computing impulse response functions, we identify shocks using a Cholesky decomposition. When identifying monetary policy shocks, monetary policy is assumed to be able to react to risk appetite shocks in the same quarter, as in Gilchrist and Zakrajsek (2012).

The TVARs are estimated over disjoint subsamples with the thresholds determined by the credit-to-GDP gap. We compute responses when the gap is high (above its trend) and when the gap is low (below its trend). This permits us to test for nonlinear dynamics: whether a shock to ALLM or monetary policy (for example) has a different effect in times of high versus low excess credit. Thus, our baseline specification is a threshold VAR based on the level of a measure $X_t$ (usually the credit-to-GDP gap), which has a sample mean of $\mu_X$, is:

$$(1) \qquad y_t = c^{(j)} + A(L)^{(j)} y_{t-1} + \varepsilon_t^{(j)} \begin{cases} j = \text{high, if } X_t > \mu_X \\ j = \text{low, if } X_t \leq \mu_X \end{cases}$$

where $y_t$ is the vector of endogenous variables described above and we define $\mu_X = 0$.

# 3. Baseline Results

## 3.1 Risk Appetite and Credit

We start with a system that includes risk appetite but excludes credit: real GDP, the GDP deflator, the unemployment rate, our risk appetite measure ALLM, and the federal funds rate. Figure 3 shows the impulse response functions with respect to a shock to ALLM in a linear system (i.e. without a threshold feature). Higher risk appetite leads to an expansion, with real GDP rising and unemployment falling. Next, we replace risk appetite with the credit-to-GDP gap. The impulse response functions with respect to unexpected moves in the credit gap are shown in Figure 4. In contrast to the results for risk appetite, an unexpected move in the credit gap initially has no effect on GDP or unemployment, but with a substantial lag leads to an output contraction and increase in unemployment.

Risk appetite and the credit-to-GDP gap appear to be capturing different concepts. In particular, risk appetite could set the stage for credit growth. To determine whether a shock to ALLM can stimulate a reaction in the credit-to-GDP gap, we next include both variables in a VAR.[5] As described in section 2.4, we identify shocks to ALLM using a Cholesky decomposition in which monetary policy is permitted to react within the same quarter as the shock to ALLM.

Figure 5 shows the impulse response functions with respect to shocks to ALLM in a six-variable linear system with both ALLM and the credit-to-GDP gap. Initially real GDP rises and the unemployment rate falls with the benefits peaking about eight quarters after the shock, suggesting that ALLM functions as an indicator of financial conditions. The credit-to-GDP gap rises, responding more slowly than GDP and unemployment, peaking about 16 quarters after the shock. Further out, 20 quarters from the shock, economic conditions deteriorate with GDP contracting and unemployment rising. Including both financial variables in the system helps to clarify the dynamics: a positive impulse to risk appetite eases financial conditions and stimulates economic activity, but also leads over time to a pick-up in excessive borrowing and, ultimately, subpar growth. Because the results differ significantly depending on whether the system includes the credit-to-GDP gap, they suggest that credit is an important transmission channel for changes in risk appetite.

Given the evident importance of credit in the transmission of risk appetite shocks, we estimate the model after dividing the sample into two parts – when the credit-to-GDP gap is above and below zero. This specification permits nonlinear dynamics to emerge. The results are shown in figure 6.

The response to a shock to risk appetite when the credit gap is low (blue lines) shows an increase in output, inflation, and a decline in unemployment; moreover, the credit-to-GDP gap increases modestly. In a high credit gap environment (red lines), the IRFs for a shock to risk appetite show a similar increase in output and a decline in unemployment in the near-term. Of particular interest, the credit-to-GDP gap rises significantly more in response to an ALLM shock in a high credit gap environment than in a low credit gap one. Moreover, the rise in the credit gap appears to lead to contractions in real GDP and increases in unemployment, similar to the dynamics for a direct

[5] Danielsson et al. (2015) find that low stock price volatility, which they interpret as a measure of risk appetite, leads to a subsequent increase in the credit-to-GDP gap.

impulse to the credit-to-GDP gap. These results suggest that a positive shock to risk appetite in a high credit gap environment leads to a near-term expansion, but may also may sow the seeds for weaker economic performance in subsequent periods. In contrast, a shock to risk appetite in a low credit gap period does not suggest the same costs and inter-temporal trade-off for economic activity. These results suggest that the credit gap is a vulnerability, where a high credit gap leaves the economy less resilient to shocks.

### 3.2 Monetary Policy

We next turn to the role of monetary policy, and in particular its interactions with the credit gap. Figure 7 shows IRFs with respect to a shock to monetary policy (identified using a Cholesky decomposition) in our baseline linear specification. As shown, the system reacts in the expected fashion: prices decline, unemployment rises and economic activity contracts.

Figure 8 shows the IRFs with respect to a shock to monetary policy in our nonlinear specification, with the threshold based on the credit-to-GDP gap. As before, the blue (red) lines show the impulse response functions from the system estimated in low (high) credit-to-GDP gap periods. There are important differences in the dynamics of the system in response to a monetary policy shock between high and low credit-to-GDP gap periods. When the credit gap is low, the system reacts as expected: GDP and prices fall and the unemployment rate rises. Interestingly, ALLM falls immediately following the shock, reinforcing the tightening of monetary policy. However, when the credit gap is high, monetary policy appears ineffective for real activity. Real GDP, prices, and the unemployment rate do not react significantly to the shock. Further, ALLM rises immediately following the shock, providing an offset to a contractionary effect of tighter monetary policy. These results suggest that the transmission of monetary policy to the real economy depends significantly on the level of the credit-to-GDP gap. We investigate this finding in greater detail in Section 4.

## 4. Monetary Policy Transmission and Credit

In this section, we evaluate further the results that monetary policy is less effective when the credit gap is high. First, we decompose our sample into periods of increasing vs. decreasing credit-to-GDP gaps rather than high or low gap. Second, we employ a different strategy to identify monetary policy shocks and a different outcome variable. Our findings collectively provide support for the view that the relative ineffectiveness of monetary policy when the credit gap is high is because the transmission to longer-maturity interest rates is attenuated, and that policy is less effective during periods of rising credit gaps than in declining gaps.

## 4.1 Peak-to-Trough Credit Cycle Decomposition

To help to understand why monetary policy might be less effective in high credit states, we look more carefully at the cycle for the credit-to-GDP gap, which is high both before and after a cyclical peak – during the boom and the subsequent bust. We focus appropriately on the gap given the focus of the literature on the stock of debt. However, one might conjecture that the monetary policy transmission mechanism also depends on the reason for the high level of credit-to-GDP. In the "lean vs. clean" taxonomy of Stein (2013a), monetary policy might be more effective when used to lean against rapidly increasing credit or when used to clean up following a post-boom contraction. First, as asset price increases and associated credit growth gain steam, monetary policy may be less effective at restraining activity (see Dokko et al. (2009) for muted effects on house prices and residential investment), perhaps because an overriding speculative motive made increases in the cost of funds a relatively less important consideration (Foote et al. (2012); Cheng et al. (2014)). Second, monetary policy may be less effective at stimulating activity after a credit-fueled boom, perhaps because the overhang of debt accumulated during the boom reduces consumers' or firms' capacity to borrow (Guerrieri and Lorenzoni (2015); Dobridge (2016)) or because the boom stimulated a misallocation of resources (Mian, Sufi, and Verner (2015)).

One way to test this hypothesis is to divide the sample into periods of an increasing credit-to-GDP gap, from the troughs to the peaks of the measure and into periods of a decreasing credit-to-GDP gap, from the peaks to the troughs. Figure 9 shows the impulse responses to a monetary policy shock in a system with the sample divided in this fashion. The blue lines show the IRFs in post-boom periods. It does appear that in such periods, monetary policy has an effect on real variables and on the credit-to-GDP gap. During periods of rising credit-to-GDP gaps, however, monetary policy shocks appear to have no effect on the system. These results support an interpretation that the previous result that monetary policy is ineffective when the credit gap is high is because it cannot slow the economy or credit when credit is booming.

## 4.2 Identifying Shocks to Monetary Policy Using High-Frequency Data

We investigate further why monetary policy shocks appear to have little effect when the credit gap is high, using an alternative identification strategy and with a different outcome variable. In particular, we analyze the impact of a monetary policy shock on government bond forward rates, following the approach of Hanson and Stein (2015) (henceforth referred to as "HS"), and test whether the response of distant forward rates to shocks to shorter-maturity rates differs between high credit gap and low credit gap states. HS find that, based on data from 1999 to 2012, forward rates respond significantly to changes in short-term nominal rates on FOMC days; they further find that most of the response is driven by movements in forward real rates rather than inflation. HS attribute the movements to changes in term premiums rather than to changes in the path of short rates at distant horizons, consistent with "reach for yield" behavior by investors who prefer current income to a holding-period return. When monetary policy changes, investors adjust to mitigate the change in current yields; for example, if policy loosens, these investors rebalance to longer-term bonds to gain yield, which (in equilibrium) reduces term premiums. Conversely, if policy tightens, investors sell longer-term bonds and term premiums rise.

In contrast to HS, we are interested in determining whether the response of longer maturity yields to monetary policy surprises is attenuated in high credit-gap periods, thus providing a mechanism for our result that monetary policy shocks do not affect GDP growth when the credit gap is high. We replicate the HS analysis using nominal government rates for 1975 to 2014, and estimate regressions separately for high and low credit-to-GDP gap periods.

We estimate the following regression:

$$(2) \qquad \Delta f_t^{X(n)} = \alpha_{X(n)} + \beta_{X(n)} \Delta y_t + \Delta \varepsilon_t^{X(n)}$$

Where f indicates the forward, n the maturity and X indicates if the forward is of a nominal bond (X = \$) or a real bond (X = TIPS)

The estimated betas for the regressions are shown in the top panel of Figure 10 for nominal yields and Figure 11 for real yields (the "All" line in Figure 11 exactly replicates HS). For parallelism with our other results, we use an estimation period back to 1975 for nominal Treasury yields

(TIPS are not available before 1999). The estimated betas for nominal forward rates are higher in the low credit-to-GDP gap state than in the high credit gap state, and differences are statistically different out to eight years.[6] Figure 11 for real yields also shows significant differences in betas between low and high credit gap periods for forward rates out to roughly 7 years ahead. One possible reason for why the betas in high credit gap periods are lower is that investors who want to rebalance their portfolios to gain yield when short-term rates fall have more opportunities to increase credit risk for the additional yield in high credit versus low credit periods, and thus do not have extend their duration risk by as much.

## 5. Robustness Tests and Extensions

### 5.1 Using EBP Instead of ALLM

As an alternative to our risk appetite measure, ALLM, we estimate our system using the excess bond premium. Because higher values of ALLM correspond to greater risk appetite while higher values of the EBP correspond to lower risk appetite, we actually use the negative of the EBP in our estimation. As before, we estimate a nonlinear system with the sample divided by the credit-to-GDP gap. IRFs with respect to shocks to EBP and to monetary policy are shown in Figures 12 and 13. Similar to a shock to ALLM, a shock to EBP in a high credit gap state stimulates a large enough credit boom to ultimately lead to a recession, although the magnitudes of effects on GDP, unemployment, and the credit gap are smaller. In addition, monetary policy is ineffective in high credit gap states even in the system estimated using EBP instead of ALLM. Thus, our results are robust to the use of EBP, which has been used often to predict economic performance, which supports our conclusion that of monetary policy ineffectiveness in high credit gap periods.

### 5.2 Robustness to alternative measures of excess credit

The use of the credit-to-GDP gap raises certain questions about the underlying trend, and it is useful to test whether the level of credit (rather than a ratio to GDP) also results in the same general findings. Second, because actual GDP falls in bad times, one might be concerned that the causation runs from recessions to higher credit-to-GDP ratios. Figure 14 shows the results of an

[6] Differences between the betas for the high and low credit gap periods for the sample back to 1975 rather than back to 1999 are smaller in magnitude at closer horizons, but betas for both samples converge to about .4 at far distant horizons.

alternative specification in which the credit-to-GDP gap is replaced with the log level of credit outstanding. In order to limit the number of changes in specification, as before, high/low vulnerability periods are defined relative to the credit-to-GDP gap. As shown, results using log level of credit are similar to those when using the credit-to-GDP gap: An upward shock to ALLM during either high or low vulnerability periods results immediately in real GDP growth and a rise in credit. However, the same shock in a high vulnerability period eventually results in lower economic performance than the in a low vulnerability period. Moreover, the boom in GDP experienced in a high vulnerability state is shorter-lived than that experienced in a low vulnerability state. In addition, a shock to monetary policy with the log level of credit (not shown) yields similar results to those reported based on the credit-to-GDP gap.[7]

In other estimations, not shown, we evaluate a shock to ALLM when the system contains the credit-to-GDP ratio, based on potential rather than actual GDP. We find similar results in that a shock to ALLM in a low credit gap state leads to a sustained increase in GDP, rise in prices, and initial decline in unemployment, and higher credit, but the standard errors for most of the variables are larger. In a high credit gap state, the initial increase in GDP is followed by weaker growth, which is considerably weaker than in the low credit gap state, though growth is not significantly below zero. In addition, we evaluate a shock to ALLM when the system contains the credit-to-GDP ratio, but we define stricter thresholds for the credit gap to be high or low. Specifically, a high or low credit gap is defined when the gap is either half a standard deviation above or below the trend, effectively restricting the sample to observations where the credit gap is further away from zero. Our results are not much affected by this alternative threshold.

We also estimate the baseline nonlinear system based on credit by the type of borrower, either households or nonfinancial businesses. This division is suggested in part because many studies have focused solely on household credit, but there is higher variability in business debt than household debt in the U.S. Impulse responses from shocks to ALLM to systems with either household or business credit, with the combined credit-to-GDP gap as the threshold, are similar to results reported above when credit is aggregated, and the results are consistent with higher frequency cycles for business than household credit. However, when the threshold is only the specific type of credit (ignoring the other), shocks to ALLM do not lead to a recession. We

[7] Results available upon request.

conclude that one form of credit is not of greater concern than the other, and that it is the sum of both household and business which matters for macroeconomic performance.

## 6. Conclusion

In this paper, we evaluated the connections between risk appetite, credit, and monetary policy in a threshold VAR framework to allow for nonlinear dynamics. We found that the transmission of risk appetite shocks functions much like shocks to financial conditions, and results are similar to those found with other measures of risk appetite, like the EBP. However, in a system with nonfinancial credit, we find important nonlinear effects. When the credit gap is low, shocks to risk appetite stimulate economic activity and a sustained expansion. By contrast, when the credit gap is high, shocks to risk appetite, while also stimulating economic activity in the short run, lead to excess borrowing and ultimately economic contractions.

With respect to monetary policy, we also find the transmission depends importantly on the credit-to-GDP gap. Impulses to monetary policy, as expected, lead to declines in activity when the credit gap is low, but policy effectiveness is significantly reduced when the credit-to-GDP gap is high. These results suggest that monetary policy transmission is hindered in periods of excess borrowing. This ineffectiveness appears to be more consistent with stories in which monetary policy has difficulty stopping a credit boom rather than stimulating the economy after a large debt overhang has taken hold, based on findings from evaluating the transmission of monetary policy to far forward Treasury rates in high vs low credit gap periods, and from decomposing our sample into periods of credit growth – from troughs to peaks of the credit-to-GDP gap – versus credit moderation – from peaks to troughs. Moreover, risk appetite does not decline when monetary policy tightens in high credit periods, as it does in low credit periods, indicating again that transmission channels depend on the credit gap.

Given the important difference in monetary policy transmission, policymakers have an incentive to prevent the credit gap from becoming excessive. That is, our results highlight that policy makers should be especially attentive to risk appetite when credit growth starts to exceed output growth when the gap is near or above trend. In addition, some recent research has focused on the costs and benefits of using monetary policy to lean against the wind and prevent the buildup of credit (Svensson, 2016 and Gourio, Kashyap, and Sim, 2016). These models evaluate the inter-temporal tradeoff from reducing activity in the near-term for the potential benefit of reducing a crisis in the future. Our findings that monetary policy is ineffective in high credit gap periods indicate that these models should allow for nonlinearities in the transmission channels and condition on the level of credit gap. Additional research is also needed on evaluating the relative merits of using macroprudential policies or monetary policy to reduce credit.

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**Table 1. Sample statistics by credit-to-GDP gap (CY) and risk appetite (ALLM)**

| | No. of obs. | Unemployment rate | | GDP growth[b] | Deflator growth | Fed funds effective | |
|---|---|---|---|---|---|---|---|
| | | Level | Change[a] | | | Level | Change[a] |
| | | | | | | | |
| CY low | 94 | 6.71 | -8.72 | 3.28 | 3.65 | 6.56 | 1.88 |
| CY high | 66 | 6.25 | 8.00 | 2.18 | 2.52 | 4.66 | -10.49 |
| | | | | | | | |
| ALLM low | 78 | 7.14 | 8.44 | 1.80 | 2.98 | 5.20 | -10.49 |
| ALLM high | 82 | 5.93 | -11.59 | 3.80 | 3.38 | 6.32 | 3.35 |

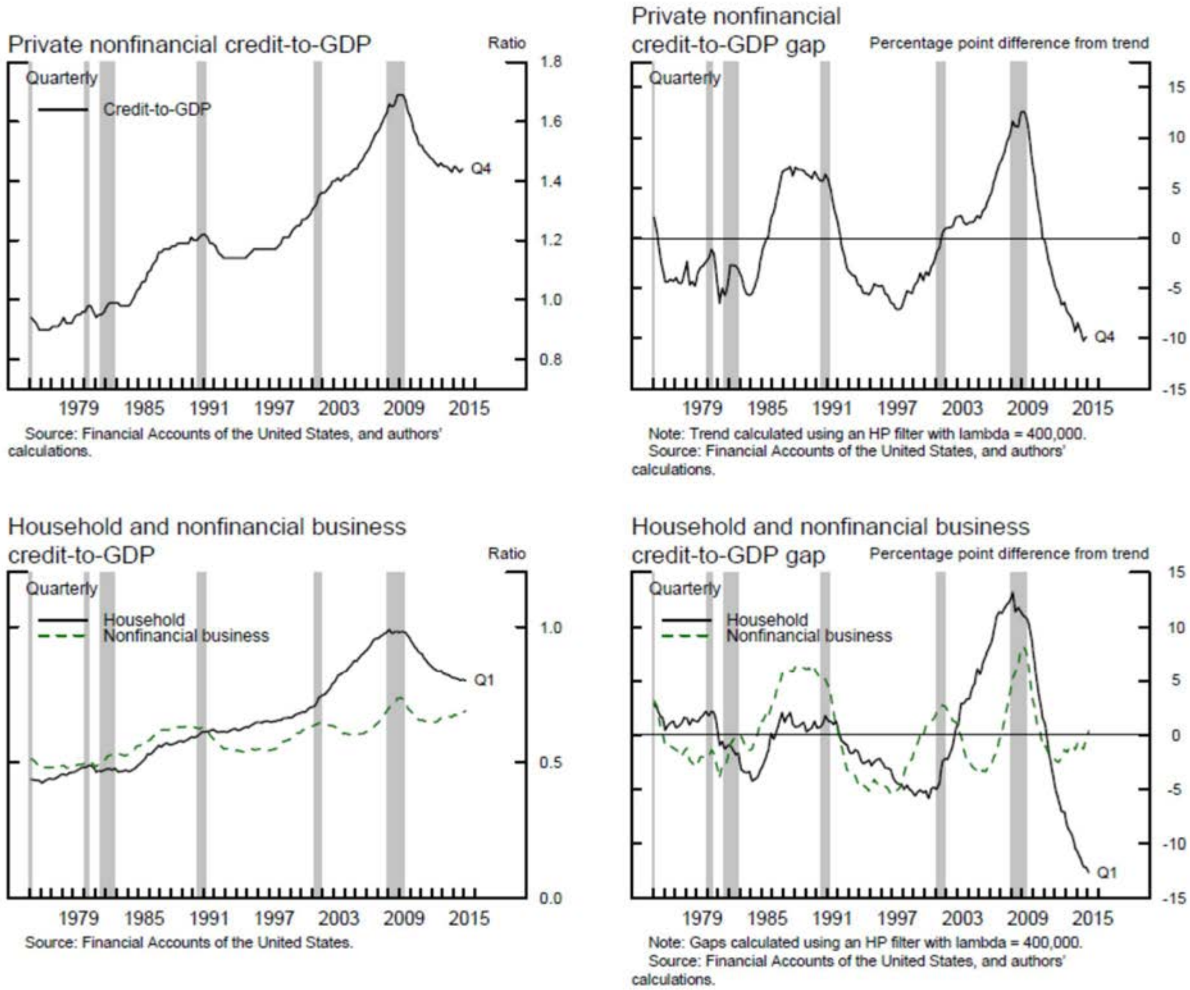
Note. Unemployment rate level, deflator growth, effective fed funds level in percent.
[a] change in basis points.
[b] 400x quarterly change in log level.

**Table 2. Monetary policy changes by credit-to-GDP gap (CY) and risk appetite (ALLM)**

| Number of periods in which… | Fed funds decreased | Fed funds unchanged | Fed funds increased |
|---|---|---|---|
| CY low | 30 | 31 | 33 |
| CY high | 20 | 26 | 20 |
| | | | |
| ALLM low | 23 | 37 | 18 |
| ALLM high | 37 | 20 | 35 |

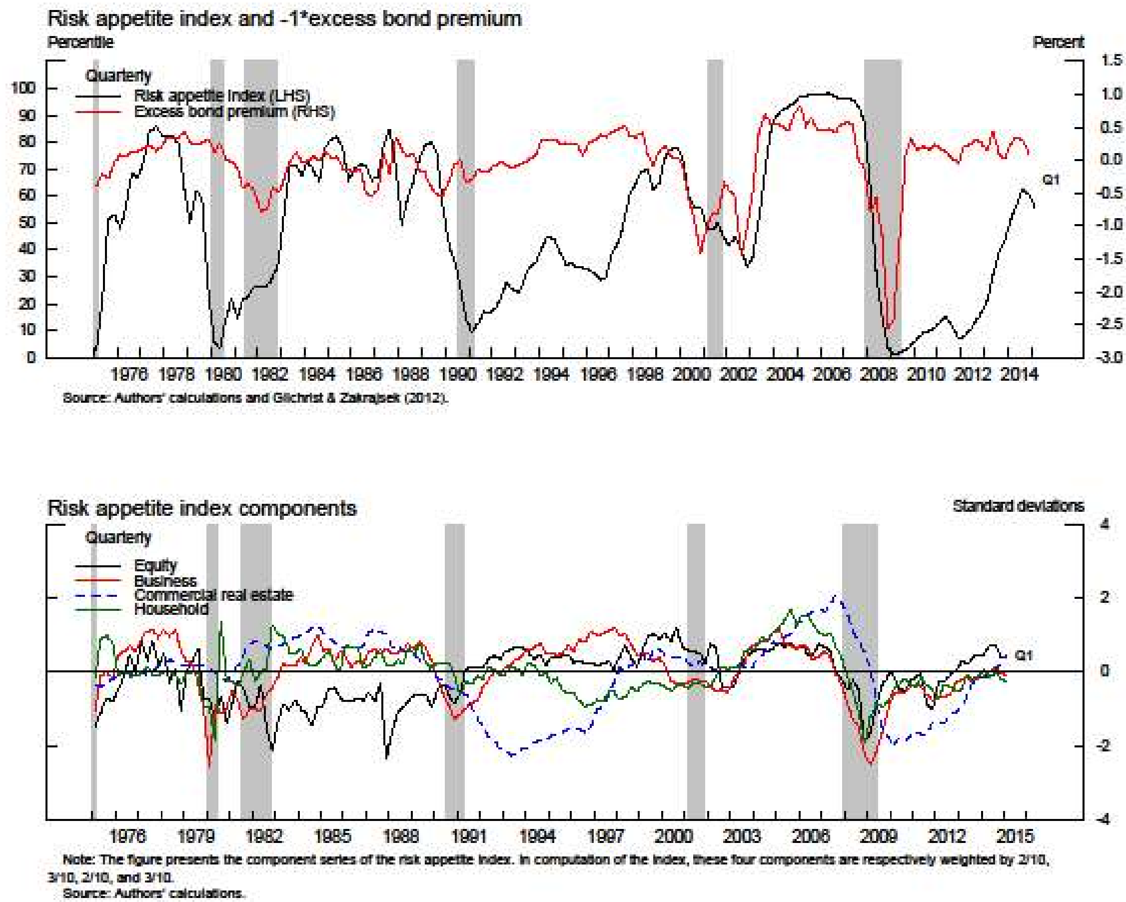
Note. Columns labeled decreased (increased) refer to quarters in which the effective funds rate decreased (increased) 25 basis points or more; quarters in which the effective federal funds rate changed less than 25 basis points in absolute value are labeled unchanged.

**Figure 1. Credit-to GDP ratio and Credit gap**



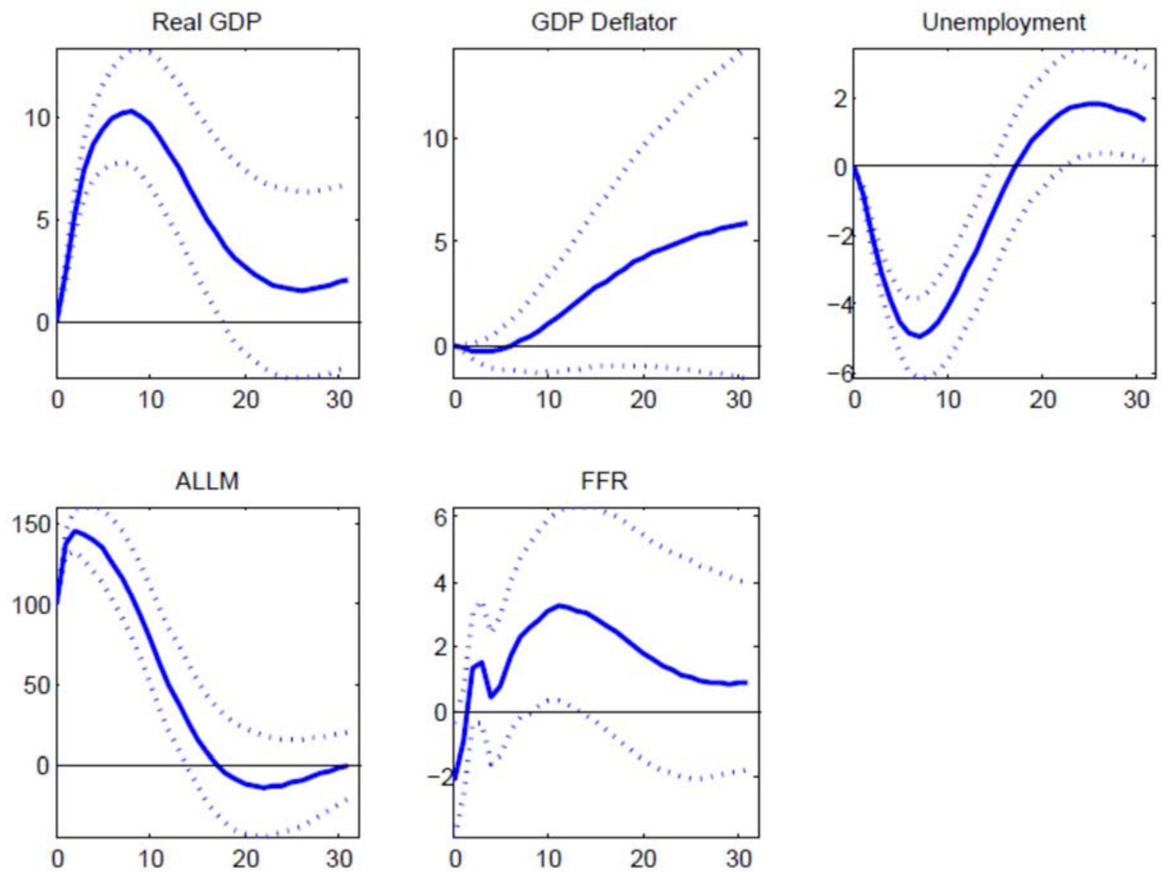

Note. The panels in the figure give various measures of the ratio of credit to GDP from 1975 to 2014, and the ratio relative to a trend, at a quarterly frequency with NBER recessions shaded.

**Figure 2. Risk appetite index ALLM and Excess bond premium, and ALLM components**



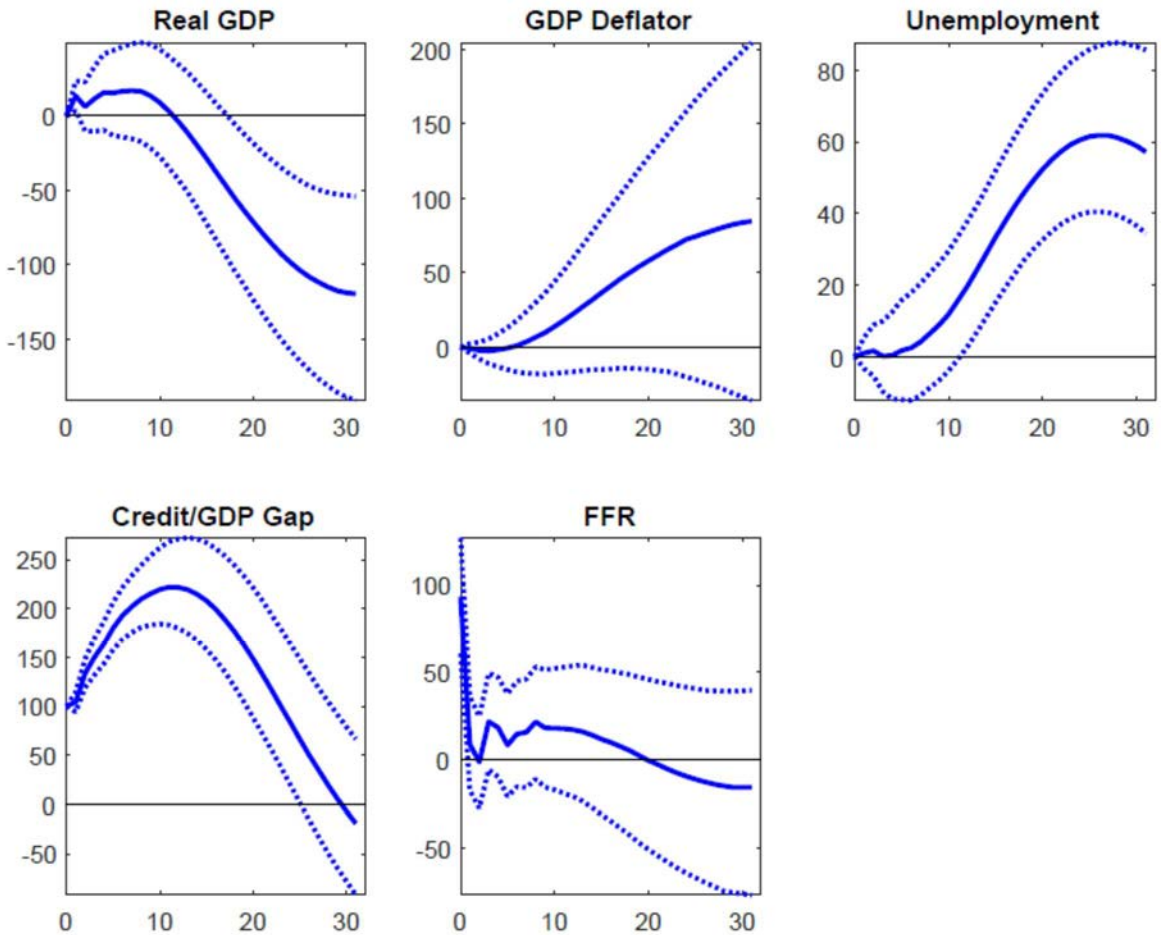

Note. The two panels in the figure show various measures of risk appetite at a quarterly frequency, with NBER recessions shaded.

**Figure 3. ALLM shock without credit-to-GDP gap, linear**



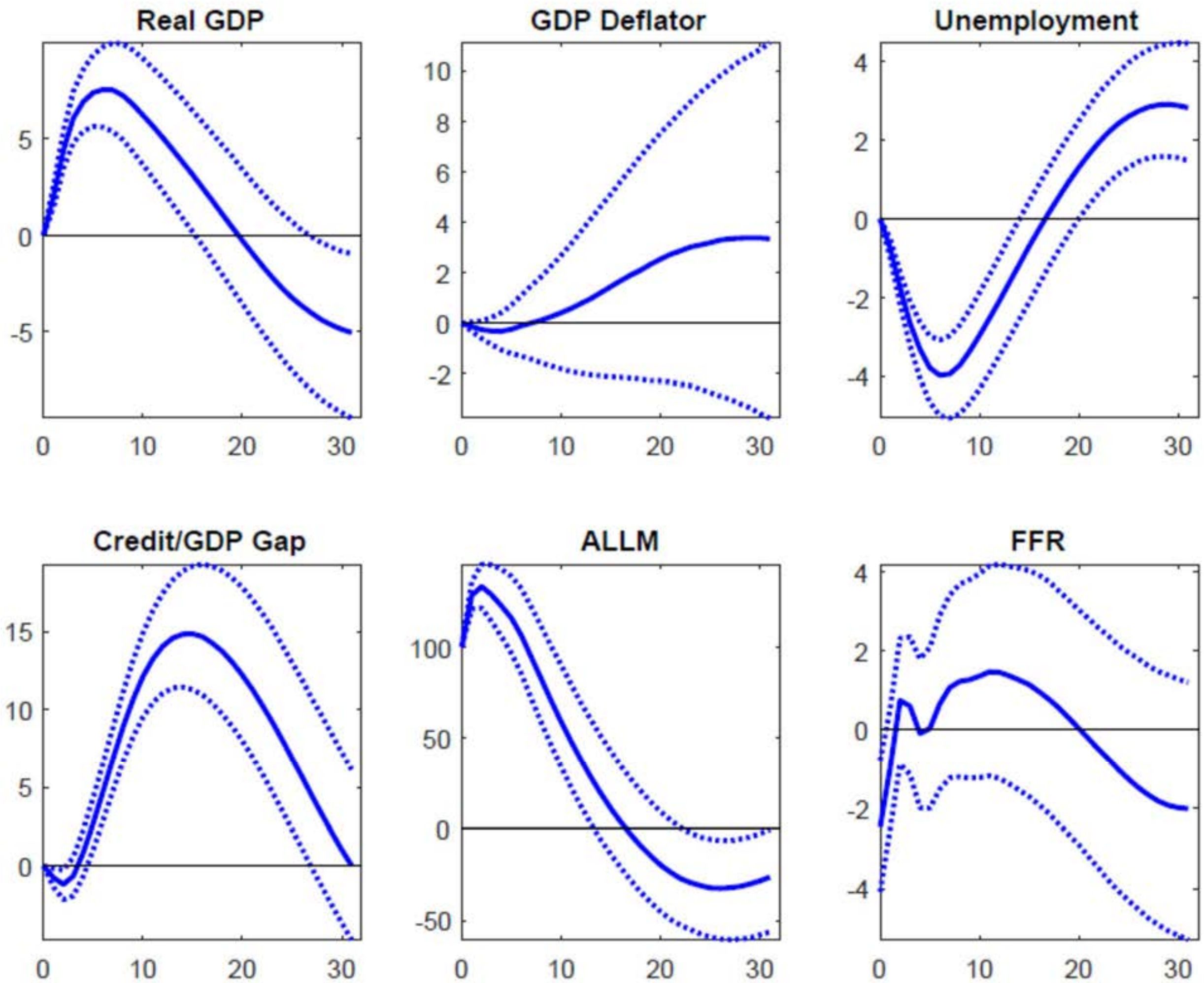

Note. The solid line reports the median impulse reponse to a shock to risk appetite (ALLM). The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 4. Credit-to-GDP gap shock without ALLM, linear**



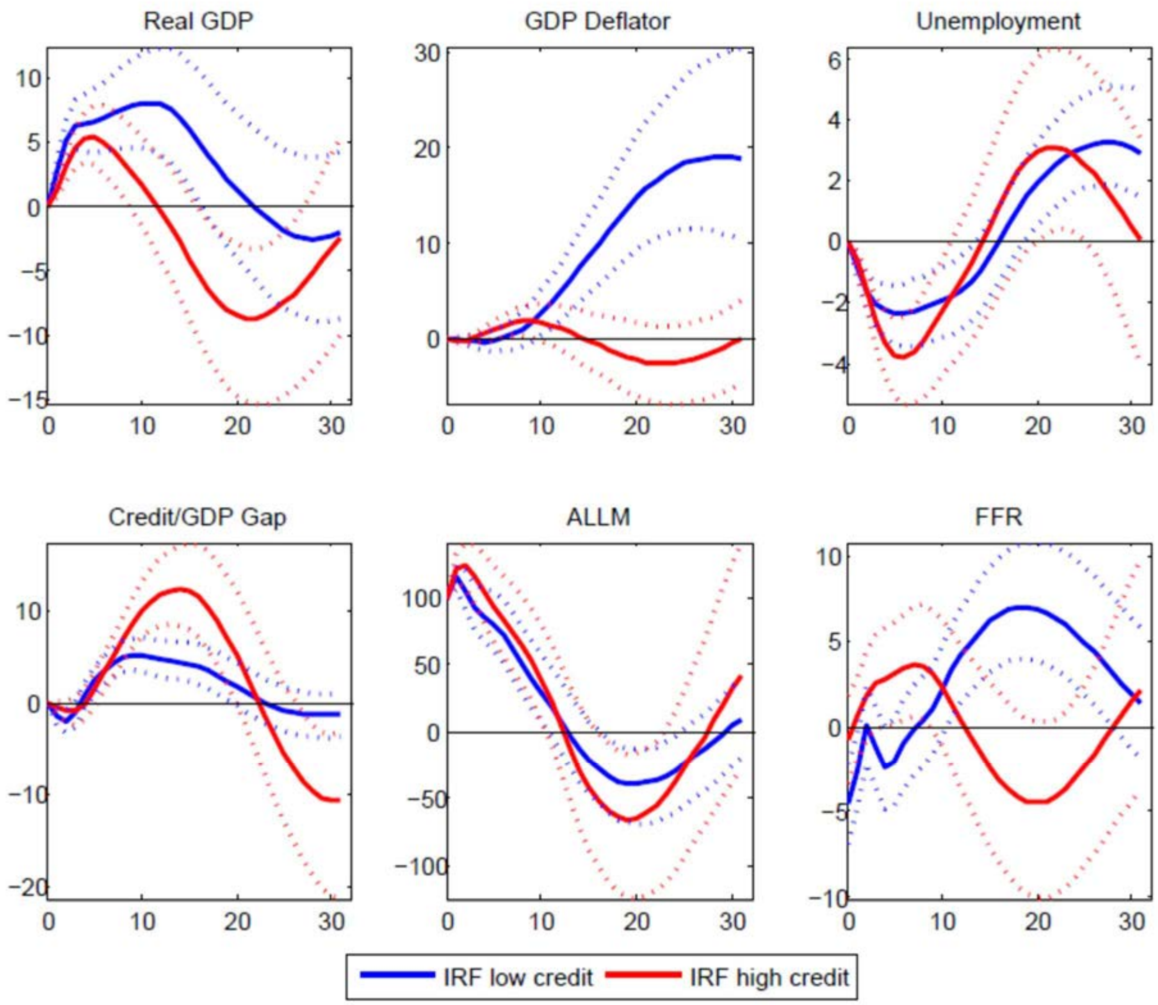

Note. The solid line reports the median impulse reponse to a shock to the credit-to-GDP gap. The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 5. ALLM shock, linear**



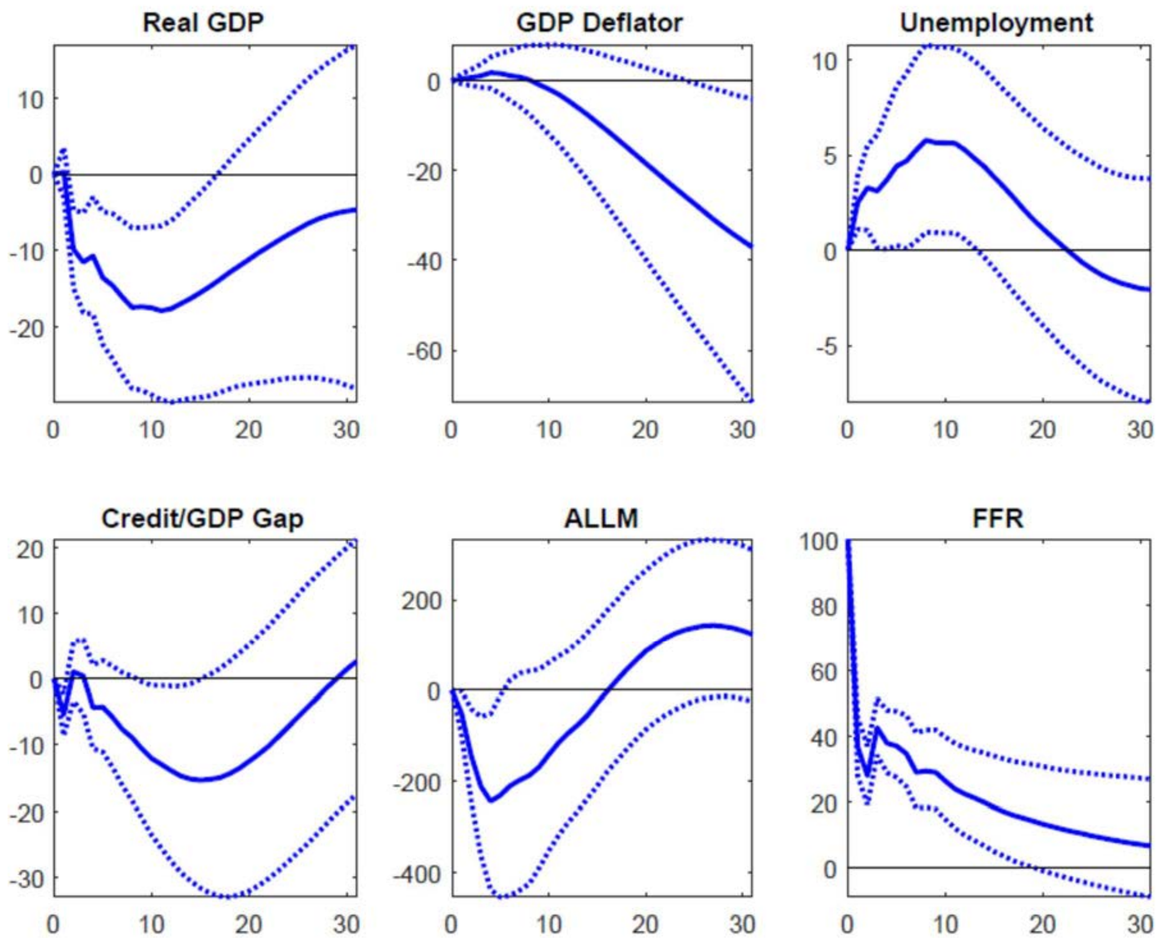

Note. The solid line reports the median impulse reponse to a shock to risk appetite (ALLM). The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 6. ALLM shock, nonlinear with credit-to-GDP threshold**



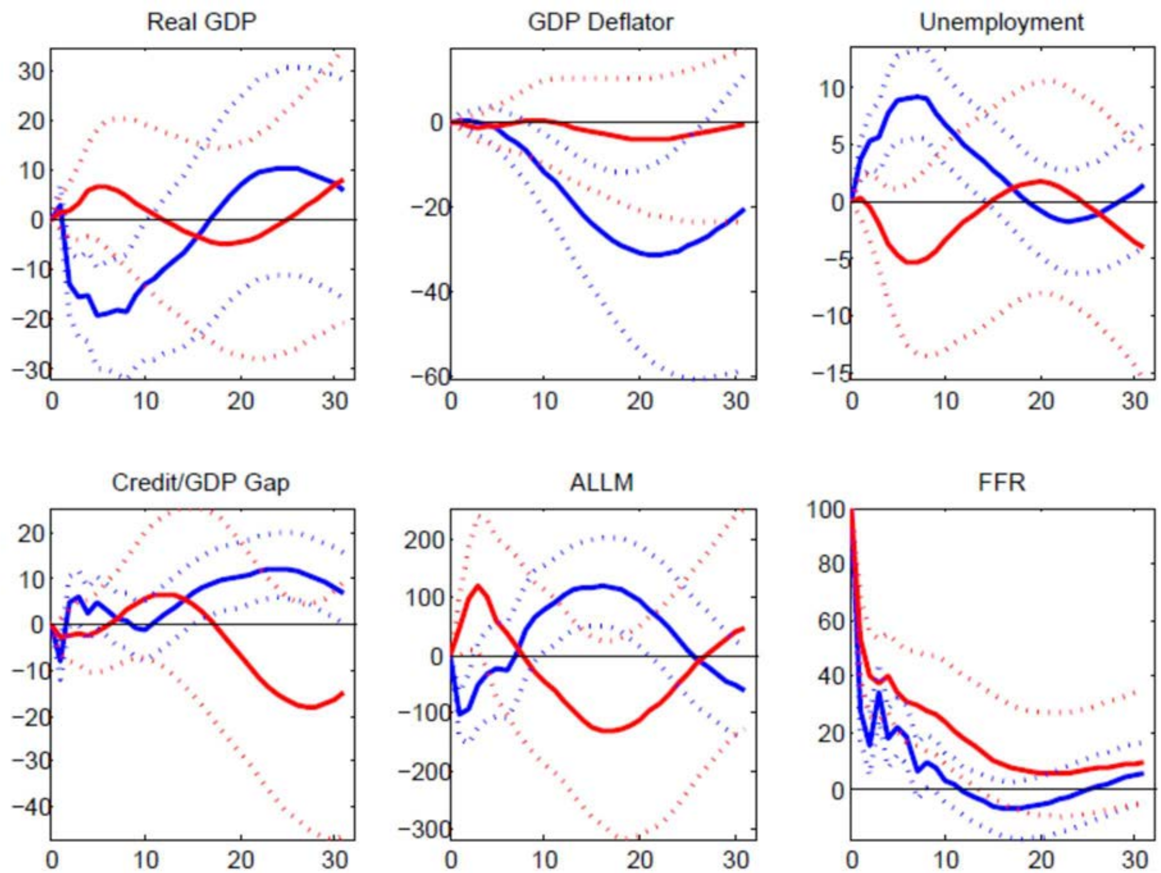

Note. The solid blue line reports the median impulse reponse to a shock to risk appetite (ALLM) when the credit-to-GDP gap ratio is below zero. The solid red line reports the median impulse reponse to a shock to risk appetite (ALLM) when the credit-to-GDP gap ratio is above zero. The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 7. Monetary policy shock, linear**



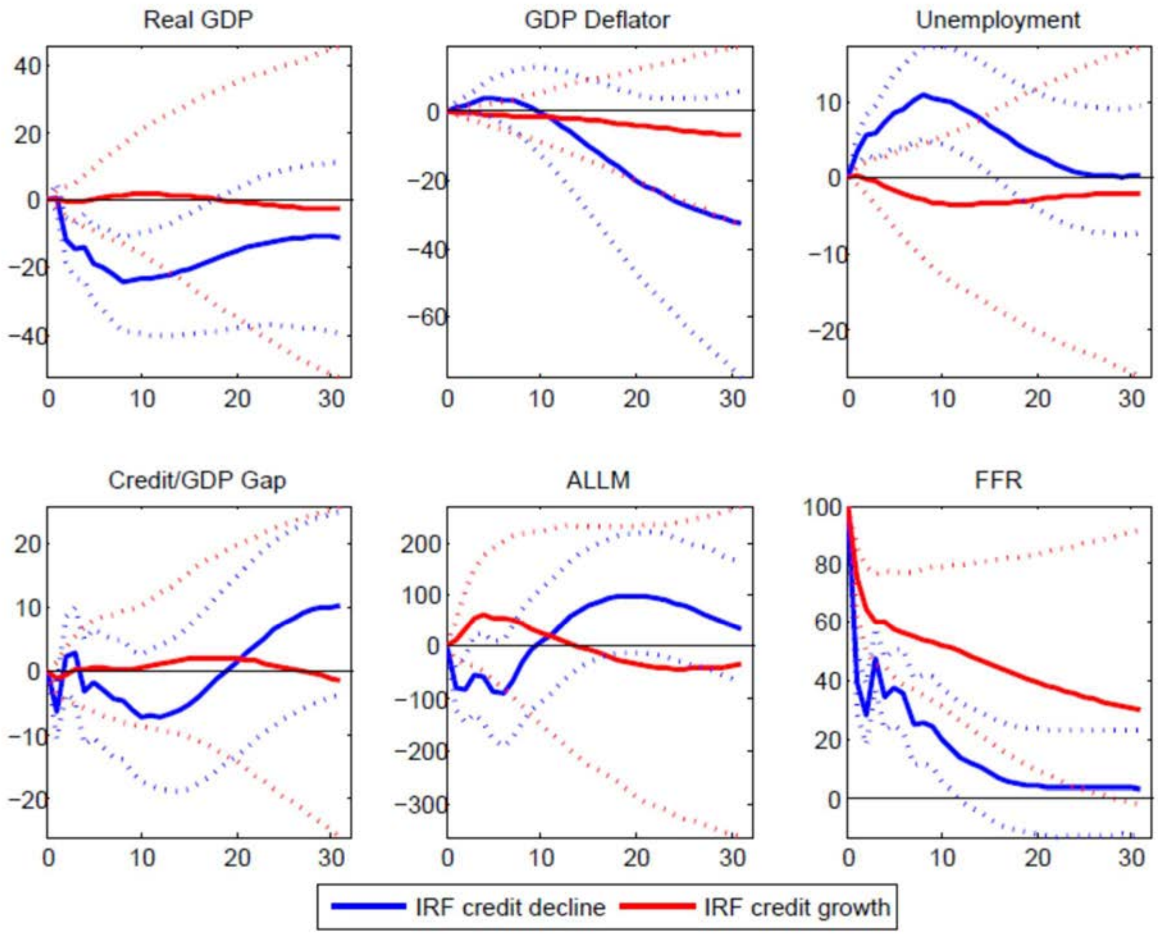

Note. The solid line reports the median impulse reponse to the federal funds rate (FFR). The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 8. Monetary policy shock, nonlinear with credit-to-GDP gap threshold**



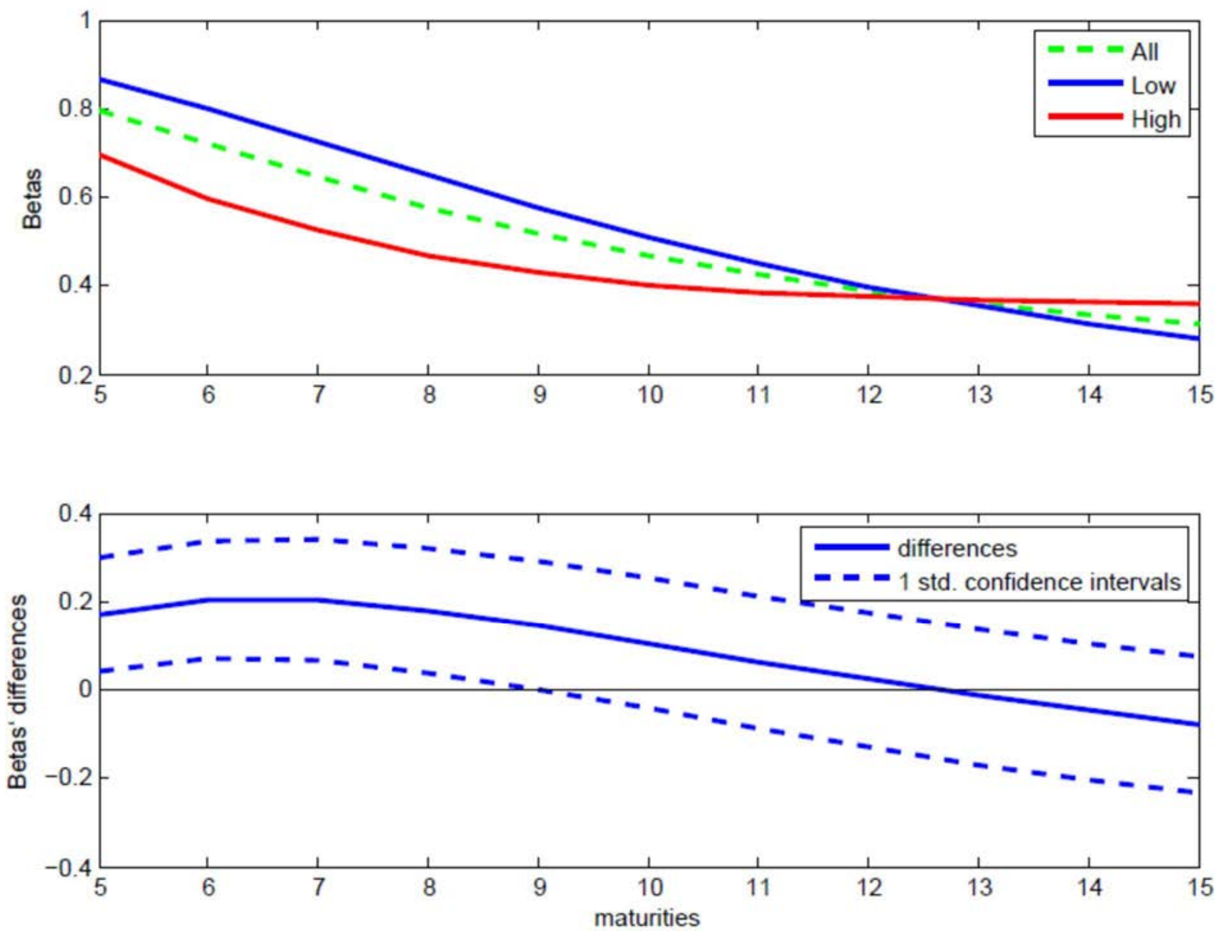

Note. The solid blue line reports the median impulse reponse to the federal funds rate (FFR) when the credit-to-GDP gap is below zero. The solid red line reports the median impulse reponse to the federal funds rate (FFR) when the credit-to-GDP gap is above zero. The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 9. Monetary policy shock, nonlinear with credit-to-gdp gap growth threshold**



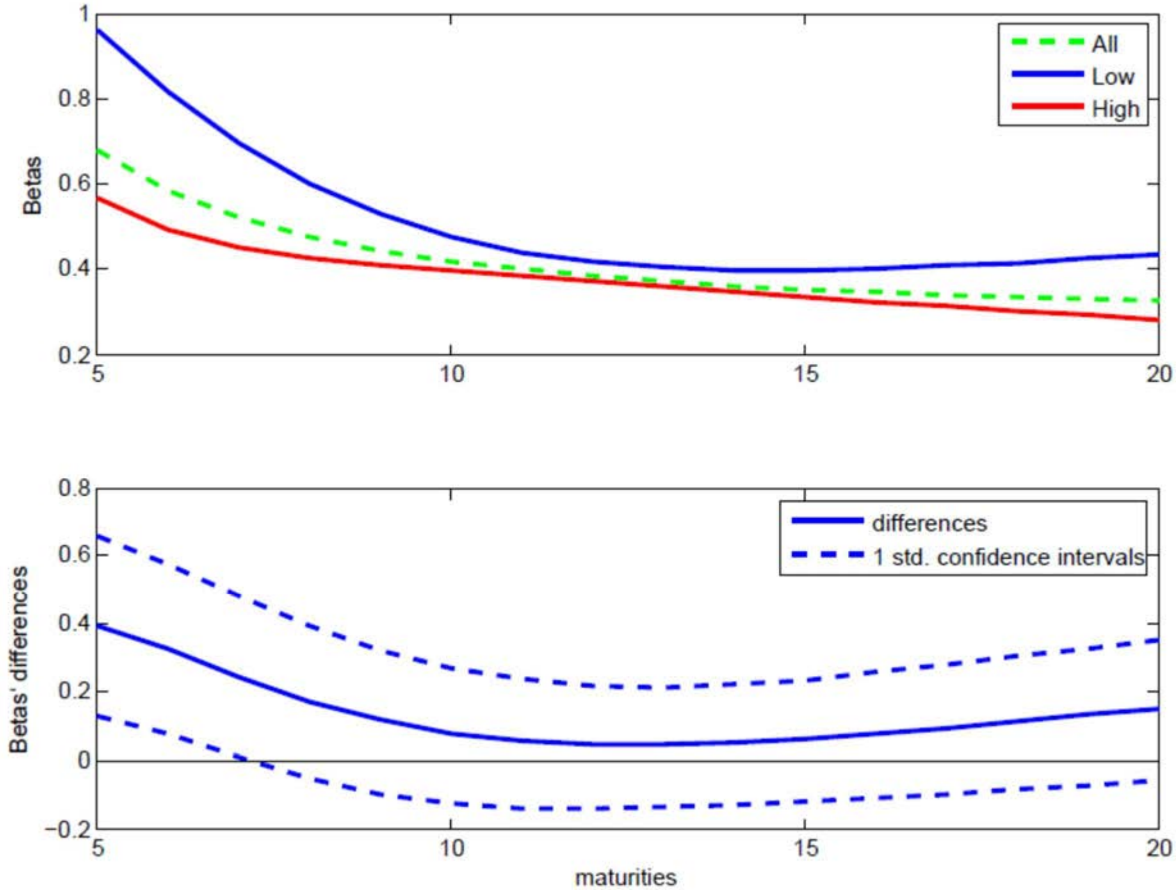

Note. The solid blue line reports the median impulse reponse to the federal funds rate (FFR) when the credit-to-GDP gap is declining. The solid red line reports the median impulse reponse to the federal funds rate (FFR) when the credit-to-GDP gap is increasing. The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 10. Estimated betas for distant forward nominal rates by credit-to-gdp gap, 1975 to 2014**



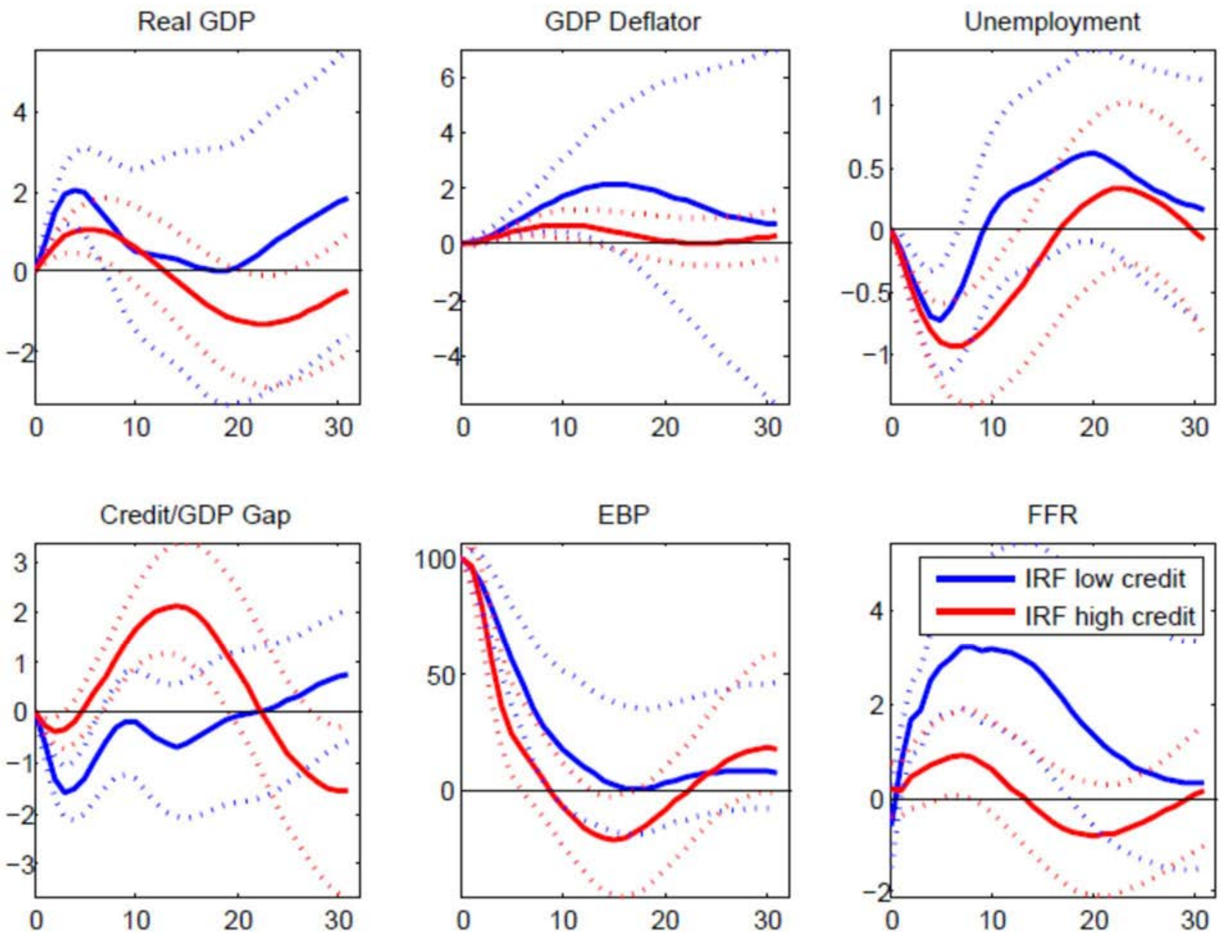

Note. The solid blue line in the upper panel reports the daily change in nominal government bond forward rates, from 5- to 20-year maturity, due to a monetary policy shock measured as the daily change in the two-year bond yield, when the credit-to-GDP gap is below zero. The solid red line in the upper panel reports the daily change in nominal government bond forward rates, from 5- to 20-year maturity, due to a monetary policy shock measured as the daily change in the two-year bond yield, when the credit-to-GDP gap is above zero. The dashed green line reports the daily change in nominal government bond forward rates due to a monetary policy shock for the full sample. In the lower panel, the solid blue line reports the difference between the changes in forward rates when the credit-to-GDP gap is high versus when it is low. The dotted lines report a one standard deviation confidence intervals (obtained through block bootstrap with blocks of dimension equal 8.

**Figure 11. Estimated betas for distant forward real rates by credit-to-gdp gap, 1999 to 2014**



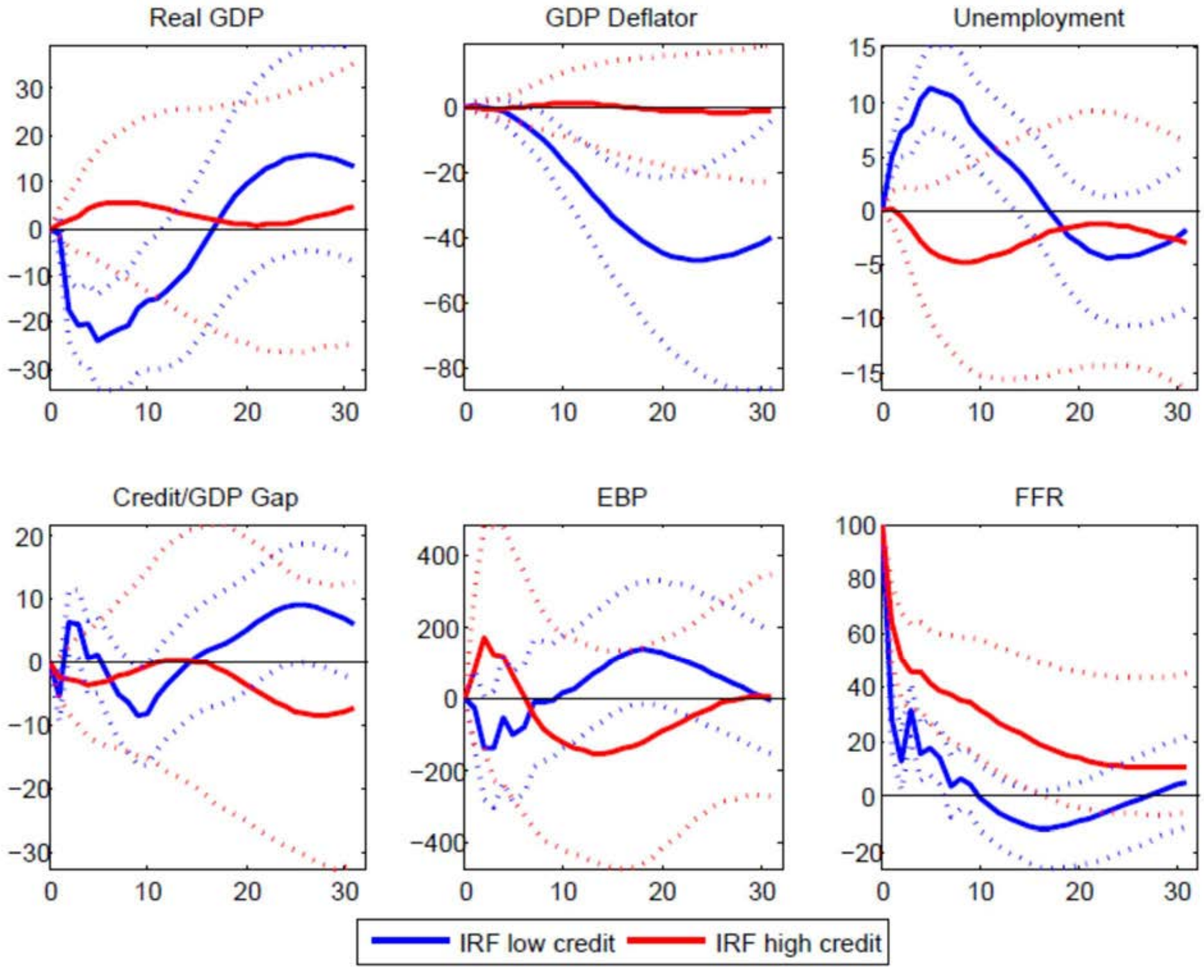

Note. The solid blue line in the upper panel reports the daily change in real government bond forward rates, from 5- to 20-year maturity, due to a monetary policy shock measured as the daily change in the two-year bond yield, when the credit-to-GDP gap is below zero. The solid red line in the upper panel reports the daily change in real government bond forward rates, from 5- to 20-year maturity, due to a monetary policy shock measured as the daily change in the two-year bond yield, when the credit-to-GDP gap is above zero. The dashed green line reports the daily change in nominal government bond forward rates due to a monetary policy shock for the full sample. In the lower panel, the solid blue line reports the difference between the changes in forward real rates when the credit-to-GDP gap is high versus when it is low. The dotted lines report a one standard deviation confidence intervals (obtained through block bootstrap with blocks of dimension equal 8.

**Figure 12. Excess bond premium shock, nonlinear with credit-to-GDP gap threshold**



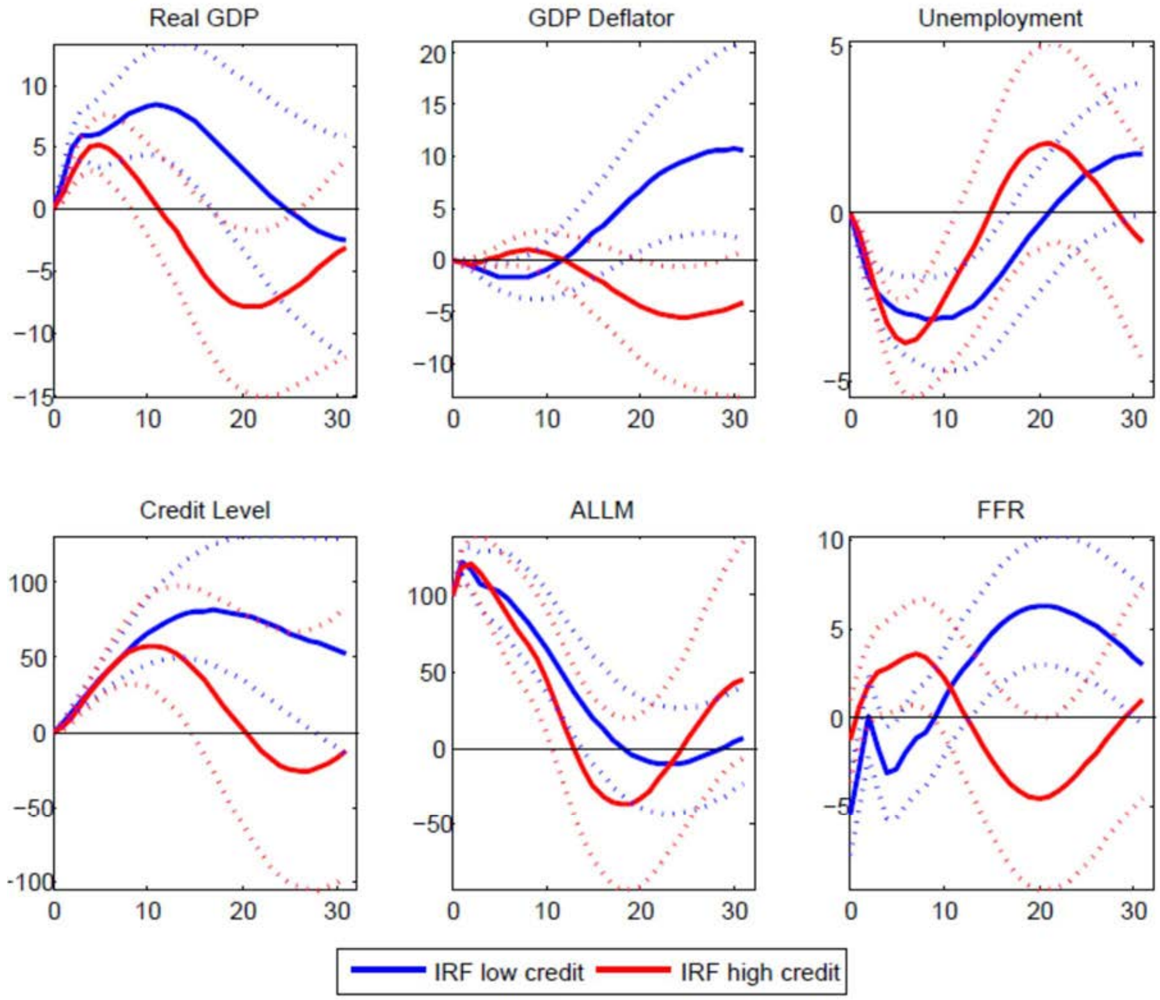

Note. The solid blue line reports the median impulse reponse to a shock to excess bond premium (EBP) when the credit-to-GDP gap ratio is below zero, and the system includes EBP rather than ALLM. The solid red line reports the median impulse reponse to a shock to excess bond premium (EBP) when the credit-to-GDP gap ratio is above zero, and the system includes EBP rather than ALLM. The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 13. Monetary policy shock with excess bond premium, nonlinear with credit-to-gdp gap threshold**




Note. The solid blue line reports the median impulse reponse to the federal funds rate (FFR) when the credit-to-GDP gap is below zero, and the system includes the excess bond premium (EBP) rather than ALLM. The solid red line reports the median impulse reponse to the federal funds rate (FFR) when the credit-to-GDP gap is above zero, and the system includes the excess bond premium (EBP) rather than ALLM. The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

**Figure 14. ALLM shock with credit level, nonlinear with credit-to-GDP gap threshold**




Note. The solid blue line reports the median impulse reponse to a shock to risk appetite (ALLM) when the credit-to-GDP gap ratio is below zero and the system includes the (log) level of credit rather than the credit-to-GDP gap. The solid red line reports the median impulse reponse to a shock to risk appetite (ALLM) when the credit-to-GDP gap ratio is above zero and the system includes the (log) level of credit rather than the credit-to-GDP gap. The dotted lines report one standard deviation confidence intervals for each impulse repsonse.