Hutchins Center Working Paper #39

November 2017

Credit, Financial Conditions, and Monetary Policy Transmission

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November 30, 2017

Abstract

We show that the effects of financial conditions and monetary policy on U.S. economic performance depend nonlinearly on nonfinancial sector credit. When credit is below its trend, an impulse to financial conditions leads to improved economic performance and monetary policy transmission works as expected. By contrast, when credit is above trend, a similar impulse leads to an economic expansion in the near-term, but then a recession in later quarters. In addition, tighter monetary policy does not lead to tighter financial conditions when credit is above trend and is ineffective at slowing the economy, consistent with evidence of an attenuated transmission of policy changes to distant forward Treasury rates in high-credit periods. These results suggest that credit is an important conditioning variable for the effects of financial variables on macroeconomic performance.

David Aikman, Bank of England; Andreas Lehnert, Federal Reserve Board; Nellie Liang, Brookings Institution; Michele Modugno, Federal Reserve Board. An earlier version of this paper was circulated as “Financial Vulnerabilities, Macroeconomic Dynamics, and Monetary Policy,” FEDS, Jul. 7, 2016. We benefitted from helpful comments from Tobias Adrian, William Bassett, Richard Berner, Rochelle Edge, Scott Brave, Oscar Jorda, Michael Kiley, Luc Laeven, Kevin Lansing, Natacha Valla, and from participants at conferences as well as university and central bank seminars. Collin Harkrader and Skeet Singleton provided excellent research assistance. Any remaining errors are own responsibility. The views expressed here are ours and not those of our employers.

The authors did not receive financial support from any firm or person for this article or from any firm or person with a financial or political interest in this article. Neither is currently an officer, director, or board member of any organization with an interest in this article.

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1. Introduction

The global financial crisis highlighted the importance of credit and financial conditions on the dynamics of macroeconomic performance. This phenomenon is not new. Empirical cross-country studies find 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, high credit growth and asset bubbles combined lead to significantly weaker economic recoveries (Jorda, Schularick and Taylor (2013)). The consequences of financial crises can be severe (Reinhart and Rogoff (2009)), 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 larger if there is a permanent loss in output following the financial crisis (Atkinson, Luttrell, and Rosenblum (2013)).

As a result, researchers and policymakers have been developing measures of the financial vulnerability of the economy, such as excess nonfinancial sector credit or leverage of the financial system – often referred to as macrofinancial "imbalances" (Adrian, Covitz, and Liang (2015)). When macrofinancial imbalances are high, the economy is seen as more fragile and less resilient to adverse shocks. The Basel Committee on Bank Supervision (2010) has encouraged using excess private nonfinancial credit as a measure of expected future losses to the banking system, and assigns this indicator an important role in setting the new countercyclical capital buffer. Researchers also are adding measures of financial imbalances to macroeconomic models, which have traditionally lacked a role for them (Brunnermeier and Sannikov (2014)).

In this paper, we use a threshold vector autoregression (TVAR) model to study the influence of private nonfinancial credit in the dynamic relationship between financial conditions and monetary policy and macroeconomic performance in the U.S. from 1975 to 2014. Specifically, we examine the role of private nonfinancial credit in conditioning the response of the U.S. economy to impulses to financial conditions and monetary policy. 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.

We use a broad measure of credit to households and nonfinancial businesses provided by banks, other lenders, and market investors. We follow conventional practice to measure high credit by when the credit gap (credit-to-GDP ratio minus its estimated long-run trend) is above zero (see Borio and Lowe (2002, 2004); Borio and Drehmann (2009)) and, alternatively, by when multi-year growth in the credit-to-GDP ratio is above its average.

To incorporate financial conditions, we construct a financial conditions index (FCI) combining information from asset prices and non-price terms, such as lending standards, for business and household credit, following Aikman et al (2017). In studies of monetary policy transmission, FCIs represent the ease of credit access, which will affect economic behavior and thus the future state of the economy. In our paper, we interpret shocks to the FCI as reflecting factors such as time-varying risk premia of investors, which may be determined by bank capital constraints (He and Krishnamurthy, 2012), or endogenous reactions of financial intermediaries via value-at-risk (VaR) constraints to episodes of low volatility (Brunnermeier and Pedersen (2009), Brunnermeier and Sannikov (2014), and Adrian and Shin (2014)). For comparison, we also consider the excess bond premium (EBP) of Gilchrist and Zakrajsek (2012) as an alternative measure of financial conditions.

We find the following results. First, credit is an important channel by which impulses to financial conditions affect the real economy. We find that positive shocks to financial conditions are expansionary and lead to increases in real GDP, decreases in unemployment, and increases in the credit-to-GDP gap. Most empirical papers have focused on either credit (Schularick and Taylor, 2012) or financial conditions (Gilchrist and Zakrajsek, 2012), but not both.

Second, the effect of impulses to financial conditions is nonlinear. In specifications that permit different dynamics depending on the level of the credit gap, the expected expansionary effects from a positive impulse to financial conditions are evident when the credit-to-GDP gap is low. However, when the credit-to-GDP gap is high, initial expansionary effects dissipate but lead to further increases in credit, which, in turn, lead to a deterioration in performance in later quarters. That is, consistent with the credit boom literature, we find that more sustained credit growth is followed by a sharper economic contraction, but only when the credit gap is already high.

This result highlights a distinction between the effects of accommodative financial conditions and high credit. The credit gap is less volatile than, and reacts with a lag to, financial conditions. When credit growth is sustained and the credit gap builds following looser financial conditions, the economy becomes more prone to a recession, perhaps because households and businesses are more fragile as a consequence of their leverage. The importance of credit for macroeconomic dynamics holds whether we use the fairly broad FCI described above or one narrowly focused on risk premia in corporate bonds, such as the EBP.

Third, we find that the monetary policy transmission channel also is nonlinear and 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, a tightening in monetary policy does not lead to tighter financial conditions, as expected, and has no effect on output, unemployment, and credit. This loosening of asset valuations and lending standards when credit is high works against the contractionary effect of the monetary policy shock.

We investigate further why monetary policy transmission is attenuated in high credit gap periods. 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 of forward rates at far horizons in reaction to monetary policy shocks can be attributed to a class of investors requiring steady income streams who remove duration by selling longer-maturity Treasuries following a short-term rate increase, leading to an 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 impact in high credit-gap states. This finding is consistent with investors making fewer adjustments to holdings of Treasury securities when there are ample credit products available to investors to earn additional yield when the credit gap is high.

We conducted a large number of robustness tests. Importantly, our results are robust to using the EBP as an alternative financial conditions indicator and an alternative ordering of the FCI and monetary policy shocks in the TVAR. The results also are robust to measuring high credit periods using growth in credit-to-GDP computed over long periods, such as eight years, alternative measures of excess credit, including a specification with the (log) level of credit, or using potential rather than actual GDP to calculate the credit gap. In addition, we evaluate whether the nonlinearities in economic performance may reflect factors other than credit, such as whether financial conditions are tight or loose, but find that the nonlinear effects are related to loose financial conditions only when credit is high, reinforcing our findings that credit has an independent role in explaining performance. Our empirical analysis, however, does not explain what leads to credit booms and busts, but to document nonlinear effects of financial conditions and monetary policy conditional on the credit gap or growth in credit-to-GDP. These empirical results can be useful for structural models that could link credit to financial conditions or monetary policy, and allow for nonlinear effects of shocks to economic performance based on credit.

Overall, this paper is the first to document the joint nonlinear dynamics of credit, financial conditions, and monetary policy transmission, adding to other studies that have identified a role for shocks to credit aggregates, asset prices, or investor risk sentiment to contribute to business cycle fluctuations. Our results are consistent with an intuitively appealing story in which an impulse to financial conditions when credit is high stimulates economic growth, but also over time stimulates even more borrowing by households and businesses, and leaves the economy vulnerable to a shock and negative spillovers, precipitating a recession. High credit also interferes with the monetary policy transmission mechanism. One possible explanation, as described above, is that high-credit periods also feature ample credit products, attenuating the need for yield-oriented investors to adjust the duration of their portfolios in reaction to changes in short-term rates.

Our paper is related to several strands of the literature. Our empirical result that private nonfinancial sector credit, and not just financial conditions, matters for real activity and employment in the U.S. supports the literature on the role of credit given asymmetric information in business cycles, starting with Bernanke and Gertler (1989). Moreover, in models with collateral constraints and pecuniary externalities, an economic expansion increases the value of borrowers' collateral and leads to excessive borrowing, which can result in more borrower defaults when asset prices fall and thus sharper economic contractions (Bianchi and Mendoza (2011), Jeanne and

Korinek (2010)). In addition, individuals do not consider the effects on aggregate credit or negative spillovers of their defaults when they make their borrowing decisions (as suggested in a model by Korinek and Simsek (2014)).

Our findings also are consistent with other empirical studies that show financial conditions can affect macroeconomic performance, when frictions lead to 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)). Adrian, Boyarchenko, and Giannone (2016) document that financial conditions can forecast downside risks to GDP growth. These papers look at financial conditions, mainly risk spreads and lending standards, which can vary with binding capital constraints of financial intermediaries, but do not separately incorporate nonfinancial credit. Jorda, Schularick, and Taylor (2013) show that the severity of recessions following credit booms is greater if there also had been an increase in equity prices or house prices, but they do not incorporate monetary policy in their estimations. By contrast, Brunnermeier et al (2017) find that credit expansions do not have independent effects on economic performance; instead, the contractions that follow credit expansion reflect monetary policy and financial conditions.

Our paper is also related to the growing empirical literature that finds that transmission channels for financial conditions may operate differently depending on underlying conditions. Our finding that the strength of the monetary policy transmission varies depending on the level of the credit gap adds to a growing literature on monetary policy and credit. Using firm-level data, Ottonello and Winberry (2017) find that the level and distribution of business debt affect the monetary policy transmission mechanism, with more indebted firms using the opportunity afforded by a decrease in rates to pay down debt rather than invest. In an aggregate study focused on household debt, residential investment, and house prices, Alpanda and Zubairy (2017) find that the transmission of monetary policy is attenuated in periods when household debt is high. In addition, Hubrich and Tetlow (2015), using a regime switching model, find that the effects of monetary policy are relatively weak when the economy is in a financial crisis state.

The ineffectiveness of monetary policy in a high credit gap state also is relevant for evaluating the use of monetary policy or macroprudential policies to reduce vulnerabilities and future crises.

Recent work on financial and macroeconomic stability emphasize the welfare benefits of separate roles for macroprudential policies to manage credit growth and financial sector resilience, while monetary policy should focus on price stability and output (Smets (2014), Svensson (2016), see Adrian and Liang (2016) for a survey). Our results show the importance of successful macroprudential policies for effective monetary policy transmission. They may also suggest that if macroprudential policy is ineffective – either because macroprudential policies are not used or tighter standards for regulated firms push activities into unregulated firms – at preventing excess credit build-ups, monetary policymakers should consider potential downside risks to output from high credit levels.

The remainder of our paper is organized as follows: in section 2 we describe our data and specification; in section 3 we characterize the dynamics of the system with respect to impulses to financial conditions based on the credit gap and credit growth. In section 4, we characterize the transmission of monetary policy in low and high credit states. 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 financial conditions measure, the credit-to-GDP gap, and credit-to-GDP growth. 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 is defined to be a financial crisis by 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 (2012)), 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 Credit-to-GDP measures

We follow the literature in defining the credit-to-GDP gap as the difference between the ratio of nonfinancial private sector debt to nominal GDP and an estimate of its trend, designed to be slow-moving. 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 (middle panel). The gap we report, consistent with the Basel III recommendation, is based on final estimates of credit-to-GDP.[1]

A 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 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 bottom panels 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

[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)).

[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

in1990: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 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.

Given some uncertainty about the estimated trend in credit, we also use growth in the credit-to-GDP ratio as an alternative to the credit-to-GDP gap. In particular, we focus on credit-to-GDP growth for eight years (32 quarters), log (credit-to-GDP_t) – log (credit-to-GDP_{t-32}) relative to its mean, roughly the maximum length of the average business cycle, rather than growth over shorter periods. Longer periods capture sustained credit growth rather than shorter periods which may be noisier signals of build-ups of excess credit. This measure also is closer in spirit to Schularick and Taylor (2012) and Jorda, Schularick and Taylor (2013) which look at growth in the ratio of bank loans to the nonfinancial sector to GDP, from trough to peak, relative to its mean. In our empirical analysis, we consider some other alternative measures as well, including the level of credit rather than its gap to a trend and the credit-to-GDP gap based on potential GDP.

2.2 Measures of financial conditions

Financial conditions indexes are summary measures of the ease with which borrowers can access credit. They have been found to help to predict future economic growth. English, et al (2005) show that looser financial conditions lead to lower output gaps at four quarters- and eight quarters-ahead.

FCIs typically incorporate both price and non-price measures. Higher asset valuations relative to historical averages may reflect lower risk premia and greater risk-taking behavior. Rapidly rising real estate prices relative to rents are viewed by many economists as key sources of financial fragility (see, for instance, Cecchetti (2008), Iacoviello (2005), and Jorda, Schularick, and Taylor (2015)). Dell'Ariccia, Igan and Laeven (2008) show that lending standards (denial rates and loan-

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).

to-income ratios) deteriorated more when credit growth was strong in 2000 to 2006. Others have emphasized the information in bond risk premiums and non-price measures, such as the share of nonfinancial corporate bond issuance that is speculative-grade (Stein (2013b) and Lopez-Salido, Stein, and Zakrajsek (2016)). 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 high asset prices and low volatility may spur risk taking, with the potential for a destabilizing unraveling when prices eventually reverse.

Our FCI captures borrowing conditions for both businesses and households, and is based on a consistent set of variables for the estimation period starting in 1975. In contrast, many do not start until the 1990s (see Aramonte et al, 2017). It is constructed by taking the weighted sum of normalized time series related to asset valuations and lending standards for different sources of business and household credit. The overall index is then a weighted average of the standardized index for the two sectors – this is in the spirit of the methodology in Aikman et al (2017). The components of each sector are:

(1) Business sector: The S&P 500 price-earnings ratio to measure corporate sector valuations; the BBB-rated corporate bond yield to Treasury yield; the share of nonfinancial corporate bond issuance that is speculative-grade, used to represent investor willingness to take risk (Stein (2013a), Lopez-Salido, Stein, and Zakrajsek (2015); the index of credit availability from the National Federation of Independent Business survey of small businesses to capture credit conditions for such borrowers; and growth in real commercial real estate prices to represent commercial real estate valuations.

(2) Household sector: the residential house price-to-rent ratio to represent house price valuations, and lending standards for consumer installment loans from the Senior Loan Officer Opinion Survey (SLOOS) to represent banks willingness to provide loans to households (Dell'Ariccia, Igan and Laeven (2008)).

To link to the existing literature, we compare our FCI to the EBP, which is based on corporate bond prices. A higher FCI value represents looser financial conditions, representing greater willingness to accept risk. Both the FCI and the negative of EBP (the top panel of Figure 2) are more volatile than the credit-to-GDP gap and show more cycles. The business credit component of our FCI not surprisingly is quite similar to the EBP, although it 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. The non-corporate nonfinancial business sector, a proxy for small businesses, represents one-third of the nonfinancial business sector credit. Our FCI also reflects changes in house prices and residential mortgage credit availability, which has cycles distinct from corporate asset markets.[3]

The contemporaneous correlation of the FCI and the credit-to-GDP gap is low, but the data show that it tends to lead the credit-to-GDP gap (Figure 2, middle panel). This lead structure suggests that strong financial conditions tend to create the conditions for a period of a high credit gap. To illustrate the leading properties of the FCI for the credit-to-GDP gap, we conduct an out-of-sample forecast exercise. In this exercise, we compare the accuracy of the credit-to-GDP gap forecasts obtained through a bivariate VAR for the credit-to-GDP gap and the FCI with the accuracy of the forecast obtained with two alternative AR models. The bivariate VAR is estimated with nine lags, in order to capture the maximum correlation between the FCI and credit-to-GDP gap at nine quarters. The alternative AR models for the credit-to-GDP gap are estimated with one lag, to control for parameters' proliferation that may affect forecast accuracy, and with nine lags to be comparable to the bivariate VAR. The forecasts are obtained estimating the models' parameters recursively. The first estimation sample is 1975:Q1 to 1982:Q1 in order to obtain the 12-quarter ahead forecast for 1985:Q1. The last estimation sample is 1975:Q1 to 2014:Q3 in order to obtain the 1-quarter ahead forecast for 2014:Q4. The forecast accuracy is therefore evaluated on the sample 1985:Q1 to 2014:Q4.

The table in the bottom panel of Figure 2 reports the ratio of the root mean squared forecast errors (RMSFE) of the VAR(9) to the RMSFE of the AR(1) and the AR(9) for 1-, 4-, 8-, and 12-quarters

[3] The correlation of our FCI and (negative) EBP is .32. The correlation of the business component of our FCI and (negative) EBP is .41.

ahead. Values below one indicate that the VAR performs better than the competing model. We test the equality of forecast accuracy with the Diebold and Mariano (1995) test. As shown, values are significantly below one in all comparisons, indicating the VAR outperforms the competing models at each horizon. These results highlight the forecasting power of the FCI for the credit-to-GDP gap in future quarters.

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 FCI 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 the FCI. Periods when the FCI is low (indicating financial conditions are tighter than average) 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 FCI 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 the FCI 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 the credit-to-GDP gap and FCI, there are a reasonable number of quarters in each of the categories of easing, tightening, or unchanged.[4] For example, when the credit-to-GDP gap is either high or low, the distributions of changes in the federal funds rate across decreased, unchanged, and increased is roughly equal.

2.4 Specification

Our primary goal is to characterize the effect of shocks to the FCI 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, or whether credit-to-GDP growth is above or below average.

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 (if the variables 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
- Financial conditions (FCI) defined so that higher values indicate looser financial conditions and higher investor risk appetite
- Federal funds rate, effective, per annum (FFR).

Following Giannone et al. (2015), real GDP and the GDP deflator enter the models in annualized

[4] 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.

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.[5] In all instances we use nine lags of the vector of dependent variables, which allows us to capture the lead-lag relationship between the FCI and the credit gap, which has a maximum correlation at nine 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; that is, whether a shock to the FCI or monetary policy has a different effect in times of high versus low excess credit. Thus, our baseline specification is a TVAR based on the level of a measure X_t (usually the credit-to-GDP gap), which has a sample mean of μ_X:

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

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

3. Baseline Results

3.1 Financial Conditions and Credit

Figure 3 shows the impulse response functions (IRFs) with respect to shocks to the FCI in a six-variable linear system that includes both the FCI and the credit-to-GDP gap. We identify shocks to the FCI using a Cholesky decomposition in which monetary policy is permitted to react within the same quarter as the shock to FCI (as estimated in Gilchrist and Zakrajsek (2012)). Real GDP rises and the unemployment rate falls in response to a positive impulse to the FCI, with the responses peaking about eight quarters after the shock. The credit-to-GDP gap rises, responding more slowly

[5] 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.

than GDP and unemployment, peaking about 16 quarters after the shock. Further out, 20 quarters from the shock, the economy deteriorates with GDP contracting and unemployment rising. Including both financial variables in the system helps to clarify the dynamics: a positive impulse to financial conditions stimulates economic activity, but also leads over time to a build-up in credit and, ultimately, subpar growth. English et al (2005) showed a stimulative effect on GDP from looser financial conditions, but they did not include the credit-to-GDP gap and effects beyond eight quarters.

We next examine whether the response of the economy to an FCI shock varies depending on the level of the credit-to-GDP. This question is motivated by the post-crisis literature's focus on the proposition that high levels of imbalances leave the economy more vulnerable to negative shocks. To do so, 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 4.

When the credit gap is low (blue lines), shocks to the FCI lead to an increase in output, inflation, and a decline in unemployment; moreover, the credit-to-GDP gap increases modestly. In contrast, shocks to the FCI in a high credit gap environment (red lines), result in a significantly larger increase in the credit-to-GDP gap than in a low credit gap one. And while there is a boost to economic activity in the short term, GDP contracts and unemployment increases after about twelve quarters. These results suggest that a positive shock to financial conditions that occurs in a high credit gap environment generates an inter-temporal tradeoff: activity expands in the near term, but an increase in indebtedness that results from the expansion may sow the seeds for weaker economic performance in subsequent periods. In contrast, a shock to financial conditions in a low credit gap period does not suggest the same costs and inter-temporal trade-off for economic activity. These results suggest that a positive credit gap is an indicator of macroeconomic vulnerability, which leaves the economy more prone to a recession.

The IRFs for a shock to financial conditions when credit is measured by growth in the credit-to-GDP ratio are shown in Figure 5. The results are similar to those based on the credit-to-GDP gap, indicating the results are robust to alternative measures of high and low credit periods. The nonlinear effects are consistent with Bauer and Grazienga (2016), who find that the effect of the credit gap on the probability of a crisis 8 to 12 quarters ahead for a sample of 18 countries depends on the initial level of the credit gap. Their paper, however, does not explore the role of financial conditions on the credit gap.

We offer several alternative structural interpretations of our financial conditions shock. First, following He and Krishnamurthy (2012, 2013), this shock could reflect shifts in financial intermediaries' equity, with knock-on consequences for the risk-bearing capacity of the marginal investor and hence risk premia. Second, following Brunnermeier and Pedersen (2009), Brunnermeier and Sannikov (2014), and Adrian and Shin (2014), it could reflect the endogenous reactions of financial intermediaries via value-at-risk (VaR) constraints to episodes of low volatility. Third, following Christiano, Motto and Rostagno (2014), it could reflect episodes in which the cross-sectional, idiosyncratic dispersion in investment project outcomes is perceived to have changed. In each of these models, increases in financial conditions lead to economic expansions.

3.2 Monetary Policy

We next turn to the role of monetary policy, and in particular its interactions with the credit gap. Figure 6 shows the responses of the economy to a shock to monetary policy (identified using a Cholesky decomposition) in our nonlinear specification with the threshold based on the credit-to-GDP gap. As before, the blue lines show the IRFs from the system estimated in low credit-to-GDP gap periods, and the red lines show the IRFs in high credit 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. However, when the credit gap is high, monetary policy appears ineffective, as real GDP, prices, and the unemployment rate do not react significantly to the shock.

A proximate explanation for these different effects of monetary policy shocks appears to be related to the behavior of financial conditions. In particular, when the credit gap is low, the FCI falls following a contractionary monetary policy shock, reinforcing the tightening of monetary policy. In contrast, when the credit gap is high, the FCI actually increases following the monetary policy shock, acting as an offset to a contractionary effect of tighter monetary policy. We show later (in Section 5.1) that the EBP behaves similarly to the FCI following a monetary policy shock.

Results for a threshold based on growth in credit-to-GDP are similar to those based on the credit gap (Figure 7). Both sets of results suggest that the transmission of monetary policy to the real economy depends significantly on credit, through its effects on financial conditions, and the effects are nonlinear.

Our finding that the strength of the monetary policy transmission mechanism varies over the financial cycle is consistent with predictions from the large literature analyzing the role of financial frictions in the monetary transmission mechanism (see Bernanke, Gertler and Gilchrist, 1999). Asymmetric information between borrowers and lenders gives rise to a credit spread, a premium in the interest rate paid by the borrower over and above the risk-free rate, which depends inversely on borrowers' net worth. A tightening in monetary policy reduces profits and asset values, depressing borrowers' net worth. This leads to an increase in the credit spread, which magnifies the decline in real activity and increases the persistence of the economy's response to the shock (see Gertler and Karadi (2015) for empirical evidence). It is plausible to expect the strength of this 'financial accelerator' to vary over the cycle: It will be weak in "good" times -- states of the world when credit is freely available for households and firms and we expect the credit-to-GDP ratio is high and rising -- and strong in "bad" times – states of the world when borrowing constraints are binding we expect credit-to-GDP to be low and falling.

This asymmetry also is a common finding in models where a credit channel is present, including those that emphasize frictions in the financial intermediary sector. For instance, in Gertler and Karadi's (2011) model, an agency problem between intermediaries and depositors generates an endogenous 'market determined' constraint on intermediary leverage. When this constraint binds, the impact of a tightening in monetary policy is amplified by its impact on intermediary equity and hence credit supply. This is also the case in Van den Heuvel's (2002) model, in which dynamically-optimizing banks engage in maturity transformation, a consequence of which is that their profits and hence equity falls in response to a tightening in monetary policy. If risk-based capital requirements are binding, then unless banks are able to issue fresh equity or reduce dividends, they will be forced to restrict lending. These financial accelerator mechanisms are more likely to act powerfully in bad times, when bank equity is scarce, than in good times, when banks tend to be highly profitable.

4. Nonlinear Monetary Policy Transmission

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"). We use high-frequency data 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 in 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:

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

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 8 for nominal yields and Figure 9 for real yields (the "All" line in Figure 9 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 9 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 gap versus low credit gap periods, and thus do not have to extend their duration risk by as much.

5. Robustness Tests and Extensions

We describe a large number of robustness tests, including using EBP rather than FCI as a financial conditions indicator, alternative measures of credit, and alternative sources of uncertainty. Overall, the robustness results support our interpretation that the effects of financial conditions and monetary policy on economic growth depend nonlinearly on credit.

5.1 Using EBP instead of FCI

First, as an alternative to our FCI, we use the EBP in the nonlinear system with the sample divided by the credit-to-GDP gap. Because higher values of FCI correspond to greater risk appetite while higher values of the EBP correspond to lower risk appetite, we use the negative of the EBP in our estimation. IRFs with respect to shocks to EBP and to monetary policy are shown in Figures 10

[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.

and 11. Similar to a shock to FCI, 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 FCI. As with the FCI, the (negative) EBP loosens following a contractionary impulse to monetary policy, suggesting our earlier results that our results are not related to the construction of our FCI. Overall, 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.

In addition, we follow Gilchrist and Zakrajsek (2012) in their EBP analysis by placing the FCI before the monetary policy rate in the TVAR. For robustness, we tested the specification with FCI after the policy rate and found results were unchanged.

5.2 Robustness to alternative specifications of credit

The use of the credit-to-GDP gap raises certain questions about the underlying trend, and we have shown already that the empirical results are robust to using credit-to-GDP growth (see Figures 5 and 7). We evaluate two other measures of credit, the log level of credit (rather than a ratio to GDP and the ratio of credit to potential GDP rather than actual GDP, because actual GDP falls in bad times, and one might be concerned that the causation runs from recessions to higher credit-to-GDP ratios. Figure 12 shows the results of an 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, high and low vulnerability periods are defined relative to the credit-to-GDP gap as before. As shown, results using log level of credit are similar to those when using the credit-to-GDP gap: An upward shock to FCI during either high or low vulnerability periods results immediately in real GDP growth and a rise in credit. In addition, the same shock in a high vulnerability period eventually results in weaker economic performance than in a low vulnerability period, consistent with the results with credit-to-GDP gap. Moreover, a shock to monetary policy with the log level of credit yields similar results (not shown) to those reported based on the credit-to-GDP gap.[7]

Similarly, a shock to FCI when the credit-to-GDP ratio is based on potential GDP leads to very similar results as when the ratio is based on actual GDP (not shown), 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 FCI 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.

5.3 Robustness to other conditioning variables

In another set of robustness tests, we evaluate whether credit may reflect other sources of uncertainty. These tests are in the spirit of Barnichon et al (2017), who look at the effects of a shock to credit supply (as measured by the EBP or similar indicators) vary by the state of the business cycle or the sign of the shock, although they do not have credit-to-GDP measures in their VAR model. We split the sample based on whether financial conditions are high or low (above or below average), and do not find any evidence of nonlinearities from a shock to FCI: A positive impulse to FCI conditioned on either low or high FCI leads to growth in the near term, and has little effect on performance in the medium term. These results suggest that the nonlinear effects from conditioning on credit are not simply reflecting differences in financial conditions and that asymmetric transmission is through credit, not asset prices and risk-taking behavior.

To further evaluate our interpretation of credit, we look at when both FCI and the credit gap are high, which effectively splits the sample between credit boom periods versus other periods.

[7] Robustness results described in this section and not shown are available upon request.

Similar to our baseline results based on high versus low credit gap periods, we find nonlinear effects from an impulse to FCI, with significantly higher GDP growth in the near-term quarters and lower growth in the medium term, though the effects in the quarters further out are not significant given the smaller number of observations. In addition, conditioning on the interaction of high FCI and high credit, an impulse to monetary policy does not have significant results on growth in credit boom periods, similar to results when conditioning on high credit. In addition, the effects in other periods (low credit and low FCI, and low credit and high FCI) work as expected, with tighter monetary policy able to slow economic growth and prices.[8]

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 FCI 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 FCI do not lead to a recession. We 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 among financial conditions, credit, and monetary policy in a threshold VAR framework that allows for nonlinear dynamics. Indeed, we find that the effects of shocks to financial conditions and monetary policy vary importantly depending on whether the credit-to-GDP gap is low or high, i.e., whether credit is below or above estimates of its trend.

When the credit gap is low, positive shocks to financial conditions stimulate economic activity and

[8] We also split on whether the economy is in a recession or expansion, but the number of periods in which the economy was in a recession is too small a sample to yield significant effects.

result in a sustained expansion. By contrast, when the credit gap is high, positive shocks to financial conditions, while stimulating economic activity in the short run, lead to excess borrowing and ultimately economic contractions.

With respect to monetary policy, when the credit gap is low, contractionary impulses to monetary policy, as expected, lead to declines in economic activity. However, the effectiveness of policy is significantly reduced when the credit gap is high. In such periods, financial conditions do not decline when monetary policy tightens, as it does in low credit periods, indicating again that transmission channels depend on the credit gap. In addition, results based on the reaction of forward rates to monetary policy surprises suggest that the attenuation is significant at horizons up to seven years ahead. These results suggest that monetary policy transmission is hindered in periods of high credit.

Taken together, our results suggest that theory and policy should address the role of credit in the transmission of monetary policy and financial conditions. In particular, economic dynamics of particular relevance to policymakers appear significantly different when credit-to-GDP has grown significantly faster than average for some time. This dynamic bears on the costs and benefits of using monetary policy to lean against the wind and prevent the buildup of credit (Svensson (2016), Gourio, Kashyap, and Sim (2016)). Moreover, it points to the benefit from additional research evaluating the potential for macroprudential policies to reduce the vulnerabilities associated with excess credit.

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Table 1. Sample statistics by credit-to-GDP gap (CY) and financial conditions (FCI)

	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
FCI low	78	7.14	8.44	1.80	2.98	5.20	-10.49
FCI high	82	5.93	-11.59	3.80	3.38	6.32	3.35

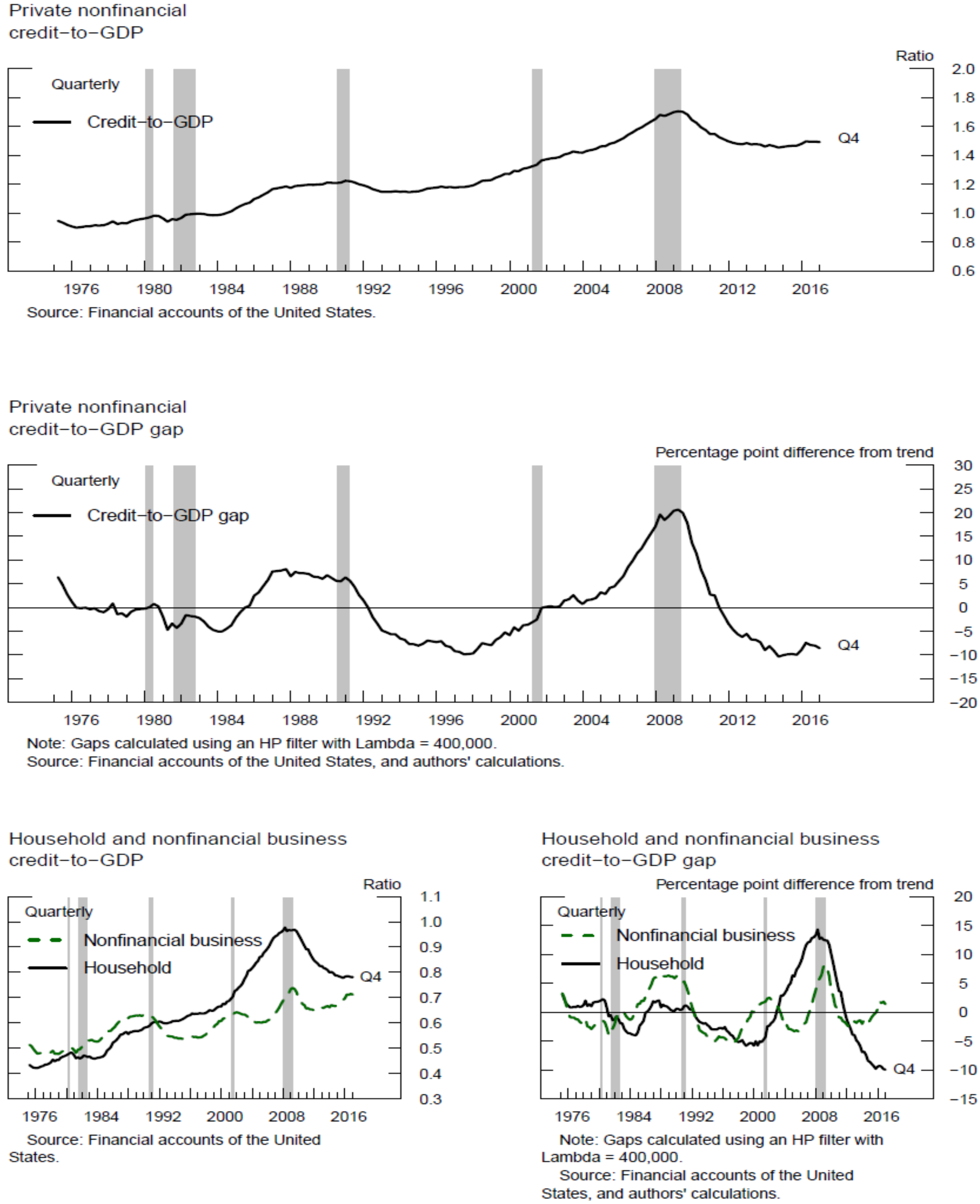
Note. Unemployment rate level, deflator growth, effective fed funds level in percent.
[a] change in basis points.
[b] 400x quarterly change in log level.

Table 2. Monetary policy changes by credit-to-GDP gap (CY) and financial conditions (FCI)

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

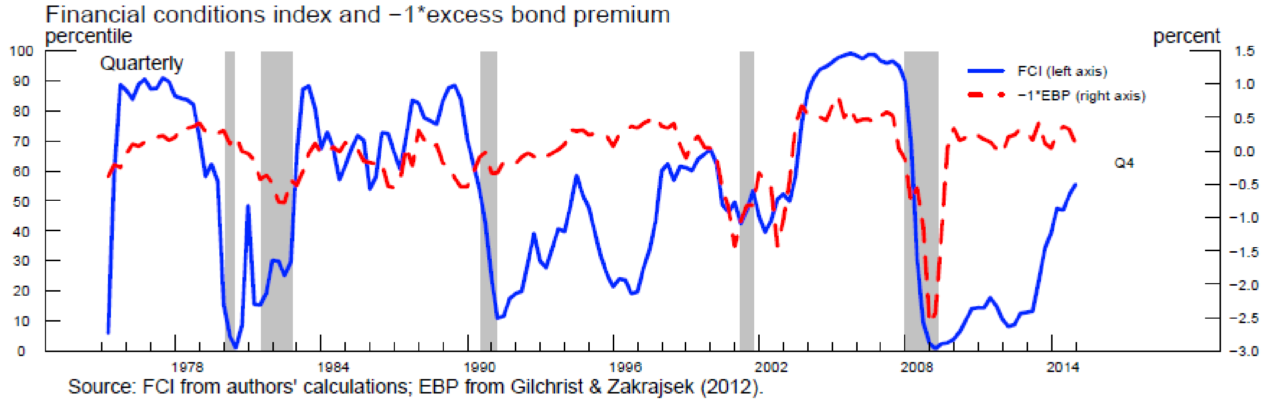
Note. Columns labeled decreased (increased) refer to quarters in which the effective funds rate decreased (increased) 25 basis points or more; quarters in which the effective federal funds rate changed less than 25 basis points in absolute value are labeled unchanged.

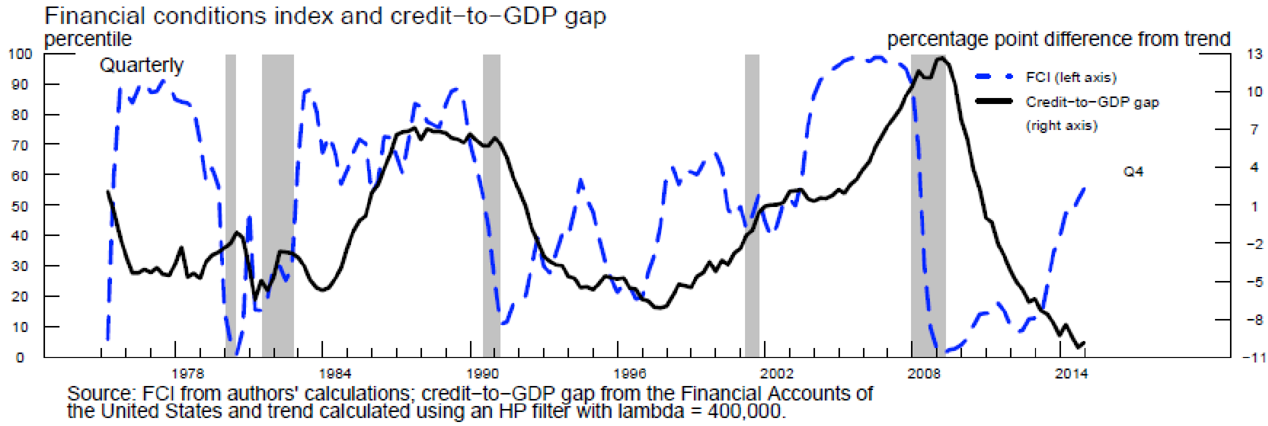
Figure 1. Credit-to GDP ratio and Credit gap



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. Financial Conditions Index, Excess Bond premium, and Credit-to-GDP Gap





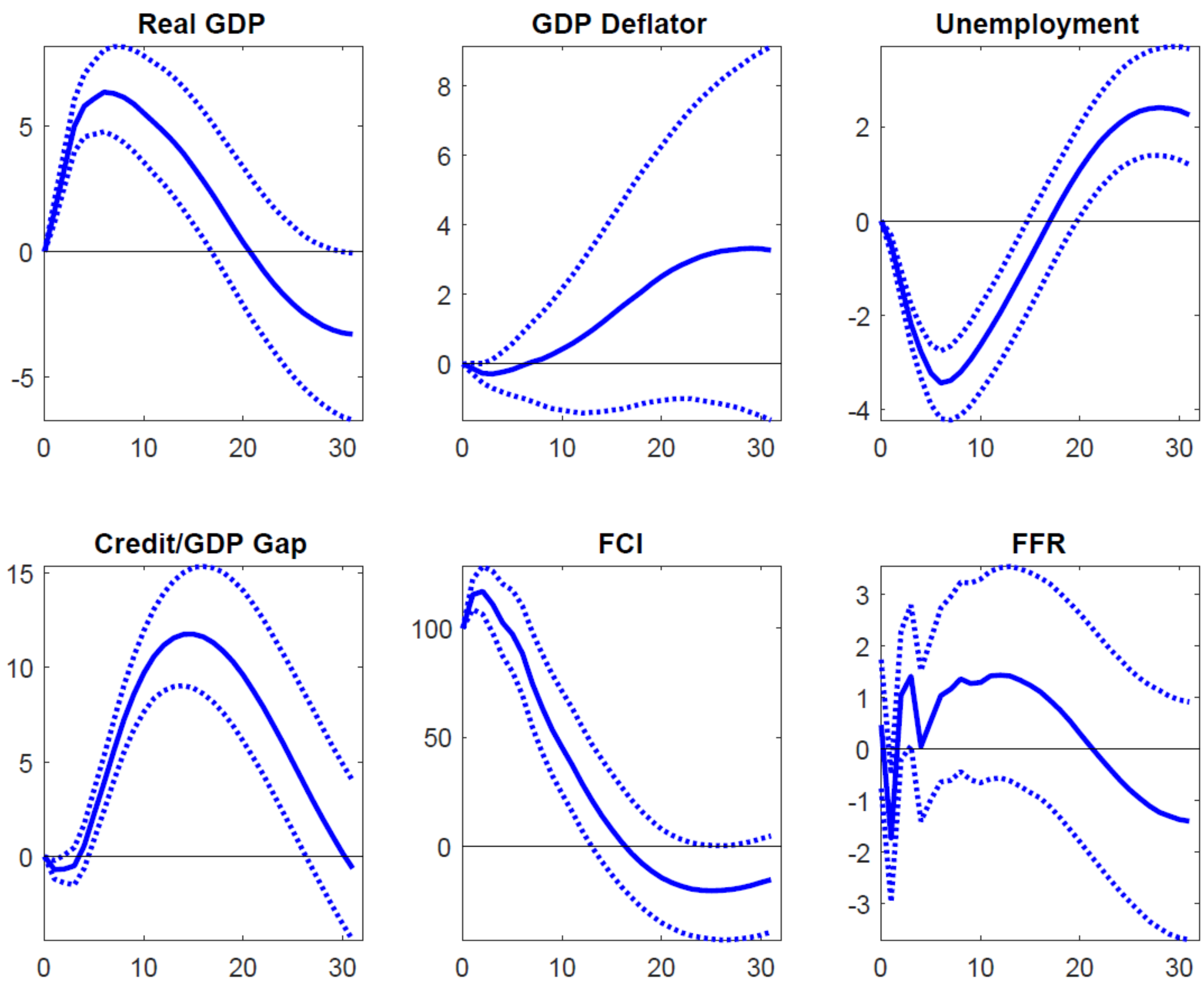
Ratio of Root Mean Squared Forecast Errors of Bivariate VAR to AR models for Credit-to-GDP Gap, by forecast horizon

	1 quarter	4 quarters	8 quarters	12 quarters
AR (9)	0.93**	0.83**	0.81*	0.85*
AR (1)	0.76***	0.71**	0.72**	0.76**

The symbols *, **,*** indicate that we can reject the hypothesis of equality between the alternative forecasts with 10%, 5% and 1% significance level.

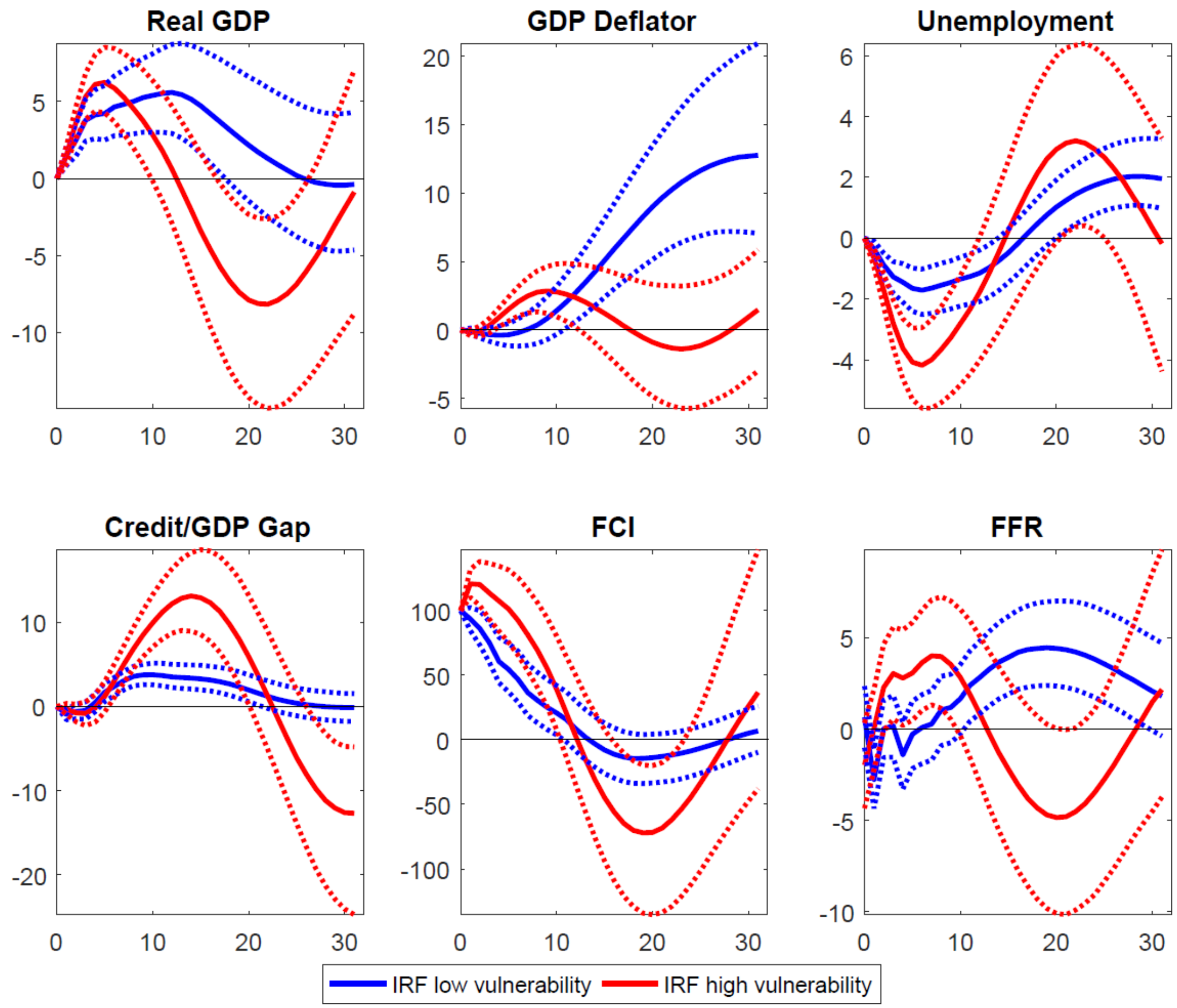
Note. The top panel shows the FCI and EBP at a quarterly frequency, with NBER recessions shaded. The middle panel shows the the FCI and the solid line the credit-to-GDP gap. The numbers in the table (lower panel) represent the ratio of root mean squared forecast errors for a bivariate vector autoregressive model with nine lags, related to a autoregressive model with one lag and a autoregressive model with nine lags for forecast horizons of one, four, eight, and twelve quarters.

Figure 3. Financial Conditions Index (FCI) shock, linear



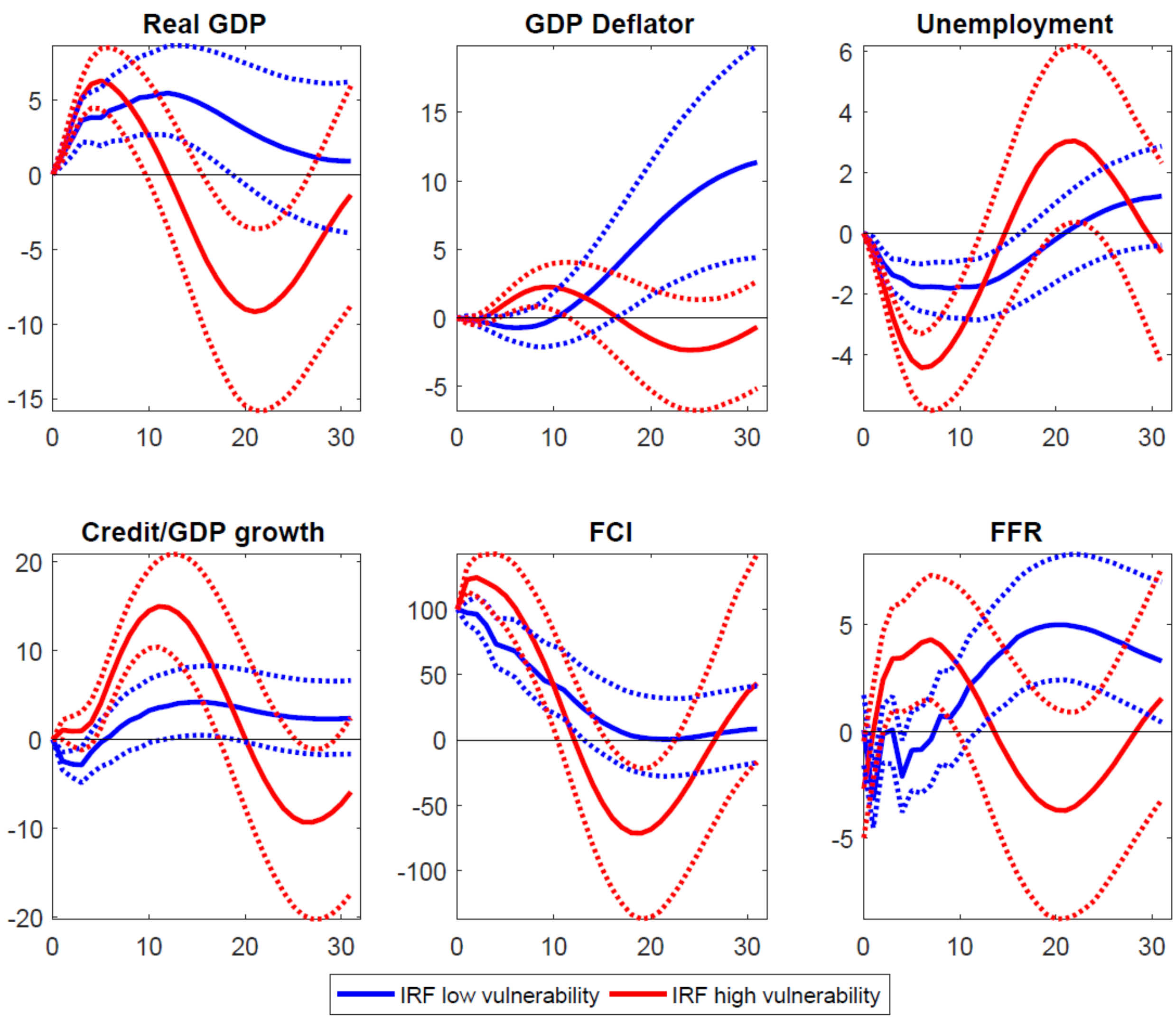
Note. The solid line reports the median impulse reponse to a shock to financial conditions (FCI). The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

Figure 4. Financial Conditions Index (FCI) shock, nonlinear with credit-to-GDP gap threshold



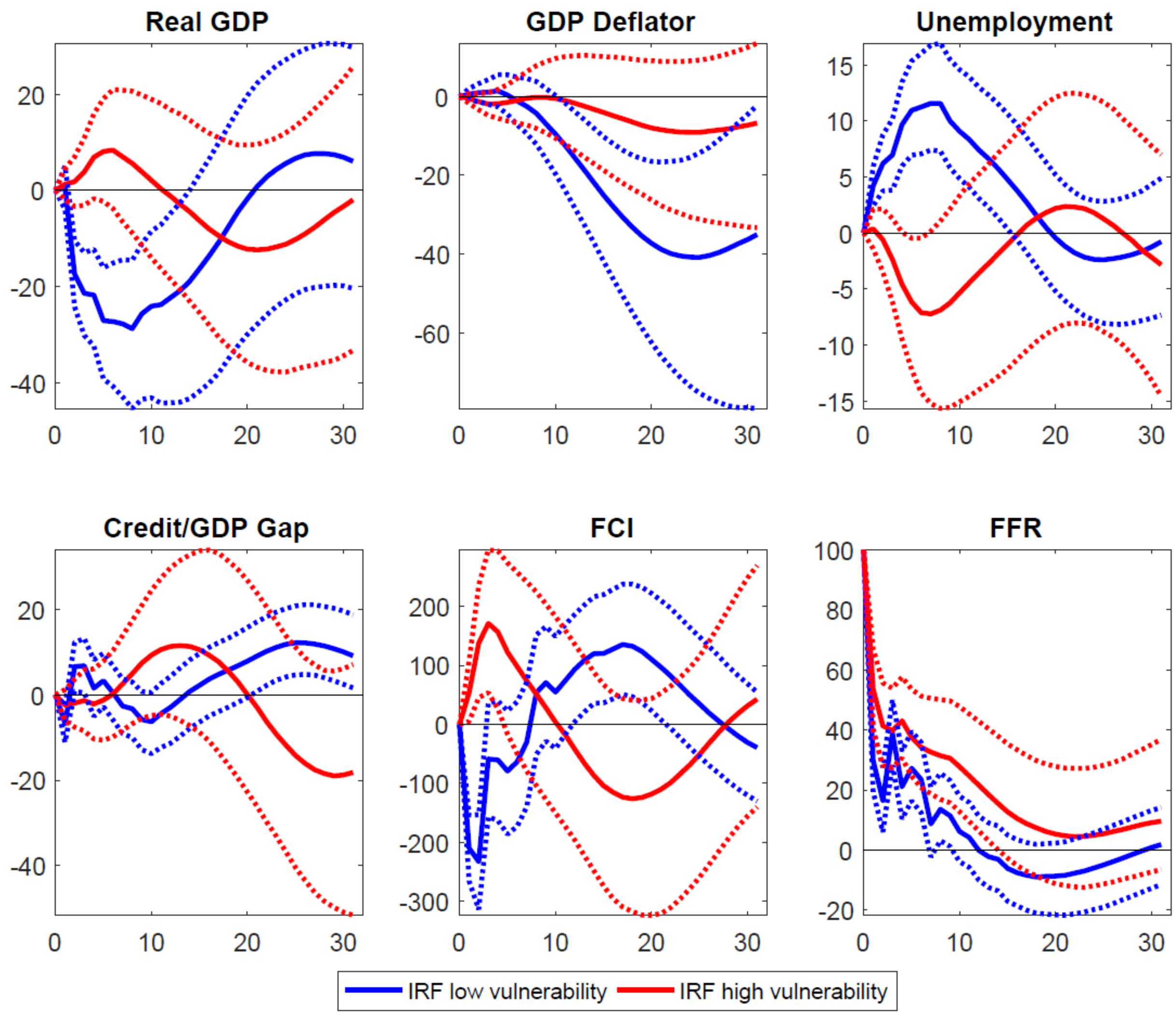
Note. The solid blue line reports the median impulse reponse to a shock to financial conditions (FCI) when the credit-to-GDP gap ratio is below zero. The solid red line reports the median impulse reponse to a shock to FCI when the credit-to-GDP gap ratio is above zero. The dotted lines report one standard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

Figure 5. Financial Conditions Index (FCI) shock, nonlinear with credit-to-GDP growth threshold



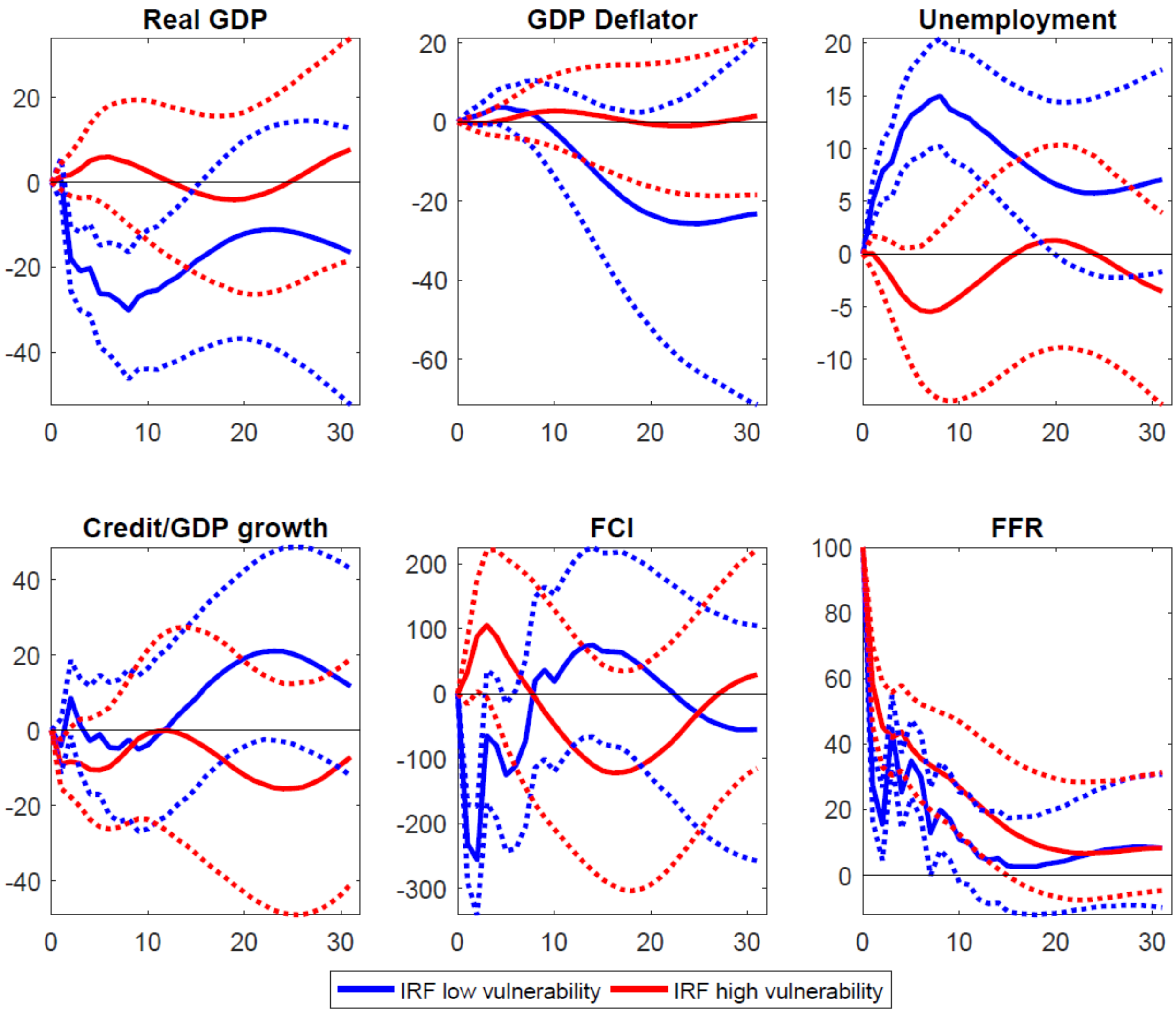
Note. The solid blue line reports the median impulse reponse to a shock to financial conditions (FCI) when credit-to-GDP growth is below zero. The solid red line reports the median impulse reponse to a shock to FCI when credit-to-GDP growth is above zero. The dotted lines report one standard deviation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

Figure 6. Monetary policy (FFR) shock, nonlinear with credit-to-GDP gap threshold



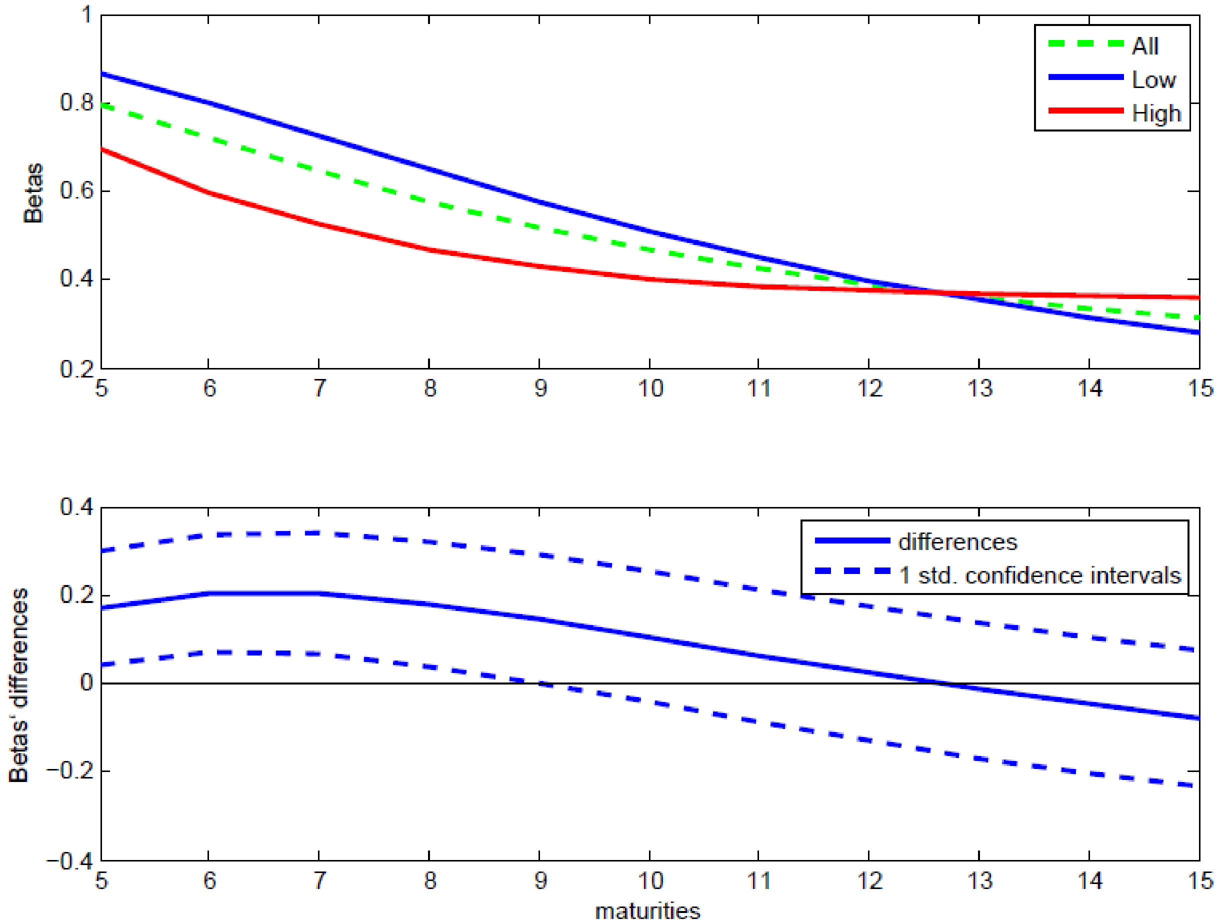
Note. The solid blue line reports the median impulse reponse to the federal funds rate (FFR) when the credit-to-GDP gap is below zero. The solid red line reports the median impulse reponse to the federal funds rate (FFR) when the credit-to-GDP gap is above zero. The dotted lines report one standard deviation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

Figure 7. Monetary policy (FFR) shock, nonlinear with credit-to-gdp growth threshold



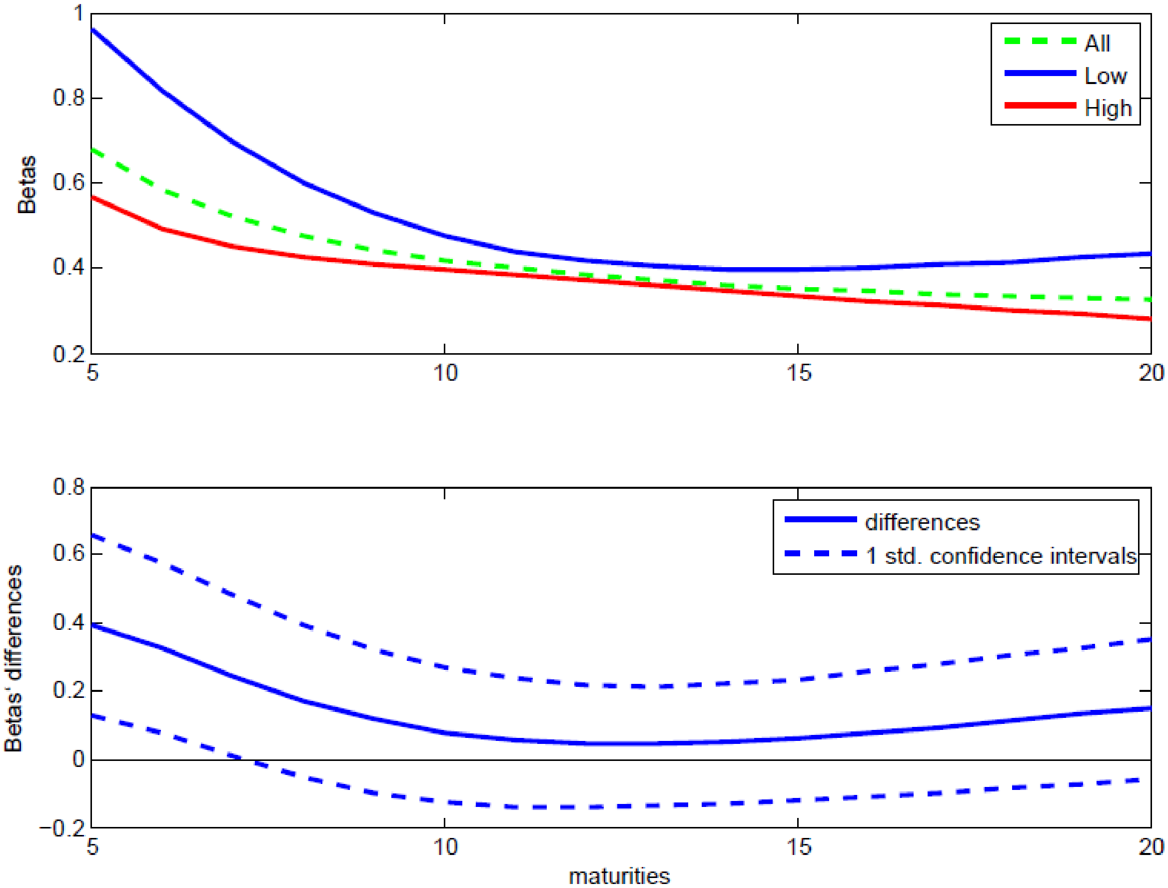
Note. The solid blue line reports the median impulse reponse to the federal funds rate (FFR) when credit-to-GDP growth is below its mean. The solid red line reports the median impulse reponse to the federal funds rate (FFR) when credit-to-GDP growth is above its mean. The dotted lines report one standard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

Figure 8. Estimated betas for distant forward nominal rates by credit-to-gdp gap, 1975 to 2014



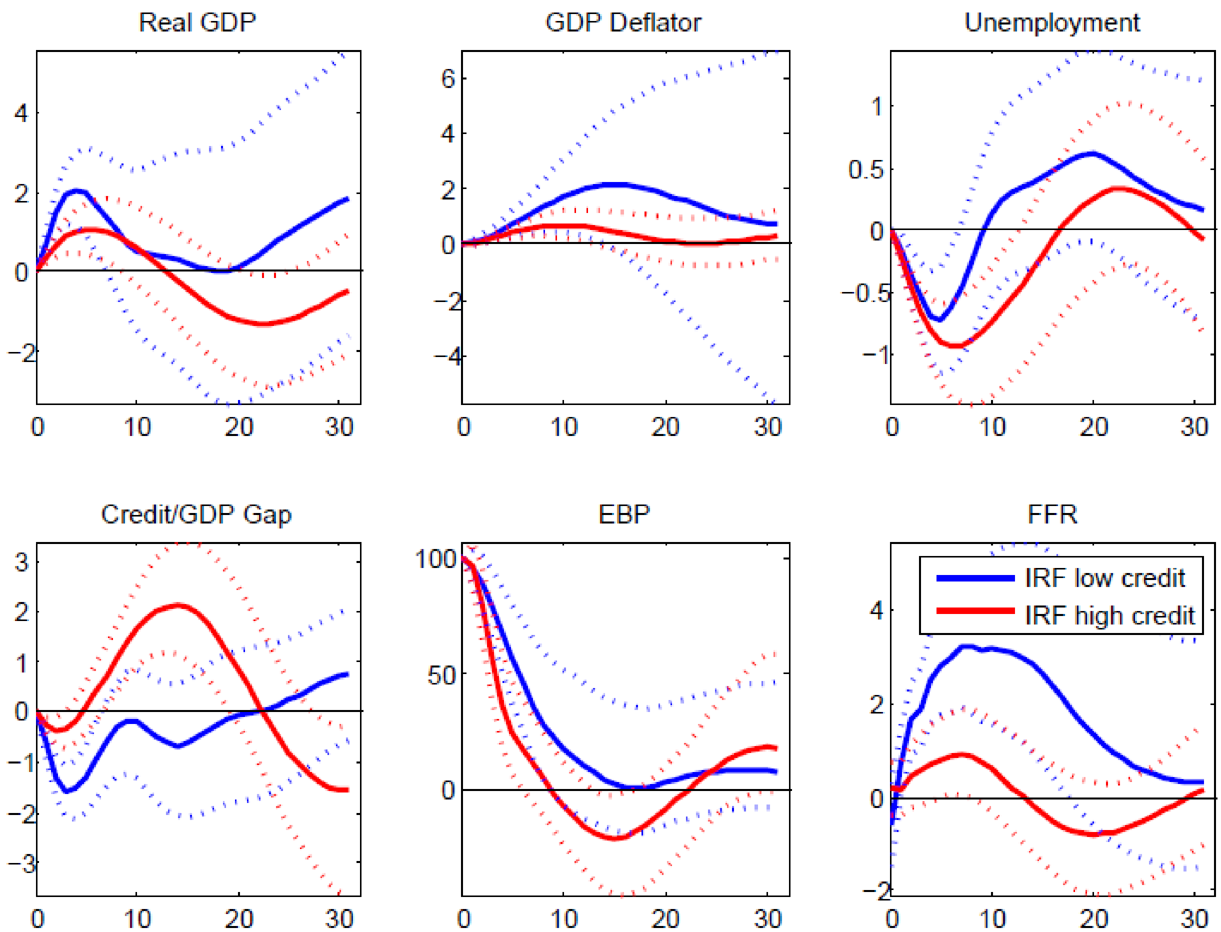
Note. The solid blue line in the upper panel reports the daily change in nominal government bond forward rates, from 5- to 20-year maturity, due to a monetary policy shock measured as the daily change in the two-year bond yield, when the credit-to-GDP gap is below zero. The solid red line in the upper 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 9. Estimated betas for distant forward real rates by credit-to-gdp gap, 1999 to 2014



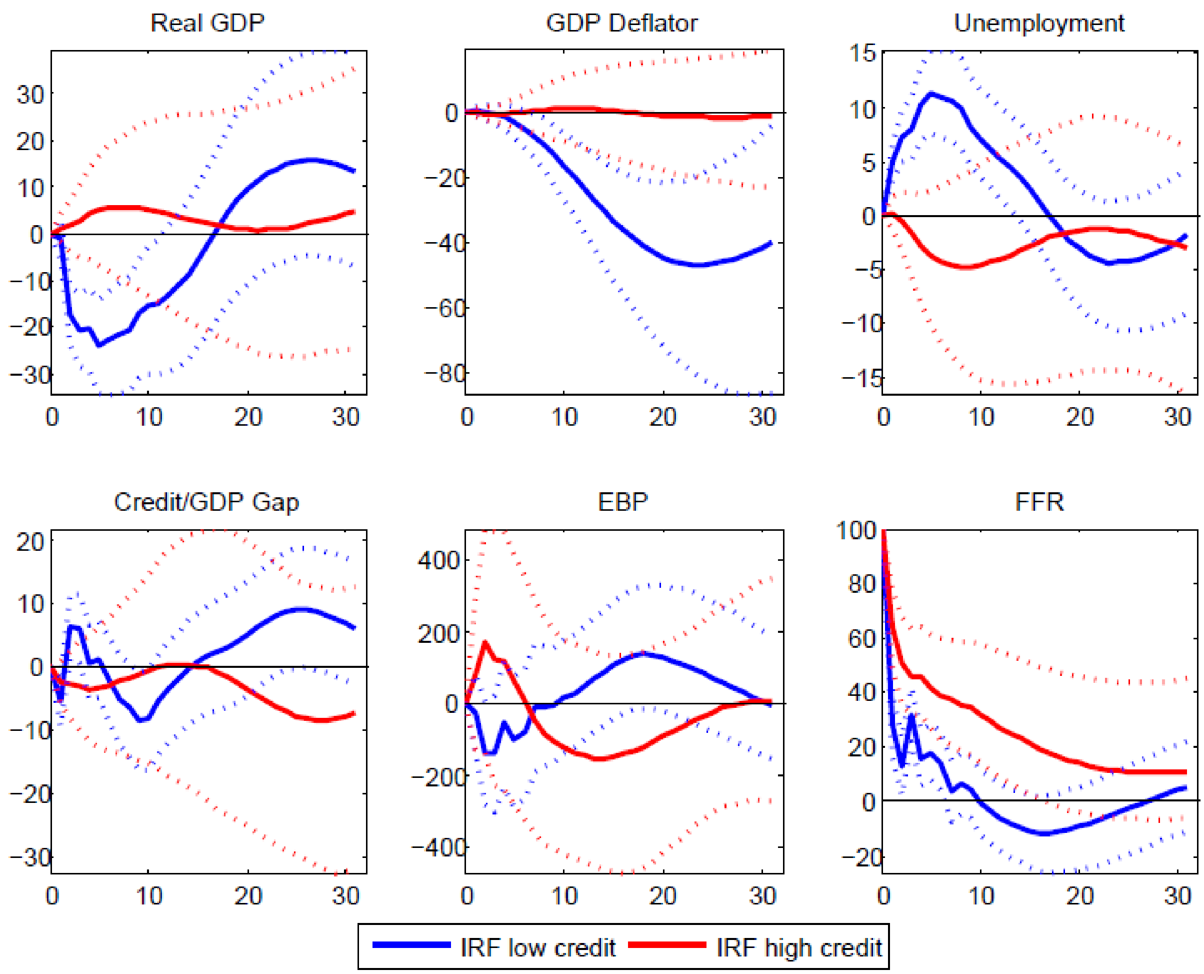
Note. The solid blue line in the upper panel reports the daily change in real government bond forward rates, from 5- to 20-year maturity, due to a monetary policy shock measured as the daily change in the two-year bond yield, when the credit-to-GDP gap is below zero. The solid red line in the upper panel 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 10. Excess bond premium shock, nonlinear with credit-to-GDP gap threshold



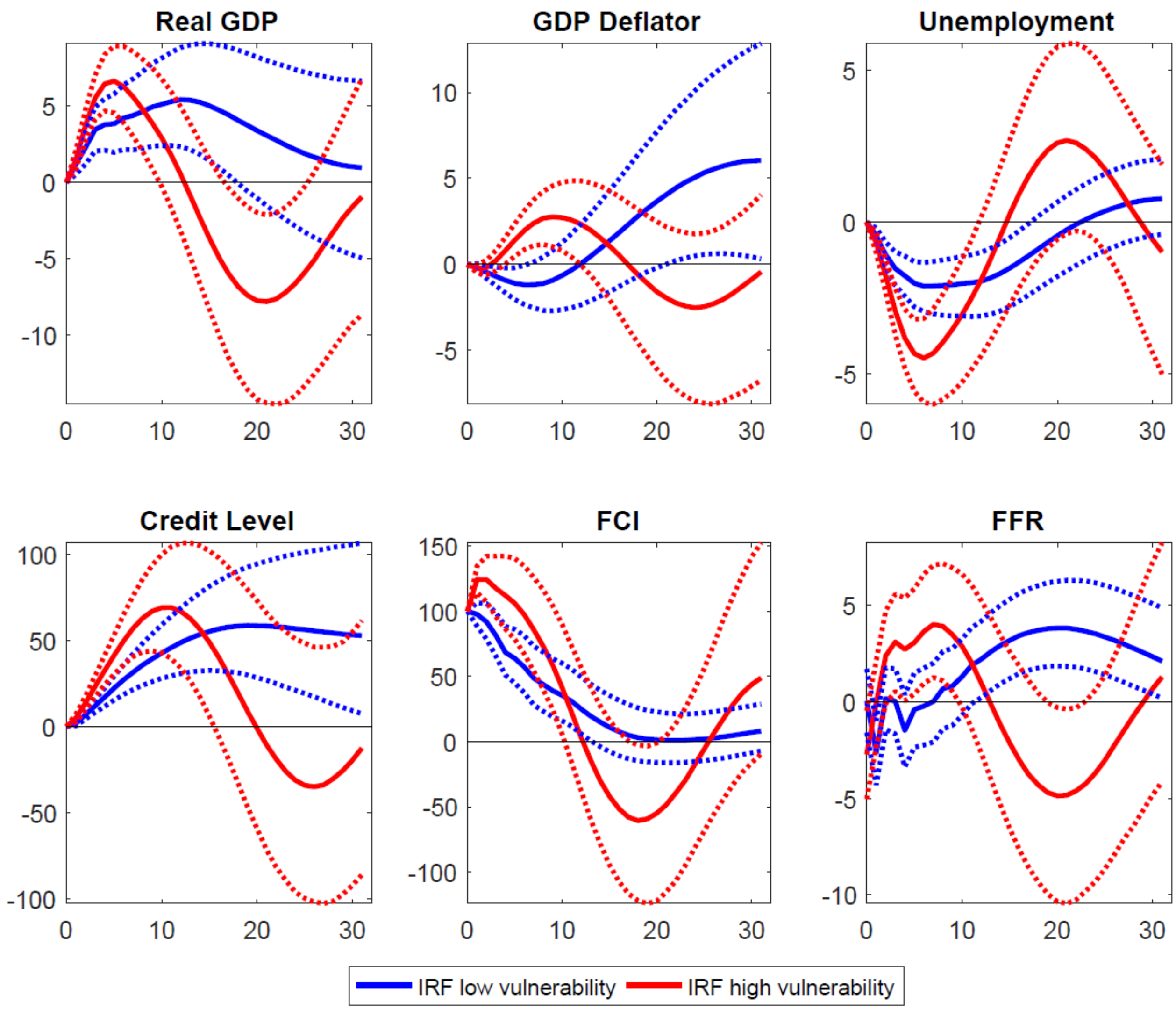
Note. The solid blue line reports the median impulse reponse to a shock to the negative of the excess bond premium (EBP) when the credit-to-GDP gap ratio is below zero, and the system includes (negative) EBP rather than FCI. The solid red line reports the median impulse reponse to a shock to the (negative)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

Figure 11. 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 (negative) excess bond premium (EBP) rather than FCI. 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 (negative) excess bond premium (EBP) rather than FCI. The dotted lines report one standard deviation confidence intervals for each impulse repsonse.

Figure 12. Financial conditions index (FCI) 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 FCI 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 FCI 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.

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