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Financial Vulnerabilities, Macroeconomic Dynamics, and Monetary Policy*

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Abstract

We define a measure to be a financial vulnerability if, in a VAR framework that allows for nonlinearities, an impulse to the measure leads to an economic contraction. We evaluate alternative macrofinancial imbalances as vulnerabilities: nonfinancial sector credit, risk appetite of financial market participants, and the leverage and short-term funding of financial firms. We find that nonfinancial credit is a vulnerability: impulses to the credit-to-GDP gap when it is high leads to a recession. Risk appetite leads to an economic expansion in the near-term, but also higher credit and a recession in later years, suggesting an intertemporal tradeoff. Monetary policy is generally ineffective at slowing the economy once the credit-to-GDP gap is high, suggesting important benefits from avoiding excessive credit growth. Financial sector leverage and short-term funding do not lead directly to contractions and thus are not vulnerabilities by our definition.

Keywords: Financial stability and risk, monetary policy, credit

JEL classification: E58, E65, G28

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1 Introduction

The recent global financial crisis highlighted in dramatic fashion the damage to economic performance from falling asset prices amid high levels of credit and fragile financial institutions. Policymakers have since been encouraged to monitor the financial system for the buildup of so-called macrofinancial "imbalances" that could make the system vulnerable to shocks such as a large decline in asset prices. Indeed, cross-sectional studies of advanced economies have found that private nonfinancial sector credit and asset valuations are early warning indicators of economic recessions and financial crises (see Borio and Lowe (2002), Drehmann and Juselius (2015), Schularick and Taylor (2012)). In addition, studies have found that high credit growth and asset bubbles combined lead to significantly weaker economic recoveries (see Jordà et al. (2013)). Financial stability monitoring frameworks, based on this growing body of theoretical and empirical research, focus on the levels and growth rates of these macrofinancial imbalances as potential vulnerabilities of the financial system (see Adrian et al. (2015)).

In this paper, we systemically evaluate several commonly-cited macrofinancial imbalances for whether they lead to higher risks to future macroeconomic performance. We shed empirical light on this question using a threshold VAR model using data for the U.S. economy from 1975 to 2014. Using alternative measures of macrofinancial imbalances, we test whether shocks to the measures lead to subpar economic performance, specifically lower GDP and a higher unemployment rate. We test for nonlinear dynamics by dividing the sample into periods depending on whether the measure is above or below its average. Measures of financial imbalances that are found to lead to weaker expected economic performance are defined to be "vulnerabilities." (Henceforth, we use the term *vulnerability* to refer generically to variables that measure candidate macrofinancial imbalances that might lead to economic contractions.)

We examine four vulnerabilities often cited in studies of financial crises: private-sector debt, investor sentiment or asset valuations, financial-sector leverage and maturity transformation among financial institutions.[1] We briefly describe each candidate vulnerability in turn, how we measure it, and the rationale for including it in our framework.

Note that the first two of our candidate vulnerabilities, debt and asset valuations, are conceptually different from financial-sector leverage and maturity transformation. The first set are economy-wide measures and do not depend on particular institutional features. The second are defined relative to specific financial institutions such as money market mutual funds or banks.

The first measure is private-sector debt, using primarily the credit-to-GDP gap, defined as the difference between the ratio of private nonfinancial sector credit outstanding to GDP and its long-term trend (e.g.,Borio and Lowe (2002, 2004); Borio and Drehmann (2009)).[2] We also evaluate alternative disaggregations of this measure–household vs. business borrowers, bank

[1] We do not consider the current-account balance as a potential vulnerability in our framework. While this has been emphasized in cross-country studies of small open economies, we leave this as a future exercise in our framework.

[2] Borio and Lowe (2002) evaluate the roles of rapid credit growth and rising asset prices as amplifiers, and find in cross-section analysis that the private nonfinancial credit-to-GDP gap is a high-quality early-warning indicator of recessions, and also is useful when combined with property prices.

vs. nonbank credit, debt collateralized by property vs. other debt-to test more hypotheses about specific vulnerabilities, such as the role of real estate, which is often identified as a key risk to financial stability.

A second measure is the extent of "froth" in financial markets – that is, relatively rich asset valuations or relatively high investor risk appetite. We construct a direct measure of investor risk appetite, dubbed ALLM, based on asset valuations and lending standards in four markets: business credit, commercial real estate, household credit (including consumer credit and residential mortgages), and equities. We also consider the excess bond premium of Gilchrist and Zakrajek (2012) as a measure of risk appetite, which has been found to be a useful predictor of macro performance. Higher asset values relative to historical averages may reflect greater risk-taking behavior which could lead to a buildup in financial vulnerabilities and make the economy less resilient to 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 Jordà et al. (2015)). Others have emphasized the information in bond risk premiums (Stein (2013b) and Lopez-Salido et al. (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.

The third measure is the leverage of the financial sector. This is an obvious potential vulnerability because more-leveraged financial institutions are less able to absorb losses. Faced with solvency concerns, these intermediaries may need to shrink, with negative consequences for the broader economy from fire sales or reduced credit supply. Of course, the leverage of financial intermediaries cannot rise in the absence of investor willingness to finance their borrowing, suggesting that risk appetite may play some role in leverage, a dynamic highlighted by Geanakoplos (2010). Further, Adrian and Shin (2010, 2014) document that the leverage employed by a crucial class of financial institution–broker dealers–is highly procyclical, in line with the tendency of asset price volatility to be low in booms and high in busts. We construct an aggregate measure of total assets to equity for financial intermediaries that use leverage, including depository institutions, insurance companies, broker dealers, finance companies, REITs, and holding companies from the Financial Accounts of the United States.

A fourth measure is related to maturity transformation of financial institutions. This function and its role as an amplification mechanism have been studied by Adrian and Boyarchenko (2015) and Gertler and Kiyotaki (2015), among others. We approximate maturity transformation by financial intermediaries with non-deposit claims that are pay-on-demand but that carry credit risk, based on Bao et al. (2015). Our measure comprises five components which have data back to 1975: repurchase agreements (repo), securities lending, retail and institutional money market mutual funds (MMMFs), and commercial paper. The greater the prevalence of these "runnables", the greater the exposure of the economy to a self-fulfilling withdrawal by investors which in turn precipitates a series of fire sales and deleveraging by financial intermediaries. In principle, the importance of this channel has been recognized since Diamond and Dybvig (1983). More recently, wholesale liabilities of the banking sector have been found to be an indicator of banking crises in cross-sectional studies (Anundsen et al. (2014)), and short-term liabilities in the repo market and asset-backed commercial paper market were subject to runs in the U.S. financial crisis (Gorton and Metrick (2012) and Covitz et al. (2013)). Krishnamurthy and Vissing-Jorgensen (2015) argue that issuance of Treasury debt affects the supply of short-term liquid claims issued by financial institutions, which are associated with financial crises.

We have three primary findings. First, our tests indicate that private-sector credit is indeed a vulnerability in the sense of presaging economic contractions. Specifically, impulses to the credit-to-GDP gap lead to decreased output and higher unemployment when the credit gap is above zero, indicating that the credit gap is a vulnerability. These results suggest that when the economy has a high credit gap, it is more vulnerable to adverse events which lead to recessions. By contrast, in the early phase of the financial cycle when the credit gap is low, credit shocks do not have adverse effects; indeed, they stimulate economic growth, consistent with the equilibrium relationship between debt and economic growth more common to macroeconomic models.

A second primary finding is that impulses to risk appetite lead to a near-term improvement in economic performance, reflecting that higher values capture more favorable financial conditions. However, impulses to risk appetite in high credit gap states also lead to a further increase in the credit gap, and subsequently to a recession. These results highlight that there may be an inter-temporal tradeoff between looser financial conditions and higher growth in the near-term and a recession in later years from a build-up in credit. Moreover, when the credit gap is low, such a tradeoff does not appear to exist, as a positive impulse to risk appetite boosts economic activity, further supporting our interpretation that private credit is a vulnerability.

A third primary finding is that system responses to monetary policy impulses also are nonlinear and depend importantly on the level of the credit gap. When the credit gap is low, impulses to monetary policy lead to an increase in unemployment, a contraction in GDP, and a decline in credit, all as expected. However, when the credit gap is high, output, unemployment, and credit appear unresponsive to similar impulses to monetary policy.

We investigate further why monetary policy is less effective in high credit gap periods. First, we redefine the threshold so that the sample is divided in periods when the credit-to-GDP ratio is rising or falling, rather than when it 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.

Second, in a system with both the credit gap and risk appetite, a positive shock to the effective fed funds rate, i.e. a tightening of monetary policy, when the credit gap is high leads to an increase, not a decrease, in risk appetite. This easing of financial conditions offsets, in part, the contractionary effect of a monetary policy shock. This offset may help to explain the finding that monetary policy is ineffective in boom periods.

Third, following Hanson and Stein (2015), we use high-frequency data to identify monetary policy shocks and longer-maturity bond yields as an outcome measure. We find that the transmission of monetary policy to forward Treasury rates differs between high and low credit gap periods, consistent with less transmission in high credit states.

We conduct a number of robustness tests of our primary results, particularly in cases where the variable we use may only imperfectly measure the underlying vulnerability. For example, as discussed earlier, we use a number of different proxies for the level of asset valuations or investor risk appetite. In addition, we consider alternatives to the credit-to-GDP gap, including a specification with just the (log) level of credit and replacing actual GDP with potential GDP.

Turning to the financial-sector candidate vulnerabilities, we do not find empirical support that financial sector leverage or runnable liabilities satisfy our definition of a vulnerability. Neither appear to have direct effects on real activity. Positive impulses to these measures when they are low lead to a rise in prices and a monetary policy response, and a rise in unemployment in later quarters. There are a few possible explanations for why financial sector variables are not vulnerabilities. Adrian and Shin (2010) suggest a strong linkage between financial leverage and asset prices and volatility, and thus, potentially, risk appetite, but not necessarily to real economic activity. A decline in leverage, however, could be driven either by mounting losses, as following a peak in the credit cycle, or by increased risk aversion, as in periods of low risk appetite and tight financial conditions. It may also be the case that, because of the growth of the derivatives market, leverage and short-term funding has become more difficult to measure.

Our results bear on several strands of the literature. We show that a number of macrofinancial aggregate measures have implications 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). Our results indicate that a high credit gap 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 et al. (2015) and Mian et al. (2015)), 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)). In addition, while others have identified a role for shocks to certain credit aggregates and asset prices to contribute to business cycle fluctuations, this paper is the first to systematically examine a full set of commonly-cited financial vulnerabilities, including those specific to the financial sector.

Second, our 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. Hubrich and Tetlow (2012) use a regime switching model to evaluate the relative effectiveness of monetary policy by whether the economy is in a financial crisis state. 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.

Finally, our finding that monetary policy is less effective when the credit gap is high, combined with our finding that a high credit gap is a vulnerability, suggests that credit is costly and may lead to more severe recessions. For example, Jordà 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).[3]

[3] For example, in the fourth year after the peak, in a normal recession, the economy is well into a recovery, with real GDP per capita estimated to be 3.8 percentage points higher than the cyclical peak. But had credit exceeded average levels by one standard deviation, real GDP per capital would be estimated to be 1.8 percentage points less, at 2.0 percent. In the case of a financial recession, the effects are larger. In the

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) 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) look at whether monetary policy should respond 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. They find that optimal interest rate policy does respond to crisis risk, but only by a very small amount. Our results provide stronger support for the use of monetary policy: credit is a vulnerability and a high credit gap leaves the economy less resilient and more prone to a recession. Given monetary policy is not effective in a high credit gap state, there are high returns to policymakers from avoiding such states. More targeted macroprudential policies may be a preferable way to reduce credit, but a high share of market-based finance may lead to situations in which such macroprudential measures' effectiveness is diminished and monetary policy should also be considered.

The remainder of our paper is organized as follows: in section 2 we describe and characterize our proxies for vulnerability; in sections 3 and 4 we evaluate whether the credit-to-GDP gap and risk appetite, respectively, satisfy our definition of a vulnerability. In section 5, we evaluate our findings regarding the monetary policy transmission process. In section 6 we evaluate whether the measures tied to the leverage and maturity transformation of financial institutions, satisfy our definition. Section 7 concludes.

2 Data and Specification

In this section we describe the candidate measures of vulnerabilities that we test and the specification that we use to test them. In terms of the series, in certain cases important structural changes in the financial environment – including changes to the U.S. bankruptcy code – will motivate the use of certain subperiods of our sample. 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.

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fourth year after the peak, the economy has still not recovered, the GDP per capita level is -2.8 percentage points below the cyclical peak for average excess credit. If credit were one standard deviation higher, real GDP per capita would be as low as 3 percentage points lower, at -5.8 percent. These suggest significant effects for excess credit on the severity of the subsequent recession.

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, which is designed to be slow-moving. In addition to testing this broad measure, we also test the components in three separate decompositions of the credit-to-GDP gap:

1. A sectoral decomposition of credit provided to households vs. to businesses;.
2. A collateral decomposition of credit backed by property (commercial or residential) vs. other forms of credit; that is, unsecured credit or credit secured by non-property collateral.
3. A bank vs. nonbank decomposition, based on where the credit exposures are being held.

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 is based on final estimates of credit-to-GDP; real-time estimates provided an earlier warning and showed the sustained increase starting earlier, during the mid-1990s (see Edge and Meisenzahl (2011) for a discussion of real-time vs final estimates of the credit-to-GDP gap.)

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 and the credit gap estimated using *potential* GDP. This latter measure in particular removes the mechanical increase in the ratio (and hence the gap) caused by a decline in GDP.

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 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.

Decomposing the credit-to-GDP ratio into its components shows that the upward trend in the U.S. is largely due to an increase in household credit. 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. Household credit rose both because of the extensive margin – more households became homeowners – and the intensive margin – existing homeowners took on more debt. 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.[4] 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).

Household and business credit-to-GDP gaps (middle panel of figure 1) clearly illustrate 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. Differences in the household and business credit gaps may be important for setting macroprudential policies if one of the sectors proves to be a more prominent vulnerability than the other, and we evaluate this proposition in estimations below.

The bottom panels of figure 1 decompose the credit-to-GDP ratio into credit provided by banks and nonbanks. Our measure of nonbank credit gathers many different types of providers, including: shadow banks, which offer credit which is funded by short-term debt without insurance or a public backstop; the GSEs; pension funds and life insurers, which tend to have long-dated liabilities; and mutual funds, which issue shares that are loss-absorbing (see Bassett et al. (2015) for more detail).

The bank credit-to-GDP ratio appears to be stationary, and has gone through three cycles, roughly in sync with household credit, with peaks in the late 1970s, late 1980s, and then in 2009.

The nonbank credit-to-GDP ratio shows a secular upward trend, due importantly to the growth of shadow banks and the GSEs, though it too fell sharply in 2008, when shadow banking collapsed. Rajan (2005) argues that developments in financial markets – deregulation, technological and financial innovations, and globalization–have lowered financial frictions and improved efficiency, but may also lead to new and higher risks. For example, credit that is increasingly funded via financial markets rather than bank deposits makes credit more sensitive to market disturbances.

2.2 Measures of risk appetite

Our second candidate measure is an index related to investors' willingness to accept risk that we constructed (denoted ALLM). This measure is based on price and non-price measures. To link the existing literature we compare our measure to the excess bond premium measure (EBP) of Gilchrist and Zakrajek (2012) based on the corporate bond prices. Both measures (the top panel of figure 2) are more volatile than the credit-to-GDP ratio and show more cycles.

We construct our measure, ALLM, in the spirit of the methodology described in Aikman et al. (2015). The measure includes indicators of asset price valuations and lending standards in four areas: equity markets; business credit; commercial real estate; and household

[4] 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). A large pre-crisis literature debated the extent to which the GSEs lowered borrowing costs for homeowners. This debate centered in large part on the role of the GSEs' *retained portfolios*; that is, the GSEs' practice of buying the very securities they issued. See Passmore (2005).

and residential mortgage credit. The overall measure is then a weighted average of the standardized index for each of the four sectors.[5] The bottom panel of figure 2 shows the four components.

The business credit component of ALLM not surprisingly ise 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 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 Financial sector leverage

The final two candidate vulnerabilities we consider relate to features of the financial sector, starting with the leverage of financial-sector institutions. We construct an aggregate measure of total assets (A) to equity (E) for financial intermediaries that use leverage, including depository institutions, insurance companies, broker dealers, finance companies, real-estate investment trusts (REITs), and financial holding companies.

As shown in figure 3 this measure, "AE", has a downward secular trend, reflecting primarily a substantial increase over recent decades in regulatory capital requirements for the banking sector. Required capital among banks increased following the first Basel capital accords in 1988 and again starting in 2009 with the post-crisis capital reforms, including the stress testing regime and Basel III. The series, adjusted for a long-term trend, features significant variation over time, including peaks in 1986, 1998 and 2004–2006. Since the start of the recent crisis, the series has fallen sharply and has remained quite low.

This variable is highly correlated (contemporaneous ρ=.65) with our risk appetite variable, suggesting that once adjusted for a secular trend, it may reflect risk-taking behavior of financial institutions and the willingness of investors to provide debt financing.

2.4 Runnable liabilities

A fourth vulnerability we consider is also related to financial institutions, specifically their short-term funding. The measure we employ is based on wholesale short-term funding instruments which are "runnable," that is, pay-on-demand instruments issued by private agents with an embedded promise but are defaultable; see Bao et al. (2015) for a more detailed description. We include five components which have data back to 1975: repurchase agreements (repo), securities lending, retail and institutional money market mutual funds (MMMFs),

[5]The index is constructed as the weighted sum of the CDFs of the following time series: stock market volatility (actual before 1989 and the VIX after), the S&P 500 price-earnings ratio; the BBB-rated corporate bond spread to Treasury; the share of nonfinancial corporate bond issuance that is speculative-grade; the index of credit availability from the NFIB survey of small businesses; a commercial real estate price index deflated into real terms, commercial real estate debt growth, household residential house price-to-rent ratio, and lending standards for consumer installment loans from SLOOS.

and financial commercial paper. These components all proved vulnerable to investor runs in the financial crisis, and were a major amplification mechanism for the losses on subprime mortgages (Gorton and Metrick (2012); Covitz et al. (2013); McCabe (2010)).[6]

The ratio of runnables to GDP and the gap relative to trend are shown in the top two panels of figure 3. This ratio reflects structural as well as cyclical changes in money markets that have taken place since the mid-1970s. Growth of runnables accelerated in the late 1970s when interest rates and volatility began rising sharply in 1978, and the FOMC reformed its policy framework in October 1979, after it became evident that their previous policy of gradualism was not working to fight inflation and reverse inflation expectations. Higher short-term rates and volatility, combined with Regulation Q – which set ceilings on rates that commercial banks and thrifts could offer on deposits – spurred the growth in nondeposit assets such as money market funds and hence the runnables measure.

The large rise in runnables in the late 1970s was concentrated in repo, and then in MMMFs in the early 1980s, until regulatory changes to ease Regulation Q restraints permitted banks and thrifts to offer competitive accounts in 1982.[7]

Growth in runnables moderated for a couple of years, until repo rose again in 1984, after Congress enacted the Bankruptcy Amendments Act of 1984, which amended Title 11 of the U.S. Code covering bankruptcy. The legislation exempts repo in Treasury and agency securities, and other securities, from the automatic stay provision of the Bankruptcy Code. In practice, it enabled lenders to liquidate the underlying securities and resolved a major question about the status of repo collateral in bankruptcy proceedings.

Since these important structural changes in runnable liabilities occurred, they continued to grow until peaking at nearly 80 percent of GDP in 2008. The falloff of the runnable gap from its peak started about a year earlier than for the credit-to-GDP gap, and is even larger in magnitude.

Given the important structural changes in the demand and supply of runnable liabilities that took place in the mid-1980s, we conduct our analysis using the sample under the current legal regime (1985–2014).

[6]We exclude uninsured deposits at banks for two reasons: it is possible that depositors still view uninsured deposits to have some implicit backstop from the government, as suggested by implicit subsidies measured on debt issued by banks; and reporting forms for banks prior to 1980 did not distinguish between insured and uninsured, and the limit for insured deposits was raised to $250,000 during the financial crisis (which subsequently expired), but the reporting forms were not adjusted quickly enough to capture the change. We also exclude commercial paper issued by nonfinancial corporations because we are interested in short-term liabilities of financial firms. If money market mutual funds purchase CP issued by nonfinancial firms it would be included in our measure of runnables.

[7]First there was greater use of repo as corporations saw the opportunity cost rise of holding idle cash when market rates were rising. Banks benefited as well since repo rates were not subject to Regulation Q and they were not required to hold reserves if the repo was collateralized by Treasuries. There also was a notable rise in the growth of marketable Treasury debt after 1974 that increased the amount of available collateral. In addition, as investors were turning to MMMFs to earn higher rates, these accounts grew rapidly until the Garn St. Germain Act of 1982 directed the Depository Institutions Deregulation Committee (DIDC) to authorize accounts at banks and thrifts that could be competitive. In particular, DIDC authorized money market deposit accounts (MMDAs), available as of December 14, 1982, and Super NOW accounts, available as of January 5, 1983, but MMMF assets had already grown from $4 billion in 1977 to $235 billion at year-end 1982. (Regulation Q was phased out entirely by 1986.)

2.5 Sample statistics

Table 1 gives sample statistics for our candidate vulnerability measures. In each case, the measures are divided into periods above their means (labeled "high vulnerability") and below their means (labeled "low vulnerability"). 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. Both the credit-to-GDP and the runnables-to-GDP gaps show a similar pattern: when they are low, real GDP growth and the inflation rate are higher than in periods when they are 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 high vulnerability by these measures are associated with lower economic growth, low but rising unemployment and loosening monetary policy, suggesting that they occur near business cycle troughs.

The similarities between ALLM and AE are striking. Periods of low ALLM and AE 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 and AE are associated with good economic performancehigher real GDP growth andfalling unemployment.

These results raise the obvious question of how correlated our measures are. Figure 4 shows standardized values of all four vulnerabilities; that is, each vulnerability normalized to have zero mean and a unit standard deviation. All four vulnerabilities are quite low in the early 1990s and have peaks somewhere in the 2004 to 2009 period, with ALLM and the leverage gap peaking earlier and the credit-to-GDP and runnables gaps peaking later. In general, the credit-to-GDP gap and the runnables gap appear correlated with each other, and they lag ALLM and the AE gap.

Table 2 gives the simultaneous pairwise correlations among these measures. The credit-to-GDP and runnables gap are fairly well correlated ($\rho = 0.63$). These two measures are however essentially uncorrelated with ALLM ($\rho = 0.10$ and 0.23 respectively) and less correlated with AE ($\rho = 0.28$ and 0.11 respectively).

As one might expect, our risk appetite index and leverage measure are fairly well correlated ($\rho = 0.70$). Note that ALLM is also somewhat correlated with the (negative) EBP ($\rho = 0.34$).

Given our focus on the interaction of the effectiveness of monetary policy with our vulnerability measures, we report the number of quarters in which the effective funds rate rose (fell) by 25 basis points or more conditional on whether the vulnerability measure 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. The results are shown in table 3. Overall, for each of the candidate vulnerability measures, there are a reasonable number of quarters in each of the categories of easing, tightening, or unchanged. [8] Focusing just on the credit-to-GDP gap – the measure under which we evaluate the monetary policy transmission mechanism – the minimum sample size ($N = 15$) is for the combination of a high gap and policy tightening

[8]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.

(46 total observations). Thus, our sample is not degenerate.

2.6 Specification

Our primary goal is to characterize the effect of shocks to our candidate measures of financial vulnerability on economic performance. We focus specifically on whether these effects differ depending on whether the vulnerability is high or low.

We characterize these effects using threshold vector autoregressions 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; the shocks are 100 basis points for the vulnerability measures or monetary policy as appropriate (e.g. the shock to the credit-to-GDP gap used in the IRFs is 100 basis points). Our baseline specifications contain the following variables:

- 100 × logarithm of real Gross Domestic Product.
- 100 × logarithm of the Gross Domestic Product deflator.
- Unemployment rate.
- Measure of financial vulnerability defined so that higher values indicate increased vulnerability
- Federal funds rate (effective), per annum.

In all instances we use nine lags of the vector of dependent variables.

In computing impulse response functions, we identify shocks using a Cholesky decomposition. When identifying shocks to vulnerability measures, the shocks are ordered so that monetary policy reacts to all shocks in a period: the vulnerability measure reacts to all shocks within a quarter save monetary policy; and the unemployment rate, the GDP deflator, and real GDP react to shocks to the vulnerability measure and monetary policy with a one-quarter lag. This ordering is a reasonable strategy to identify shocks to slow-moving aggregates such as credit, runnables and leverage. When identifying monetary policy shocks, monetary policy is assumed to be able to react to risk appetite shocks in the same quarter. When identifying ALLM shocks, we reverse the order and permit ALLM to react in the same quarter as monetary policy. This is reasonable because ALLM contains financial market prices, so there may be significant within-quarter reactions to monetary policy shocks.

The VARs are estimated over disjoint subsamples with the thresholds determined by the vulnerability measure. We compute responses when the vulnerability measure is high (above its mean) and when the vulnerability measure is low (below its mean). This permits us to test for nonlinear dynamics: whether a shock to vulnerability (for example) has a different effect in times of high vs. low vulnerability. Thus, our baseline specification is a threshold VAR based on the level of the candidate vulnerability measure X_t, which has a sample mean of μ_X, is:

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

Where y_t is the vector of endogenous variables described above.

Our empirical characterization of the relationship of measures of vulnerability explores three elements. First, whether a positive shock to the measure results in subpar economic performance. Second, whether the effect of the vulnerability shock is nonlinear: that is, its ability to forecast subpar economic growth varies significantly in periods when it is high vs. low. Third, whether the effect of the monetary policy shock is also nonlinear: that is, whether the reaction to monetary policy shocks differs between high and low vulnerability states. One would be particularly interested whether the effect of the monetary policy shock is less in high vulnerability states. (We restrict this final analysis just to the credit-to-GDP gap for space reasons; we consider analysis of this vulnerability to be the main contribution of this paper.)

3 Credit-to-GDP Gap As Vulnerability

We begin by evaluating the gap between the log of the credit-to-GDP ratio and its trend, estimated using a Hodrick-Prescott filter (with $\lambda = 400,000$).

Real GDP appears in our baseline specification both directly and as a component of the credit-to-GDP gap. When we compute the impulse responses to shocks to the credit-to-GDP gap we do not mechanically adjust real GDP or the gap to reflect this accounting relationship. Thus, shocks to the gap can be interpreted as shocks to credit.

3.1 Baseline Results

Figures 5 and 6 show impulse response functions (IRFs) with respect to innovations to the credit-to-GDP gap and to monetary policy. These results are based on the system estimated over the full sample, without a threshold feature. As shown, following a shock to the credit-to-GDP gap, economic activity and prices are largely unaffected, though a rise in monetary policy eventually leads to a recession and an increase in the unemployment rate. The evolution of the system following an innovation to monetary policy is as expected: activity contracts in the near-term the unemployment rate rises, and the credit-to-GDP gap also shrinks. Based on these results, it is not clear that the credit-to-GDP gap satisfies our definition of a vulnerability since the eventual decline in activity and increase in the unemployment rate are likely driven by the monetary policy reaction function.

Turning now to the system estimated using a threshold, figures 7 and 8 show impulse response functions with respect to shocks to the credit-to-GDP gap and to monetary policy, respectively. The blue (red) lines show the impulse response functions from the system estimated in low (high) credit-to-GDP gap periods.

The threshold VAR results highlight important distinctions between high and low credit-to-GDP gap periods. Importantly, the results from periods when the credit-to-GDP gap is high indicate that the gap satisfies our definition of a vulnerability. As shown by the red lines in figure 7, in periods when the credit-to-GDP gap is high, an upward shock to credit presages subpar economic performance in the form of an eventual rise in the unemployment rate and decline in real GDP. These responses are statistically different from zero at the 16th and 84th percentiles. The deterioration in economic conditions takes several quarters to materialize. In contrast, when the credit-to-GDP gap is low, an upward shock to the credit gap results in a near-term boost to GDP and to prices, rather than a contraction (shown by the blue lines). Moreover, monetary policy reacts to the system dynamics and the unemployment rate eventually rises. These quite different dynamics between high and low credit gap periods suggest a nonlinear response to credit shocks, with more costly effects on the economy when the credit-to-GDP ratio is above its long-run trend.

Because monetary policy responds to credit shocks, either directly or indirectly through their effects on output and inflation, we report results holding monetary policy constant to better evaluate the effects of the credit shock. Figure 8 shows the response to a monetary policy shock in our baseline threshold specification. Figure 9 shows results with the coefficients in the equation describing the reaction of the effective fed funds rate to other variables in the system set to zero. The estimation effectively gives the dynamics of the system with monetary policy shut down. In these IRFs, there is a clear difference in economic performance following a shock to the credit-to-GDP gap depending on whether the gap is high or low. As shown by the blue lines, the unemployment rate does not rise following a shock to the credit-to-GDP gap when the gap is low and monetary policy is shut off. Thus, the finding of rising unemployment in later quarters in the low credit gap case appears to be related to the monetary policy reaction. At the same time, the finding of a decline in GDP and rise in unemployment from a positive shock to credit in a high state does not appear to be related to the higher policy rate, supporting our conclusion that high credit is a vulnerability.

The system responses to monetary policy shocks also differ based on the credit gap. As shown by the blue lines in figure 8, in low credit gap periods, shocks to monetary policy have the expected effect on macroeconomic variables: an increase in the policy rate results in a contraction in real GDP and prices, and an increase in the unemployment rate. The credit-to-GDP gap does not increase, suggesting that credit has contracted with GDP. In high gap periods (red lines), by contrast, monetary policy shocks have no effects on the evolution of the system, as values are largely unchanged and confidence bands for the IRFs are wide. This difference in the system's dynamics is important, since it suggests that monetary policy is not effective in high gap periods. We evaluate further the monetary policy effects in Section 5 below, after reviewing robustness tests and results for the candidate vulnerabilities in the remainder of this section.

3.2 Robustness Tests

The use of the credit-to-GDP gap as a candidate indicator of vulnerability raises certain questions. First, although we argue that shocks to this measure can be interpreted as credit shocks, it is instructive 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 10 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, as before, high/low vulnerability periods are defined relative to the credit-to-GDP gap. As shown, an upward shock to the *level* of credit during either high or low vulnerability periods results in real GDP growth. However, the same shock in a high vulnerability period 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. From this we conclude that the economy responds differently to shocks to credit in high and low credit-to-GDP gap states, with economic performance relatively worse in a high gap state. However, in neither the high nor the low state does a shock to the credit level produce a recession. We can speculate that this is because the shock in levels is so persistent that it takes a long time to peter out. While the credit expansion is underway, economic activity continues to grow as well, with the ultimate end of the expansion happening far in the future.

To remove the mechanical effect of recessions in increasing the credit-to-GDP ratio, figure 11 shows the results in a specification in which the credit-to-GDP gap is estimated using *potential* GDP. Comparing figures 7 and 11 shows very small differences.[9]

3.3 Is All Credit Created Equal?

Our credit-to-GDP gap vulnerability measure is based on total private nonfinancial debt. Thus, it lumps together forms of debt that might be expected to have different relationships to asset prices and economic activity. For a variety of reasons, one might suspect that different forms of debt may pose more or less danger to the financial system.

In order to test whether, in fact, all credit is created equal, we revised our baseline specification in the following way: we divided total credit, D_t into two components, D_t^a and D_t^b where $D_t^a + D_t^b = D_t$. We then form separate credit-to-GDP ratios using each component, $d_t^j = D^j/\text{Nominal GDP}_t,\ j = a, b$, and compute trend and cycle components of d_t^j using the Hodrick-Prescott filter with $\lambda = 400,000$ as before. We then estimate the baseline system using two candidate vulnerability measures, the gaps x_t^a and x_t^b. In order to keep the number of specifications limited, we continue to define periods of high/low vulnerability using the total credit-to-GDP gap X_t. We then test whether a shock to a particular form of credit leads to subpar economic performance in periods of high vulnerability.

We consider disaggregations of total credit by the type of borrower and the type of lender: first, into debt owed by households vs. debt owed by (nonfinancial) businesses, second into credit provided by banks vs. nonbanks and third into debt collateralized by property vs. other forms of debt.

These divisions were suggested in part by the boom-bust cycle that ended in 2009. The boom was associated with borrowing by households and provided by the nonbank sector.

As an example of our results, figures 12 and 13 show IRFs to shocks to the household and business credit-to-GDP gaps, respectively. (During high credit gap periods, a shock to business credit presages subpar economic performance (figure 13). The lack of a similar result for a shock to household credit (12) is something of a surprise given the role of household

[9]Of course, potential GDP is a real concept while in our analysis nominal credit is deflated by nominal GDP. To form nominal potential GDP we multiply potential (real) GDP by the actual price level. Any mechanical effect via the price level would still be in place.

credit in the recent financial crisis, though the household credit gap has fewer cycles. Table 4 summarizes the results of our decompositions. In summary, in periods when the aggregate credit-to-GDP gap is high, upward shocks to business and nonproperty debt are followed by economic contractions. Both bank and nonbank credit also have this property. These results suggest that in high vulnerability periods policymakers should *also* focus on forms of credit that are not traditionally associated with housing bubbles; of course, measures such as mortgage credit growth warrant attention as suggested by the extensive literature documenting the relationship between housing credit booms and subsequent busts.

4 Risk Appetite As Vulnerability

In this section we describe results using the index of risk appetite (ALLM) we described in Section 2. Here, we divide the sample into periods in which ALLM is above or below its mean. Impulses to ALLM lead to similar macroeconomic outcomes in both environments (figure 14). In particular, in a low ALLM environment, an impulse to ALLM leads to a short-run expansion in output and decline in unemployment. In a high ALLM environment, the effects are similar, although the increase in GDP and decline in unemployment are more modest. In both high and low ALLM, the initial shock peters out over time, and monetary policy is unaffected.

Thus, ALLM does not satisfy our definition of a vulnerability. Rather, ALLM functions more as an indicator of financial conditions, where an increase eases borrowing constraints and boosts economic activity. As intuition would suggest, the effects are greater when the index is low – when borrowing constraints are relatively tight.

As a further check on this result, figure 15 shows the same results using the negative of the excess bond premium (EBP) in place of ALLM. The results are quite similar: upward shocks to the negative EBP (i.e. a lower excess bond premium) presage economic expansions, with the effect stronger in low periods than in high periods.

4.1 Credit and risk appetite

Risk appetite and the credit-to-GDP gap may be capturing different concepts. In particular, risk appetite could set the stage for credit growth. Danielsson et al. (2015) find that low volatility – a measure of risk appetite – leads to an increase in the credit-to-GDP gap. To determine whether a shock to ALLM can stimulate a reaction in the credit-to-GDP gap, we include both in a VAR. As described in section 2.6, 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.

Results in this augmented system are shown in figure 16. As before, we divide our sample into periods when the credit-to-GDP is above or below its mean. 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 also show an increase in output and a decline in unemployment. 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 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. A shock to risk appetite in a low credit gap period does not suggest the same costs and inter-temporal for economic activity.

5 Monetary Policy in High and Low Vulnerability States

In this section, we evaluate further the results that monetary policy is less effective when the credit gap is high. First, we show this result is robust to the alternative specifications we described above (alternative measures of credit and an alternative cyclical definition). Second, we look at how the risk appetite measure responds differently to an increase in the policy rate during high and low credit gap periods. Third, 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.

5.1 Robustness Tests

We showed above that the results that the credit-to-GDP gap is a vulnerability are robust to using the (log) level of credit or using potential GDP to define the credit measure. We now also test if the result that the effects of monetary policy differ by low and high credit states are robust to these alternative measures for credit. Figures 17 and 18 show that results for the effects of a shock to monetary policy for these two alternative measures of credit are similar to the results for the credit-to-GDP gap, and reinforce the baseline results that monetary policy is more effective in low-vulnerability states than in high.

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)), 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 et al. (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 19 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.

5.2 Monetary Policy Shocks and Risk Appetite

Some additional insight into why monetary policy may not be effective in a high credit gap state is seen from the results from a shock to monetary policy in a system with both the credit gap and ALLM. When the credit gap is low, a shock to monetary policy leads to a sharp drop in ALLM, and to a deterioration in activity, lower prices, and higher unemployment (Figure 20). In this low credit case, the transmission to ALLM reinforces the tightening effect of monetary policy. In sharp contrast, in a high credit state, a shock to monetary policy actually leads to an increase, rather than a decrease, in ALLM. This boost to financial conditions in a high credit gap period may counter any slowing effects on the economy from a tighter stance of monetary policy.

5.3 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 nominal 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 in 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:

$$\Delta f_t^{X(n)} = \alpha_X(n) + \beta_{X(n)} \Delta y_t^{\$(2)} + \Delta \epsilon_t^{X(n)} \tag{2}$$

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 21 for nominal yields and figure 22 for real yields. We exactly replicate the HS results for the nominal and real forward rate responses on FOMC announcement dates; the reported results differ slightly because we extend the sample period to the end of 2014. The estimated betas are significant at all horizons. Of particular note, we find significant differences between the betas in high and low credit gap periods, as reported in the bottom panels. For nominal rates, the response of the forward rate in the high credit gap state is 0.8 at 5 years ahead, so that a 100 basis point increase in the 2 year yield results in an 80 basis point increase in the five year instantaneous forward. Note that this is significantly below the coefficient of 1.4 in the low credit gap state. This difference suggests a greater transmission of monetary policy to longer-term rates in low credit states. Differences are statistically different out to eight years ahead, and diminish as the change in the forward rate falls at further horizons.

We next extend the estimation period back to 1975 to match the sample period for our TVAR analysis for nominal Treasury yields (TIPS are not available before 1999). The results, shown in figure 23, are similar as for the shorter sample: the estimated betas 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.[10] 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.

6 Vulnerabilities Related to Financial Institutions

6.1 Financial Leverage As Vulnerability

Figure 24 shows the impulse response to a shock to the gap between financial-sector leverage, AE, and an estimate of its long-run trend. As shown, the shock has a stimulative effect on economic activity when the leverage gap is both high and low, and a rise in prices when the gap is low. A subsequent monetary policy response leads to a rise in unemployment in later quarters. Hence this measure of leverage does not satisfy our definition of a macroeconomic vulnerability.

Leverage poses a threat to the solvency of individual financial institutions: all else equal, an institution with less equity can withstand a smaller shock before imposing losses on its debt holders. However, we find that shocks to the leverage gap do not, in the aggregate, presage subpar economic growth. As we discussed in Section 2, there is strong evidence that the AE gap is correlated with overall financial conditions and risk appetite. This high

[10]Differences for this sample are smaller in magnitude at closer horizons than when the sample started in 1999, but betas for both samples converge to about .4 at far distant horizons.

correlation may reflect that, in our sample, there is a strong secular trend downward in financial leverage. Deviations from this trend reflect cyclical variation in the risk-taking behavior of financial institutions. Moreover, additional risk-taking of financial firms may be reflected mostly in higher asset prices and with only an indirect effect on economic activity to the extent it leads to an increase in private sector credit.

6.2 Runnable Liabilities As Vulnerability

As discussed in Section 2, the prevalence of runnable liabilities in the economy has varied in response to legal and regulatory changes, moves in short-term interest rates, and the funding choices of businesses. These liabilities represent a structural vulnerability to the extent that they are backed by less liquid assets and issued by institutions without access to a lender of last resort.

Figure 25 shows the response of the system to a shock to the runnables-to-GDP gap estimated using only the data following the bankruptcy reform in 1984. In states where this gap is high, real GDP, inflation, the unemployment rate and monetary policy do not react significantly. In states where this gap is low, by contrast, an upward shock to the gap results in somewhat similar effects as a shock to AE, with a modest rise in prices, a monetary policy response, and then an increase in unemployment. As with AE, the results for runnables suggest it is not a vulnerability. While results for these financial-sector variables do not suggest a linkage to the real economy, further work to interact with private credit may be worth pursuing.

7 Conclusion

In this paper we systematically evaluated in a threshold VAR framework a set of macrofinancial variables to determine whether they represented economic vulnerabilities. We considered the nonfinancial sector credit-to-GDP gap, risk appetite, financial sector leverage and runnable liabilities, and allowed for nonlinear responses.

We find that the credit-to-GDP gap is a vulnerability, with impulses to the credit gap leading to a decline in real GDP and a rise in unemployment when the credit gap is high. In contrast, impulses to the credit gap when it is low are expansionary. Thus there are important nonlinearities which suggest that high credit periods are costly because it leaves the economy vulnerable to shocks that lead to recessions. We decompose the credit-to-GDP gap into components related to the source of funding and the type of borrower. We find that impulses to business credit and credit supplied by nonbanks lead to economic declines when the aggregate credit gap is high. These results suggest that it is also important to monitor types of credit not associated with housing markets.

In a system without the credit-to-GDP gap, shocks to our risk appetite measure (ALLM) are not followed by economic contractions. However, in a system that does include the credit-to-GDP gap, shocks to ALLM lead to recessions if the credit-to-GDP gap is above average. Thus, shocks to risk appetite appear to stimulate credit and, with considerable lag, to a recession.

Our results also indicate that impulses to monetary policy, as expected, lead to declines in activity when the credit gap is low, but that policy effectiveness is reduced when the credit-to-GDP gap is high. These results suggest that the credit gap affects monetary policy transmission channels in high credit states. This could be consistent with stories in which monetary policy has difficulty stopping a credit boom or in which monetary policy has difficulty stimulating the economy once a recession with a debt overhang has taken hold. We decomposed our sample into periods of credit growth – from troughs to peaks of the credit-to-GDP gap – versus credit moderation – from peaks to troughs. We found that monetary policy is less effective in the former case, when credit is growing rather, than in the latter case, when credit is moderating, suggesting that monetary policy has greater difficulty coping with a credit boom than a debt hangover following a credit bust. Moreover, in high credit periods, monetary policy tightening does not lead to a reduction in risk appetite in high credit periods as it does in low credit periods, indicating again that transmission channels depend on the credit gap. Given this important difference, policymakers may want to avoid high credit gap periods from taking hold.

Macroprudential tools, such as countercyclical capital buffers or loan-to-value ratios could be used to limit credit growth, though they may not be completely effective if some lenders and borrowers are out of the reach of regulatory and supervisory policies. Monetary policy could also be used to limit excessive credit growth in low credit periods, but may result in a broader credit restriction and a slowdown in current economic activity. Additional research is needed to evaluate the relative costs of using macroprudential policies and monetary policies to reduce credit, and inter-temporal tradeoff from reducing activity in the near-term for the potential benefit of reducing a crisis in the future.

References

Adrian, T. and N. Boyarchenko (2015). Intermediary leverage cycles and financial stability. Staff Report 567, Federal Reserve Bank of New York.

Adrian, T., D. Covitz, and J. N. Liang (2015). Financial stability monitoring. *Annual Review of Financial Economics 7*, 357–395.

Adrian, T. and H. S. Shin (2010). Liquidity and leverage. *Journal of Financial Intermediation 19*(3), 418–37.

Adrian, T. and H. S. Shin (2014). Procyclical leverage and value-at-risk. *Review of Financial Studies 27*(2), 373–403.

Aikman, D., M. Kiley, S. J. Lee, M. G. Palumbo, and M. Warusawitharana (2015). Mapping heat in the U.S. financial system. Finance and Economics Discussion Series 2015-59, Board of Governors of the Federal Reserve System.

Ajello, A., T. Laubach, D. López-Salido, and T. Nakata (2015). Financial stability and optimal interest-rate policy. Working Paper, Federal Reserve Board.

Anundsen, A. K., F. Hansen, K. Gerdrup, and K. Kragh-Srensen (2014). Bubbles and crises: The role of house prices and credit. Working Paper 14/2014, Norges Bank.

Bao, J., J. David, and S. Han (2015). The runnables. FEDS Notes, Federal Reserve Board.

Bassett, W., A. Daigle, R. Edge, and G. Kara (2015). Credit-to-gdp trends and gaps by lender- and credit-type. FEDS Notes, Federal Reserve Board.

Bernanke, B. and M. Gertler (1989). Agency costs, net worth, and business fluctuations. *American Economic Review 79*(1), 14–31.

Borio, C. and M. Drehmann (2009). Assessing the risk of banking crises - revisited. Working paper, BIS.

Borio, C. and P. Lowe (2002). Assessing the risk of banking crises. *BIS Quarterly Review 2002*, 43–54.

Borio, C. and P. Lowe (2004). Securing sustainable price stability: should credit come back from the wilderness? Working Paper 157, BIS.

Brunnermeier, M. and Y. Sannikov (2014). A macroeconomic model with a financial sector. *American Economic Review 104*(2), 379–421.

Cecchetti, S. G. (2008). Measuring the macroeconomic risks posed by asset price booms. In J. Y. Campbell (Ed.), *Asset Prices and Monetary Policy*, pp. 9–43. NBER Books.

Cheng, I.-H., S. Raina, and W. Xiong (2014). Wall street and the housing bubble. *American Economic Review 104*(9), 2797–2829.

Covitz, D., N. Liang, and G. A. Suarez (2013). The evolution of a financial crisis: Collapse of the asset-backed commercial paper market. *The Journal of Finance 68*(3), 815–848.

Danielsson, J., M. Valenzuela, and I. Zer (2015). Volatility, financial crises and minsky's hypothesis. VoxEU.org.

Diamond, D. W. and P. H. Dybvig (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy 91*(3), 401–19.

Dobridge, C. L. (2016). Fiscal stimulus and firms: A tale of two recessions. Finance and Economics Discussion Series 2016-013, Federal Reserve Board.

Dokko, J., B. Doyle, M. Kiley, J. Kim, S. Sherlund, J. Sim, and S. Van den Heuvel (2009). Monetary policy and the housing bubble. Finance and Economics Discussion Series 2009-49, Board of Governors of the Federal Reserve System.

Drehmann, M. and M. Juselius (2015). Leverage dynamics and the real burden of debt. Working Paper 501, BIS.

Edge, R. M. and R. R. Meisenzahl (2011). The unreliability of credit-to-GDP ratio gaps in real time: implications for countercyclical capital buffers. *International Journal of Central Banking 7*(4), 261–298.

Foote, C. L., K. S. Gerardi, and P. S. Willen (2012). Why did so many people make so many ex post bad decisions? the causes of the foreclosure crisis. Public Policy Discussion Paper 12-2, Federal Reserve Bank of Boston.

Geanakoplos, J. (2010). The leverage cycle. In *NBER Macroeconomics Annual 2009*, Volume 24, pp. 1–65. NBER.

Gertler, M. and N. Kiyotaki (2015). Banking, liquidity, and bank runs in an infinite horizon economy. *American Economic Review 105*(7), 2011–2043.

Giannone, D., M. Lenza, and G. E. Primiceri (2015, May). Prior Selection for Vector Autoregressions. *The Review of Economics and Statistics 2*(97), 436–451.

Gilchrist, S. and E. Zakrajek (2012). Credit spreads and business cycle fluctuations. *American Economic Review 102*(4), 1692–1720.

Gorton, G. and A. Metrick (2012). Getting up to speed on the financial crisis: A one-weekend-reader's guide. *Journal of Economic Literature 50*, 128–50.

Guerrieri, V. and G. Lorenzoni (2015). Credit crises, precautionary savings, and the liquidity trap. Working paper, University of Chicago.

Hancock, D., A. Lehnert, W. Passmore, and S. M. Sherlund (2006). The competitive effects of risk-based bank capital regulation: An example from U.S. mortgage markets. Finance and Economics Discussion Series 2006-46, Board of Governors of the Federal Reserve System.

Hanson, S. G. and J. C. Stein (2015). Monetary policy and long-term real rates. *Journal of Financial Economics 115*(3), 429–448.

Hubrich, K. and R. J. Tetlow (2012). Financial stress and economic dynamics: the transmission of crises. Finance and Economics Discussion Series 2012-82, Board of Governors of the Federal Reserve System.

Iacoviello, M. (2005). House prices, borrowing constraints and monetary policy in the business cycle. *American Economic Review 95*(3), 739–764.

Jordà, O., M. Schularick, and A. M. Taylor (2013). When credit bites back. *Journal of Money, Credit and Banking 45*(2), 3–28.

Jordà, O., M. Schularick, and A. M. Taylor (2015). Betting the house. *Journal of International Economics 96*(1), 2–18.

Korinek, A. and A. Simsek (2014, March). Liquidity trap and excessive leverage. NBER Working Paper 19970, National Bureau of Economic Research.

Krishnamurthy, A. and A. Vissing-Jorgensen (2015). The impact of treasury supply on financial sector lending and stability. *Journal of Financial Economics 118*, 571–600.

Laeven, L. and F. Valencia (2008). Systemic banking crises: A new database. IMF Working Paper WP/08/224, International Monetary Fund.

Litterman, R. B. (1979). Techniques of forecasting using vector autoregressions. Working Papers 115, Federal Reserve Bank of Minneapolis.

Litterman, R. B. (1980). A Bayesian Procedure for Forecasting with Vector Autoregression. Working papers, Massachusetts Institute of Technology.

Lopez-Salido, D., J. C. Stein, and E. Zakrajsek (2015). Credit-market sentiment and the business cycle. Finance and Economics Discussion Series 2015-028, Board of Governors of the Federal Reserve System.

McCabe, P. (2010). The cross section of money market fund risks and financial crises. Finance and Economics Discussion Series 2010-51, Board of Governors of the Federal Reserve System.

Metiu, N., B. Hilberg, and M. Gril (2014). Financial frictions and global spillovers. Discussion Paper 04/2015, Deutsche Bundesbank.

Mian, A. R., A. Sufi, and E. Verner (2015, September). Household debt and business cycles worldwide. NBER Working Paper 21581, National Bureau of Economic Research.

Passmore, W. (2005). The GSE implicit subsidy and the value of government ambiguity. Finance and Economics Discussion Series 2005-5, Federal Reserve Board.

Reinhart, C. M. and K. S. Rogoff (2009). The aftermath of financial crises. *American Economic Review 99*(2), 466–72.

Schularick, M. and A. M. Taylor (2012). Credit booms gone bust: Monetary policy, leverage cycles, and financial crises, 1870-2008. *American Economic Review 102*(2), 1029–61.

Stein, J. C. (2013a, October). Lean, clean, and in-between. At the National Bureau of Economic Research Conference: Lessons from the Financial Crisis for Monetary Policy, Boston, Massachusetts, October 18, 2013.

Stein, J. C. (2013b, February). Overheating in credit markets: origins, measurement and policy responses. Speech given at the "Restoring household financial stability after the great recession: Why household balance sheets matter" research symposium sponsored by the Federal Reserve Bank of St. Louis, St. Louis, Missouri, February 7.

Svensson, L. E. (2015). A simple cost-benefit analysis of using monetary policy for financial-stability purposes. In O. J. Blanchard, R. Rajan, K. S. Rogoff, and L. H. Summers (Eds.), *Rethinking Macro Policy III: Progress or Confusion*. International Monetary Fund.

Table 1: Sample statistics by vulnerability measure

		Unemployment rate				Fed funds	
	Num. of obs.	Level	Δ^a	Real GDP[b]	Inflation[b]	Level	Δ^a
Credit-to-GDP gap (CY)							
Low	89	6.73	−8.40	3.23	3.77	6.38	3.58
High	68	6.28	11.04	2.10	2.61	4.42	−18.28
Runnables-to-GDP gap (RUN)							
Low	68	7.00	−8.09	3.20	3.64	4.56	13.22
High	89	6.18	6.21	2.39	2.99	6.28	−20.48
Risk appetite index (ALLM)							
Low	78	7.12	12.19	1.68	3.10	4.95	−21.67
High	79	5.96	−12.00	3.79	3.44	6.10	9.70
Assets-to-Equity (AE)							
Low	87	6.97	4.67	2.15	3.08	5.72	−8.53
High	70	5.99	−5.76	3.48	3.51	5.30	−2.60

[a]Change in basis points.
[b]400× quarterly change in log level.

Table 2: Correlations of candidate vulnerability measures

	CY	*RUN*	*ALLM*	$-1\times EBP$	*AE*
CY	1.00				
RUN	0.63	1.00			
ALLM	0.10	0.23	1.00		
$-1\times EBP$	−0.34	−0.38	0.34	1.00	
AE	0.28	0.11	0.70	0.32	1.00

Table 3: Effective federal funds rate conditional on candidate vulnerability measures

	Quarters in which funds rate								
	Eased			*Unchanged*			*Tightened*		
	N	*Level*	Δ	*N*	*Level*	Δ	*N*	*Level*	Δ
Credit-to-GDP gap (CY)									
Low	17	7.32	-140	41	4.10	0	31	8.89	88
High	24	5.05	-82	29	3.42	-2	15	5.36	52
Runnables-to-GDP gap (RUN)									
Low	11	5.20	-102	36	2.59	-2	21	7.59	99
High	30	6.28	-107	34	5.11	0	25	7.86	57
Risk appetite index (ALLM)									
Low	25	5.60	-126	40	2.77	-4	13	10.44	124
High	16	6.60	-75	30	5.22	2	33	6.68	57
Assets-to-Equity (AE)									
Low	23	6.66	-126	42	3.16	-2	22	9.63	101
High	18	5.13	-80	28	4.80	0	24	6.00	53

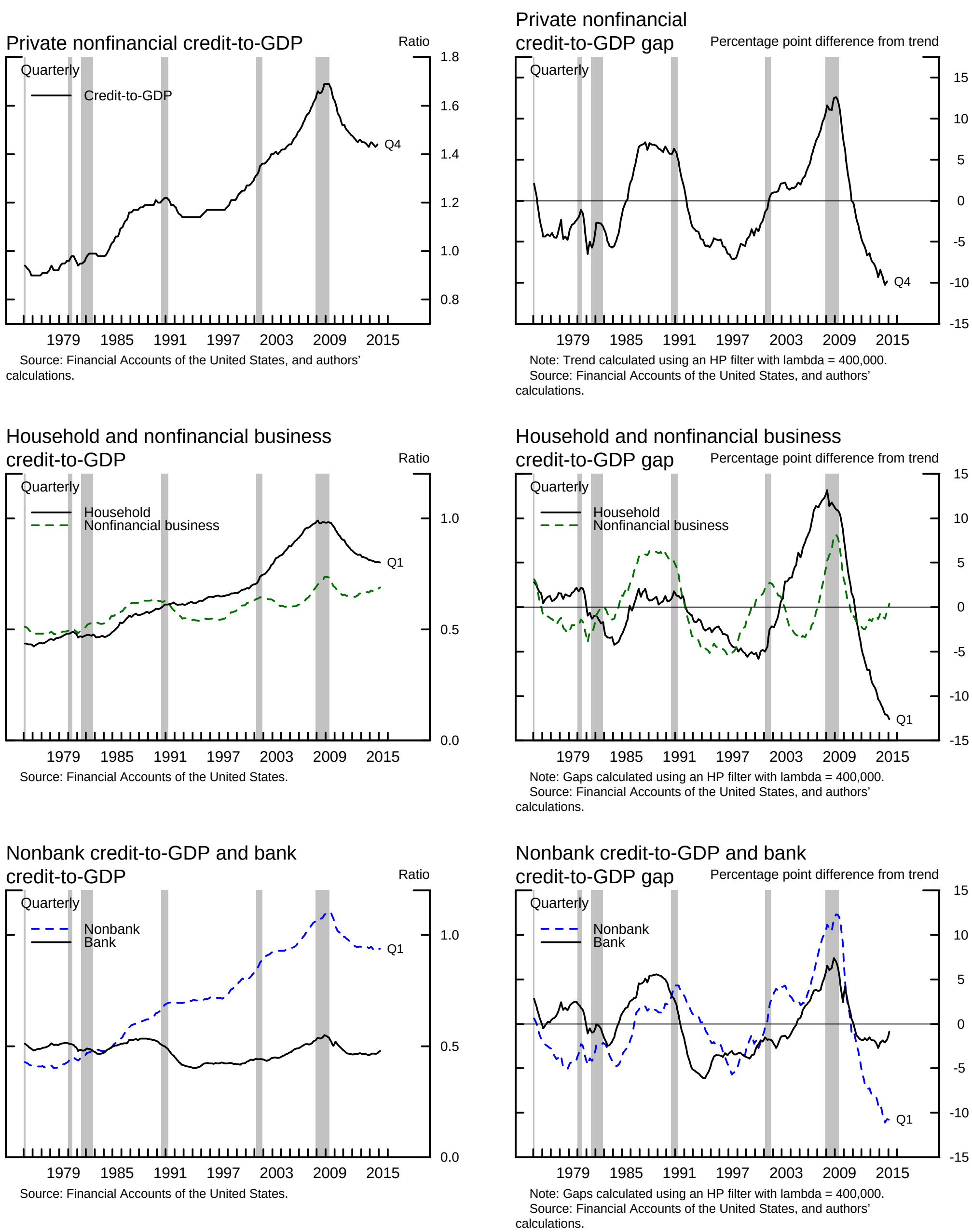
NOTE. Columns labeled "Eased" ("Tightened") refer to quarters in which the effective federal funds rate increased (decreased) 25 basis points or more; quarters in which the effective federal funds rate changed less than 25 basis points in absolute value are label-led "Unchanged".

Table 4: Results disaggregating the credit-to-GDP gap

Shock to	Real GDP response when vulnerability is: Low	High
Household vs. nonfinancial business debt		
Household debt	Expansion	Expansion
Business debt	Expansion[a]	Contraction
Property vs. nonproperty debt		
Property debt	Expansion	Expansion
Nonproperty debt	Contraction	Contraction
Bank vs. nonbank credit		
Bank credit	Expansion	Contraction[a]
Nonbank credit	Expansion	Contraction[a]

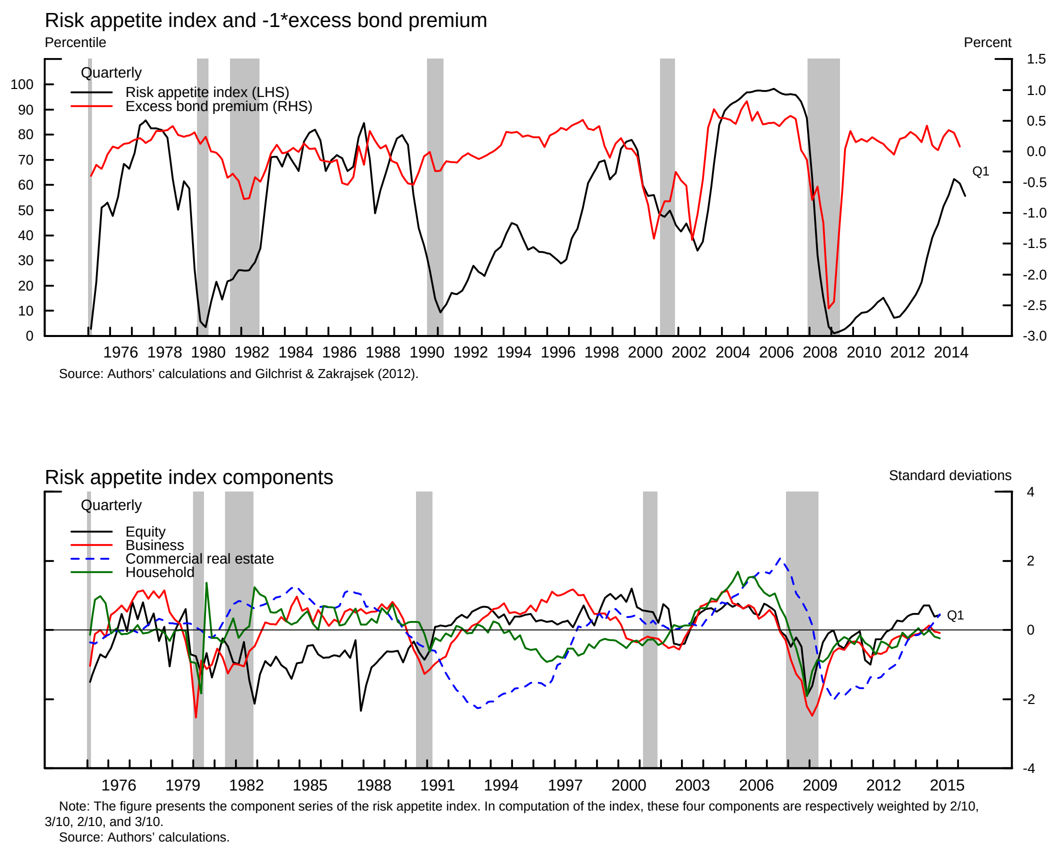
a Indicates response is not statistically different from zero.

Figure 1: Measures of the credit-to-GDP ratio



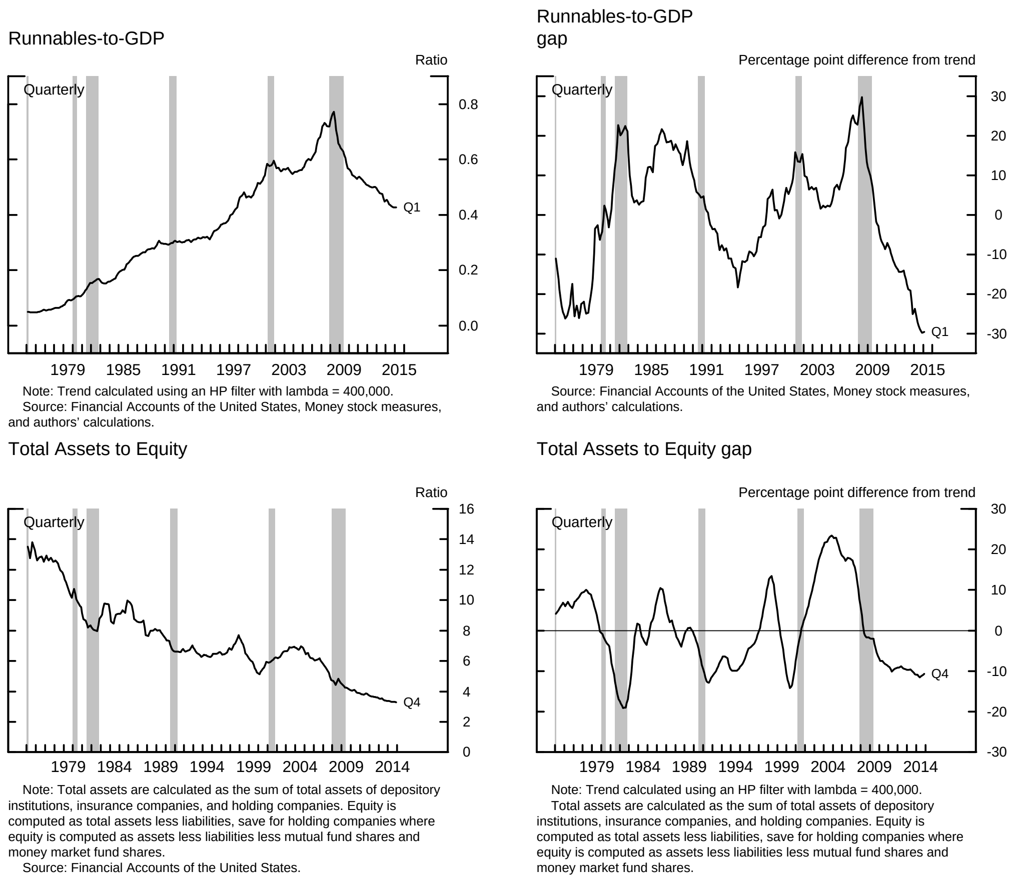
Notes: The six panels in the figure give various measures of the ratio of credit to GDP from 1975–2014 as a quarterly frequency with NBER recessions shaded as well as their associated gaps to a trend. The top left panel shows the ratio to GDP of private nonfinancial credit and the top right panel shows the associated gap. The middle left panel shows the ratio of household credit to GDP (solid line) and nonfinancial business (dashed line) and the middle right panel shows the associated gaps. The bottom left panel shows the ratio of bank credit to GDP (solid line) and nonbank credit (dashed line) and the bottom right panel shows the associated gaps.

Figure 2: Measures of risk appetite: ALLM, its components and the EBP



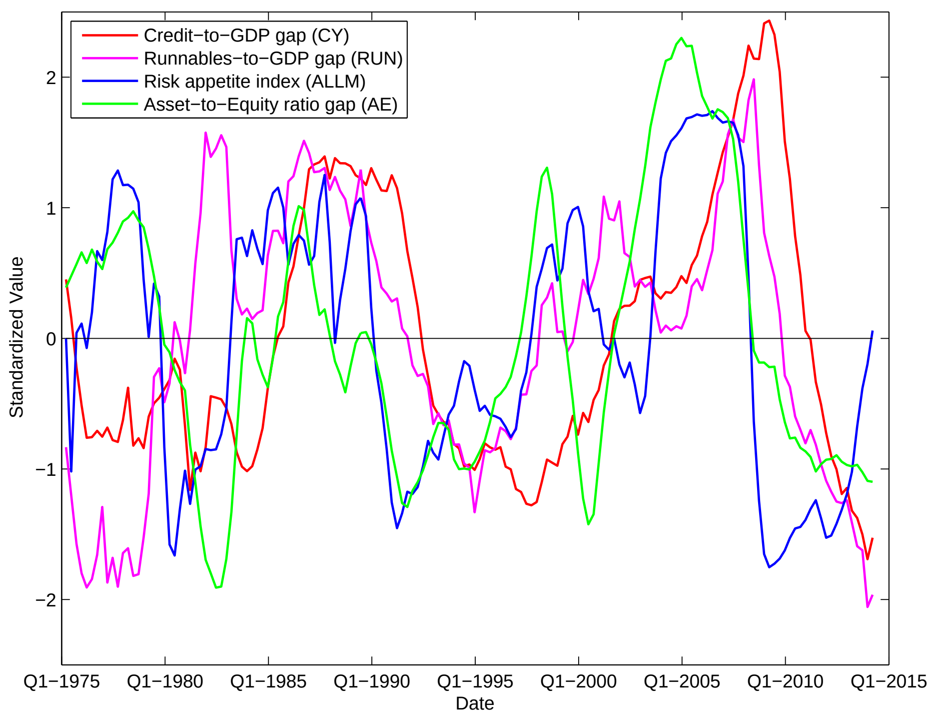
Notes: The two panels in the figure show various measures of risk appetite at a quarterly frequency from 1975–2014 with NBER recession shaded. The top panel shows ALLM (the black line) and the negative of the excess bond premium (EBP) (the red line). The bottom panel shows the four components of ALLM: equity (the black line), business (the red line), commercial real estate (the blue line) and household (the green line).

Figure 3: Financial Leverage and Runnables



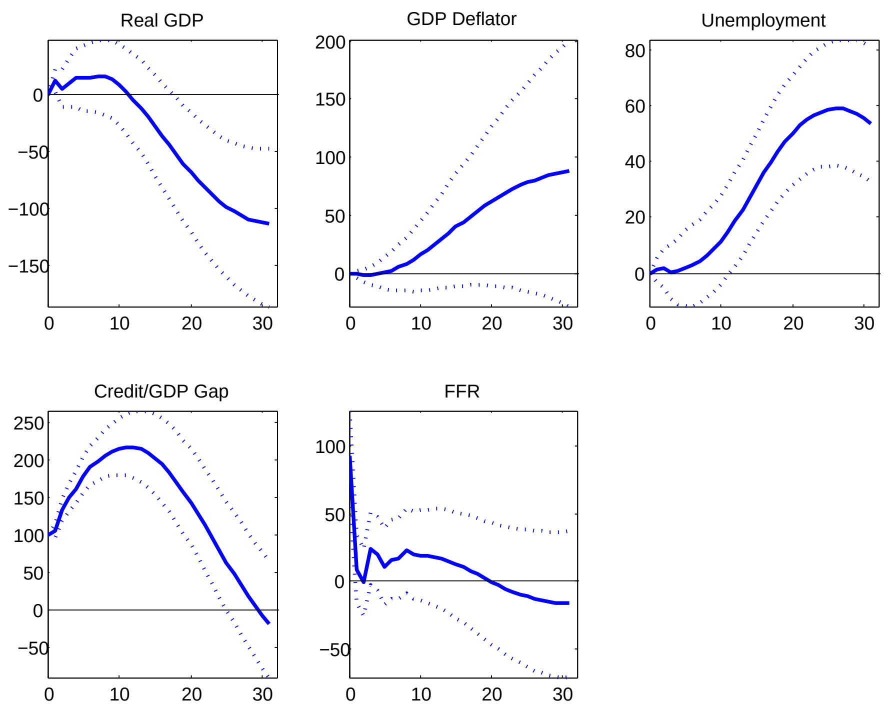
Notes: The four panels in the figure give various measures of the ratio of runnables to GDP and assets to equity from 1975–2014 as a quarterly frequency with NBER recessions shaded as well as their associated gaps to a trend. The top left panel shows the ratio of runnables to GDP and the top right panel shows its associated gap. The bottom left panel shows the ratio of assets to equity and the bottom right panel shows its associated gap.

Figure 4: Standardized Vulnerability Measures



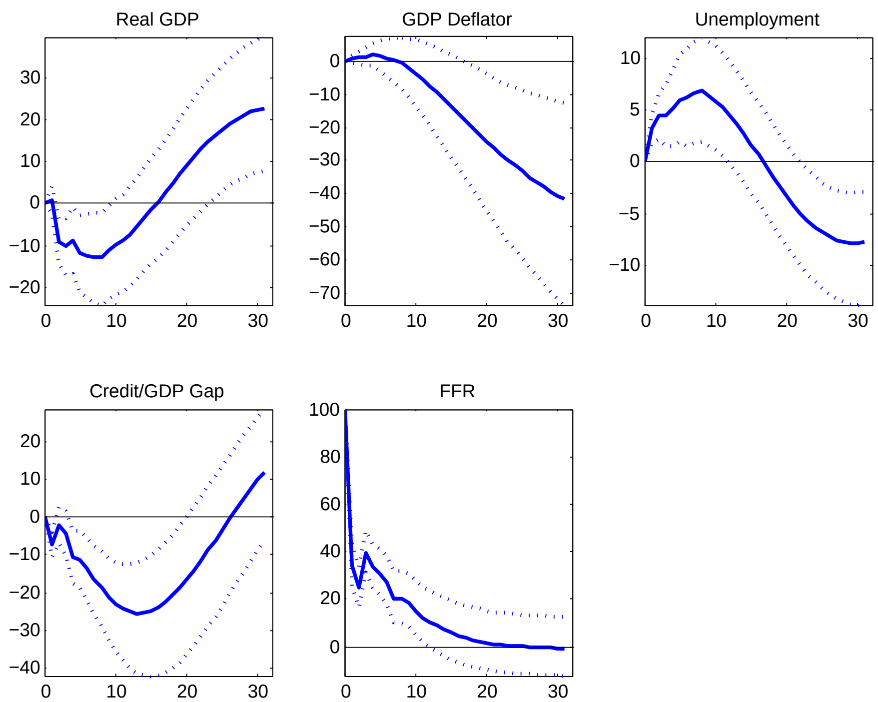
Notes: The figure plots the four potential vulnerabilities we consider; each has been normalized to have mean zero and a unit standard deviation. The series are plotted quarterly from 1975–2014. Plotted are the credit-to-GDP gap (red line), the runnables-to-GDP gap (magenta line), ALLM (blue line) and the asset-to-equity ratio gap (green line).

Figure 5: Credit shock when using credit-to-GDP as a measure of vulnerability (full sample)



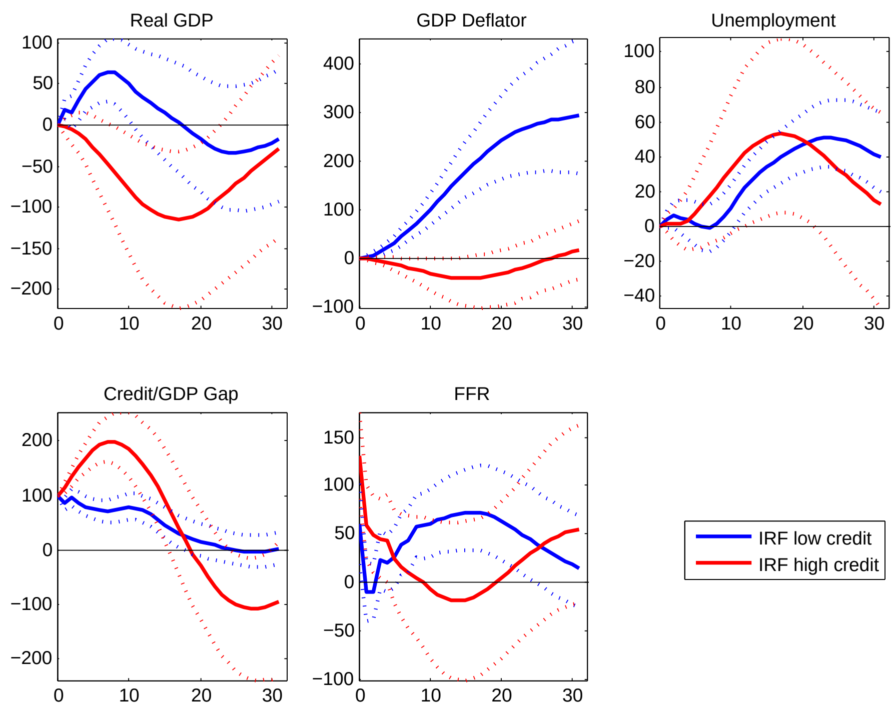
Notes: The solid line reports the median impulse response to a shock to the credit-to-GDP gap. The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 6: Monetary policy when using the credit-to-GDP gap as a measure of vulnerability (full sample)



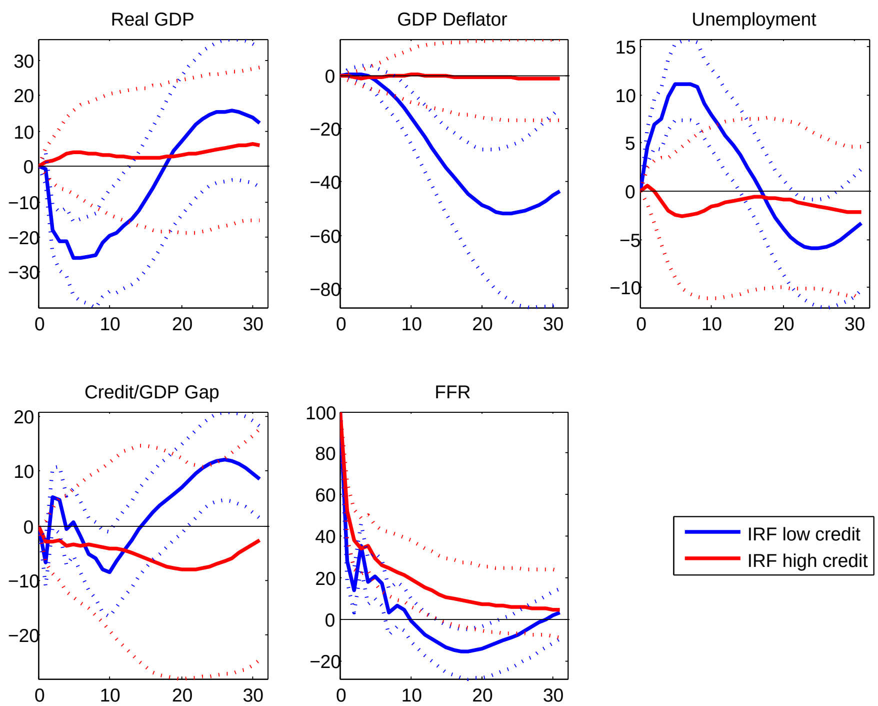
Notes: The solid line reports the median impulse response to a shock to the federal funds rate (FFR). The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 7: Credit shock when using credit-to-GDP as a measure of vulnerability



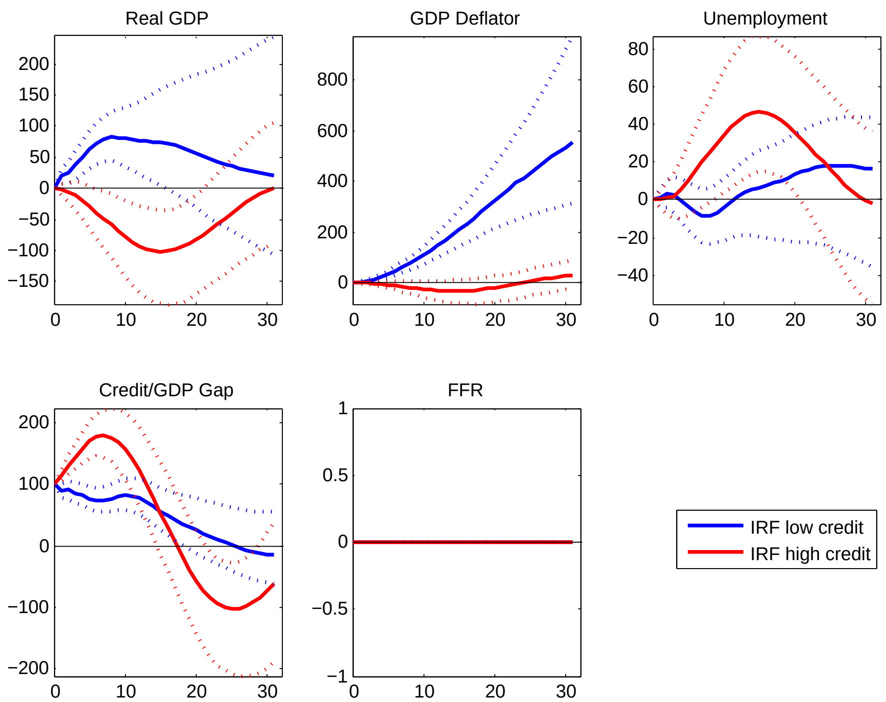
Notes: The solid blue line reports the median impulse response to a shock to the credit-to-GDP gap when the credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to the credit-to-GDP gap when the credit-to-GDP gap is above zero. The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 8: Monetary policy when using the credit-to-GDP gap as a measure of vulnerability



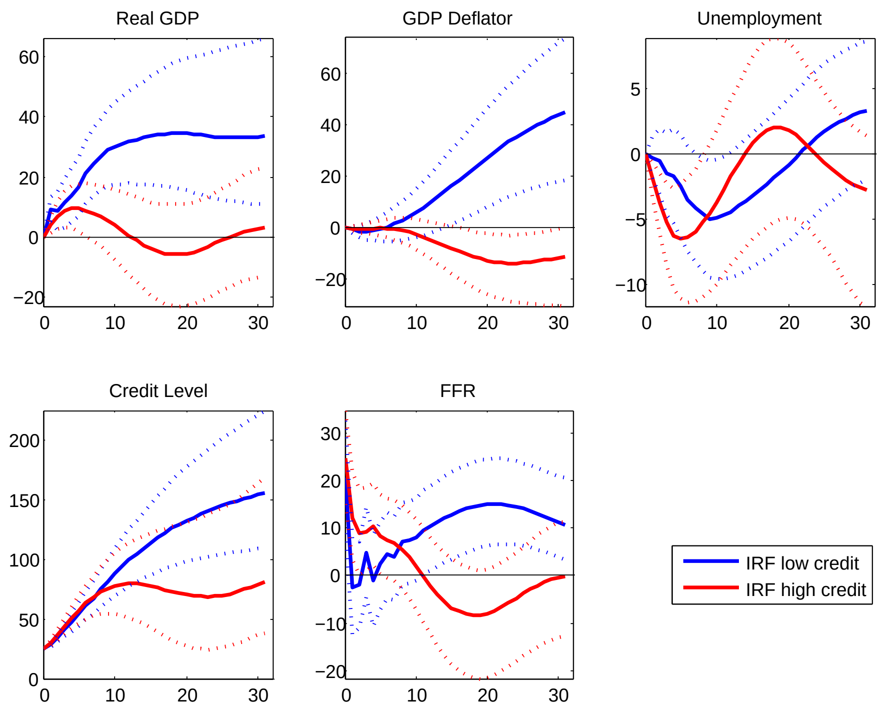
Notes: The solid blue line reports the median impulse response to a shock to the federal funds rate (FFR) when the credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to the FFR when the credit-to-GDP gap is above zero. The dotted lines report one standard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

Figure 9: Credit shock using the credit-to-GDP gap as a measure of vulnerability with monetary policy response shut off



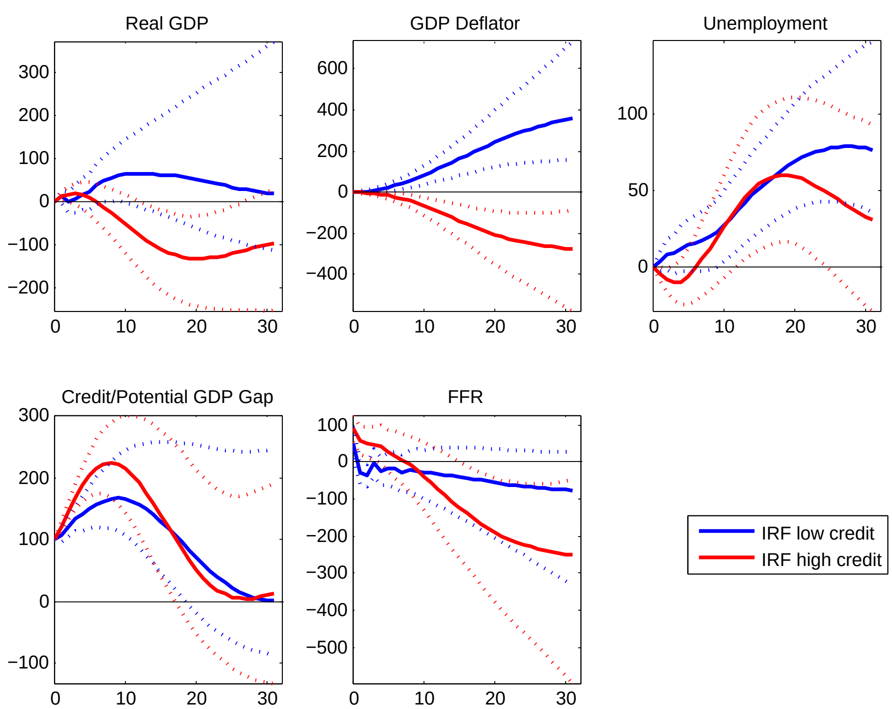
Notes: The solid blue line reports the median impulse response to a shock to the credit-to-GDP gap when the credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to the credit-to-GDP gap when the credit-to-GDP gap is above zero. The dotted lines report one standard deviation confidence intervals for each impulse response. We set to zero the coefficients that capture the reaction of the federal funds rate, shutting down the monetary policy reaction to a shock to the credit-to-GDP gap

Figure 10: Shock to the level of credit when using the credit-to-GDP gap as a measure of vulnerability



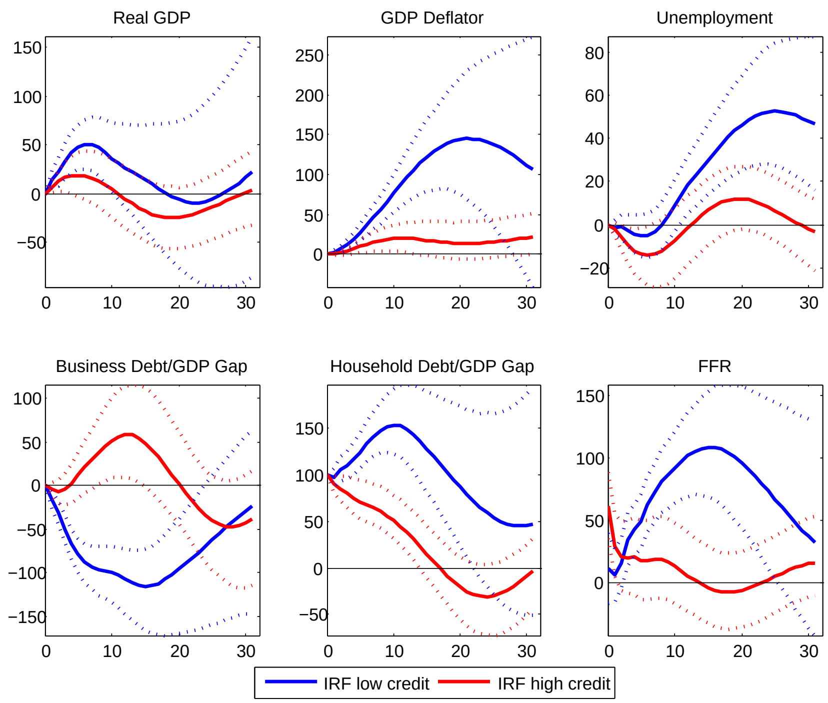
Notes: The solid blue line reports the median impulse response to a shock to the level of credit when the credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to the level of credit when the credit-to-GDP gap is above zero. The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 11: Credit shock using potential GDP to estimate the credit-to-GDP gap



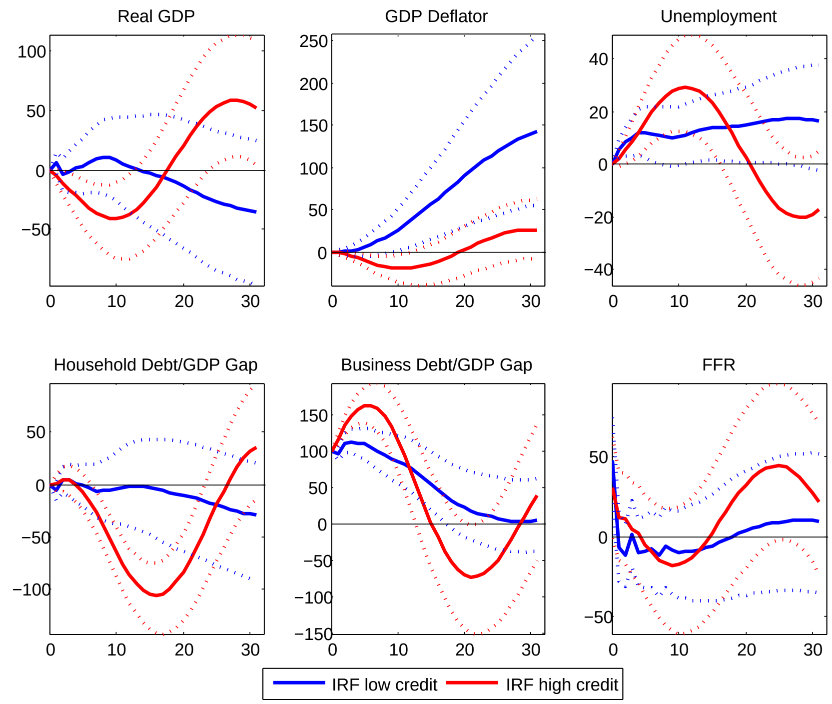
Notes: The solid blue line reports the median impulse response to a shock to the credit-to-potential GDP gap when the credit-to-potential GDP gap is below zero. The red solid line reports the median impulse response to a shock to the credit-to-potential GDP gap when the credit-to-potential GDP gap is above zero. The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 12: Response to a shock to household credit in a system with the credit-to-GDP gap disaggregated between household and business credit.



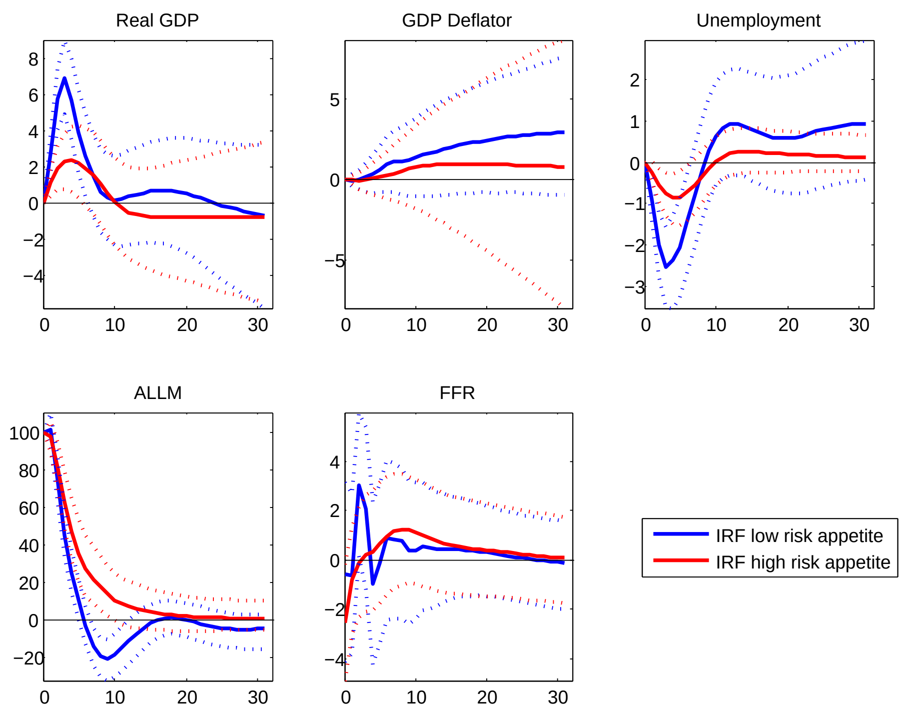
Notes: The solid blue line reports the median impulse response to a shock to household credit-to-GDP gap when total credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to household credit-to-GDP gap when total credit-to-GDP gap is above zero. The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 13: Response to a shock to business credit in a system with the credit-to-GDP gap disaggregated between household and business credit.



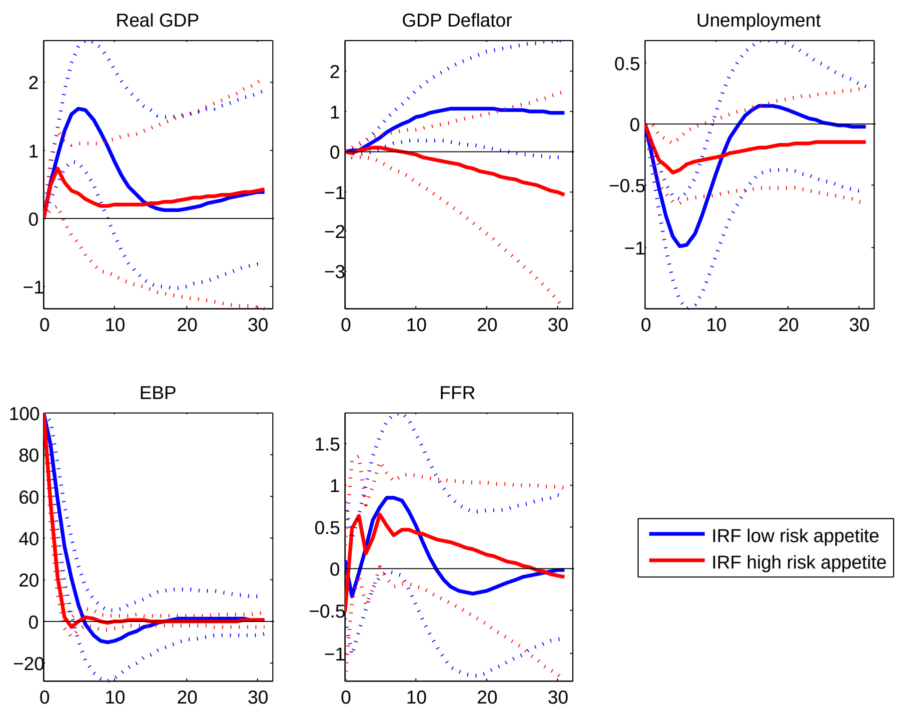
Notes: The solid blue line reports the median impulse response to a shock to nonfinancial business credit-to-GDP gap when ttotal credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to the nonfinancial business credit-to-GDP gap when total credit-to-GDP gap is above zero. The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 14: Impulse response to a shock to our constructed measure of risk appetite (ALLM)



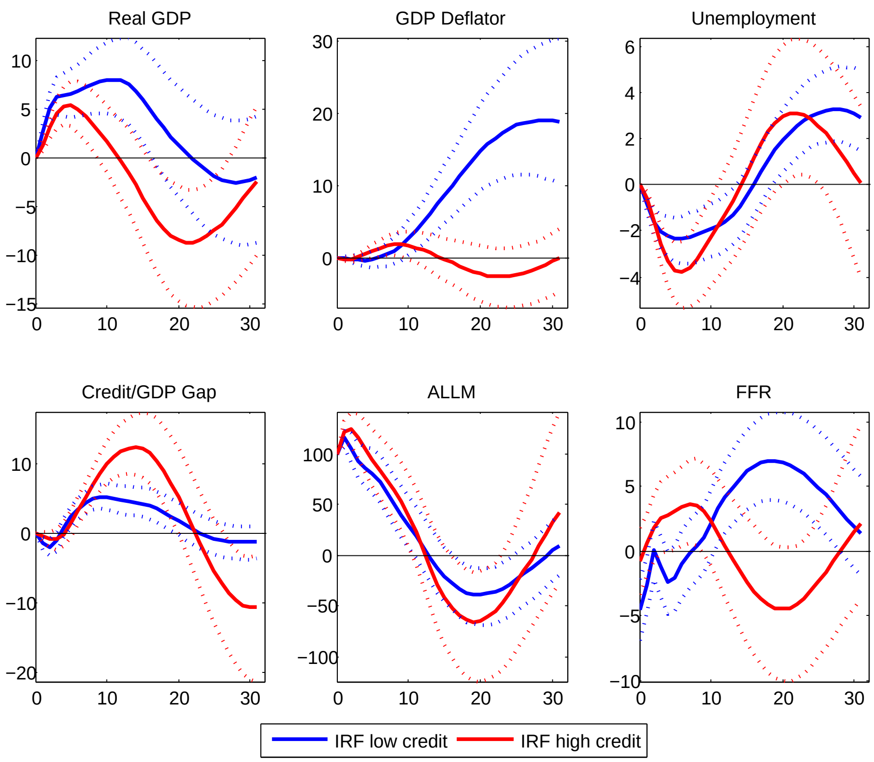
Notes: The solid blue line reports the median impulse response to a shock to our risk appetite measure (ALLM) when ALLM is below its historical mean. The red solid line reports the median impulse response to a shock to ALLM when ALLM is above its historical mean. The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 15: Impulse response to a shock to the negative excess bond premium (EBP)



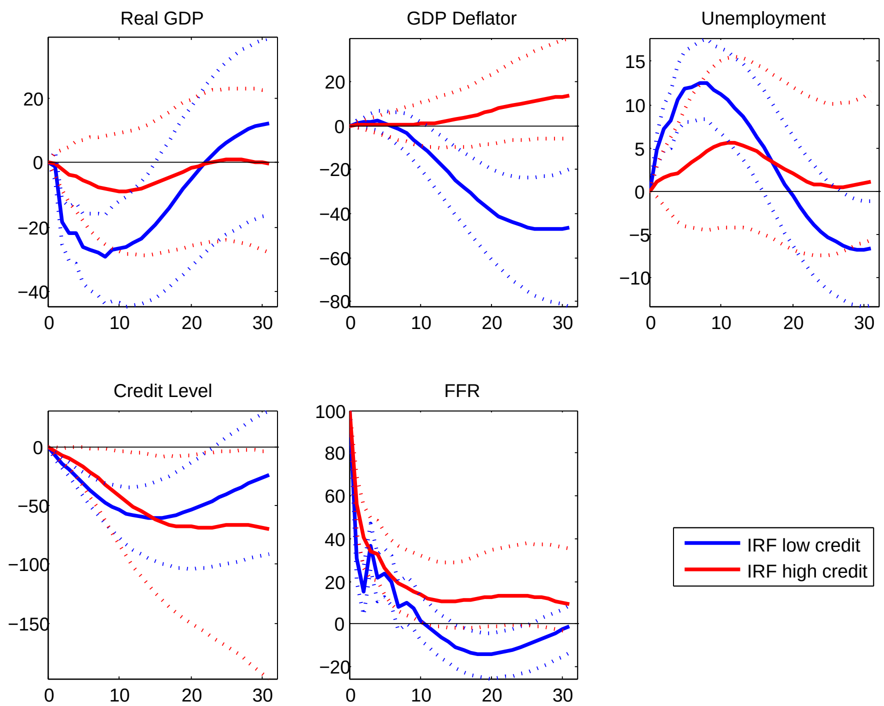
Notes: The solid blue line reports the median impulse response to a shock to the excess bond premium (EBP) when EBP is below its historical mean. The red solid line reports the median impulse response to a shock to EBP when EBP is above its historical mean. The dotted lines report one standard deviation confidence intervals for each impulse response.

Figure 16: Impulse responses to a shock to our constructed measure of risk appetite, ALLM (in a system containing the credit-to-GDP gap where high/low vulnerability periods are defined using the aggregate credit-to-GDP gap).



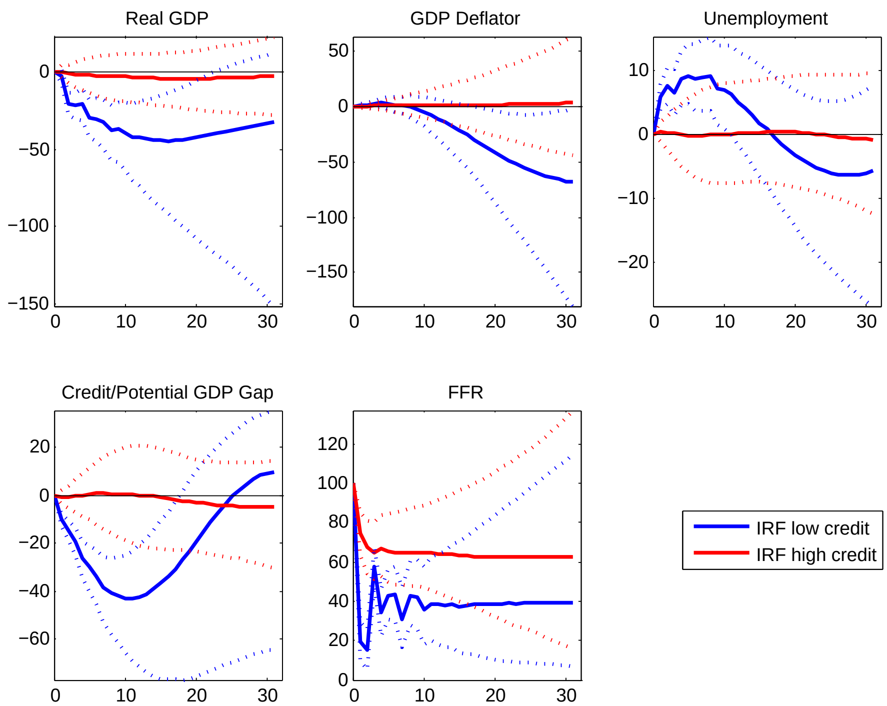
Notes: The solid blue line reports the median impulse response to a shock to our risk appetite measure (ALLM) when the credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to ALLM when the credit-to-GDP gap is above zero. The dotted line reports respective one standard deviation confidence intervals for the impulse response.

Figure 17: Shock to monetary policy in a system with the level of credit, using the credit-to-GDP gap as a measure of vulnerability



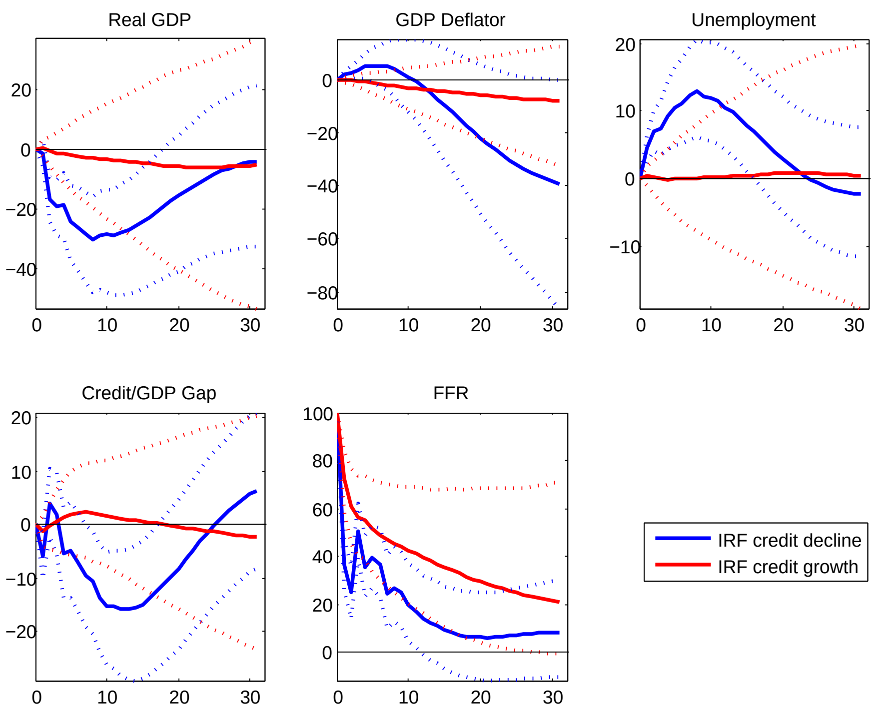
Notes: The solid blue line reports the median impulse response to a shock to the federal funds rate (FFR) when the credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to the FFR when the credit-to-GDP gap is above zero. The dotted lines report one standard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

Figure 18: Shock to monetary policy in a system with the level of credit-to-potential GDP gap, using the credit- to-potential GDP gap as a measure of vulnerability



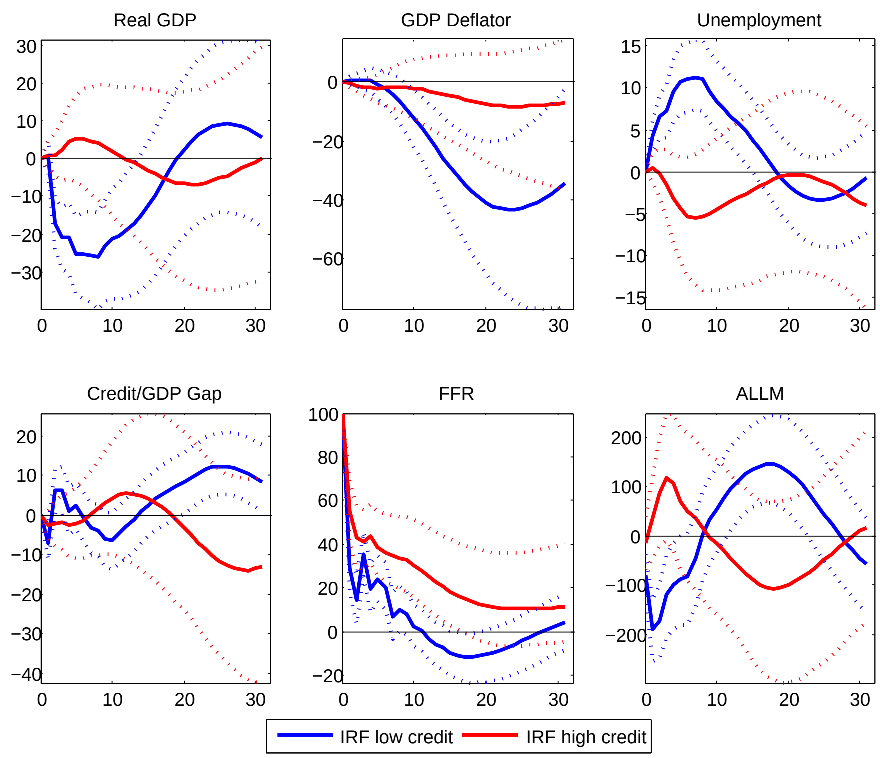
Notes: The solid blue line reports the median impulse response to a shock to the federal funds rate (FFR) when the credit-to-potential GDP gap is below zero. The red solid line reports the median impulse response to a shock to the FFR when the credit-to-potential GDP gap is above zero. The dotted lines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

Figure 19: Impulse response to a monetary policy shock when the sample is divided into periods of increasing credit-to-GDP gap (red lines) and decreasing credit-to-GDP gap (blue lines).



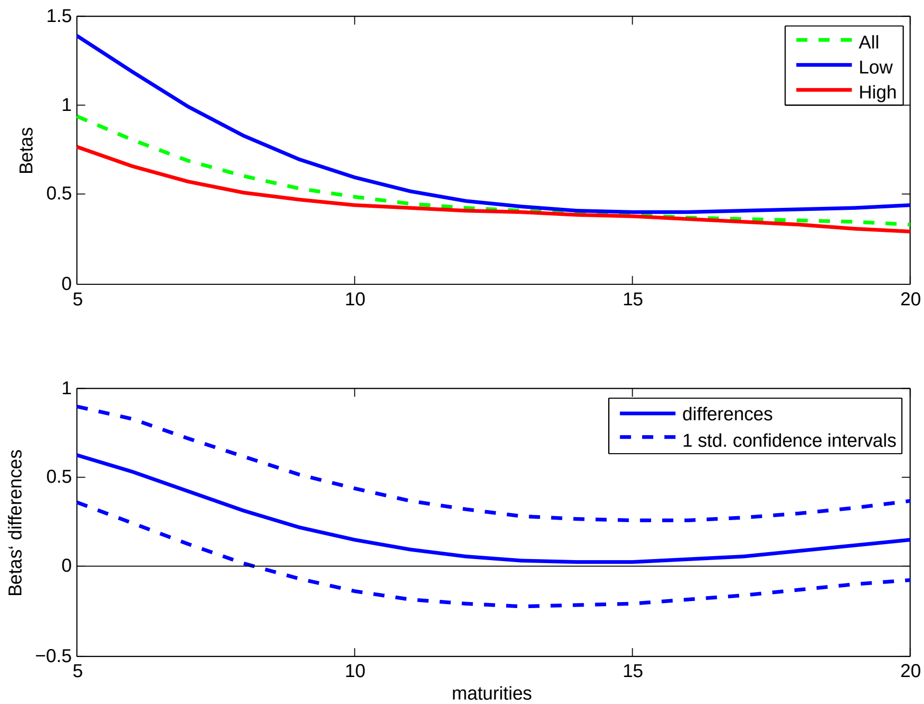
Notes: The solid blue line reports the median impulse response to a shock to the federal funds rate (FFR) when the credit-to-GDP gap is declining. The red solid line reports the median impulse response to a shock to the FFR when the credit-to-GDP gap is increasing. The dotted lines report one standard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

Figure 20: Impulse response to a monetary policy shock in a system containing our measure of risk appetite (ALLM) and the credit-to-GDP gap where high/low vulnerability periods are defined using the aggregate credit-to-GDP gap).



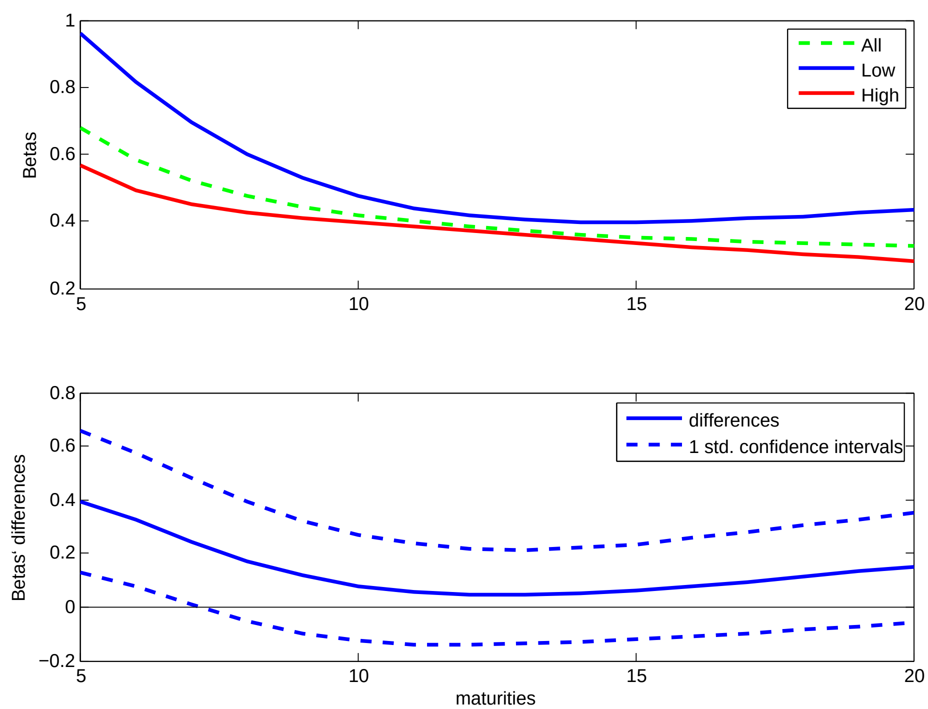
Notes: The solid blue line reports the median impulse response to a shock to the federal funds rate (FFR) when the credit-to-GDP gap is below zero. The red solid line reports the median impulse response to a shock to the FFR when the credit-to-GDP gap is above zero. The dotted lines report one standard deviation confidence intervals for the impulse response.

Figure 21: Change in nominal forward rates (%) from 1999 when the sample is divided into periods of high credit-to-GDP gap (red lines) and low credit-to-GDP gap (blue lines).



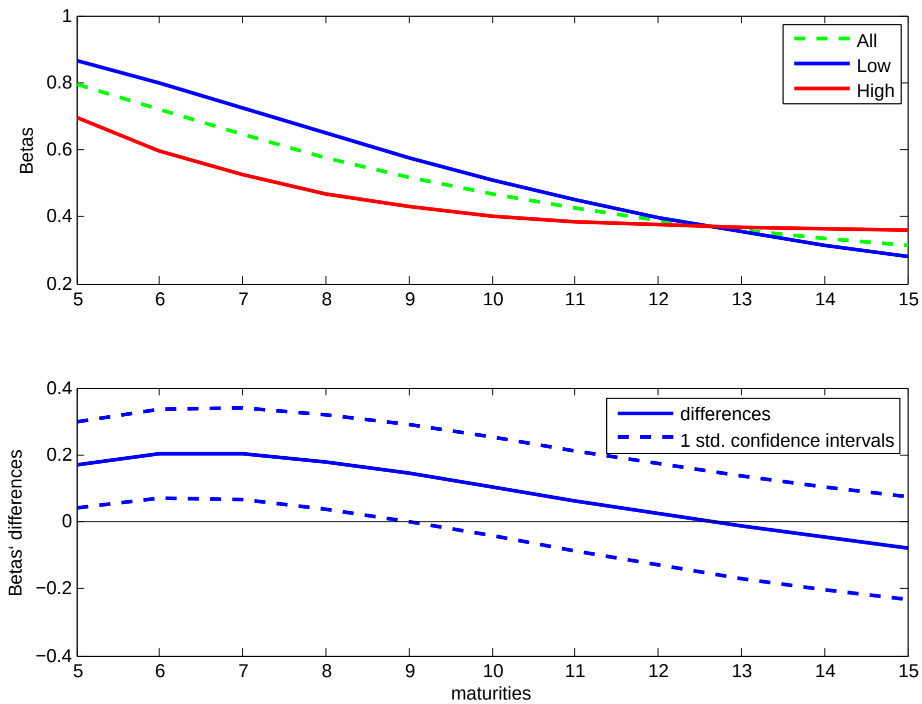
Notes: The solid blue line in the upper panel reports the daily change in nominal government bond forward rates, from 5 to 20-year maturity, due to a monetary policy shock, measured through the daily change in the 2-year bond yield, when the credit-to-GDP gap is below zero. The red solid line reports the daily change in nominal government bond forward rates due to a monetary policy shock when the credit-to-GDP gap is above zero. The dotted green line reports the daily change in nominal government bond forward rates due to a monetary policy shock on all the sample. In the lower panel, the solid blue line reports the difference between the changes in forwards when the credit-to-GDP is high versus when it is low. The dotted lines report 1 standard deviation confidence intervals (obtained through block bootstrap with blocks of dimension 8)

Figure 22: Change in real forward rates (%) from 1999 when the sample is divided into periods of high credit-to-GDP gap (red lines) and low credit-to-GDP gap (blue lines).



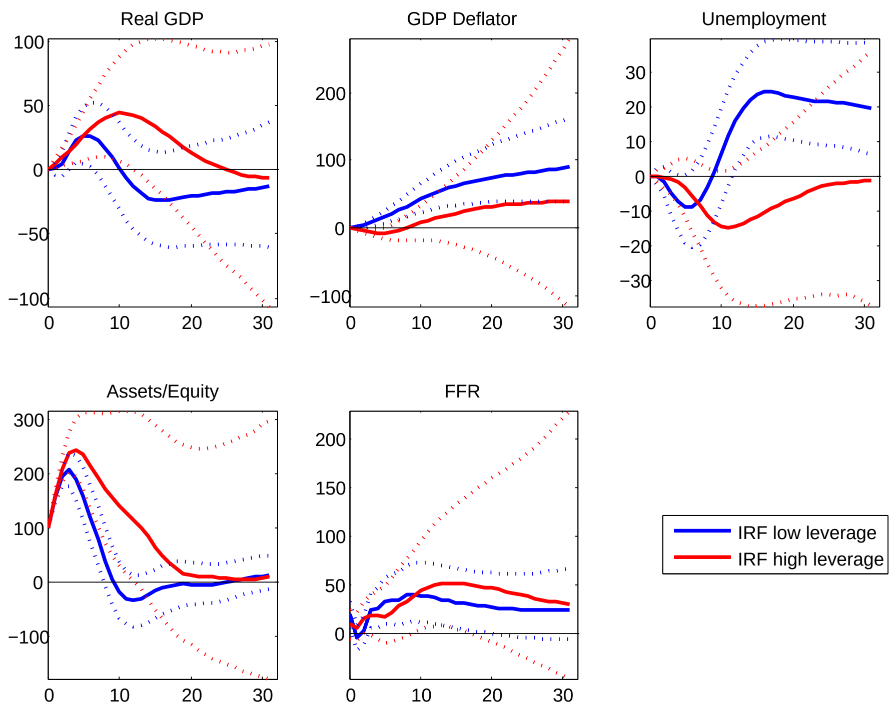
Notes: The solid blue line in the upper panel reports the daily change in real government bond forward rates, from 5 to 20-year maturity, due to a monetary policy shock, measured through the daily change in the 2-year bond yield, when the credit-to-GDP gap is below zero. The red solid line reports the daily change in real government bond forward rates due to a monetary policy shock when the credit-to-GDP gap is above zero. The dotted green line reports the daily change in real government bond forward rates due to a monetary policy shock on all the sample. In the lower panel, the solid blue line reports the difference between the changes in forwards when the credit-to-GDP is low versus when it is high. The dotted lines report 1 standard deviation confidence intervals (obtained through block bootstrap with blocks of dimension 8).

Figure 23: Change in nominal forward rates (%) from 1975 when the sample is divided into periods of high credit-to-GDP gap (red lines) and low credit-to-GDP gap (blue lines).



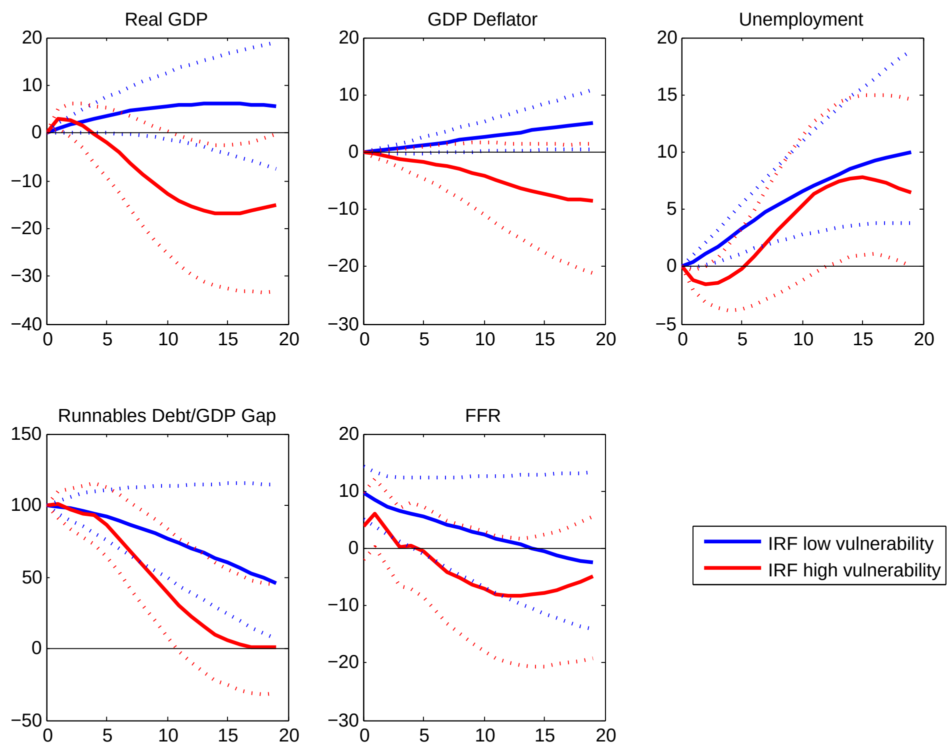
Notes: The solid blue line in the upper panel reports the daily change in nominal government bond forward rates, from 5 to 15-year maturity, due to a monetary policy shock, measured through the daily change in the 2-year bond yield, when the credit-to-GDP gap is below zero. The red solid line reports the daily change in nominal government bond forward rates due to a monetary policy shock when the credit-to-GDP gap is above zero. The dotted green line reports the daily change in nominal government bond forward rates due to a monetary policy shock on all the sample. In the lower panel, the solid blue line reports the difference between the changes in forwards when the credit-to-GDP is low versus when it is high. The dotted lines report 1 standard deviation confidence intervals (obtained through block bootstrap with blocks of dimension 8).

Figure 24: Impulse response to a shock to our leverage measure, AE



Notes: The solid blue line reports the median impulse response to a shock asset-to-equity gap when this gap is below zero. The red solid line reports the median impulse response to a shock to asset-to-equity gap when this gap is above zero. The dotted lines report one standard deviation confidence intervals for the impulse response.

Figure 25: Impulse response to a shock to runnable liabilities estimated over the sample after the Bankruptcy Amendments Act of 1984 (1985:Q1–2014:Q4).



Notes: The solid blue line reports the median impulse response to a shock to the runnable liabilities-to-GDP gap when this gap is below zero. The red solid line reports the median impulse response to a shock to the runnable liabilities-to-GDP gap when this gap is above zero. The dotted lines report one standard deviation confidence intervals for each impulse response.