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WORKING PAPER

Monetary Policy Transmission and Trade-offs in the United States: Old and New

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Monetary Policy Transmission and Trade-offs in the United States: Old and New*

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Abstract

This study shows that, in the United States, the effects of monetary policy on credit and housing markets have become considerably stronger relative to the impact on GDP since the mid-1980s, while the effects on inflation have become weaker. Macroeconomic stabilization through monetary policy may therefore have become associated with greater fluctuations in credit and housing markets, whereas stabilizing credit and house prices may have become less costly in terms of macroeconomic volatility. These changes in the aggregate impact of monetary policy can be explained by several important changes in the monetary transmission mechanism and in the composition of macroeconomic and credit aggregates. In particular, the stronger impact of monetary policy on credit is driven by a much higher responsiveness of mortgage credit and a larger share of mortgages in total credit since the 1980s.

JEL classification: E52

Keywords: monetary policy trade-offs, monetary transmission mechanism, inflation, credit, house prices.

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1 Introduction

The debate about monetary policy trade-offs has traditionally focused on the trade-off between inflation and output stabilization. The periodic occurrence of aggregate supply shocks, for example, forces central banks to choose between stabilizing output at the cost of higher inflation volatility and vice versa (e.g. Taylor (1979, 1998), Bernanke (2004)). A key parameter of this trade-off is the impact of monetary policy on real output relative to inflation, or the slope of the short-run Phillips Curve. In recent years, however, the focus has shifted to a potential trade-off between macroeconomic and financial stability. Specifically, in the wake of recurrent boom-bust cycles in credit and asset markets, there have been questions about the financial stability implications of an overly narrow focus of monetary policy on macroeconomic stability.[1] Some pundits have suggested that it may be desirable for monetary policy to lean systematically against the build up of financial imbalances, i.e. to pursue in such situations a tighter policy than would be indicated by macroeconomic conditions alone in order to counteract risks to financial stability (e.g. BIS (2014), Borio (2014), Adrian and Liang (2016), and Filardo and Rungcharoenkitkul (2016)). Sceptics have, however, argued that the macroeconomic costs of such a policy would exceed its benefits (e.g. IMF (2015), Svensson (2014, 2016, 2017)). In essence, the existence and form of a macro-financial stability trade-off crucially depends on the impact of monetary policy on output and inflation relative to that on financial variables such as the volume of credit and house prices.

In this paper, we examine the evolution of the old and new monetary policy trade-offs in the United States over the post-war period. The U.S. economy and financial system have indeed gone through substantial changes since the late 1970s that could have altered the transmission of monetary policy, and hence the monetary policy trade-offs.

The transition to a regime of low and stable inflation in the early 1980s, which has been linked to price-stability oriented monetary policy and globalization, has likely reduced the inflationary consequences of macroeconomic shocks, including monetary policy shocks. Better anchored inflation expectations and, as a consequence, smaller second-round effects via wages have mitigated the impact of shocks on prices and nominal wages as well as on the real economy.[2] Low inflation over the past couple of decades has also been associated

[1]Several papers have suggested that accommodative monetary policy to stimulate the macroeconomy played a key role in the build up of financial imbalances prior to the Great Financial Crisis, e.g. Taylor (2007, 2009), Iacoviello and Neri (2010) and Eickmeier and Hofmann (2013). Yet, the literature has not reached a consensus on this point as there are also studies suggesting otherwise, e.g. Del Negro and Otrok (2007), Jarociński and Smets (2008), and Dokko et al. (2009).

[2]Boivin et al. (2011) provide evidence of weaker effects of monetary policy shocks on inflation expectations since the mid-1980s. For evidence of reduced second-round effects following demand and supply shocks, see Hofmann et al. (2012). More generally, "good policy" in the form of price stability-oriented

with an apparent flattening of the empirical Phillips Curve (e.g. Roberts (2006), Benati (2007)), consistent with simple New Keynesian theories (Ball et al. (1988)) or inflation stabilizing monetary policy (Roberts (2006)). A flatter Phillips Curve would mean that any change in economic slack engineered by monetary policy would have smaller effects on inflation, altering the traditional output-inflation trade-off.

At the same time, several structural changes have probably strengthened monetary transmission through credit and housing markets, modifying the trade-off between financial and macroeconomic stability. Two such structural changes stand out. First, financial liberalization and innovation have progressed rapidly. This affected in particular the housing finance system with greater integration into capital markets through securitization, rising loan-to-value ratios and greater accessibility of mortgage equity. As a consequence, U.S. homeownership and the level of debt relative to income have increased significantly. In addition, the composition of debt has evolved, with a greater share of mortgages and a more important role of non-bank lenders as a result of securitization. These developments may have strengthened the effects of monetary policy on housing and mortgage markets through interest rate and balance-sheet channels (e.g. Iacoviello and Minetti (2003), and Calza et al. (2013)). Moreover, the greater role of non-banks in financial intermediation as a result of securitization could have strengthened the so-called risk-taking channel of monetary policy by increasing the exposure of the supply of credit to swings in investor risk appetite (Borio and Zhu (2008), IMF (2016)).[3]

Second, there has been a considerable tightening in the regulation of home building over the past decades, resulting in less elastic housing supply in several parts of the U.S. (Glaeser et al. (2005)). Less elastic housing supply means that any change in housing demand, such as through a loosening of monetary conditions, yields larger changes in house prices. With credit availability increasingly tied to housing collateral values as a result of the structural changes described in the previous paragraph, this would also translate into larger effects of monetary policy on credit markets.

Ultimately, whether and how the structural changes in the U.S. economy have altered the monetary transmission mechanism and the trade-offs faced by the Federal Reserve remains an empirical question. In the following, we assess this question using vector autoregressions (VARs) in the spirit of Christiano et al. (1996). More precisely, following

monetary policy is widely seen as an important factor behind the drop in macroeconomic volatility since the mid-1980s (the "Great Moderation"), see e.g. Bernanke (2004).

[3] Some regulatory reforms and financial innovations could have reduced the macroeconomic impact of monetary policy. For example, the phasing out of Regulation Q ceilings on deposit rates in the early 1980s could have weakened the bank lending channel of monetary transmission by mitigating deposit outflows that negatively impacted bank loan supply when interest rates increased (McCarthy and Peach (2002), Mertens (2008)). Similarly, securitization could have reduced the impact of monetary policy on economic activity by opening a new source of funding for banks (Estrella (2002)).

Boivin et al. (2011) and Den Haan and Sterk (2011), we estimate VARs over the sub-samples 1955-1979 and 1984-2008, reflecting the widespread notion that a change in macro-financial interrelations might have occurred sometime in the early 1980s.[4]

We first explore changes in the effects of monetary policy at the aggregate level. Our findings suggest that there have been substantial changes in monetary policy transmission and trade-offs since the mid-1980s:

- The effects of monetary policy on the price level relative to those on real GDP have become weaker, consistent with a flattening of the Phillips Curve documented in previous studies. Price stability-oriented monetary policy has therefore become more costly in terms of real output volatility. The decline in real GDP associated with a lowering of the price level through tighter monetary policy has, for example, (almost) doubled in the more recent sample period.
- At the same time, the effects of monetary policy on credit and house prices relative to those on the macroeconomy have become considerably stronger, which is a new result. Specifically, a monetary expansion that raises real GDP by 1% in the post-1984 sample period leads to a rise in real house prices and real credit by, respectively, 3.8% and 2.3%. Before the 1980s, this was only 0.1% and 0.9%, respectively. This suggests that macroeconomic stabilization by means of monetary policy has become associated with greater fluctuations in credit and housing markets. In reverse, stabilizing credit and house prices through monetary policy has become less costly in terms of macroeconomic volatility.

We also explore changes in the transmission mechanism at the disaggregated level by adding sub-aggregates from the national and financial accounts to the baseline VAR. This allows us to pin down what drives the aggregate results and to reveal relevant changes in the monetary transmission mechanism that are not visible at the aggregate level. We document several striking developments since the mid-1980s:

- Whereas the overall effect of monetary policy on real GDP was similar in both periods, there were significant changes in its composition. On the one hand, there was a weakening of the impact on GDP in the post-1984 sample period due to i) greater import leakage, and ii) less procyclical government expenditures. On the other hand, the effects of monetary policy on residential investment and noncorporate non-residential investment are considerably larger in the post-1984 period. A

[4] For the benchmark estimations, our sample period ends in 2008Q4, when the federal funds rate reached the zero lower bound. However, as we will show, extending the sample period beyond 2008 does not materially alter the results.

notable finding in this context is also that non-residential investment of noncorporates responded much more strongly than that of corporates in the second sample period, but not in the first. This implies that the larger effect of monetary policy on small as opposed to large firms' investment, established in numerous studies since the seminal contribution of Gertler and Gilchrist (1994), is only a post-1984 phenomenon.

- The stronger effects of monetary policy on aggregate credit since the mid-1980s is the result of i) an increased share of mortgage credit in total credit combined with ii) a substantial rise in the sensitivity of mortgages to monetary policy shocks over time. In the most recent sample period, monetary policy thus mainly affected credit to households and noncorporate firms, as these borrowers rely heavily on mortgage credit. This finding is essentially the other side of the medal of the greater effects of monetary policy on residential investment, noncorporate non-residential investment and house prices described above. In contrast, the impact on corporate debt has become much weaker, reflecting this sector's increasing ability to smooth monetary shocks through debt securities issuance and C&I loan drawdowns.
- When considering transmission to the counterparties to mortgage debt, we observe that a monetary tightening has a negative impact on bank and private non-bank mortgage lending, and that this effect has increased significantly over time. By contrast, for Agency- and GSE-related mortgage lending, a countercyclical response emerges in the more recent sample period, probably reflecting the public policy mandate and implicit government backing of these institutions. Monetary policy therefore seems to get into all the cracks of the housing finance system, except for the quasi-public part of it.

The remainder of the paper is organized as follows. Section 2 presents evidence on changes in the effects of monetary policy on the U.S. economy at the aggregate level, as well as a discussion of the implications for monetary policy trade-offs. Section 3 then explores differences in monetary transmission at the disaggregate level through the U.S. national and financial accounts. Finally, section 4 concludes.

2 Changes in the effects of monetary policy over time

2.1 Methodology

We start the analysis by assessing changes in the aggregate effects of U.S. monetary policy in the post-war period, following the large VAR-based literature on the macroeconomic and financial effects of an unexpected change in policy-controlled interest rates (e.g. Sims (1992), Bernanke and Mihov (1995), Leeper et al. (1996), Christiano et al. (1996, 1999), Peersman (2005), Eickmeier and Hofmann (2013)). Our baseline VAR has the following representation:

$$Y_t = c + A(L)Y_{t-1} + B\varepsilon_t. \tag{1}$$

where c is a matrix of constants and seasonal dummies and Y_t a vector of endogenous variables comprising: (i) log real GDP; (ii) the log GDP deflator; (iii) log commodity prices; (iv) log real house prices; (v) the effective federal funds rate; and (vi) log real credit to the private non-financial sector. Real GDP, the GDP deflator and the federal funds rate are taken from the FRED database. For commodity prices, we use the Thomson-Reuters commodity price index from Global Financial Data. Real house prices are obtained by deflating the nominal house price index from Shiller (2015) with the GDP deflator. For total credit to the private non-financial sector, we use a broad measure given by the sum of total credit market debt (debt securities and loans) and total trade credit liabilities (trade payables) of the household and non-financial business sectors from the Financial Accounts of the United States (Federal Reserve Statistical Release Z.1). Real credit is obtained by deflating nominal credit by the GDP deflator.

Real GDP and the GDP deflator form the macroeconomic block of the VAR model. We use the GDP deflator as our aggregate price level measure, but the results are similar when we use the CPI or the personal consumption deflator. The commodity price index is included in order to eliminate a price puzzle, i.e. a counter-intuitive increase in the price level after a monetary contraction that plagues many VAR studies.[5] House prices and credit are included to capture developments in the housing and credit market. Finally, the federal funds rate is the monetary policy instrument.

The monetary policy shock is identified using a standard Cholesky identification scheme with the variables ordered as they are listed above. Monetary policy shocks are, therefore, assumed to have no contemporaneous impact on output, the price level and real house prices, but could affect real credit flows immediately. The policy interest rate, in turn, is assumed to respond to contemporaneous changes in all variables except for credit. This ordering, which is consistent with previous studies (e.g. Christiano et al. (1996)), reflects the notion that real output and goods and house prices are rather sluggish and do not

[5] Sims (1992) first demonstrated this anomaly and showed that it tended to disappear when commodity prices were included in the VAR. He suggested that this was the case because the Federal Reserve responded to commodity prices as an indicator of future inflation, so that its omission from the model would produce a price reaction that mainly reflected the response of monetary policy to perceived future inflation. Subsequent studies have, however, questioned the success of this modelling strategy (e.g. Den Haan and Sterk (2011)). In our case, the inclusion of the commodity price index and total credit was instrumental in eliminating a price puzzle in the first sample period, while there was generally no price puzzle in the second sample period.

respond within a quarter to a monetary impulses, while financial flows are more flexible so that an immediate response cannot be ruled out. That said, changing the ordering of the variables hardly affects the results.[6]

We estimate the VAR in (log) levels with four lags, which allows to account for implicit cointegrating relationships in the data (Sims et al. (1990)). This is particularly important in the present case, given the evidence of a long-run relationship between credit and house prices that significantly influences the dynamics of both variables (see Goodhart and Hofmann (2007, 2008), Hofmann (2003, 2004)).[7] It is also for this reason that we prefer the use of log-level VARs throughout the analysis (also in the disaggregate analysis that follows later), as opposed to a factor-augmented VAR (FAVAR) as developed by Bernanke et al. (2005) where all variables are required to be stationary. In our application, that would mean estimating the model in first differences and thus losing any long-run relationship in the dynamics of the system.

We assess changes in the effects of monetary policy by estimating the VAR over two sample periods. The first is 1955Q1-1979Q4 and the second is 1984Q1-2008Q4. The sample split follows Boivin et al. (2011), and Den Haan and Sterk (2011). It is motivated by the observation that there is widespread notion that a structural change in macro-financial dynamics in general and in the transmission of monetary policy more specifically has probably occurred in the early 1980s, but that the exact date of the break cannot be identified with any precision. For this reason, several years of data around the likely break are excluded from the estimation, i.e. the years 1980-1983. We also exclude the post-2008 period because policy rates were at the zero lower bound and additional monetary policy stimulus was provided through other policy tools, in particular large-scale asset purchases, rendering the policy rate an inaccurate summary indicator of the monetary policy stance. That said, running our VAR also including data for the period 2009-2015, and using a so-called shadow federal funds rate as the proxy policy instrument over this period, yields very similar results, as discussed in more detail below.[8]

[6] Note that alternative approaches to identifying monetary policy shocks, such as the narrative approach by Romer and Romer (2004) or the high-frequency approach by Gertler and Karadi (2015), cannot be used for our analysis because the required data are not available for the early part of our sample period.

[7] Johansen cointegration tests indeed indicate the existence of long-run relationships between the variables in the VAR. A more explicit analysis of these long-run relationships is, however, not necessary for our purpose and is also beyond the scope of this paper.

[8] As an alternative, we could have estimated a VAR model with time-varying parameters (TVPs) and stochastic volatility in the spirit of Primiceri (2005). While TVP-VARs are sophisticated tools to model time-variation in the transmission mechanism, they suffer however from the drawback that only few variables can be included in the model, which significantly restricts the modelling and analysis of the transmission mechanism.

2.2 Empirical results

Figure 1 shows the median impulse responses of each variable to a monetary policy shock over horizons of up to 32 quarters, together with 16th and 84th percentiles error bands. The impulse responses for the early sample period are in red (dotted lines), and those for the recent sample period in blue (full line with grey error bands). The peak effects on the key variables are reported in Table 1. In order to eliminate the effect of a change in the size of the interest rate innovation on the impulse responses, we re-scale the size of the shock to be the same in both sample periods, i.e. to 100 basis points. Note that there may still be differences in the monetary policy reaction function that could distort a direct comparison of the impulse responses in both periods. For this reason, it is more appropriate to focus on changes over time in *relative* terms, i.e. to assess whether the effects on some variables have increased or decreased relative to the effects on others, which implicitly accounts for changes in the reaction function.

Comparing the sub-sample results, we observe several significant changes in the effects of monetary policy. Specifically, the effects of monetary policy on the price level have become relatively weaker over time compared to the effects on real GDP. In the first period, the price level displays a very persistent response, with a peak drop of 1.3% after 32 quarters, the maximum horizon we consider for the impulse responses. This compares with a trough in the aggregate price level response of -0.5% after 18 quarters in the second period. We also note that there is a more delayed impact on real GDP in the second sample period, with the trough reached after 12 instead of 7 quarters. The maximum decline is somewhat smaller in the second period (1.4% versus 1.7% in the first period), but the error bands overlap.

By contrast, the dynamic effects of monetary policy on house prices and credit, as well as on commodity prices, have become much larger over time compared to those on output and the price level. While real house prices do essentially not respond in the first period, they drop by 5.6% after 12 quarters in the recent sample period. The impact on credit has more than doubled in size and has become more persistent, i.e. real credit falls by up to 1.5% after 8 quarters in the first period and by up to 3.3% after 18 quarters in the second.[9] Finally, we also find a stronger negative response of commodity prices over time. They do not respond significantly in the first sample, but drop by more than 9% after 13 quarters in the second period.

Our result that the macroeconomic effects of monetary policy have become more de-

[9] Before decreasing, credit displays a small significant short-term increase after a monetary tightening in both periods. This initial increase is not a puzzle as it reflects increases in some components of credit that non-financial corporations in particular can draw on when monetary conditions tighten, as will be discussed and analysed in more detail later on.

layed since the early 1980s is in line with the existing literature, e.g. Boivin et al. (2011), Den Haan and Sterk (2011), and Belongia and Ireland (2016). However, while we find only a modest decline in the impact of monetary policy shocks on real output, earlier studies found a substantial reduction with effects that are even not significantly different from zero in the more recent period. This discrepancy probably reflects differences in the treatment of credit and house prices. While we have included these two variables in the VAR to capture potentially important channels of monetary transmission, preceding studies have usually not considered these two variables in conjunction. Indeed, as shown in Hofmann and Peersman (2017), VARs that do not include credit and house prices obtain much smaller effects of monetary policy shocks on output, i.e. there appears to be a missing variables problem when credit and house prices are omitted from the VAR. Both variables seem to have become key factors in the transmission of monetary policy in the U.S. since the mid-1980s. On the other hand, the finding of a substantially stronger impact of monetary policy on house prices and credit is a new result.[10] It is consistent with the cross-county evidence reported by Iacoviello and Minetti (2003), and Calza et al. (2013) that house prices and credit respond significantly more strongly in countries with more liberalized financial systems.

The results are broadly robust to an extension of the sample to the post-2008 period. Since end 2008, the federal funds rate was at its zero lower bound and additional monetary policy stimulus was provided through other policy tools, in particular large-scale asset purchases. As a consequence, the policy rate does not represent an accurate summary indicator of the monetary policy stance over this period, which complicates the analysis of monetary transmission in a VAR setup like ours. Following Belongia and Ireland (2016), we re-run the VAR including data for the period 2009-2015 and use the Wu and Xia (2016) shadow federal funds rate as the policy instrument over this period.[11] The appendix shows that this exercise yields very similar results for the baseline VAR. The peak effects are slightly smaller, which might reflect reduced policy effectiveness in the recovery from the Great Financial Crisis, as suggested e.g. in BIS (2015). That said, since the macro-financial dynamics that unfolded in the wake of the crisis were as unusual as the policy responses that they triggered, we prefer to proceed in the following disaggregated analysis

[10]The response pattern of house prices over the second sample period is comparable to those reported by previous VAR-based studies estimated over a similar sample period, e.g. Jarocinski and Smets (2008), Del Negro and Otrok (2007), Eickmeier and Hofmann (2013), and Bjørnland and Jacobsen (2013). The omission of house prices in the analysis probably explains why Den Haan and Sterk (2011) do not find a notable change in the response of household credit since the mid-1980s.

[11]Wu and Xia (2016) use a non-linear term structure model to estimate a shadow federal funds rate that would capture conventional and unconventional monetary policy since 2009. Reflecting the range of expansionary unconventional monetary policy measures deployed by the Federal Reserve over this period, the shadow rate was in negative territory over this period, falling as low as -3%.

with the model estimated up to 2008.[12]

2.3 Implications for monetary policy trade-offs

In the previous sub-section, we showed that monetary policy has a more subdued impact on the price level since the mid-1980s, while the response of real output has quantitatively not changed much. In addition, we documented a substantially stronger impact on house prices and credit. As a consequence of these changes in monetary transmission, the monetary policy trade-offs between output and price stability, on the one hand, and between macroeconomic and financial stability, on the other hand, have evolved considerably. The weaker impact of monetary policy on the price level compared to real output reflects a flattening of the Phillips Curve over the recent period, which renders price stability-oriented policy more cumbersome and more costly in real output terms. This is illustrated in Table 2, which reports for both periods the peak effects on real GDP induced by a monetary policy shock that shifts the price level by one percent (at its peak). The table reveals that reducing the GDP deflator by one percent comes at the cost of a 1.3% fall in real output in the first period, compared to a drop of 2.4% in the second. Conversely, a monetary policy-induced one percent output stimulus is associated with a 0.8% and 0.4% rise in the price level in respectively the first and second period. Thus, maintaining price stability has become more costly in real output terms, while output stabilization gives rise to less inflation volatility compared to the pre-1980s period.

On the other hand, the stronger impact on credit and house prices relative to GDP suggests that stimulating or reducing output and inflation in the short run now comes at the cost of greater credit and house price swings than in the past. Specifically, as can be seen in Table 2, engineering a one percent impact on real GDP through monetary policy involved essentially no effect on house prices and a 0.9% peak change in real credit in the first period. However, in the second period, the maximum changes in house prices and credit are respectively 3.7% and 2.2%. The rise in house price and real credit volatility is even stronger for a monetary stimulus that exerts a one percent increase in the price level, i.e. house prices and credit increase by respectively 0.4% and 1.2% in the early sample period, compared to 8.8% and 5.2%, respectively, in the more recent sample period.

Another implication of the changes in transmission is that monetary policy has apparently become a more effective tool for leaning against house price and credit booms, owing to the greater interest rate sensitivity of these variables and the weaker macroeconomic

[12] The results of the disaggregated estimations over the sample extended beyond 2008 and using the shadow rate as the policy instrument are qualitatively similar to those reported in the following sections and are available upon request.

repercussions of monetary policy shocks. A monetary policy-induced one percent impact on real credit implied a maximum effect on real GDP of more than 1% in the first period, but of less than 0.5% in recent times. Furthermore, the output costs of lowering real house prices by one percent have declined from 3.2% to 0.3%. That said, a fully-fledged analysis of the net benefits of leaning-against-the-wind policies is beyond the scope of this paper.[13] The main point to take away here is that monetary transmission in the U.S. seems to have changed in a way that increases the net benefits of a leaning against the wind policy, and that normative studies in this respect should take this into account.[14]

3 What explains the changes? A disaggregated analysis

In this section, we delve deeper into the economic and financial accounts in order to assess how monetary policy is transmitted through the components of output and credit. This exercise serves two purposes: (i) understanding which underlying factors are driving the changes in monetary transmission at the aggregate level; and (ii) shedding light on potentially policy-relevant changes in monetary transmission at the disaggregated level.

3.1 Methodology

We analyze monetary transmission through the economic and financial accounts based on an extended version of our baseline VAR. Specifically, we re-estimate the VAR separately including output and credit sub-aggregates, akin to the VAR analysis of transmission through the flow of funds of Christiano et al (1996). However, in order to keep the identified monetary policy shock invariant to the inclusion of additional variables in the system, we assume, following Peersman and Smets (2001), that each additional variable does not affect the variables that were included in the benchmark VAR. Formally, we estimate a block exogenous system of the form:

$$\begin{bmatrix} Y_t \\ z_t \end{bmatrix} = c + \begin{bmatrix} A(L) & 0 \\ C(L) & D(L) \end{bmatrix} \begin{bmatrix} Y_{t-1} \\ z_{t-1} \end{bmatrix} + \begin{bmatrix} B & 0 \\ b & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^Y \\ \varepsilon_t^z \end{bmatrix} \tag{2}$$

[13] Whether leaning against the wind is beneficial depends on a number of factors. One is the impact of monetary policy on the financial cycle, in particular on house prices and credit as leading indicators of financial crisis (see e.g. Schularick and Taylor (2012), Drehmann and Juselius (2013), Gertler and Hofmann (2016)). Other factors include the ultimate effect of a policy-induced drop in house prices and credit on crisis probability and how this longer term benefit compares with the short-term output costs of tighter policy. See Svensson (2014, 2016, 2017), Adrian and Liang (2016), and Filardo and Rungcharoenkitkul (2016) for quantitative analyses in this respect.

[14] Note also that, in the second period, the effect of a contractionary monetary policy shock on the credit-to-GDP ratio is initially positive but then turns significantly negative, with a drop of up to 2% over medium-term horizons. In the first period, by contrast, the response of the credit-to-GDP ratio is positive in the short term and then becomes insignificant at longer horizons.

where Y is the vector of endogenous variables defined as before and z is the additional variable included in the model, which is assumed to be affected by, but not to affect itself the variables in Y.[15] We use the same Cholesky ordering as in (2) to identify the monetary policy shock. For the additional variables added to the VAR, we further impose impact restrictions that are consistent with the Cholesky scheme used to identify the monetary policy shock. Specifically, for real GDP components we impose the restriction that they do not respond to the monetary policy shock on impact ($b = 0$), consistent with the identifying restrictions on aggregate real GDP. Credit sub-aggregates are allowed to react on impact to a change in monetary conditions (b unrestricted), just like aggregate credit.

The interest rate elasticity of an economic or financial aggregate to an interest rate shock can be written as $\frac{\partial Y}{\partial i} = \sum_j \frac{\partial Y_j}{\partial i}\frac{Y_j}{Y}$ where $\frac{\partial Y}{\partial i}$ is the interest rate elasticity of the aggregate, $\frac{\partial Y_j}{\partial i}$ is the interest rate elasticity of a sub-component and $\frac{Y_j}{Y}$ is the component's share in the aggregate. A rise in the interest rate elasticity of the aggregate could therefore be due to two factors: an increase in the interest rate elasticity of one or several sub-components, or a rise in the share of more interest rate sensitive sub-components. Thus, the evolution over time of both the sub-aggregates' shares and interest rate elasticities needs to be assessed to understand the changes at the aggregate level documented in the previous section.

3.2 Transmission to GDP components

We start by exploring changes in transmission to the macroeconomy, i.e. to the components of aggregate GDP, using data from the National Income and Product Accounts (NIPA) provided by the Bureau of Economic Analysis. Table 3 shows for the two sample periods the average share of components in total GDP, the elasticity of the components at the peak real GDP response (i.e. after 7 quarters in the first period and after 12 quarters in the second period) and the estimated contribution of the components to the peak real GDP response measured as the component's elasticity weighted by its share. Note that the sum of the contributions does not exactly equal the elasticity of aggregate GDP because the components' elasticities are estimated without restrictions, whereas all components are implicitly restricted to have the same dynamics in the aggregate estimations. Figure 2 reports the full impulse responses of the components.

The results show that the interest rate elasticity of private consumption and private residential investment has increased over time, but that this increase has been offset by

[15] Note that the sub-aggregates are anyway part of the aggregates included in the benchmark VAR. The results are generally also very similar when we include the additional variable in the main block of the VAR model. These results are available upon request.

greater import leakage and, to a lesser extent, a less procyclical reaction of government expenditures. The contribution of personal consumption to the peak decline in real GDP has gone up from -0.85 to -1.10 percentage points, while that of residential investment has almost doubled from -0.17 to -0.32 percentage points. Figure 2 shows that residential investment is the GDP component that responds fastest and strongest to a monetary impulse. The peak impact of monetary policy has more than doubled between the two periods, from -4.5% after 4 quarters in the first period to -9.5% after 9 quarters in the second. The elasticity and contribution of non-residential investment has essentially not changed between the two periods.

In spite of the stronger impact of monetary policy on private GDP components, aggregate GDP responds more weakly in the second period because of a considerable change in the dynamic reaction of imports and government expenditures. Real imports have become more interest rate sensitive over time. At the same time, the import-to-GDP ratio has more than doubled between the two periods. As a result, the countervailing contribution of imports to the peak drop in GDP has increased from 0.17 percentage points to 0.66 percentage points (Table 3).[16] The larger negative contributions of the private GDP components in the second period are therefore largely offset by greater import leakage. At the same time, the contribution of government expenditures has decreased from -0.15 percentage points to zero, reflecting a less procyclical reaction pattern (Table 3). While government expenditures drop significantly in the wake of a monetary tightening in the first period, they decrease only slightly immediately after the shock, and then move back to baseline when the private GDP components contract in the second period (Figure 2). Only after 16 quarters, when private GDP is recovering, there is a significant fall in government expenditures.

A striking additional observation from the analysis of the NIPA aggregates is a substantial change in the relative effects of monetary policy impulses on the corporate and the noncorporate business sectors, shown in Figure 3. While the peak impact on corporate non-residential investment has not changed over time, noncorporate non-residential investment responds much more strongly in the second period, with a peak impact that increases almost fourfold to -8.5%. As a consequence, noncorporate investment has become more sensitive to monetary policy than corporate investment, while the opposite was the case before the 1980s. This change in the response of corporate and noncorporate investment reflects significant changes in the impact of monetary policy on the two sectors' funding conditions, as will be shown in the following sub-section.

[16] The contribution of real exports to the peak response of GDP is in both periods very small, in the second even zero (Table 3). The impulse reponses (Figure 2) show that exports display a somewhat counterintuitive initial increase in the second period. As it has no effect on the main results of the analysis, we do not further explore this "puzzle" here.

3.3 Transmission to credit components

We next assess the drivers of the change in the response of aggregate credit. This assessment is based on a breakdown of total credit by instrument and borrowing sector provided by the Financial Accounts of the United States (Federal Reserve Statistical Release Z.1). To this end, we analyze monetary transmission through the two broad instrument categories of total non-financial sector private credit (mortgages versus other credit),[17] and through the three non-financial private borrowing sectors (households, corporates and noncorporates). The results are presented in the same way as in the previous sub-section. Table 4 shows for the two sample periods the average component shares in total credit, the component elasticity at the peak response of total credit (after 8 quarters in the first period and after 18 quarters in the second period) and the contribution of the components to the peak response of total credit measured as the component's elasticity at the peak credit response weighted by its share (noting again that the sum of contributions does not equal the aggregate credit elasticity due to the unrestricted nature of the estimations). Figure 4 displays the full impulse responses of the credit components.

The results reveal that the stronger reaction of credit in the second period is mainly driven by a significant increase in the interest rate elasticity of mortgage debt and a larger share of mortgages in total credit (Table 4). Since the bulk of mortgage loans is to households and noncorporate firms, it is the stronger response of these two borrowing sectors' mortgages that makes the largest contribution to the increase in the aggregate credit response to a monetary policy shock over time. In particular, the contribution of household mortgages to the peak credit response has increased from -0.3 to -1.2 percentage points, while that of noncorporate mortgages has gone up from -0.1 to -0.7 percentage points. Overall, the contribution of mortgage credit to the peak response of total credit has increased from -0.5 percentage points to -2.3 percentage points (Table 4).

The elasticity and contribution of other (non-mortgage) types of credit has essentially not changed between the two periods. There have, however, been notable changes at the borrowing sector level. Specifically, the interest rate elasticity of non-mortgage debt of households and noncorporates has increased, while that of corporates has decreased (see Table 4). Figure 4 shows that the response of corporate non-mortgage debt is in fact never significantly negative in the second period. It significantly increases for up to 8 quarters after a monetary tightening and then returns to baseline. This compares to a short-lived initial increase and a significant drop after 6 quarters in the first period.

[17] Non-mortgage credit comprises consumer credit and trade credit for the household sector, C&I loans, trade credit and debt securities for the corporarate sector and C&I loans and trade credit for the noncorporate sector.

The differential impact of monetary policy on mortgage and non-mortgage debt translates into disparate total debt responses at the borrowing sectors' level, reflecting the significant cross-sectoral differences in funding structure. While the response of household and noncorporate debt is considerably stronger in the second period, that of corporate debt is much weaker (Figure 4). This result reflects primarily differences in the weight of mortgage debt across the three borrowing sectors, as documented in Table 4. Since the bulk of household and noncorporate debt takes the form of mortgages, the changes in the mortgage responses are also reflected in these sectors' aggregate debt reactions. By contrast, since mortgages account only for a small share of corporate debt, the significant increase in interest rate sensitivity that is also registered for corporate mortgages does not feed through to the sector's aggregate debt impulse response.

These results also suggest that the notion that small (noncorporate) firms are more strongly impacted by monetary policy than large (corporate) firms because they are more financially constrained (Gertler and Gilchrist (1994), Christiano et al. (1996)) holds true only since the 1980s. In fact, corporate debt contracted more than noncorporate debt in the first sample period. For the second period, we find that noncorporate debt declines strongly, while corporate borrowing escapes essentially unscathed from a monetary tightening. This is the consequence of the ability of corporates to raise funds through many channels, including debt securities, while noncorporates are fully impacted by the stronger transmission of monetary policy through mortgage credit. This difference in the impact of monetary policy on the funding situation of the two sectors is also reflected in the reaction of their non-residential investment, as discussed in the previous sub-section.

3.4 Transmission to mortgage debt counterparties

The significant rise in mortgage debt since the 1970s was accompanied by major changes on the counterparty side. In particular, an increasing share of mortgages has been held by non-banks, driven by the expansion of the securitization.[18] This raises the question whether the increased sensitivity of mortgages to monetary policy is linked to this change on the counterparty side, as securitized and retained mortgages could be affected by different types of transmission channels.[19]

[18] For a review of the factors that have promoted the rise of securitization, see Gorton and Metrick (2012).

[19] Peersman and Wagner (2015) develop a model where retained loans are driven by a bank risk-taking channel (Adrian and Shin (2010)), while securitized loans are affected by a search-for-yield (or investor risk-taking) channel (Borio and Zhu (2008)). A monetary tightening increases the costs for banks of retaining loans on their balance sheets and reduces investor demand for securitized assets, implying that both retained and securitized mortgages should be negatively affected by a monetary tightening, but probably to different extents.

Against this background, we assess the transmission of monetary policy through the mortgage finance sector, distinguishing between four different types of mortgage debt counterparties: (i) direct mortgage holdings of banks (or retained bank mortgages);[20] (ii) direct mortgage holdings of non-banks (in particular of the household sector, the life-insurance sector and finance companies); (iii) mortgages securitized by GSEs; and (iv) mortgages securitized by private-label ABS issuers. The latter can only be analyzed for the second period as these entities came into existence only in the 1980s. We organize the results in the same way as in the two previous sub-sections. Table 5 shows for the two sample periods the average component shares in total mortgages, the elasticities at the peak response of total mortgages (after 7 quarters in the first period and after 20 quarters in the second period) and the contributions to the peak response measured as the component elasticity at the peak weighted by the component share. We note also here that the sum of the contributions does not have to, and in fact does not, equal the aggregate mortgage elasticity due to the unrestricted estimations of the individual components. Figure 5 shows the full impulse responses.

The results reveal that the stronger response of mortgage credit over time reflects at the counterparty level larger interest rate elasticities of the direct mortgage holdings of banks and non-banks, although their combined share in total mortgages has dropped from almost 95% to less than 60% between the two periods (Table 5). The interest rate elasticity of retained bank mortgages has increased significantly (Figure 5), possibly reflecting a strengthening of the bank risk-taking channel linked to the dynamics of house prices and corresponding collateral values (Peersman and Wagner (2015)). Non-bank direct mortgage holdings display a persistent fall in the second period, compared to a slight, albeit not statistically significant increase in the earlier period.

Securitized mortgages, in contrast, do not contribute to the larger response of aggregate mortgages (Table 5). Figure 5 further shows that securitized mortgages display reaction patterns that differ starkly from those of aggregate mortgages. Moreover, the responses of GSE- and private-label securitized mortgages also differs considerably, suggesting that an expansion of the shadow banking sector after a monetary tightening as documented in Den Haan and Sterk (2011) and Nelson et al. (2015) probably conceals important differences in the monetary impact within that sector.[21] Specifically, we find that private-

[20] Banks are private depository institutions (PDIs), i.e. commercial banks and credit unions.

[21] Den Haan and Sterk (2011) find that, over the period from the mid-1980s to the Great Financial Crisis, non-bank holdings of mortgages increased after a monetary policy shock while those directly held by banks fell. Nelson et al. (2015) find that the financial assets of banks decline after a contractionary monetary policy shock, while those of the shadow bank sector expand, reflecting in their view the increased demand of banks for collateralizable mortgage-backed securities. Den Haan and Sterk (2011) and Nelson et al. (2015) interpret their findings as a potentially worrisome expansion of the less-regulated non-bank (or shadow bank) sector in the wake of a monetary tightening.

label securitized mortgages decline sharply and rapidly after a monetary tightening in the second sample period (by up to 7% after 3 quarters), possibly indicating a strong investor risk-taking channel at work for these securities. This negative response persists up until 16 quarters after the shock, but the share of the private-label securitized mortgages in total mortgages is too small (7.3%) to have a notable impact on the aggregate mortgage reaction.

By contrast, GSE-securitized mortgages display a countercyclical response, which has become more pronounced over time.[22] In the first period, GSE-securitized mortgages slightly increase initially after the shock, and fall significantly only after 16 quarters, i.e. when retained bank mortgages have returned to baseline. In the second period, GSE-securitized mortgages increase significantly by approximately 2% after 12-16 quarters (i.e. when retained bank mortgages register their largest decline), and only start to fall when mortgage lending by other institutions recovers. The countercyclical dynamics of GSE-securitized mortgages may reflect these institutions' mandate to stabilize mortgage markets and foster home ownership. It may also reflect countercyclical investor demand for GSE securities because of their perceived lower riskiness. Such a perceived lower riskiness may be the result of an implicit government guarantee and the requirement that the securitized loans conform with OFHEO guidelines, including maximum loan amounts and minimum down payment and credit requirements.[23] These factors have probably played out more strongly over the more recent period when the GSEs gained market share and the outstanding pool and hence the liquidity of GSE securities increased.

An alternative explanation for the countercyclical reaction of GSE securities is the collateral demand by banks for repurchase transactions (repos). Nelson et al. (2015) develop a model in which banks increase securitization at the expense of loans held on their balance sheet after a monetary tightening because they want to increase the pool of collateralizable assets available for repos. In order to assess the relevance of this channel, we assess differences in the impact of a monetary policy shock on the holdings of GSE securities and of private-label mortgage-backed securities (MBS) by banks and by non-banks. To do this, we follow Den Haan and Sterk (2011) by using the information provided in the Call Reports to back out banks' holdings of securitized mortgages (as described in Appendix A of their paper). However, we go one step further and disentangle banks' GSE securities holdings from their private-label MBS holdings.[24]

[22] Peek and Wilcox (2003) find evidence of a countercyclical contribution of GSEs to mortgage credit flows.

[23] See Passmore (2005) for a discussion of the implicit government backing for the GSEs.

[24] These calculations reveal that, in the second period, the overall share of mortgages held by banks increase by 10 percentage points when the indirect holdings through securities are also taken into account. Over this period, banks held on average around a quarter of outstanding GSE securitized mortgages, and about 15% of the outstanding stock of private-label securitized mortgages.

The impulse responses of bank and non-bank holdings of GSE securities and of private-label MBSs lend support to the notion of a repo collateral channel. Figure 6 shows that banks increase both their GSE securities holdings as well as their private-label MBS holdings in the second period. Bank holdings of these securities increase significantly both immediately after the monetary tightening, and again after 18 quarters when the economic, housing and credit market downturns are playing out in full. This effect appears to be present only over the recent period, as banks' GSE holdings dropped significantly after a tightening in the first period. This change over time may reflect the enormous growth of repo markets since the 1980s, and the associated increase in the demand for collateralizable assets (Gorton and Metrick (2012)). Non-bank investors, by contrast, aggressively shed private-label MBSs in the immediate aftermath of the tightening in the second period. The peak drop is almost 20% after two quarters. This response pattern further supports the notion of a strong investor risk-taking channel for private-label MBSs. For non-bank holdings of GSEs we find, as for bank holdings, a significant increase around the trough of the monetary tightening-induced economic and credit downturn, probably reflecting investor flight to safety.

4 Conclusions

Our analysis of the post-war U.S. monetary transmission process indicates that a number of significant and policy relevant changes have occurred since the mid 1980s. The effects on the price level relative to those on output have become weaker, reflecting the flattening of the Phillips Curve highlighted in other studies. This implies that the traditional trade-off between price and output stability has changed, i.e. price stability oriented monetary policy has become more costly in terms of real output volatility. At the same time, the effects of monetary policy on credit and house prices relative to those on the macroeconomy have become considerably stronger. Macroeconomic stabilization through monetary policy has therefore become associated with greater fluctuations in credit and housing markets. In reverse, trying to stabilize credit and house prices through monetary policy now seems to come at a lower cost in terms of macroeconomic volatility.

The stronger impact over time of monetary policy on housing and credit markets is also reflected in important changes in transmission at the disaggregated level. Monetary transmission through residential investment and noncorporate non-residential investment has become stronger. At the aggregate output level, this effect is, however, superseded by other factors, in particular greater import leakage of demand impulses and a less pro-cyclical response of government expenditures to monetary policy shocks. Furthermore, the stronger transmission through aggregate credit is driven by mortgages, i.e. the component that is most closely linked to housing market developments. As a consequence, monetary policy mainly affects funding conditions of households and noncorporate firms, who mainly rely on mortgage credit. The impact of monetary policy on corporates is much weaker, reflecting this sector's ability to smooth out monetary shocks through debt securities issuance and C&I loan drawdowns. Overall, the changes in the effects of monetary policy on house prices, credit markets, residential and noncorporate non-residential investment are all closely linked to each other.

Finally, our analysis of monetary transmission to the mortgage lending sector (i.e. the counterparties of mortgage debt) shows that a monetary tightening has a negative impact on mortgage loans retained by banks and on private non-bank mortgage lending. By contrast, Agency- and GSE-related mortgage lending increases in a countercyclical way after a monetary tightening. Monetary policy therefore seems to get into all the cracks of the housing finance system, except for the quasi-public part of it.

A Appendix - VAR model with shadow federal funds rate

Figure A1 shows the impulse response functions when the second sample period is extended to 2015Q4, by using the Wu and Xia (2016) shadow federal funds rate for the post-2008 period. As can be seen, the conclusions of the paper are robust for this extension. The peak effects on real GDP, GDP deflator, house prices and credit are somewhat lower, i.e. -0.9%, -0.4%, -4.0% and -2.1% instead of -1.4%, -0.5%, -5.6% and -3.3% we obtained for the baseline VAR. However, the corresponding trade-offs (relative effects), turn out to have changed more over time than those reported in the main part of the paper.

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Table 1 - Peak effects of monetary policy

	1955-1979		1984-2008	
	Impact	horizon	Impact	horizon
Real GDP	-1.74	7	-1.44	12
Price level	-1.28	32	-0.50	18
Real house prices	-0.20	32	-5.64	12
Real credit	-1.47	8	-3.27	18

Note: Peak effects of a 100 bps interest rate shock with corresponding horizon (quarter).

Table 2 - Monetary policy trade-offs

	Shifting real GDP		Shifting the price level		Shifting real house prices		Shifting real credit	
	1955-1979	**1984-2008**	**1955-1979**	**1984-2008**	**1955-1979**	**1984-2008**	**1955-1979**	**1984-2008**
Real GDP	1.00	1.00	1.34	2.42	3.26	0.27	1.08	0.46
	[1.00 1.00]	[1.00 1.00]	[0.88 2.27]	[1.62 3.83]	[1.90 6.78]	[0.19 0.36]	[0.85 1.39]	[0.37 0.57]
Price level	0.75	0.41	1.00	1.00	2.43	0.11	0.81	0.19
	[0.44 1.14]	[0.26 0.62]	[1.00 1.00]	[1.00 1.00]	[1.30 4.89]	[0.07 0.16]	[0.42 1.42]	[0.11 0.32]
Real house prices	0.31	3.67	0.41	8.83	1.00	1.00	0.33	1.70
	[0.15 0.53]	[2.79 5.14]	[0.20 0.77]	[6.17 14.58]	[1.00 1.00]	[1.00 1.00]	[0.15 0.61]	[1.34 2.30]
Real credit	0.93	2.17	1.23	5.23	3.04	0.59	1.00	1.00
	[0.72 1.17]	[1.74 2.68]	[0.70 2.41]	[3.16 9.16]	[1.63 6.69]	[0.43 0.75]	[1.00 1.00]	[1.00 1.00]

Note: Estimated peak impacts on the variables in the respective row, induced by a monetary policy shock that shifts the variables in the column by 1%.
16th and 84th percentiles are in brackets.

Table 3 - Effects of monetary policy on GDP components

	Component/GDP (%)		Impact on component (%)		Contribution to total impact	
	1955-1979	1984-2008	1955-1979	1984-2008	1955-1979	1984-2008
Personal consumption	60.2	65.2	-1.40	-1.68	-0.85	-1.10
Non-residential investment	11.4	12.8	-4.17	-4.05	-0.47	-0.52
Residential investment	4.9	4.7	-3.42	-6.77	-0.17	-0.32
Government expenditures	22.5	19.6	-0.65	0.05	-0.15	0.01
Export	5.8	9.6	-0.87	-0.24	-0.05	-0.02
Import	-5.5	-12.3	-3.08	-5.32	0.17	0.66
Change in inventories	0.8	0.4				
Total	100.0	100.0			-1.51	-1.29

Note: Component/GDP is calculated based on U.S. National Income and Product Accounts data; impact on components is the estimated effect on the component in the quarter of the peak the impact on real GDP; contribution to total impact is the product of component share and impact.

Table 4 - Effects of monetary policy on private non-financial sector credit components

	Component/total credit (%)		Impact on component (%)		Contribution to total impact	
	1955-1979	1984-2008	1955-1979	1984-2008	1955-1979	1984-2008
Mortgages	41.1	45.8	-1.33	-5.03	-0.55	-2.31
Other credit	58.9	54.2	-1.65	-1.89	-0.97	-1.02
Total	100.0	100.0			-1.51	-3.33
Households	43.2	48.0	-1.27	-3.53	-0.55	-1.70
Mortgages	*26.9*	*32.7*	*-1.09*	*-3.62*	*-0.29*	*-1.18*
Other credit	*16.3*	*15.3*	*-2.22*	*-2.93*	*-0.36*	*-0.45*
Noncorporates	15.2	15.0	-1.20	-7.20	-0.18	-1.08
Mortgages	*9.3*	*10.3*	*-0.98*	*-7.22*	*-0.09*	*-0.74*
Other credit	*5.9*	*4.7*	*-0.63*	*-4.18*	*-0.04*	*-0.20*
Corporates	41.7	37.0	-1.89	-0.89	-0.79	-0.33
Mortgages	*4.9*	*2.9*	*-2.99*	*-10.6*	*-0.15*	*-0.31*
Other credit	*36.7*	*34.1*	*-1.71*	*-0.14*	*-0.63*	*-0.05*
Total	100.0	100.0			-1.52	-3.10

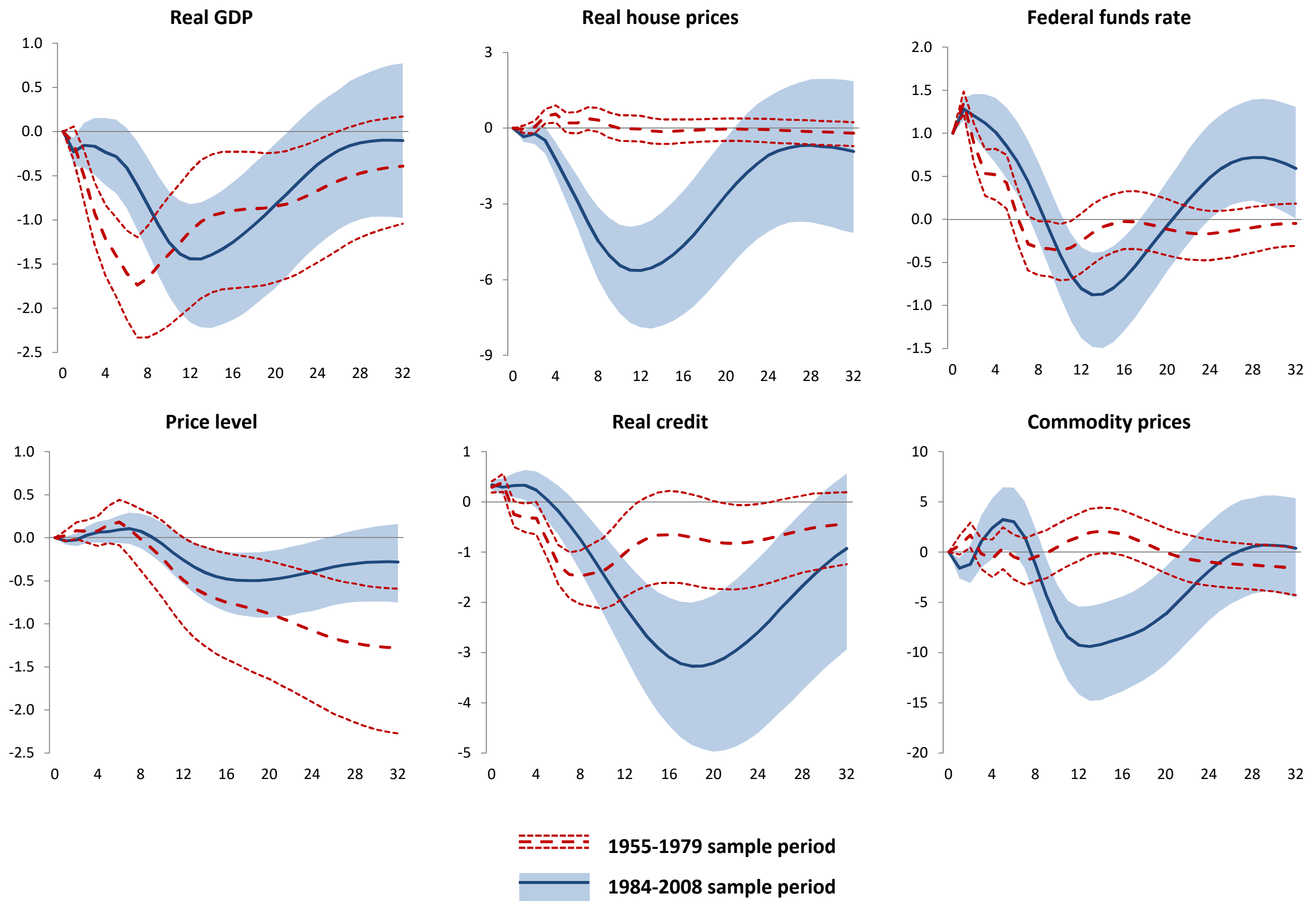
Note: Component/total credit is calculated based on U.S. Financial Accounts data; impact on component is the estimated effect on the component in the quarter of the peak impact on total real credit; contribution to total impact is the product of component share and impact.

Table 5 - Effects of monetary policy on mortgage counterparties

	Component/total mortgages (%)		Impact on component (%)		Contribution to total impact	
	1955-1979	1984-2008	1955-1979	1984-2008	1955-1979	1984-2008
Direct holdings by banks	59.3	40.6	-2.12	-5.65	-1.26	-2.29
Direct holdings by non-banks	35.4	17.3	0.29	-3.98	0.10	-0.69
Securitized by GSEs	5.3	34.8	-0.11	0.04	-0.01	0.02
Securitized by private-label ABS issuers	0.0	7.3	0.00	1.30	0.00	0.09
Total	100.0	100.0			-1.16	-2.87

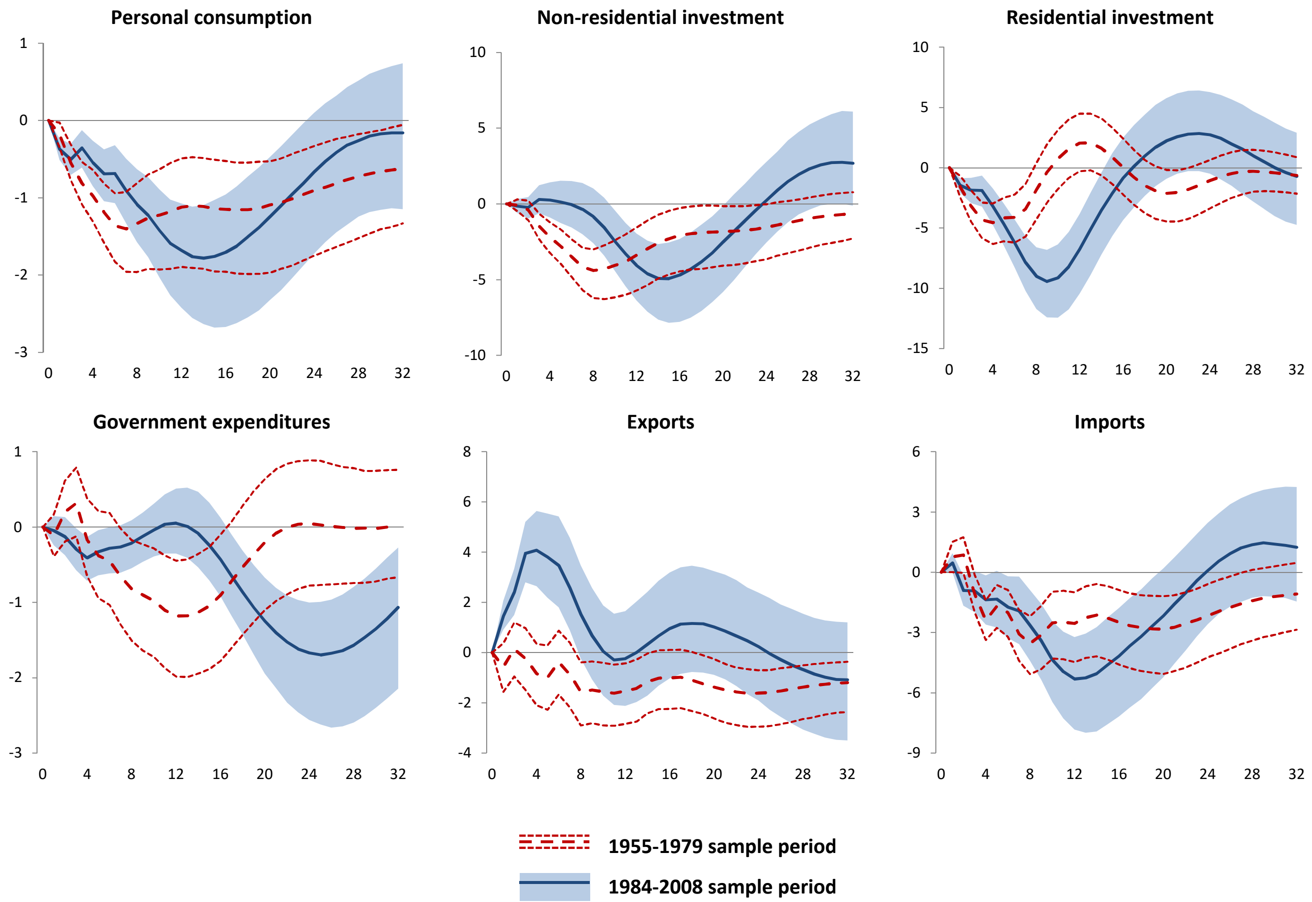
Note: Component/total mortgages is calculated based on U.S. Financial Accounts data; impact on component is the estimated effect on the component in the quarter of the peak impact on total real mortgages; the contribution to the total impact is the product of component share and impact.

Figure 1 - Impulse responses to a monetary policy shock



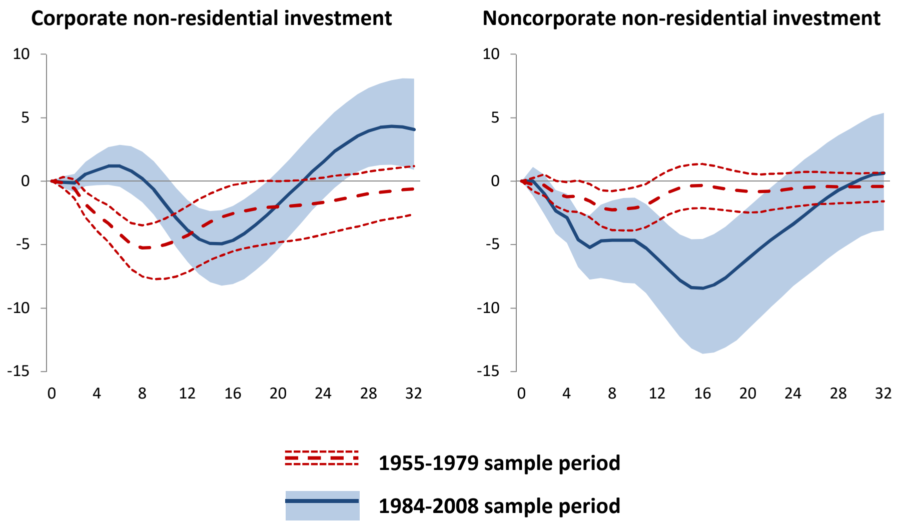
Note: Median responses to a 100 bps shock with 16th and 84th percentiles error bands; horizon is quarterly.

Figure 2 - Impulse responses of GDP components



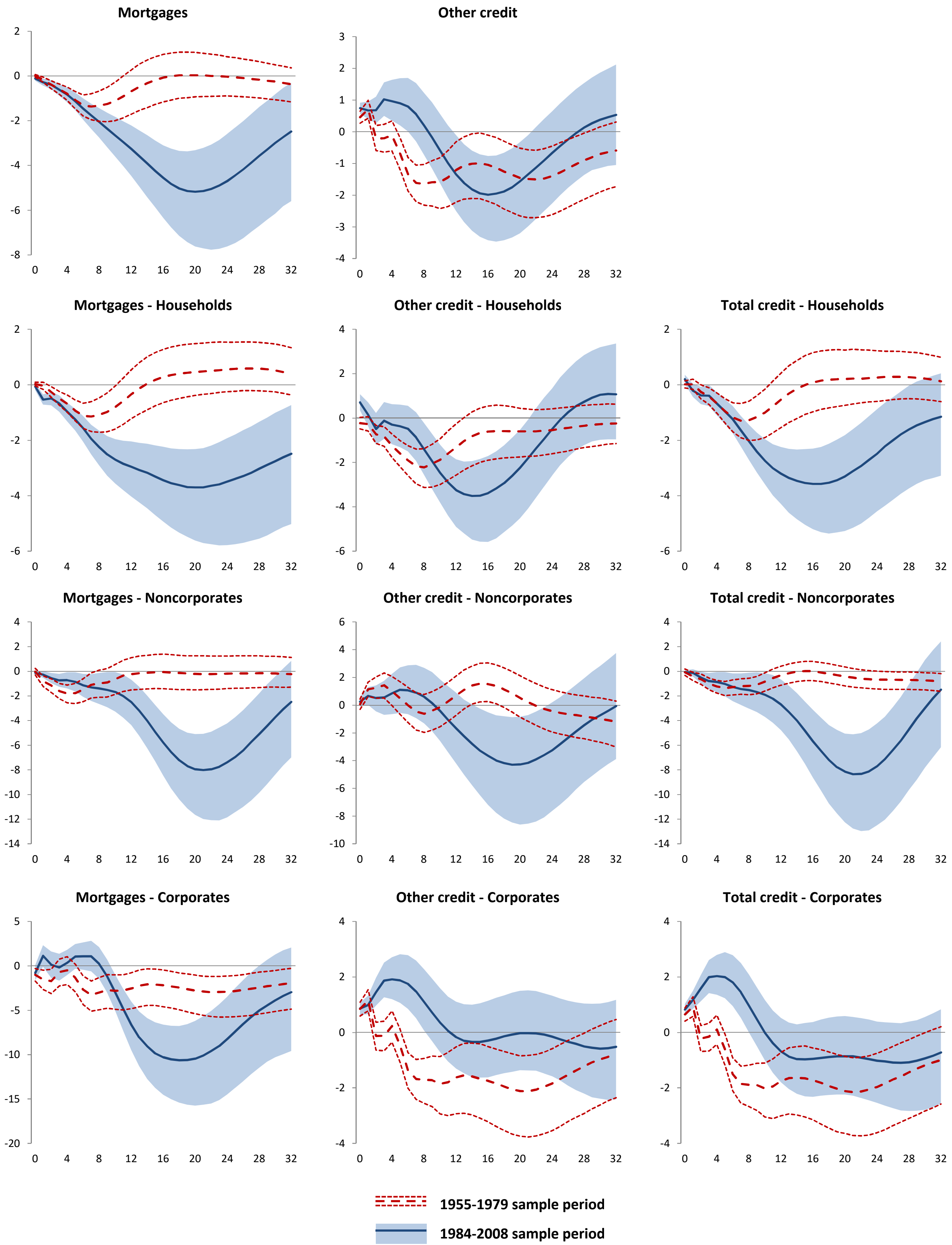
Note: Median responses to a 100 bps shock with 16th and 84th percentiles error bands; horizon is quarterly.

Figure 3 - Impulse responses of non-residential investment



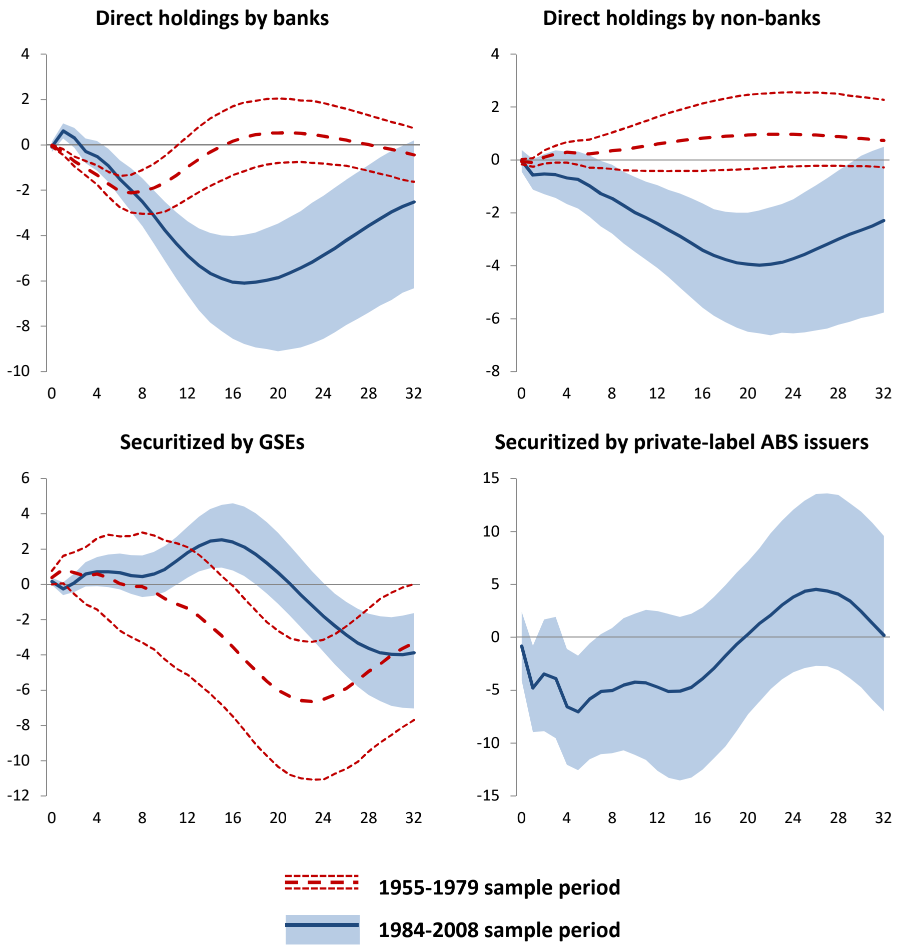
Note: Median responses to a 100 bps shock with 16th and 84th percentiles error bands; horizon is quarterly.

Figure 4 - Impulse responses of private non-financial credit components



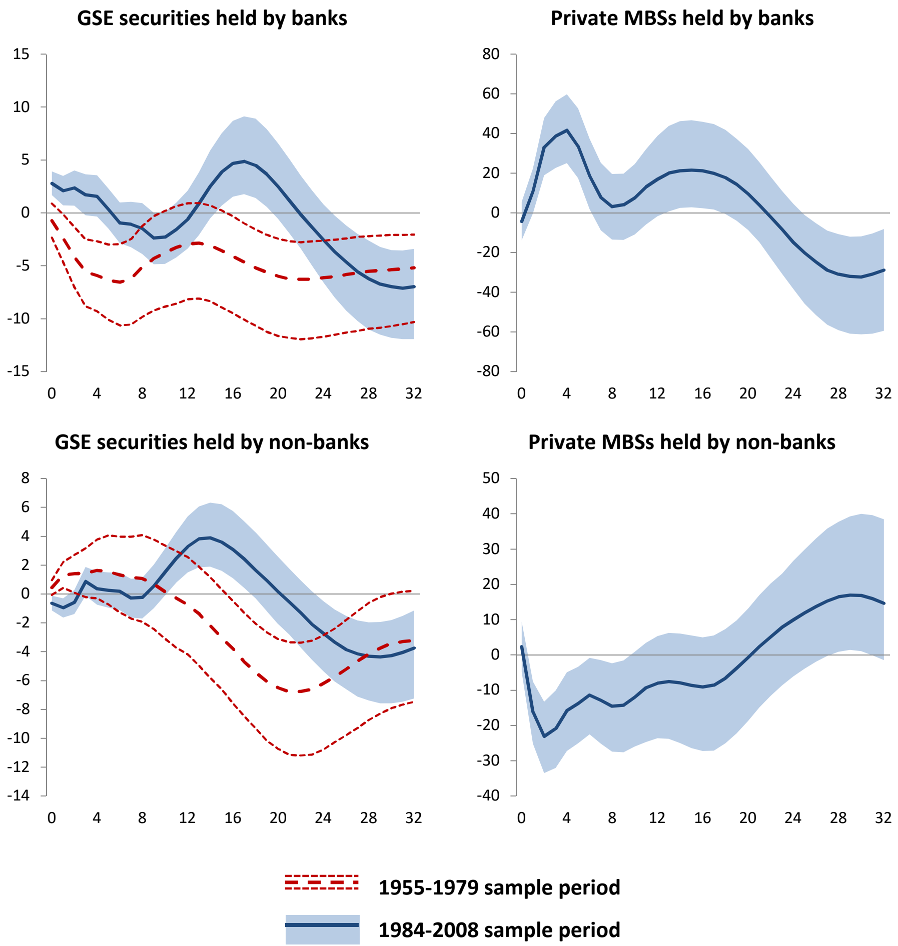
Note: Median responses to a 100 bps shock with 16th and 84th percentiles error bands; horizon is quarterly.

Figure 5 - Impulse responses of mortgage counterparties



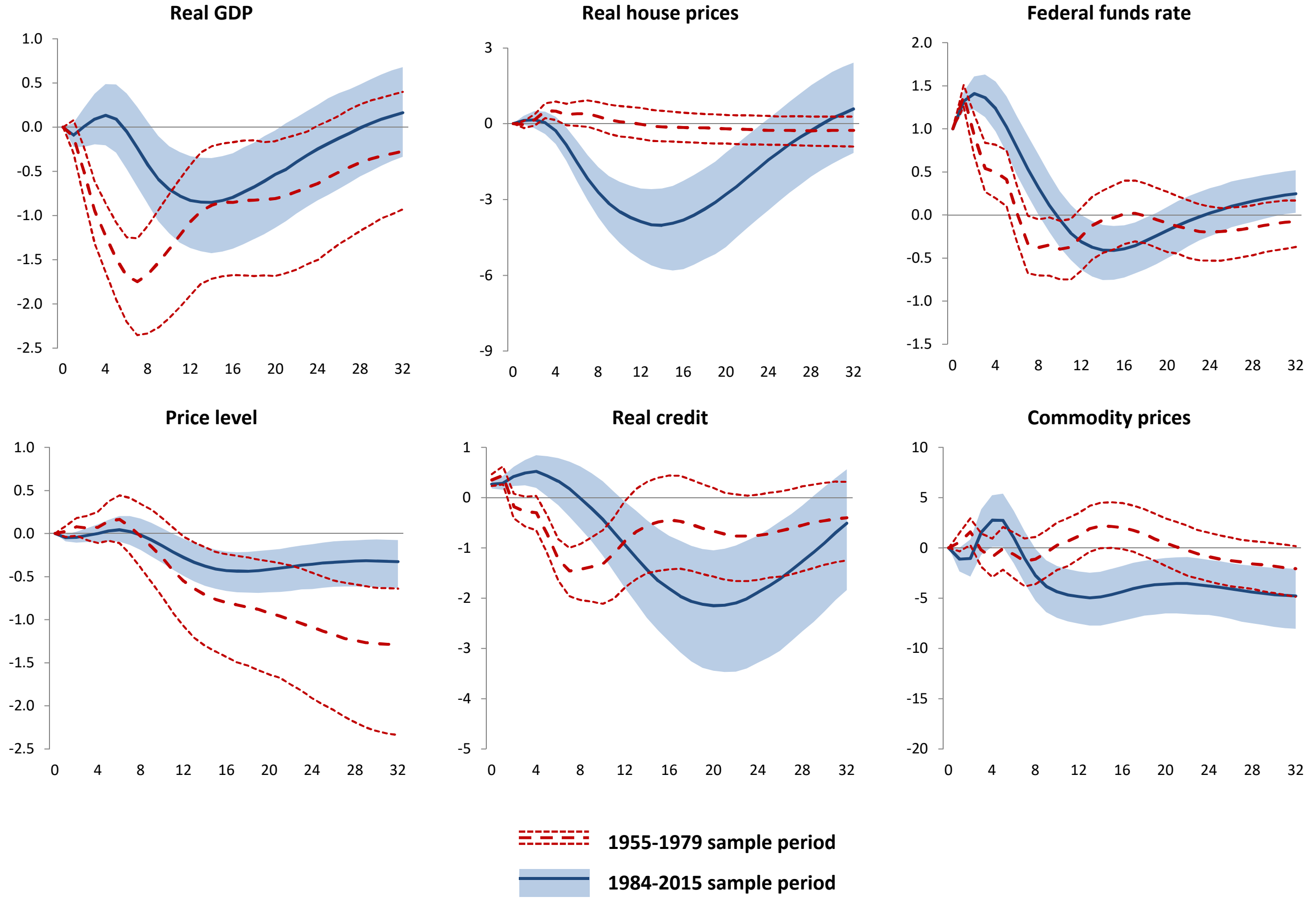
Note: Median responses to a 100 bps shock with 16th and 84th percentiles error bands; horizon is quarterly.

Figure 6 - Impulse responses of GSE and private securitized mortgages



Note: Median responses to a 100 bps shock with 16th and 84th percentiles error bands; horizon is quarterly.

Figure A1 - Impulse responses based on shadow federal funds rate over extended sample period



Note: Median responses to a 100 bps shock with 16th and 84th percentiles error bands; horizon is quarterly. Shadow federal funds rate from Wu and Xia (2016) for the period 2009-2015.