Monetary Policy in Times of Financial Stress

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Abstract

This paper provides a comprehensive study of the US monetary policy that investigates the Federal Reserve's reaction to financial markets during 1985:Q1 – 2008:Q4. We analyse two main questions. Firstly, does the Fed react directly to the indicators of financial stress and, if so, is such reaction linear? Secondly, does the policy response to inflation and output gap change in light of financial instability, i.e. is the standard Taylor rule an asymmetric function for the Fed? These questions are examined with respect to four different dimensions of financial market stress: credit risk, liquidity risk, bear market conditions and overall financial conditions. The results indicate direct response by the Fed to developments in the financial sector. The stock price index, interest rate spread, stock market liquidity index and financial conditions index are all statistically significant in the estimated augmented Taylor rules. Moreover, the reaction to financial variables under consideration is found to be strongly dependent on business cycle. Financial markets seem to be highly important to central bankers at the Fed during economic recessions; however, financial sector significance decreases considerably when the economy is booming. In addition, we also find some support that the Fed responds to financial market stress indirectly. During elevated financial stress the Fed's reaction to inflation declines to some extent while output gap parameter becomes statistically insignificant. Finally, it appears that the Fed's response to financial market stress strengthens significantly following the financial crisis leading to a much lower policy rate as compared to the previous episodes of financial turmoil.

Keywords: monetary policy; financial market stress; financial crisis; Taylor rule; regime switching; asymmetric reaction function

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1. Introduction

The global financial crisis in 2007-2009 and the subsequent Euro zone debt crisis have challenged policy makers worldwide during the past five years. The linkage between financial markets, real economy and monetary policy has been vastly discussed in the literature admitting the importance of well-functioning financial sector to real economy. In response to extreme developments in credit and financial markets monetary authorities in the United States, United Kingdom and euro-area have eased their policies substantially since late 2007. The key policy rates were sharply reduced to near-zero level and liquidity operations carried out by the three central banks were enhanced to increase liquidity in the markets. In addition, unconventional policies such as quantitative and credit easing have been implemented in order to put the economy back on track and remain in place until today.

Despite strong interconnectedness between economic and financial sectors, the standard monetary policy framework as defined by the so-called Taylor rule does not consider financial and credit markets (Taylor, 1993). Nevertheless, financial developments should not be ignored by monetary policy makers for at least two reasons. Firstly, sudden and sharp swings in financial and credit markets could lead to financial and economic crises (Borio and Lowe, 2004; Bauducco, Bulir and Cihak, 2008). Secondly, financial imbalances such as excessive stock price or credit growth might help predict future financial and economic instability (English, Tsatsaronis and Zoli, 2005; Hakkio and Keeton, 2009). As a result, some argue in favour of central bank's reaction to financial markets besides traditional target variables, i.e. inflation level and output gap (Goodhart and Hofmann, 2002; Roubini, 2006; Curdia and Woodford, 2010).

The standard Taylor rule has been examined by a large body of literature and its practical implementation has been challenged in terms of numerous aspects. As a result, the standard specification of the Taylor rule has undergone several augmentations. For instance, it is widely accepted that it should imply a gradual and forward-looking monetary policy (Clarida et al., 1998; Orphanides, 2001; Dolado, Pedrero and Ruge-Murcia, 2004). In addition, some include financial variables as the additional regressors. The debate as to whether central banks should also react to asset prices and other financial imbalances has received vast attention among academics and economists since early 2000s (Bernanke and Gertler, 1999; Cecchetti et al., 2000; Borio and Lowe, 2004; Curdia and Woodford, 2010).

This paper focuses on the monetary policy of the Federal Reserve during 1985:Q1 – 2008:Q4. Historically, the Federal Reserve reacted aggressively to the disruptions in financial markets causing the policy rate to deviate from the standard Taylor rule recommendations. For instance, the stock market crashes in 1987 and 2000-01, Russian default in 1998 followed by the LTCM liquidation, and the most recent financial crisis are all associated with prompt actions taken by the Fed to prevent meltdown of the financial system (Neely, 2004; Roubini, 2006; Kahn, 2010). On the other hand, policy makers at the Fed did not appear to had done much to prevent the rising stock price bubble in early 2000s or the housing price bubble that burst in 2006 (Roubini, 2006). Therefore, we argue that the Fed may be following a different monetary policy framework during stressful conditions in financial markets as compared to normal times.

Our contribution to the literature is that we provide a comprehensive study of the US monetary policy and the Federal Reserve's reaction to financial markets with respect to different dimensions of financial stress during multiple episodes of financial turmoil, including the most recent financial crisis. Moreover, we account for potential asymmetry related to business cycle when analysing the Fed's response to the financial sector. In our empirical analysis we estimate both linear and asymmetric Taylor-type policy rules augmented with proxies for financial conditions and compare the Fed's monetary policy framework across high and low financial market stress regimes before and during the recent financial crisis. Two main research questions are analysed with respect to four dimensions of financial stress: credit risk, liquidity risk, bear market conditions and overall financial conditions. Firstly, we ask whether the Fed reacts directly to the indicators of financial stress and, if so, whether such reaction is linear with respect to business cycle. Secondly, we examine if the policy response to inflation and output gap changes in light of financial instability, i.e. if the standard Taylor rule is an asymmetric function for the Fed.

The main findings show that financial market proxies, such as stock price index, interest rate spreads and financial conditions index, enter the estimated Taylor rules statistically significantly indicating the direct response by the Fed to developments in the financial sector. Moreover, the reaction to financial variables under consideration is found to be strongly dependent on business cycle. Financial markets seem to be more important to central bankers at the Fed during economic recessions, while their significance decreases considerably when the economy is booming. We find weak evidence for the indirect Fed's response to financial market stress as its reaction to inflation declines slightly and output gap parameter becomes statistically insignificant during elevated financial stress. On the contrary,

when financial markets are stable, the reaction function of the Fed is described by the forward-looking Taylor rule with both inflation and output gap parameters positive and strongly significant. Finally, we provide evidence that the financial crisis in 2008-2009 has reshaped the Fed's policy framework considerably. Both direct and indirect response to financial market stress by the Fed strengthens significantly in light of the financial crisis implying a much lower policy rate as compared to the previous episodes of financial turmoil. In general, the results imply a lower policy rate in times of heightened financial market stress and are in line with similar studies (Castelnuovo, 2003; Chadha, Sarno and Valente, 2004; Montagnoli and Napolitano, 2005; Belke and Klose, 2010; Kasai and Naraidoo, 2012; Gnabo and Moccero, 2013).

The remainder of this paper is organized as follows: Section 2 briefly describes origins and development of the Taylor rule, as well as discusses related theoretical and empirical studies. Section 3 outlines the methodology that is used to estimate the Taylor-type rules specified in the paper. Brief data description is provided in Section 4. The main empirical results are analysed in Section 5 and the robustness tests are briefly discussed in Section 6. Section 7 concludes.

2. The Taylor rule: Literature review
2.1. Origins, criticism and development

Taylor (1993) proposed a representative policy rule for the US that implies a short-term interest rate response to inflation and output deviations from their target levels:

$$i_t = r^* + \pi_t + 0.5(\pi_t - \pi^*) + 0.5\hat{y}_t \qquad (1)$$

where i_t is a short-term interest rate, i.e. nominal federal funds rate, r^* denotes equilibrium real interest rate, π_t is the current rate of inflation over the previous four quarters, π^* is the target rate for inflation and $\hat{y}_t$ is the percentage deviation of real GDP from its potential level at the time t. Equation (1) can be rearranged as follows:

$$i_t = \alpha + 1.5\pi_t + 0.5\hat{y}_t \qquad (2)$$

where $\alpha = r^* - 0.5\pi^*$. The above equations embed the so-called "Taylor principle", i.e. policy rate is raised by more than an increase in inflation to guarantee an increase in real

interest rate (Taylor, 1993). The Taylor rule has received considerable attention and recognition in the monetary policy literature as well as among monetary authorities. Even though Taylor (1993) argues that such reaction function does not have to be followed mechanically and discretion could be used to some extent, it is believed to be a good benchmark rule for explaining and assessing the past monetary policy in the United States (Taylor, 1999; Kahn, 2012). On the other hand, there are several issues with implementing this policy rule in practice (Orphanides, 2001; Kozicki, 1999; Osterholm, 2005; Orphanides, 2007).

First of all, central banks do not have current economic data at the time of the decision making as it only becomes available with lags. Macroeconomic data is usually revised following the initial release. Orphanides (2001) argues that depending on the type of data that is used to estimate the Taylor-type policy rules, the estimated reaction coefficients could differ significantly. Hence, this should be accounted for when estimating policy rules, i.e. real-time data should be preferred to *ex post* revised data. On the other hand, other studies do not find significant differences between the regression analysis based on real-time and *ex post* data (Osterholm, 2005; Mehra and Minton, 2007).

In addition, the standard rule implies backward-looking monetary policy with no policy inertia. However, in the literature it has been widely acknowledged that a forward-looking monetary policy framework that allows for a gradual interest rate adjustment represents actual behaviour of central bankers much better (Clarida et al., 1998; Taylor and Williams, 2010; Nikolsko-Rzhevskyy; 2011). Gerlach-Kristen (2004) provides several reasons why the inclusion of lagged interest rate into the Taylor rule leads to a better description of monetary policy. Firstly, a gradual adjustment of interest rate enables central banks to reduce the possibility of disrupting financial markets. Secondly, the policy is communicated to market participants better and it allows financial sector to anticipate the changes in policy rate. Finally, central banks might be uncertain about the exact state and structure of the economy and by gradually changing interest rate policy makers minimize the chances of any policy reversals.

Moreover, it has been noted that monetary policy makers tend to deviate from the Taylor rule as in Taylor (1993). Inflation and output gap parameters appear to be time-varying leading to deviations from the recommended policy rate occurring over time (Judd and Rudebusch, 1998; Taylor 1999; Blinder and Reis, 2005; Orphanides and Wieland, 2008; Mehra and Sawhney, 2010; Kahn, 2012). To some extent, this deviation might be explained

by a central bank's reaction to additional information such as shocks to financial sector since the standard Taylor rule does not account for such developments (Blinder and Reis, 2005).

Finally, the standard Taylor rule is a linear function associated with a quadratic loss function for policy makers where equal weights are placed on the devations of output and inflation from target levels independently of the size or direction of such departures (Dolado, Pedrero and Ruge-Murcia, 2004; Florio, 2009). However, in reality central banks might be responding to developments in macroeconomic variables in a way that could not be captured by a simple linear equation. Such asymmetries could emerge due to asymmetric preferences of central bankers, a non-linear aggregate supply function, or both (Dolado, Pedrero and Ruge-Murcia, 2004). For instance, if central bankers had asymmetric preferences with a non-quadratic loss function, then positive and negative deviations of dependent variables from their targets would be assigned different weights in a policy rule (Florio, 2009).

The worldwide financial turmoil that burst out in late 2008 was a wake-up call for central bankers. It has been recognised that price stability alone cannot guarantee financial stability and that elevated financial instability can lead to macroeconomic and price instability (Carney, 2014). As it will be discussed further in the text, some studies argue for the inclusion of additional explanatory variables into the Taylor rule that are related to financial market developments.

2.2. Should central banks react to financial imbalances and do they?

The financial crisis in 2007-2009 has revived the interest in the relationships between monetary policy, real economy and financial sector. Mishkin (2011) argues that developments in the financial sector have a far greater impact on economic activity than it has been previously realised and that price and output stability emphasized within the standard framework of monetary policy do not guarantee financial stability.

Firstly, excessive credit growth, increasing financial leverage and large upward shifts in asset prices could result in financial and economic instability once such upward trend is reversed (Borio and Lowe, 2004; English, Tsatsaronis and Zoli, 2005; Hakkio and Keeton, 2009). Sharp corrections of asset prices, for instance, a fall in the US housing prices that started in 2006, could lead to a substantial contraction of consumption and investment. In addition, deterioration in creditworthiness of firms and households due to balance sheet problems and increased counterparty risk in the financial system could magnify negative

effects of falling asset prices on real economy. As a result, financial intermediation might be disabled as such, feeding back into a further economic decline (Neely, 2004; Ferguson, 2005; Wadhwani, 2008; Botzen and Marey, 2010).

Secondly, developments in financial markets might be viewed as good predictors of future financial instability (Borio and Lowe, 2002; Schularick and Taylor, 2009). For instance, English, Tsatsaronis and Zoli (2005) show that financial variables such as interest rate spreads, asset prices, and credit aggregates are useful when forecasting the future developments of output and investment. In order to monitor overall financial conditions, various composite indices, such as financial stress indices (FSIs) and financial conditions indices (FCIs), might be helpful (Carlson, Lewis and Nelson, 2012).

Many studies are in favour of leaning against the wind in response to asset price misalignments as it would improve macroeconomic conditions by reducing inflation and output variability, and might help prevent costly asset price bubbles (Cecchetti et al., 2000; Goodhart and Hofmann, 2002; Botzen and Marey, 2010). Cecchetti et al. (2000) argue that even though it is rather difficult to identify and measure asset price misalignments, it is possible to do so. In addition, the literature provides support for different financial variables to be directly included into the Taylor-type monetary policy rule, such as interest rate spread or credit growth. It is believed that such an augmented policy rule helps increase welfare and macroeconomic stability by reducing negative impact of financial instability on real economy (Christiano et al., 2008; Curdia and Woodford, 2010; Gilchrist and Zakrajshek, 2011; Bailliu, Meh and Zhang, 2012).

Nevertheless, until recently the dominant view in the academic literature was that stock prices should be taken into the account by a central bank only to the extent they affect future expected inflation and output (Bernanke and Gertler, 1999; Vickers, 2000). Moreover, Assenmacher-Wesche and Gerlach (2010) argue that tightening monetary policy in response to excessive growth in credit and asset prices could depress real growth substantially. Overall, no clear consensus has been reached in the literature with respect to central bank's response to financial imbalances.

On the other hand, empirical evidence across different countries in general provides support that central banks do react to financial imbalances. For instance, using the identification technique based on the heteroskedasticity of stock market returns, Rigobon and Sack (2003) measure the Fed's reaction to the movements in stock market during 1985 - 1999. The results indicate that "a 5 percent rise in the S&P500 index increases the probability of a 25 basis point tightening by just over a half" (Rigobon and Sack, 2003: p.640). Similarly,

using the same technique Furlanetto (2011) finds positive and significant response of the Fed to stock market returns. However, this reaction appears to be much weaker during the past decade.

In addition, Chadha, Sarno and Valente (2004) examine monetary policy reaction to stock price indices and exchange rates using regression analysis for the United States, the United Kingdom, and Japan during 1979 - 2000. The results indicate that the Fed and Bank of England react to asset prices and exchange rates directly and do not treat them solely as informational variables to forecast inflation and output developments. On the contrary, Bernanke and Gertler (1999) empirically estimate the augmented Taylor rule for the US during 1979 – 1997 and find that the policy rate response to stock market returns is small, statistically insignificant and negative. Similarly, Furlanetto (2011) do not find evidence of monetary policy reaction to stock prices in the euro-area and five inflation targeting countries: New Zealand, Canada, Norway, the United Kingdom and Sweden over the period of 1999 – 2006.

There is also some empirical evidence supporting central bankers' response to financial variables other than stock prices. Gerlach-Kristen (2004) estimates the Taylor rule augmented with credit spread for the Fed. The results show that the spread between 10-year Treasury bond and Moody's Baa corporate bond yields is positive and statistically significant, i.e. a lower interest rate is prevailing during the periods of higher credit spread (Gerlach-Kristen, 2004). Similar results are also provided in Alcidi, Flamini and Fracasso (2011). In addition, Montagnoli and Napolitano (2005) examine forward-looking policy reaction functions augmented with financial conditions index for four regions: the Euro Area (sample period stars at 1995), US, UK and Canada during 1985 – 2005. The financial conditions index (FCI) is constructed with the focus on the real exchange rates, real house prices and real stock prices. The FCI enters the Taylor rule positively and statistically significantly for the US, the UK and Canada. This finding implies a lower interest rate when financial conditions tighten. In contrast to Montagnoli and Napolitano (2005), Castro (2011) demonstrates that the ECB reacts to the constructed FCI while this is not the case for the Fed and the Bank of England. Overall, the empirical evidence for central banks response to financial developments does not seem to be clear-cut.

2.3. Asymmetric central bank's reaction to financial markets

Historically, the Fed provided support to financial markets in light of severe disruptions and increased systematic risk in the financial system. The events such as the stock market crash in 1987, Asian financial crisis in 1997, Russian default in 1998 followed by the collapse of the Long-Term Capital Management hedge fund, terrorist attacks in September 2001, and the global financial crisis in 2007-2009 threatened the US economy and price stability (Neely, 2004; Kahn, 2010). Consequently, the Fed took prompt actions in all cases in order to prevent meltdown of the financial system (Neely, 2004; Cecchetti, 2009; Kahn, 2010; Gertler and Karadi, 2013). On the other hand, the Fed did not seem to react aggressively neither to the rising stock price bubble in late 1990s nor to the housing price bubble that burst in 2006. This might be an indication of asymmetric monetary policy with respect to financial markets (Roubini, 2006; Hofmann and Bogdanova, 2012). We argue that the Fed follows a different policy framework during the periods of financial market stress. In other words, a short-term interest rate is set in response to additional information other than inflation and output gap, for instance, developments in asset prices, financial market conditions, and interest rate spreads.

Recent literature on the Taylor rule provides empirical evidence with respect to changing central bankers' behaviour during the periods of increased financial market stress. For instance, Belke and Klose (2010) analyse monetary policy of the Fed and ECB before and after the start of the global financial crisis. Using the GMM, they estimate the Taylor type reaction functions augmented with different financial variables: credit and money growth, long-term/short-term interest spread, stock and real estate prices. The findings support the argument that both central banks generally respond to the additional variables and their policy change in light of extreme financial turmoil in 2007 - 2009.

In the pre-crisis period, i.e. during 1999 – 2007, the Fed's response to inflation is positive and significant but below unity; however, it becomes even smaller in size and mostly turns negative during the subprime crisis while still remaining significant. On the other hand, the output gap parameter does not provide a clear picture as to whether the Fed's reaction to it changed. Policy rate response to output gap remains positive and significant across the specifications after the start of the crisis, and while it decreases in some of them, the size of the coefficient increases in the specifications with credit growth variables. Furthermore, the Wald test indicates significant difference between the coefficients only in some cases. With regard to the financial variables, they remain statistically significant in the subprime period;

however, some of them change the sign (Belke and Klose, 2010). For instance, negative coefficients of asset price inflation turn positive during the financial crisis. The findings imply an asymmetric response of the Fed to asset prices, i.e. reducing policy rate when asset prices fall in crisis but accommodating asset price increases during good times.

With respect to the ECB's policy preceding the subprime crisis, the inflation coefficient always violates the "Taylor principle" while response to the output gap is around unity and significant. Following the start of the crisis, the reaction to inflation increases significantly, indicating stronger ECB's preferences towards price stability; whereas the output gap parameter, even though still significant, drops and turns negative (Belke and Klose, 2010). The ECB's response to financial variables is statistically significant during the crisis period; however, some of the coefficients differ in size and sign as compared to the pre-crisis sample. For example, there is some evidence of stronger policy easing in response to decreasing credit growth and increasing interest rate spread post-2007 than prior to the crisis. In addition, regression analysis indicates a decline in policy inertia for both the Fed and ECB during 2007 - 2009.

More evidence for the asymmetric Fed's reaction towards stock market developments is provided in Mattesini and Becchetti (2009). They develop the measure of stock price misalignments using the S&P500 data for the period 1980 – 2001. The Index of Stock Price Misalignment (ISPM) is then included into the Taylor rule. The GMM estimates show that when only negative values of the ISPM are included into the regression, they are positive and statistically significant. However, the same is not true when only the positive index values are considered. In this case the ISPM coefficients are mostly negative and insignificant. The overall results imply a lower policy rate when stock prices are falling below their fundamental values as compared to when they are increasing above fundamentals (Mattesini and Becchetti, 2009). Consistently, Hoffmann (2013) estimates the Taylor rule augmented with dummy variables for positive and negative deviations of asset prices from the trend. He demonstrates that the Fed cut policy rate in the light of falling stock prices below the trend but the policy rate was not increased in response to increasing stock prices above the trend during 1987 - 2009.

Different monetary policy framework in light of the global financial crisis is also identified for the UK. Martin and Milas (2013) investigate the BoE's policy during 1992 – 2010. After estimating the policy rule with the GMM, they find that prior to the financial crisis the BoE's monetary policy can be described by the standard Taylor rule; however, the reaction coefficient to inflation falls sharply, becomes negative and insignificant during 2007

– 2010, while the response parameter to output gap also decreases but remains positive and significant. In addition, Martin and Milas (2013) estimate the Taylor rules augmented with the IMF financial stress index for the UK and the Federal Reserve Bank of Kansas City Financial Stress Index. These additional variables are found to be insignificant prior to the crisis; however, both indices become statistically significant during the crisis period. Meanwhile, the inflation and output gap coefficients are in line with expectations in the pre-2007 sample; however, during the crisis reaction to inflation turns insignificant and drops sharply, while response to output gap decreases but remains significant and positive.

Hence, Martin and Milas (2013) argue that the BoE follows a non-linear policy rule and using smooth transition model demonstrate that the policy rule determined as a weighted average of crisis and no-crisis policy regimes reflects the UK monetary policy best. The weight is the probability of a financial crisis and is modelled as a function of financial stress index exceeding its threshold value. Such policy rule allows for multiple regime switches and implies that in a no-crisis period the policy rate is specified by the standard Taylor rule; however, the reaction function only embeds response to financial stress index and output gap during the crisis. The inflation parameter turns insignificant and output gap coefficient declines. Overall, intense financial market stress leads to substantial reduction in the policy rate (Martin and Milas, 2013).

In addition, Borio and Lowe (2004) present some empirical evidence of asymmetric response by the central banks in the US and Japan to credit growth and asset price deviations from respective trends during 1983 - 2002. The results of the estimated augmented Taylor rules show that in light of adverse financial imbalances, i.e. negative credit and equity gap, policy makers in Japan and US tend to loosen policy by more than suggested by inflation and output gap tendencies, i.e. the policy rate is lower when financial conditions worsen. However, this only seems to be the case in the specifications without gradual adjustment of interest rate. Generally, Borio and Lowe (2004) do not find significant reaction to the positive credit and equity gaps.

Baxa, Horvath and Vasicek (2013) apply the time-varying parameters model and analyse the reaction functions of the central banks in the US, UK, Australia, Canada and Sweden during early 1980s - 2009. The Taylor rule is augmented with the IMF financial stress index as well as with its three sub-indexes to capture different types of financial stress: bank-related, stock market and exchange rate stress. The results show that, in general, short-term interest rate is set lower during elevated financial market stress, i.e. the calculated financial stress effect weighs negatively on interest rate in bad times. All central banks are

found to keep their policy rates some 50-100 basis points lower in light of financial stress as compared to counterfactual policy setting in normal times.

In addition, Baxa, Horvath and Vasicek (2013) briefly comment on the estimated coefficients of standard variables in the Taylor rule over time. They show that during the last decade the inflation parameter decreased somewhat and it turned negative during the recent financial crisis in the case of the UK and US. It is argued that this is due to lower inflation expectations, while negative estimates are justified by extraordinary financial conditions around 2008-2009 and sharp interest rate cuts but unchanged inflation expectations at same time. The output gap reaction coefficient does not seem to vary significantly over time across the countries. Furthermore, time-varying financial stress parameter is mostly insignificant, confirming the argument that it is only relevant during times of high stress, such as the latest financial crisis (Baxa, Horvath and Vasicek, 2013).

Similarly to the above studies, Alcidi, Flamini and Fracasso (2011) argue that uncertainty and financial instability affect the way monetary policy is conducted in the US leading to policy regime switches. They analyse the US monetary policy during the Greenspan period until 2005:Q4 and demonstrate that a linear Taylor rule augmented with corporate bond yield spread does not capture the actual policy framework very well. Hence, the non-linear augmented Taylor rule is then estimated using the logistic smooth transition regression model where transition variable is the corporate spread between Moody's Baa corporate bond and 10-year US Treasury bond yields as a proxy for policy makers' general concerns regarding the health of the financial system. The results show that inflation and output gap reaction coefficients are insignificant in high-spread regime and only a lagged interest rate remains a significant determinant. On the other hand, during low-spread regime, the specification of a policy rule is captured by the spread-augmented Taylor rule (Alcidi, Flamini and Fracasso, 2011).

The non-linear policy rule is also preferred in the case of South Africa. Kasai and Naraidoo (2012) examine monetary policy of the South African Reserve Bank during 2000 – 2008 by recursively estimating of linear and non-linear policy rules augmented with financial conditions index. For the first estimation window, i.e. 2000:M1 – 2005:M12, linearity is rejected and the estimation of a non-linear specification indicates that the SARB's response to inflation, output gap and financial conditions is asymmetric with respect to output gap deviation from equilibrium. The reaction to inflation is more pronounced during economic contractions, while output gap parameter is greater during expansionary periods. In addition,

the policy response to financial conditions becomes stronger in recessions than in economic booms. Nevertheless, all coefficients are statistically significant for both regimes.

The results of recursive expanding window regressions indicate that in the linear model inflation parameter remains somewhat stable until 2007 and then drops. The output gap parameter also shows a decline towards the end of sample and even turns insignificant and negative in late 2007. The reaction to the financial index only drops slightly. In the non-linear model it is evident that inflation coefficient decreases over time during economic contractions but moves upwards in economic booms after 2007. With respect to the output gap, the parameter is increasing at the end of the sample during recessions but declines constantly and turns negative during expansions. Kasai and Naraidoo (2012) also find that since the start of global financial crisis financial conditions became equally important in both economic regimes, while the parameter is somewhat higher during economic downturn prior to 2007.

The paper by Gnabo and Moccero (2013) is quite close to our empirical analysis of the indirect response to financial stress by the Fed. However, we use a longer sample period including the financial crisis in 2008 – 2009, and we also define policy regimes in a different way. Gnabo and Moccero (2013) estimate a non-linear Taylor rule using smooth transition regression model during 1987 – 2005. The transition between two regimes is modelled on the basis of the level of economic risk. They use two measures to capture economic risk: the measure of dispersion associated with the outlook of inflation derived from the surveys and the VXO index by the Chicago Board Options Exchange as a proxy of financial market stress. The results show that the Fed responds to inflation and output gap positively and significantly; however, it becomes more responsive to the output gap when economic risk level is higher, while its reaction to inflation does not seem to change between the two regimes.

Overall, the literature provides supportive evidence across countries that monetary policy framework tends to vary across different regimes of financial market stress. The rest of this paper examines the monetary policy conducted by the Fed with the focus on its reaction to financial imbalances.

3. Methodology and specifications

Following Clarida, Gali and Gertler (1998, 2000), the regression analysis in this paper is based on a forward-looking Taylor rule that allows for gradual adjustment of the policy rate:

$$i_t = \left(1 - \sum_{j=1}^{n} \rho_j\right)\left(\alpha + \beta \pi_{t+k} + \gamma \hat{y}_t\right) + \sum_{j=1}^{n} \rho_j i_{t-j} + \varepsilon_t \qquad (3)$$

where $\rho \in [0;1]$ denotes the degree of policy inertia (we use two lags of dependent variable to eliminate serial autocorrelation), π_{t+k} is the expected inflation rate k periods ahead where $k = 4$, $\hat{y}_t$ represents a contemporaneous output gap, and ε_t is an error term. We expect that the "Taylor principle" holds, i.e. $\beta > 1$, and parameter γ is positive and close to 0.5. This implies that a short-term interest rate is increased in response to higher inflation expectations or output growth above its potential trend.

In order to estimate a forward-looking Taylor rule, the Generalized Method of Moments (GMM) model with instrumental variables is mostly used in the literature to account for endogeneity (Clarida et al., 1998, 2000; Chadha et al, 2004; Mehra and Sawhney, 2010). Contemporaneous information on target variables is not available to policy makers at the time of decision making due to lags in data release and its subsequent revisions. In the GMM approach, instrumental variables reflect any information in central bank's possession at the time of decision making that helps to forecast future inflation and output. Consequently, the expected values of target variables in equation (3) can be changed with their realized values. However, Nikolsko-Rzhevskyy (2011) highlights several issues with the GMM in practice. Firstly, he argues that policy makers do not know realized values of variables in real time and this information cannot be included into the information set. In addition, finding good instrumental variables to account for endogeneity is very challenging. Finally, it might not be appropriate to include realized values of variables into the reaction function because they are not the cause of central bank's policy but rather the result of it. As an alternative, the ordinary least squares method could be used with real-time data to estimate the Taylor rule (Orphanides, 2001; Mehra and Minton, 2007; Molodtsova et al., 2008; Nikolsko-Rzhevskyy, 2011).

Accordingly, we use the ordinary least squares (OLS) for the regression analysis of the Fed's policy with the survey-based measure of one-year-ahead inflation expectations. Equation (3) is our benchmark regression in order to evaluate how well the Taylor rule tracks historical interest rate decisions by the Fed. Subsequently, the baseline reaction function is augmented with four different financial variables included one by one in order to test the hypothesis of a direct Fed's response to developments in financial markets:

$$i_t = \left(1 - \sum_{j=1}^{n} \rho_j\right)\left(\alpha + \beta \pi_{t+4} + \gamma \hat{y}_t + \mu x_t\right) + \sum_{j=1}^{n} \rho_j i_{t-j} + \varepsilon_t \qquad (4)$$

where x_t is a selected financial variable at the time t. The sign of parameter μ could be either positive or negative depending on the type of a financial indicator.

We previously argued that financial instability could eventually lead to a sharp decline in economic activity. Accordingly, during recessions central bank's reaction to financial markets might be more pronounced than otherwise. In order to compare the Fed's response to financial markets during recessions versus economic expansions, the US recession dummy is added to the policy rule:

$$i_t = \left(1 - \sum_{j=1}^{n} \rho_j\right)\left(\alpha + \beta \pi_{t+4} + \gamma \hat{y}_t + \mu^R D^R x_t + \mu^{NR}\left(1 - D^R\right)x_t\right) + \sum_{j=1}^{n} \rho_j i_{t-j} + \varepsilon_t \qquad (5)$$

where D^R is a dummy variable that takes value 1 to indicate the US recessions as per the NBER peak to trough of business cycle dates and zero otherwise; μ^R and μ^{NR} are the reaction parameters to a financial variable during recessions and expansions respectively.
We expect to find a stronger Fed's reaction to the financial sector during economic downturn as compared to economic boom.

As it has been discussed earlier, some argue that monetary policy makers only take financial information into the account to the extent it influences future inflation and output. Hence, indirect response to financial markets by a central bank could be detected through the changes in its reaction to inflation and output gap across different regimes of financial conditions. For this reason, we analyse the Fed's response to standard target variables in the Taylor rule during high and low financial market stress. In general, we expect the policy rate to be much lower during financial market stress as compared to normal times.

Several methods could be used to model multiple regimes when estimating the Taylor rule: smooth transition regression models (Florio, 2009; Alcidi, Flamini and Fracasso, 2011; Castro, 2011; Martin and Milas, 2013), Markov-Switching models (Valente, 2003; Assenmacher-Wesche, 2006), and time-varying parameter regressions (Kim and Nelson, 2006; Trecroci and Vassalli, 2010; Baxa, Horvath and Vasicek, 2013). Alternatively, sample period could be split into sub-samples to account for different regimes over time, such as crisis versus pre-crisis periods (Belke and Klose, 2010; Martin and Milas, 2013). Finally, dummy variables could also denote switching regimes as in Mattesini and Becchetti (2009).

In our empirical analysis we firstly select several financial variables that are potentially causing the shifts in policy reaction function. Then, we set a threshold for each of them that would help to identify elevated financial market stress based on historical data. It is then tested whether the policy rule parameters change once a threshold is breached. As in Borio and Lowe (2004), we use a dummy variable approach. We construct financial market stress dummies that take value 1 if the threshold indicating elevated financial stress is breached to reflect financial turmoil and zero otherwise. This approach allows us estimate the Fed's asymmetric response to inflation and output gap conditional on the developments in financial markets. The following equation is estimated:

$$i_t = \left(1 - \sum_{j=1}^{n} \rho_j\right)\left(\alpha + \beta^D D^X \pi_{t+4} + \beta^{ND}\left(1 - D^X\right)\pi_{t+4} + \gamma^D D^X \hat{y}_t + \gamma^{ND}\left(1 - D^X\right)\hat{y}_t\right) + \sum_{j=1}^{n} \rho_j i_{t-j} + \varepsilon_t \quad (6)$$

where D^X is a dummy that takes value 1 if financial market stress is intense and zero otherwise. The reaction coefficients to inflation and output gap during intense financial stress are denoted by β^D and γ^D. Similarly, β^{ND} and γ^{ND} are the parameters during normal times. The Fed's response to inflation and output gap is expected to fall in times of financial turmoil due to other factors potentially influencing central bank's policy decisions.

4. Data

We use quarterly data that is mainly collected from the Federal Reserve Bank of St. Louis database FRED II for the sample period 1985:Q1 - 2008:Q4. The dependent variable is the effective Federal Reserve funds rate (i_t). The measure of expectations for one-year-ahead annual average inflation measured by the GDP price index is provided by the Survey of

Professional Forecasters (π_{t+4}). The output gap is measured as the percentage deviation of seasonally adjusted log real GDP from its Hodrick-Prescott trend ($\hat{y}_t$). In addition, we use four financial variables (x_t): Citi Financial Conditions Index (*FCI*), the spread between the Moody's Baa corporate bond and Aaa corporate bond yields (*CSPR*), a year-on-year change in S&P 500 stock price index (*SP500*) and the aggregate stock market liquidity index (*LIQ*). The time series of Citi FCI is made available via Hatzius et al. (2010). The index of aggregate liquidity in stock market is constructed and later updated as the equally weighted average of the liquidity measures of individual stocks on the NYSE and AMEX (Pastor and Stambaugh, 2001). More details on the data and data sources are provided in Appendix 1.

Regarding the Fed's direct response to financial markets, μ is expected to be positive for the stock returns, Citi FCI and liquidity index. The Fed's response parameter to credit spread is expected to be negative. This implies that, given a sharp fall in equity returns, deteriorating financial conditions, a decline in liquidity levels or a steep jump in credit spreads, the policy rate is reduced accordingly. In other words, intense financial market stress is associated with more accommodative monetary policy stance. In the second part of our empirical investigation, we construct the dummies to use in equation (6) based on the four financial variables. They all take value 1 when the financial stress is high and zero otherwise. Figure 1 plots the financial variables together with the dummies associated with each of them[1].

[Figure 1 here]

The first dummy D^{FCI} indicates financial instability when Citi FCI is below its historical average value. This index is constructed to have a mean of zero with negative values indicating contractionary financial conditions (see Appendix 1). **Figure 1** shows that the index fell sharply and was well below zero during the global financial crisis. Historically, it also plunged and became negative during the recessions or periods of financial instability in 1987, 1990 - 1991, 1998 - 2000, and 2002 - 2003. The credit spread dummy D^{CSPR} becomes active when the credit spread rises above its historical average since high values of the spread indicate deteriorating conditions in financial markets, i.e. increasing credit risk, higher financing cost, etc. The past disturbances in financial markets are picked up by the spikes in

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[1] The shaded areas represent NBER recession dates. See Appendix 1 for more details on how the dummy variables are constructed.

this measure. The stock market stress is represented by the dummy D^{SP} that takes value 1 when S&P500 stock price index falls below its 2-year moving average. Similarly to other two, this measure appears to identify the main episodes of financial turmoil during the sample period quite well. Sharp declines in stock returns coincide with stock market crash in 1987 and early 2000s, as well as with the global financial crisis in 2007-09. Finally, we identify financial market stress when the aggregate stock market liquidity index falls below its historical average level less one standard deviation (D^{LIQ}). One standard deviation is deducted from the average due to too many "crises" indicated if the historical average is chosen as a threshold. The major past events of financial instability are clearly denoted by pronounced declines in aggregate stock market liquidity index.

In addition, financial instability appears to coincide with the US recessions. As **Figure 1** shows, all constructed dummies capture recessionary periods in the US quite well and indicate a strong link between economic recessions and financial market stress. The three recessions are picked up by stock market and credit spread dummies. Citi FCI dummy identify two of the recessionary periods while liquidity index captures the last recession. Furthermore, all four measures of financial stress clearly pick up the recession related to the global financial crisis. Overall, this provides support for our argument that reaction to financial market stress could be asymmetric with respect to business cycle.

5. Empirical results
5.1. Basic and augmented Taylor rules

We start with the estimation of the basic equation (3) over the sample period 1985:Q1 – 2008:Q4 (we exclude the period of zero lower bound). The results are reported in the first column of **Table 1**. Both coefficients as well as interest rate smoothing terms are statistically significant at 1% level and correctly signed. The "Taylor principle" is not violated as the inflation parameter is well above unity. With regards to output gap, the reaction coefficient of 0.98 even though higher than 0.5 proposed by Taylor (1993) is similar to what is found in the literature. These estimates are consistent with Clarida et al. (2000), Orphanides (2001) and others.

As we are interested in the Fed's reaction to developments in financial markets, we next estimate equation (4) including the Citi FCI, corporate spread, annual stock returns and aggregate liquidity measure one by one. The estimates of the augmented Taylor rules are

provided in columns 2-5 in **Table 1.** The inflation parameter complies with the "Taylor principle" and is around 2, while the output gap reaction coefficient is close to one across all specifications. Both response coefficients are positive and statistically significant at 1% significance level. These estimates are consistent with the baseline Taylor rule estimated above. In addition, all financial variables are correctly signed and significantly different from zero at 1% and 5% levels with the exception of stock market liquidity variable that is significant at 10% level. Furthermore, the standard errors of the augmented regressions drop slightly as compared to the standard errors of the baseline equation during 1985:Q1 – 2008:Q4.

Similarly to Montagnoli and Napolitano (2005), we find that the policy rate is reduced in response to a fall in the FCI, i.e. in light of deteriorating financial conditions. Moreover, worsening liquidity conditions, declining stock returns and increasing corporate spread are also associated with easier monetary policy. The credit spread parameter is negative as expected and is similar in magnitude to the estimated coefficients in Castelnuovo (2003) and Gerlach-Kristen (2004). In line with Chadha, Sarno and Valente (2004), the response parameter to returns on equities is relatively small in absolute value (0.05) but statistically significant.

Overall, this provides support to the argument that the Fed responds directly to financial markets with interest rate set lower in the face of financial turmoil and higher during good times. On the other hand, the linear augmented Taylor rules might not be able to fully explain the historical Fed's policy.

[Table 1 here]

5.2. Recessions versus expansions

In this section we address the second part of the first research question and test the hypothesis of an asymmetric Fed's response to financial markets with respect to business cycle. It is expected that during recessions monetary policy makers are much more concerned about negative developments in the financial system. The last four columns of **Table 1** present the estimation results of equation (5).

The results clearly indicate that the Fed reacts very strongly to all four financial variables during contraction in economic activity. As recessionary periods tend to be accompanied with troubled financial sector, monetary policy is loosened in order to shield

real economy from the negative impact of financial instability. In contrast, all four variables turn to be statistically insignificant during economic expansions. Moreover, the policy rate response to the Citi FCI, corporate spread, stock returns and stock market liquidity significantly increases in absolute size during recessions as indicated by the Wald test p-values reported in **Table 1**. Furthermore, standard errors decrease after the asymmetry with respect to booms and busts is taken into the account. Overall, our findings show that asymmetry is present in the Fed's reaction function with respect to financial markets and economic activity. Similar results for South Africa are provided in Kasai and Naraidoo (2012).

5.3. High versus low financial market stress

In this section we examine the second research question and estimate equation (6). The periods of intense financial market stress are identified using the dummy variables as defined earlier. The results are summarized in **Table 2** columns 1 to 4. During normal times, the short-term interest rate response to inflation is highly significant at 1% level and is always above one. This indicates strong anti-inflationary preferences of central bankers. The response parameter to output gap is also statistically significant at conventional significance levels and is close to unity in all specifications. The results, therefore, are very similar to the estimates of the benchmark equation provided in **Table 1**.

On the other hand, the story is somewhat different in light of financial instability. First of all, in general still significant inflation parameter β^D is smaller than β^{ND} in all specifications. Moreover, the estimated β^D invalidates the "Taylor principle" and is statistically insignificant when aggregate liquidity in stock market drops sharply. According to the Wald test p-values reported for each pair of the coefficients, the inflation parameters differs significantly between the two regimes in three out of four cases; however, only at 10% confidence level. With respect to the reaction to output gap, **Table 2** indicates that during financial stress the Fed's reaction to output gap becomes generally statistically insignificant and does not provide a clear picture as to how it changes in magnitude across the two regimes. The size of reaction coefficient in good financial conditions is higher in two specifications out of four as compared to the parameter during unfavourable conditions in financial markets. However, the Wald test does not indicate any statistically significant difference between both parameters.

We expected to find a significant drop in reaction to inflation associated with financial market stress as reported in the literature discussed above; however, there only appears to be a slight decline in the inflation parameter. Even though Baxa, Horvath and Vasicek (2013) argue that the Fed's response to inflation declined substantially after terrorist attacks in 2001 and during the recent crisis, our initial results do not indicate this. Moreover, the results with respect to the output gap provide mixed evidence for a change in reaction.

[Table 2 here]

5.4. The financial crisis

Similarly to Martin and Milas (2013) study for the UK, we find that during normal times the Fed seems to be following the Taylor rule but it breaks down somewhat in light of financial stress. However, the results are mixed in terms of output gap and we find no evidence of a substantial change in the policy makers' reaction to inflation. On the other hand, these results could be driven by the fact that our analysis focuses is not only on the most recent financial crisis as, for instance, in Belke and Klose (2010), but on other historical periods of financial turmoil as well. Hence, once the past periods of financial turmoil are explicitly considered, the Fed does not appear to have changed significantly its policy towards price stability during intense financial stress.

In order to test the impact of the financial crisis, we construct a new dummy variable D^{07-08} that only takes value of 1 during 2007:Q4 − 2008:4Q, i.e. the period that also coincides with the latest US recession, and estimate equation (6) again. This result is reported in the last column of **Table 2**. As expected, during the most recent financial crisis the inflation parameter decreases substantially, turns negative and insignificant. The Wald test shows that the difference between two response coefficients is now statistically significant at 1% level. Hence, the past periods of financial turmoil appear to wash away the effects of the financial crisis to significant extent. The negative point estimate of the inflation is consistent with Baxa, Horvath and Vasicek (2013). They demonstrate that the Fed's response to inflation decreased sharply and even turned slightly negative during the recent financial crisis. Belke and Klose (2010), Martin and Milas (2013) also report much smaller and negative inflation parameter around 2007 − 2009 for the US and UK respectively. The negative point estimate

of inflation coefficient is consistent with sharp reductions in policy rates and relatively stable or high inflation levels.

On the other hand, the last column of **Table 2** reports a higher response to output gap during the most recent financial crisis. Even though it is not significantly higher as compared to the coefficient during normal times; it is positive and statistically significant. Hence, the policy framework with respect to output gap does not appear to change substantially due to the global crisis.

Finally, we also apply the new dummy to the equation (5) in order to see whether there is any change to the direct Fed's response to financial markets following the crisis as compared to the period prior the last quarter of 2007. **Table 3** shows how the financial crisis reshapes the Fed's policy considerably regarding its reaction to financial imbalances. Only the stock returns and Citi FCI appear to be significant prior to late 2007. In contrast, all four additional variables become highly significant in light of the global financial crisis. Hence, the unprecedented negative effects of the financial crisis appear to lead to a different monetary policy framework while the previous episodes of financial turmoil fade into insignificance. For instance, prior the crisis 1% (percentage point) increase in credit spread does not reduce the policy rate. In light of the financial crisis 1% unfavourable change in the spread implies a 377 basis points lower interest rate.

6. Robustness

This section briefly discusses the robustness of our empirical results reported in Section 5. Firstly, we estimate equations for alternative sample periods: the original sample period is extended to start with the Volcker's period and then it is shortened to the beginning of the Greenspan's Chairmanship: 1979:Q4 – 2008:Q4 and 1987:Q4 – 2008:Q4. Secondly, we use the Chicago National FCI, spread between Moody's Baa corporate bond and 10-year US Treasury yields, Macroeconomic Advisers Monetary and Financial Conditions Index, and the spread between 3-month LIBOR and US Treasury bill rates as alternative financial variables. Thirdly, the policy rules in Section 3 are re-estimated using real-time data for real GDP time series. Finally, we use the GMM with *ex post* data on real GDP instead of the OLS in order to account for endogeneity. We do not report detailed results here; however, they are available upon request. In general, our results reported in Section 5 are robust with respect to various changes to the benchmark model such as different data types and alternative methodology.

7. Conclusions

This paper briefly discusses the origins and development of the Taylor rule as well as some practical issues encountered in the literature on monetary policy rules. The main focus is on the analysis of the link between US monetary policy and developments in financial markets. Financial imbalances and distress in the financial system have a strong negative impact on the economic activity. Hence, monetary policy makers might find it beneficial to take into account financial information when making policy decisions in order to contribute to more stable economic conditions. Numerous studies provide supportive theoretical and empirical evidence for central banks' reaction to financial imbalances. We provide a comprehensive analysis of the US monetary policy and Fed's reaction function with respect to different dimensions of financial market stress and business cycle across the multiple periods of financial turmoil including the most recent financial crisis.

The results indicate a strong direct reaction of the Fed to prevailing financial conditions, stock market returns, interest rate spreads and aggregate stock market liquidity. Moreover, strong and significant reaction to the financial variables during recessionary periods usually disappears or becomes significantly smaller during economic expansions. Nevertheless, the results appear to be driven by the recent financial crisis. We find that the Fed generally follows the Taylor rule complemented with somewhat moderate response to financial developments until late 2007. In light of the global financial crisis the evidence points to a substantially stronger reaction to financial market stress while the response parameter to inflation drops significantly and becomes negative. Overall, deteriorating financial market conditions and elevated financial market stress are associated with lower monetary policy rate as compared to normal times.

In general, the empirical findings support our argument that the Fed is not only reacting to the developments in financial markets, but it also responds to financial turmoil asymmetrically and reacts more aggressively when stress in the financial system is high or economy is in the recession. This result provides insight into the future policy decisions during times of financial instability.

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Figure 1. Financial market variables and financial stress dummies
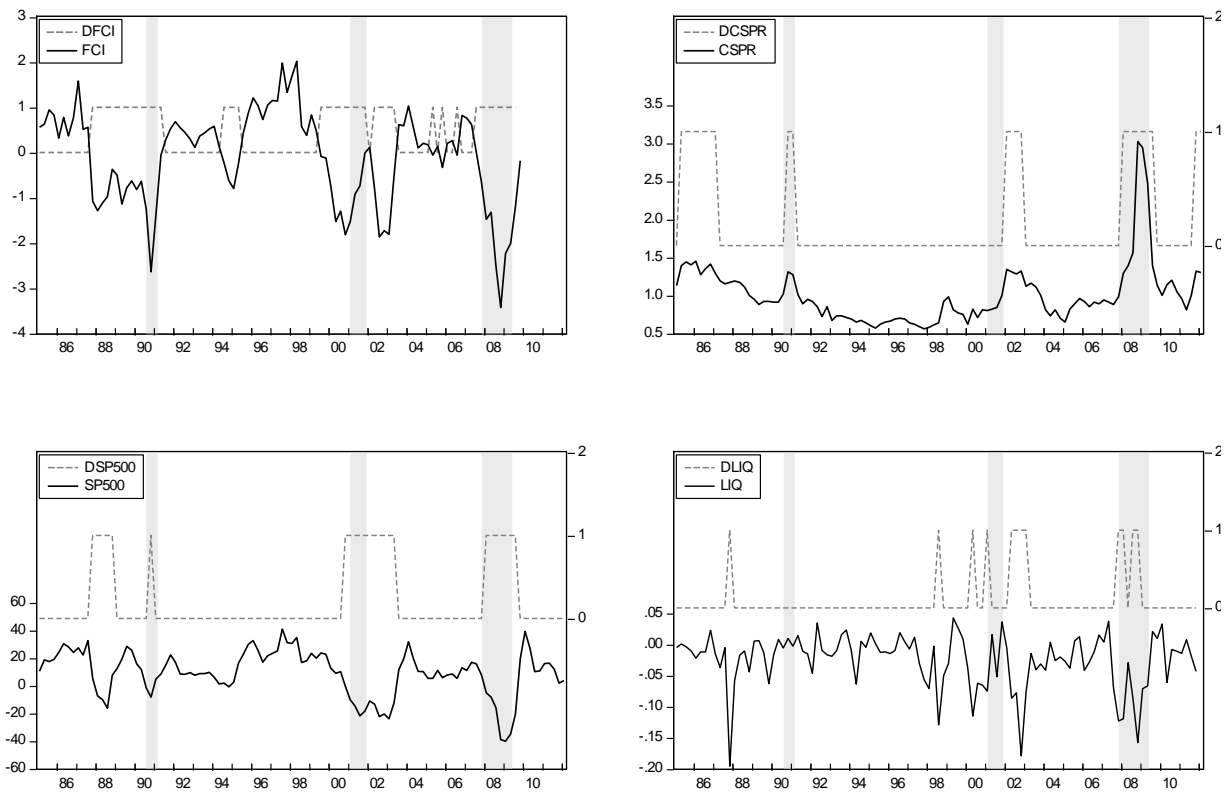
Notes: Each graph represents one of the four x_t variables with a corresponding dummy D^X that identifies the periods of intense financial stress. The shaded areas denote recessionary periods in the US based on the NBER business cycle dates.

Table 1: Direct reaction to financial market developments

	(1) BASELINE	*(2)* FCI	*(3)* CSPR	*(4)* SP500	*(5)* LIQ	*(6)* FCI	*(7)* CSPR	*(8)* SP500	*(9)* LIQ
α	-1.29 (1.21)	-1.32 *(1.04)*	1.61 ***(1.38)***	-1.25 *(0.98)*	-0.18 *(1.13)*	-0.79 *(0.99)*	0.25 *(1.01)*	-0.33 *(1.04)*	0.06 *(1.06)*
ρ_1	1.47*** (0.08)	1.44*** *(0.09)*	1.35*** ***(0.09)***	1.40*** *(0.10)*	1.47*** *(0.09)*	1.38*** *(0.08)*	1.32*** *(0.07)*	1.38*** *(0.09)*	1.39*** *(0.10)*
ρ_2	-0.58*** (0.07)	-0.57*** *(0.08)*	-0.48*** ***(0.08)***	-0.54*** *(0.09)*	-0.58*** *(0.08)*	-0.50*** *(0.07)*	-0.44*** *(0.06)*	-0.50*** *(0.08)*	-0.51*** *(0.08)*
β	2.13*** (0.42)	2.17*** *(0.37)*	2.34*** ***(0.44)***	1.96*** *(0.34)*	1.90*** *(0.41)*	2.10*** *(0.38)*	1.98*** *(0.33)*	1.84*** *(0.38)*	1.75*** *(0.37)*
γ	0.98*** (0.35)	1.07*** *(0.34)*	0.91** ***(0.44)***	0.84*** *(0.31)*	1.04*** *(0.37)*	1.03*** *(0.29)*	1.03*** *(0.25)*	0.87** *(0.37)*	1.21*** *(0.27)*
μ	-	1.03** *(0.40)*	-3.67*** ***(1.21)***	0.05** *(0.02)*	0.19* *(0.11)*	-	-	-	-
μ^{NR}	-	-	-	-	-	0.19 *(0.25)*	-0.68 *(0.83)*	0.01 *(0.02)*	0.03 *(0.05)*
μ^{R}	-	-	-	-	-	2.60** (1.06)	-4.34*** *(1.09)*	0.24** *(0.10)*	0.52*** *(0.18)*
SE	0.36	0.34	0.33	0.35	0.35	0.31	0.29	0.33	0.32
$\mu^{NR} = \mu^{R}$	-	-	-	-	-	0.03	0.00	0.06	0.00

Notes: This table reports the OLS estimates of equation 3, 4 and 5 during the period 1985:Q1 – 2008:Q4. Column 1 presents estimates of the baseline rule. Columns 2-5 show estimates of eq. 4 and columns 6-9 report estimates of eq. 5 for each of the financial variables. The last row represents Wald test p-values of the null hypothesis that $\mu^{NR} = \mu^{R}$ for each financial variable. Standard errors are reported in parentheses: entries in *italic* represent White heteroskedasticity-consistent standard errors; entries in ***bold italic*** denote Newey-West standard errors. Aforementioned standard errors are used where appropriate on the basis of the results of White heteroskedasticity test and Ljung–Box Q test. SE denotes the standard error of the estimated model. *, **, *** indicate statistical significance at 10%, 5% and 1% level respectively.

Table 2: Indirect reaction to financial market developments

	(1) D^{FCI}	*(2)* D^{CSPR}	*(3)* D^{SP500}	*(4)* D^{LIQ}	*(5)* D^{07-08}
α	-1.65 (1.24)	-1.64 (*1.62*)	-1.26 (1.15)	-0.48 (1.17)	0.06 (*0.76*)
ρ_1	1.49*** (0.08)	1.43*** (*0.08*)	1.45*** (0.08)	1.46*** (0.08)	1.29*** (*0.08*)
ρ_2	-0.60*** (0.07)	-0.53*** (*0.07*)	-0.56*** (0.07)	-0.57*** (0.07)	-0.45*** (*0.07*)
β^{ND}	2.49*** (0.48)	2.38*** (*0.59*)	2.22*** (0.40)	1.93*** (0.40)	1.73*** (*0.28*)
γ^{ND}	1.25** (0.59)	0.97** (*0.44*)	1.03*** (0.39)	1.02*** (0.39)	1.26*** (*0.23*)
β^D	2.00*** (0.42)	1.69*** (*0.56*)	1.72*** (0.46)	0.95 (0.69)	-1.41 (*1.02*)
γ^D	1.09** (0.44)	1.05 (*1.22*)	0.75 (0.59)	1.02 (0.62)	1.99*** (*0.62*)
SE	0.36	0.35	0.35	0.35	0.31
$\beta^{ND} = \beta^D$	0.09	0.17	0.09	0.05	0.00
$\gamma^{ND} = \gamma^D$	0.83	0.94	0.70	0.99	0.26

Notes: This table reports the OLS estimates of Equation 6 during the period 1985:Q1 – 2008:Q4. Columns 1-4 report estimates of Eq. 6 for each financial market stress dummy. Column 5 shows estimates of Eq. 6 where financial stress dummy captures only the last financial crisis/last recession, i.e. takes value 1 during 2007:Q4 – 2008:Q4. The last two rows represent Wald test p-values of the null hypotheses that $\beta^{ND} = \beta^D$ and $\gamma^{ND} = \gamma^D$ respectively. See also Table 1 notes.

Table 3: Direct reaction to financial market developments during 2007-2009 crisis

	(1) *FCI*	*(2)* *CSPR*	*(3)* *SP*500	*(4)* *LIQ*
α	-0.47 (0.80)	0.49 *(1.24)*	-0.78 (0.91)	0.09 (0.90)
ρ_1	1.36*** (0.08)	1.32*** *(0.07)*	1.38*** (0.09)	1.37*** (0.09)
ρ_2	-0.50*** (0.07)	-0.47*** *(0.06)*	-0.52*** (0.08)	-0.50*** (0.08)
β	1.91*** (0.30)	1.89*** *(0.31)*	1.90*** (0.33)	1.74*** (0.32)
γ	1.09*** (0.24)	1.07*** *(0.28)*	0.82*** (0.30)	1.20*** (0.24)
μ^{NR}	0.48** (0.20)	-0.96 *(0.98)*	0.03* (0.02)	0.03 (0.05)
μ^{R}	2.48** (0.94)	-3.77*** *(1.05)*	0.21*** (0.07)	0.56*** (0.15)
SE	0.32	0.31	0.33	0.31
$\mu^{NR} = \mu^{R}$	0.04	0.01	0.02	0.001

Notes: This table reports the OLS estimates of Equation 5 during the period 1985:Q1 – 2008:Q4. Columns 1-4 correspond to columns 6-9 in Table 1 and show estimates of Eq. 5 where financial markets stress dummy captures only the last financial crisis/last recession, i.e. takes value 1 during 2007:Q4 – 2008:Q4. See also Table 1 notes.

Appendix 1. Data

Variable	Description	Source	Sample
Interest rate	Effective Federal Funds Rate (quarterly average)	Federal Reserve Economic Data at FREDII database http://research.stlouisfed.org/fred2/	1979:Q4 – 2012:Q1
Expected inflation	The median forecasts for one-year-ahead annual average inflation measured by the GDP price index	Survey of Professional Forecasters http://www.phil.frb.org/research-and-data/real-time-center/survey-of-professional-forecasters/historical-data/inflation-forecasts.cfm	1979:Q4 – 2012:Q1
Output gap	The percentage deviation of the log real GDP (seasonally adjusted) from its Hodrick-Prescott trend (lambda 1600). The HP trend is calculated using the data for the period 1979:Q4 – 2012:Q1	Real GDP data obtained from Federal Reserve Economic Data at FREDII database http://research.stlouisfed.org/fred2/	1979:Q4 – 2012:Q1
CITI FCI	Citi Financial Conditions Index: includes corporate spreads, money supply, equity values, mortgage rates, the real trade-weighted dollar index, and energy prices The index is stated in terms of standard deviations from norms, so that a zero FCI is consistent with a normal prospective pace of expansion. Positive index readings represent environments in which financial variables are collectively exerting and expansionary force on the economy; negative figures represent contractionary conditions	Provided in Hatzius et al. 2010, available online at: http://www.princeton.edu/~mwatson/ Monthly data converted into quarterly by taking three month average of the index The index is constructed by D'Antonio (2008).	1983:Q1 – 2009:Q4
SPR1	Interest rate spread between Moody's Seasoned Baa Corporate Bond Yield (average of daily data) and Moody's Seasoned Aaa Corporate Bond Yield (average daily data).	Federal Reserve Economic Data at FREDII database http://research.stlouisfed.org/fred2/	1979:Q4 – 2012:Q1
SP	Percentage year-on-year change in S&P500 index	Federal Reserve Economic Data at FREDII database http://research.stlouisfed.org/fred2/	1979:Q4 - 2012:Q1
LQ	Index of aggregate liquidity in stock markets is constructed in Pastor and Stambaugh (2001) as the equally weighted average of the liquidity measures of individual stocks on the NYSE and AMEX, using daily data within the month and is negative in general (some positive value exists) and larger in absolute magnitude when liquidity is lower Quarterly measures obtained by averaging monthly data	Available online at: http://faculty.chicagobooth.edu/lubos.pastor/research/liq_data_1962_2011.txt	1979:Q1 – 2011:Q4

Appendix 1. Data (continued)

Dummy variable	Description	Source	Sample
D^{CITI}	Dummy variable which takes value 1 when CITI Financial conditions Index (*CITI FCI*) is negative/below average value	Citi index series provided in Hatzius et al. 2010, available online at: http://www.princeton.edu/~mwatson/publi.htm The index is constructed by D'Antonio (2008)	1983:Q1 – 2009:Q4
D^{SPR1}	Dummy variable which takes value 1 when interest rate spread between Moody's Seasoned Baa Corporate Bond Yield and Moody's Seasoned Aaa Corporate Bond Yield (*SPR1*) is above its historical average. Historical average is calculated using the data for the sample 1919:Q1 – 2012:Q1	Federal Reserve Economic Data at FREDII database http://research.stlouisfed.org/fred2/	1979:Q4 – 2012:Q1
D^{SP}	Dummy variable which takes value 1 when S&P500 index at a given quarter is smaller than its 2-year moving average	Federal Reserve Economic Data at FREDII database http://research.stlouisfed.org/fred2/	1979:Q4 - 2012:Q1
D^{LQ}	Dummy variable which takes value 1 when aggregate liquidity index (*LQ*) is less than its average minus one standard deviation (-0.07403). The average and standard deviation are calculated from the sample 1963:Q1 – 2011:Q4	LQ series is provided by Lubos Pastor: http://faculty.chicagobooth.edu/lubos.pastor/research/	1979:Q1 – 2011:Q4
D^{REC}	Dummy variable which takes value 1 during recessionary periods as defined by NBER	Federal Reserve Economic Data at FREDII database http://research.stlouisfed.org/fred2/	1979:Q4 – 2012:Q1