Has the Fed Responded to House and Stock Prices? A Time-Varying Analysis *

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First Version: February, 2016

Abstract

We ask whether the Fed has responded systematically to asset prices and whether this response has changed over time. We estimate a structural VAR with time-varying parameters and stochastic volatility to identify potential time variation in the coefficients on inflation, output gap, house prices and stock prices. To recover the systematic component of monetary policy, we interpret the interest rate equation in a VAR as an extended monetary policy rule. For the estimated monetary policy rule we find time-variation in the coefficients for house prices and stock prices but fairly stable coefficients over time for inflation and output gap. Our results point out that the systematic component of monetary policy in the U.S. i) attached a positive weight to real house price growth but lowered it prior to the crisis and eventually raised it again and ii) cared episodically about real stock price growth in the 1987 stock market crash period.

Keywords: Bayesian VAR, Time-varying parameters, Monetary policy, House prices, Stock market

JEL codes: C32, E44, E52, E58

*This paper should not be reported as representing the views of Norges Bank. The views expressed are those of the authors and do not necessarily reflect those of Norges Bank. For useful comments we thank Fabio Canova, Jordi Galí and seminar participants at Norges Bank.

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1 Introduction

The length and the severity of the Great Recession favored a large interest on the evolution of US monetary policy over the period that preceded the recent economic slump. The debate concerns the response of the Federal Reserve to its traditional objectives (such as inflation and a measure of real economic activity) as well as the possible direct response to additional variables (such as different measures of asset prices) to integrate financial stability considerations. On the one hand, in fact, Taylor (2007, 2009) argues that the interest rate was too low for too long, as the Fed lowered its response to inflation over the period 2000-2007. To support his argument, he shows that the historical interest rate was significantly lower than the value prescribed by the well-known Taylor rule that is considered as a good benchmark for monetary policy. On the other hand, the financial nature of the Great Recession strengthened the view that monetary policy should pay more attention and eventually respond directly to asset prices (cf. Lowe and Borio (2002) Cecchetti et al. (2002); Stein (2014)). Proponents of this view challenge "the conventional wisdom" that the Fed should not (and did not) react to asset prices, based on the influential contributions by Bernanke and Gertler (2000, 2001) that dismiss a direct response to asset prices.

In this paper we take one step back and we evaluate to what extent the Fed reacted to asset prices in the context of a positive analysis. In particular, we consider whether stock prices and house prices entered the Fed's reaction function with a positive and significant coefficient. Our key contribution is that we conduct our experiment in a VAR model with time-varying parameters and stochastic volatility (TVP-SV-VAR, henceforth), following Primiceri (2005). More specifically, we interpret the interest rate equation in our VAR with five variables (interest rate, inflation rate, output gap, house prices and stock prices) as an extended monetary policy rule in the spirit of Arias et al. (2015). This set-up allows us to track the systematic response to stock prices and house prices over our sample period which goes from 1975:Q2 to 2008:Q4. As far as we know, the seminal contributions in this literature (cf. Bernanke and Gertler (2000), and Rigobon and Sack (2003)) and the following extensions are all based on models with constant coefficients. The use of a model with time-varying coefficients and stochastic volatility is crucial to investigate whether the response to asset prices changed over time but also to evaluate Taylor's claim that the response to inflation declined in the pre-Great Recession period.

Our main result is that the Fed, according to our model, responded to house prices and stock prices. While the response to stock prices was mild and episodic, in keeping with results from the previous literature, the response to house prices was significant, from a statistical point of view but also in an economic sense. We estimate the coefficient for house price growth to be about one third of the inflation coefficient in the monetary policy rule. Moreover, we identify non-negligible time variation in the coefficients. The coefficient on stock prices is higher around the end of the 80s, thus capturing a special response to the stock market crash of 1987, whereas it is relatively low and stable in the last part of the sample. Furthermore, the coefficient on house price inflation exhibits larger swings: we identify a lower response around the mid 90s and also in the Pre-Great Recession period. Nevertheless, the magnitude of the coefficient is relatively large even in the pre-Great Recession period. Finally, the coefficients on inflation and the output gap and the interest rate smoothing term are relatively stable over time, with the partial exception of the mid 90s.

While we do not find major evidence of time-variation in the coefficients for inflation and the output gap, the use of a model with time-varying coefficients and stochastic volatility turns out to be crucial for detecting the Fed's response to house price growth and to stock market returns. In fact, when we shut down time variation in the coefficients or stochastic volatility, the model does not detect any response to house price growth. Therefore, we conclude that having a model with time-varying coefficients and stochastic volatility is crucial in order to analyze our research question. This finding is robust to changing the order of the variables in our VAR, used for identification, as well as replacing the output gap with alternative output measures.

This paper contributes to two strands of the literature. First, we obviously complement previous studies on the monetary policy response to stock prices in the context of empirical models such as single equation models estimated with GMM, VAR models and DSGE models. Bernanke and Gertler (2000) estimated Taylor-type rules with a GMM methodology for the US and Japan over the period 1979-1997 and find evidence of a very small response, always statistically insignificant and in some cases even negative. Rigobon and Sack (2003) argue that the literature based on single equation estimation fails to find a significant interaction between monetary policy and stock prices because it does not properly consider the simultaneous interdependence between interest rates and stock prices due to the presence of weak instruments. They estimate a VAR identified through heteroskedasticity (in which zero-restrictions on the contemporaneous interaction between interest rates and stock prices are not needed) and conclude that the response of monetary policy to stock prices is positive and significant over the period 1985-1999. The same result emerges in Castelnuovo and Nisticò (2010), in an estimated dynamic stochastic general equilibrium (DSGE) model where monetary policy responds to fluctuations in the stock market, and in Bjørnland and Leitemo (2009), in a VAR identified using a combination of short-run and long-run restrictions.[1] Nevertheless, a more recent literature argues that previous results depend to some extent on the chosen sample period. Furlanetto (2011) extends until 2007 the sample period used by Rigobon and Sack (2003) and concludes that the positive response identified over the period 1985-1999 is largely driven by the stock market crash of 1987. In addition, he finds evidence of a reduced response in more recent years. Ravn (2012) introduces a non-linearity in the same model and shows that monetary policy reacts significantly to stock price drops but not to stock market booms. Therefore, those results seem to suggest that the use of a model with time-varying coefficients may be necessary to investigate properly the relationship between monetary policy and stock prices.

We contribute also to a second (and more recent) strand of literature that introduces asset prices into time-varying parameter VAR models. Prieto et al. (2016) use data on several financial variables (including house prices and stock prices) to investigate the time-varying transmission mechanism and the relative importance of various financial

[1] Importantly, while several papers study the response of monetary policy to stock prices, the response to house prices is largely unexplored. A notable exception is Finocchiaro and Heideken (2013) who estimate the house price coefficient in a monetary policy rule and finds evidence of a positive and significant response in the US in the context of a DSGE model. Bjørnland and Jacobsen (2013) provide evidence on the (conditional) response of interest rates to shocks originating in the stock market and in the housing sector but do not report the coefficients in the interest rate equation.

shocks. However, they do not consider the systematic component of monetary policy in their analysis. Gali and Gambetti (2015) study the time-varying response of stock prices to monetary policy shocks when the monetary policy response to stock prices is fixed (either at zero or at the value estimated by Rigobon and Sack (2003)). While our model is similar, our focus is on the opposite relationship, i.e. the response of monetary policy to stock prices.

Finally, we contribute also to the debate on the monetary policy stance in the pre-Great Recession period initiated by Taylor (2007, 2009). Belongia and Ireland (2015) estimate a TVP-SV-VAR models with three variables (a measure of inflation, the interest rate and a measure of real economic activity) and find evidence of a lower response to inflation in recent years, thus supporting the Taylor's evidence. Our model can be seen as an extension of their model to include asset prices in the analysis. Importantly, we do not find the same evidence of lower response to inflation in recent years. The difference in results can be ascribed to two sources. First, we include house price growth and stock prices in the monetary policy reaction function. Second, we report the time evolution of the sum of the coefficients on the contemporaneous and lagged variables, while Belongia and Ireland (2015) only report the time evolution of the contemporaneous coefficients.

The paper proceeds as follows. Section 2 lays out the model and the details of the estimation. Section 3 presents our results and a sensitivity analysis. Section 4 relates our results to the debate on the monetary policy stance in the pre-Great Recession period. Finally, Section 5 concludes.

2 Econometric Model

To study whether the FED responded to asset prices in the Pre-Great Recession period, we avail ourselves of the time-varying parameters and stochastic volatility SVAR model à la Primiceri (2005) and Cogley and Sargent (2005).

The reduced form VAR representation is given by

$$x_t = c_t + B_{1,t}x_{t-1} + ... + B_{p,t}x_{t-p} + u_t,\ t = 1, ..., T, \tag{2.1}$$

where x_t is a $n \times 1$ vector of endogenous variables, c_t is a $n \times 1$ vector of time-varying coefficients that multiply constant terms, $B_{i,t}$, $i = 1, ..., p$ are $n \times n$ matrices of time-varying coefficients and $u_t \sim MVN(0, \Omega_t)$, where $A_t \Omega_t A_t' = \Sigma_t \Sigma_t'$, with Σ_t diagonal and A_t, the contemporaneous (time-varying) coefficients matrix, lower triangular. In stacked form, the model is equal to:

$$X_t = C_t + B_{1,t} X_{t-1} + ... + B_{p,t} X_{t-p} + A_t^{-1} \Sigma_t \varepsilon_t \tag{2.2}$$

$$\Leftrightarrow X_t = B_t Z_t + A_t^{-1} \Sigma_t \varepsilon_t, \tag{2.3}$$

where $Z_t \equiv I_n \bigotimes [1, x_{t-1}, ..., x_{t-p}]$.

The time-varying parameters evolve according to $B_t = B_{t-1} + \nu_t$, $\alpha_t = \alpha_{t-1} + \zeta_t$, $\log \sigma_t = \log \sigma_{t-1} + \eta_t$[2]. It is assumed that the innovations in the model are jointly normal distributed with the following variance-covariance matrix:

$$V = \text{Var}\left(\begin{bmatrix} \varepsilon_t \\ \nu_t \\ \zeta_t \\ \eta_t \end{bmatrix} \right) = \begin{bmatrix} I_n & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & W \end{bmatrix}. \tag{2.4}$$

The structural representation is recovered via a recursive identification scheme. Following Primiceri (2005), we use the first 10 years of data as a training sample to calibrate the priors for estimation over the actual sample period which starts in 1985Q3. We apply the same hyperparameters as in Primiceri (2005) and set the lag length of p=1.[3] The total number of Gibbs sampling iterations is 150,000 with a burn-in of 100,000 draws.[4] We keep the remaining 50,000 and use every 100th for inference. Finally, when necessary, we truncate the autoregressive matrices to yield stationary draws[5].

[2]To check the validity of these assumptions we run a rolling window constant parameter VAR model. We find random-walk behaviour in the first difference of the coefficients, a result which substantiates the validity of the assumptions.

[3]We regress the residuals of our model on the exogenous regressors and find no evidence of statistically significant coefficients. The residuals and regressors are thus uncorrelated which points the fact that no significant lags have been omitted.

[4]We follow the updated MCMC procedures suggested by Del Negro and Primiceri (2015). They retain most of the procedures in Primiceri (2005) except that sampling of stochastic volatilities is preceded by sampling of states for mixture components approximations to errors with log chi-square distributions.

[5]In all applications, the number of stationary draws was always above 2/3.

2.1 Data

In our VAR, we consider quarterly data from 1975Q2 to 2008Q4. In particular the vector $X_t = [\Pi_t \quad \widetilde{Y}_t \quad \Delta H_t \quad \Delta S\&P_t^{500} \quad FFR_t]'$ consists of Π_t, year-over-year percentage changes in the deflator for personal consumption expenditures (excluding food and energy), $\widetilde{Y}_t$, output gap measured as the percentage-point difference between actual and potential GDP, ΔH_t, percentage growth of real Freddie Mac House price index, $\Delta S\&P_t^{500}$, percentage growth of real S&P 500 index, and finally FFR_t, federal funds rate. Asset prices are deflated by core PCE. All raw series are drawn from the Federal Reserve Bank of St. Louis' FRED database.

2.2 Systematic Component of Monetary Policy

The systematic component of monetary policy is recovered from the structural representation of our TVP-SV-VAR(1) model which is given by

$$A_t X_t = A_t C_t + A_t B_{1,t} X_{t-1} + \Sigma_t \varepsilon_t \tag{2.5}$$

or, equivalently, and omitting constant terms

$$\underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21,t} & 1 & 0 & 0 & 0 \\ a_{31,t} & a_{32,t} & 1 & 0 & 0 \\ a_{41,t} & a_{42,t} & a_{43,t} & 1 & 0 \\ a_{51,t} & a_{52,t} & a_{53,t} & a_{54,t} & 1 \end{bmatrix}}_{At} \underbrace{\begin{bmatrix} \Pi_t \\ \widetilde{Y}_t \\ \Delta H_t \\ \Delta SP_t \\ R_t \end{bmatrix}}_{X_t}$$

$$= \underbrace{\begin{bmatrix} ab^1_{11,t} & ab^1_{12,t} & ab^1_{13,t} & ab^1_{14,t} & ab^1_{15,t} \\ ab^1_{21,t} & ab^1_{22,t} & ab^1_{23,t} & ab^1_{24,t} & ab^1_{25,t} \\ ab^1_{31,t} & ab^1_{32,t} & ab^1_{33,t} & ab^1_{34,t} & ab^1_{35,t} \\ ab^1_{41,t} & ab^1_{42,t} & ab^1_{43,t} & ab^1_{44,t} & ab^1_{45,t} \\ ab^1_{51,t} & ab^1_{52,t} & ab^1_{53,t} & ab^1_{54,t} & ab^1_{55,t} \end{bmatrix}}_{A_t B_{1,t}} \underbrace{\begin{bmatrix} \Pi_{t-1} \\ \widetilde{Y}_{t-1} \\ \Delta H_{t-1} \\ \Delta SP_{t-1} \\ R_{t-1} \end{bmatrix}}_{X_{t-1}} + \underbrace{\begin{bmatrix} \sigma_{1,t} & 0 & 0 & 0 & 0 \\ 0 & \sigma_{2,t} & 0 & 0 & 0 \\ 0 & 0 & \sigma_{3,t} & 0 & 0 \\ 0 & 0 & 0 & \sigma_{4,t} & 0 \\ 0 & 0 & 0 & 0 & \sigma_{5,t} \end{bmatrix}}_{\Sigma_t} \underbrace{\begin{bmatrix} \varepsilon_{\pi,t} \\ \varepsilon_{Y,t} \\ \varepsilon_{H,t} \\ \varepsilon_{SP,t} \\ \varepsilon_{R,t} \end{bmatrix}}_{\varepsilon_t} . \tag{2.6}$$

Looking at the fifth row, we have

$$\begin{aligned} & a_{51,t}\Pi_t + a_{52,t}\widetilde{Y}_t + a_{53,t}\Delta H_t + a_{54,t}\Delta S\&P_t^{500} + R_t \\ & = ab_{51,t}^1\Pi_{t-1} + ab_{52,t}^1\widetilde{Y}_{t-1} + ab_{53,t}^1\Delta H_{t-1} + ab_{54,t}^1\Delta S\&P_{t-1}^{500} + ab_{55,t}^1 R_{t-1} + \sigma_{5,t}\varepsilon_t^R. \end{aligned} \tag{2.7}$$

Bringing R_t on the left hand side yields

$$\begin{aligned} R_t = & -a_{51,t}\Pi_t - a_{52,t}\widetilde{Y}_t - a_{53,t}\Delta H_t - a_{54,t}\Delta S\&P_t^{500} \\ & + ab_{51,t}^1\Pi_{t-1} + ab_{52,t}^1\widetilde{Y}_{t-1} + ab_{53,t}^1\Delta H_{t-1} + ab_{54,t}^1\Delta S\&P_{t-1}^{500} + ab_{55,t}^1 R_{t-1} \\ & + \sigma_{5,t}\varepsilon_t^R, \end{aligned} \tag{2.8}$$

where the coefficient $ab_{55,t}^1$ captures the degree of interest rate smoothing.

We will focus on the time evolution of the sum of the coefficients on the contemporaneous and lagged variables (e.g. $-a_{51,t}+ab_{51,t}^1$ for Π_t). This is motivated by two reasons. The first is an economic one and deals with the fact that central banks might not have information on current data and thus rather consider some linear or weighted combination of the desired current and lagged coefficients. The second is an econometric one and it recognizes the fact that in autoregressive models the coefficients on the lags of a process can compensate each other, concentrating on a single coefficient would thus be misleading if one seeks to explore the contribution of a given variable on the interest rate path.

3 Results

We find significant and time-varying coefficients on asset prices such as real house price and real stock price growth. As to standard objectives of monetary policy, we provide evidence of fairly stable coefficients on inflation and output gap. Finally, we show that taking into account time-varying parameters as well as stochastic volatility is important.

The reported systematic components of monetary policy are for the period ranging from 1985:Q3 to 2008:Q4 since we discard the observations which have already been used in the training sample to set up the priors in our TVP-SV-VAR(1) estimation procedure.

3.1 Baseline Results

To give some guidance on how to interpret the magnitude of the sum of the coefficients on a current and lagged variable consider as an example the following Taylor type rule featuring interest rate smoothing:

$$R_t = (1 - \rho_r)(c + \omega_\pi \pi_t + \omega_y \tilde{y}_t) + \rho_R R_{t-1}, \tag{3.1}$$

where c contains the inflation and output gap objectives. The coefficients generally considered standard in a Taylor (1993) rule are 1.5 on inflation and 1 on output gap. Thus, if ρ_r is found to be equal to 0.85, as shown in Figure 1, one should expect ω_π and ω_y to be close to 0.225 and 0.15 respectively.

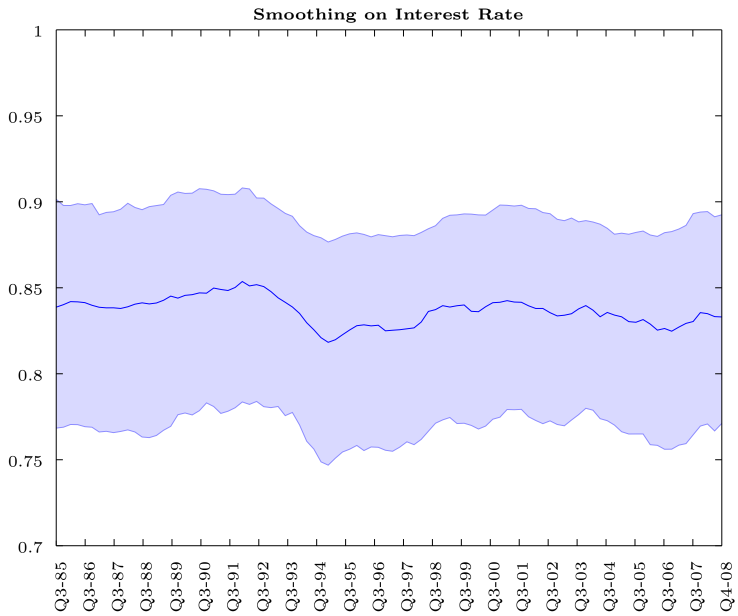

Figure 1: Degree of Interest Rate Smoothing, Baseline Model.

This is in line with the magnitude of the sum of coefficients on current and lagged core PCE inflation and output gap shown in Figure 2. The coefficients are fairly stable over time with evidence of a gradual decrease and subsequent increase in the inflation coefficient from early 1992 to late 1998. The output coefficient features the inverse pattern and thus (partially) compensates the decline in the inflation coefficient.

Next, we answer the main questions of interest to this paper, namely i) whether the Fed responded systematically to asset prices and ii) whether this response changed over time. The evidence shown in Figure 3 provides a positive answer to both questions.

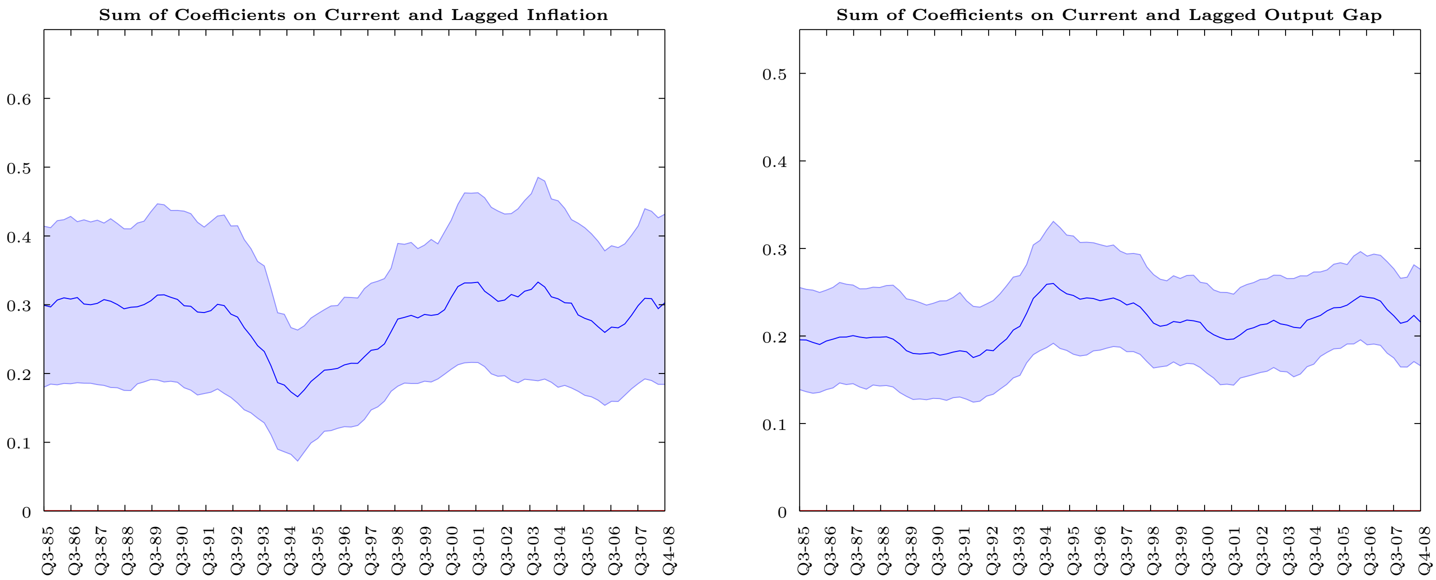

Figure 2: Sum of Coefficients on Inflation and Output Gap, Baseline Model.

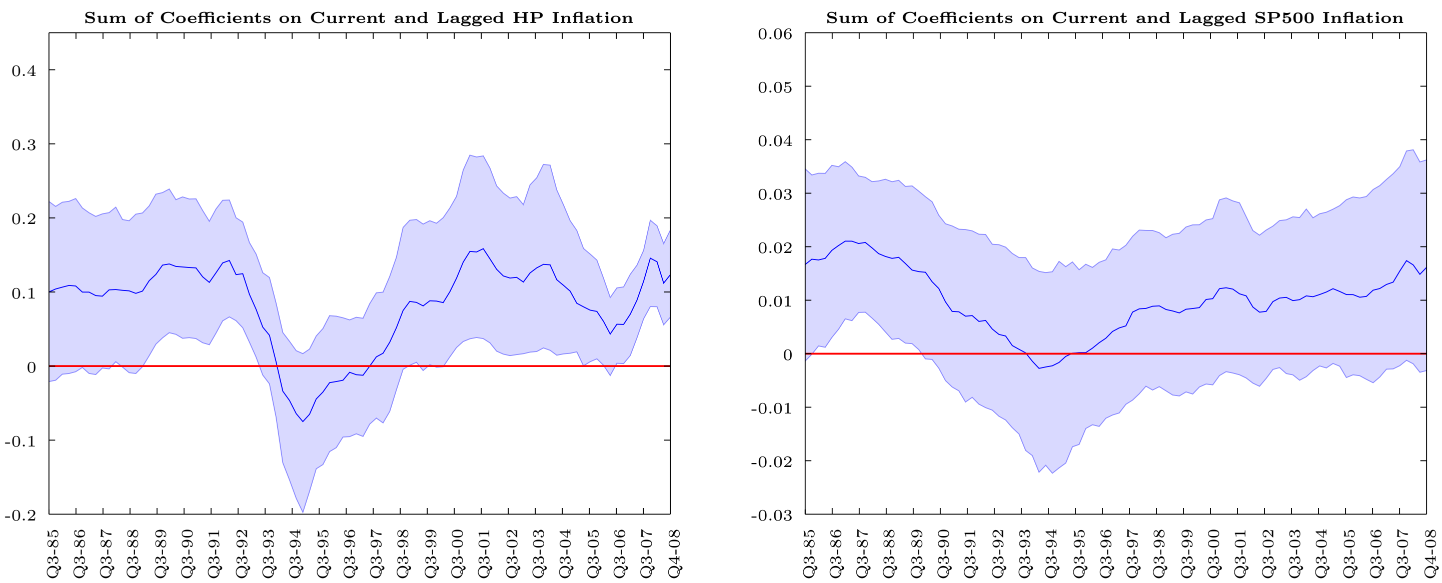

Figure 3: Sum of Coefficients on Real House Price and S&P 500 Growth, Baseline Model.

Indeed, the real S&P 500 growth coefficient is significant and equal to 0.02 around the 1987 financial crisis and otherwise (weakly) insignificant. The magnitude of the coefficient is in the ballpark of the one found by Rigobon and Sack (2003). Moreover, our results are in line with Furlanetto (2011) which shows that the positive and significant coefficient found by Rigobon and Sack (2003) relies on the 1987 financial crisis period being present in the sample. The most interesting picture is the one drawn by the real house price growth coefficient. The latter is significant and roughly equal to 0.1 (about one third of the inflation coefficient) during the 1990-1992 recession (also related to the savings and loan crisis) and in the period following the dot-com bubble. Interestingly, the coefficient gradually decreases from early 2004 and starts rising again back to its previous level in the year prior to the outburst of the financial crisis in 2007:Q4[6].

4 Sensitivity Analysis

In this section we perform robustness checks on the results of the baseline model.

In the first exercise we change the ordering of the variables in our econometric model. More specifically we change the vector X_t from $X_t = [\Pi_t\ \widetilde{Y}_t\ \Delta H_t\ \Delta S\&P_t^{500} FFR_t]'$ to $X_t = [\Pi_t\ \widetilde{Y}_t\ FFR_t\ \Delta H_t\ \Delta S\&P_t^{500}]'$. This is motivated by the fact that one could argue that restricting house prices and stock prices to not respond contemporaneously to monetary policy shocks is an implausible assumption. This argument does not sound unreasonable in light of the financial and thus fast-moving nature of the asset price.[7] The results from this exercise point towards a level shift in the coefficients on real house price and real S&P 500 growth but do not change the main conclusions that the FED responded to house prices and that it did so in a time-varying fashion.

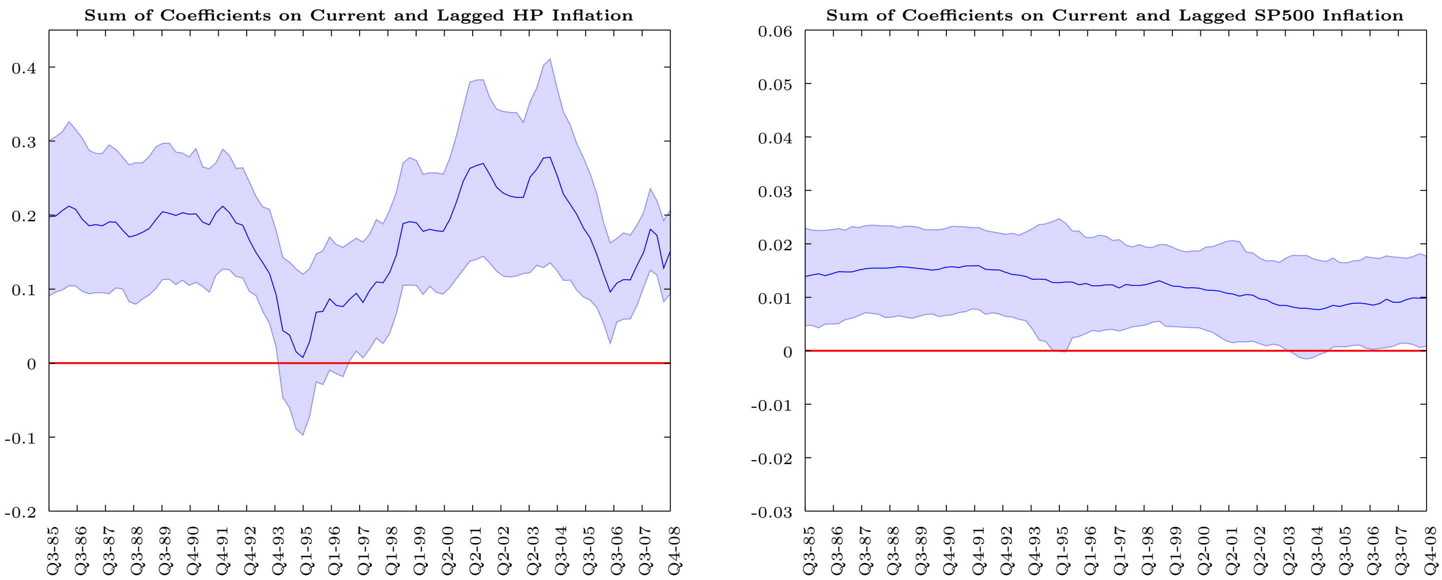

Figure 4: Sum of Coefficients on Real House Price and S&P 500 Growth, Reordered Model with $X_t = [\Pi_t\ \widetilde{Y}_t\ FFR_t\ \Delta H_t\ \Delta S\&P_t^{500}]'$.

[6]In fact, the change in coefficients is close to statistically significant as the 68% credibility intervals prior and during the crisis almost do not overlap.

[7]While allowing for contemporaneous interdependence between the interest rate and asset prices, such as in Bjørnland and Leitemo (2009) would be desirable, standard routines for estimating TVP-SV-VARs, as in Primiceri (2005) and Cogley and Sargent (2005), impose a recursive structure on the VAR.

In the second exercise we use output growth instead of output gap as a measure of real economic activity since one might argue that the output gap is a rough estimate as well as an imperfect measure of its theoretical counterpart. Performing this robustness check does not affect the pattern in the real S&P 500 growth coefficient but it does point towards almost no time-variation being present coefficient on real house price growth which, however, is still statistically and economically significant.

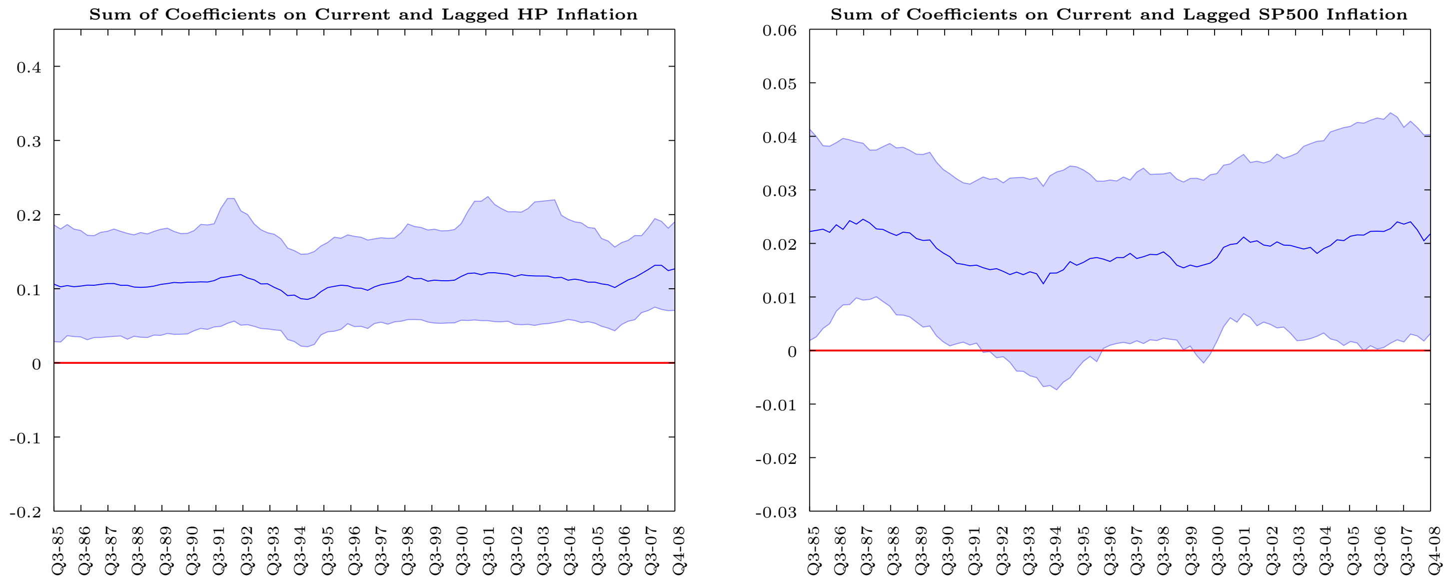

Figure 5: Sum of Coefficients on Real House Price and S&P 500 Growth, Baseline Model with Output Growth ΔY instead of $\widetilde{Y}$.

The last three exercises are devoted to understand in how far there is the need to allow for time-variation and stochastic volatility in our econometric model. As becomes evident from Figures 6, 7 and 8 it is crucial to account for both channels. Indeed, shutting down one or both of them would lead a researcher to mistakenly infer that the FED did not care about asset prices in its conduct of monetary policy.

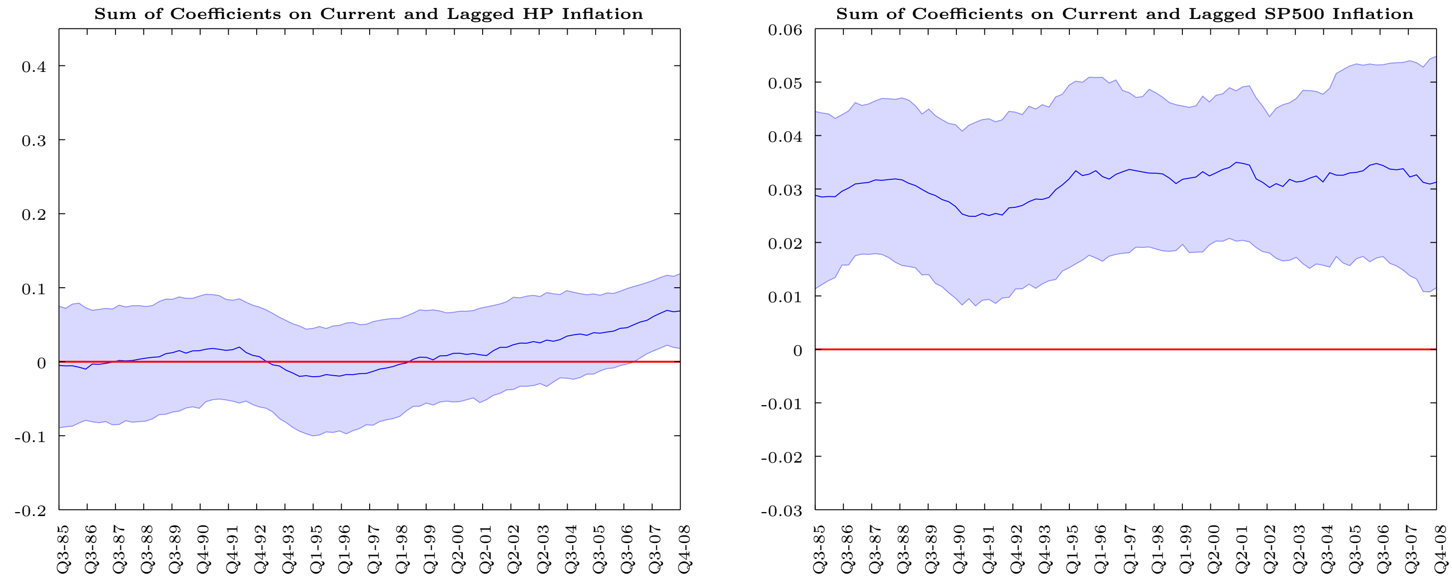

Figure 6: Sum of Coefficients on Real House Price and S&P 500 Growth, Model with No Stochastic Volatility.

Figure 7: Sum of Coefficients on Real House Price and S&P 500 Growth, Model with No Time-Variation in A_t and $B_{1,t}$.

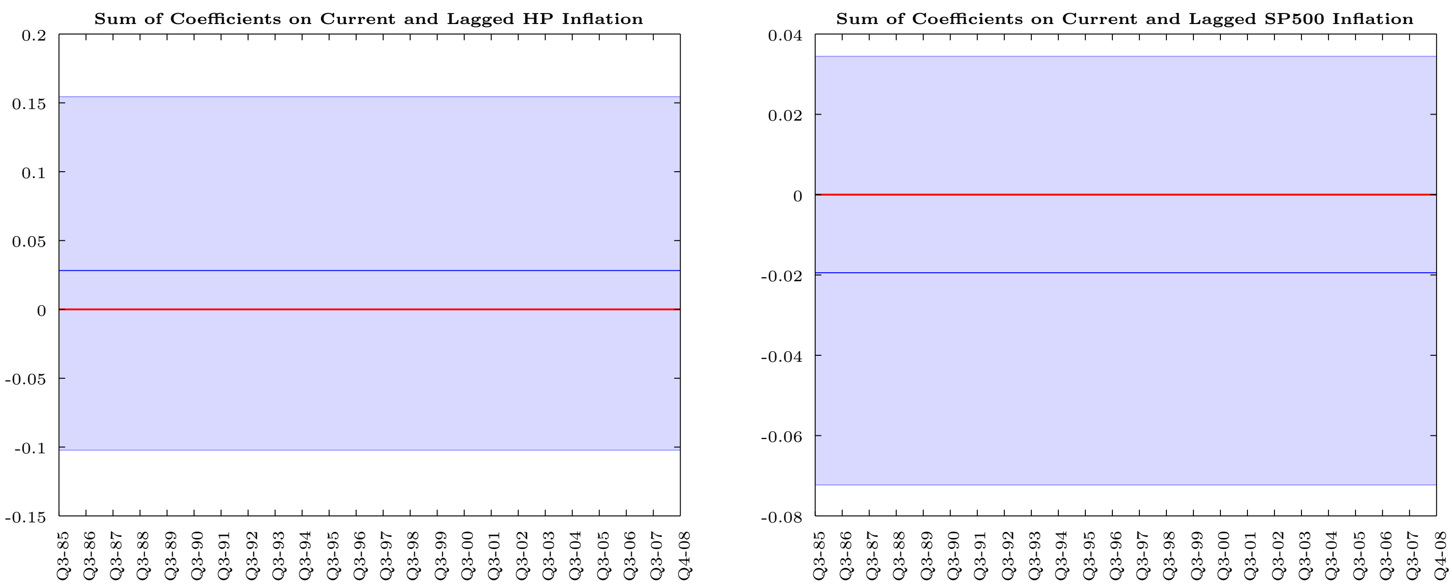

Figure 8: Sum of Coefficients on Real House Price and S&P 500 Growth, Model with No Stochastic Volatility and No Time-Variation in A_t and $B_{1,t}$.

5 Taylor Rule Debate

Consider the “Taylor Rule” given by

$$R_t = \Pi_t + 0.5\ \tilde{Y}_t + 0.5\ (\Pi_t - 2) + 2.$$

Recently, Taylor argued that the FOMC policy has been “too low for too long” compared to the interest rate path prescribed by his formula. In his blog post, see Bernanke (2015), Bernanke shows that using i) real-time data, ii) a modified Taylor rule with a coefficient of 1 for the output gap and iii) PCE inflation instead of GDP inflation the “great deviation” pointed out by Taylor does not emerge.

In this section we explore whether the interest rate path implied by our VAR favours or undermines the arguments recently brought forward by Taylor.

To begin with, consider the fitted interest rate implied by our TVP-SV-VAR(1) model:

$$\begin{aligned} R_t = & -\hat{a}_{51,t}\Pi_t \ -\hat{a}_{52,t}\widetilde{Y}_t \ -\hat{a}_{53,t}\Delta H_t \ -\hat{a}_{54,t}\Delta S\&P^{500}_t \\ & +a\hat{b}^{1}_{51,t}\Pi_{t-1} \ +a\hat{b}^{1}_{52,t}\widetilde{Y}_{t-1} \ +a\hat{b}^{1}_{53,t}\Delta H_{t-1} \ +a\hat{b}^{1}_{54,t}\Delta S\&P^{500}_{t-1} \ +a\hat{b}^{1}_{55,t}R_{t-1}. \end{aligned}$$

Figure 9 shows that the implied VAR interest rate fits well the actual interest rate movements.

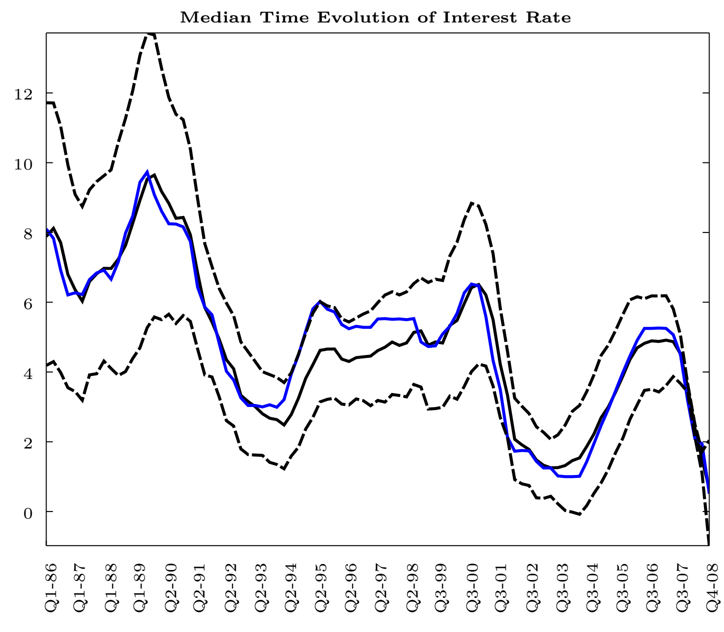

Figure 9: VAR Implied Interest Rate (black) vs Actual Interest Rate (blue).

Next, we use real-time data for core PCE inflation and output gap[8] (the first is only available from 1996:Q2 onwards) and plot the interest rate path implied by the VAR estimated coefficients of the interest rate equation in Figure 10.

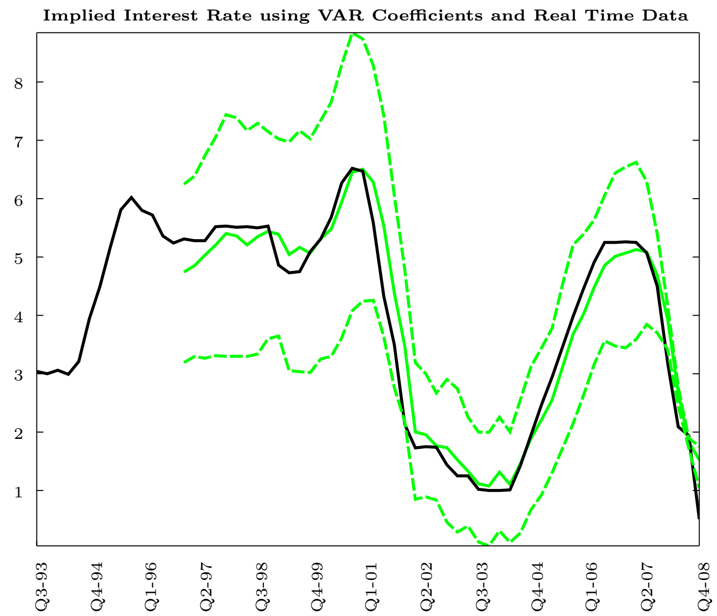

Figure 10: VAR Implied (green) vs Actual Interest Rate (black), Real-Time Data.

In both cases, in line with Bernanke's results, we find no evidence of the interest rate having been "too low for too long". We find the same results when output growth is used instead of output gap as a measure of real activity.

6 Conclusion

The main contribution of this paper is to provide evidence on the time-varying response of monetary policy to stock prices and house prices. We find that the response to stock price fluctuations has been small and episodic, in keeping with the previous literature. Our main result, that as far as we know is new in the literature, is that we find a significant response to house prices, both in economic and statistical terms. While the response to house prices declines somewhat in the pre-Great Recession period, our evidence shows that the Fed considers variables other than inflation and real economic activity in its

[8]Real-time data come from the Federal Reserve Bank of Philadelphia's Real-Time Data Center for Macroeconomists. To download the dataset follow and for more information on the data source follow the links provided in Bernanke's blogpost "The Taylor Rule: A benchmark for monetary policy?".

estimated reaction function. Furthermore, we cannot identify a decline in the response to inflation, thus supporting Bernanke (2015)'s reading of the recent monetary history.

References

Arias, J. E., D. Caldara, and J. F. Rubio-Ramirez (2015). The Systematic Component of Monetary Policy in SVARs: An Agnostic Identification Procedure. International Finance Discussion Papers 1131, Board of Governors of the Federal Reserve System (U.S.).

Belongia, M. T. and P. N. Ireland (2015). The Evolution of US Monetary Policy: 2000-2007. Boston College Working Papers in Economics 882, Boston College Department of Economics.

Bernanke, B. (2015). The Taylor Rule: A benchmark for monetary policy? Ben Bernanke's blog, Brookings.

Bernanke, B. and M. Gertler (2000). Monetary Policy and Asset Price Volatility. NBER Working Papers 7559, National Bureau of Economic Research, Inc.

Bernanke, B. S. and M. Gertler (2001). Should Central Banks Respond to Movements in Asset Prices? *American Economic Review 91*(2), 253–257.

Bjørnland, H. C. and D. H. Jacobsen (2013). House Prices and Stock Prices: Different Roles in the US Monetary Transmission Mechanism. *Scandinavian Journal of Economics 115*(4), 1084–1106.

Bjørnland, H. C. and K. Leitemo (2009). Identifying the interdependence between US monetary policy and the stock market. *Journal of Monetary Economics 56*(2), 275–282.

Castelnuovo, E. and S. Nisticò (2010). Stock market conditions and monetary policy in a DSGE model for the U.S. *Journal of Economic Dynamics and Control 34*(9), 1700–1731.

Cecchetti, S. G., H. Genberg, and S. Wadhwani (2002). Asset Prices in a Flexible Inflation Targeting Framework. NBER Working Papers 8970, National Bureau of Economic Research, Inc.

Cogley, T. and T. J. Sargent (2005). Drift and volatilities: Monetary policies and outcomes in the post wwii u.s. *Review of Economic Dynamics 8*(2), 262–302.

Del Negro, M. and G. Primiceri (2015). Time-varying structural vector autoregressions and monetary policy: A corrigendum. *Review of Economic Studies 82*(4), 1342–1345.

Finocchiaro, D. and V. Q. Heideken (2013). Do Central Banks React to House Prices? *Journal of Money, Credit and Banking 45*(8), 1659–1683.

Furlanetto, F. (2011). Does Monetary Policy React to Asset Prices? Some International Evidence. *International Journal of Central Banking 7*(3), 91–111.

Gali, J. and L. Gambetti (2015). The effects of monetary policy on stock market bubbles: Some evidence. *American Economic Journal: Macroeconomics 7*(1), 233–57.

Lowe, P. and C. Borio (2002). Asset prices, financial and monetary stability: exploring the nexus. BIS Working Papers 114, Bank for International Settlements.

Prieto, E., S. Eickmeier, and M. Marcellino (2016). Time variation in macro-financial linkages. *Journal of Applied Econometrics* (Forthcoming).

Primiceri, G. (2005). Time varying structural vector autoregressions and monetary policy. *Review of Economic Studies 72*(3), 821–852.

Ravn, S. H. (2012). Has the Fed Reacted Asymmetrically to Stock Prices? *The B.E. Journal of Macroeconomics 12*(1), 1–36.

Rigobon, R. and B. Sack (2003). Measuring The Reaction of Monetary Policy to the Stock Market. *The Quarterly Journal of Economics 118*(2), 639–669.

Stein, J. C. (2014). Incorporating Financial Stability Considerations into a Monetary Policy Framework : a speech at the International Research Forum on Monetary Policy, Washington, D.C., March 21, 2014. Speech 796, Board of Governors of the Federal Reserve System (U.S.).

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy 39*(1), 195–214.

Taylor, J. B. (2007). Housing and Monetary Policy. NBER Working Papers 13682, National Bureau of Economic Research, Inc.

Taylor, J. B. (2009). The Financial Crisis and the Policy Responses: An Empirical Analysis of What Went Wrong. NBER Working Papers 14631, National Bureau of Economic Research, Inc.