Does Monetary Policy generate Asset Price Booms and Busts?*

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Abstract
Asset prices are a key channel of the transmission of monetary policy. Yet, the implementation of expansionary monetary policies in recent years has raised concerns that they could generate asset price booms. Rather than evaluating the effect of monetary policy on asset prices overall – one of the usual transmission channels –, we assess the effect of monetary policy on the bubble component of asset prices. The identification of bubbles remains an open issue as there is no consensus on the appropriate model for determining the fundamental value of an asset. In this paper, we resort to several approaches – structural or statistical – and estimate their common denominator using a Principal Component Analysis to obtain a synthetic measure of booms and busts for three assets – stocks, bonds and housing – in the euro area and in the United States. We then assess the linear and non-linear impact of overall and unconventional monetary policy shocks on these bubble components. Monetary shocks are identified through VAR, the approaches of Romer and Romer (2004) and Kuttner (2001) or from a forward-looking Taylor rule. Our results suggest that there is no strong and stable causal link between monetary policy and asset price bubbles.

Keywords: Asset price bubbles, Monetary policy, Quantitative Easing, Federal Reserve, ECB.

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1. Introduction

Since 2009, central banks have implemented expansionary monetary policies to support economic activity and prevent industrialized economies from deflation. Interest rates quickly reached the zero lower bound leading central banks to resort to exceptional measures. The introduction of unconventional monetary policy has given rise to a growing literature assessing the impact of those measures as well as their transmission channels. More recently, the focus has turned to the potential adverse effects of expansionary monetary policies. Some financial commentators were prompt to see asset price bubbles when stock prices resumed. Those warnings are notably fueled by the observed correlation between the size of the Federal Reserve's balance sheet in the US and the stock market prices (Figure 1). This debate echoes the critics raised by Taylor (2009) who suggested that the sustained period of low interest rate in the United States between 2001 and 2004 has fueled the boom in the housing market and caused thereafter the subprime crisis. These critics challenge the former consensus between economists –sometimes called "Jackson Hole Consensus" [1] – on the role of monetary policy regarding asset price and financial stability. Rudebush (2005) conditioned the behaviour of monetary policy makers towards asset price bubbles to a positive response to the three following questions. First, can central banks identify bubbles? Second, are bubbles harmful for the economy? Third, does monetary policy influence bubbles? This paper aims at contributing to this debate by providing an assessment of the impact of monetary policy shocks in the euro area and in the United States on asset price booms and busts. It is mainly related to Rudebush (2005)'s first and third questions but does not deal with the second question.

The effectiveness of unconventional monetary policy essentially hinges on the transmission on asset prices through various channels.[2] According to the portfolio rebalancing channel, the purchases of a given asset by central banks push the price of this asset up leading agents to seek for substitutes, which trigger increase of other asset price. The positive impact on asset prices may also result from an improvement of future economic conditions and from a signaling channel, as current decisions provide information on future interest rates. Conventional monetary policy is also expected to influence asset prices[3] since change in policy rates are expected to be passed-through long-term interest rates and to other asset prices. Empirical evidence has broadly confirmed the positive link between expansionary monetary policy and asset prices.[4] The rise of asset prices following expansionary monetary policy is then expected – and seen as a sign of its effectiveness – as a step in the transmission channel of monetary policy. However, an excessive increase in asset prices entails risk for financial stability. Bubbles jeopardize the functioning of the financial system; generate a misallocation of capital and cause recessions. It is then necessary to refine our understanding of the impact of monetary policy on asset prices. Not all increases in asset prices are bubbles. It is then needed to identify which part of the change in asset prices may entail a risk for financial stability and which is related to the normal response of asset prices to monetary policy. Adding the path of dividends, which are considered as fundamentals in stock prices valuation models, may explain, at least for a sub-period, the increase in US stock prices

[1] See Smets (2014) who presents three different views on the attitude of central banks towards financial stability.

[2] See Joyce, McLaren and Young (2012) or Krishnamurthy and Vissing-Jorgensen (2011) for surveys on the transmission channels of QE.

[3] See Boivin, Kiley and Mishkin (2002) for a survey on the transmission channels of monetary policy.

[4] For standard monetary policy, see the early literature developed by Rigobon and Sack (2004) and Bernanke and Kuttner (2005) for stock prices, and Giuliodori (2005), for house prices. A burgeoning literature has recently focuses on the impact of non-standard measures and has highlighted a significant impact of unconventional monetary policy. See Joyce et al. (2011a), Fiordelisi et al. (2014) or Rogers et al. (2014).

(Figure 1). Thus, it seems crucial to disentangle between asset price movements driven by fundamentals and movements non-related to fundamentals.

Yet, separating the wheat from the chaff is a tricky issue and supposes to define and identify the fundamental value of an asset. Under rational expectations, without imperfect information and when agents are risk-neutral, the asset's fundamental value is the expected discounted value of future dividends. A bubble solution exists and it is fully rational in this model. Besides, the definition of the fundamental value may change when one or several of the aforementioned hypotheses are relaxed. Therefore the identification of the bubble component remains subject to high uncertainty and a lot of models have also developed to account for irrational behaviors of economic agents.[5] As reminded by Gurkaynak (2005), econometric tests of asset price bubbles are fragile as they fail to disentangle between bubbles and misspecifications of the underlying theoretical model. To avoid the pitfalls of the identification of the bubble component, literature has also relied on a statistical definition of excessive – positive or negative – changes in asset prices. It then referred to boom or bust periods, identified either through a statistical filter (see for example Goodhart and Hofman, 2008, for house prices) or from methods determining turning points – peaks and troughs – as in Bordo and Wheelock (2007). It must be noted that the paper only deals with asset price bubbles though we admit that financial imbalances do not boil down to asset prices. Here we focus on price indicator whereas financial leverage and credit booms, that also matter, are related to the source of financing[6] and are consequently left for further research.

The first contribution of this paper is to propose an agnostic method to single out the bubble's components for three financial assets. As mentioned above, the existing empirical literature does not provide a clear approach to detect and estimate the non-fundamental component of asset prices. Even the words may change across research papers. Some authors identify booms and bust while others explicitly refer to the concept of bubble. In what follows, we make no distinction between these labels. We estimate "fundamental values" for stock, bonds and housing prices from different models: an expected cash-flow model complemented by a risk-premium effect, a model called the full information model taking into account all the available financial and macroeconomic information and a HP-filtered cycle component. For each model, the bubble term is either the residual from estimated models or the cycle component from the HP-filter model. For each model, we also consider as a bubble indicator, the cumulated filtered residuals and the cumulated cycle component. Besides, we also resort to a statistical approach where booms (respectively busts) periods are identified with dummies according to positive (respectively negative) significant deviations from trend. A principal component analysis is then carried out with all bubble terms and used to build a synthetic measure of stock, bonds and housing markets in the euro area and in the United States.

The second contribution of this paper is to assess the impact of monetary policy shocks on these bubble indicators. Monetary policy shocks are measured either by Taylor rules residuals, a Romer and Romer (2004), the Kuttner (2001) or VAR models. The paper is close to the contribution of Gali and Gambetti (2015). But, Contrary to Gali and Gambeti (2015), we don't rely on a single definition of the fundamental value and resort to several approaches to identify bubbles episodes. A distinction is made between standard monetary policy, measured by the EONIA rate or the Federal Funds rate, and unconventional monetary

[5] See Scherbina (2013) for a survey on how bubbles arise in rational expectations models or behavioral models.

[6] Adrian and Shin (2008) point to the role of financial intermediaries in the build-up of financial imbalances and suggest central banks to focus on the financial leverage.

policy, measured either by shadow rates à la Wu and Xia (2016) or the amount of assets purchased by the ECB and the Federal Reserve. The main objective of the paper is then to assess whether central banks may affect the size of bubbles with monetary policy. Does accommodative monetary policy fuel bubbles? Or does restrictive monetary policy deflate bubbles? By examining three asset markets, we also test whether the behavior of asset price bubbles are similar across markets and control for the spillovers between each market. Finally, we raise the issue of potential non linearities and assess the reaction of bubbles to restrictive and accommodative monetary policy shocks.

Our identification suggests that several booms and busts episodes have occurred in the United States and in the euro area since 1986 and 1999 respectively. The main results when looking at linear evidence are that contractionary overall monetary stance shocks have a slightly positive effect on the bubble component of stock markets - reflecting as in Gali and Gambetti (2015) the positive reaction of a rational bubble to an increase in interest rate -, and that expansionary unconventional monetary shocks have a negative effect on the same bubble component. For other markets, results are either inconclusive or specific to the area considered. The main results when looking at non-linear evidence are the following. First, contractionary overall monetary stance shocks have a negative effect on the bubble component of stock markets whereas expansionary shocks have a positive effect. Second, contractionary unconventional monetary shocks have a positive effect on the bubble components of the stock and housing markets whereas expansionary shocks have a negative effect. Accommodative unconventional monetary policy seems not to fuel bubbles. Consequently, our results do not suggest a strong and stable causal link between monetary policy and asset price bubbles. It may then be difficult for central banks to manage controlling asset price bubbles through the use of monetary policy tools.

The remainder of this paper is organized as follows. In Section 2 we present the literature on the relationship between monetary policy and asset prices as well as literature on identifying bubbles. Section 3 presents the identification of asset price booms and busts. In Section 4 we investigate the effect of monetary policy on these components. Section 5 concludes.

2. Related Literature

The objective of this paper is to assess whether monetary policy in the US and in the euro area has encouraged the build-up of bubbles on asset markets and whether it is able to deflate existing bubbles. It is related to the vast literature dealing with the impact of monetary policy decisions on the financial markets (e.g. Rigobon and Sack (2004), Bernanke and Kuttner (2005) and Gürkaynak et al. (2005) for the US and Angeloni and Ehrmann (2003), Bohl et al. (2008), Andersson and Overby (2009) and Filbien and Labondance (2012) for the Euro Area). More precisely, our analysis refers to two strands of the existing literature, one that tackles the issue of asset price bubbles' identification and the other, which deals with the effect of monetary policy on asset bubbles.

2.1. Bubble Identification

Asset price bubbles are not observed and should then be measured though an identification where asset price movements are decomposed between the fundamental and the bubble components. There is yet no consensus on the most appropriate empirical model, reflecting theoretical controversies on the way bubbles are considered in the literature. According to Brunnermeier (2008), "*Bubbles are typically associated with dramatic asset price increases followed by a collapse. Bubbles arise if the price exceeds the asset's fundamental value*". Two interpretations of bubbles emerge from this definition. On the one hand, the notion of bubble seems to be inherently related to the ability to define and calculate the fundamental value of an asset. In the expected cash-flow model, the fundamental value for a stock is the expected value of future actualized dividends. Blanchard and Watson (1982) show that bubbles exist as a solution to the forward-looking equation for securities with infinite maturity. Bubble is then a rational stochastic deviation from the fundamental value, which is equal to the sum of expected cash-flows. Others see bubbles outside the rational expectations paradigm and consider them as a rapid increase in asset prices as emphasized by the first sentence in Brunnermeier's definition. Here, the precise definition of the fundamental is of minor importance. It is recognized that its determination is highly uncertain and that agents' behaviour is the key determinant of bubbles. Kindleberger (2005) and Schiller (2015) have emphasized and documented bubbles' episodes in financial history, defined as exuberant increase in asset prices.

The diversity of empirical approaches used on the literature to identify bubble mimic these views as some will define the bubble term as the deviation to the fundamental value determined according to a theoretical model while others will favour statistical approaches. Gali and Gambeti (2015) disentangle between the fundamental and the bubble component where the fundamental value for stock prices is defined according the expected cash-flow model. Basile and Joyce (2001) suggest that asset price returns is equal to the free-risk interest rate plus a constant risk premium. Bubbles arise when stock or land returns exceed this normal return. The theoretical definition of the fundamental value is then less precise than on the expected cash-flow model but it remains that a bubble is viewed as the deviation from the *normal* value. For the housing market, O'Meara (2015) identifies bubbles from a structural model where house prices result from a demand and supply model, which is estimated.

Statistical approaches rely on appropriate data filtering methods. Using the same approach, some authors may explicitly mention bubbles while others prefer to refer to booms and busts. Goodhart and Hofman (2008) define boom periods for real house prices as a persistent deviation – more than 5% and lasting at least 12 months – of the real price from a smooth trend calculated on a one-sided Hodrick-Prescott (HP) filter. Bordo and Jeanne (2002) identified price boom and bust when the 3-year moving average growth rate deviates from 1.3 times the series standard deviation. This definition is close to Alessi and Detken (2011) for a real aggregate asset price index including equity prices, residential and commercial property prices. A boom is a 1.75 standard deviation from a HP trend. Detken and Smets (2004) also build a synthetic measure based on equity, commercial and residential prices for 18 industrialized countries between 1970 and 2002. The booms are defined as a 10% deviation from a HP trend. Bordo and Landon-Lane (2013) characterize a boom by an expansion phase, with a yearly increase of 5 % for real house price and 10% for real stock prices, of at least two years followed by a significant correction, greater than 25% of the expansion. Jorda et al. (2015) label a bubble a period of a significant increase in asset prices followed by a correction. They define a price-elevation signal, when the real asset price diverge by more than one-standard deviation from the HP trend and a price-correction signal, when prices fall by 5% at least over a 3-year period.

2.2. Monetary Policy and Asset Price Bubbles

Once the hypothesis of bubble is accepted, the link with the stance of monetary policy has to be clarified. For Taylor (2009), it is clear that monetary policy has fuelled the housing boom in the United States. However, Taylor (2009) does not explicitly identify the bubble term but rather assumes that the housing market in the United States was characterized by a bubble.

He argues that the monetary policy implemented by the Federal Reserve has been too much expansionary for too long leading to an excessive growth of housing prices. It is indeed suggested that house prices dynamics would have been tamed if interest rates had followed the Taylor rule. This diagnostic and the conclusions have yet been challenged by Dokko et al. (2009) who show that monetary policy have not been that expansionary regarding past episodes of expansions. Besides, according to simulations realized with the Federal Reserve FRB/US model, they suggest that the housing market dynamic would not have been strongly modified if interest rates had followed the Taylor rule. Monetary policy was then not responsible for the boom that was mainly driven by other factors. Based on VAR models rather than on a structural model, Del Negro and Otrok (2007) also concluded that monetary policy weakly contributed to the housing price dynamic in the United States. They do not rely on a definition of bubbles but provide a distinction between regional factors and common factors in the price dynamics. They find that the common factor has become dominant in the post-2000 period. Then, a VAR analysis suggests that a restrictive monetary policy shocks has a weakly significant negative impact on this common factor. Beyond the United States, O'Meara (2015) finds significant but small effects of monetary policy on the house price bubble for 10 OECD countries with an analysis of house prices based on a structural model.

By observing the relative path dynamics of several variables (inflation rate, interest rates notably) during the period preceding the burst in asset prices, Bordo and Wheelock (2007) provide evidence of a weak correlation between interest rate and stock prices. Though, interest rates have been low in the 60-month period before the US boom in the US, such a correlation has not systematically occurred for other post-1970 booms and for other countries. Contrasting Bordo and Wheelock (2007) results, Detken and Smets (2004), Ahrend, Cournède and Price (2008) and Khan (2010) find that asset prices, and notably house prices, increase when short-term interest rates are below levels suggested by a Taylor rule. There is yet no systematic correlation with stock prices as significant increase of asset prices are also observed when monetary policy is in line with a Taylor rule. But it must be stressed here that the authors consider the house price and do not provide clear evidence that the rise in asset price can be considered as excessive. They only suggest that other housing market indicators suggest market buoyancy. Basile and Joyce (2001) find no strong contribution of monetary policy – either measured by interest rates or monetary aggregates – to the variance of bubbles. More recently, Gali and Gambeti (2015) suggest that monetary policy tightening in the US may increase asset prices. While, the increase of the interest rate reduces the fundamental value of stocks, it increases the bubble component, as the bubble solution in a rational expectations model grows with the interest rate. The total effect of monetary policy is then uncertain depending on the size of the bubble. For a small bubble component, the standard effect though the fundamental value dominates and the rise in interest rates decreases asset prices. But, when the bubble component is large, monetary policy tightening feeds the bubble and the asset price increase.

The overall sentiment stemming from empirical literature is that monetary policy, and notably interest rates,[7] would weakly contribute to asset price bubbles. The following analysis will also test this hypothesis and will notably consider the role of unconventional monetary policy.

[7] Jorda, Schularick and Taylor (2013 and 2015) suggest that over a long sample period, bubbles have largely been correlated with credit booms.

3. Identifying Asset Price Booms and Busts

3.1. A Range of Bubble Models

The first step is to identify bubble components from alternative specifications. Considering the second part of the Brunnermeier (2008)'s definition of bubbles, we calculate them estimating a proxy for the fundamental values for stock, bond and house prices. The alternative approach is to rely on statistical approaches to identify periods of excessive price dynamics. To this end, we first estimate the expected cash-flow model by OLS (equation 1) and using an error-correction model (ECM, see equation 2 and table 1 for the list of estimated models). For stock and house markets, prices are determined either by dividends or rents, the long term interest rate, considered as a discount factor, and a proxy for the risk-premium. The introduction of the risk-premium may account for a risk-taking channel of monetary policy. Consequently, the bubble component is supposed to be purged from risk-taking behaviours, which may also influence asset prices. For the bond market, prices are determined by the long-term interest rate and the proxy for the risk-premium (coupons being constant over the lifetime of the asset). These models may also be estimated as error correction models (called model 2, see equation 2):

$$y_t = \alpha_0 + \alpha_1.D_t + \alpha_2.r_t + \alpha_3\phi_t + \epsilon_t^{OLS} \tag{1}$$

$$\begin{aligned} dy_t = -\alpha.(y_{t-1} - \alpha'_0 - \alpha'_1.D_t - \alpha'_2.r_t - \alpha'_3.\phi_t) \\ + \alpha_4(L).dy_t + \alpha_5(L).dD_t + \alpha_6(L).dr_t + \alpha_6(L).d\phi_t + \epsilon_t^{ECM} \end{aligned} \tag{2}$$

Where y_t is the asset price, D_t is the associated cash flow, r_t is the discount factor measured by the risk-free interest rate, and ϕ_t a proxy for the risk premium. According to equations (1) and (2), the asset price has 3 components: a fundamental value, a component related to risk-taking and the bubble component. From these equations, we compute two bubble's indicators. The first is simply based on standard residuals: ϵ_t^{OLS} and ϵ_t^{ECM}. The second measure is the sum of the filtered (with the Christiano-Fitzgerald method) residuals as long as these residuals have the same sign. This second measure is reset to zero whenever the residuals change sign. Thus we take into account the cumulative and dynamic process associated with a bubble formation. As pointed out by Filardo (2004), small deviations from fundamentals may not matter so that the cumulated residuals would provide a better measure of significant and persistent deviations from fundamentals.

An alternative model is to estimate models where asset prices are represented by projections against the full range of variables included in the information set. By selecting a large set of macroeconomic and financial variables equations (3) and (4) provide an estimate of the best predictor of the asset price. Bubble components are then captured either by residuals series ν_t^{OLS} and ν_t^{ECM} or by cumulated filtered residuals:

$$y_t = \beta_0 + \beta(L).y_t + \beta_1.M_t + \beta_2.F_t + \nu_t^{OLS} \tag{3}$$

$$\begin{aligned} dy_t = -\theta.(y_{t-1} - \beta'_0 - \beta'_1(L).M_t - \beta'_2(L).F) \\ +\beta'_3(L).dy_t + \beta'_3(L).dM_t + \beta'_3(L).dF_t + \nu_t^{ECM} \end{aligned} \tag{4}$$

M_t and F_t are vectors of macroeconomic (rents and dividends, industrial production, GDP, real disposable income, inflation, confidence indicators and oil price) and financial variables (real long term interest rate, monetary and credit aggregates, other asset prices and VIX indicator). Lags of the endogenous variable are also integrated in the estimation. For all exogenous variables, up to 3 lags are included in the equation. Specifications with leads have also been tested but do not change the result and the residual dynamics. These estimations have then not been retained here. While equations 1 and 2 are considered as representing the standard-model for asset prices adjusted by a time-varying risk premium, equations 3 and 4 are agnostic and should be considered as best in-sample prediction of asset prices taking into-account a large set of relevant information.

Then we consider models corresponding to statistical approaches for calculating bubbles. First, we compute a model where the bubble component is defined as the cycle-component from a HP filter. The bubble indicator is either built as the cycle component or as cumulated-filtered deviation from the trend. As for previous models (represented by equations 1 to 4), the standard residuals or cycle-component provides a static (instantaneous) measure of the "boom and bust" component. The filtered (with the Christiano-Fitzgerald method) and cumulated residuals capture the cumulative component of "booms and busts" and provides a dynamic and cumulative picture of the over- or under-valuation of asset prices.

Finally, we identify a last model where boom and bust periods are selected though a statistical approach where boom (respectively bust) period is defined as a deviation from the trend above (respectively below) 1.3 standard-deviation, so 80% of the data lies within the bounds (see Bordo and Jeanne, 2002). A synthetic description of all models is presented in Table 1.

We estimate these different models for three asset prices: stocks, bonds and housing, for the United States and the euro area. Data are available from January 1999 to September 2015 for the euro area and from January 1986 to October 2015 in the US (see Table A in appendix for data description and sources).

The stock price indexes are the S&P 500 for the US and Eurostoxx index for the euro area. Each asset price is deflated by the CPI. Bonds prices are government 10-year benchmark bonds. House prices in the euro area stem from a quarterly index for residential property prices calculated by the ECB. A linear interpolation is implemented to get monthly data. In the US, we use Shiller's monthly data. Real asset price dynamics is represented in Figure A in the Appendix. From a simple visual inspection, it seems that cycles for equity prices are shorter than for housing prices confirming the result emphasized by Drehman et al. (2012) showing that equity prices behave differently form credit-to-GDP ratio and property prices.

Considering the standard expected cash-flow model for asset prices, fundamental value is simply defined as the discounted value of future cash-flows (dividends for stocks and rents for housing prices). In the United States, the Bureau of Economic Analysis provides dividends series paid by corporations and rents received by households. Data are available at a quarterly frequency.[8] For the euro area, quarterly dividends paid by financial and non-financial corporations and quarterly rents received by households are available from Eurostat for the five biggest euro area countries. The long-term interest rates – stemming from benchmark government bonds – are used as the discount factor. The standard model may be extended to account for a time-varying risk-premium. To this end, we use the VIX indicator – the Chicago board of trade volatility index –, which is often used as a proxy for uncertainty and market appetite for risk. Yet, this model may not fully account from all available information. As explained below, fundamental value is also identified with a

[8] For all quarterly date, we use linear interpolation, so that all estimates are made on monthly data.

model estimated on a large set of information, including macroeconomic and financial indicators such as: real disposable income, inflation, real GDP,[9] industrial production, oil prices, confidence indicators,[10] financial stress indicators (VIX and CISS), 3-month interbank interest rate, monetary (M2 in the US and M3 for the euro area) and credit aggregates (credits granted by commercial banks in the US and credit counterparties of monetary aggregate in the euro area).

Table 2 summarizes the descriptive statistics for the series capturing the 11 identified bubble components for each asset and Table 3 provides information on their correlation structure.

3.2. A Principal Component Analysis of Bubbles

In order to summarize the information provided by the static and cumulated residuals of the different models (the four estimated models, the HP cycle decomposition and the dummy identification model), we perform a Principal Component Analysis (PCA) with the first factor maximizing the common variables of the 11 series. In addition to reduce information in one series, another advantage of the PCA is to remove the evolution of each series that would be specific to that series and provides a robust measure of the "booms and busts" component of asset prices. All bubbles components and the corresponding PCA for each asset price are plotted in Figures 2 and 3 for the Euro area and the United States. Table 4 describes the main characteristics of the estimation of our synthetic measure. The first principal component for stock market bubbles and bonds market explains respectively one third and 28 % of total variance in the United States and in the Euro area (table 4). It is less for the housing market bubble: 26 % for the US market and 24 % in the Euro area. Besides, the highest loading factors are generally on the two statistical models (HP filter model and dummy variable model) and then on the expected cash-flow models.

In the case of stock prices, the main booms and busts periods identified though the principal component analysis for the Euro area and the United States matches the identification issued from a pure statistical approach where booms (respectively busts) are signalled by a deviation of prices above (respectively below) the trend equal to +/- 1.3 standard-deviation. This identification illustrated by dummy variables generally coincides with the peaks and troughs issued from the PCA. In the euro area, booms, signalled by the positive dummy, would have occurred from March 2000 until January 2001 and from March 2007 until February 2008. Besides, a rise in the indicator is observed since January 2014. This boom at the end of the sample is of lesser magnitude than previous booms and is not signalled by the pure statistical approach. Busts periods in the Euro area stock markets are identified from the end of 2002 to mid-2003 and from October 2008 – after the Lehman Brother collapse – until October 2009. It may be noted that the PCA is still negative after mid-2003 suggesting that the bust would have last more than what is signalled by the statistical approach. In the United States, there would have been a short bubble period in February-April 1987 followed by a crash. The PCA indicates a first trough in October 1987 followed by a stronger fall in August 1988. The dotcom bubble is also clearly identified by the PCA and the pure statistical approach. The bubble period would have started in September 1999, a bit earlier than in the Euro area and it would have stopped in October 2000. The peak for the PCA is reached in March 2000. A boom is also identified in 2007 (April-December) followed by a crash in stock

[9] GDP and disposable income are quarterly data and have been linearly interpolated to monthly frequency.
[10] For the euro area, confidence indicators – for households and industry – are from the European Commission while in the US we use the Conference Board consumer confidence indicator and the Institute for supply management as a confidence indicator for firms.

markets. As for the euro area, the PCA indicator increases at the end of the sample and becomes positive from May 2012. It may then be suggested that our identification approach matches with periods where this issue has been raised in the media and in the public debate. It also seems that since 1999, stock market booms and busts periods in the United States and the euro area are correlated, though peaks and troughs lag a few months in the euro area.

On the Euro area bond markets, peaks for PCA are observed in June 2005, June 2010, May 2012 and January 2015. It should be pointed out that the PCA indicator is positive from December 2008 until December 2010, which is counterintuitive as this period has been marked by the start of the European sovereign debt crisis. The positive bubble is also identified in the period preceding the “Whatever it takes” announcement made by Mario Draghi in July 2012 at a time where sovereign risk-premia did rise significantly. In the United States, there are several peaks in March 1987, October 1993, December 1998, June 2003, December 2008 and July 2012. All peaks but the June 2003-September 2005 period coincides with booms identified with the pure statistical approach.

Finally, turning to housing market there is a clear disconnection in the euro area between the signal sent by the statistical approach and the PCA indicator. With the statistical approach, a bubble would have been signalled from December 2006 until August 2007 whereas the peak of PCA is reached later in January 2010, a date considered as a bust period with the statistical approach. The same negative correlation is observed in 2010 and 2011. The two indicators – PCA and the dummies – are more in line for the US housing market. The peak for the PCA is reached by the end of 2006. It is highest value over all the period and has then been followed by a bust in 2008 until the beginning of 2013. Over the end of period, the PCA is still positive indicating a new bubble on the US housing market, but which is yet of lesser magnitude than in 2006. The visual inspection of boom-bust periods would also indicate that the duration of cycles is higher for housing markets than for stock market, in line with the results highlighted by Drehman et al. (2012) since 1985.

4. The Empirical Strategy

Analysing the effect of monetary policy requires addressing several issues for the identification of exogenous monetary shocks. Several methods have been used in the empirical literature and may lead to significant discrepancies in the responses to monetary policy shocks.[11] Here we use alternative approaches to identify monetary policy shocks and assess their impact on asset price booms and busts. We notably resort to an augmented Romer and Romer (2004)'s narrative approach following insights from the information friction literature and take into account the information sets of both policymakers and private agents. It is applied to both the overall monetary policy stance and unconventional monetary policy. We then assess the impact of monetary policy shocks with the local projection method proposed by Jorda (2005). Besides, the local projection method may easily account for potential non-linearities and asymmetries in the transmission of monetary policy, and enable us to disentangle the impact of restrictive and accommodative shocks. Robustness analyses are also carried out with innovations identified with the Kuttner's (2011) approach and with shocks stemming from estimations of forward-looking Taylor rules. Finally, we complement the linear analysis with a VAR approach in which shocks and impulse responses are estimated in a single step.

[11] See Coibion (2012) for a recent discussion on the impact of monetary policy on the US economic activity, unemployment rate and inflation.

4.1. Local Projections

Assessing the impact of shocks on a given economic variable may be realized either through VAR models or with Jorda's Local Projection Method. Considering that exogenous structural shocks are known, Jorda (2005) suggests estimating a set of h regressions representing the impulse response of the dependent variable at the horizon h to a given shock at time (t):

$$y_{t+h} = \alpha + \beta_h \epsilon_t + \sum_{i=1}^{K} \phi_{h,i}. y_{t-i} + \eta_{t+h} \quad (5)$$

where y_{t+h} is the dependent variable – the PCA bubble measure - at the horizon h, ϵ_t represents the monetary shock, either on the overall policy stance or only for unconventional measures, and y_{t-i} are lags of the dependent variable. This equation may be easily modified to account for asymmetries:

$$y_{t+h} = \alpha + \beta_h \epsilon_t. D_t + \beta_h \epsilon_t. (1 - D_t) + \sum_{i=1}^{K} \phi_{h,i}. y_{t-i} + \eta_{t+h} \quad (6)$$

where D is a dummy variable for restrictive monetary policy shocks.

4.2. Identification of Monetary Shocks

With the local projection method, exogenous monetary policy shocks need to be identified *ex ante*. The question of the most relevant identification strategy for taking care of endogeneity issues remains an open question. Empirical literature on monetary policy has often resorted to VAR models. However, timing assumptions in recursive identifications – reasonable for real variables and their sluggish reaction to shocks and low sampling frequency – are not relevant when applied to financial variables or fast-moving variables. There is generally no strong reason to suppose that some asset prices move faster than others. Romer and Romer (2004) resort to a *narrative* approach where they first derive a policy variable – the intended federal funds rate change – and then regress the resulting series on the information set of the monetary authority to purge from endogenous reactions about current and future economic developments. Yet because of different existing information set (Romer and Romer 2000, Blinder et al. 2008, Hubert 2015), the Romer and Romer (2004)'s identification approach may underestimate the extent to which market participants are able to predict future interest rate decisions. As discussed in Blanchard et al. (2013) and Ricco (2015), the presence of information frictions significantly modifies the identification problem. We therefore propose an identification that combines insights from the work of Romer and Romer (2004) and from the information frictions literature. We thus require the estimated monetary shocks to be orthogonal to both central bank's and private agents' information sets and to macro and financial market information for the identification of monetary shocks to be achieved. Finally, in a context of imperfect information, the new information is only partially absorbed over time and, estimated surprises are likely to be a combination of both current and past structural shocks.

Standard monetary policies are generally described by policy rates: the federal funds rate for the US and the EONIA rate for the euro area. Yet, these indicators of monetary policy stance do not fully account for unconventional monetary policy.[12] Two measures of unconventional monetary policy are considered. The shadow rate, estimated by Wu and Xia (2016), captures the overall monetary stance by representing conventional and unconventional policies in the interest rate space. The second measure corresponds to the amount of assets held for monetary policy purposes. For the Federal Reserve, data are taken from table H.4.1 and

[12] In the Euro area, the Eonia has decreased below the main refinancing operation rate notably because of non-standard measures. It can then be argued that the Eonia partially reflect unconventional monetary policy.

notably includes Treasury securities and Mortgaged-backed assets. It may be considered as the best indicator to capture QE programmes implemented in the US. In the euro area, data is called Securities Held for Monetary Policy Purposes (SHMPP) in the Weekly financial statement published by the ECB. It includes the Securities Market Program, the 1st, 2nd and 3rd Covered Bond Purchase Programs, the Asset-Backed Securities Purchase Program and the most recent Public Sector Purchase Programme. The amount of securities held by the Federal Reserve and the ECB for monetary policy purposes are plotted in Figure 4.

We also use macroeconomic forecasts from central banks (ECB and FOMC projections) and private agents: ECB and US Surveys of Professional Forecasters (SPF). The ECB/Eurosystem staff macroeconomic projections for the euro area are produced quarterly since June 2004. They are published during the first week of March, June, September and December and are presented as ranges for annual percentage changes in both HICP (the Harmonized Index for Consumer Prices) and real GDP. The FOMC publishes forecasts for key macroeconomic variables – inflation, real and nominal GDP growth, and unemployment – twice each year in the Monetary Policy Report to the Congress since 1979. Since October 2007, the publication of these FOMC forecasts has become quarterly and its horizon extended by one additional year. FOMC forecasts for current and next year was realized each year in late January/early February and late June/early July until 2007Q3, then in January, April, June and October until 2012Q4, and since then in March, June, September and December. We consider forecasts of the Personal Consumption Expenditures (PCE) measure of inflation and real GDP. These forecasts are published as two ranges encompassing each individual FOMC member's forecasts: the "full range" includes the highest and the lowest forecasts while the "central tendency" removes the three highest and three lowest forecasts. As standard in the literature, we use the midpoint of the full range. The ECB's SPF is a quarterly survey of expectations for the rates of inflation, real GDP growth and unemployment in the euro area. Participants are experts affiliated with financial or non- financial institutions in the European Union. SPF forecasts are produced in February, May, August and November. HICP is measured as average annual percentage change for current and next years. The US SPF is collected from approximately 40 panelists and published by the Federal Reserve Bank of Philadelphia. SPF forecasts are also published in February, May, August, and November, and CPI forecasts are provided as year-over-year percent changes. We consider the median of individual responses as the SPF inflation forecast in our analysis. These benchmark monetary shocks are estimated over the full sample for the US but only since 2004 for the euro area because of the data availability constraint mentioned beforehand.

Our benchmark measures of exogenous monetary shocks, inspired from Romer and Romer (2004), are then estimated based on the following equations from which we extract the residuals:

$$i_t = \beta_0 + \beta_1\, i_{t-1} + \beta_2\, \Omega_t + \beta_3\, \Psi_t + \beta_4\, X_{t-1} + \beta_5\, Z_t + \varepsilon'_t \quad (7)$$

$$\varepsilon'_t = \beta_6 + \beta_7\, \varepsilon'_{t-j} + \varepsilon_{rr,t} \quad (8)$$

where i_t is the monetary policy instrument, either the shadow rate or the amount of securities held for monetary policy purposes. We assume that the monetary shock must be orthogonal to the contemporaneous policymakers' information set Ω_t, to the private agents' one Ψ_t, to lagged financial market variables embedded in X_{t-1}, and to a vector Z_t of contemporaneous macroeconomic variables. The two series of shocks are labelled MP-Shocks-RR or QE-Shocks-RR. A consequence of the timing of the right-hand-side vectors in equation (7) is that monetary shocks can have contemporaneous effects on financial market variables, but do not affect contemporaneously central bank's and private agents' information sets or macroeconomic variables. We believe that arguing that the policy decision is only based on past data realisations or that it does not move markets in real-time are fragile assumptions. The policymakers' information set Ω_t comprises ECB (resp. FOMC) inflation and output projections for current and next calendar years, Ψ_t includes the ECB (resp. US) SPF inflation forecasts for 1, 2 and 5 years ahead (resp. next quarter and next year), X_t contains the CISS (resp. the VIX) and the oil price growth rate, and Z_t comprises current and lagged values of the inflation rate, industrial production and the monthly-interpolated real GDP growth rate.

When extracting this exogenous component, the inclusion of both private and central bank forecasts in the regression model enables us to deal with three concerns. First, forecasts encompass rich information sets. Private agents and policymakers' information sets include a large number of variables. Bernanke et al. (2005) show that a data-rich environment approach modifies the identification of monetary shocks. Forecasts work as a FAVAR model as they summarise a large variety of macroeconomic variables as well as their expected evolutions. Second, forecasts are real-time data. Private agents and policymakers base their decisions on their information set in real-time, not on ex-post revised data. Orphanides (2001, 2003) show that Taylor rule-type reaction functions estimated on revised data produce different outcomes when using real-time data. Third, private agents and policymakers are mechanically incorporating information about the current state of the economy and anticipate future macroeconomic conditions in their forecasts and we need to correct for their forward-looking information set.

A first alternative for identifying monetary surprises is to estimate a forward looking Taylor rule equation augmented with oil prices and a financial stress index (included in the vector Y_t). This equation is estimated over the full sample. The monetary policy shock (labelled MP-Shocks-TR or QE-Shocks-TR) is then the residuals of the following equation:

$$i_t = \beta_8 + \beta_9\, i_{t-1} + \beta_{10}\, \pi_{t+6} + \beta_{11}\, y_{t+6} + \beta_{12}\, Y_{t+6} + \varepsilon'_{tr,t} \quad (9)$$

A second alternative is to follow Kuttner (2001)'s methodology to identify monetary policy shocks in both the Euro area and the US using changes in the price of futures contracts. Kuttner (2001) identifies monetary surprises by accounting for the forward-looking nature of financial data. For a monetary policy event on day d of the month m, the monetary shock can be derived from the variation in the rate implied by current-month futures contracts on that day. Because of data availability, this series of monetary surprises are available from 2000 onwards. This identification of monetary shocks relies on the financial market participants' interpretation of the monetary news disclosed that day, which encompasses central bank decisions, related to conventional or unconventional tools, and central bank information released at the same time. The price of the future being computed as the average monthly rate, the change in the futures rate must be augmented by a factor related to the number of days in the month affected by the change:

$$\varepsilon_{kutt,t} = \frac{D}{D-d}\left(f^0_{m,d} - f^0_{m,d-1}\right) \quad (10)$$

$\varepsilon_{kutt,t}$ is the unexpected interest rate variation which constitutes a monetary shock, $f^0_{m,d}$ is the current-month futures rate and D is the number of days in the month and d the day of the decision. Figure 5 plots the Kuttner (2011)'s shocks together with the shocks to the overall monetary policy stance and shocks to unconventional measures for the euro area and the United States using the two methods described previously.

We assess the relevance of the identification strategy in two ways. First, Table 5 shows normality and autocorrelation tests together with some descriptive statistics and the correlation of shocks. We also assess the autocorrelation and normality of these shocks. This calls for putting less emphasis on Taylor rule type shocks in the US as these shocks are auto-correlated. Figure 6 plots the distribution of the estimated shocks. Second, if our estimated series of monetary shocks are relevant, they should be unpredictable from movements in data. We assess the predictability of the estimated shock series with Granger-causality type tests using 9 macroeconomic and financial variables. Table 5 shows the adjusted R^2 and F-stats of an OLS estimation that aims to test the null hypothesis that our estimated series of exogenous shocks are unpredictable. It shows that the Romer-Romer-type shock series are relevant to be used in our second-stage estimations and that the Taylor rule-type shocks series are not perfectly exogenous.

4.3. A VAR model

Finally, a structural VAR model is also estimated to decompose residuals in the policy instrument equation into mutually orthogonal components with a structural economic interpretation. We augment the standard VAR used for monetary policy analysis with the bubbles components for each market. Therefore, the vector of endogenous variables includes the real GDP growth (GDP), inflation (CPI), the monetary policy instrument (shadow rate), the three bubble measures, oil prices and a financial stress index (CISS for the Euro area and VIX for the United States). Let Z_t = [GDP, CPI, Oil, Financial stress, PCA_Bubble_Housing, PCA_Bubble_Stock, PCA_Bubble_Bonds, shadow rate]' represents the (*8* x *1*) vector that contains the endogenous variables at date *t*:

$$AZ_t = a + \sum_{k=1}^{4} B_k Z_{t-k} + CE_t \tag{11}$$

where the B matrix is *(8 x 8)* and $A = I_8$. The reduced-form errors E_t combine the structural innovation to a given variable with the contemporaneous responses to the other variables. The recursive identification assumption postulates that the structural errors are independent, and that reduced-form errors are related to structural errors through a lower triangular C matrix. This means that the covariance between the reduced-form errors is attributed to the structural error of the variable ordered previously in Z_t, and that the structural error is uncorrelated to the reduced-form errors of the preceding variables. This recursive identification therefore depends on the ordering of the variables in the Z_t vector.

We assume that shifts in real GDP and inflation may produce a contemporaneous change in all market (oil, financial stress index and bubbles) and policy variables. The market variables react to monetary shocks only with a lag. While this assumption seems fragile as financial market variables may react instantaneously to a policy decision, the rationale here is to put the policy variable last in the vector of endogenous variables so monetary policy may react instantaneously to all other variables in order to get the most conservative estimates of the monetary shock. Concerning the relative position of the three bubble variables, we assume that the housing market is the slowest to react following Drehman, Borio and Tsatsaronis (2012). We assume that bond markets react more quickly than stock markets because of their higher volumes traded and liquidity.

5. The Effect of Monetary Policy on Asset Price Booms and Busts

5.1. The Linear Effects of the Overall Monetary Stance

We first illustrate the impact of monetary policy shocks on bubbles without disentangling between restrictive and accommodative, standard monetary policy and unconventional monetary policy. Figures 7 and 8 show, for the euro area and the United States respectively, the response of the three different bubble components to a positive shock, i.e. a contractionary shock, to the overall monetary policy stance using our benchmark shocks (RR), the Taylor rule-type shocks (TR), the Kuttner (2001)'s surprises and Cholesky VAR innovations.

We find, for the euro area, a slight positive effect of shocks to the overall monetary stance on the bubble component of stock markets, consistent with Gali and Gambetti (2015), but no effect on the bubble component of bond and housing prices. The response for stocks is significant at the 10% level when monetary policy innovations are issued from a Taylor rule estimation or from the VAR. The peak of the response is reached after 12-18 months. With Kuttner shocks, the response is weakly significant in the short run (less than 6 months), while the response of the stock bubble is not significant when monetary policy shocks are identified with the RR approach. For the United States, we find a positive effect of the restrictive monetary policy shock on the bubble components of stock and housing markets, but not on the bond market. For stock markets, the response is significant whatever the methods used to identify shocks. The peak is observed 6-12 months after the shock with TR shocks or Kuttner shocks. It would later (after 18 months) with RR shocks.

According to these results, a more restrictive (respectively accommodative) monetary policy would not help to deflate (respectively contribute to inflate) bubbles but would rather increase (respectively decrease) bubble components of the stocks market in the Euro area and in the United States and of the housing market in the United States only. Assuming that there is no asymmetry between the effect of restrictive and accommodative shocks, these results would lead us to conclude that there is no conclusive evidence that expansionary policy cannot be made responsible for increasing bubbles.

5.2. The Linear Effects of Unconventional Monetary Policy

The responses of bubbles to unconventional monetary policy shocks are illustrated by figures 9 for the Euro area and 10 for the United States. It assesses whether QE-type programmes create bubbles. Contrary to overall monetary stance shocks, a positive unconventional monetary shock indicates an expansionary monetary policy. From the benchmark RR and the TR models, we show that stock market bubble decrease in the Euro area following an accommodative monetary policy. The peak effect is reached before the 12th month. The bubble component of the stock market increases in the United States after an expansionary unconventional monetary policy shock but only in the very short term and with the benchmark model. It then decreases with a peak reached after 12 months in the benchmark model as well as in the TR model. The stock market bubble's response is never significant in the VAR models.

Turning to bonds markets, bubbles response is significantly negative only for the United States in the TR and VAR models. Concerning the housing market, results are contradictory between the United States and the Euro area. Bubble decreases in the Euro area with the RR shocks and increases in the United States with the TR shocks[13] and also for a very short period in the VAR model.

The results would then suggest that expansionary unconventional monetary policy would reduce bubbles in the stock market with a peak observed before the 12th month in the Euro area and after the 12th month in the United States. Evidence is otherwise mixed for the bonds and the housing markets.

[13] It may also be noticed that bubble significantly decreases after 24 months.

Under the hypothesis that transmission of positive and negative monetary policy shocks is symmetric, results suggest that expansionary monetary policy – standard and unconventional – would not create stock markets' bubbles. The evidence even suggests that it would reduce them while restrictive monetary policy would inflate the bubble's component of the stock market. The responses of bubbles on the housing markets are less conclusive and rarely significant in the bond markets.

5.3. The Non-Linear Effects of the Overall Monetary Stance

The next step is to account for potential asymmetries in the response of bubbles to monetary policy shocks. Here we disentangle between restrictive and expansionary shocks. Responses of bubbles to monetary shocks identified from the shadow rate with the RR, TR and Kuttner's approaches are exhibited in figures 11 and 12 for the euro area and the United States respectively.

For the Euro area, we find that contractionary shocks have a negative effect on the bubble component of stock markets whereas expansionary shocks have a positive effect. Restrictive monetary policy would then help to deflate stock market bubbles while expansionary monetary policy would fuel them. Responses are significant for all but contractionary TR shocks. The pattern is the opposite for the housing market for which contractionary shocks would fuel bubbles while accommodative shocks would reduce the size of the bubble's component. Responses from the Kuttner's surprises are yet not significant. Finally, estimations suggest that the bubble's component of the bond market in the Euro area does not react to monetary policy shocks whatever the sign of the shock suggesting that there are no non-linear effects.

For the United States, the outcome is similar for the stock market: contractionary shocks have a negative effect on bubbles' components whereas expansionary shocks have a positive effect. Evidence is inconclusive for the housing market and the only significant response is observed in the case of restrictive TR shocks for which the bubble's component would increase. Finally, it seems that there are no non-linear effects for bubbles of the bond market.

5.4. The Non-Linear Effects of Unconventional Monetary Policy

Figures 13 and 14 show, for the euro area and the United States respectively, the response of the three bubble components to both contractionary and expansionary shocks to unconventional monetary policies. These estimates are based on shorter subsamples: from 2011m7 for euro area and from 2008m11 for the United States.

For the Euro area, we find that contractionary shocks have a positive effect on the bubble components of the stock and housing markets whereas expansionary shocks have a negative effect. The pattern is the opposite for the bond market for which contractionary shocks have a negative effect on its bubble component and expansionary shocks have a positive effect. Responses are similar for the United States for the stock and housing markets and it seems that there are no non-linear effects on the bubble component of the bond market.

Here again, the evidence suggests that expansionary monetary policy would not be responsible for bubbles in the stock market in the Euro area and in the United States. The response of the bubble component of the stock market decreases after an accommodative shock. Besides, there is also some evidence for an increase in the size of the stock market bubble in the Euro area after a restrictive shock of unconventional monetary policy. It is also suggested that a restrictive unconventional monetary policy would increase bubbles of the housing market in the Euro area and in the United States. An accommodative monetary policy would increase the bubble on the housing market but only in the Euro area.

6. Conclusion

Financial stability is now undoubtedly an objective for policymakers. The issue remains about whether central banks should change the conduct of monetary policy to achieve this goal. The answer to this question critically hinges on the influence of monetary policy on asset prices as stated by Rudebush (2005). Yet, it must be reminded that the reaction of asset prices is also part of the transmission channel of monetary policy. Central bankers must then avoid schizophrenic behavior, seeking to increase or decrease asset price as a way to stimulate the transmission channels of monetary policy and thwarting simultaneously asset price movements fearing financial instability. Consequently, central banks need to know if asset price movements are desirable or when monetary policy has negative side-effects. This paper deals with this issue and assesses the impact of monetary policy shocks on asset price bubbles.

To this end, we propose to identify bubbles on stocks, bonds and housing markets through different approaches and to build a synthetic measure of booms and busts. On the recent period – 1986 for the United States and 1999 for the Euro area – several booms and busts have been identified. Yet, it is not clear that the most recent period is characterized by bubbles contrary to what is sometimes claimed. Though bubble components are positive in the stock market, the size of the bubble is far below previous peaks in the Euro area and in the United States.

The main results when looking at non-linear evidence are the following. First, contractionary overall monetary stance shocks have a negative effect on the bubble component of stock markets whereas expansionary shocks have a positive effect. Second, contractionary unconventional monetary shocks have a positive effect on the bubble components of the stock and housing markets whereas expansionary shocks have a negative effect, and the opposite on the bubble component of the bond market.

The main results when looking at linear evidence are that contractionary overall monetary stance shocks have a positive effect on the bubble component of stock markets, and that expansionary unconventional monetary shocks have a negative effect on the same bubble component. For other markets, results are either inconclusive or specific to the area considered.

These results suggest that monetary policy is neither fueling nor a relevant instrument for central banks to control asset price bubbles. Not only is the identification of bubbles not an easy task but the reaction of asset price misalignments to monetary policy decision is at best uncertain. Further research is needed on how policymakers through monetary and macro-prudential policies may stabilize the economy and dampen financial risks all the more as financial instability may not only be seen through asset price bubbles.

References

Adrian T. and H.S. Shin, 2008, “Financial intermediaries, financial stability and monetary policy”, *FRB of New York staff report,* 346.

Alessi L. and C. Detken, 2011, “Quasi-real time early warning indicators for asset price boom / bust cycles: a role for global liquidity”, *European Journal of Political Economy* 27, 520-533.

Ahrend R., B. Cournède and R. Price, 2008, “Monetary policy, market excesses and financial turmoil”, *OECD Working Paper* n°597.

Andersson M. and L. Overby, 2009, “Which News Moves the Euro Area Bond Market?”, *German Economic Review*, 10(1), 1-31.

Angeloni I. and M. Ehrmann, 2003, “Monetary Transmission in the Euro Area: Early Evidence“, *Economic Policy*, 18, 471-488.

Basile A. and J.P. Joyce, 2001, “Asset bubbles, monetary policy and bank lending in Japan: an empirical investigation, *Applied Economics*, 33, 1737-1744.

Bernanke B.S. and M. Gertler, 2001, “Should central banks respond to movements in asset prices?”, *American Economic Review* vol.91 n°2, 253-257.

Bernanke Ben and Kuttner Kenneth (2005), “What Explains the Stock Market's Reaction to Federal Reserve Policy?”, *Journal of Finance*, 60, 1221–1257.

Bernanke, Ben, Jean Boivin, and Piotr Eliasz (2005). “Measuring the Effects of Monetary Policy: A Factor-augmented Vector Autoregressive (FAVAR) Approach”, *Quarterly Journal of Economics*, 120(1), 387–422.

Blanchard Olivier, and Mark Watson (1982). “Bubbles, rational expectations and financial markets”, in *Crisis in the Economic and Financial Structure*, ed. P. Wachtel. Lexington, MA:Lexington.

Blanchard, Olivier, Jean-Paul L’Huillier, and Guido Lorenzoni (2013). “News, Noise, and Fluctuations: An Empirical Exploration,” *American Economic Review*, 103(7), 3045–70.

Blinder, Alan, Michael Ehrmann, Marcel Fratzscher, Jakob De Haan, and David-Jan Jansen (2008). “Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence,” *Journal of Economic Literature*, 46(4), 910–45.

Bohl M., P. Siklos and D. Sondermann, 2008, “European Stock Markets and the ECB's Monetary Policy Surprises”, *International Finance*, 11(2), 117-130.

Boivin J., M.T Kiley and F.S. Mishkin, 2010, “How has the monetary transmission mechanism evolved over time?”, in *Handbook of Monetary Economics* vol.3, edited by Benjamin M. Friedman and Michael Woodford, 369-422.

Bordo, Michael, and Olivier Jeanne (2002). “Monetary policy and asset prices: does ‘Benign Neglect’ make sense?”, *International Finance*, 5(2),139–164.

Bordo M.D and D.C. Wheelock, 2007, “Stock market booms and the monetary policy in the twentieth century”, *Federal Reserve Bank of St. Louis Review*, March-April, 91-122.

Bordo M.D. and J. Landon-Lane, 2013, “Does expansionary monetary policy cause asset price booms; some historical and empirical evidence”, *NBER Working Paper* n°19585.

Brunnermeier M.K., 2008, “Bubbles”, *The New Palgrave Dictionary of Economics,* second edition edited by S.N. Durlauf and L.E. Blume.

Coibion O., 2012, “Are the effects of monetary policy shocks big or small”, *American Economic Journal: Macroeconomics*, 4(2), 1-32.

Del Negro M. and C. Otrok, 2007, “99 Luftballons: monetary policy and the house price boom across the US states”, *Journal of Monetary Economics* 54, 1962-1985.

Detken C. and F. Smets, 2004, “Asset price booms and monetary policy”, *ECB Working Paper* n°364.

Dokko J., B. Doyle, M. Kiley, J. Kim, S. Sherlund, J. Sim and S. Van den Heuvel, 2009, “Monetary policy and the housing bubble”, *Federal Reserve Board Discussion Series* 49.

Drehman M., C. Borio and K. Tsatsaronis, 2012, “Characterising the financial cycle: don’t lose sight of the medium term!”, *BIS Working Paper* n°380.

Borio Claudio, and Philip Lowe (2002), “Asset prices, financial and monetary stability: exploring the nexus”, *BIS Working Paper*, No 114.

Farmer R.E.A, 2013, “Qualitative easing: a new tool for the stabilisation of financial markets”, *Bank of England Quarterly Bulletin* Q4, 405-413.

Filardo A, 2004, “Monetary policy and asset price bubbles: calibrating the monetary policy trade-offs”, *BIS Working Papers* n°155.

Filbien, Jean-Yves and Fabien Labondance, 2012, “Réactions des marchés d’actions de la zone euro aux annonces non anticipées de la BCE”, *Brussels Economic Review*, 55(2), 179-204.

Galí Jordi and Luca Gambetti (2015), “The Effects of Monetary Policy on Stock Market Bubbles: Some Evidence”, *American Economic Journal: Macroeconomics*, 7(1), 233-57.

Goodhart C. and B. Hofmann, 2008, “House prices, money, credit, and the macroeconomy”, *Oxford Review of Economic Policy*, 24(1), 180–205.

Gurkaynak Refet (2005). “Econometric test of asset price bubbles: taking stock”, *Federal Reserve Board Finance and Economics Discussion Series* n°04.

Gürkaynak, Refet, Brian Sack and Eric Swanson (2005). “Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements”, *International Journal of Central Banking*, 1(1), 55-93.

Hubert, Paul (2015). “Revisiting the Greenbook's Relative Forecasting Performance”, *Revue de l’OFCE*, 137, 151-179.

Jordà Òscar, 2005, “Estimation and inference of impulse responses by local projections”, *American Economic Review,* 95(1), 161-182.

Jordà Òscar, M. Schularick, and A.M. Taylor, 2015, “Leveraged Bubbles”, *Journal of Monetary Economics* 76, 1-20.

Jordà Òscar, M. Schularick, and A.M. Taylor, 2013, “When credit bites back”, *Journal of Money Credit and Banking*, 45(s2), 3-28.

Joyce M., N. McLaren and C. Young, 2012, “Quantitative easing in the United Kingdom: evidence from financial markets on QE1 and QE2”, *Oxford Review of Economic Policy*, 28(4), 671-701.

Kahn G.A., 2010, “Taylor rule deviations and financial imbalances”, Federal Reserve Bank of Kansas City Economic Review, Second Quarter, 63-99.

Kindleberger C.P., 2005, *Manias, Panics and Crashes: A History of Financial Crises*, 5th Edition, New York Wiley.

Krishnamurthy, A. and A. Vissing-Jorgensen, 2011. “The effects of quantitative easing on interest rates: channels and implications for policy”, *Brookings Papers on Economic Activity*, vol. 2, pp. 215–87.

Kuttner K., 2001, “Monetary policy surprises and interest rates: evidence from the fed funds futures market”, *Journal of Monetary Economics*, 47, 523-544.

O’Meara G., 2015, “Housing bubbles and monetary policy: a reassessment”, *mimeo*.

Orphanides, Athanasios (2001). “Monetary Policy Rules Based on Real-Time Data”, *American Economic Review*, 91, 964–985.

Orphanides, Athanasios (2003). ‘Historical monetary policy analysis and the Taylor rule’, *Journal of Monetary Economics*, 50, 983–1022.

Ricco, Giovanni (2015). “A new identification of fiscal shocks based on the information flow,” European Central Bank Working Paper Series, No. 1813.

Rigobon R. and B. Sack, 2004, “The impact of monetary policy on asset prices”, *Journal of Monetary Economics*, 51(8), 1553–1575.

Romer, Christina, and David Romer (2000). “Federal Reserve Information and the Behavior of Interest Rates,” *American Economic Review*, 90 (3), 429–457.

Romer, Christina, and David Romer (2004). (2004) “A New Measure of Monetary Shocks: Derivation and Implications,” *American Economic Review*, 94(4), 1055–1084.

Rudebush G.D., 2005, “Monetary policy and asset price bubbles”, *FRBSF Economic Letter*, 18.

Scherbina A., 2013, “Asset price bubble: a selective survey”, *IMF Working paper* n°13/45.

Schiller R.J, 2015, *Irrational Exuberance,* 3rd edition Princeton University Press.

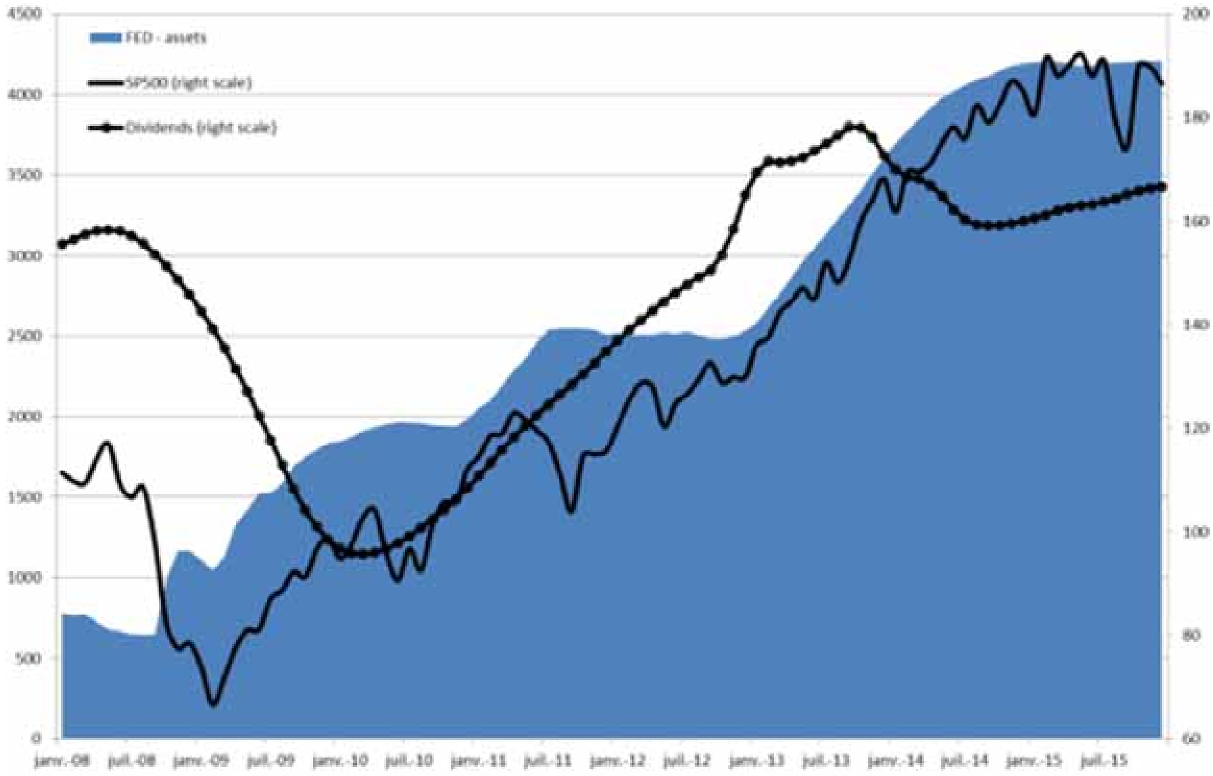
Smets F., 2014, “Financial stability and monetary policy: How closely interlinked?”, *International Journal of Central Banking* vol.10 n°2, 263-300.

Taylor J. B., 2009, “The financial crisis and the policy responses: an empirical analysis of what went wrong”, *NBER Working Paper*, No. 14631.

White W., 2009, “Should monetary policy lean or clean?”, *Federal Reserve Bank of Dallas Working Paper*, No. 34.

Wu J. C. and F. D. Xia, 2016, “Measuring the macroeconomic impact of monetary policy at the Zero lower bound”, *Journal of Money Credit and Banking*, 48(2-3), 253-291.

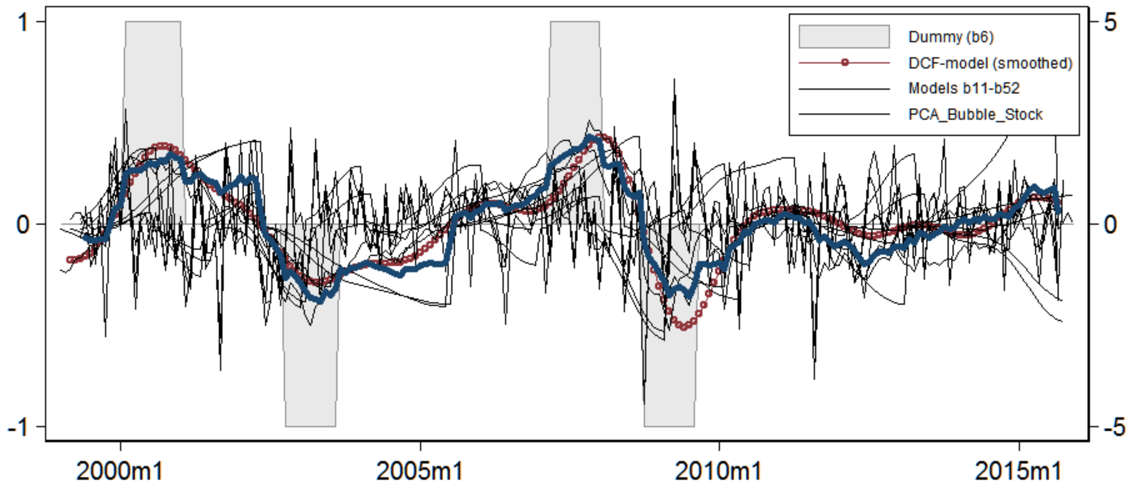
Figure 1. QE and stock market prices in the US



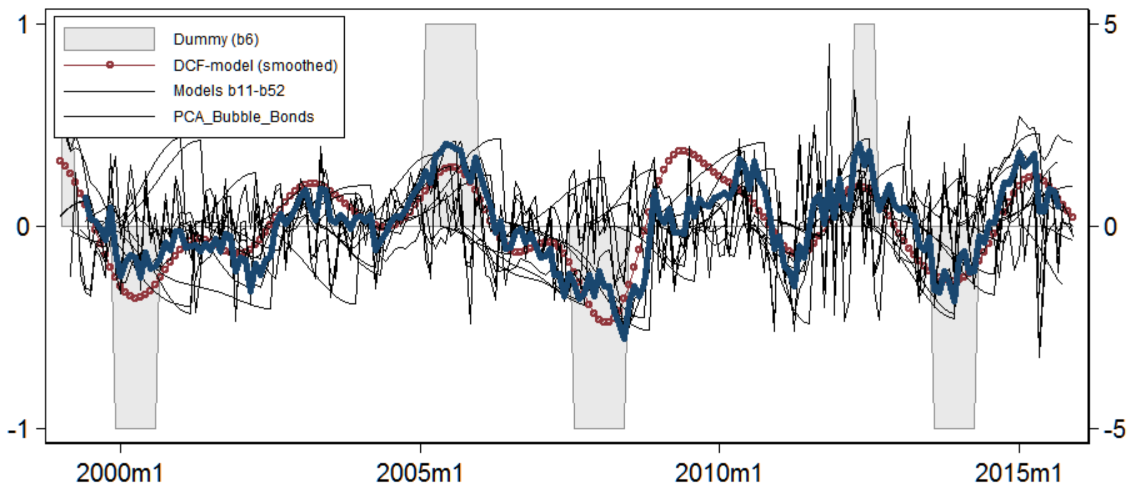
Note: *2010 = 100, y_axis in Bn$.* Dividends paid shows strong seasonality and have been smoothed by a 12-month moving average. Sources: Datastream, Federal Reserve and Bureau of Economic Analysis.

Figure 2. Booms and Bust cycles in the euro area

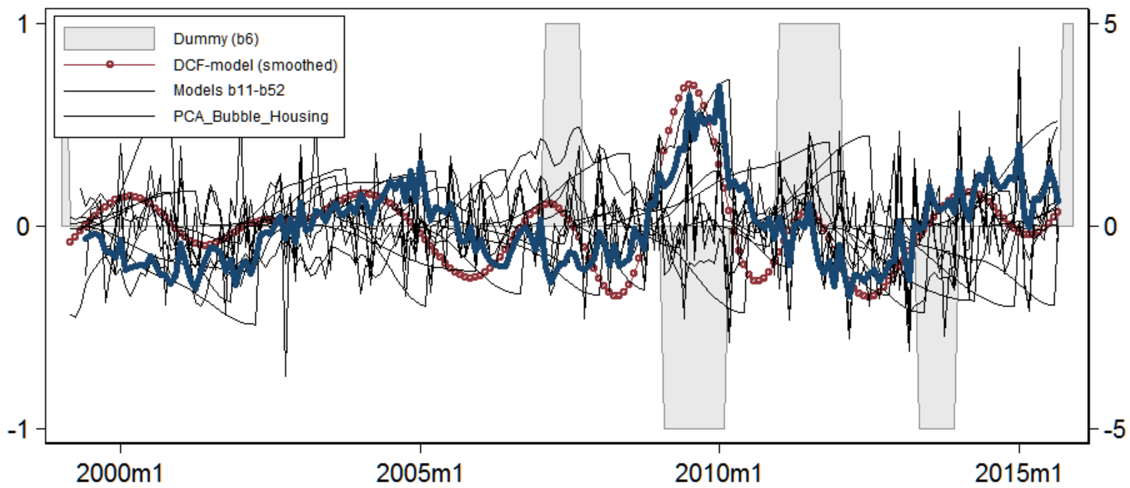
Stocks



Bonds

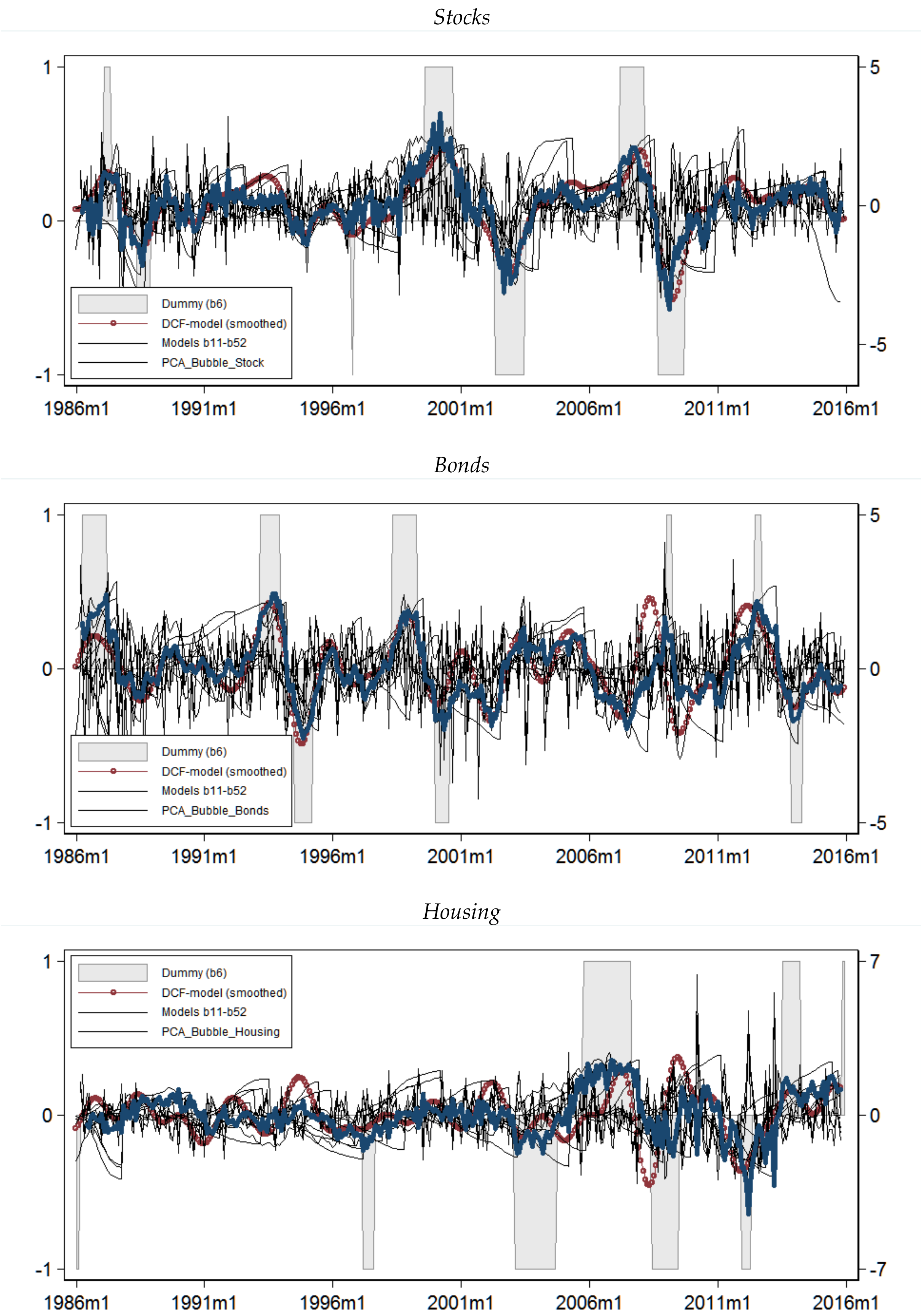


Housing



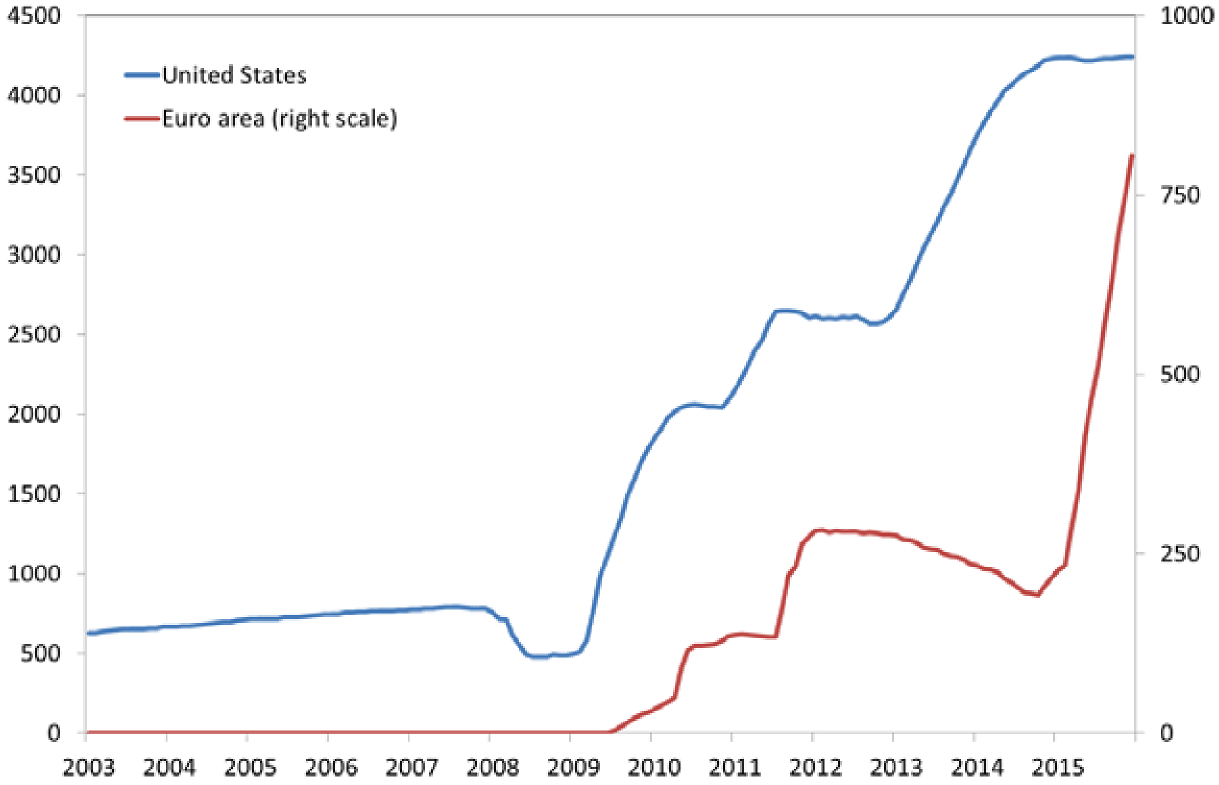
Source: authors' estimations.

Figure 3. Booms and Bust cycles in the United States



Source: authors' estimations.

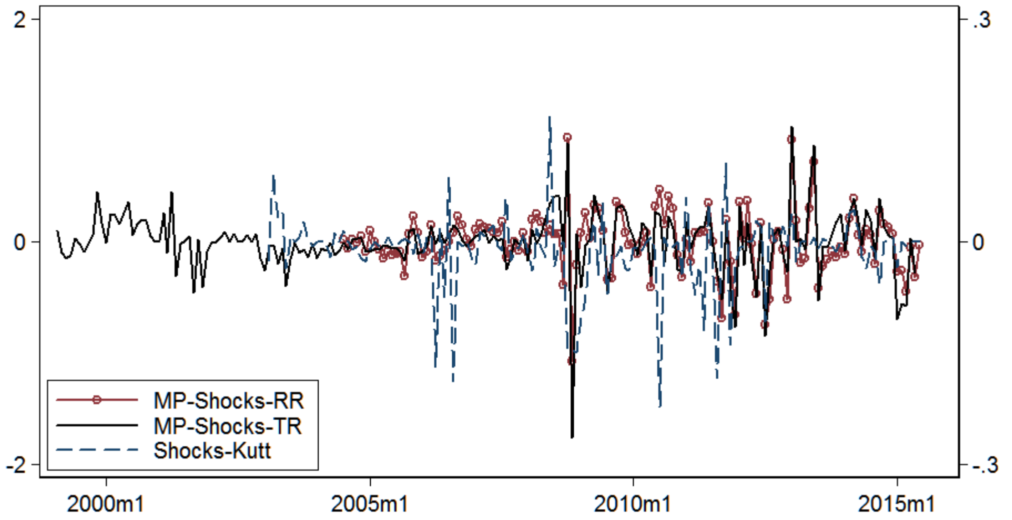
Figure 4. Unconventional measures in the US and in the euro area



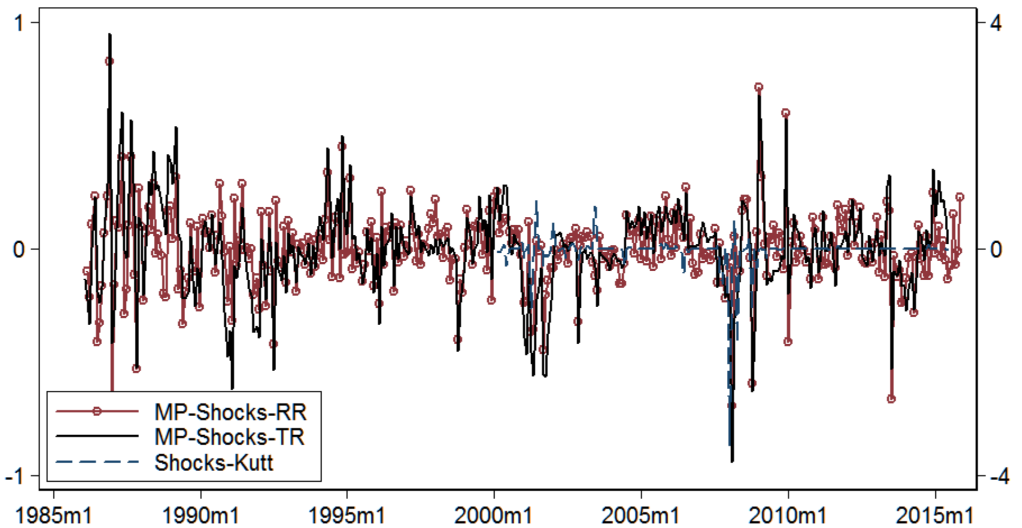
Note: *$, €, Bn*. Sources: ECB (WFS) and Federal Reserve (Table H.4.1).

Figure 5. Monetary Policy shocks

Euro area Monetary policy stance shocks (shadow rate)

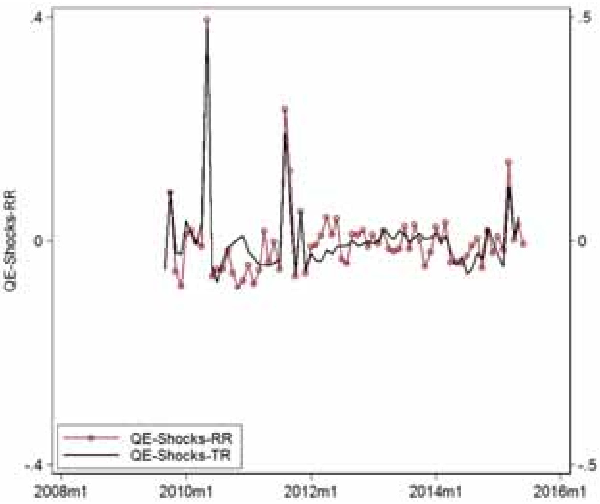


US Monetary policy stance shocks (shadow rate)



Unconventional policy shocks (shmpp)

Euro Area



United States

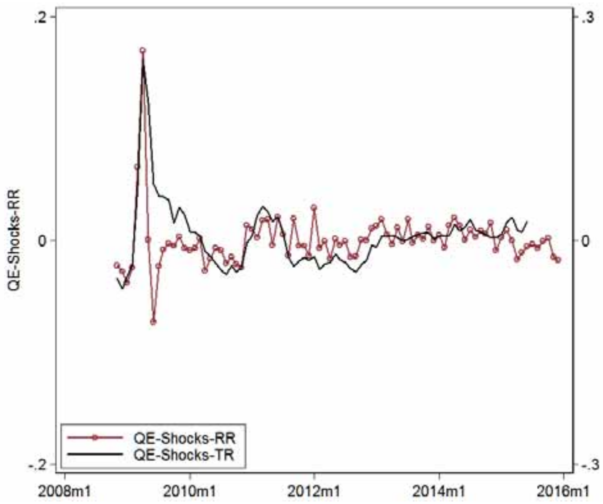
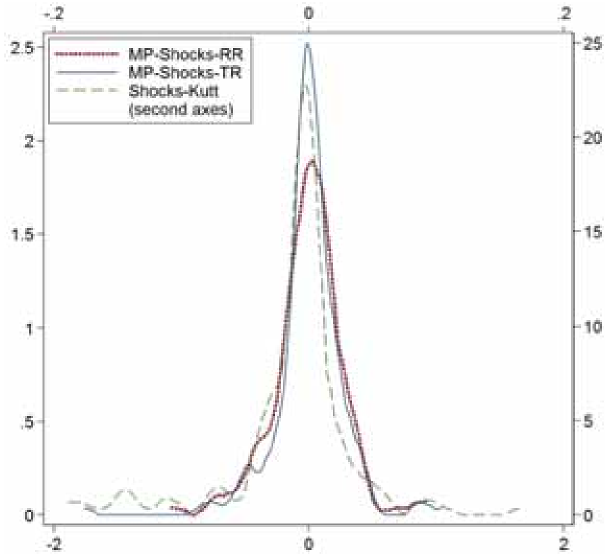


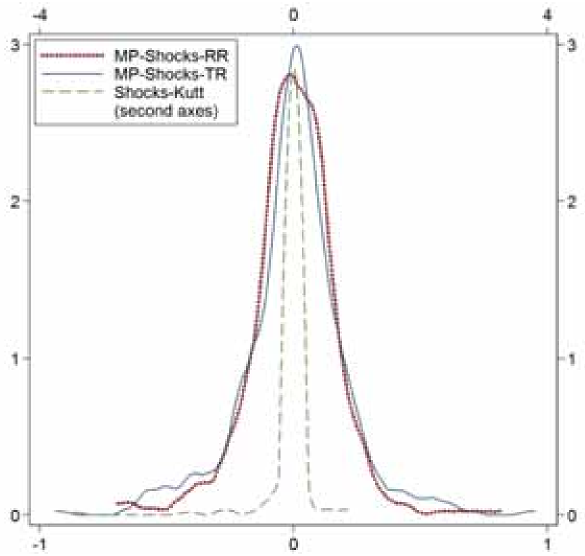
Figure 6. Distribution of Monetary Policy shocks

Monetary policy stance shocks (shadow rate)

Euro Area

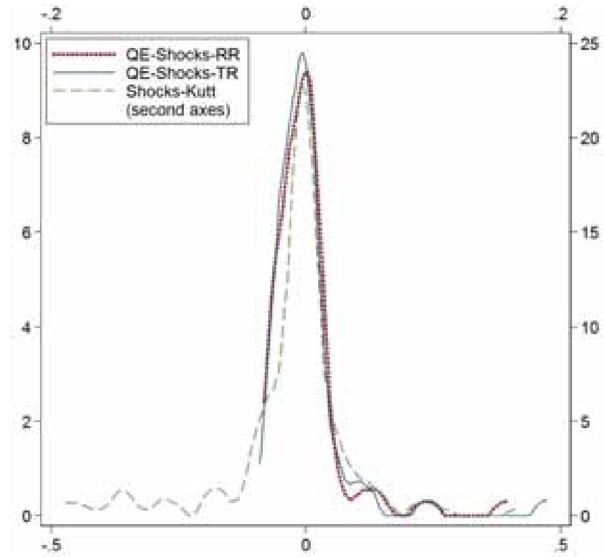


United States



Unconventional policy shocks (shmpp)

Euro Area



United States

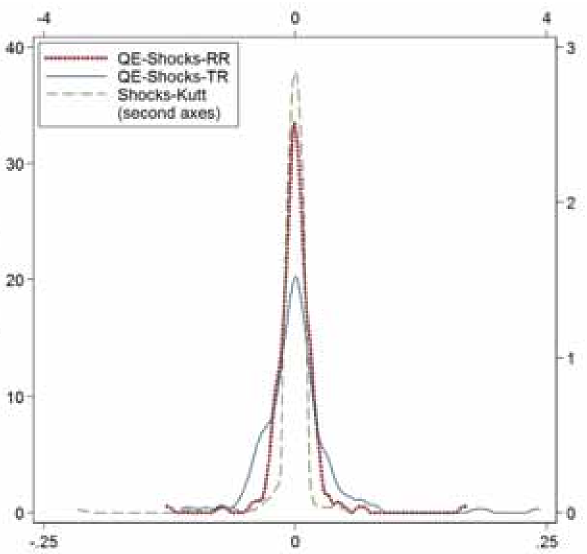
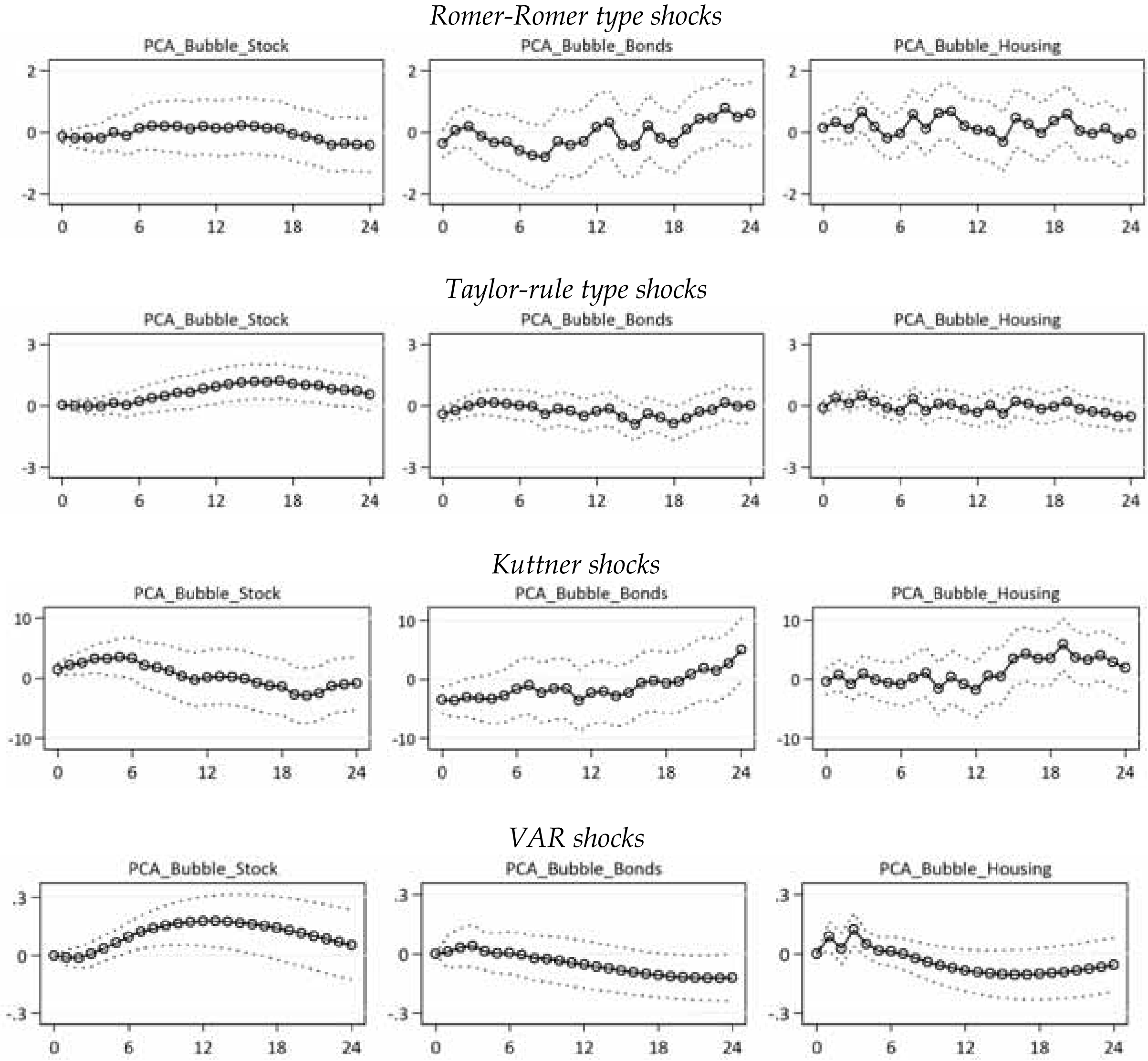


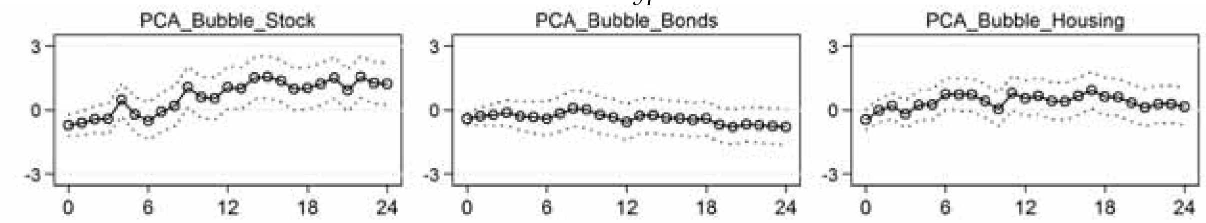
Figure 7. Bubble responses to a positive (contractionary) shock to the overall monetary stance in the euro area



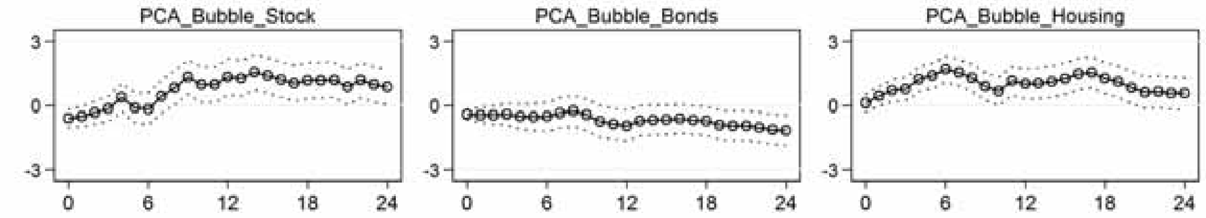
Note: Authors' estimations. Dotted lines are 90 per cent confidence intervals.

Figure 8. Bubble responses to a positive (contractionary) shock to the overall monetary stance in the United States

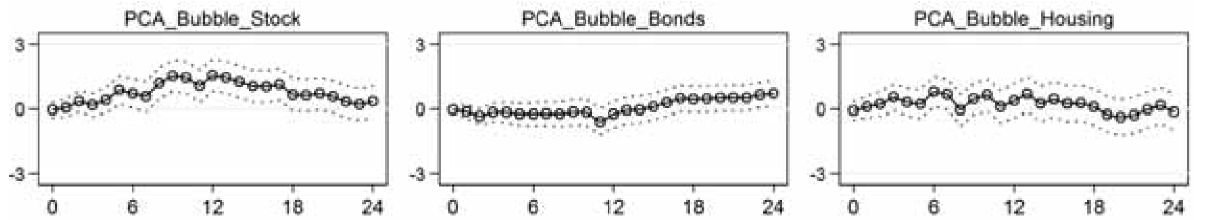
Romer-Romer type shocks



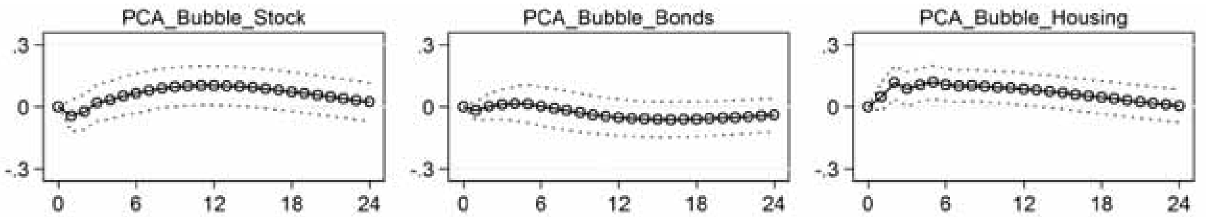
Taylor-rule type shocks



Kuttner shocks

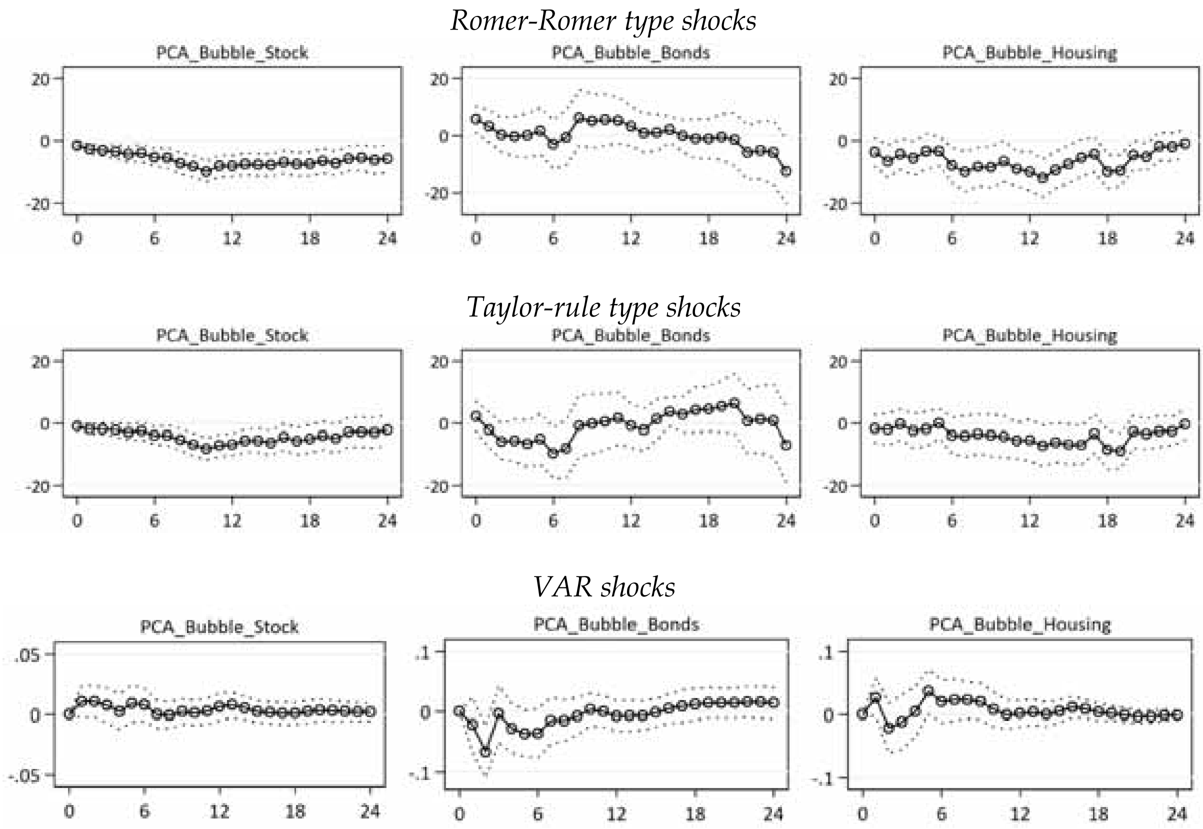


VAR shocks



Note: Authors' estimations. Dotted lines are 90 per cent confidence intervals.

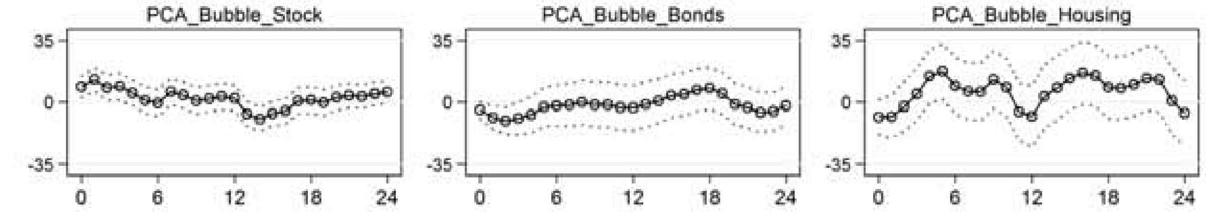
Figure 9. Bubble responses to a positive (expansionary) shock to unconventional monetary policies in the euro area



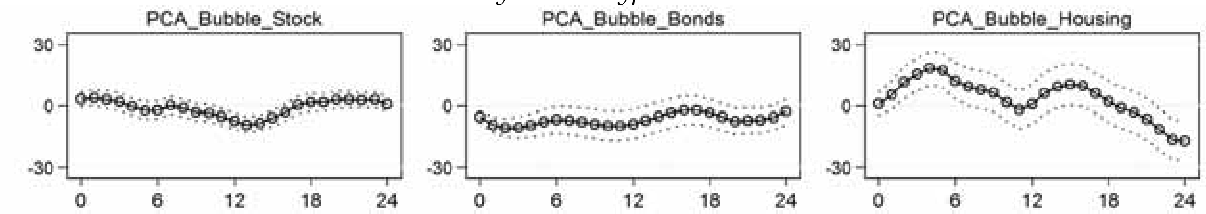
Note: Authors' estimations. Dotted lines are 90 per cent confidence intervals.

Figure 10. Bubble responses to a positive (expansionary) shock to unconventional monetary policies in the United States

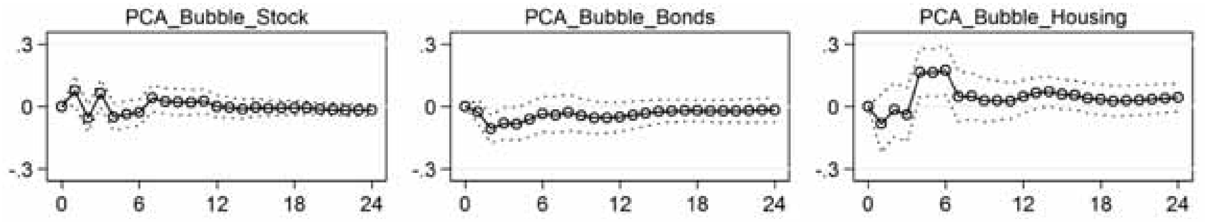
Romer-Romer type shocks



Taylor-rule type shocks



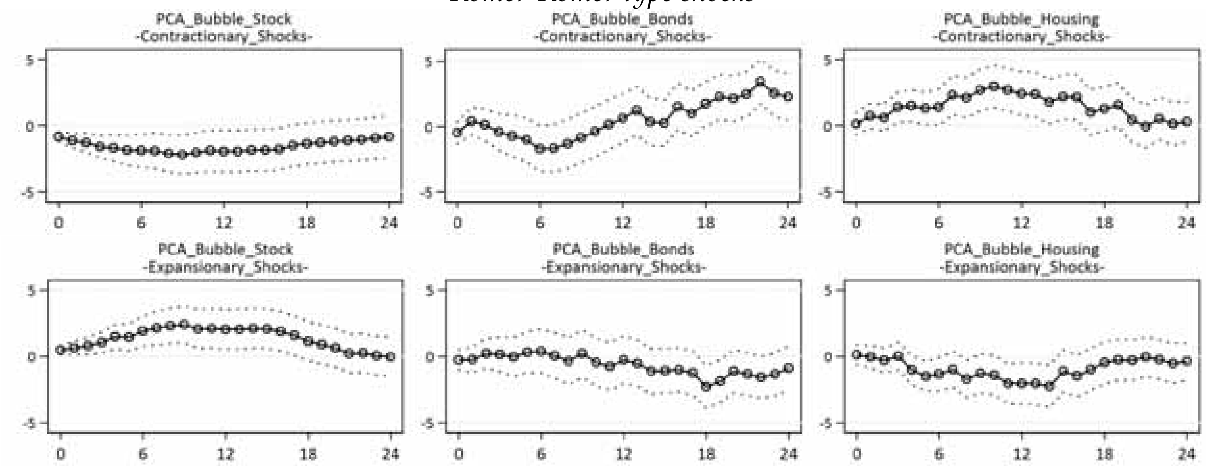
VAR shocks



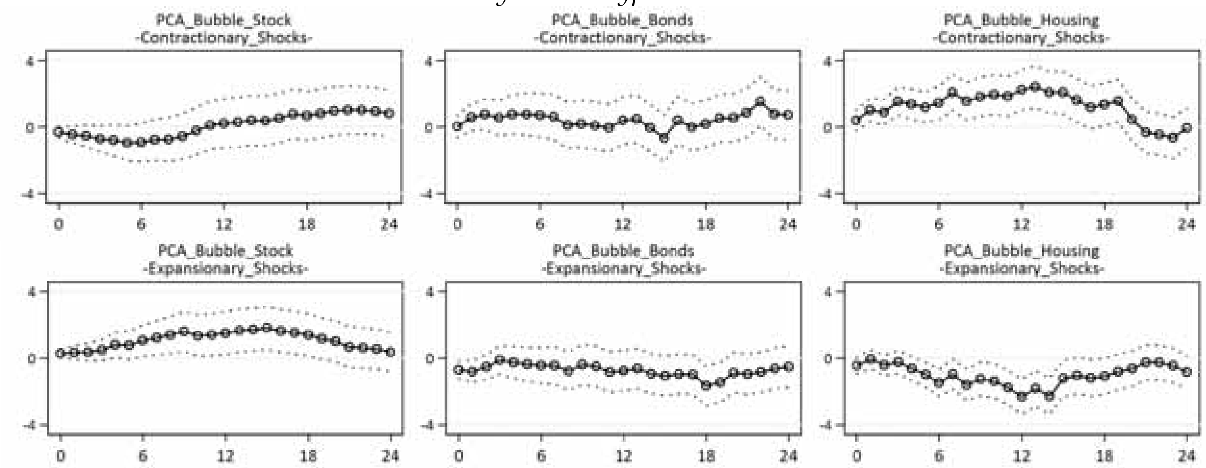
Note: Authors' estimations. Dotted lines are 90 per cent confidence intervals.

Figure 11. Non-linear effects of shocks to the overall monetary stance in the euro area

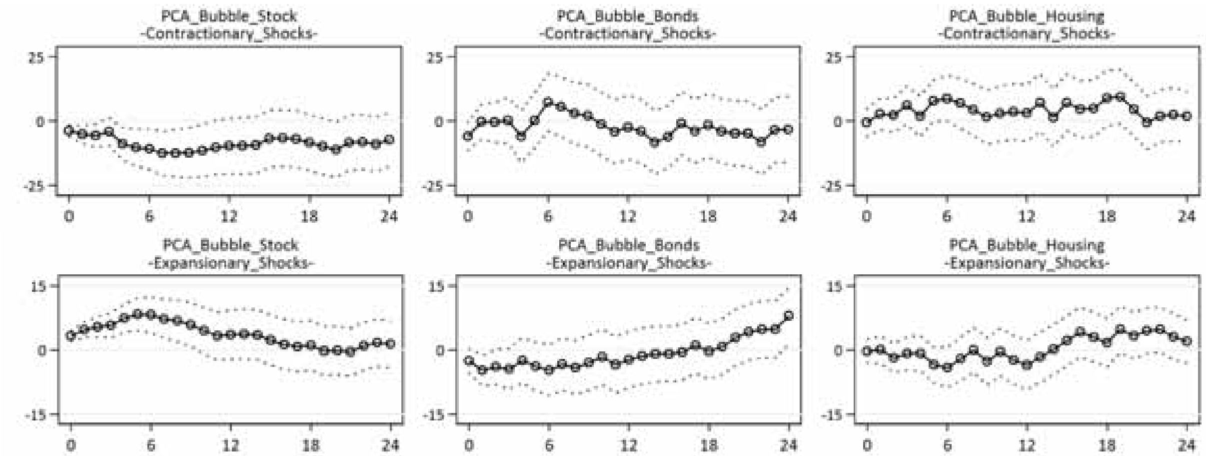
Romer-Romer type shocks



Taylor-rule type shocks



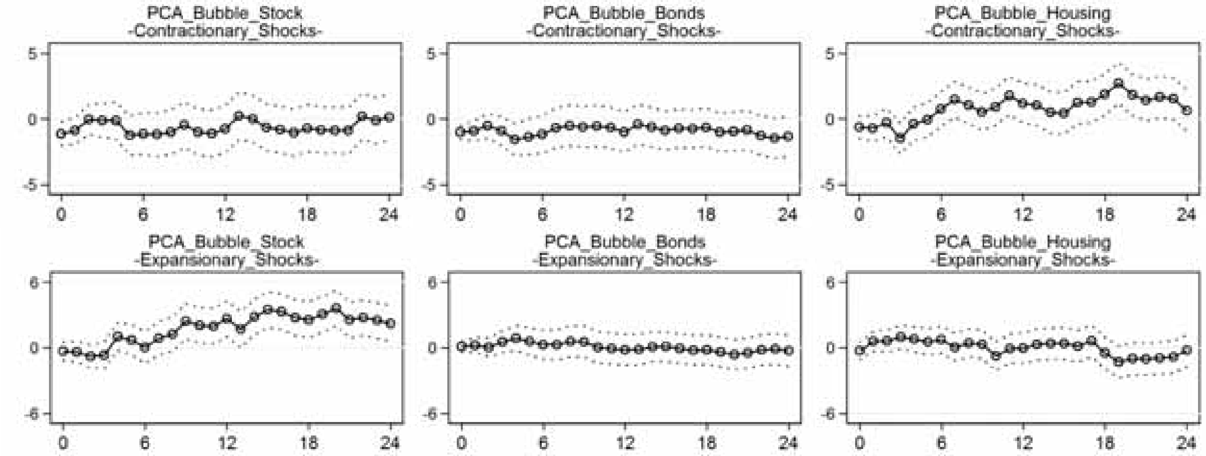
Kuttner shocks



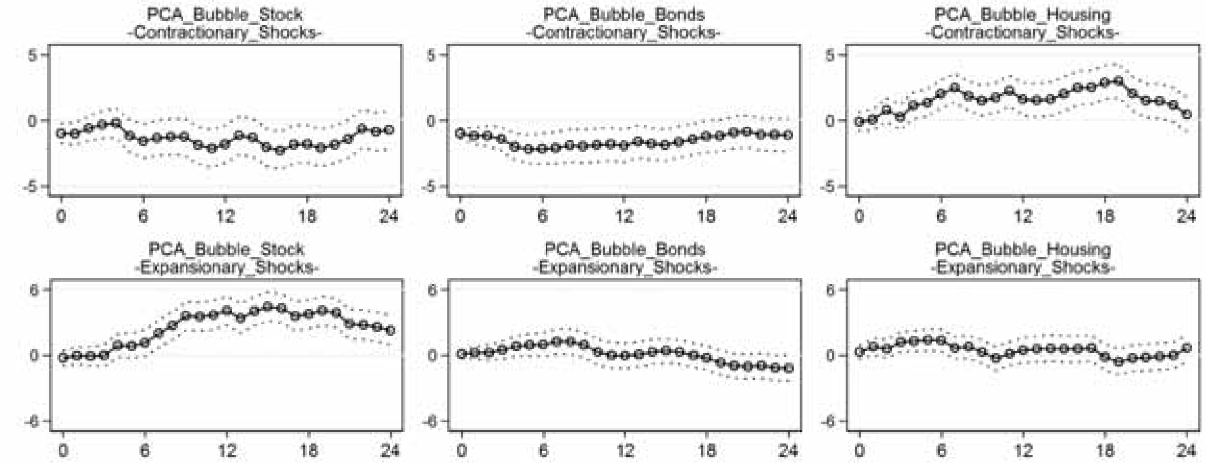
Note: Authors' estimations. Dotted lines are 90 per cent confidence intervals.

Figure 12. Non-linear effects of shocks to the overall monetary stance in the United States

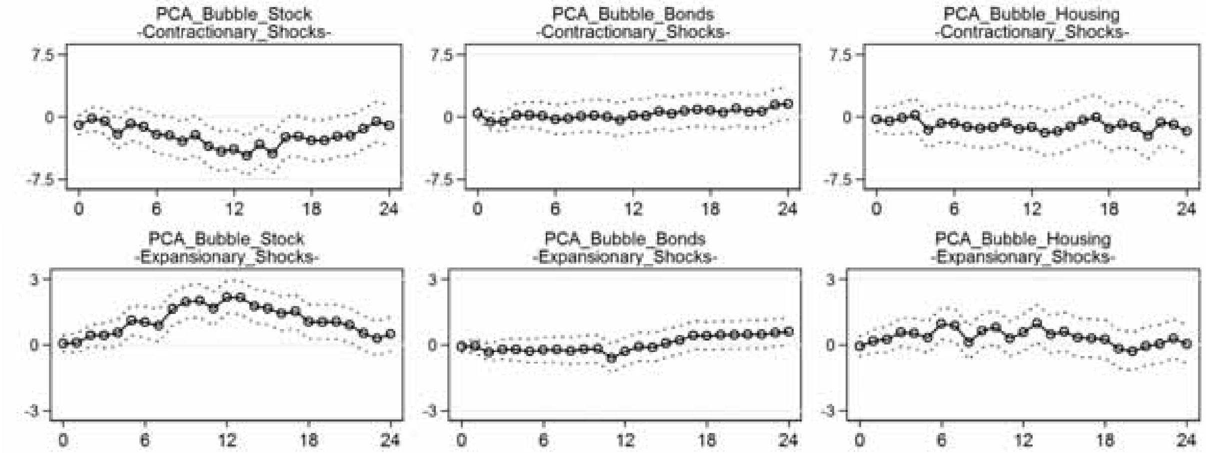
Romer-Romer type shocks



Taylor-rule type shocks



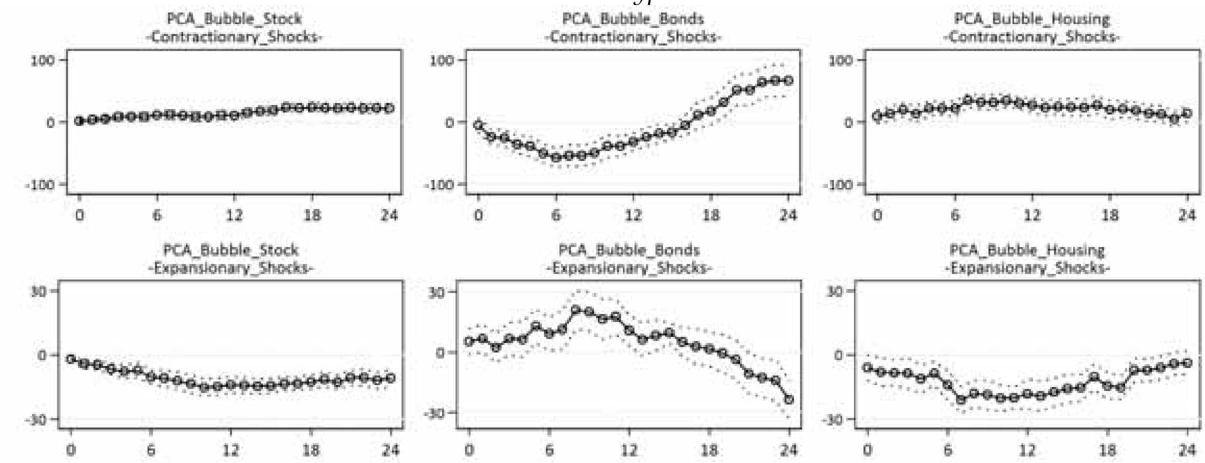
Kuttner shocks



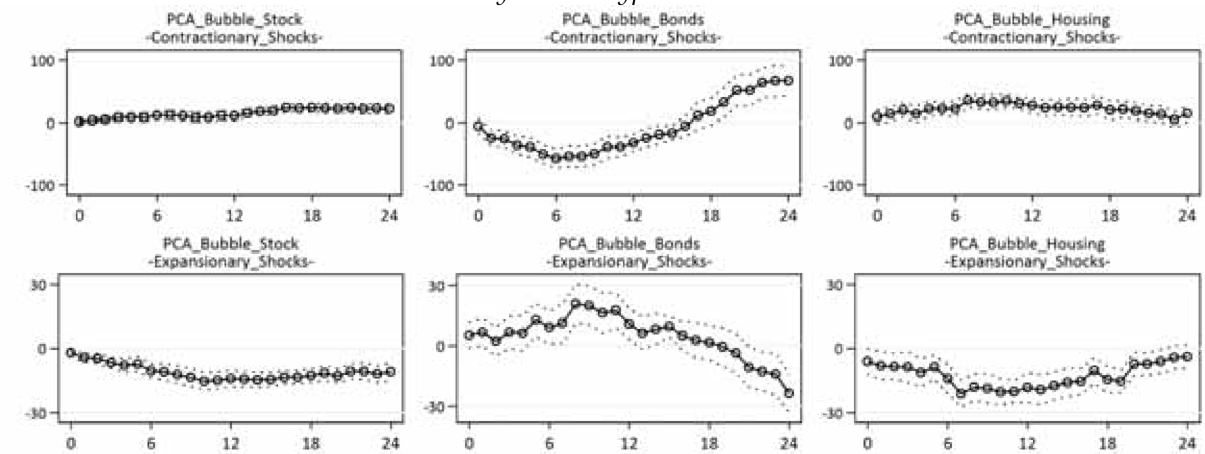
Note: Authors’ estimations. Dotted lines are 90 per cent confidence intervals.

Figure 13. Non-linear effect of shocks to unconventional monetary policies in the euro area

Romer-Romer type shocks



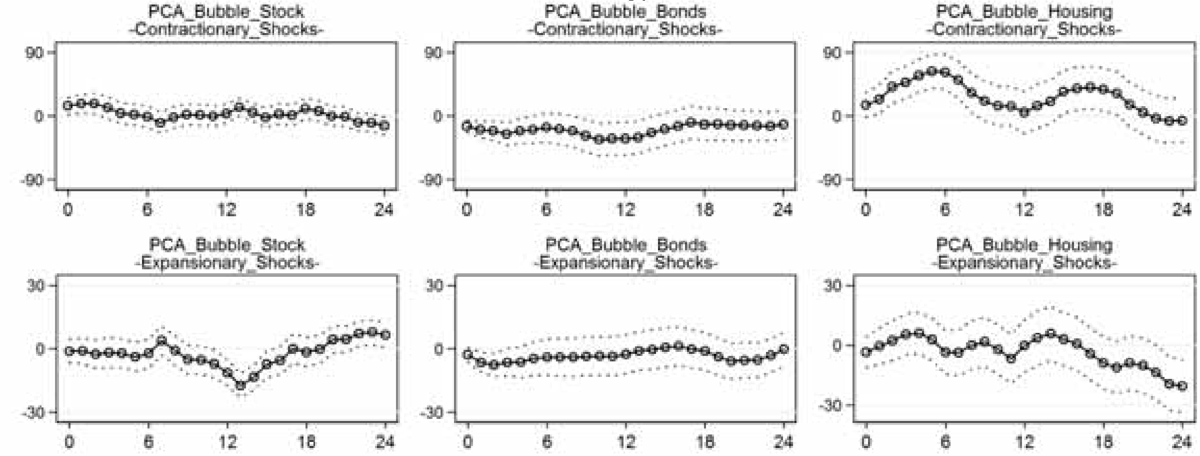
Taylor-rule type shocks



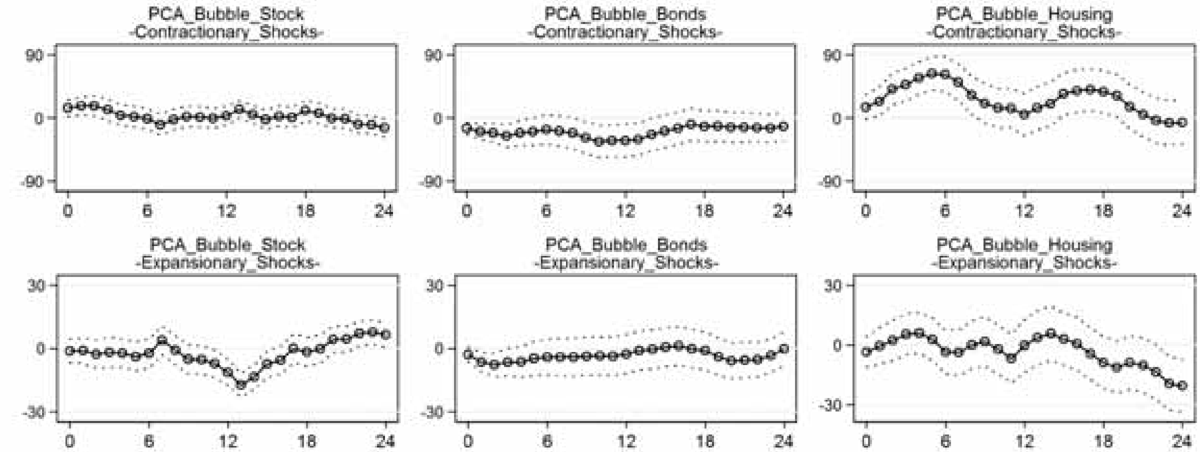
Note: Authors' estimations. Dotted lines are 90 per cent confidence intervals.

Figure 14. Non-linear effect of shocks to unconventional monetary policies in the United States

Romer-Romer type shocks



Taylor-rule type shocks



Note: Authors' estimations. Dotted lines are 90 per cent confidence intervals.

Table 1. Range of Bubble models

ID	Model	Estimation Method	Bubble identification
b11	Expected cash-flow	OLS	Residual
b12	Expected cash-flow	OLS	Filtered and cumulated residual
b21	Expected cash-flow	ECM	Residual
b22	Expected cash-flow	ECM	Filtered and cumulated residual
b31	All available information	OLS	Residual
b32	All available information	OLS	Filtered and cumulated residual
b41	All available information	ECM	Residual
b42	All available information	ECM	Filtered and cumulated residual
b51	Trend-Cycle Decomposition	Hodrick-Prescott Filter	Cycle component
b52	Trend-Cycle Decomposition	Hodrick-Prescott Filter	Filtered and cumulated cycle
b6	Statistical approach	Christiano-Fitzgerald Filter	Deviation from the trend above 1.3 standard deviation

Table 2. Descriptive Statistics for each bubble series

Euro Area						United States					
Model	Obs	Mean	Std. Dev.	Min	Max	Model	Obs	Mean	Std. Dev.	Min	Max
						Stock					
b11	199	0.000	0.211	-0.421	0.541	b11	360	0.000	0.219	-0.696	0.656
b12	199	0.154	2.456	-4.843	5.472	b12	360	0.161	1.967	-4.571	4.845
b21	198	0.000	0.046	-0.205	0.152	b21	358	0.000	0.045	-0.274	0.119
b22	198	0.024	0.159	-0.430	0.322	b22	358	0.012	0.157	-0.502	0.344
b31	196	0.000	0.020	-0.055	0.056	b31	355	0.000	0.030	-0.093	0.098
b32	196	0.010	0.067	-0.123	0.259	b32	355	0.001	0.084	-0.291	0.233
b41	198	0.000	0.044	-0.192	0.157	b41	357	0.000	0.043	-0.242	0.107
b42	198	-0.010	0.123	-0.336	0.219	b42	357	0.016	0.141	-0.336	0.359
b51	204	0.000	0.164	-0.432	0.337	b51	360	0.000	0.109	-0.382	0.291
b52	204	0.161	2.490	-4.739	5.280	b52	360	0.041	1.421	-3.303	3.650
b6	204	0.005	0.471	-1	1	b6	360	-0.011	0.422	-1	1
						Bonds					
b11	204	0.000	0.067	-0.171	0.183	b11	360	0.000	0.107	-0.314	0.278
b12	204	-0.076	0.430	-1.051	0.817	b12	360	-0.034	0.744	-1.801	1.969
b21	202	0.000	0.014	-0.043	0.033	b21	358	0.000	0.018	-0.055	0.067
b22	202	0.000	0.035	-0.080	0.080	b22	358	-0.008	0.092	-0.353	0.163
b31	196	0.000	0.005	-0.012	0.021	b31	355	0.000	0.002	-0.010	0.008
b32	196	0.000	0.010	-0.023	0.021	b32	355	0.000	0.007	-0.020	0.020
b41	198	0.000	0.013	-0.043	0.033	b41	357	0.000	0.017	-0.051	0.068
b42	198	-0.002	0.030	-0.068	0.065	b42	356	-0.001	0.114	-0.380	0.244
b51	204	0.000	0.034	-0.091	0.095	b51	360	0.000	0.044	-0.093	0.115
b52	204	-0.033	0.305	-0.816	0.627	b52	360	-0.010	0.492	-1.136	1.110
b6	204	-0.049	0.484	-1	1	b6	360	0.053	0.416	-1	1
						Housing					
b11	199	0.000	0.061	-0.137	0.205	b11	358	0.000	0.131	-0.268	0.371
b12	199	0.004	0.312	-0.664	1.131	b12	358	0.007	0.576	-1.585	1.581
b21	197	0.000	0.004	-0.013	0.016	b21	356	0.000	0.004	-0.012	0.021
b22	197	0.000	0.019	-0.035	0.040	b22	356	0.000	0.010	-0.030	0.024
b31	196	0.000	0.001	-0.004	0.003	b31	355	0.000	0.002	-0.007	0.014
b32	196	0.000	0.003	-0.006	0.009	b32	353	-0.001	0.009	-0.023	0.021
b41	197	0.000	0.004	-0.011	0.018	b41	356	0.000	0.003	-0.010	0.017
b42	197	-0.001	0.008	-0.021	0.019	b42	355	0.000	0.012	-0.027	0.024
b51	199	0.000	0.014	-0.031	0.035	b51	358	0.000	0.035	-0.100	0.090
b52	199	-0.007	0.128	-0.281	0.278	b52	358	0.034	0.321	-0.712	0.835
b6	204	0.025	0.481	-1	1	b6	360	-0.033	0.471	-1	1

Table 3. Correlation structure

Euro Area — Stock

	b11	b12	b21	b22	b31	b32	b41	b42	b51	b52	b6
b11	1.00										
b12	0.63	1.00									
b21	-0.06	-0.12	1.00								
b22	0.07	-0.22	0.25	1.00							
b31	0.09	0.06	0.42	0.05	1.00						
b32	0.22	0.14	0.02	-0.22	0.11	1.00					
b41	-0.09	-0.10	0.95	0.20	0.45	0.03	1.00				
b42	-0.11	-0.29	0.22	0.77	0.04	-0.32	0.22	1.00			
b51	0.82	0.48	0.13	0.38	0.11	0.31	0.08	0.11	1.00		
b52	0.66	0.88	-0.09	-0.06	0.09	0.26	-0.10	-0.25	0.61	1.00	
b6	0.65	0.31	0.00	0.43	0.04	0.16	-0.03	0.26	0.79	0.44	1.00

United States — Stock

	b11	b12	b21	b22	b31	b32	b41	b42	b51	b52	b6
b11	1.00										
b12	0.38	1.00									
b21	0.14	-0.06	1.00								
b22	0.31	0.04	0.21	1.00							
b31	0.14	0.00	0.67	0.13	1.00						
b32	0.16	0.13	0.04	0.30	0.19	1.00					
b41	0.09	-0.13	0.95	0.11	0.70	0.00	1.00				
b42	0.15	-0.19	0.18	0.64	0.13	0.37	0.17	1.00			
b51	0.71	0.55	0.28	0.52	0.26	0.29	0.18	0.24	1.00		
b52	0.31	0.87	-0.05	0.11	0.03	0.15	-0.11	-0.13	0.56	1.00	
b6	0.52	0.48	0.10	0.48	0.11	0.35	0.00	0.20	0.72	0.53	1.00

Euro Area — Bonds

	b11	b12	b21	b22	b31	b32	b41	b42	b51	b52	b6
b11	1.00										
b12	0.27	1.00									
b21	0.10	0.00	1.00								
b22	0.33	-0.06	0.19	1.00							
b31	0.07	0.01	0.33	-0.02	1.00						
b32	0.12	-0.04	0.03	-0.03	0.23	1.00					
b41	0.03	0.04	0.95	0.12	0.35	0.04	1.00				
b42	0.12	0.11	0.26	0.74	0.01	-0.04	0.25	1.00			
b51	0.50	0.62	0.12	0.27	0.13	0.09	0.13	0.25	1.00		
b52	0.26	0.76	-0.13	-0.19	0.06	0.06	-0.11	-0.09	0.65	1.00	
b6	0.15	0.38	0.05	0.19	0.04	0.02	0.03	0.22	0.62	0.54	1.00

United States — Bonds

	b11	b12	b21	b22	b31	b32	b41	b42	b51	b52	b6
b11	1.00										
b12	0.51	1.00									
b21	0.11	-0.04	1.00								
b22	0.02	0.05	0.15	1.00							
b31	0.02	0.05	0.13	0.01	1.00						
b32	0.19	0.17	-0.04	-0.04	0.22	1.00					
b41	0.08	-0.04	0.94	0.14	0.14	-0.04	1.00				
b42	0.03	-0.02	0.12	0.84	0.01	-0.10	0.15	1.00			
b51	0.55	0.44	0.13	0.16	0.05	0.16	0.12	0.21	1.00		
b52	0.38	0.53	-0.11	-0.13	0.07	0.45	-0.09	-0.01	0.61	1.00	
b6	0.44	0.38	0.00	0.13	0.00	0.05	0.00	0.15	0.64	0.43	1.00

Euro Area — Housing

	b11	b12	b21	b22	b31	b32	b41	b42	b51	b52	b6
b11	1.00										
b12	0.36	1.00									
b21	0.17	0.08	1.00								
b22	0.24	0.30	0.15	1.00							
b31	0.02	-0.01	0.24	0.03	1.00						
b32	-0.19	0.00	-0.06	0.04	0.19	1.00					
b41	0.16	0.02	0.90	0.00	0.26	-0.04	1.00				
b42	0.43	0.24	0.19	0.45	0.05	-0.18	0.11	1.00			
b51	0.16	-0.17	0.15	-0.03	0.06	0.05	0.17	0.14	1.00		
b52	-0.22	-0.38	-0.07	-0.11	0.02	0.33	-0.04	-0.33	0.44	1.00	
b6	-0.21	-0.28	0.01	0.15	0.06	0.16	0.01	-0.13	0.46	0.50	1.00

United States — Housing

	b11	b12	b21	b22	b31	b32	b41	b42	b51	b52	b6
b11	1.00										
b12	0.22	1.00									
b21	0.00	-0.07	1.00								
b22	0.24	0.22	0.08	1.00							
b31	0.02	-0.08	0.60	0.05	1.00						
b32	0.16	0.24	0.06	0.62	0.11	1.00					
b41	-0.02	-0.11	0.92	0.06	0.65	0.07	1.00				
b42	0.09	-0.09	0.07	0.75	0.05	0.48	0.11	1.00			
b51	0.60	0.15	-0.14	0.20	-0.05	0.36	-0.15	0.09	1.00		
b52	0.17	0.37	-0.07	-0.19	-0.08	0.07	-0.09	-0.30	0.48	1.00	
b6	0.21	0.27	-0.11	0.06	-0.05	0.25	-0.12	-0.08	0.60	0.50	1.00

Table 4. PCA estimation

United States				Euro Area			
Principal components/correlation			Obs = 355	Principal components/correlation			Obs = 196
Rotation: (unrotated=principal)				Rotation: (unrotated=principal)			
	Eigenvalue	Proportion	KMO stat		Eigenvalue	Proportion	KMO stat
PCA_Stock	3.79	0.34	0.71	PCA_Stock	3.66	0.33	0.67
PCA_Bonds	3.11	0.28	0.56	PCA_Bonds	3.13	0.28	0.62
PCA_Housing	2.86	0.26	0.61	PCA_Housing	2.63	0.24	0.57
Principal component scoring coefficients (eigenvectors)				Principal component scoring coefficients (eigenvectors)			
Variable	PCA_Stock	PCA_Bonds	PCA_Housing	Variable	PCA_Stock	PCA_Bonds	PCA_Housing
b11	0.35	0.41	0.32	b11	0.47	0.31	0.39
b12	0.30	0.40	0.29	b12	0.40	0.41	0.38
b21	0.21	0.06	-0.28	b21	-0.02	0.16	0.27
b22	0.31	0.10	0.19	b22	0.06	0.20	0.26
b31	0.21	0.07	-0.22	b31	0.07	0.12	0.05
b32	0.23	0.21	0.27	b32	0.19	0.06	-0.22
b41	0.16	0.06	-0.29	b41	-0.03	0.16	0.23
b42	0.19	0.11	0.07	b42	-0.06	0.23	0.40
b51	0.47	0.48	0.47	b51	0.46	0.51	-0.13
b52	0.31	0.43	0.33	b52	0.45	0.40	-0.43
b6	0.41	0.41	0.40	b6	0.39	0.40	-0.31

Note: Kaiser-Meyer-Olkin measure of sampling adequacy

Table 5. Properties of estimated shocks

Euro area					
Descriptive statistics					
Variable	Obs	Mean	Std. Dev.	Min	Max
mpshock_rr	132	0.00	0.28	-1.08	0.93
mpshock_tr	196	0.00	0.28	-1.76	1.04
mpshock_kutt	149	-0.01	0.05	-0.22	0.17
qeshock_rr	69	0.00	0.07	-0.08	0.39
qeshock_tr	69	0.00	0.08	-0.09	0.47
Correlation					
	mpshock_rr	mpshock_tr	mpshock_kutt	qeshock_rr	qeshock_tr
mpshock_rr	1				
mpshock_tr	0.89	1			
mpshock_kutt	0.13	0.21	1		
qeshock_rr	-0.25	-0.22	-0.07	1	
qeshock_tr	-0.28	-0.19	-0.07	0.90	1
Shapiro-Francia normality test					
Variable	Obs	W'	V'	z	Prob>z
mpshock_rr	132	0.94	6.50	3.77	0.00
mpshock_tr	196	0.86	21.68	6.35	0.00
mpshock_kutt	149	0.81	24.42	6.48	0.00
qeshock_rr	69	0.69	21.03	5.88	0.00
qeshock_tr	69	0.62	25.55	6.25	0.00
Autocorrelation test		Predictability of exogenous shock series			
	AR(1) coef.		F-stat	p-value	Adjusted R^2
mpshock_rr	-0.01	mpshock_rr	0.69	0.71	-0.02
mpshock_tr	0.00	mpshock_tr	4.82	0.00	0.15
mpshock_kutt	-0.01	mpshock_kutt	1.45	0.17	0.03
qeshock_rr	0.00	qeshock_rr	1.07	0.40	0.01
qeshock_tr	0.04	qeshock_tr	1.40	0.21	0.05
United States					
Descriptive statistics					
Variable	Obs	Mean	Std. Dev.	Min	Max
mpshock_rr	357	0.00	0.17	-0.69	0.83
mpshock_tr	353	0.00	0.21	-0.94	0.95
mpshock_kutt	185	-0.04	0.33	-3.47	0.85
qeshock_rr	154	0.00	0.02	-0.13	0.17
qeshock_tr	149	0.00	0.04	-0.11	0.24
Correlation					
	mpshock_rr	mpshock_tr	mpshock_kutt	qeshock_rr	qeshock_tr
mpshock_rr	1				
mpshock_tr	0.85	1			
mpshock_kutt	0.13	0.20	1		
qeshock_rr	-0.16	-0.10	0.21	1	
qeshock_tr	-0.07	-0.04	0.13	0.57	1
Shapiro-Francia normality test					
Variable	Obs	W'	V'	z	Prob>z
mpshock_rr	357	0.94	16.37	6.00	0.00
mpshock_tr	353	0.95	14.45	5.73	0.00
mpshock_kutt	185	0.37	96.37	9.40	0.00
qeshock_rr	154	0.70	39.46	7.47	0.00
qeshock_tr	149	0.78	28.08	6.77	0.00
Autocorrelation test		Predictability of exogenous shock series			
	AR(1) coef.		F-stat	p-value	Adjusted R^2
mpshock_rr	0.01	mpshock_rr	0.23	0.99	-0.02
mpshock_tr	0.44***	mpshock_tr	3.67	0.00	0.06
mpshock_kutt	-0.06	mpshock_kutt	2.35	0.02	0.06
qeshock_rr	0.17**	qeshock_rr	0.66	0.75	-0.02
qeshock_tr	0.77***	qeshock_tr	11.43	0.00	0.39

Note: The vector of variables for predictability tests includes lagged values of inflation, ipi, gdp, shadow, eonia (or ffr), oil, m3 (or m2), ciss (or vix), and bonds.

APPENDIX

Table A. Data sources and Description

Concept	Euro Area				United States			
	Abbreviation	Description	Source	Frequency	Abbreviation	Description	Source	Frequency
Asset Price								
Stock	eurostoxx	Eurostoxx	Datastream	Monthly	sp500	S&P 500	Datastream	Monthly
Bonds	bonds	Government 10-year benchmark bonds	Datastream	Monthly	bonds	Government 10-year benchmark bonds	Datastream	Monthly
Housing	housep	residential property prices	ECB	Quarterly	housep	Shiller's monthly data	Shiller's monthly data	Monthly
Discounted value of future cash-flows								
Dividends	divid_rsa	Dividends paid by financial and non-financial corporations	Eurostat	quarterly	divid_rsa	Paid dividends by corporations	Bureau of Economic Analysis	Quarterly
Rents	rent	rents received by households	Eurostat	quarterly	rent	rents received by households	Bureau of Economic Analysis	Quarterly
Discount factor	txlg	long-term interest rates	Datastream	Monthly	txlg	long-term interest rates	Datastream	Monthly
Risk Premium	vix	Volatility Index	Chicago Board Options Exchange	Monthly	vix	Volatility Index	Chicago Board Options Exchange	Monthly
All available information								
disposable income	rdb	real disposable income	Eurostat	Quarterly	rdb	real disposable income	Bureau of Economic Analysis	Quarterly
real GDP	gdp	real GDP	Eurostat	Quarterly	gdp	real GDP	Bureau of Economic Analysis	Quarterly
industrial production	ipi	industrial production	Eurostat	Monthly	ipi	industrial production	Bureau of Economic Analysis	Monthly
oil prices	oil	oil prices	Datastream	Monthly	oil	oil prices	Datastream	Monthly
Inflation	inf	Inflation	Eurostat	Monthly	inf	inflation	Bureau of Economic Analysis	Monthly
confidence indicators	csind & cscons	Confidence indicators for households and industry	European Commission	Monthly	csind & cscons	Confidence indicators for consumers and firms	Conference Board & ISM	Monthly
Financial stress	ciss	CISS	ECB	Monthly	kcfsi	Kansas City Financial indicator	FRED	Monthly
interbank interest rate		3-month interbank interest rate	Datastream	Monthly		3-month interbank interest rate	Datastream	Monthly
Monetary Aggregate	m3	M3	ECB	Monthly	m2	M2	FRED	Monthly
Credit Aggregate	m3_credit	Credit counterparties of monetary aggregate	ECB	Monthly	credit	Credits granted by commercial banks	FRED	Monthly
Monetary policy								
Policy rate	eonia	EONIA rate	Datastream	Monthly	fedfunds	Federal funds rate	Datastream	Monthly
shadow rate	shadow	shadow rate	Wu and Xia (2016)	Monthly	shadow	shadow rate	Wu and Xia (2016)	Monthly
Securities held for monetary purpose	shmp	Securities Held for Monetary Policy Purposes (SHMPP)	ECB	Monthly	shmpp	Table H.4.1 including Treasury securities and Mortgaged-backed assets	Federal Reserve	Monthly

Note: All nominal variables are deflated by CPI.

Figure A. Real asset prices

Euro area

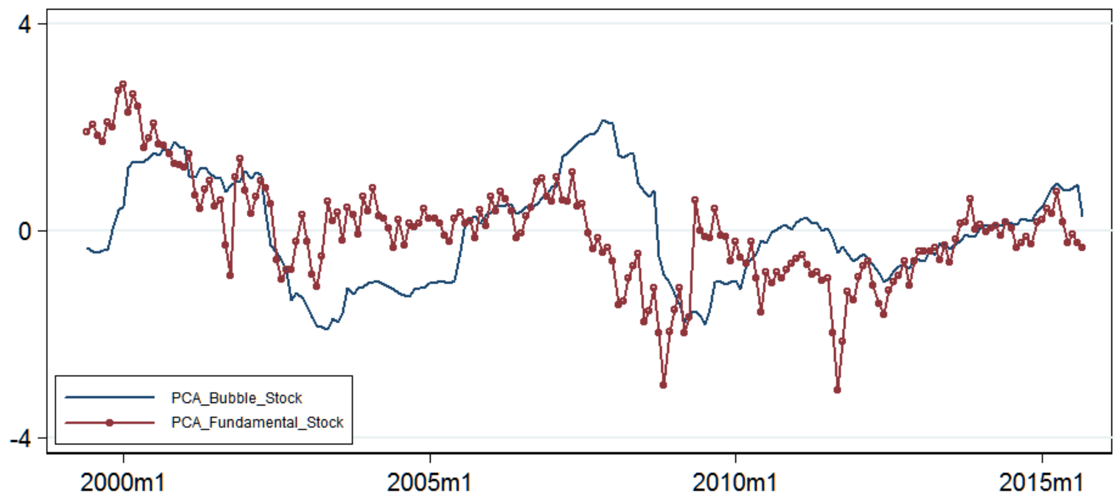
Note: *1999=100.* Sources: Datastream, ECB and Eurostat.

United States

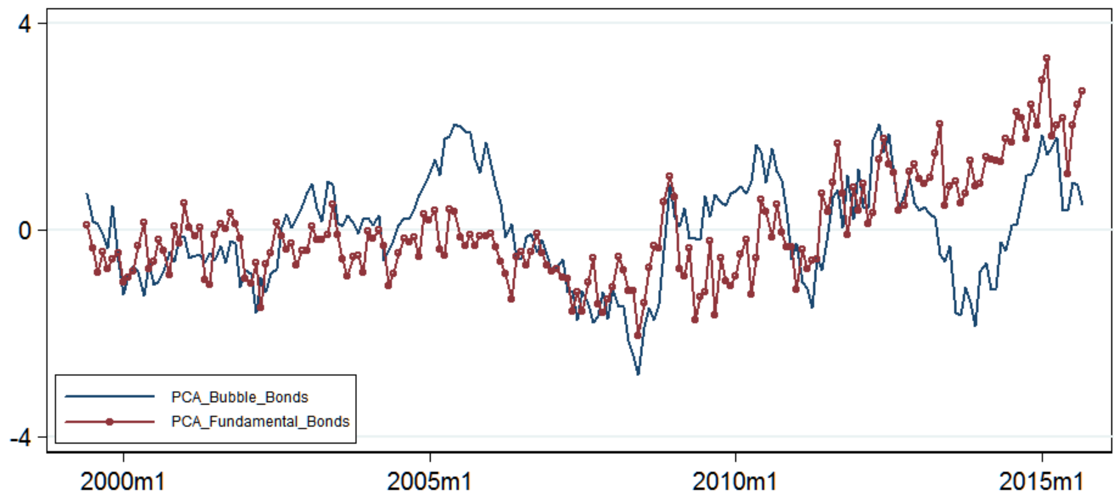
Note: 1986=100. Sources: Datastream, Robert Shiller and Bureau of Economic Analysis.

Figure B. Bubbles and Fundamentals in the euro area

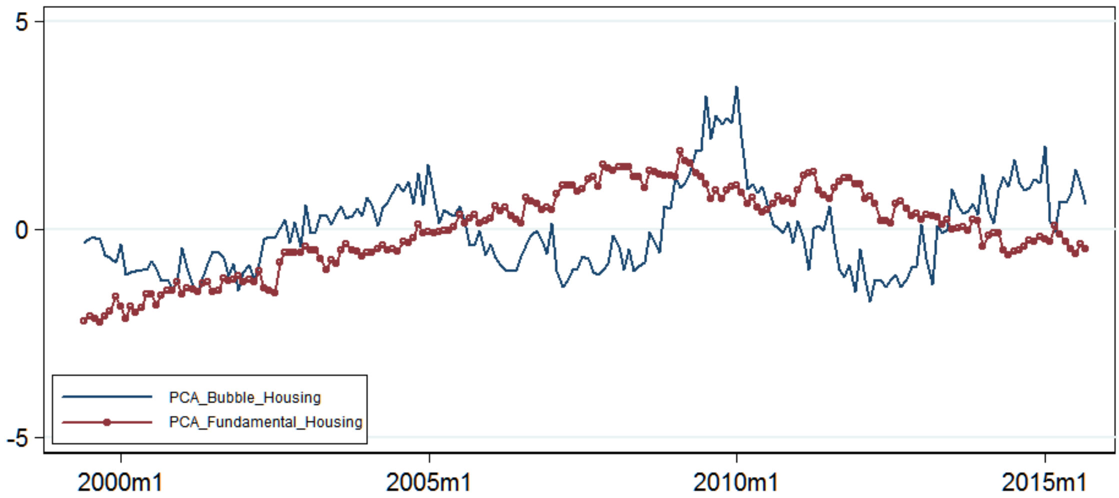
Stocks



Bonds



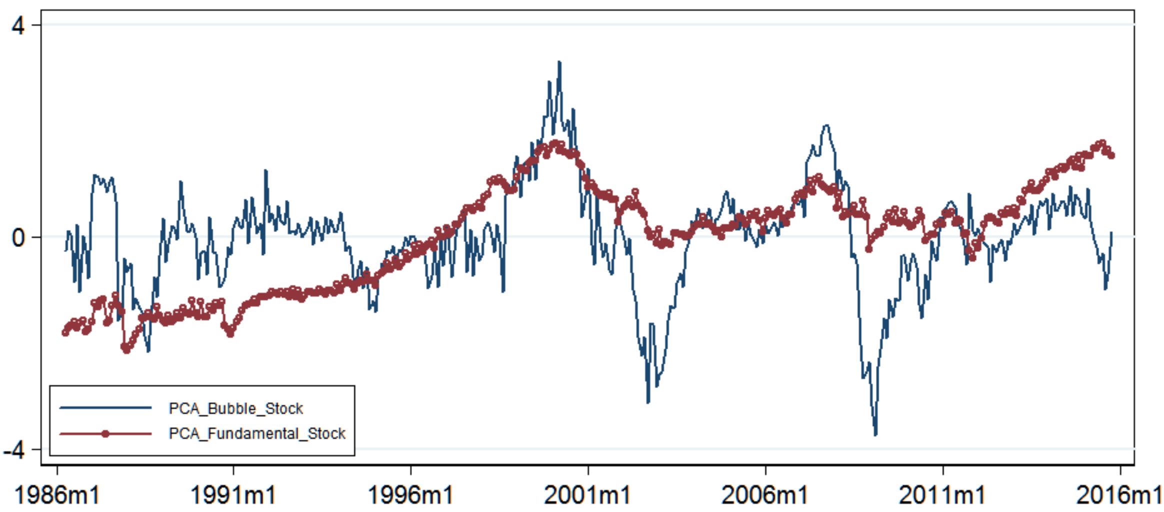
Housing



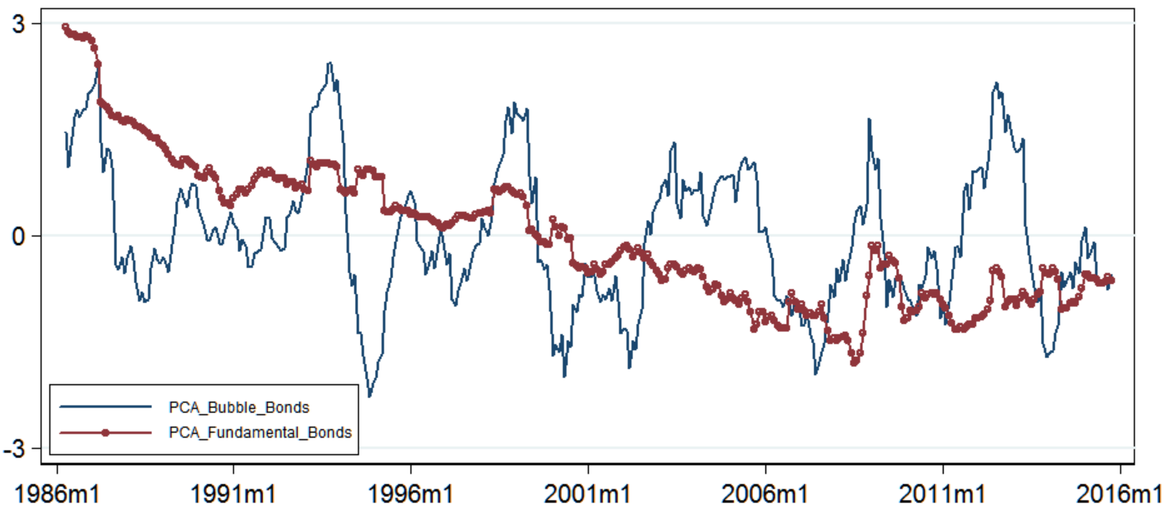
Sources: authors' estimations.

Figure C. Bubbles and Fundamentals in the United States

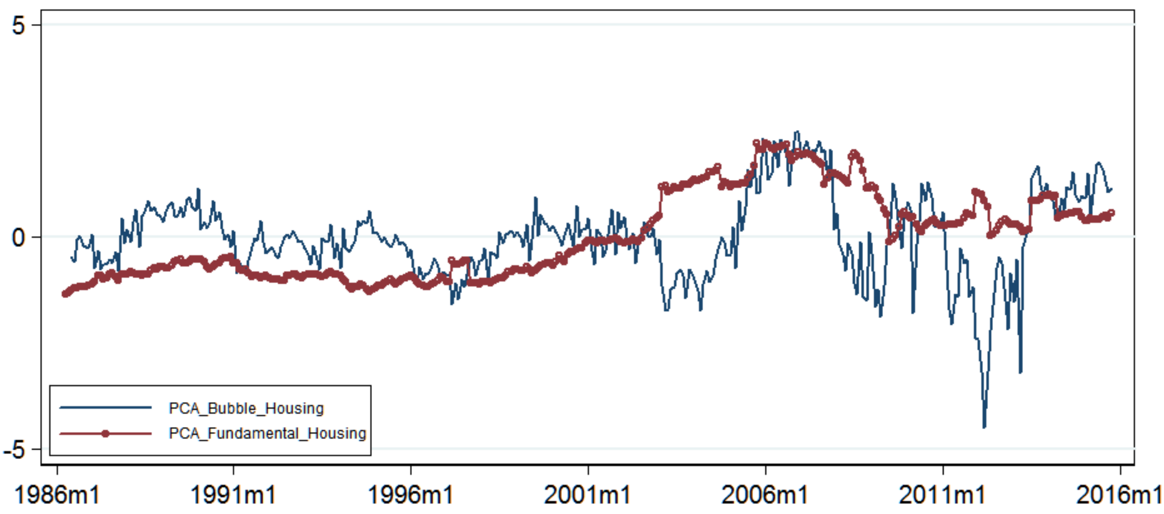
Stocks



Bonds



Housing



Sources: authors' estimations.