10-2020

To Lean or Not to Lean Against an Asset Price Bubble? Empirical Evidence

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Recommended Citation

Evgenidis, Anastasios and Malliaris, A. (Tassos) G.. To Lean or Not to Lean Against an Asset Price Bubble? Empirical Evidence. Economic Inquiry, 58, 4: 1958-1976, 2020. Retrieved from Loyola eCommons, School of Business: Faculty Publications and Other Works, http://dx.doi.org/10.1111/ecin.12915

Economic Inquiry WEAI

TO LEAN OR NOT TO LEAN AGAINST AN ASSET PRICE BUBBLE? EMPIRICAL EVIDENCE

ANASTASIOS EVGENIDIS and ANASTASIOS G. MALLIARIS

Since the Global Financial Crisis of 2007–2009, economists are reconsidering the appropriate role of monetary policy towards equity bubbles. This paper contributes to these deliberations by estimating the response of the stock market to monetary policy tightening by using a Bayesian time-varying VAR model. By introducing the cyclically adjusted price/earnings ratio, we propose a method that estimates its fundamental and bubble components. We find that asset prices will initially fall and eventually rise again but without the risk of feeding the bubble. Counterfactual policy experiments provide additional evidence that monetary policy can lean against equity and housing prices. (*JEL* E50, E52, E58)

I. INTRODUCTION

Considering the importance of financial stability for policymakers, the issue of whether monetary policy may help achieve this goal is crucial and hinges on the impact of monetary policy on asset prices. This paper is motivated by the Galí (2014) and Galí and Gambetti (2015) papers, among several other important contributions in the area of monetary policy, known as "lean vs. clean." The theoretical Galí (2014) paper decomposes an asset price into its fundamental component and a bubble term. The fundamental component is the sum of present value of future dividends discounted by some rate of interest (denoted by i and determined by monetary policy). When i increases, the fundamental price decreases. This result is not controversial because it follows from a discounting formula. However, as Galí (2014) argues, the bubble component has no payoffs to discount and this means that any increase in i will tend to increase the size of the bubble. This implies that tighter monetary policy may actually further inflate the bubble because increases in i decrease the fundamental component but increase the bubble component of the asset price.

Having Galí (2014) as a theoretical construction, Galí and Gambetti (2015) challenge the conventional assessment that monetary policy can deflate a bubble by leaning against it with interest rate increases. The authors show that tightening monetary policy reduces the fundamental value of the asset and inflates the bubble component. Consequently, a sizable increase in the interest rate, if the asset bubble has increased substantially (and the fundamental value declines only a little), may cause the leaning against the bubble to actually further increase the stock market's value.

Three recent contributions now challenge Galí (2014) and Galí and Gambetti (2015). First, Allen, Barlevy, and Gale (2017) question the assertion by Galí (2014) that in the case of rational asset price bubbles the bubble component must grow in equilibrium at the rate of interest. Allen, Barlevy, and Gale (2017) show that when they modify Galí's model to allow for the possibility that a central bank which raises the interest

ABBREVIATIONS

ADF: augmented Dickey-Fuller
CAPE: Cyclically Adjusted Price/Earnings Ratio
Fed: Federal Reserve
FFR: Federal Funds rate
IP: production index
PPI: producer price index
QE: quantitative easing
QT: quantitative tightening
UMP: unconventional monetary policy
VAR: vector autoregression

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Economic Inquiry
(ISSN 0095-2583)
Vol. 58, No. 4, October 2020, 1958–1976
doi:10.1111/ecin.12915
Online Early publication June 24, 2020

rate might crowd out resources that would have otherwise been directed to the bubble, the Galí result does not follow. Thus, the authors restore the intuitive result that an increase in the interest rate lowers both the fundamental and the bubble components.

Second, Beckers and Bernoth (2016) also challenge the theoretical predictions of Galí by generalizing the concept of rational bubbles to a broader idea of asset mispricing. They also reassess the empirical findings of Galí and Gambetti (2015) by employing a less restrictive econometric strategy to identify monetary policy shocks and conclude that monetary policy tightening lowers stock prices significantly. Third, Blot, Hubert, and Labondance (2017) also reassess Galí and Gambetti (2015) and empirically find that the effects of monetary policy on asset bubbles are asymmetric. This means that restrictive monetary policy cannot deflate asset price bubbles whereas expansionary policies do fuel such bubbles.

This paper contributes in four dimensions. First, we examine the "lean" option by using a Bayesian TV-VAR model. Instead of using Galí and Gambetti's (2015) controversial "rational bubble," we introduce the cyclically adjusted price/earnings ratio (CAPE) developed by Campbell and Shiller (1998). This measure is calculated by taking the price of the S&P 500 index and dividing by average inflation-adjusted earnings from the previous 10 years. The advantage of using CAPE is that this P/E ratio moves slowly because of its 10-year smoothing. More importantly, it is bounded with a cyclical behavior that can be used at any point in time to make a comparison of the current price to past high and low values. The range of these bounds changes over time to reflect the evolution of financial markets but the anchoring of CAPE on a 10-year earning average, further adjusted for inflation, moderates the magnitude of such changes. In contrast, when directly using the S&P 500 index, (that was around 100 in 1971 and is over 3,200 in mid-January 2020), bubbly local peaks are eventually followed by even higher ones, thus preventing any benchmarking.

Galí (2014) imposes restrictive assumptions that cannot easily be generalized, to guide central bank initiatives. In our paper, by introducing CAPE and determining its bubbly range, we investigate whether monetary policy can moderate increases in CAPE. A priori, there are three possibilities: increases in the federal funds rate (FFR) would, (i) increase CAPE, which would be consistent with Galí and Gambetti; or (2) decrease CAPE or (3) perhaps show a nonlinear response in view of CAPE's long-cyclical behavior. This third option, if confirmed by the data can be viewed as a generalization of the existing specialized version of up or down responses to leaning against bubbles. Our approach is not motivated by a theoretical framework of bubble formation. Rather, we propose a CAPE derived threshold that allows us to obtain an estimate of the bubble component in order to measure what is a fair price for the total stock market and how to use this to obtain empirical implications.

The second contribution is to introduce an additional tool for monetary policy. Constrained by the zero lower bound, the Federal Reserve (Fed) in the post-2008 period introduced unconventional monetary policy (UMP) measures in the form of quantitative easing (QE) to stimulate the economy. One of the risks of QE is that very low borrowing costs and easy opportunities to leverage a financial position may lead to asset price bubbles and financial instability upon their crash. This motivates our work to use our TV-VAR model augmented with one additional variable, the yield spread as the difference of the 10-Year Treasury Note rate less the 3-month Treasury Bill rate, in order to estimate the time-varying impact of UMP shocks on asset prices.

The third contribution investigates whether bubble formation is influenced by central bank policies. Brunnermeier and Schnabel (2016) report that numerous bubbles have been fueled by easy monetary policies. Bernanke and Kuttner (2005) find that a surprise cut in the policy rate is associated with a 1% increase in stock prices. Rigobon and Sack (2004) have a similar result. A survey on similar topics is presented in Claessens and Kose (2017). Our goal is to explore this issue further by constructing counterfactual scenarios via conditional forecasts. We perform two different scenarios; one that investigates the impact of conventional monetary expansion on asset price bubbles and another that examines the effects of QE on asset prices.

The fourth contribution addresses housing prices. There is much agreement that the Global Financial Crisis was triggered by the bursting of the housing bubble. However, there is no agreement as to what had caused the housing bubble. Later in the paper, we briefly discuss the main arguments developed by John Taylor and Ben Bernanke to explain the causes of the housing bubble. To empirically test these arguments, we perform one last counterfactual that allows us to assess whether a strong contractionary monetary tightening could have substantially shortened and reduced the housing bubble.

We now provide a short overview of the main results. Impulse response analysis presents evidence of nonlinear effects of monetary policy on both the stock market bubble and the fundamentals. Specifically, there is a strong decline in asset prices in the first 10 months after a tightening of monetary policy, followed by a gradual increase of the bubble term which tends towards zero in the long term. Our result supports the conventional wisdom regarding the impact of monetary policy on stock price bubbles and contrasts with the view that the size of the bubble increases persistently in response to a tightening monetary policy. Additionally, we examine the most recent impact of UMP shocks on asset prices. We find that such shocks push up asset prices, implying that QE might trigger asset price bubbles and financial instability.

Counterfactual policy scenarios help to illuminate these issues by examining whether the appearance of bubbles is influenced by monetary policy. Our results suggest that aggressive monetary tightening, in the form of interest rate increases in the period before the burst of the dotcom bubble, would have limited the sharp stock market expansion. More recently, extensive implementation of QE did lead to inflated asset prices for a protracted period. Lastly, considering the impact of monetary policy on the housing market, scenario analysis suggests that if the Fed had responded much more aggressively in 2003–2004 by adopting a frontloaded policy, it would have substantially reduced the rise in house prices.

The remainder of the paper is organized as follows. Section II offers a review of the relevant literature. Section III provides a detailed description of the data and the econometric methodology used. Section IV presents and discusses the results. Section V concludes by briefly summarizing the contributions made in this paper on the debate of “lean vs. clean.”

II. LITERATURE REVIEW

The classic book that first addressed the importance of asset price bubbles is Kindleberger (1978). From the first edition of this book, through its several revisions, up to the last version by Kindleberger and Aliber (2015), new bubbles were added to illustrate their continued presence in the economic landscape. What emerges from these books is that asset bubbles have been occurring for the past few centuries across many countries. Often, they cause limited macroeconomic problems but in certain occurrences these bubbles may lead to an economic depression, as in the case of the 1929 Stock Market Bubble Crash or to a major recession as in the 2007 U.S. housing market bubble crash. Central banks are concerned with asset bubbles because of the risks associated with their crashes. Kashyap and Siegert (2020) argue that stretched asset valuations also matter for financial stability.

Reinhart and Rogoff (2009) offer a more comprehensive quantitative analysis of economic crises than that of Kindleberger (1978). The scope of their book is chronologically very long, going back to pre-1800, and broad in terms of countries, covering as many as 66 countries. Crises of various varieties are examined, such as inflation, currency crashes, banking crises, sovereign debt crises, and others. Many economic crises are unrelated to asset price bubbles, but the authors describe how some banking crises developed from the bursting of stock market bubbles or housing bubbles.

A more technical debate about asset price bubbles and monetary policy was launched by Greenspan (1996), then Federal Reserve Chairman, who was the first to clearly state the challenge faced by central banks in the presence of asset price bubbles. A large number of papers were motivated by Greenspan (1996). Bernanke and Gertler (1999, 2001) argued that the pursuit of price stability contributes to financial stability and therefore central banks should ignore asset bubbles. Evanoff, Kaufman, and Malliaris (2012) offer an overview of the literature on asset bubbles with an emphasis on the Global Financial Crisis. By now, there are major reviews, such as Jones (2015), Claessens and Kose (2017), and Evanoff and Malliaris (2018) which trace the evolution of ideas on the topic of bubbles and monetary policy. Also, it was quickly agreed that asset bubbles that matter to monetary policy are stock market aggregates and housing or real estate aggregates. Price bubbles that carry an inconsequential risk to impact the real economy in a significant way such as individual stocks, commodities, regional housing, or currencies, are not considered by central banks.

During the decade of 1996–2007, while researchers were addressing, both theoretically and empirically, bubble related questions, the U.S. economy went through the building up of the internet bubble, its bursting, a brief economic recession, and another bubble, this time in housing, during 2002–2007. Jones (2015) gives a thoughtful discussion of the literature during this period and the consensus that slowly developed. Issing (2011) called it the Jackson Hole consensus that endorsed the "clean after the bubble bursting" choice. The brief and low cost recession that followed the internet bubble crash during the 8-month period of March 2001 to November 2001, motivated Blinder and Reis (2005) to state: *If the mopping-up strategy worked this well after the mega-bubble burst in 2000, shouldn't we assume that it will also work well after other, presumably smaller, bubbles burst in the future? Our suggested answer is apparent*.

It is now known, from the painful costs of the Great Recession that resulted from the bursting of the housing bubble, that the Blinder and Reis (2005) suggested answer for inaction during the growth of an asset bubble was shortsighted. Kohn (2006), Mishkin (2008), Dudley (2010), Jones (2015), Yellen (2014), Malliaris (2012, 2016), and Claessens and Kose (2017) evaluate how the Global Financial Crisis impacted the "clean vs. lean" literature and how during the last 10 years, researchers have focused on the "leaning" choice. Brunnermeier and Schnabel (2016) empirically document that central banks have fueled asset price bubbles repeatedly over time and across countries. Their evidence supports that central banks are not asset bubble-neutral. Some evidence of the bubble non-neutrality of central banks is also offered by Hayford and Malliaris (2001, 2004). Thus, if central banks are not bubble-neutral but instead contribute to bubble development, they have two choices: To lean against the bubbles they produce, or to clean after the bursting. Furthermore, since central banks and the Fed in particular, chose not to lean against the housing bubble and bore the huge risks of the Great Recession, should leaning against a future bubble be preferable to cleaning? It is at this phase of the heated examination that Galí (2014) and Galí and Gambetti (2015) dispute of the effectiveness of monetary policy to lean against a bubble.

III. METHODOLOGY AND DATA

A. Data

As mentioned above, one chief difference between Galí and Gambetti (2015) and our paper is the use of CAPE. Galí and Gambetti (2015) rely on a theoretical model to decompose the stock market price into fundamental and bubble components that respond in exactly opposite ways to an increase in the Fed funds rate. Namely, the fundamental component declines while the bubble component increases. We admit that the profession currently does not have an acceptable model to decompose an asset price but could use a valuation proxy such as CAPE. CAPE has lower and upper bounds from about 5 to 45. CAPE, as indicated earlier is a cyclically adjusted price/earnings ratio that is calculated by taking the price of the S&P 500 index and dividing by an average inflation-adjusted earnings from the previous 10 years. By construction, CAPE has minimized noise because of its averaging of earnings over a 10-year period and also because of excluding the influence of inflation.

To construct the bubble series, we begin with a given CAPE level and calculate a 10-year moving average plus 1.5 times this moving average's standard deviation as a threshold for over- and under-valuation.[1] We propose a 10-year CAPE to be consistent with Shiller's logic that a 10-year period average for the Shiller P/E can account for cyclical adjustments for the highly volatile stock prices. If, in a given month, the CAPE value is greater than its 10-year moving average plus 1.5 times this 10-year standard deviation, we call this over-valuation or bubble and is equal to CAPE minus threshold. We consider the fundamental CAPE to be the actual CAPE less the bubble component. On the other hand, we define under-valuation or negative bubble, as the quantity of CAPE below its threshold which, again, is calculated as the difference between CAPE and the threshold. The meaning of a negative bubble is that there is a negative mispricing. The construction of the bubble component as both positive and negative values enriches our data and our analysis to capture the asymmetries argued by Greenspan (1996) and Issing (2009, 2011). The fundamental asymmetry between the stock market and monetary policy is this: when the stock

1. A much lower threshold, for instance 1 standard deviation, would produce too many equity bubble periods while a much higher one, such as 2 standard deviation, would give only a few bubble periods. Thus, we choose 1.5 as the average between too low and very high.

FIGURE 1
CAPE and Threshold

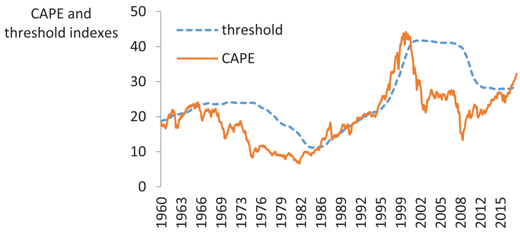
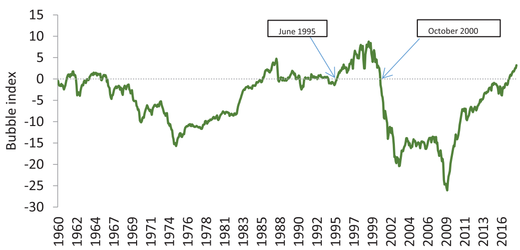


FIGURE 2
Bubble Component



market declines or crashes, monetary policy does not hesitate to implement an easy monetary policy; however, when the market grows euphorically for several months, monetary policy is less decisive.

Figures 1 and 2 convey similar information. Figure 1 illustrates the original CAPE index together with the calculated threshold index and Figure 2 shows the bubble series.[2] In Figure 1, note that when CAPE (solid line) is above the threshold (dashed line), we detect positive bubbles; when CAPE is below the threshold, we detect negative bubbles. Correspondingly in Figure 2, when the bubble component crosses above zero, we identify bubble periods; when it crosses below zero, we identify negative bubbles.

The results suggest that our proposed method identifies both historical episodes of exuberance that took place over the period examined. In particular, the figures demonstrate the overpricing or bubbly period of 1995–2001 and for those who remember the October 19, 1987 one-day correction of about 20%, the graph illustrates the presence of a brief bubble prior to its crashing. It is worth noting that our bubbly periods coincide with the ones detected by some well-developed bubble detection mechanisms in the econometrics literature. Specifically, econometric tests performed by Phillips, Shi, and Yu (2015) identified periods of exuberance in the market including the Black Monday and the dot-com bubble. Particularly in relation to the dot-com bubble, their strategy detects mildly explosive market behavior 5 years before the market crashes, exactly as shown in Figure 2.

Also, note that the Global Financial Crisis of 2007–2009 was not preceded by a bubble in the stock market as judged by the CAPE and our proposed threshold. This is true because the cyclically adjusted 10-year real earnings remained stable while the stock market as measured by the S&P 500 was growing at a moderate rather than exuberant rate. This finding is also consistent with the tests performed by Phillips, Shi, and Yu (2015), which do not identify the subprime mortgage crisis in 2009 as a bubble expansion.

Additional evidence is provided by Phillips, Wu, and Yu (2011), where the exuberant behavior in the Nasdaq stock market is very similar to the bubble periods as identified in Figure 2. In particular, Phillips, Wu, and Yu's (2011) recursive ADF tests for the log real Nasdaq price index detects for the first time in July 1995 the presence of exuberance in the data. The evidence in support of price exuberance becomes stronger from that point on until September 2000. After that date, there is little evidence of exuberance in the data, as in our paper. Also, Phillips, Shi and Yu's recursive ADF tests for the real Nasdaq price index detects some explosive behavior before the 1987 crash although it is short-lived. In particular, the exuberance starts in 1986 and ends in September 1987. Again, the duration of the bubble period as identified in their paper is very similar to the one observed in Figure 2.[3]

One final comment regarding Figures 1 and 2. Notice that since the end of the last recession (in June 2009), the S&P 500 index has grown faster than the cyclically adjusted real earnings and in 2017, the index is in a bubbly state. This latter evidence highlights the ability of our proposed method to capture the longevity and resilience of high asset prices observed in the last years.

2. The graph of the fundamental component is constructed as the difference between the actual CAPE less the bubble component is included in the Appendix, Supporting information.

3. We are grateful to an anonymous referee for suggesting the papers of Phillips, Wu, and Yu (2011) and Phillips, Shi, and Yu (2015) that provide supporting evidence for our methodology.

Our model includes the following five variables: industrial production index (IP), producer price index (PPI), the FFR controlled by the Fed and the two CAPE components described above. IP and PPI indices are used as the primary target variables of monetary policy. Given that the ultimate goal of monetary policy is to achieve price stability, we use the PPI index as a key variable to evaluate the impact of monetary policy on prices. Regarding the proxy for the business cycle, data on GDP are not available on a monthly basis, therefore we use IP as a measure of economic activity. We use monthly data for the period 1960:01 up to 2017:12. Our macroeconomic variables are taken from the Federal Reserve Economic Database while CAPE is taken from Shiller's online database. IP and PPI are transformed in log-levels, while no transformation is implemented for the FFR and the CAPE components.

B. Empirical Model

We examine our reflections as described in Section II with reference to the first two contributions by adopting a TV-VAR model. We use a TV-VAR as it allows us to grasp the possible changes in the underlying structure of the U.S. macroeconomy and also, to take into account the fact that the overall effect of a change in monetary policy in stock prices may have changed over time as the size of the bubble changes. Consider the following form:

$$(1) \quad Y_t = B_{0,t} + B_{1,t}Y_{t-1} + \cdots + B_{p,t}Y_{t-p} + \epsilon_t, \quad \epsilon_t \sim N(0, \Omega_t),$$

where Y_t contains the vector of r endogenous variables, p denotes the lag length that is set equal to four based on information criteria, $B_{0,\,t}$ is a $r \times 1$ vector referring to the constant terms, $B_{i,\,t}$ is the $r \times r$ matrix which contains the lags of the endogenous variables and ϵ_τ is an $r \times 1$ vector of white noise process distributed as *i.i.d*, with Ω_t being the covariance matrix. Following Primiceri (2005), the time varying covariance matrix Ω_t is decomposed as follows:

$$(2) \quad \Omega_t = A_t^{-1} H_t (A_t^{-1})',$$

where the matrix H_t is a diagonal matrix of the stochastic volatilities and the matrix A_t is a lower triangular matrix which captures the contemporaneous interactions of the endogenous variables. Both time-varying matrices are defined as follows:

$$(3) \quad H_t = \begin{bmatrix} h_{1,t} & 0 & 0 & 0 & 0 \\ 0 & h_{2,t} & 0 & 0 & 0 \\ 0 & 0 & h_{3,t} & 0 & 0 \\ 0 & 0 & 0 & h_{4,t} & 0 \\ 0 & 0 & 0 & 0 & h_{5,t} \end{bmatrix},$$

and

$$(4) \quad A_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ a_{21,t} & 1 & 0 & 0 & 0 \\ a_{31,t} & a_{32,t} & 1 & 0 & 0 \\ a_{41,t} & a_{42,t} & a_{43,t} & 1 & 0 \\ a_{51,t} & a_{52,t} & a_{53,t} & a_{54,t} & 1 \end{bmatrix},$$

where $h_{i,\,t}$ evolve as geometric random walks:

$$(5) \quad lnh_t = lnh_{t-1} + \nu_t.$$

Following Primiceri (2005), we postulate the coefficients $B_{i,\,t}$ and the non-zero and non-one elements of the matrix A_t to evolve as driftless random walks:

$$(6) \quad B_t = B_{t-1} + \eta_t.$$

$$(7) \quad a_t = a_{t-1} + \tau_t.$$

Furthermore, we assume that the vector $[\epsilon_t, \eta_t, \tau_t, \nu_t]'$ is distributed as:

(8)

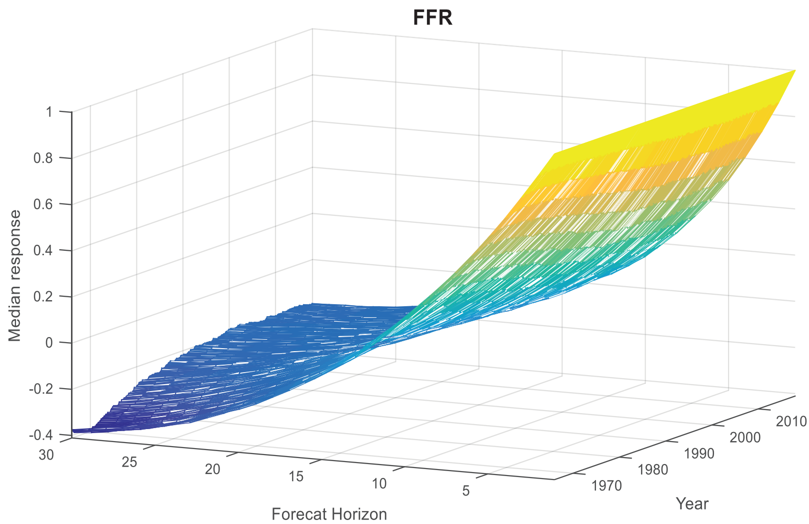
$$\begin{bmatrix} \epsilon_t \\ \eta_t \\ \tau_t \\ \nu_t \end{bmatrix} \sim N(0, V), \text{ with } V = \begin{bmatrix} \Omega & 0 & 0 & 0 \\ 0 & Q & 0 & 0 \\ 0 & 0 & S & 0 \\ 0 & 0 & 0 & Z \end{bmatrix} \text{ and}$$

$$Z = \begin{bmatrix} \sigma_1^2 & 0 & 0 & 0 & 0 \\ 0 & \sigma_2^2 & 0 & 0 & 0 \\ 0 & 0 & \sigma_3^2 & 0 & 0 \\ 0 & 0 & 0 & \sigma_4^2 & 0 \\ 0 & 0 & 0 & 0 & \sigma_5^2 \end{bmatrix}.$$

Identification of Structural Shocks. To identify monetary policy shocks we follow the relative literature on the monetary policy transmission (see Christiano, Eichenbaum, and Evans 1999 among others), by adopting a recursive ordering of the variables based on the Cholesky decomposition of the VAR covariance matrix as $\Omega = A_0 A_0'$, where A_0 represents a time-varying structural impact matrix (which is not necessarily lower triangular).

The ordering of our macroeconomic and financial variables is fairly standard in the literature and implies that slow-moving variables

FIGURE 3
FFR Response to an FFR Shock



(economic activity and prices) are assumed to not respond contemporaneously to unanticipated changes in monetary policy. In contrast, fast-moving variables (asset prices) are allowed to respond contemporaneously to monetary policy shocks (Bernanke and Kuttner 2005). Therefore, the FFR is ordered after economic activity and inflation. This assumption is based on the belief that the transmission of monetary policy shocks to the real economy is evident only with a lag. In addition, the FFR is ordered before CAPE components, implying that monetary policy shocks influence stock prices instantaneously but not vice versa, that is, the central bank does not react contemporaneously to idiosyncratic changes in the stock market. Our baseline specification is thus consistent with Furlanetto (2011) who finds that in the United States, the monetary policy response to asset prices shocks declines over time and becomes statistically insignificant during the bubble period of 2003–2007. The impulse responses can be sensitive to a different identification scheme that considers the possibility that the Fed does react contemporaneously to stock price surprises. Thus, we test the robustness of our results when sign restrictions are applied (see robustness checks in Section V).

Estimation. The model in Equations (1)–(8) is estimated using the Bayesian methods described by Kim and Nelson (1999). In particular, we employ a Gibbs sampling algorithm that approximates the posterior distribution. A description of the prior and posterior distributions is given in the technical Appendix 1. Here we summarize the basic algorithm, which involves the following steps:

1. The VAR coefficients $B_{i,t}$ and the off-diagonal elements of the covariance matrix A_t are simulated by using the methods described in Carter and Kohn (1994).
2. The volatilities of the reduced-form shocks H_t are drawn using the date-by-date blocking scheme in Jacquier, Polson, and Rossi (1994).
3. The hyperparameters Q and S are drawn from an inverse Wishart distribution, while the elements of Z are simulated from an inverse gamma distribution.

IV. DISCUSSION OF RESULTS

A. The Impact of FFR on the Macroeconomy and Stock Markets

Figures 3–7 show the responses of our five variables to a policy rate increase generated by the TV-VAR model. We use the first 5 years to train our sample, therefore the figures depict the responses from 1966 up to 2017.

Figure 3 shows the response of the FFR, the variable that is shocked. The figure shows the increase of the FFR by 100 basis points in the

FIGURE 4
Response of Industrial Production to an FFR Shock

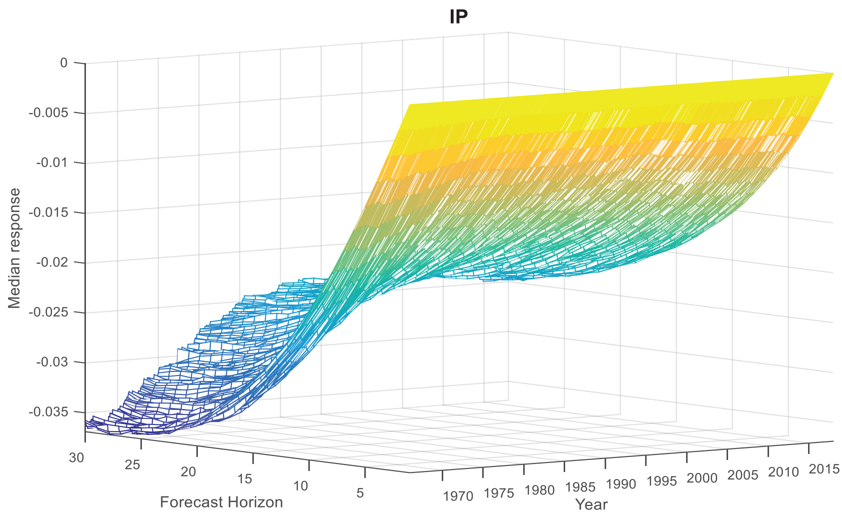
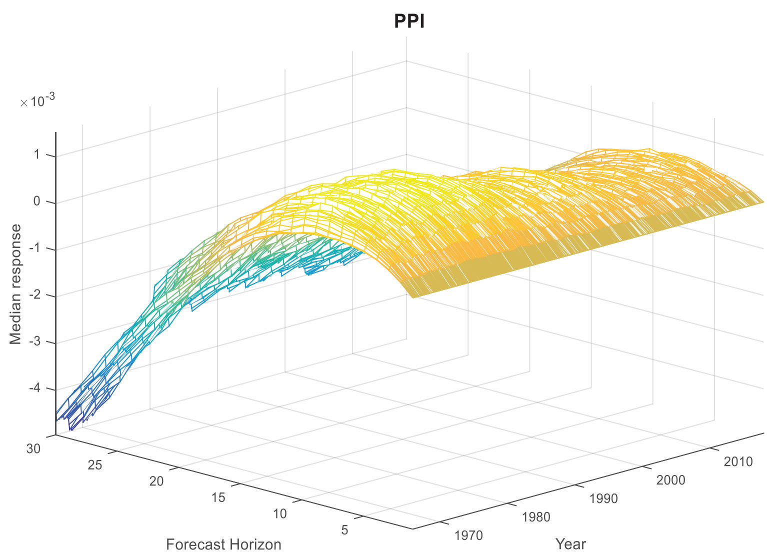


FIGURE 5
Response of Prices to an FFR Shock



first period that dies out smoothly in the following months. Figure 4 displays the response of industrial production. Note that generally, a contractionary monetary policy leads to a noticeable decrease in IP as would be expected. There is some evidence of time-variation, as indicated by the more intense decline of IP until the late 1970s, compared to the impact of the shock in the post-1980s period, which seems to be smaller in magnitude. This is due to the effect of the Great Moderation which contained low and stable inflation and which signaled a period of significant decline in macroeconomic volatility.

Figure 5 depicts the impulse responses of prices. Broadly speaking, the tightening of monetary policy appears to lead to a substantial

FIGURE 6
Response of the Fundamental Component to an FFR Shock

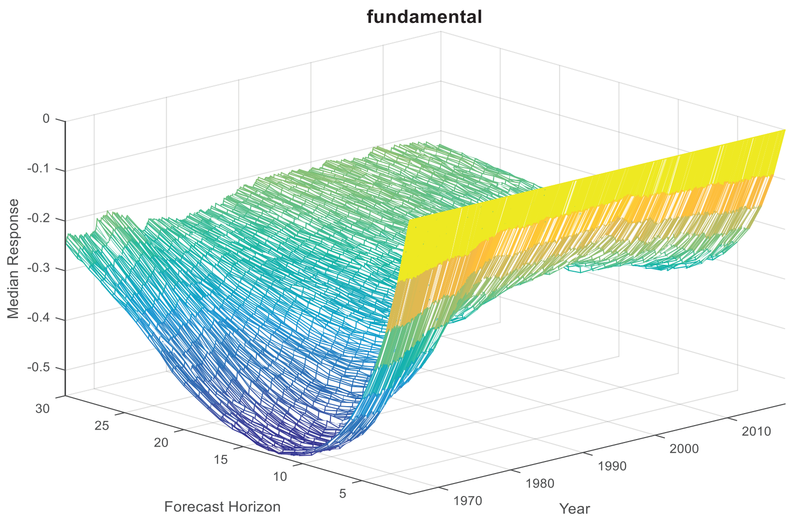
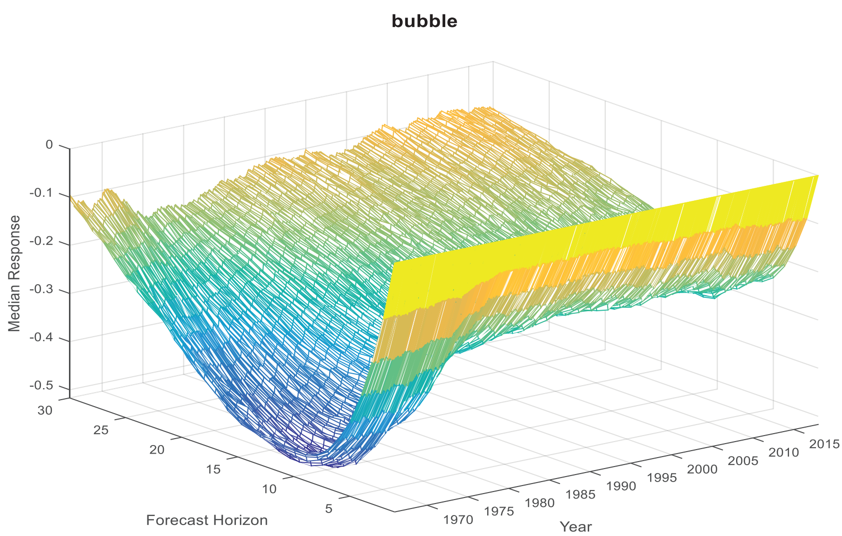


FIGURE 7
Response of the Bubble Component to an FFR Shock



and persistent decline in prices after a small positive reaction for a short period as a result of the shock. This behavior of inflation is consistent with the conventional view of the lag effect of monetary policy under which monetary changes take much longer to affect prices than output. Regarding the time-varying nature of the response, similar to the IP response, there is evidence of an increased impact on prices in the 1970s consistent with the great inflation period characterized by high and persistent inflation, coupled with recessions. In addition, starting from the early 1990s onward, we observe that the initial rise is becoming more and more shortened with prices below zero declining faster.

We next turn our attention on the responses of the CAPE components. Figures 6 and 7 show the responses of the fundamental and the bubble components correspondingly. As expected, there is a significant drop of the fundamental component following the contractionary policy shock as the latter decreases future economic growth and thus firms' profitability and future dividend payouts. The most interesting result however comes from Figure 7 which suggests a similar, clear reduction of the bubble component in response to the shock. Taking both results together, the implication is that CAPE falls, offering a contrast with the Galí and Gambetti (2015) evidence of an increase in CAPE due to growing bubbles.

Focusing on the bubble term, note that its strong decline is reversed almost a year after the shock, as we observe a gradual increase of the bubble term which tends towards zero in the medium term. This implies that a contractionary monetary policy initially decreases stock market prices, which eventually resume their growth. This finding highlights the nonlinear nature of the CAPE response, suggesting that asset prices will initially fall and eventually rise again but without the risk of feeding the bubble. Our finding also contrasts with the Galí and Gambetti (2015) result in which the observed pattern of the bubble increases persistently through the sample period in response to a contractionary monetary shock. Overall, our analysis supports the conventional wisdom regarding the impact of monetary policy on stock price bubbles and contrasts with the view that the size of the bubble increases persistently in response to a tightening monetary policy.

Robustness Checks. We re-estimate our model by using an alternative identification scheme. As explained above, the traditional Cholesky identification that we use assumes that monetary policy shocks influence stock prices instantaneously but that the central bank does not react contemporaneously to idiosyncratic changes in the stock market. There is however another strand of literature (Bjørnland and Leitemo 2009; Rigobon and Sack 2003) which argues that the Fed reacts to changes in stock market. Thus, we seek to test the robustness of our results by considering a different identification scheme that is a mix of long-run restrictions as in Bjørnland and Leitemo (2009), augmented with sign restrictions following Arias, Rubio-Ramírez, and Waggoner (2018) and Binning (2013). Essentially, we allow for two-way contemporaneous responses between the stock market and the policy rate. The identification is described next.

We start by assuming that industrial production and inflation do not respond contemporaneously to contractionary monetary policy shocks. This assumption mirrors the restrictions implied in Cholesky decomposition and is based on the belief that the transmission of monetary policy shocks to the real economy is evident only with a lag. On the other hand, we allow the fundamental component to decrease on impact while the bubble component is also allowed to respond, yet the sign of the response is left unrestricted. The imposed sign on the fundamental component is motivated by the economic theory (see Beckers and Bernoth 2016) which predicts a decrease of the fundamental component of share prices in response to a contractionary monetary policy shock, since the latter decreases future economic growth and thus firms' profitability and future dividend payouts. Note that an opposing effect may appear if market participants are less informed about the future path of output and inflation than the policymakers. Within our context however, we assume that market participants and the Fed share the same information set and thus we identify monetary policy shocks that can be interpreted as standard Taylor-rule type shocks.

In addition, following Bjørnland and Leitemo (2009), we interpret an increase in the bubble component as a stock price shock in the form of a non-fundamental shock that is motivated by speculative behavior.[4] We assume that this shock has no immediate effect on economic activity or inflation, and that the sign of the response of the fundamental component is left unconstrained. Similarly, monetary policy is allowed to respond to the stock price shock, yet the sign of the response is left unrestricted. Last, following Bjørnland and Leitemo (2009), we assume that monetary policy does not have any long-run effects on economic activity and stock prices.

Overall, we find that the results (reported in Appendix A.3, Supporting information) are not affected by this alternative identification scheme. We note a persistent decline in industrial production and PPI throughout the sample period in response to a tightening of monetary policy, whereas the initial decline of the bubble

4. Note that for a robustness check, we also assume an increase in the fundamental component as a stock price shock that is motivated by the arrival of news regarding the future path of macroeconomic fundamentals. Results (not reported but available upon request) are largely unaffected.

component (and the fundamental) in response to the shock is followed by a gradual increase which tends towards zero at the end of the forecast horizon.

We perform a series of other robustness checks. We first estimate different versions of our baseline model by considering variations of our proposed threshold for over- and under-valuation. In particular, we consider two versions where we calculate an 8-year and a 12-year moving average (instead of 10-year) plus 1.5 times this moving average's standard deviation as a threshold. We also consider two more versions where we calculate a 10-year moving average plus 1.2 and plus 1.8 (instead of 1.5) times this moving average's standard deviation as a threshold. As a last robustness check, we investigate whether the inclusion of a different inflation variable alters our results. In this case, we include the consumer price index instead of the PPI. The responses of the bubble component under all five robustness checks are depicted in Appendix A.3, Supporting information. In all cases, results are largely unchanged, pointing to a decline of the bubble component in response to the shock, followed by a gradual increase which tends towards zero at the end of the forecast horizon.

B. The Impact of UMP on the Macroeconomy and Stock Markets

The analysis above has focused on whether monetary policy surprises drive bubbles. However, in the post-2008 period the Fed responded to the worsening economic crisis by cutting its policy rate to nearly zero, where it remained until late 2015. Constrained by the zero lower bound, the Fed used UMP tools such as QE (or large-scale asset purchases) to stimulate the economy. As part of this policy, the Fed purchased government bonds by issuing central bank money. QE can affect demand in a number of ways. One of the main channels of transmission is the portfolio balance channel. As the price of the long-term bonds and related financial assets increases, demand is stimulated through wealth effects and lower borrowing costs. However, the risk here is that very low borrowing costs and easy opportunities to leverage a financial position may lead to asset price bubbles and financial instability.

Following Kapetanios et al. (2012), we measure the impact of such UMP shocks by including in the TV-VAR one additional variable, the spread between the 10-year Treasury Note and the 3-month Treasury Bill rate. In order to identify UMP shocks we use the sign restrictions scheme proposed by Kapetanios et al. (2012) and Baumeister and Benati (2013), according to which an expansionary yield spread shock leads to a contemporaneous decrease in the yield spread, rises in inflation, IP and the fundamental CAPE, but leaves the policy rate unchanged. In contrast, an expansionary conventional monetary policy shock decreases the policy rate and results in rises in IP, inflation and the fundamental CAPE.

We shall also highlight that we estimate two other versions of the benchmark model (results not depicted here but are available upon request) in order to provide alternative identifications of UMP shocks. In the first specification, we add the Fed's balance sheet to identify monetary policy shocks while in the second specification, we follow Wu and Xia (2016) by using the shadow rate as a measure for the stance of monetary policy. The responses from both alternative estimations of UMP shocks are largely unchanged compared to the benchmark model.

The sample spans the period from 2003:01 up to 2017:12 to be consistent with the period during which the Fed's balance sheet and the shadow rate data are available. We use the first 60 observations as a training sample with the estimation carried out starting in January 2008, when the Fed intervened by lowering the main refinancing interest rate until the zero lower bound became binding a few months later. The estimated responses of IP, prices and the bubble component are shown in Figures 8–10.[5]

Figure 8 shows that UMP shocks lead to a gradual increase in industrial production. Also, note that the pattern of the IP responses to the shock has changed little over time. Regarding inflation, we observe a similar behavior. The responses display a positive and progressive increase following the yield spread reduction. One can also notice that in terms of magnitude, the increase of inflation responses is more intense until 2014, whereas after that date the impact of the shock has been shortened. This is possibly due to the fact that asset purchases were halted in 2014. Overall, consistent with the literature (Baumeister and Benati 2013; Evgenidis and Salachas 2019; Weale and Wieladek 2016),

5. Responses of the FFR, the yield spread and the fundamental are not reported to save space but can be provided upon request. The fundamental component increases in response to an UMP shock, as expected.

FIGURE 8
Response of IP to a Yield Spread Reduction

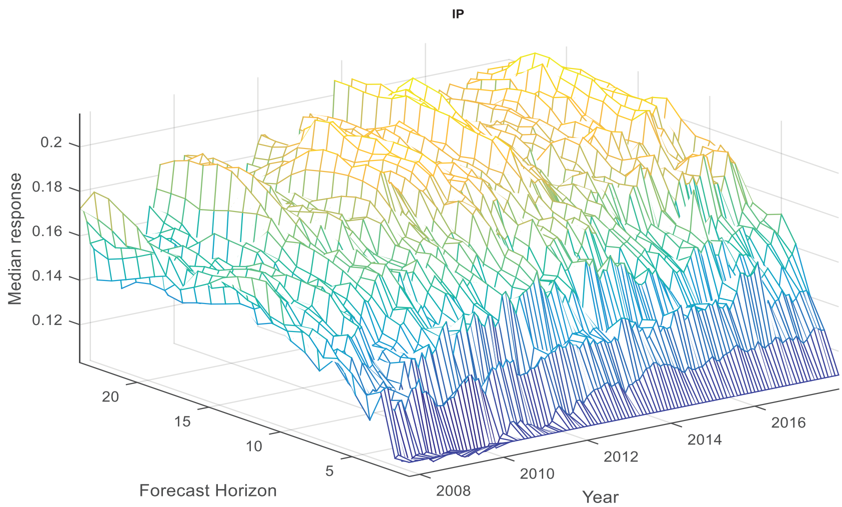
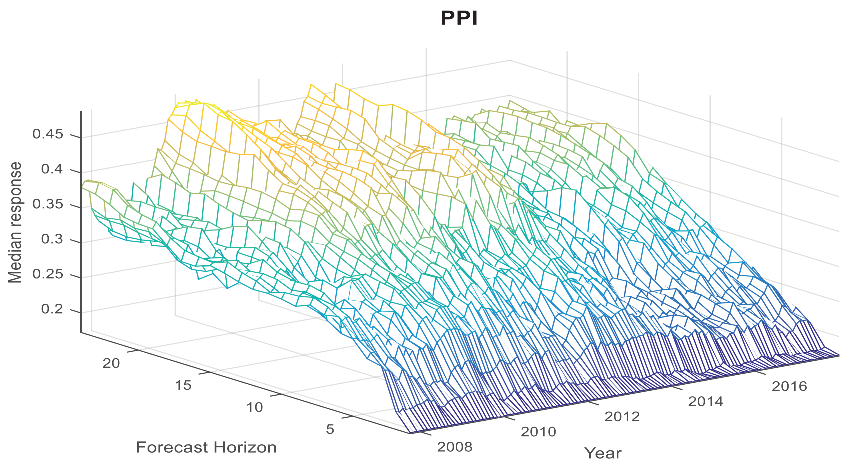


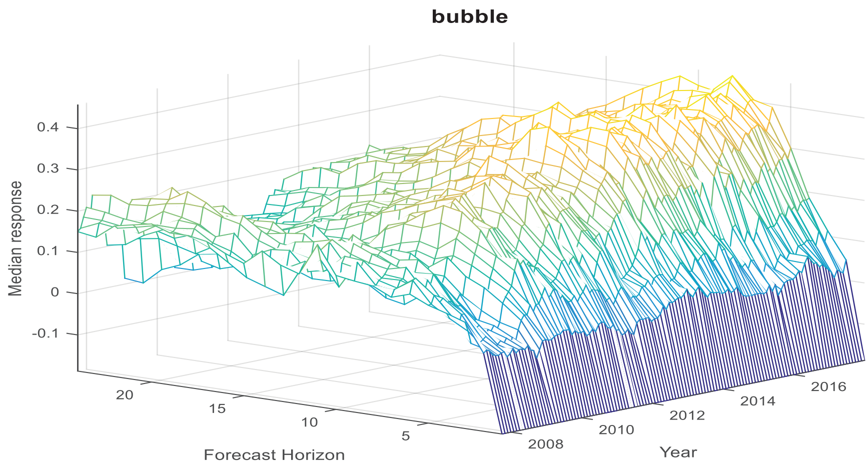
FIGURE 9
Response of Prices to a Yield Spread Reduction



our findings highlight the importance of UMP in propelling economic recovery and preventing disinflationary pressures. We also offer evidence which supports the conclusion that the asset purchases program has been effective and decisive in averting problematic macroeconomic outcomes in the United States.

Our analysis turns now to the impact of UMP shocks on asset prices as denoted by the bubble component (Figure 10). The result is interesting since it highlights that the bubble response exhibits different patterns. In particular, note that initially the response decreases substantially on impact. However, immediately after, there is a gradual increase that becomes positive 2–3 months following the shock. The positive reaction of the bubble component is not surprising given that one of the possible ways through which QE aims to stimulate the economy is by pushing up asset prices. This implies that a persistent increase in CAPE due to extensive QE might trigger asset price bubbles and financial instability.

FIGURE 10
Response of the Bubble Component to a Yield Spread Reduction



We explore this possibility in more detail in the next section.

C. *Scenario Analysis—The Role of Monetary Policy in Asset Price Bubbles*

In the following two sections we conduct several counterfactual policy experiments in order to investigate whether central bank policies might have fuelled asset and housing bubbles. In order to produce forecasts, we follow Kapetanios et al. (2012), Meyer and Zaman (2013), and Mumtaz and Theophilopoulou (2017) and rely on a time-invariant Bayesian VAR (BVAR) version of the model presented in 3.2 (i.e., the parameters in 1 are not allowed to vary overtime).[6] Details on the estimation of the BVAR as well as the conditional forecasts are provided in the technical Appendix 2.

We carry out out-of-sample forecasts conditional on an assumed path of policy variables.[7] We perform two different experiments: one that investigates the impact on asset prices of a conventional monetary expansion and another that examines the effects from QE. For the first experiment, we use the same variables as in Section A with the only difference being that, as we are

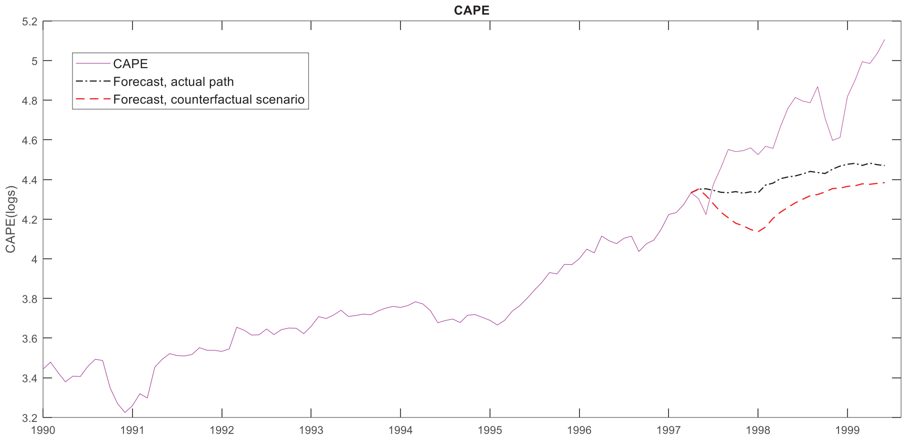
6. First, a disadvantage of the time-varying VAR approaches is that their predictions are highly inaccurate compared to those from time invariant BVAR models. Specifically, Kapetanios et al. (2012) show that time varying VAR models produce poor forecasts. According to the authors, this may be because agents in these models learn very slowly. For example, if the initial point of the forecast is in a downturn, agents will remain pessimistic for a long period despite the potential monetary policy stimulus. To confirm this, we estimate the counterfactuals in Sections C and D by using the TV-VAR model instead of the BVAR. Results (not reported here but available upon request) suggest that the projections are highly inaccurate compared to the actual data.

Another reason why TV-VARs are not suitable for our experiments in Sections C and D is that they can capture significant changes in monetary policy regimes, and they are also consistent with deviations from the rational expectations hypothesis. This implies that agents use simple forecasting rules to form their projections about the evolution of macroeconomic variables. Taken together, the previous two arguments suggest that TV-VARs seem particularly plausible during crisis and postcrisis periods. This is because during these periods significant changes in monetary policy regimes take place. Agents have no idea how various shocks have changed the structure of the economy thus they use “rules of thumb” to obtain information about the new state. During the recent financial crisis for example, where the Fed introduced for the first time nonstandard monetary policy tools such as quantitative easing, it would make sense for the agents to depart from the rational expectation hypothesis and use simple forecasting models to learn about the new state of the economy. Note however that the estimation period of the counterfactuals that we build in Sections C and D excludes the crisis and the postcrisis years during which the Fed undertook the massive asset purchases that led the amount of Treasuries in its balance sheet to $1.6 trillion. This renders TV-VARs unsuitable for this analysis.

7. Following Banbura, Giannone, and Lenza (2015), we implicitly assume in these experiments that the counterfactual forecast paths involve shocks small enough not to violate the Lucas (1976) critique. Indeed, the disturbances that we create in the system in the form of scenario assumptions are not too big to provoke a significant change in the behavior of economic agents which could in turn, change the underlying structure of the economy and thus the estimated parameters. See also Kilian and Lewis (2011) and references in their paper for an analysis of this issue.

FIGURE 11

Counterfactuals; the Impact of a Strong Monetary Tightening on Asset Prices



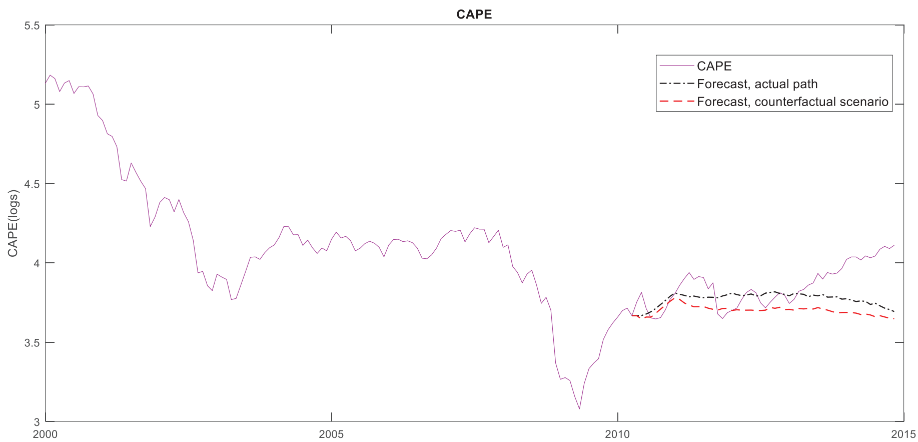
interested in producing CAPE forecasts, we consider CAPE instead of its components. The model is estimated from 1960:01 up to 1997:03 and then is used to perform two conditional forecasts until 1999:05. The period that is used in our counterfactual experiment coincides with the historical increase observed in CAPE due to the emergence and persistence of the equity asset price bubble, which, a few months later collapsed, destabilizing the US economy. The first conditional forecast assumes that the FFR equals its observed value over the forecast horizon, let us call it the actual path. The second conditional forecast, the counterfactual scenario, assumes that the path of the FFR is higher than observed by 200 basis points over the forecast horizon. This implies a prolonged contractionary policy. The difference between the two conditional forecasts captures the potential impact that a tightening monetary policy would have had on asset prices.

In a similar vein, we estimate another BVAR model to perform our second experiment; this time to examine the recent impact of QE on asset prices. For this model, we use the same variables as in Section B with the only difference being that we consider CAPE instead of its components. Following Kapetanios et al. (2012), we assume that QE affects the economy by reducing the yield spread by 100 basis points. The VAR model is estimated from 1960:01 until 2010:03 and then is used to carry out two conditional forecasts up to 2014:04. The actual path assumes that the yield spread follows its historical values while the counterfactual considers that the path of the yield spread is higher than the actual by 100 basis points over the forecast horizon. This can be considered as quantitative tightening (QT). Additionally, we set the short-term interest rate to its observed value over the forecast horizon so that our counterfactual experiment takes into account the fact that QT is conducted in the zero lower bound environment. As before, we are interested in the difference between the two conditional forecasts, which in this case shows whether QE has contributed in fueling asset prices. Figures 11 and 12 show the results of the two counterfactual experiments. Each figure shows the actual data for the CAPE (solid line), together with the median conditional forecast under the actual path (dash-dotted line) and the counterfactual scenario (dashed line).

Figure 11 suggests that the forecast of CAPE under the actual policy implemented is much higher compared to the forecast under the counterfactual experiment. This result is even more interesting when one considers that the actual FFR prevailed at the period in which our forecasting experiment is conducted was relatively stable, at around 5%. Therefore, this finding indicates that if the Fed had followed a tougher contractionary policy during that period, it would have reduced the asset price bubble and thus it would have probably mitigated the impact of the internet bubble.

Figure 12 shows that the forecast distribution associated with the counterfactual QT scenario is lower than the forecast under the actual QE

FIGURE 12
Counterfactuals; the Impact of QE on Asset Prices



policy implemented. This pattern is evident for the whole forecasting period. Our finding suggests some evidence for the hypothesis that the massive asset purchases under QE from 2010 to 2014 sent asset prices to high levels for a prolonged period of time, thus, raising concerns of the appearance of asset price bubbles. Taking the evidence of the two experiments together, we conclude that an aggressive monetary tightening, that is, leaning against the bubble, would have limited the sharp stock market expansion in the late 1990s while extensive implementation of QE more recently would have led to inflated asset prices for a protracted period.

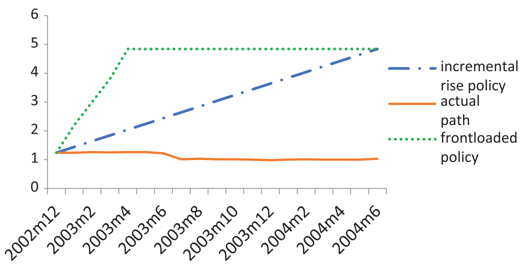
D. Scenario Analysis—The Role of Monetary Policy in Housing Bubbles

We remarked earlier that central banks need to be concerned with stock market and housing bubbles because their bursting significantly reduces wealth and investments. Having analyzed the impact of monetary policy on the stock market, we now analyze the housing bubble of 2004–2007. Taylor (2007) argues that the Greenspan Fed kept FFR too low for too long and such a policy fueled the housing bubble. Taylor (2007) of course realizes that subprime mortgages, regular mortgages with both fixed and variable interest rates, innovations in mortgage backed securitizations, inaccurate assessments by credit rating agencies, hedging by credit default swaps, government policies encouraging housing ownership and numerous other factors, all contributed to the housing bubble. However, he chooses to focus on monetary policy to illustrate that substantial deviations of monetary policy from the Taylor rule confirm the reluctance of the Fed to lean against the housing bubble.

Bernanke (2010) gives a long and careful debate to Taylor. The central thesis of Bernanke is that the housing market was driven by low long-term interest rates that stimulated the high demand for mortgages and housing ownership. These long-term interest rates were not impacted by the central bank's FFR policies. Bernanke emphasizes that the central bank has limited influence on long-term interest rates and proposes that these rates were low, not because of an easy monetary policy but rather because of a global glut of savings, with China being the primary source (see also Wachter 2015 for a concise description of explanations offered in the literature for the housing bubble).

To examine whether the absence of a strong contractionary monetary tightening in 2003 and 2004 might have fueled the housing bubble, we perform the following experiments. We estimate a BVAR by including IP, PPI, FFR, CAPE and one extra variable, Shiller's national home price index. The model is estimated from 1987:01, as this is the earliest available date for the home price index, up to 2002:12. The model then is used to perform two counterfactual policy scenarios, from 2003:01 until 2004:06. We choose this period since first, it allows us to investigate Taylor's argument in favor of a monetary tightening that should have happened during these years,

FIGURE 13
Counterfactual Paths for FFR



and second, this period coincides with the emergence and persistence of the housing bubble in the United States.

In our first counterfactual, we adopt an experiment close to the spirit of Taylor (2007) by assuming that the FFR follows an incremental adjustment by 20 basis points. In our second counterfactual, we assume a frontloaded policy, that is, hikes in the FFR concentrated in the beginning and policy stabilizing thereafter. Note that in both cases, the actual path assumes that the FFR follows its historical values. Figure 13 shows the two different counterfactual paths for the FFR. Note that the actual policy (solid line) in the period during which our counterfactuals take place, was loosening than contractionary, as the FFR fluctuated at very low levels and the Fed never raised it. Figures 14 and 15 show the results of the simulations using the two different counterfactual scenarios. The solid line shows the historical data, the dash-dotted line shows the median forecast under the actual path and the dashed line depicts the median forecast under the counterfactual scenario.

As Figure 14 reveals, evidence that house prices were systematically different under a policy of incremental adjustments in FFR appears to be negligible. On the contrary, Figure 15 shows that the forecast distribution associated with the alternative counterfactual scenario is lower than the forecast under the actual policy implemented. This pattern is particularly evident from mid-2003 onwards.

Our results indicate that the policy strategy does matter when the Fed seeks to mitigate housing booms. In particular, a frontloaded monetary policy normalization would have avoided much of the housing boom as opposed to an incremental rise in the FFR. Hence, the actual low rates set at that time did fuel the housing bubble and as the model shows, had the Fed responded much more aggressively in 2003, it would have substantially reduced the rise in housing prices. The findings are closer to the spirit of Taylor (2007) who suggested an early policy rate hike but differ on the implementation strategy, as we suggest that a gradual FFR adjustment would not have produced the desirable outcome in housing markets. The reason why a frontloaded monetary tightening as shown in our counterfactual would have managed to effectively deflate the housing bubble is that this policy would more forcefully signal the Fed's decisiveness to follow all the necessary actions to control the housing boom.

V. DISCUSSION AND CONCLUSIONS

Considering the importance of financial stability for central bank policymakers, the issue of whether monetary policy may help achieve this goal is of great interest and depends on the effect of monetary policy on asset prices. In this regard, central banks need to know if movements in asset prices resulting from a change in monetary policy are desirable or whether monetary policy has negative side effects.

In this paper, we deal with this issue and seek to uncover the impact of monetary policy shocks on asset price bubbles. Using Bayesian VAR models, we obtain the following empirical results showing how asset prices may respond to a central bank that chooses to lean against such a bubble. First, we propose that the Fed should consider using the CAPE as a measure of stock market valuation. We propose a modification to CAPE to obtain an estimate of a bubble. We describe the advantage of such a measure and find evidence of nonlinear effects of monetary policy on both the stock market bubble and the fundamentals. Specifically, there is a strong decline in the first 10 months after an increase in the FFR, followed by a gradual increase of the bubble term which tends towards zero in the long term. Our findings are in line with conventional wisdom and closely related studies (Allen, Barlevy, and Gale 2017; Beckers and Bernoth 2016; Dudley 2010; Mishkin 2008, 2010) who advocate that raising rates dampens bubbles rather than amplifying them and contrast with the view of Galí (2014) and Galí and Gambetti (2015) who support that the size of the bubble increases persistently in response to a tightening monetary policy.

Additionally, structural analysis reveals that UMP shocks push up asset prices, implying that

FIGURE 14
Counterfactuals; the Impact of Tightening Monetary Policy on the Housing Market (Incremental Rise)

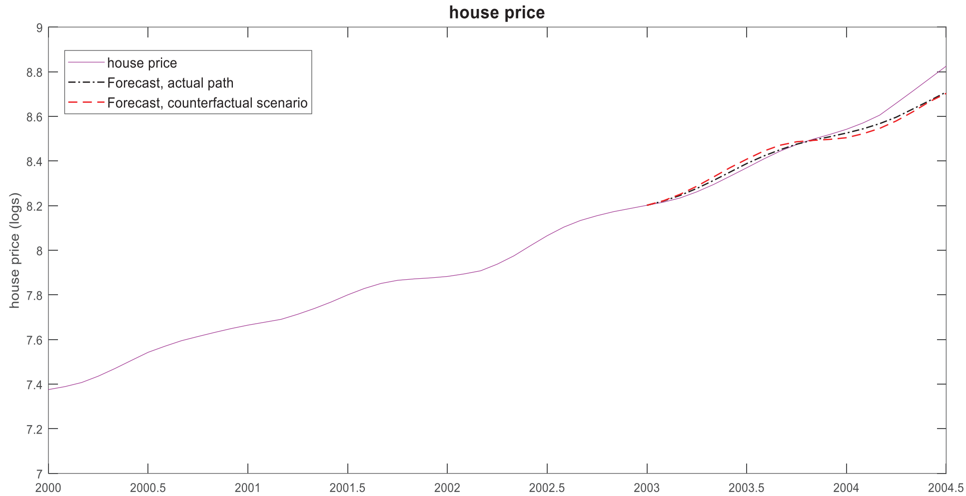
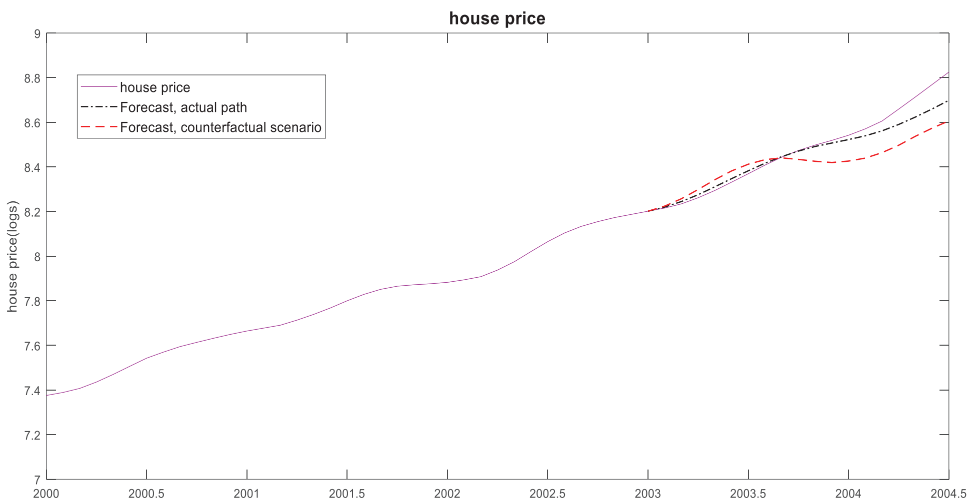


FIGURE 15
Counterfactuals; the Impact of Tightening Monetary Policy on the Housing Market (Frontloaded Policy)



QE might have triggered asset price bubbles and financial instability.

Counterfactual policy scenarios help to shed light on the above issues by simulating several monetary policy paths in order to assess whether deflation (or inflation) of asset price bubbles is influenced by central bank policies. Our results suggest that an aggressive monetary tightening in the form of policy rate increases in the late 1990s, in the period before the burst of the dotcom bubble, would have limited the asset price bubble. In addition, more recently, extensive implementation of QE did lead to inflated asset prices for a protracted period. This latter result coincides with the findings of Blot, Hubert, and Labondance (2017) who support that expansionary policies do fuel such bubbles. Last, we conduct another policy scenario, this time to investigate the impact of monetary policy on housing prices. Our results suggest that if the Fed had responded much more aggressively in 2003–2004 by adopting a strong tightening policy, it would have substantially reduced the rise in house prices.

Our general conclusion is this: if a central bank chooses to use a tighter monetary policy in the traditional setting of increasing Fed funds to moderate a stock market bubble or a housing bubble, these asset prices will respond in moderation. There is no evidence of catastrophic declines. Asset prices will initially fall and will eventually rise again but without the risk of feeding the bubble. As our counterfactuals show, the Fed need not be concerned that by leaning against the potential asset bubble, it is causing financial instabilities equivalent to the bursting of the bubble that it tries to regulate.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Supporting information