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Trade-offs between Macroeconomic and Financial Stability Objectives*

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Abstract

Ten years after the 2008-09 global financial crisis, most advanced economies have recovered and global economic growth has taken hold. However, partly due to accommodative financial conditions, financial risks are on the rise while inflation remains subdued. This revives the debate on the role of monetary policy in containing financial risks. This paper provides a framework to investigate trade-offs between macroeconomic and financial stability when the central bank has a financial stability objective. Relying on a New Keynesian model with an endogenous financial bubble, our simulations suggest that a central bank attempting to “lean against the wind” may face trade-offs between inflation/output stability and financial stability. We therefore argue that the interest rate should be used for achieving traditional macroeconomic goals, and a second, macroprudential instrument should complement the policy rate to tackle financial risk accumulation.

Keywords: Monetary policy objectives, financial stability, trade-offs.

JEL classification: E61, E44, E52, E58.

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1 Introduction

Ten years after the 2008-09 global financial crisis (GFC), global economic growth has taken hold, supported by largely expansionary monetary policies in major advanced economies. Low interest rates have played a key role in supporting the economic recovery, and despite gradual normalization, the monetary policy stance remains accommodative especially given still low inflation. In parallel, vulnerabilities to the global financial system have increased: debt (both private and public) have reach historical highs, banks are highly leveraged, and investors' risk appetite is on the rise. Favorable financial conditions (low interest rates) have fueled financial risks. These developments not only remind us of the pre-2008 GFC period, but they also highlight the challenges faced by central banks. Loosening financial conditions and increasing risks may call for monetary policy tightening, while inflation far below targets would require opposite policy actions. Although the prudential toolkit aiming to ensure financial stability has further expended since 2008, especially with the broad-based adoption of macro-prudential policies, the role of monetary policy remains subject to debate and disagreement among policymakers as well as researchers. This paper contributes to the debate by providing, based on a theoretical framework, new insights on policy trade-offs that central banks may face.

The existing literature discusses various channels through which monetary policy can affect financial sector stability. According to the risk-taking channel (Borio and Zhu, 2012), maintaining low interest rates for a protracted period of time increases financial risks through higher incentives to search for yields (Rajan, 2005). For financial corporations, low interest rates can increase interest margins, boost firm's value and increase leverage which ultimately translates into higher risk exposure (Adrian and Shin, 2010). A credible and predictable monetary policy framework can also encourage risk-taking behavior. Indeed, as sound policies reduce uncertainty, participants in the financial market may underestimate underlying risks. For the private non-financial sector low interest rates increase the value of collateral and therefore provide further room for borrowing.

In view of the above, should monetary policy respond to financial imbalances? The related discussion has long been summarized around the "lean versus clean" debate. The "clean" view supports a clear division of labor between monetary and prudential policies, with the

former focusing on inflation (or macroeconomic) stability. It is argued that not only financial imbalances or bubbles are hard to detect, but also the policy interest rate is ineffective or too blunt an instrument to address specific financial risks. Moreover, the macroeconomic costs associated with policy tightening in response to potential financial stability risks may be higher than the costs of a crisis if the risk materializes. Therefore, monetary policy interventions are expected only to contain the consequences of crises when they occur. Proponents of the “lean” support a more active role of central banks in preventing “unsafe” developments in the financial sector. The policy interest rate can be used as a tool to curb bubbles’ growth, thereby preventing financial crises and associated damaging effects for the rest of the economy. In addition, in period of crisis, monetary policy may have limited room for maneuver to cleanup, because of the zero lower bound on the interest rate. Hence, a more proactive intervention is warranted.

Before the 2008 GFC, a widespread consensus supported the “clean” approach, with most central banks adopting a “benign neglect” attitude toward financial imbalances, *i.e.* only reacting to these to the extent that they affect inflation. However, the 2008 experience reveals how costly and long-lasting the consequences of a crisis can be. Despite unprecedented policy measures, the global economy contracted sharply and only recovered very slowly over the past decade (Woodford, 2012). The pre-crisis period also showed that central banks can face trade-offs between macroeconomic stability and financial stability. Despite remarkable achievements in terms of controlling inflation, monetary policy did not prevent financial risks from accumulating.

A decade after the GFC, the role of monetary policy in preventing financial imbalances remains subject to debate (IMF, 2015). However, the key question seems to be how best central banks can act, rather than whether they should act at all. Rudebusch (2005) argues that, ideally, a moderate adjustment of the policy interest rate in response to financial imbalances could contain bubbles and reduce the risks of broader macroeconomic crises. Higher interest rates, implying higher borrowing costs can contribute to reduce leverage not only for households and the corporate sector, but also for banks (DellAriccia et al., 2014). For Smets et al. (2014), central banks should keep an eye on financial stability, as this will allow them to lean against the

wind when necessary while maintaining the price stability objective. However, as illustrated by the current global economic and financial conditions, such policies may give rise to trade-offs.

The Tinbergen principle commends using as many instruments as objectives to be achieved (and to assign the best instrument to the dedicated objective). A “leaning against the wind” policy can generate trade-offs because of the violation of this principle. De Grauwe and Gros (2009) show that a trade-off between inflation and financial stability can emerge when the economy faces a technological shock, or when investors’ behavior is characterized by too optimistic beliefs in financial markets (“animal spirits”). It may be dangerous for central banks to pursue a financial stability objective because this may require a tighter monetary policy than what is needed to tame inflation (Dell’ariccia, 2010; Mishkin, 2011, among others).

King (2012) identifies three scenarios where a trade-off can emerge between macroeconomic stability and financial stability. First, (too optimistic) misperception on the part of households, businesses and financial institutions about future incomes, leading to unsustainable spending and increase in the level of debt. Second, the “cycle of confidence”, reflecting the fact that a prolonged period of stability (both macroeconomic and financial stability) can encourage exuberant behavior and subsequently generate instability. Third, trade-offs can appear due to the risk-taking channel, as described earlier. King (2012) further points out that adding financial shocks to the traditional Taylor curve¹ moves the frontier upper and to the right, *i.e.* adding financial stability to the traditional macroeconomic stabilization objectives increases the volatility of both inflation and output. Although Issing (2003) suggests that the trade-off between inflation stability and financial stability is more likely to occur in the short-term, a more recent analysis by Fahr and Fell (2017) shows that even when considering financial cycles, monetary policy is always less effective than macro-prudential policies in addressing financial stability risks.

In most cases, the literature discussed above does not resort formally to a theoretical model when discussing trade-offs between monetary policy objectives in the “leaning against the wind” setup. Notable exceptions are cases where trade-offs are assessed in the presence of macroprudential policies, for example in several DSGE models (Agenor et al., 2012; Beau et al., 2013

¹ The Taylor curve depicts the standard central bank’s objectives, namely inflation and output stabilization, and suggests that a trade-off can emerge between these objectives in the context of supply shocks.

or Christensen et al., 2011).² Shukayev and Ueberfeldt (2016) investigates trade-offs between policy objectives in a context where banks are exposed to runs on their short-term liabilities. They find that relying on the short-term interest rate, monetary policy can mitigate this risk (and preserve investment) but at the cost of higher inflation and output volatility.

To the best of our knowledge, this paper is the first to explicitly rely on a theoretical model, with an endogenous financial bubble, to investigate the existence of trade-offs when the central bank applies a “leaning against the wind” type of policy. Our analytical framework starts with a hybrid reduced form three-equation New Keynesian model, which we supplement with a fourth equation reflecting an asset price bubble. We further assume that the policy interest rate can affect the probability that the bubble bursts (*i.e.* financial risk materializes), making the bubble endogenous to the macro-framework. Moreover, asset price deviations are intuitively assumed to affect aggregate demand. In this framework, we define financial instability as the volatility of asset prices’ deviations from their fundamental values. Thus, the bubble process is assumed to capture risk accumulation in the financial sector. We explore changes in inflation, output and bubble volatilities in response to various types of shocks and different responses of the central bank.

Our model can be related to the work of Filardo (2000, 2001 and 2004).³ All these papers treat the question of whether or not monetary policy should respond to asset prices via the interest rate, but the first major difference with our paper is that they do not address trade-offs between macroeconomic and financial stability objectives. The emergence of such trade-offs is our main research question. Additionally, these papers use a backward looking simple model with an augmented Taylor rule. We however opt for a hybrid framework with both backward and forward looking terms as this type of model allows us to not only better fit the data (Fuhrer and Moore, 1995, Estrella and Fuhrer, 2002) but also to account for habits in

² For an empirical assessment of trade-offs, see End (2010).

³ Bordo and Jeanne (2002) and Kent and Lowe (1997) are also close to our paper. Bordo and Jeanne (2002) use a more complex model, where private agents’ credit is taken into account. They study the dilemma of whether the central bank should lean or clean by considering non-linear Taylor type rules that depend on both macroeconomic fundamentals and private sector expectations. Kent and Lowe (1997) use a model where, the probability of the asset price bubble to burst is influenced by the level of the interest rate. We argue that it is rather changes in interest rates that impact this probability and less the levels, but propose a robustness test on this issue. Moreover, in their model, the bubble only emerges once and no other bubbles occur after its collapse, whereas we consider the reaction of the economy to successive bubbles.

consumption or the fact that not all firms adjust their prices in each period of time. Moreover, by considering a hybrid model we partly respond to the Lucas critique by taking into account rational expectations. Another difference between Filardo (2000) and our paper comes from the supposed impact of the bubble on the economy. While Filardo (2000) assumes that inflation in asset prices has a direct impact on general price inflation, we include the bubble in the IS equation, implying only an indirect impact on inflation. We justify this choice by the fact that asset prices influence aggregate demand through several well acknowledged transmission channels: the wealth effect, Tobin's Q or the financial accelerator mechanism.⁴ In addition, while Filardo (2001) and Filardo (2004) clearly distinguish the fundamental and the speculative part of asset prices, we simply define the bubble as the difference between these two components. This assumption, in line with Filardo (2004), implies that in our model we only care for the speculative part of asset prices, meaning the one which creates financial instability.

Our results suggest that, when the central bank directly responds to financial imbalances, a trade-off indeed emerges between its primary objective of price stability and the financial stability objective. This finding emphasizes the limits of the leaning against the wind strategy. More precisely, employing such a strategy may generate a conflict between the objectives of the monetary authority. While financial stability remains a major concern, central banks should focus on their traditional inflation (and output gap) stability objective and rely on other (macroprudential) instruments to deal with financial imbalances.

The remainder of the paper is organized as follows. Section 2 presents the model with an emphasize on the bubble process. Section 3 discusses the results of the different scenarios considered. Robustness tests are conducted in section 4 and section 5 concludes.

2 The Model

This section first describes how we model the financial bubble, and then the rest of the macroeconomic framework, and especially how the bubble fits into it.

⁴ Granville and Mallick (2009) also make the assumption in their New Keynesian model that asset prices influence demande. Empirical evidence on financial stress conditions influencing output fluctuations can be found in Mallick and Sousa (2013).

2.1 The Bubble

The buildup of financial imbalances follows a process a la Blanchard and Watson (1982). The rational asset price bubble takes the following linear form:

$$b_t = \begin{cases} \frac{1+\bar{i}}{\bar{q}}(b_{t-1} - \tilde{q}_t) + \varepsilon_t^b & \text{if the bubble persists, } (q_t) \\ \varepsilon_t^b & \text{otherwise, } (1 - q_t) \end{cases} \quad (1)$$

where b_t denotes asset price deviations from its fundamental value at time t . The bubble is assumed to persist with probability q_t and to burst with probability $(1 - q_t)$. \bar{q} is the threshold value of q_t above which the bubble bursts. \tilde{q}_t is the difference between q_t and \bar{q} . Finally, \bar{i} is the equilibrium interest rate and ε_t^b is an exogenous shock with zero mean. Equation (1) suggests the bubble is self-fulfilling and grows without any connection to fundamentals when $\frac{1+\bar{i}}{\bar{q}} > 1$. This characterizes a phenomenon where a bubble in a specific market can be driven by (too optimistic) expectations that these asset prices will keep growing over subsequent periods.

By construction, the bubble in equation (1) is strictly exogenous since it does not depend on any economic variables or policy changes. Although exogenous bubbles are commonly used in macroeconomic models (Bernanke and Gertler, 1999; Cecchetti et al., 2000; Badarau and Popescu, 2014, among others), it is well recognized that asset prices are sensitive to changes in the economic environment. Especially, as discussed above, the experience of the 2008 GFC as well as the current global economic environment suggest that the monetary policy stance is likely to play a key role in (at least partly) driving market participants' behavior in the financial market. To incorporate this into our model, we realistically assume that the policy interest rate can affect the probability q_t that the bubble bursts.

$$\tilde{q}_t = -\gamma \Delta i_{t-1} \quad (2)$$

where Δi_{t-1} is the change in the short term interest rate from one period to another. Equation (2) suggests that an interest rate increase will tend to reduce the probability that the bubble persists, and by construction increases the probability that the bubble bursts.⁵ Such a correction

⁵ A change in the monetary policy stance can affect the behavior in the financial market by diverting investments toward different (more profitable) segments of the market, or simply by restricting access to liquidity.

of the monetary policy stance may be warranted when the authorities are willing to stop the buildup of imbalances sooner than later, in order to reduce the subsequent costs in case the risk materializes. In other words, this can be seen as a preventive intervention through which the central bank may want the bubble to “burst” before risk accumulation becomes too excessive. However, such policy affects not only the duration, but also the size of the bubble. Indeed, a higher interest rate will translate into an upward reaction of the bubble.⁶

Equation (2) also assumes that bubbles are likely to be more affected by changes in the interest rate rather than levels. Consider for example a first scenario where the short-term interest rate increases from 1 to 2%, and a second scenario where the rate goes from 1.5 to 2%. In both cases, the interest rate reaches the same level, however, in the first scenario, the rate increases by 1 percentage point, whereas the hike is of only 0.5 percentage point in the second one. It seems straightforward to assume that market reactions would be more important in the first scenario (this would be in line with current speculations regarding the pace of the Fed monetary policy normalization).^{7,8}

Substituting equation (2) into equation (1) gives the following expression:

$$b_t = \left[\frac{1 + \bar{i}}{\bar{q}} (b_{t-1} + \gamma \Delta i_{t-1}) \right] D + \varepsilon_t^b \quad (3)$$

where D is a dummy variable which takes the value of 1 as long as the bubble lasts, and 0 when it bursts.

For example, the housing market tends to tighten in a low interest rate environment, as it is currently the case in many advanced economies. A sharp correction of the policy interest rate not only increases the cost of housing, therefore affecting demand, it also increases the probability of default on mortgages (to the extent that these are flexible interest rates mortgages). This can contribute to significantly depress the housing market, but also the financial sector as whole depending on banks’ exposure to mortgages.

⁶ Gali (2014) also argues that an increase in the policy rate in reaction to a growing bubble will entail a positive effect on the bubble’s growth.

⁷ Note however that we also perform our simulations based on a version of the model that includes the level and not the change in the interest rate. This does not change our main findings. See the robustness section for more details.

⁸ A similar approach is used in Gruen et al. (2005). Their macroeconomic model includes an asset price bubble and compares the optimal monetary policy response for two types of policymakers: a skeptic one which implements a (standard) inflation targeting-type of policy, and an activist one which responds to asset price bubbles. In their sensitivity analysis, it is assumed that the probability that the bubble burst is affected (with a lag) by the difference between the short-term interest rate and its optimal path, chosen by the skeptic policymaker.

2.2 The Macroeconomic Framework

The macroeconomic framework is modeled based on a three-equation New Keynesian model. The log-linear inter-temporal transformations of these equations take the following forms:

$$\pi_t = \alpha \mathbb{E}_t(\pi_{t+1}) + (1 - \alpha)\pi_{t-1} + \lambda y_t + \varepsilon_t^\pi \quad (4)$$

$$y_t = \delta \mathbb{E}_t(y_{t+1}) + (1 - \delta)y_{t-1} + \sigma \left(i_t - \mathbb{E}_t(\pi_{t+1}) \right) + \varphi b_t + \varepsilon_t^y \quad (5)$$

$$i_t = \beta_i i_{t-1} + (1 - \beta_i)(\beta_\pi \pi_t + \beta_y y_t + \beta_b b_t) \quad (6)$$

where π_t , y_t and i_t represent respectively the inflation rate, the output gap, and the short-term nominal interest rate under the central bank's control. The ε s are exogenous shocks normally distributed, and \mathbb{E}_t denotes the expectation operator. α , λ , δ , σ , φ , β_i , β_π , β_y , and β_b are the model's parameters.

Equation (4) represents a hybrid New Keynesian Phillips curve where current inflation is a function of both past and expected inflation, and current output gap. The hybrid IS curve (equation (5)) describes the current output gap as a function of its lagged and expected values, and the real interest rate. This equation differs from the conventional specification of the IS curve because of the inclusion of a new term: the bubble. Equation (5) assumes a positive relationship between asset price deviations from fundamentals and the output gap. Coming back to our example on the housing market, overvaluations of housing increase the value of collateral, boost leverage and therefore consumption. This translates directly into higher output.⁹ Filardo (2004), supporting the relationship between aggregate demand and the bubble, argues that the fundamental component of asset prices does not really matter for output or its components. Instead, the bubble (the non-fundamental component) can affect aggregate demand by distorting economic decisions: changes in consumption through a wealth effect, changes in investment via the cost of capital, changes in government spending through the tax channel.

⁹ Although we do not provide micro-foundations for including the bubble in the demand equation, the very intuitive arguments we develop support such a framework. Note however that given the model's specification where the Phillips curve is a function of the aggregate demand, in the end the bubble also affects (indirectly) the aggregate supply.

Finally, equation (6) describes the central bank’s reaction function. The monetary policy instrument is set in response to deviations of inflation from the target, the output gap, as well as asset prices deviations from their fundamental value (the bubble). Moreover, a smoothing parameter is included in order to limit interest rate volatility. The central bank’s reaction function portrays an augmented Taylor rule with a financial variable, framing a leaning against the wind policy. As discussed earlier, such policy may be warranted to reinforce financial stability. Tightening the policy stance could contribute to contain increasing and unsustainable financial imbalances, which subsequently could generate a financial crisis with related significant macroeconomic effects.

2.3 Model solution and calibration

The four-equation model described above is solved relying on the Blanchard-Kahn method (Blanchard and Kahn, 1980). This is a commonly used approach in the literature. However, the specification of the bubble equation gives our model a less standard structure. In this respect, the model is solved for two states of nature: first, when the bubble persists (*i.e.* $D = 1$ in equation (3)) and second, when the bubble is simply a random shock (D is equal to 0).¹⁰ We switch between the two states of nature depending on the value of D . To decide whether the bubble continues to grow or bursts in the next period, we use a random variable drawn from the uniform distribution over the interval 0–1. We compare this random variable to the probability of the bubble to persist, q_t : if its value is inferior to q_t , D is equal to 1, otherwise D is 0.

The model is calibrated based on estimated parameters for the euro area, using monthly data over 1999-M09 to 2007-M12. While using standard definitions for variables in the model, a key issue is how to measure financial imbalances (the bubble). We use the MSCI (Morgan Stanley Capital International) index, which is an aggregate index measuring equity valuations. The deviations from fundamental values are assessed based on the Arbitrage Pricing Model (APM), where actual equity prices are compared with their “fair values”. Fair values of equity

¹⁰ When the dummy is 0, the Blanchard-Kahn conditions are verified and the model is stable. For $D = 1$, the model is unstable due to the bubbles equation specification. However, in the long run the economy converges in probability towards the steady state.

are estimated based on the presumption that equity price variations are affected by surprises due to shocks on various fundamental variables (See Appendix 1 for further details).

A second set of parameters from Smets (2000) and corresponding to annual data for the euro area, are used for simulating the model and check the robustness of our findings. However, two (non-standard parameters are introduced in our model specification compared to Smets (2000), namely γ and φ . As there are no previous estimates for these parameters, we set their values relying on some ad-hoc assumptions,¹¹ and we check the robustness of our main conclusions to changes in the values of those parameters . Table 1 in the appendix presents the baseline values of the parameters used to perform the simulations.

3 Results

The reduced-form model characterized by equations (3), (4), (5) and (6) is used to investigate the existence of trade-offs between macroeconomic (inflation and/or output) stability and financial stability when the central bank reacts to the financial bubble. We rely on a simple procedure which can be summarized as follows: the economy is hit by exogenous shocks (supply and/or bubble shocks corresponding to ε_t^{pi} and ε_t^b) which are assumed to randomly occur each period of time.¹² Central banks respond to these shocks by setting the short-term interest rate more or less aggressively. More precisely, we consider different values for the parameters concerning inflation, output and the bubble (β_π , β_y and β_b in equation 6). For each type of shock and each value of the β s, we generate series of variances, calculated over 1000 periods, for each argument of the central bank's reaction function (inflation, output gap and the bubble). We then graphically present the evolution of these variances, in the spirit of a Taylor-type curve, to assess the efficiency in achieving the monetary policy objectives.

Confronted with the same shocks, central banks may react differently, both in terms of measures undertaken and in terms of intensity (or aggressiveness) of the policy. For example, faced with an asset price bubble shock, a central bank may decide to react indirectly through

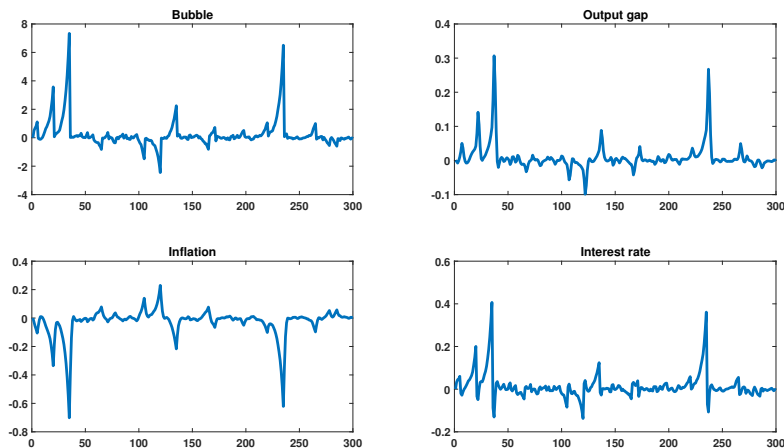
¹¹ It is assumed that the effect of the interest rate on the bubble is of the same magnitude as the effect of the real interest rate on the output gap. It is also assumed that the asset price bubble affects the aggregate demand to a lesser extent than the real interest rate.

¹² The shocks are drawn from the standard normal distribution.

a stronger response to output gap (since the bubble affects aggregate demand), thus increasing β_y . Another central bank may rather react directly by strengthening its response to the bubble, increasing β_b . Moreover, in both cases, the responses may be more or less aggressive (a sharp or a more progressive increase in β).

The analysis conducted here should not be view as an attempt to derive the optimal monetary policy stance. The purpose is much more modest and simply aims at investigating, through comparative statics, the challenges central banks can face when reacting to financial variables. More precisely, we focus on trade-offs between policy objectives. In addition, the differences in parameters in the central bank’s reaction function can be viewed as responses from different central banks to the same shocks, and not necessarily as changes in a single central banks response over time.

Figure 1: Model’s response to bubble shocks
deviation from the steady-state



Note: The response of the variables (output gap, inflation and interest rate) to consecutive random bubble shocks.

Before addressing the issue of trade-offs, we investigate the response of the model to random bubble shocks, by looking at how the output gap, inflation and the interest rate react to deviations of the asset price from its fundamentals (Figure 1). Bubble shocks are drawn from the standard normal distribution and can be either positive or negative. In response to positive bubble shocks, the output gap increases as expected. Given the policy rule, the short-term interest rate rises in reaction to higher output gap, but also in response to the bubble. The higher level of the policy rate reduces inflation in the economy with respect to its steady state

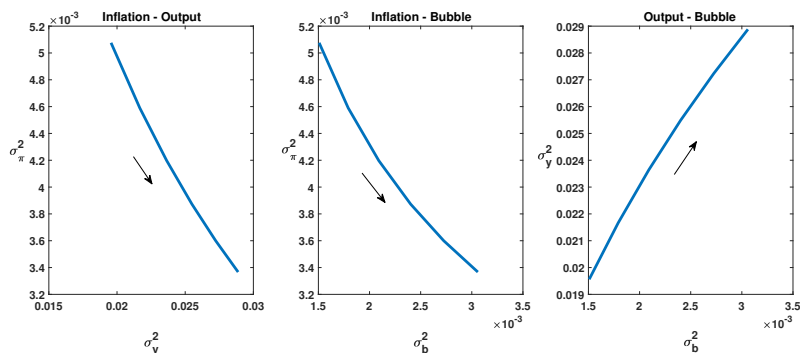
value. The opposite holds when shocks are negative (*i.e.* periods when the bubble is below 0).

We turn now to the investigation of potential trade-offs between central banks' objectives when responding to real or financial shocks. The main results are discussed considering successively the central banks responses to each type of shock: supply shocks, bubble shocks and a combination of the two.

Supply shocks

Faced with supply shocks, central banks may decide to be more or less aggressive in their reaction to the evolution of inflation. In our model, a central bank which is more aggressive to inflation has a larger β_π . This parameter varies between 1.5 and 2.5 and the arrows in Figure 2 show how volatilities evolve when β_π increases. A stronger response to inflation shocks results in better inflation stabilization, but at the cost of higher output and bubble volatility. The standard trade-off between inflation and output stabilization in a context of supply shocks emerges, but there also seems to be a trade-off between inflation and the asset price bubble. This implies that the stronger the central bank's reaction to inflation shocks, the higher the asset price bubble volatility. This finding is in line with the argumentation in De Grauwe and Gros (2009) or Issing, 2003. In addition, there seems to be no trade-off between the output gap and the asset price bubble in case of cost push shocks as their volatilities both increase.

Figure 2: Variances following supply shocks when the inflation coefficient varies

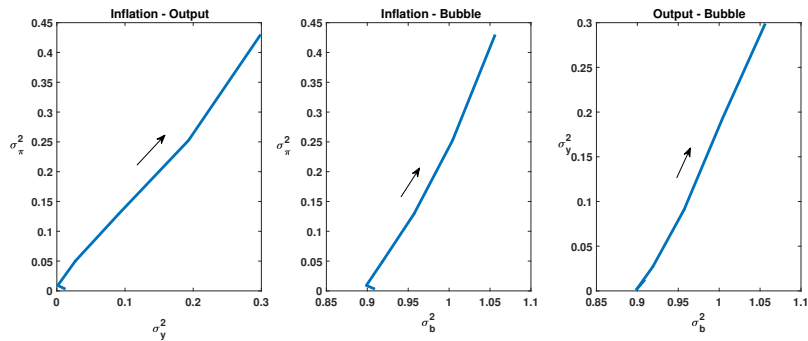


Note: Variances of inflation, output gap and the bubble following supply shocks. The response to inflation varies between 1.5 and 2.5 and all other parameters remain the same. The arrows indicate an increase in β_π .

Asset price bubble shocks

Since the asset price bubble enters the central bank’s reaction function, the short-term interest rate rises in response to positive bubble shocks and diminishes when negative bubble shocks occur. This type of reaction, intended to strengthen financial market stability, corresponds to the leaning against the wind strategy. According to Figure 3 this strategy is however unsuccessful as the volatilities of all interest variables – inflation, output and the bubble – increase. Being more aggressive to the bubble (gradual increase in β_b from 0 to 0.75) not only harms the primary objectives of the central bank, but does not even succeed in reducing the volatility of the bubble.

Figure 3: Variances following bubble shocks when the bubble coefficient varies



Note: Variances of inflation, output gap and the bubble following bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same. The arrows indicate an increase in β_b .

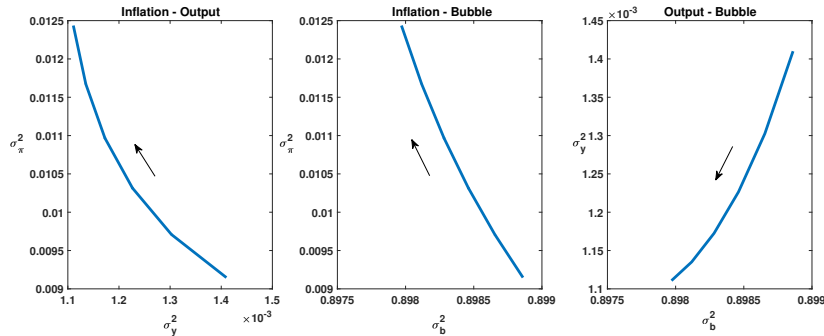
Alternatively, the central bank may choose to react indirectly to bubble shocks through a stronger response to output gap (gradual increase in β_y from 0.5 to 1.5), since it is assumed that the bubble positively affects aggregate demand. This approach seems to provide a better outcome than the former as it reduces not only the bubble, but also the output gap volatility. However, inflation volatility increases, making this strategy questionable. As a result of the central bank’s actions, a trade-off between inflation and financial stability emerges, but the bubble and the output gap seem to be better stabilized (Figure 4).¹³ This results is in line with

¹³ Figure 4 also shows that there is a trade-off between inflation and the output gap. Such a trade-off is not to be expected in the context of demand shocks in standard models. Note however that our model is different from the standard New Keynesian one, in the sense that it includes a bubble process which is assumed to affect

Granville and Mallick (2009) who show through an empirical model that asset price shocks can generate trade-offs in the long run if asset prices are not stabilized.

To some extent, these results suggests that a standard Taylor rule provides a better outcome than a pure leaning against the wind strategy, even when facing financial shocks. Although not satisfactory, the standard rule seems to be less costly.

Figure 4: Variances following bubble shocks when the output gap coefficient varies



Note: Variances of inflation, output gap and the bubble following bubble shocks. The response to output gap varies between 0.5 and 1.5 and all other parameters remain the same. The arrows indicate an increase in β_y .

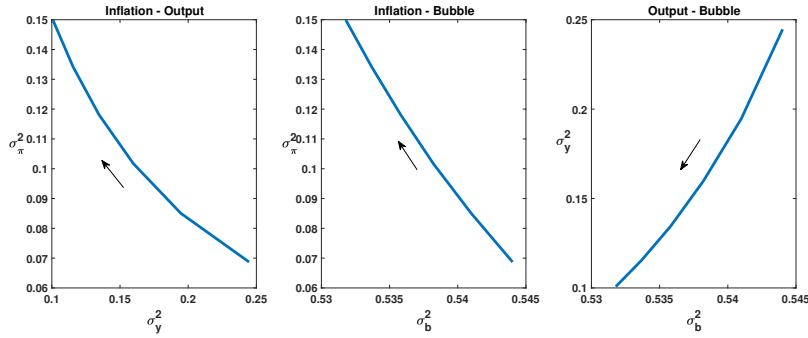
Supply and asset price bubble shocks

We assume now that the economy is faced with supply and bubble shocks at the same time. The results in this scenario are in line with the above discussion. A stronger response to output gap results in better bubble and output gap stabilization, while inflation variability increases as shown in Figure 5. A trade-off appears between inflation and the bubble stabilization, but also between price stability and output gap stability.

If monetary authorities are more adverse to the bubble (increase in β_b), once again all volatilities increase. The results in Figure 6 also show that when the central bank's reaction becomes more aggressive, all policy objectives are negatively affected (increase in output, inflation and bubble volatilities). This strategy proves to be counterproductive, leading not only to a deterioration in macroeconomic stability, but also to an increase in the bubble's volatility.

aggregate demand. When removing this assumption, we reach the common conclusion of no trade-off between inflation and output.

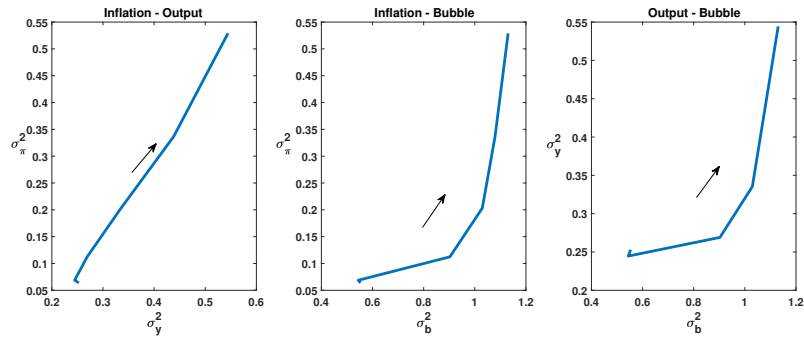
Figure 5: Variances following supply and bubble shocks when the output gap coefficient varies



Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to output gap varies from 0.5 to 1.5 and all other parameters remain the same. The arrows indicate an increase in β_y .

This finding is in line with Gali (2014) who argues that increasing the interest rate in response to a growing bubble generates higher fluctuations in the latter, as the interest rate positively affects the bubble's growth. In a different framework with another definition for financial instability, Svensson (2013) also concludes to a counterproductive effect of tightening monetary policy to stabilize the financial system.¹⁴

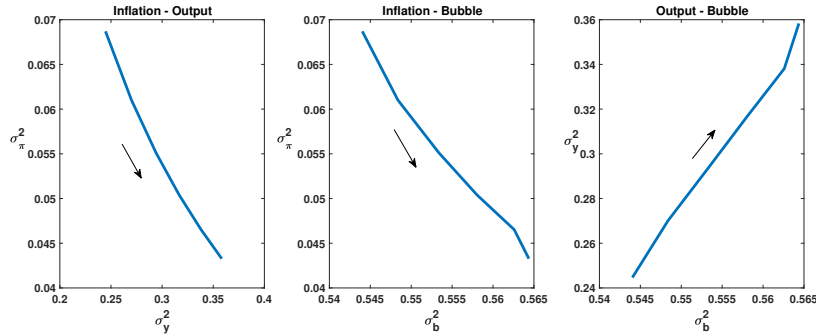
Figure 6: Variances following supply and bubble shocks when the bubble coefficient varies



Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same. The arrows indicate an increase in β_b .

¹⁴ Considering household indebtedness as an indicator of financial stability, Svensson (2013) shows that a tighter monetary policy to control the level of debt leads to an increase in the debt to GDP ratio. Tightening monetary policy more than necessary for inflation stabilization, will raise the real household debt and dampen the nominal GDP, increasing the debt to GDP ratio.

Figure 7: Variances following supply and bubble shocks when the inflation coefficient varies



Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to inflation varies from 1.5 to 2.5 and all other parameters remain the same. The arrows indicate an increase in β_π .

In response to supply and bubble shocks, an increase in the reaction to inflation lowers its volatility, while there is an increase in output gap and bubble volatilities (Figure 7). A trade-off between inflation and bubble stability emerges, in addition to the standard inflation–output gap trade-off.

Globally, these results seem all against the leaning against the wind strategy. Regardless of the type of shock, a trade-off between inflation stability and financial stability is always present.¹⁵ A reaction to the bubble (β_b different than zero) seems to be the worst case scenario as all interest variables find their volatilities aggravated. The best outcome, although not ideal, is to increase the response of the policy rate to the output gap. This allows monetary authorities to attain both financial and output gap stability, but the price stability objective is left aside in this case. Several authors now (De Grauwe and Gros, 2009, Woodford, 2012) seem in favor of this strategy, where the central bank neglects its main objective in the short run, in order to avoid or to diminish the harmful effects of a financial bubble.

4 Robustness Checks

To check the robustness of our results, various analyses are conducted. First, the bubble is assumed to be affected by the levels of the short-term interest rate rather than the changes.

¹⁵ A study based on loss functions driven from these results is presented in Appendix 2.

Second, we assess the extent to which our results are sensitive to changes in the values of the parameters φ and γ . Third, we examine different random selections for supply and financial shocks. And finally, an alternative random selection of the probability q_t is considered.

Bubble affected by levels rather than changes in interest rate

In section 2.1, it is assumed that changes in the short-term interest rate matter more for the financial sector than levels. However, it can be argued that the levels of the policy rate also matter since they can have important effects on the private sector's risk-taking behavior. We assess the extent to which our main results remain relevant if the bubble is affected by the level of the short-term interest rate rather than its changes (*i.e.* in equation (3), Δi_{t-1} is replaced by i_{t-1}). Within such a framework, our findings are the same as in the benchmark model when supply shocks are considered. The main results are also validated when bubble shocks occur and the central bank reacts to the output gap. Our conclusions slightly change however when bubble shocks occur and the central bank increases its response to the bubble. If in the main analysis, this strategy generated an increase in the variance of all variables, when the bubble is affected by the level of the short-term interest rate, the volatility of asset prices with respect to their fundamental value seems to be reduced. Nevertheless, we cannot conclude to a better outcome as a trade-off emerges between inflation and financial stability. When both supply and bubble shocks hit the economy and the central bank leans against the wind in a more aggressive way (increase in β_b), once again the trade-off between inflation and financial objectives emerges. A second difference with respect to the main results appears when β_y varies in response to bubble and supply shocks. Such a strategy succeeded in containing bubble volatility in the main analysis, whereas in this new framework the variance of the bubble increases. Although slightly different in some specific configurations, the results obtained when considering the levels of the policy rate point to the same conclusions. That is, they highlight the existence of trade-offs and the failure of the leaning strategy (Appendix 3, Figure 1).

Robustness to different values of the parameters φ and γ

The second robustness test concerns the model's parameters. First of all, our hybrid IS curve is different from the one usually used in the literature in that it includes the bubble. We therefore concentrate on the parameter of the bubble, φ in the IS curve capturing the sensitivity of demand to deviations of asset prices from fundamentals. We consider two alternative values in addition to the estimated one (see Appendix 1 for the estimation of the model's parameters). This robustness test is done only with respect to the relation between the variances of inflation and the bubble as in our main analysis no trade-off occurs between the bubble and the output gap.

In a context of asset price bubble shocks and with the central bank responding either directly to the bubble or indirectly, through a response to the output gap, we investigate the existence of this trade-off for different values of φ (between 0.10 and 0.20). The results presented in Appendix 3, Figure 2 show that whatever the value of φ considered, the more aggressive the central bank is to the bubble, the more it destabilizes inflation and the bubble. In line with our main results, responding more aggressively to the bubble only worsens the volatility in inflation and asset prices. However, when the central bank reacts indirectly to bubble shocks, the importance of the bubble parameter in the IS curve has all its importance. If the bubble only plays a small role in influencing demand (small value for φ), responding more aggressively to output gap increases both the volatility of the bubble and of inflation. Yet, a higher impact of the bubble on demand (higher value for φ) generates a trade-off between objectives: the volatility of the bubble diminishes whereas the one of inflation goes up. This is an important results as it underlines that depending on the role played by the bubble in the economy, leaning against financial imbalances can indeed reduce them but at the cost of inflation.

The same investigation is conducted for different values of γ , the sensitivity of the bubble to changes in the interest rate (with γ taking values between 0.02 and 0.07). The economy is hit by asset price bubble shocks and the central bank responds more aggressively either to the bubble or to the output gap. The findings are in line with our previous conclusions. Responding to the bubble only worsens its volatility as well as the volatility of inflation, whatever the value of γ . Considering responses to output gap, trade-offs appear between inflation and bubble stability

as in the main analysis inflation volatility increases and bubble volatility decreases (Appendix 3, Figure 3). However, the gain from reducing inflation volatility is rather limited.

Robustness to an alternative selection of shocks

As discussed earlier, the shocks are drawn on a random basis from a standard normal distribution. We perform a robustness check by considering another random selection of shocks and we conduct the same analysis as above. Regarding the responses to supply shocks, the findings are the same as in the baseline model. We also reach the same conclusions when the central bank reacts to bubble shocks by increasing β_y . These two strategies lead to trade-offs between inflation and the bubble, as well as between inflation and the output gap objectives. When supply and bubble shocks hit the economy, we find the same results as in the baseline configuration. It is only when responding to shocks by increasing the response to the bubble that results seem to contradict our previous main analysis conclusion, but confirm the results obtained when using the level of the interest rate (Appendix 3, Figure 4). All in all, whatever the central bank's strategy or the type of shock to which the economy is confronted, we notice that a trade-off between inflation and asset prices appears.

Robustness to an alternative selection of q_t

Our last robustness check concerns the values of q_t which are selected randomly from a uniform distribution over the interval $[0, 1]$. An alternative series of q_t is drawn from the same distribution and new results are computed based on these probabilities. Our findings remain the same in three scenarios: in case of supply shocks when the central bank react more aggressively to inflation, in case of bubble shocks when the central bank responds to the output gap, and in case of both supply and bubble shocks, when the monetary authority increases its reaction to inflation. The results in the other three scenarios differ from our baseline analysis in the evolution of the bubble's volatility. When bubble shocks or simultaneous supply and bubble shocks are considered, responding to the bubble leads to more asset prices instability. The evolution of the volatility in inflation and output gap does not change with respect to the baseline model. Finally, when both supply and financial shocks occur and the central bank reacts more

aggressively to output gap, the results are similar to the ones obtained while using the level of the interest rate.¹⁶

Overall, the alternative analyses conducted in this section highlight the robustness of our main result. Although some of the tests do not lead to exactly the same outcome with respect to the variance of the bubble, the main conclusions remain identical from a qualitative point of view. A leaning against the wind strategy, in which the central bank responds directly to financial instability, is subject to trade-offs between the primary inflation stabilization objective and financial stability.

5 Conclusions and Policy Implications

This paper explores the extent to which trade-offs can emerge between macroeconomic and financial stability when the central bank responds directly to financial imbalances. The macroeconomic framework employed is a New Keynesian model consisting of aggregate demand and aggregate supply equations and the central bank's reaction function. To reproduce the leaning against the wind strategy, the interest rate is modeled as an augmented Taylor-type rule in which the policy rate responds to a financial bubble. The novelty in our model is the introduction of a fourth equation meant to capture risk accumulation in the financial sector. Moreover, this bubble is modeled endogenously as the monetary policy stance has an impact on its evolution.

Our analysis of trade-offs is performed by comparing the variances of policy objectives when the economy is confronted with various types of shocks and the central bank adopts different strategies to overcome them. The main conclusion shows that central banks practicing the leaning against the wind strategy will face trade-offs between inflation and financial stability. More precisely, when the central bank responds to financial imbalances, in the best-case scenario, such a policy can succeed in dampening financial risks, but at the cost of higher price instability. Our results also seem to highlight the worse-case scenario in which the policy is counterproductive with respect to all the monetary policy objectives (increase in macroeconomic and financial instability).

¹⁶ We do not present these results due to space constraints, but provide them upon request.

While the leaning against the wind strategy may be required, this paper argues that such a policy can lead to trade-offs between objectives or even destabilize the real economy and the financial sector. Although the risk-taking channel of monetary policy highlights the potential impact of interest rates on the evolution of financial bubbles, using this instrument to respond to these imbalances can be harmful for the monetary authorities. We therefore argue that the interest rate should be used for achieving traditional macroeconomic goals, and a second instrument should complement the policy rate to tackle financial risk accumulation. The progress made after the GFC in terms of prudential regulation, including the development of a macroprudential framework, is precisely meant to relieve monetary policy from this “two objectives - one instrument” burden. However, further analysis should be conducted to test whether or not monetary and prudential policies lead to unwanted trade-offs. This is left for future research.

References

- [1] Adrian, T. and H. S. Shin (2010). *Financial Intermediaries and Monetary Economics*. Handbook of Monetary Economics. Elsevier, pp. 601–650.
- [2] Agenor, P.-R., K. Alper, and L. A. Pereira da Silva (2012). *Capital Regulation, Monetary Policy and Financial Stability*. Working Paper 1228. Research and Monetary Policy Department, Central Bank of the Republic of Turkey.
- [3] Badarau, C. and A. Popescu (2014). “Monetary policy and credit cycles: A DSGE analysis”. *Economic Modelling* 42, pp. 301–312.
- [4] Beau, D., C. Cahn, L. Clerc, and B. Mojon (2013). *Macro-Prudential Policy and the Conduct of Monetary Policy*. Working Papers Central Bank of Chile. Central Bank of Chile.
- [5] Bernanke, B. and M. Gertler (1999). “Monetary policy and asset price volatility”. *Economic Review* Q IV, pp. 17–51.
- [6] Blanchard, O. J. and M. W. Watson (1982). *Bubbles, Rational Expectations and Financial Markets*. NBER Working Paper 0945. National Bureau of Economic Research, Inc.
- [7] Blanchard, O. J. and C. M. Kahn (1980). “The Solution of Linear Difference Models under Rational Expectations”. *Econometrica* 48.5, p. 1305.
- [8] Bordo, M. and O. Jeanne (2002). *Boom-busts in asset prices, economic instability, and monetary policy*. NBER Working paper, No. 8966.
- [9] Borio, C. and H. Zhu (2012). “Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism?” *Journal of Financial Stability* 8.4, pp. 236–251.
- [10] Cecchetti, S. G., H. Genberg, and J. Lipsky (2000). *Asset Prices and Central Bank Policy*. Tech. rep. Geneva: International Center for Monetary and Banking Studies.

- [11] Christensen, I., C. Meh, and K. Moran (2011). *Bank leverage regulation and macroeconomic dynamics*. Tech. rep. 2011-32. Bank of Canada Working Paper.
- [12] De Grauwe, P. and D. Gros (2009). *A New Two-Pillar Strategy for the ECB*. CESifo Working Paper Series 2818. CESifo Group Munich.
- [13] Dell’ariccia, G. (2010). *Monetary Policy and Bank Risk-Taking*. IMF Staff Position Notes 2010/09. International Monetary Fund.
- [14] DellAriccia, G., L. Laeven, and R. Marquez (2014). “Real interest rates, leverage, and bank risk-taking”. *Journal of Economic Theory* 149.C, pp. 65–99.
- [15] End, J. W. van den (2010). *Trading off monetary and financial stability: a balance of risk framework*. DNB Working Papers 249.
- [16] Estrella, A. and J. Fuhrer (2002). “Dynamic Inconsistencies: Counterfactual Implications of a Class of Rational-Expectations Models”. *American Economic Review* 92.4, pp. 1013–1028.
- [17] Fahr, S. and J. Fell (2017). “Macroprudential policy—closing the financial stability gap”. *Journal of Financial Regulation and Compliance* 25.4, pp. 334–359.
- [18] Filardo, A. (2000). “Monetary policy and asset prices”. *Economic Review* Q III, pp. 11–37.
- [19] — (2001). *Should monetary policy respond to asset price bubbles? : some experimental results*. Research Working Paper RWP 01-04. Federal Reserve Bank of Kansas City.
- [20] — (2004). *Monetary policy and asset price bubbles: calibrating the monetary policy trade-offs*. BIS Working Paper 155. Bank for International Settlements.
- [21] Fuhrer, J. and G. Moore (1995). “Inflation Persistence”. *The Quarterly Journal of Economics* 110.1, pp. 127–159.
- [22] Gali, J. (2014). “Monetary Policy and Rational Asset Price Bubbles”. *American Economic Review* 104.3, pp. 721–752.

- [23] Granville, B. and S. Mallick (2009). “Monetary and financial stability in the euro area: Pro-cyclicality versus trade-off”. *Journal of International Financial Markets, Institutions and Money* 19.4, pp. 662–674.
- [24] Gruen, D., M. Plumb, and A. Stone (2005). “How Should Monetary Policy Respond to Asset-Price Bubbles?” *International Journal of Central Banking* 1.3, pp. 1–33.
- [25] IMF (2015). *Monetary policy and financial stability*. Tech. rep. International Monetary Fund.
- [26] Issing, O. (2003). “Monetary and financial stability: Is there a trade-off?” BIS, Basel.
- [27] Kent, C. and P. Lowe (1997). *Asset-price bubbles and monetary policy*. Reserve Bank of Australia Discussion Paper, No. 9709.
- [28] King, M. (2012). “Twenty years of inflation targeting”. London School of Economics: Bank of England.
- [29] Mallick, S. and R. Sousa (2013). “The real effects of financial stress in the Eurozone”. *International Review of Financial Analysis* 30, pp. 1–17.
- [30] Mishkin, F. (2011). “How Should Central Banks Respond to Asset-Price Bubbles? The ‘Lean’ versus ‘Clean’ Debate After the GFC”. *RBA Bulletin*, pp. 59–70.
- [31] Rajan, R. G. (2005). *Has Financial Development Made the World Riskier?* Working Paper 11728. National Bureau of Economic Research.
- [32] Ross, S. A. (1976). “The arbitrage theory of capital asset pricing”. *Journal of Economic Theory* 13.3, pp. 341–360.
- [33] Rudebusch, G. D. (2005). “Monetary policy and asset price bubbles”. *FRBSF Economic Letter*.
- [34] Shukayev, M. and A. Ueberfeldt (2016). “Monetary policy tradeoffs between financial stability and price stability”. *Canadian Journal of Economics/Revue canadienne d’économique* 51.3, pp. 901–945.

- [35] Smets, F. (2000). *What horizon for price stability*. Working Paper Series 0024. European Central Bank.
- [36] Smets, F. et al. (2014). “Financial stability and monetary policy: How closely interlinked?” *International Journal of Central Banking* 10.2, pp. 263–300.
- [37] Svensson, L. E. (2013). *”Leaning Against the Wind” Leads to Higher (Not Lower) Household Debt-to-GDP Ratio*. Tech. rep. Stockholm University.
- [38] Woodford, M. (2012). *Inflation Targeting and Financial Stability*. NBER Working Paper 17967. National Bureau of Economic Research, Inc.

Appendix 1: Parameter estimates and model calibration

This appendix first provides a very brief description of the estimation of misalignments in the equity market, and then the results of the macro-model estimated for the euro area.

As discussed in the main text, we use the APM (based on the Arbitrage Pricing Theory, Ross, 1976) approach to estimate excess returns in the equity market as a function of surprises due to shocks on various fundamentals. Especially, the estimated equation takes the form of :

$$excess R_t = \alpha_i + BX_t + \varepsilon \quad (7)$$

where *excess R* is the excess return defined as the difference between the MSCI and the risk-free rate (3-month rate), and *X* is the vector of fundamentals. *X* includes: the change in the VIX index (confidence risk), the spread between the long-term and the short-term rate (time horizon risk), change in the industrial production index, inflation, change in the nominal exchange rate, commodity price index, and volatility of daily equity returns. The equation is estimated with simple (robust) OLS, using monthly data. Fair values of the equity indices are estimated as the sum of the risk-free rate and the estimated excess return. The misalignments (under- or overvaluations) are the differences between the observed MSCI index and its estimated fair value. Because of limited data availability, this is done only for 9 Euro area countries,¹⁷ and the average is computed and used for the model calibration described below.

Regarding the parameters estimates, we follow Smets (2000) and use a GMM estimator with monthly data over 1999M09-2007M12. Results are reported hereafter.

We do not estimate the Taylor rule as the purpose of our study is precisely to analyze different reactions of the central bank. This translates in considering several values for each β parameter. Hence we depart from standard values – $\beta_\pi = 1.5$ and $\beta_y = 0.5$ – and gradually increase each of them to simulate more aggressive reactions to shocks. Moreover, given that central banks did not respond to bubbles during our sample period, no value can be found in the literature for the parameter β_b . However, even if central banks decide to react to bubbles their primary objectives remain price and output stability, implying a smaller reaction to the

¹⁷ Austria, Belgium, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden.

Table 1: Estimated parameters of a forward-looking model for the euro area economy

Output equation											
$y_t =$	0.55	$\mathbb{E}_t(y_{t+1}) +$	0.45	y_{t-1}	-0.84	$(i_t - \mathbb{E}_t(\pi_{t+1})) +$	0.15	$b_t + \varepsilon_t^y$			
	(0.06)				(0.21)		(0.08)				
Inflation equation											
$\pi_t =$	0.49	$\mathbb{E}_t(\pi_{t+1}) +$	0.51	π_{t-1}	+ 0.22	$y_t + \varepsilon_t^\pi$					
	(0.16)				(0.02)						

Note: Estimated using monthly data with GMM over the period 1999M09-2007M12. Robust standard errors are in parentheses. All data are in percent. The output gap is measured as the percentage deviation of a linear trend.

bubble than the one to inflation or output gap. Therefore β_b is first taken to be equal to 0.15 implying a rather soft reaction to the bubble. Furthermore, to imply more aggressive reactions of the central bank to different shocks, this parameter is allowed to go up to 0.75. Finally, β_i is taken equal to 0.98. The next table summarizes all the parameters used in the model.

Parameters	α	λ	δ	σ	φ	γ	\bar{q}	\bar{i}	β_i	β_π	β_y	β_b
Value	0.49	0.22	0.55	-0.84	0.15	0.06	0.8	0.04	0.98	1.5	0.5	0.15

Appendix 2: Loss function analysis

We present hereafter the results of our baseline analysis in terms of loss functions. The following tables correspond to Figures 2 to 7 in the main text. They give the values of the loss function computed using the variances of inflation and of the output gap. Three versions of the loss functions are computed. The first one assumes equal weights on inflation and output gap volatilities (0.5 - 0.5). The second one, closer to an inflation targeting central bank, supposes that the monetary authority values more inflation variance (0.9) , than output gap volatility (0.1). Last, the central bank is more interested in stabilizing output (with a weight of 0.9) than inflation (0.1). Minimal values appear in bold.

Table 2: Losses in case of supply shocks

Parameter value	Loss function (0.5 - 0.5)	Loss function (0.9 - 0.1)	Loss function (0.1 - 0.9)
$\beta_\pi = 1.5$	0,0123	0,0065	0,0181
$\beta_\pi = 1.7$	0,0131	0,0063	0,0200
$\beta_\pi = 1.9$	0,0139	0,0061	0,0217
$\beta_\pi = 2.1$	0,0147	0,0060	0,0233
$\beta_\pi = 2.3$	0,0154	0,0060	0,0249
$\beta_\pi = 2.5$	0,0161	0,0059	0,0263

Note: The loss functions are computed with variances of inflation, output gap and the bubble following supply shocks. The response to inflation varies between 1.5 and 2.5 and all other parameters remain the same.

Following supply shocks, a moderate central bank (with equal weights on inflation and output) obtains the best outcome when the parameter on inflation in the augmented Taylor rule has the smallest value considered (*i.e.* 1.5, Table 2). The same outcome is obtained for a central bank interested more in output stability. As the bubble does not explicitly represent a policy objective, the best response is thus a soft leaning against the wind (0.15) and moderate response to inflation. Of course, minimizing the loss when the central bank has a high preference for stabilizing inflation, implies a strong coefficient for β_π .

When faced with asset price bubble shocks (Tables 3 and 4), the moderate central bank minimizes social loss when it responds in a small extent to the bubble and to the output gap (0.5 and 0.15 respectively). Interestingly, responding aggressively to the bubble (high value for β_b) does not lead to minimizing losses in either scenario considered (the value of β_b is either 0

Table 3: Losses in case of asset price bubble shocks (1)

Parameter value	Loss function (0.5 - 0.5)	Loss function (0.9 - 0.1)	Loss function (0.1 - 0.9)
$\beta_b = 0$	0,0079	0,0040	0,0117
$\beta_b = 0.15$	0,0053	0,0084	0,0022
$\beta_b = 0.30$	0,0386	0,0478	0,0294
$\beta_b = 0.45$	0,1102	0,1255	0,0948
$\beta_b = 0.60$	0,2227	0,2464	0,1990
$\beta_b = 0.75$	0,3645	0,4170	0,3121

Note: The loss functions are computed with the variances of inflation, output gap and the bubble following bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same.

Table 4: Losses in case of asset price bubble shocks (2)

Parameter value	Loss function (0.5 - 0.5)	Loss function (0.9 - 0.1)	Loss function (0.1 - 0.9)
$\beta_y = 0.5$	0,0053	0,0084	0,0022
$\beta_y = 0.7$	0,0055	0,0089	0,0021
$\beta_y = 0.9$	0,0058	0,0094	0,0021
$\beta_y = 1.1$	0,0061	0,0100	0,0022
$\beta_y = 1.3$	0,0064	0,0106	0,0022
$\beta_y = 1.5$	0,0068	0,0113	0,0022

Note: The loss functions are computed using the variances of inflation, output gap and the bubble following bubble shocks. The response to output gap varies between 0.5 and 1.5 and all other parameters remain the same.

or 0.15 for the minimal loss).

Finally, when the economy faces both supply and asset prices shocks (Tables 5, 6 and 7), the optimal strategy for the moderate central bank, as well as for the central bank concerned with activity stabilization, is to have a strong reaction to the output gap (β_y equal to 1.3 and 1.5 respectively). When the central banks has a strong preference for price stability, the minimal loss is obtained when responding aggressively to inflation in the augmented Taylor rule. Note that responding to the bubble (increasing values of β_b) never leads to minimizing the loss function.

This analysis confirms that leaning against the wind is not the optimal strategy to stabilize the economy. The loss function is always minimized for small or null values of the bubble coefficient in the augmented Taylor rule.

Table 5: Losses in case of supply and asset price bubble shocks (1)

Parameter value	Loss function (0.5 - 0.5)	Loss function (0.9 - 0.1)	Loss function (0.1 - 0.9)
$\beta_y = 0.5$	0,1567	0,0863	0,2270
$\beta_y = 0.7$	0,1398	0,0960	0,1836
$\beta_y = 0.9$	0,1308	0,1075	0,1540
$\beta_y = 1.1$	0,1263	0,1198	0,1329
$\beta_y = 1.3$	0,1249	0,1324	0,1174
$\beta_y = 1.5$	0,1253	0,1450	0,1057

Note: The loss functions are computed using the variances of inflation, output gap and the bubble following bubble shocks. The response to output gap varies between 0.5 and 1.5 and all other parameters remain the same.

Table 6: Losses in case of supply and asset price bubble shocks (2)

Parameter value	Loss function (0.5 - 0.5)	Loss function (0.9 - 0.1)	Loss function (0.1 - 0.9)
$\beta_b = 0$	0,1584	0,0828	0,2340
$\beta_b = 0.15$	0,1567	0,0863	0,2270
$\beta_b = 0.30$	0,1907	0,1281	0,2534
$\beta_b = 0.45$	0,2693	0,2164	0,3222
$\beta_b = 0.60$	0,3873	0,3467	0,4280
$\beta_b = 0.75$	0,5367	0,5305	0,5429

Note: The loss functions are computed with the variances of inflation, output gap and the bubble following bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same.

Table 7: Losses in case of supply and asset price bubble shocks (3)

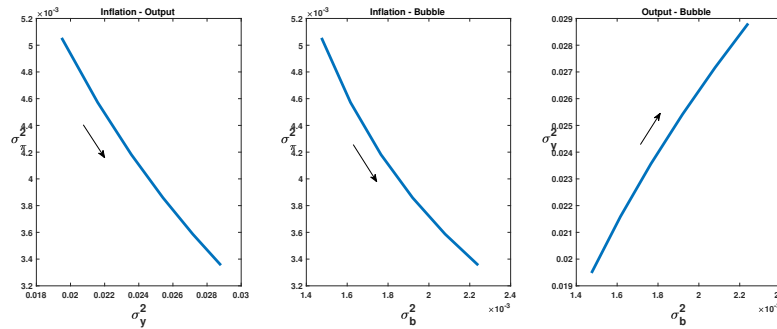
Parameter value	Loss function (0.5 - 0.5)	Loss function (0.9 - 0.1)	Loss function (0.1 - 0.9)
$\beta_\pi = 1.5$	0,1567	0,0863	0,2270
$\beta_\pi = 1.7$	0,1655	0,0819	0,2492
$\beta_\pi = 1.9$	0,1746	0,0790	0,2702
$\beta_\pi = 2.1$	0,1835	0,0770	0,2901
$\beta_\pi = 2.3$	0,1923	0,0757	0,3089
$\beta_\pi = 2.5$	0,2008	0,0748	0,3268

Note: The loss functions are computed with variances of inflation, output gap and the bubble following supply shocks. The response to inflation varies between 1.5 and 2.5 and all other parameters remain the same.

Appendix 3: Robustness Checks

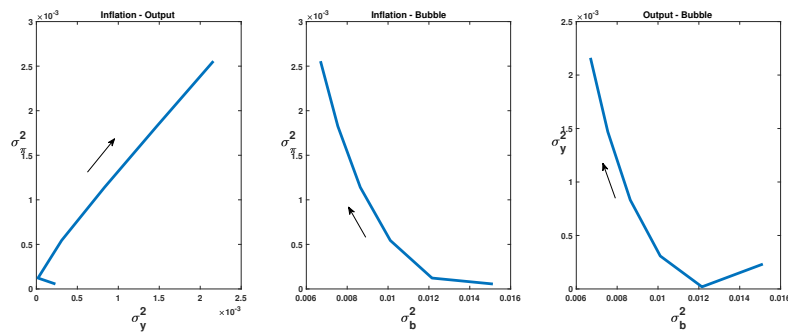
Bubble affected by levels rather than changes in interest rate

Figure (1a) Variances following supply shocks when the inflation coefficient varies



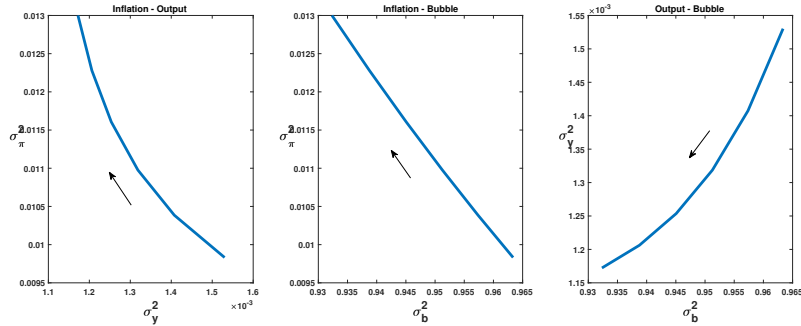
Note: Variances of inflation, output gap and the bubble following supply shocks. The response to inflation varies from 1.5 to 2.5 and all other parameters remain the same. The arrows indicate an increase in β_π .

Figure (1b) Variances following bubble shocks when the bubble coefficient varies



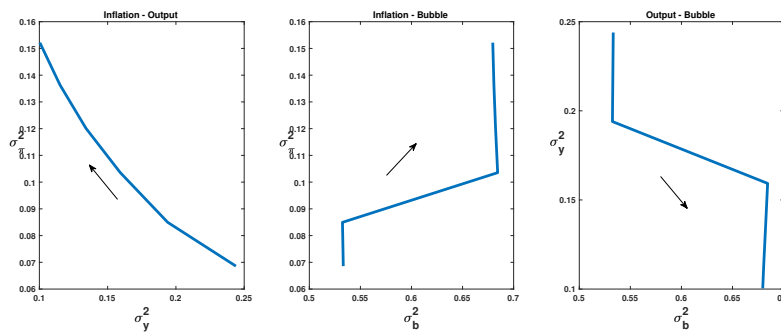
Note: Variances of inflation, output gap and the bubble following bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same. The arrows indicate an increase in β_b .

Figure (1c) Variances following bubble shocks when the output gap coefficient varies



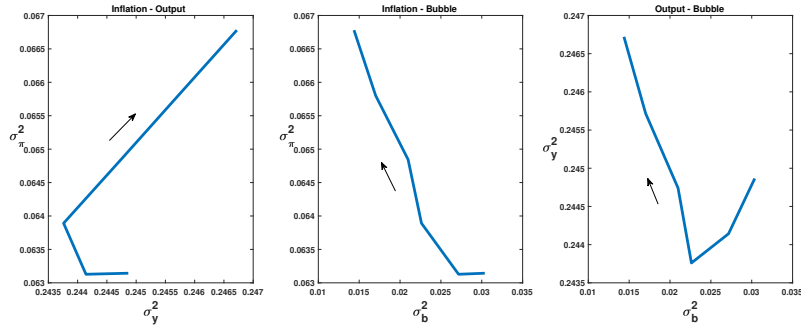
Note: Variances of inflation, output gap and the bubble following bubble shocks. The response to output gap varies from 0.5 to 1.5 and all other parameters remain the same. The arrows indicate an increase in β_y .

Figure (1d) Variances following supply and bubble shocks when the output gap coefficient varies



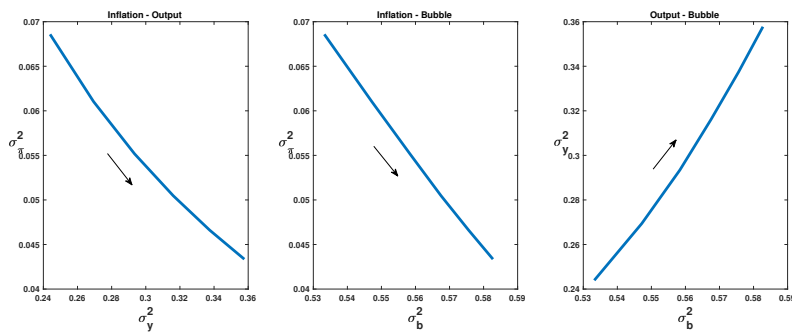
Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to output gap varies from 0.5 to 1.5 and all other parameters remain the same. The arrows indicate an increase in β_y .

Figure (1e) Variances following supply and bubble shocks when the bubble coefficient varies



Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same. The arrows indicate an increase in β_b .

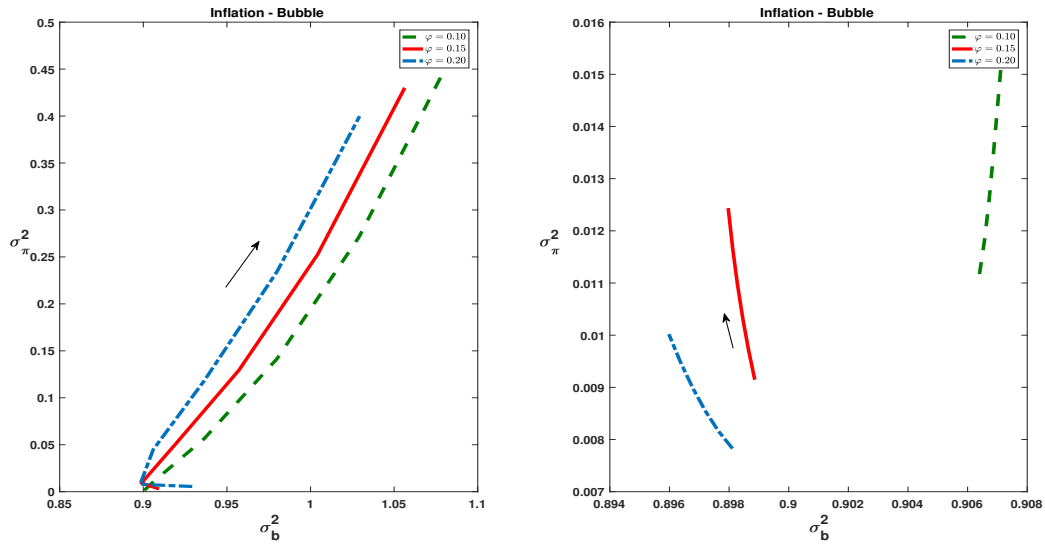
Figure (1f) Variances following supply and bubble shocks when the inflation coefficient varies



Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to inflation varies from 1.5 to 2.5 and all other parameters remain the same. The arrows indicate an increase in β_π .

Robustness to φ

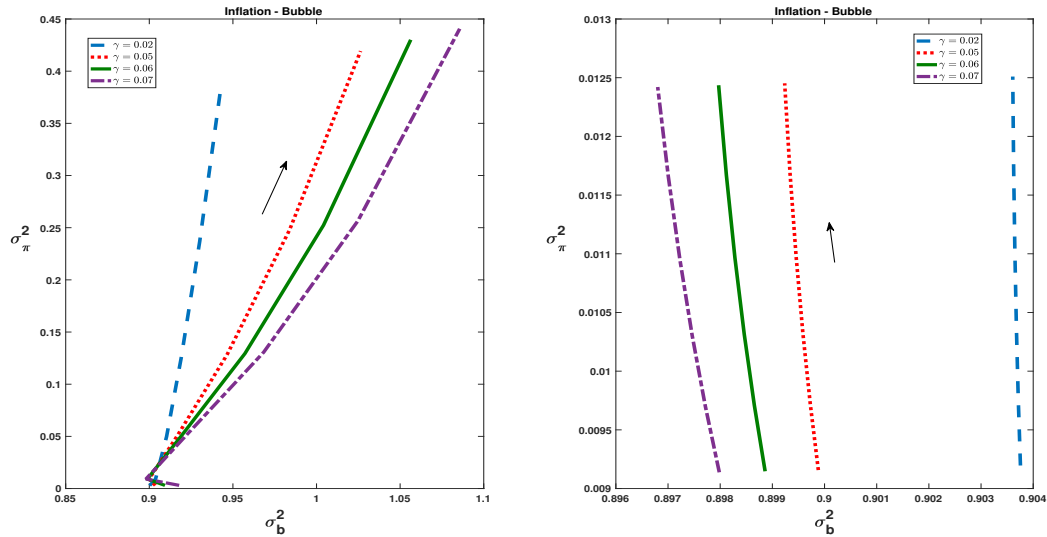
Figure (2) Variances following bubble shocks (Response to the bubble [left] and to the output gap [right])



Note: Left panel – Response to the bubble: Variances of inflation and the bubble following bubble shocks. The response to the bubble varies from 0.15 to 0.75 and all other parameters remain the same. Right panel – Response to the output gap: Variances of inflation and the bubble following bubble shocks. The response to the output gap varies from 0.5 to 1.5 and all other parameters remain the same.

Robustness to γ

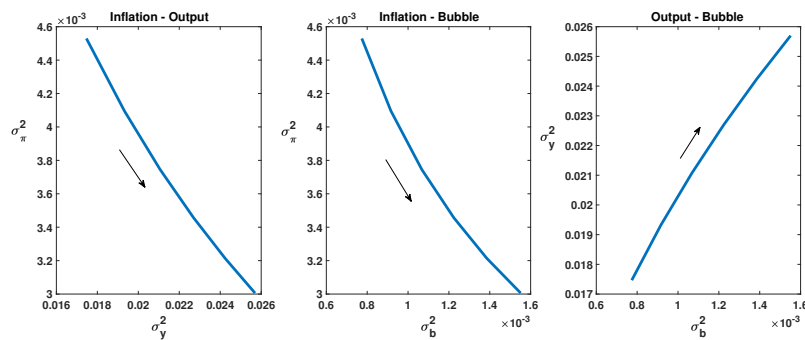
Figure (3) Bubble shocks (Response to the bubble [left] and to the output gap [right])



Note: Left panel – Response to the bubble: Variances of inflation and the bubble following bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same. Right panel – Response to the output gap: Variances of inflation and the bubble following bubble shocks. The response to the output gap varies from 0.5 to 1.5 and all other parameters remain the same.

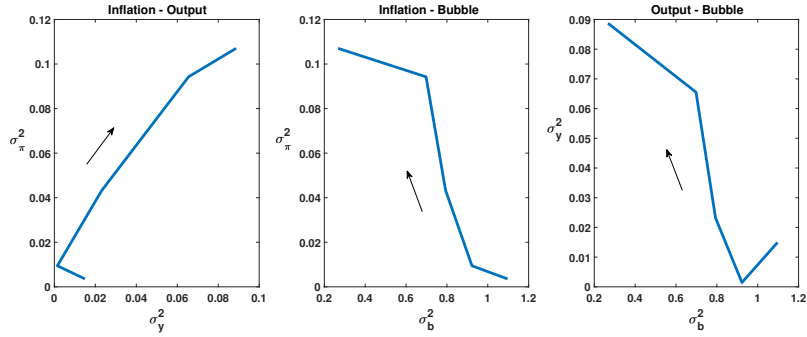
Robustness to an alternative selection of shocks

Figure (4a) Variances following supply shocks when the inflation coefficient varies



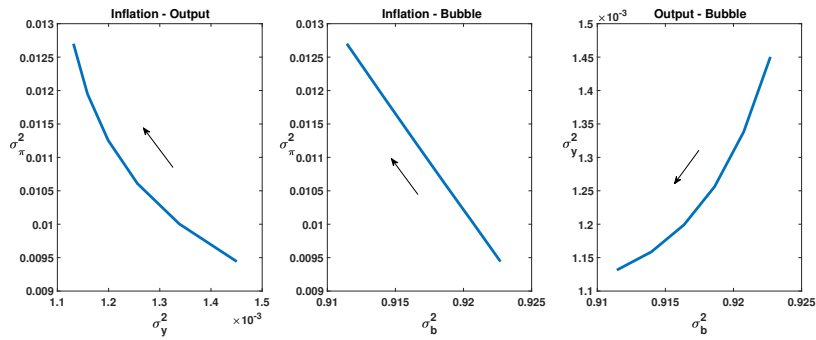
Note: Variances of inflation, output gap and the bubble following supply shocks. The response to inflation varies from 1.5 to 2.5 and all other parameters remain the same. The arrows indicate an increase in β_π .

Figure (4b) Variances following bubble shocks when the bubble coefficient varies



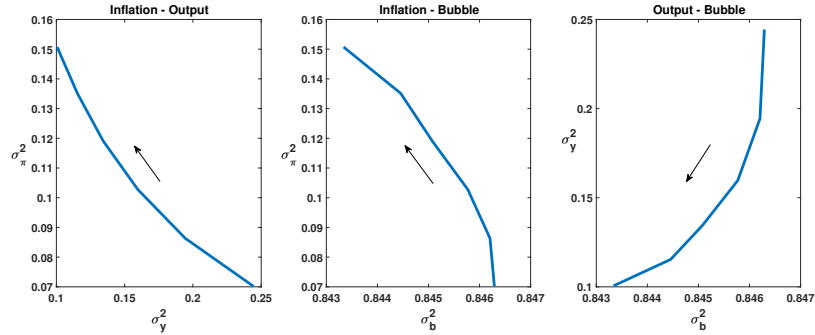
Note: Variances of inflation, output gap and the bubble following bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same. The arrows indicate an increase in β_b .

Figure (4c) Variances following bubble shocks when the output gap coefficient varies



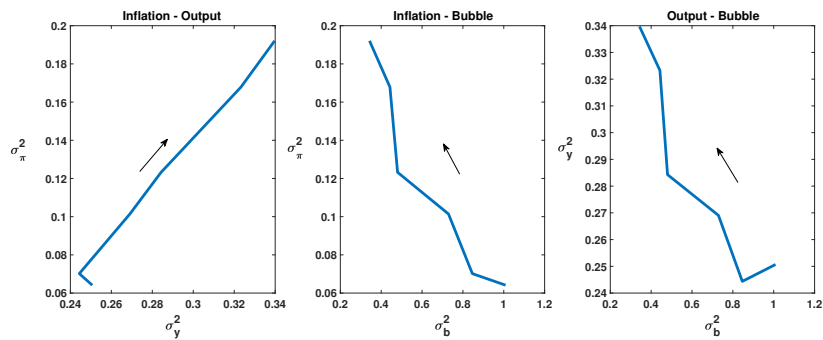
Note: Variances of inflation, output gap and the bubble following bubble shocks. The response to output gap varies from 0.5 to 1.5 and all other parameters remain the same. The arrows indicate an increase in β_y .

Figure (4d) Variances following supply and bubble shocks when the output gap coefficient varies



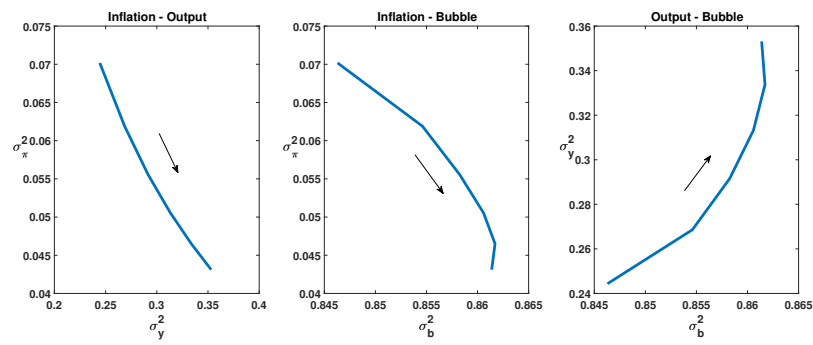
Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to output gap varies from 0.5 to 1.5 and all other parameters remain the same. The arrows indicate an increase in β_y .

Figure (4e) Variances following supply and bubble shocks when the bubble coefficient varies



Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to the bubble varies from 0 to 0.75 and all other parameters remain the same. The arrows indicate an increase in β_b .

Figure (4f) Variances following supply and bubble shocks when the inflation coefficient varies



Note: Variances of inflation, output gap and the bubble following supply and bubble shocks. The response to inflation varies from 1.5 to 2.5 and all other parameters remain the same. The arrows indicate an increase in β_π .