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Abstract

We investigate the role of monetary policy in stock price misalignments and explore whether central banks can attenuate excessive mispricing as suggested by the proponents of a "leaning against the wind" monetary policy. Decomposing stock prices into expected excess dividends, an equity risk premium, and a mispricing component, we find that prices fall more strongly in response to an increase in the policy rate than what is implied by their underlying fundamentals. This systematic overreaction suggests that tighter monetary policy may contain emerging asset price misalignments. Our findings are at odds with the predictions of a rational bubble framework, but can be explained by mispricing arising from false subjective expectations of irrational investors.

Keywords: Asset pricing, bubbles, leaning against the wind, mispricing, monetary policy, stock prices.

JEL Classification: E44, E52, G12, G14

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1 Introduction

It is commonly accepted that an easing of monetary policy raises asset prices. In fact, the asset price channel is one of the immediate channels through which central banks aim to stimulate economic activity when employment or inflation are below their target levels. However, the prolonged boom in asset prices alongside the low interest rate environment in most advanced economies after the global financial crisis in 2007/08 has placed the role of monetary policy in pronounced asset price cycles under renewed public scrutiny. As a result, the debate over the appropriate response of central banks to a perceived trade-off between their inflation targets and the risks to financial stability posed by excessively high asset prices has been reignited. While the majority of central banks have since added some form of explicit financial stability objective (Jeanneau, 2014), others argue that central banks should take an even more proactive approach and "lean against the wind" (LATW) of emerging asset price bubbles by raising key interest rates - even if this entails some costs to economic output and achieving their inflation targets (Cecchetti et al., 2000; Borio & Lowe, 2002; Woodford, 2012).

We contribute to this debate by exploring the role of monetary policy in mispricing in stock markets. While equity markets are not the only financial or real asset market that may be prone to exuberance or bubbles, stocks are priced according to a commonly accepted pricing framework. We can thus use the standard asset framework to decompose the estimated total response of stock prices to monetary policy into the responses of its fundamental drivers and a possibly non-zero mispricing component. Using the same framework, Galí & Gambetti (2015) challenge the view of supporters of a LATW policy by providing empirical evidence that a monetary policy tightening *raises* the bubble component in equity prices in line with the theoretical predictions on the behavior of rational asset price bubbles (Galí, 2014).

In this paper, we interrogate this central result of Galí & Gambetti (2015). While we also find that monetary policy triggers a temporary but sizeable mispricing in equity markets, we find the reaction of the mispricing component to an increase in the Federal Funds Rate to be *negative*. The direction of this response thus lends support to the popular notion that a monetary easing may lead to excessively high equity prices, and, reciprocally, that central banks could successfully lean against the wind of emerging asset price bubbles by raising interest rates.

We obtain this result by employing a less restrictive strategy to identify monetary policy shocks in the data. Instead of imposing strong timing restrictions between the interaction of high-frequency variables as Galí & Gambetti (2015),[1] we identify policy shocks using the approach of Arias et al. (2019) and impose relatively agnostic sign restrictions on both the response of monetary policy to key variables in our structural vector-autoregressive model (SVAR) and the impact effects of policy on these variables. This framework thus enables us to allow for non-zero and unrestricted two-way contemporaneous responses between stock prices and the policy rate, while capturing the conventional links between the federal funds rate, the real economy and other key financial asset prices.

Our findings also contribute to the broader literature on the dynamic effects of monetary policy on stock prices. In contrast to Galí & Gambetti (2015), who find a positive medium-term response of stock prices to a monetary tightening, we recover the conventional negative stock price response through our approach. Our central estimates suggest that a one per cent increase in the federal funds rate leads to a roughly eight to twelve per cent short-run fall in the S&P 500 index. These estimates are slightly larger but in line with previous work (Rigobon & Sack, 2004; Bernanke & Kuttner, 2005; Bjørnland & Leitemo, 2009).

We also answer the more general question through which channels a restrictive monetary policy shock affects stock prices. Bernanke & Kuttner (2005) consider only future expected dividends and real risk-free interest rates as fundamental determinants of stock prices. Our paper adds to the existing literature by also considering the equity premium as a potential driver of stock prices. The remaining part of stock price movements is then interpreted as the mispricing component. According to our estimates, around a quarter of the stock price decline is attributable to the policy-driven adjustment of expected future excess dividends. Another quarter of the stock price decline is explained by an increase in the equity premium. Thus, similar to Bernanke & Kuttner (2005), we find that about half of the stock price decline is not explained by the variables considered and is therefore interpreted as mispricing.

We do not attempt to answer the question whether it is optimal for central banks to lean against the wind of asset price bubbles. However, our empirical findings may potentially feed into further studies on this issue by providing estimates of both the costs and benefits of such policies. In particular, we estimate that while a one per cent increase in the federal funds rate may lower mispricing in equity prices by around five per cent, it also comes at the cost of a fall in output of around two per cent after two years.

On a theoretical front, the sign of our estimated mispricing response is also opposite

[1] Galí & Gambetti (2015) assume that monetary policy influences stock prices instantaneously but that the central bank does not react within the quarter to stock price movements. However, the assumption that the U.S. Federal Reserve does not respond contemporaneously to stock price surprises (or economic news captured by stock price movements) is rejected by Rigobon & Sack (2004); Bjørnland & Leitemo (2009); Furlanetto (2011); Lütkepohl & Netsunajev (2014).

to the predictions derived from the rational asset price bubble framework in Galí (2014). We view this as a challenge to the narrow framework of rational bubbles. However, this does not exclude the possibility of (temporary) mispricing on stock markets. We show this by applying the framework of asset mispricing of Brunnermeier & Julliard (2008), where mispricing can arise (i) from a violation of the transversality condition; and/or (ii) from false expectations of irrational investors about the stock's underlying (risk-adjusted) fundamentals, namely discounted future dividends and equity risk premia. This framework emphasizes the ambiguity in the response of a mispricing component in stock prices to monetary policy and can capture our empirical finding.

The remainder of this paper is structured as follows. Section 2 formally lays our accounting framework to decompose stock prices into a fundamental component, the expected risk premium, and a mispricing component. We describe our empirical approach and our identification strategy in Section 3. Section 4 presents our main results. We discuss the robustness of these results and compare them to the results in Galí & Gambetti (2015) in Section 5. Section 6 concludes.

2 An accounting framework for asset prices

We begin by outlining a simple accounting framework based on the asset price equation that will later guide our decomposition of the stock price response to a monetary policy shock into the partial responses driven by fundamental factors and mispricing. We extend the decomposition as applied by Galí (2014) and Galí & Gambetti (2015) by relaxing the assumption that investors are risk neutral and that the expected stock price return (the discount factor) equals the risk-free return. Instead we allow for the presence of a time-varying expected equity risk premium as Bernanke & Kuttner (2005). This section defines these stock price components, and discusses under which conditions mispricing may arise in our framework.

According to the standard asset pricing equation, the current stock market price P_t equals the sum of discounted future dividend payments D_{t+j} and the terminal value P_{t+T} under rational expectations E_t:

$$P_t = E_t\left[\sum_{i=1}^{\infty}\left(\prod_{j=1}^{i}\frac{1}{1+R_{t+j}}\right)D_{t+i}\right] + E_t\left[\lim_{T\to\infty}\left(\prod_{j=1}^{T}\frac{1}{1+R_{t+j}}\right)P_{t+T}\right]. \tag{1}$$

where R_{t+j} is the required net return on the stock between periods $t+j-1$ and $t+j$. In log-linear form (less a constant) the stock pricing equation can then be written as:

$$p_t = E_t\left[\sum_{i=1}^{\infty} \rho^{i-1}\left[(1-\rho)d_{t+i} - r_{t+i}\right]\right] + E_t\left[\lim_{T\to\infty}\left(\rho^T p_{t+T}\right)\right], \tag{2}$$

where logs of variables are denoted by lowercase letters, $r_{t+1} = \log(1+R_{t+1})$, and ρ is a parameter of the linearization defined as $\rho \equiv 1/\left(1+\exp(\overline{d-p})\right)$, where $\left(\overline{d-p}\right)$ represents the long-run average log dividend-price ratio (such that $0 < \rho < 1$) (Campbell et al., 1996).[2]

To introduce an equity premium to the pricing equation we deduct the real risk-free rate r_t^f from both dividends and the required stock return. Hence, we can rewrite equation (2) in terms of excess dividends, $d_t^e = (1-\rho)d_t - r_t^f$, and excess returns (the equity premium) that compensate investors for holding risky equity instead of alternative safe investments, $r_t^e = r_t - r_t^f$:

$$p_t = \underbrace{E_t\left[\sum_{i=1}^{\infty} \rho^{i-1} d_{t+i}^e\right]}_{p_t^F} - \underbrace{E_t\left[\sum_{i=1}^{\infty} \rho^{i-1} r_{t+i}^e\right]}_{ep_t} + \underbrace{E_t\left[\lim_{T\to\infty}\left(\rho^T p_{t+T}\right)\right]}_{p_t^B} \tag{3}$$

Thus, the stock price reflects the expected discounted value of future excess dividends (what we label the fundamental component, p_t^F), an equity risk premium (ep_t) measured by the discounted value of expected future excess stock returns, and the expected terminal value which may give rise to mispricing, p_t^B.

Mispricing in stock markets then depends on how agents form their expectations. In the rational expectations framework, the rate at which the expectation of the terminal value converges to zero determines whether the current stock price accurately reflects the stock's risk-adjusted fundamental value. Mispricing – or a *rational bubble* – in stock markets can then only result from a violation of the transversality condition, i.e. $p_t^B = E_t\left[\lim_{T\to\infty}\left(\rho^T p_{t+T}\right)\right] \neq 0$.[3]

However, mispricing may also arise when some share of investors are irrational (Campbell & Vuolteenaho, 2004). To see this we follow Brunnermeier & Julliard (2008) and assume that some investors hold subjective expectations, denoted by $\tilde{E}_t$, which may deviate from the objective expectations E_t that are consistent with the rational processing of objective data.[4] Replacing the objective expectations of rational investors in equation (3) with the subjective

[2] Campbell et al. (1996) show that the average dividend-price ratio has been about 4% annually in U.S. data. In our empirical decomposition we thus impose $\rho = 0.96$.

[3] This mispricing, when all investors are rational and are fully aware of the mispricing, can be explained in the context of overlapping generations models (see the survey of Stiglitz (1990) for a longer discussion) or in the context of intrinsic bubbles, as introduced by Froot & Obstfeld (1991).

[4] For a further elaboration on this concept, see Manski (2004) and Brunnermeier & Parker (2005).

expectations of irrational investors yields

$$p_t = \tilde{E}_t \left[\sum_{i=1}^{\infty} \rho^{i-1} d^e_{t+i} \right] - \tilde{E}_t \left[\sum_{i=1}^{\infty} \rho^{i-1} r^e_{t+i} \right] + \tilde{E}_t \left[\lim_{T\to\infty} \left(\rho^T p_{t+T} \right) \right]. \tag{4}$$

With both rational and irrational investors present, the observed stock price p_t results from the beliefs and actions of both types of investors so that (3) and (4) must hold in each period. In the presence of irrational investors, the observed stock price may, however, differ from the true fundamental value determined by objective expectations when the transversality condition holds. For instance, if irrational investors expect higher excess dividends the current stock price rises. Rational investors support this higher price level by adjusting their expectations about future excess returns ($E_t \left[\sum_{i=1}^{\infty} \rho^{i-1} r^e_{t+i}\right]$) downwards. As a result, the observed price corresponds to the expectations of all investors even though the expected paths of future surplus dividends and risk premia may differ across investor types (Brunnermeier & Julliard, 2008).

This framework thus allows us to describe the occurrence of mispricing not only in terms of a rational bubble but also as the difference between the subjective expectations of irrational investors and the objective expectations of rational investors at the observed current price p_t.[5] To see this, equate equations (3) and (4) and rearrange to get:

$$p^B_t = (\tilde{E}_t - E_t) \left[\sum_{i=1}^{\infty} \rho^{i-1} d^e_{t+i} \right] - (\tilde{E}_t - E_t) \left[\sum_{i=1}^{\infty} \rho^{i-1} r^e_{t+i} \right] + \tilde{E}_t \left[\lim_{T\to\infty} \left(\rho^T p_{t+T} \right) \right] \tag{5}$$

The two potential sources of mispricing carry different implications for the role of monetary policy in affecting the mispricing or bubble component in stock prices. As discussed in Galí (2014), a rational bubble can only be sustained (that is, the discounted terminal value does not to shrink to zero) if the mispricing component grows at the required rate of return on stocks $(1 + R_{t+j})$ in expectation in the long-run. Since both the risk-free interest rate and the expected equity premium are predicted to increase in response to a contractionary policy shock (as discussed in the next section), an increase in the policy rate will then raise the expected long-run growth rate of the bubble component and thus *exacerbate* mispricing under this framework.[6]

[5] The latter form of mispricing finds support by Adam et al. (2015) who show that subjective belief dynamics can temporarily delink stock prices from their fundamental value. For a further extensive survey on the literature relating speculative behavior to irrational and behavioral factors, see Scherbina (2013).

[6] This holds, however, only in expectation for each period *after* the policy shock. On impact, the response of a rational bubble component is, in fact, indeterminate. See Galí (2014) for a discussion of this issue.

In contrast, the mispricing component arising from differences in beliefs between rational and irrational investors is inherently indeterminate. Accordingly, the response of the mispricing component to a monetary policy shock is also indeterminate. As a result, the effect of monetary policy on mispricing in stock markets thus remains an empirical question.

3 Empirical model and identification

3.1 A structural VAR model for mispricing in stock markets

We address this question using a structural vector autoregression (SVAR) model to estimate the effect of monetary policy (in particular changes to the federal funds rate) on stock prices, expected excess dividends, and the expected equity premium. Our empirical model thus takes the general form

$$\mathbf{y}_t'\mathbf{A}_0 = \mathbf{c} + \sum_{l=1}^{m} \mathbf{y}_{t-l}'\mathbf{A}_l + \varepsilon_t' \qquad \text{for } 1 \leq t \leq T \tag{6}$$

where $\mathbf{y}_t$ is a $K \times 1$ vector of endogenous variables, $\mathbf{A}_l$ is a $K \times K$ matrix of structural parameters for $0 \leq l \leq m$, and $\mathbf{c}$ is $1 \times K$ vector of constants. The $K \times 1$ vector of structural shocks, ε_t, is normally distributed with mean zero and covariance matrix $\mathbf{I}_K$. The reduced-form VAR implied by equation (6) is $\mathbf{y}_t' = \mathbf{c} + \sum_{l=1}^{m} \mathbf{y}_{t-l}'\mathbf{A}_l\mathbf{A}_0^{-1} + u_t'$, where $u_t' = \varepsilon_t'\mathbf{A}_0^{-1}$ and $E_t[\mathbf{u}_t\mathbf{u}_t'] = \Sigma = (\mathbf{A}_0\mathbf{A}_0')^{-1}$. As Galí & Gambetti (2015), we specify the model with $m = 4$ lags of endogenous variables.

In order to estimate the effect of monetary policy on the mispricing component, p_t^B, we rely on our framework outlined in the previous section. Rearranging equation (3) yields:

$$p_t^B = p_t - \left(\underbrace{E_t\left[\sum_{i=1}^{\infty} \rho^{i-1} d_{t+i}^e\right]}_{p_t^F} - \underbrace{E_t\left[\sum_{i=1}^{\infty} \rho^{i-1} r_{t+i}^e\right]}_{ep_t} \right). \tag{7}$$

Thus, to back out the effect of a monetary policy shock on the mispricing component in stock prices, we need to estimate

$$\frac{\partial p_t^B}{\partial \varepsilon_t^m} = \frac{\partial p_t}{\partial \varepsilon_t^m} - \left(\frac{\partial p_t^F}{\partial \varepsilon_t^m} - \frac{\partial ep_t}{\partial \varepsilon_t^m} \right) \tag{8}$$

where ε_t^m is the monetary policy shock in ε_t.

The main challenge for our framework is that the fundamental component p_t^F and the equity risk premium ep_t reflect expectations about future excess dividends and excess equity returns and are hence not directly observable. To estimate the effect of a monetary policy shock on these expectations, we therefore follow a broad literature initiated by Campbell (1991) and used by Bernanke & Kuttner (2005), Brunnermeier & Julliard (2008) and Galí & Gambetti (2015) and take the (conditional) forecasts from a (S)VAR model about d_{t+i}^e and r_{t+i}^e. In line with our framework, these (conditional) forecasts can be interpreted as the objective expectations $E_t[d_{t+i}^e]$ and $E_t[r_{t+i}^e]$ consistent with the rational processing of data.

Our empirical model thus includes three blocks of variables. First, we include a measure of (log) output y_t, the (log) price level Π_t, and the policy variable i_t (the effective federal funds rate) to identify a Taylor rule-type monetary policy shock. Second, we add the real S&P500 stock price index p_t, realized (log) real dividends d_t, and the risk-free rate measured by the nominal 10-year U.S. government bond rate. From the responses of these variables, we can back out the response of excess dividends $d_t^e = (1-\rho)d_t - r_t^f$ and the excess equity return $r_t^e = r_t - r_t^f$. Finally, we add the BAA-AAA corporate bond spread cbs_t. This spread serves as a measure for expected default risk in the economy and is likely to correlate with the expected equity risk premium and help improve its (conditional) forecasts (Campbell et al., 2013).[7] Furthermore, Caldara & Herbst (2019) show that the Federal Reserve systematically responds to tighter credit market conditions (as proxied by the corporate bond spread) by easing monetary policy. As the authors show, failing to account for this response leads to a significant attenuation in the estimated dynamic effects of monetary policy on economic activity and prices.

3.2 Identification of monetary policy shocks

The simultaneity issue in identifying monetary policy shocks in the presence of financial variables is commonly known in the literature (Rigobon & Sack, 2004; Bjørnland & Leitemo, 2009; Lütkepohl & Netsunajev, 2014; Gertler & Karadi, 2015). This is also demonstrated in Galí & Gambetti (2015), who find that their empirical results are not robust to alternative assumptions used to identify the structural shocks ε_t. Specifically, the authors obtain contradictory results on the effect of monetary policy shocks on stock prices depending on whether or not they assume that the central bank responds within the same quarter to stock

[7] Our results change only marginally when adding the price-to-earnings ratio as suggested by Campbell et al. (2013) to help for forecast future dividends or required returns.

price changes (by a calibrated coefficient) or not. Allowing for contemporaneous responses of stock prices to monetary policy shocks, and of the interest rate to stock price shocks is hence crucial for our analysis.

We thus build on the identification scheme proposed by Arias et al. (2019) to identify monetary policy shocks. By imposing relatively agnostic sign restrictions on both the contemporaneous effect of monetary policy and on the systematic, contemporaneous response of the federal funds rate to selected variables in our model, this approach allows us to identify monetary policy shocks without having to impose any zero-restrictions on the contemporaneous links between stock prices and the policy rate.

Table 1 summarizes our identifying assumptions about the contemporaneous relationships between the variables in the VAR and monetary policy. With respect to the effects of a monetary policy shock, we first assume that output and inflation fall in response to a contractionary monetary policy shock as commonly found in the empirical literature and as captured in standard New-Keynesian DSGE models used for monetary policy analysis (e.g. Christiano et al. 1999; Canova & Nicolo 2002; Smets & Wouters 2007; Coibion 2012; Gertler & Karadi 2015). Further, we impose that a monetary policy tightening raises not only the short-term policy rate but also the nominal risk-free rate (here the 10-year treasury interest rate). This reflects the assumption that a change at the short end of the yield curve lifts nominal yields across the whole curve (at least marginally) (Bernanke & Kuttner, 2005). Last, we assume that dividends fall in response to a monetary policy shock whilst the corporate bond spread rises.[8]

These restrictions are imposed for two reasons. First, we want to give the fundamental factors (dividends and the nominal risk-free rate) the best possible chance of explaining any decline in equity prices we may observe. Second, these restrictions are consistent with economic theory and existing empirical evidence. The fundamental factor falls on the back of lower future economic growth, which lowers corporate profits and future dividend payouts. Moreover, a growing literature shows that monetary policy influences broader credit conditions not only by changes in the risk-free interest rate but also by changes in risk premia (Bernanke & Kuttner, 2005; Gertler & Karadi, 2015; Drechsler et al., 2018; Caldara & Herbst, 2019). In line with this literature, we therefore impose that a monetary tightening raises credit spreads.

Following Arias et al. (2019), we augment these identifying assumptions by further imposing restrictions on the *systematic* component of monetary policy. These restrictions

[8]We leave the response of dividends unrestricted in a later robustness exercise.

Table 1: Identifying restrictions

	Monetary Policy	
Variable	Effects (ε_t^m)	Response (Δi_t)
Policy rate (i_t)	+	
Output (y_t)	−	+
Price level (Π_t)	−	+
Stock price (p_t)	?	+
Dividends (d_t)	−	?
10-Year Treasury rate (r_t^F)	+	?
Corporate Bond Spread (cbs_t)	+	−

The table shows the imposed impact responses of the variables in the benchmark VAR to a monetary policy shock ε_t^m (first column), and the imposed systematic response of the federal funds rate to changes in the variables in our system (second column). Entries denoted with by a "?" are left unconstrained.

help to ensure that the policy rate responds to changes in the other variables as commonly assumed. In particular, we impose that the federal funds rate rises when output or inflation increase (all else equal) in line with standard Taylor-type interest rate rules and as modeled in standard New Keynesian DSGE models. Furthermore, and in line with Caldara & Herbst (2019), we restrict the fed funds rate to fall when financial conditions tighten exogenously as indicated by an increase in the corporate bond spreads. Finally, in our baseline model, we add the restriction that monetary policy responds to an increase in stock prices by increasing the policy rate in line with evidence found in Aastveit et al. (2021). This may be because higher stock prices have a causal, stimulatory effect via household wealth and firm valuations, or because stock prices proxy for additional forward-looking information that the Federal Reserve responds to but that are not included in our model. Importantly, this last restriction is a key deviation from the identifying assumptions in Galí & Gambetti (2015). To explore the relevance of this restriction, we allow the contemporaneous response to be estimated freely in a later robustness exercise.

4 Results

We estimate our model based on sample information from 1962:Q1 to 2018:Q4.[9] We use real GDP and its deflator as measures of output and the price index, respectively.[10] Due to

[9]We estimate the model following the specifications of Arias et al. (2019) and require 1,000 successful draws that fulfill our sign restrictions.

[10]The responses of asset prices and the underlying fundamentals are robust to including variables typically employed to capture expected inflation, such as commodity prices and non-energy commodity prices.

the impact of the effective lower bound since 2009 and the extensive use of unconventional monetary policy measures by the Federal Reserve, we use the shadow rate estimated by Wu & Xia (2014) for the period from 2009:Q1 to 2015:Q4 instead of the effective federal funds rate. We also test the robustness of our results by ending the sample in 2008:Q4 or limiting our sample like Galí & Gambetti (2015) to 2011:Q4.

To provide some perspective of the estimated overall effects of a monetary policy shock, we first show the cumulative impulse responses of real GDP, the price level, the federal funds rate and the corporate bond spread to a 100 basis point contractionary policy shock (Figure 1). Overall, the estimated dynamic responses are in line with our expectations. A policy tightening is strongly contractionary with the peak effect being observed after around two years. The price level, however, does not respond significantly beyond the imposed impact effect. The policy rate returns to its pre-shock level after around two years. Finally, the corporate bond spread rises significantly by around 15 basis points for around two years in line with Caldara & Herbst (2019), before returning to its previous level. These estimated dynamic responses, with the possible exception of the price level response, give us comfort that our dynamic model is appropriately specified.

Figure 2 shows the impulse responses of main interest. In line with the majority of the empirical literature, but in contrast to Galí & Gambetti (2015), we find that stock prices fall sharply and persistently in response to a monetary policy tightening. On impact, stock prices fall by around six per cent, and continue to fall to around twelve per cent over the next three quarters. This corresponds roughly to the stock price response to an unexpected tightening of monetary policy also estimated by Bernanke & Kuttner (2005). Note that the negative sign of this impact response was not imposed but estimated freely.

The next four panels show the responses of the drivers of this stock price decline. We estimate that the real risk-free rate rises initially by around 20 basis points but quickly returns to slightly above its pre-shock level for the remainder of the impulse horizon. Real dividends, on the other hand, fall sharply and more strongly than real GDP after about two years, by a cumulative total of about five percent. However, due to the role of the discounting factor $\rho = 0.96$, *excess* dividends ($d_t^e = (1-\rho)d_t - r_t^f$) are primarily driven by the response of the risk-free rate, falling sharply on impact and then quickly returning to just below their pre-shock level. Accordingly, the fundamental component alone (excluding the

Therefore, these are excluded in order to reduce the computational burden. Most data is obtained from Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis, available at `http://research.stlouisfed.org/fred2/`. S&P500 data and dividends are from Shiller (2005), available at `http://www.econ.yale.edu/~shiller/data.htm`. All series are deflated by the U.S. Consumer Price Index for All Urban Consumers.

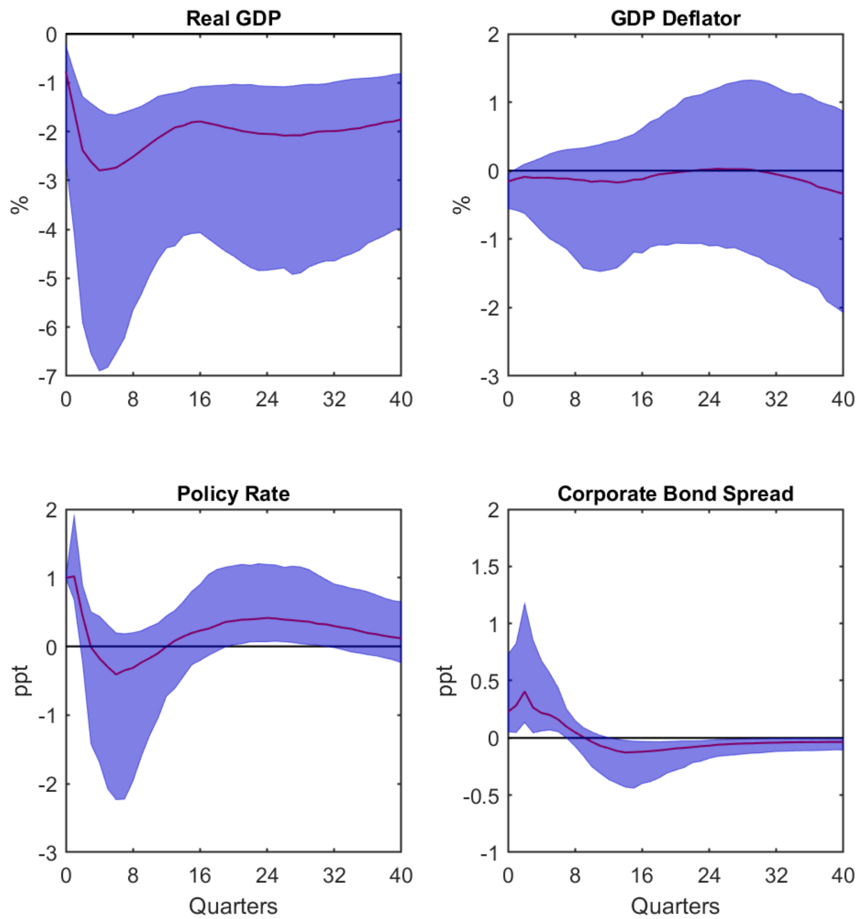

Figure 1: Responses of real GDP, the GDP deflator, the Wu & Xia (2014) shadow rate, and the corporate bond spread to a 100 bps contractionary monetary policy shock. Solid red lines show the median impulse response to the monetary policy shock, the shaded area denotes the 68% credible set.

equity risk premium) is estimated to explain only around a quarter of the fall in stock prices at any horizon (panel 6). This estimated contribution is smaller than the one estimated by Bernanke & Kuttner (2005).

With future expected excess dividends and the real rate explaining only little of the overall stock price fall, the remainder must be driven by either a large rise in the equity risk premium or a fall in the mispricing component. However, and in contrast to expectations, we find that the equity risk premium ($ep_t = E_t\left[\sum_{i=1}^{\infty} \rho^{i-1} r^e_{t+i}\right]$) *falls* initially. This is driven by both the increase in the risk-free rate and the expectation of further capital losses over the next few quarters as seen in the differential of the cumulative stock price response (top left panel). Once these initial losses have passed and the stock price index has troughed, the equity risk premium is positive, reflecting expectations of future capital gains. Adding the initial rise in the equity risk premium to the fundamental component suggests an initial *increase* in stock prices in response to a policy tightening (the risk-adjusted fundamental component, panel 7). The subsequent increase in the risk premium, however, pushes the risk-adjusted fundamental component into negative territory. From the first quarter after the shock, we thus find that all fundamental factors together explain around half of the total fall in stock prices, with the largest contribution coming from the equity risk premium.

This leaves around half of the overall stock price response unexplained. We therefore conclude that a 100 basis point increase in the policy rate lowers real stock prices by around twelve per cent, of which around six percentage points are due to a significant decline in the mispricing component. This finding extends the results of Bernanke & Kuttner (2005), but is in direct contrast to the finding of Galí & Gambetti (2015).

We thus conclude that a central bank could lean against the wind of stock price bubbles by raising its policy rates. However, our findings also suggest that such a policy comes at significant costs in terms of output losses. It is hence questionable whether the benefits of such a policy exceed the costs. We leave this question for further research.

5 Robustness

We first assess the robustness of our results to alternative identifying assumptions and a shorter sample period excluding the global financial crisis. The considered specifications are outlined in Table 2 in the Appendix. For reasons of space, Figure 3 only shows the responses of the stock price index and the mispricing component, all remaining results are available on request.

When we relax the assumption that monetary policy responds to a rise in stock prices by raising the federal funds rate and leave this response unrestricted instead, the range of estimated responses remains largely unchanged (specification 'RB1'). However, the response of the mispricing component is no longer significant. Furthermore, the estimated response of stock prices is robust when leaving the impact response of dividends ('RB2') or dividends and the risk-free interest rate ('RB3') unconstrained. But also here the reaction of the mispricing component proves to be no longer significant. Finally, we estimate the model over the sample preceding the global financial crisis only ('Excl GFC'). Again, the size of the estimated responses of the stock price and the mispricing component remain largely unchanged, yet the mispricing response turns insignificant. Overall, however, all estimated

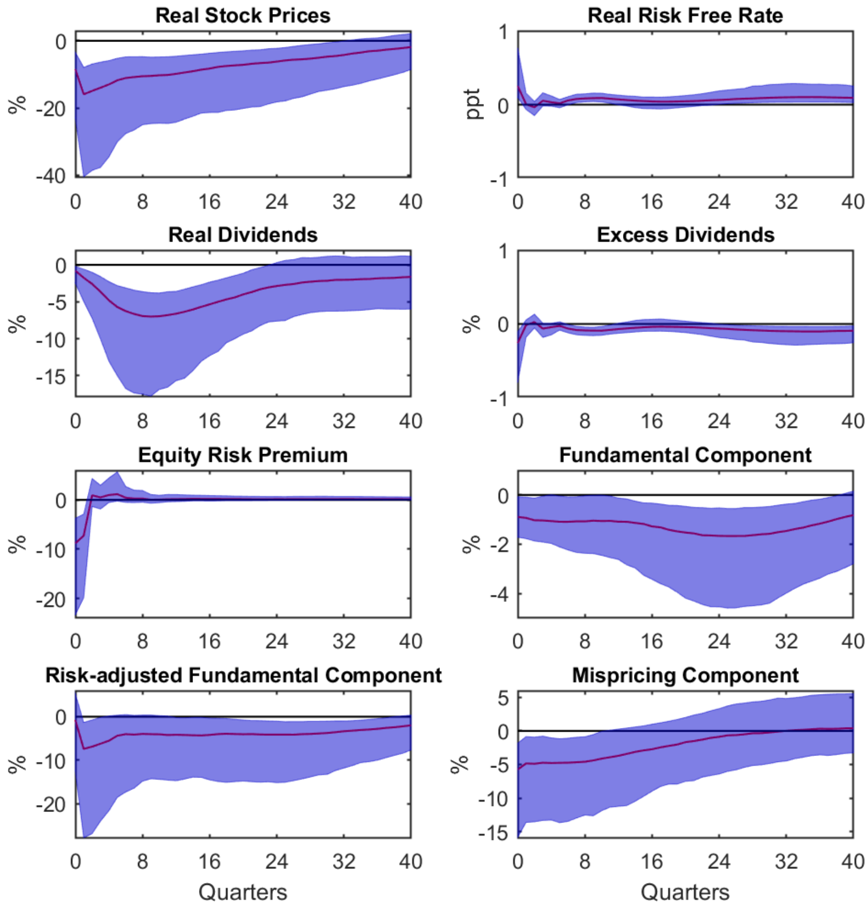

Figure 2: Responses of the S&P500 index, expected excess dividends, the expected equity premium, and the implied fundamental, risk-adjusted fundamental and mispricing components to a 100 bps contractionary monetary policy shock. See Figure 1 for further notes.

mispricing responses remain negative. Accordingly, in no specification can we confirm the result of Galí & Gambetti (2015) that an increase in the federal funds rate increases the mispricing component in stock prices.

Finally, we examine in more detail why our results are diametrically opposite to the main results of Galí & Gambetti (2015). The differences in the results may result from three main sources. First, our results are obtained when using a longer sample period than the 1962:Q1-2011:Q4 period used by Galí & Gambetti (2015). Second, the reduced-form model specifications differ. Galí & Gambetti (2015) do not specifically account for the presence of a time-varying equity risk premium and approximate the real risk-free rate with the real federal funds rate. Accordingly, their model does not include a long-term government bond yield nor the corporate bond spread. With less core variables in their model, the authors

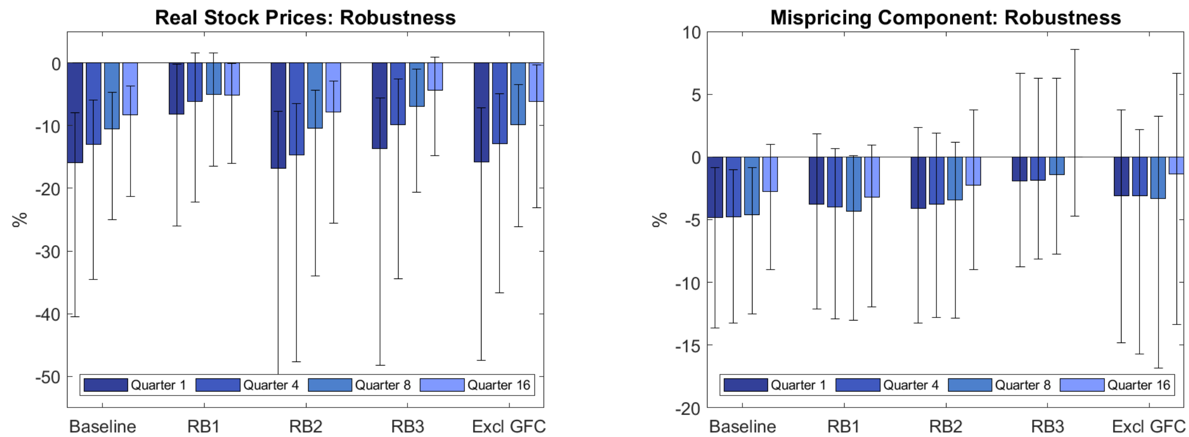

Figure 3: Median responses and 68% credible sets of the S&P500 index (left) and the mispricing component (right) to a 100 bps contractionary monetary policy shock for four selected horizons and five different model specifications (see Table 2).

include the commodity price index to capture a possibly relevant predictor for inflation. Moreover, their model is estimated in log-differences instead of log-levels. And third, they use a different identification strategy. As outlined above, they identify monetary policy shocks from a Cholesky decomposition of the impact matrix, assuming that monetary policy does respond to stock price changes within the same quarter. To investigate the source of the difference in results, we continue with the identification scheme proposed by Arias et al. (2019) and implement additional characteristics of the framework of Galí & Gambetti (2015) sequentially (see Table 3 in the Appendix).

We find that our result of a significant and sizeable negative response of stock prices to an increase in the policy rate is primarily due to our agnostic identification strategy (Figure 4).[11] That being said, in no model specification do we find evidence that monetary policy *raises* the mispricing component as found by Galí & Gambetti (2015). Using their empirical model specification and assuming that monetary policy does *not* respond to changes in stock prices, we also find a small and temporary decline in stock prices and the mispricing component (Specification 'GG1'). Allowing for *any* response of the federal funds rate to stock prices, the responses of stock prices and mispricing are even smaller ('GG2'). However, when we impose the assumption that monetary policy responds to an increase in stock prices by raising the federal funds rate, we recover our main results even using the same model specification as Galí & Gambetti (2015) ('GG3'). Estimating the model in log-differences or log-levels leaves the main results unchanged ('GG3 level').

[11]'Baseline' shows the results from our preferred specification discussed above and shown in Figures 2 and 3.

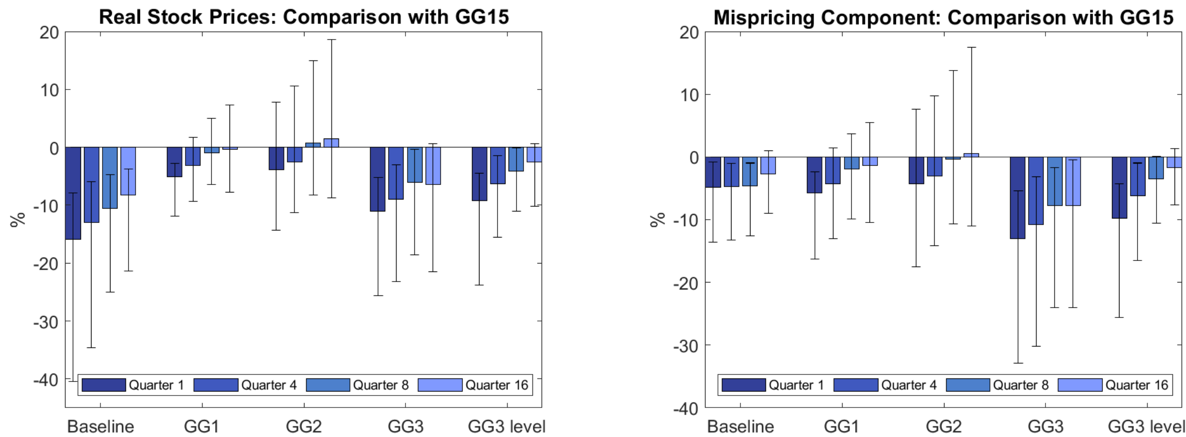

Figure 4: Median responses and 68% credible sets of the S&P500 index (left) and the mispricing component (right) to a 100 bps contractionary monetary policy shock for four selected horizons for model specifications following Galí & Gambetti (2015) (see Table 3).

6 Conclusion

In this paper, we explore the effects of monetary policy on stock prices and on their underlying fundamental components. By allowing for the possibility of stock mispricing, we address the question whether central banks could implement a leaning against the wind policy to attenuate excessive stock price developments. We show that stock prices decrease significantly and persistently in response to a monetary policy tightening. Decomposing this response into a fundamental component related to rational expectations about future discounted dividends and an expected equity risk premium, we find that these sources can only account for about half of the immediate fall in stock prices. Hence, we conclude that the other half of the decrease in stock prices can be attributed to a systematic negative response of the mispricing component. By this, we provide support to the claims of proponents of an active, leaning against the wind monetary policy. If stocks are overpriced, contractionary monetary policy could be used to lower mispricing. However, this comes at the cost of a sizable contraction in economic activity. It is therefore debatable whether conventional interest rate policy is the right tool to dampen excessive stock mispricing at all times or whether interest rates are too blunt a tool to cost-effectively reduce mispricing in stocks.

We further note that our findings are difficult to align with the predictions from the rational bubbles framework. This framework employed by the previous literature predicts that the mispricing component increases in response to a contractionary monetary policy shock in the long-run. Our findings, however, can be aligned with a framework in which a share of investors are irrational and hold false subjective expectations about the stock's underlying fundamentals. Such a framework may host a range of possible behavioral explanations such as adaptive expectations based on realized capital gains in the past, for example.

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Table 2: Identifying restrictions - Robustness

Specification	Monetary Policy	Variable							Sample
		y_t	Π_t	i_t	p_t	d_t	r_t^F	cbs_t	
Baseline	Response (Δi_t)	+	+		+	?	?	−	Full
	Effects (ε_t^m)	−	−	+	?	−	+	+	
RB1	Response (Δi_t)	+	+		**?**	?	?	−	Full
	Effects (ε_t^m)	−	−	+	?	−	+	+	
RB2	Response (Δi_t)	+	+		+	?	?	−	Full
	Effects (ε_t^m)	−	−	+	?	**?**	+	+	
RB3	Response (Δi_t)	+	+		+	?	?	−	Full
	Effects (ε_t^m)	−	−	+	?	**?**	**?**	+	
Excl GFC	Response (Δi_t)	+	+		+	?	?	−	1962:Q1-2008:Q4
	Effects (ε_t^m)	−	−	+	?	−	+	+	

The table shows the imposed signs of systematic response of the federal funds rate to changes in the variables in the system, and of the impact responses of the variables in the benchmark VAR to a monetary policy shock ε_t^m. Entries denoted with by a "?" are left unconstrained.

Table 3: Identifying restrictions - Robustness

Specification	Monetary Policy	Variable y_t	Π_t	p_t^C	i_t	p_t	d_t	r_t^F	cbs_t	Sample
Baseline	Response (Δi_t)	+	+	n.a.		+	?	?	−	Full
	Effects (ε_t^m)	−	−	n.a.	+	?	−	+	+	
GG1	Response (Δi_t)	+	+	?		**0**	?	n.a.	n.a.	1962:Q1-2011:Q4
	Effects (ε_t^m)	−	−	?	+	?	−	n.a.	n.a.	
GG2	Response (Δi_t)	+	+	?		**?**	?	n.a.	n.a.	1962:Q1-2011:Q4
	Effects (ε_t^m)	−	−	?	+	?	−	n.a.	n.a.	
GG3	Response (Δi_t)	+	+	?		+	?	n.a.	n.a.	1962:Q1-2011:Q4
	Effects (ε_t^m)	−	−	?	+	?	−	n.a.	n.a.	
GG3 level	Response (Δi_t)	+	+	?		+	?	n.a.	n.a.	1962:Q1-2011:Q4
	Effects (ε_t^m)	−	−	?	+	?	−	n.a.	n.a.	

The table shows the imposed signs of systematic response of the federal funds rate to changes in the variables in the system, and of the impact responses of the variables in the benchmark VAR to a monetary policy shock ε_t^m. Entries denoted with by a "?" are left unconstrained. 'Baseline' shows the results from our preferred specification shown in Figures 2 and 3. 'GG1' to 'GG3' show the specification following Galí & Gambetti (2015) with real GDP (y_t), the GDP deflator (Π_t), the commodity price index (p_t^C), real stock prices p_t, and dividends (d_t) specified in log-differences. 'GG3 level' replicates 'GG3' but with all variables in (log) levels.