Policymakers' Uncertainty

Anna Cieslak Stephen Hansen Michael McMahon Song Xiao*

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Uncertainty is a ubiquitous concern emphasized by policy-makers. We study how uncertainty affects decision-making by the Federal Open Market Committee (FOMC). We distinguish between the notion of the Fed-driven uncertainty that is induced by the policy choice and the classic notion of uncertainty that emanates from within the economy and which the Fed takes as given. A simple theoretical framework illustrates how the Fed-driven uncertainty introduces a wedge between the standard Taylor-type rule and the optimal decision. Using internal Fed deliberations, we provide the first quantification of the types of uncertainty that the Fed perceives and their effects on the policy stance. The FOMC members' uncertainty about inflation strongly predicts a more hawkish policy stance that is not explained either by the internal Fed's forecasts or by the measures of public uncertainty. In contrast, policymakers' uncertainty about growth has no impact on policy decisions beyond these standard controls. Consistent with a model of inflation scares, policymakers' inflation uncertainty reflects their constant worries about losing the nominal anchor. We argue that the desire to maintain inflation credibility is an important driver of the FOMC's decisions and provide evidence from the FOMC transcripts consistent with this channel.

*Cieslak: Duke University, Fuqua School of Business, NBER and CEPR, e-mail: anna.cieslak@duke.edu; Hansen: Imperial College London and CEPR, e-mail: stephen.hansen@imperial.ac.uk; McMahon: University of Oxford, CEPR, and CfM (LSE), email: michael.mcmahon@economics.ox.ac.uk; Xiao: London School of Economics, email: s.xiao2@lse.ac.uk. We thank Andy Abel, Nick Bloom, Marc Giannoni, Cam Harvey, Urban Jermann, Karel Mertens, Emanuel Moench, David Lucca, Ali Ozdagli, Ricardo Reis, Eric Swanson, and Irina Zviadadze, and conference and seminar participants at various institutions for helpful comments. Hansen gratefully acknowledges financial support from the European Research Council (Consolidator Grant Agreement 864863). McMahon gratefully acknowledges financial support from the European Research Council (Consolidator Grant Agreement 819131).

I. Introduction

Alan Greenspan famously said, "(...) uncertainty is not just a pervasive feature of the monetary policy landscape; it is the defining characteristic of that landscape" (Greenspan, 2004). Yet, despite the ubiquitous emphasis on uncertainty in central bankers' speeches and statements, we know little about how policymakers' uncertainty and, more broadly, their beliefs about higher-order moments of economic outcomes affect policy decisions. In this paper, we evaluate how uncertainty affects policy in the context of the decision-making by the Federal Open Market Committee (FOMC). To do so, we overcome important theoretical and empirical challenges.

Theoretically, the effect of uncertainty on monetary policy is ambiguous. In a frequently-quoted result, Brainard (1967) postulated that policymakers should adopt a more conservative stance when faced with uncertainty. However, the theoretical predictions are highly model-specific: depending on the assumptions about the structure of the economy and policymakers' preferences, uncertainty can induce a more or less aggressive optimal policy response or no response at all.

We introduce a general framework in which we highlight two broad types of uncertainty that impact policy, which we refer to as the Fed-driven uncertainty and the economic uncertainty. The Fed-driven type is the uncertainty about the variables that the Fed targets, such as output and inflation, that is induced by the policy choice itself. While many existing models of monetary policy under uncertainty implicitly capture this channel, the ambiguous predictions from this literature are easy to explain in our framework based on the way in which policy affects the degree of uncertainty. One important example of the Fed-driven uncertainty relates to the Fed's concern about low-probability but costly outcomes, where the probability of those outcomes depends on the policy choice. We argue that policymakers are particularly worried about the risk of losing their hard-earned credibility if they do not take a strong enough stance on inflation. We then empirically show that the Fed-driven uncertainty of this kind has been a hallmark of the Fed's decision making since the 1980s.

The second type of uncertainty emanates from the uncertainty inherent in the economy or financial markets, but importantly, it is not affected directly by the policy choice. Instead, this channel operates *through* the level of target variables and policy reacts to it only because of its impact on the variables that the Fed cares about.

Motivated by this framework, we then provide the first set of empirical results on how, if at all, the different uncertainty types affect the Fed's behavior. The challenges to answering this question pertain to both measuring policymakers' perceptions of uncertainty and disentangling their effect from other confounders, most importantly, the first-moment beliefs

about the state of the economy. Our empirical approach relies on analyzing the deliberations of the Federal Open Market Committee (FOMC) recorded in the transcripts of the scheduled FOMC meetings between 1987 and 2015. Given the wealth of information that is available, the FOMC setting is well-suited to study the impact of uncertainty on decision-making. At each meeting, we observe nearly verbatim statements by individual FOMC members and the Federal Reserve Board staff.

The richness of this information allows us to construct the three kinds of measures to describe the policymaking process. First, and most important for our analysis, we generate textual measures of FOMC policymakers' perceived uncertainty (PMU, for short) distinguishing uncertainty about inflation and real economy (as well as financial markets). For a precise attribution, we develop a set of algorithms that match uncertainty phrases with topic-specific phrases at a sentence level. Second, we construct measures of FOMC members' sentiment capturing their directional views on the economy and inflation. Third, to analyze the effects on policy, we develop a new textual measure of the policy stance based on the balance of hawkish and dovish language—the hawk-dove score—of the FOMC members. This approach allows us to span the entire 1987–2015 sample, including the zero-lower-bound period.[2] In addition, through the Greenbook (now Tealbook) forecasts prepared by the staff prior to each meeting, we also gain access to the baseline macroeconomic projections that policymakers are equipped with before they enter the meeting.

We exploit the typical structure of the FOMC meetings to derive the above measures. With minor exceptions, the meetings during our sample are comprised of two rounds, each serving different objectives. In the first round, which we refer to as the economy round, policymakers discuss the economic and financial market developments and the baseline outlook. This step lays the foundation for the second round—the policy round—which contains discussions about the appropriate policy choice and during which the policy decision takes place. We thus study how uncertainty and sentiment manifest in the economy round affect stance communicated in the policy round.

With the measures of the policymakers' beliefs and their policy stance, we provide new insights about the drivers of the decision-making at the FOMC. We find that uncertainty in the economy round of the meetings predicts policy stance even when controlling for the Greenbook forecasts and other public uncertainty measures such as VIX or economic policy uncertainty index of Baker et al. (2016).

[2]We document that the hawk-dove score varies in an intuitive way and is a highly significant predictor of the federal funds rate (FFR) target. Importantly, its predictive power for the FFR is not subsumed by the Greenbook forecasts that are usually included in estimated Taylor rules, which implies that the policy stance derived from the text reflects in large part deviations from the rule.

The key new insights stem from our ability to distinguish between the types of uncertainty, which we show to have distinct effects on policy. A higher real-economy and financial markets PMU predict a looser policy stance. To the extent that this type of uncertainty influences the economy akin to a negative demand shock, our result is broadly consistent with the standard real-options channel of uncertainty (e.g., Bloom, 2009). However, because the effect is generally subsumed by the Greenbook controls and public uncertainty measures, it also indicates that the staff forecasts largely incorporate the impact of this type of uncertainty on the economy and inflation.

By contrast, higher inflation PMU predicts a more hawkish policy stance, and its effect remains robust to controlling for a variety of plausible confounding factors. This finding suggests a new separate channel at work that has not been widely discussed in the literature: The FOMC members' desire to maintain credibility for inflation control is an important driver of the FOMC's decisions. To explore this idea further, we document that inflation PMU comoves much more closely with the positive inflation sentiment (i.e., perceptions of rising inflation) in the meeting than it does with the negative sentiment (i.e., perceptions of declining inflation). Consistent with credibility concerns introducing a wedge between objective and policymakers' perceived uncertainty, we then show that the FOMC members' inflation PMU is distinct from that of the Fed staff, and the effect of inflation PMU on policy stance is entirely driven by the FOMC members. However, given that neither inflation sentiment nor PMU predict future inflation outcomes, policymakers' inflation beliefs in the meeting are an expression of worry that does not materialize in the sample we study. We present narrative evidence from the transcripts' language consistent with this channel.

The issue of central bank efforts to maintain credibility is timely. Powell (2022), giving the remarks to open the 2022 Jackson Hole Symposium, spoke forcefully about the Fed's focus and determination regarding inflation control. Earlier, Goodfriend (1993) emphasized the role of "the acquisition and maintenance of credibility for its commitment to low inflation" during the Volcker and the early Greenspan Fed.[3] This concern with credibility is warranted. Indeed, credibility allows the FOMC to better manage economic expectations, as "achieving through word and deed" well-anchored inflation expectations can lead to better policy outcomes (Bernanke, 2022).

Therefore, our finding that the Fed-perceived inflation uncertainty affects policy on the basis of credibility concerns has important implications for how we model monetary policy decisions. Many standard New Keynesian models assume Full Information and Rational Expectations and are solved under the assumption that the central bank can, and *must*, commit to its policy reaction function. In such models, credibility is established by the once-

[3]Such concerns were modeled more formally by Orphanides and Williams (2005) and King and Lu (2022).

and-for-all announcement of the reaction function. This contrasts with the assumption of period-by-period discretion. Our results suggest the need for considering the role of central bank's fighting continually over time to establish credibility, and then using it to counter recessions when faced with adverse shocks. For instance, Debortoli et al. (2014) study imperfect commitment as a middle ground between commitment and discretion. Bianchi and Melosi (2018) consider constrained discretion in monetary policy in which the central bank is able to deviate from active inflation stabilisation temporarily but at the cost of unanchoring inflation expectations. Carvalho et al. (2022) consider expectation formation and the anchoring of longer-term inflation expectations. Relatedly, Gáti (2022) embeds a model of unanchored long-term inflation expectations in a general equilibrium New Keynesian model and finds the optimal policy is to be aggressive in the response to movements in long-run expected inflation. Our finding suggest that, over the 1987–2015 sample, the FOMC has been preemptively aggressive to prevent the *feared* changes in inflation expectations.

Our results also have implications for empirical analysis of monetary policy. In particular, the assumption of stable reaction functions seems unlikely. Clarida et al. (2000) estimated monetary policy reaction functions for the US before and after Volcker's tenure, concluding that the Fed was much more sensitive to expected inflation in the post-Volcker era. McMahon and Munday (2022b) show time-varying estimates of the FOMC reaction function are consistent with an FOMC that, having established a credible reputation for inflation fighting and in environment of anchored inflation expectations, is afforded more scope to support the economy. McMahon and Munday (2022a) present evidence that the FOMC switches between two modes of operation and that many surprises result from the endogenous switch from one mode (saving the economy) to the other (fighting inflation and building credibility). These findings are consistent with the earlier results in Cieslak (2018) and Bauer and Swanson (2020).

The remainder of the paper proceeds as follows. In Section II, we lay out the different theoretical channels proposed in the literature through which uncertainty can affect monetary policy and illustrate the effects of uncertainty on policy in a simple framework. In Section III, we discuss our empirical strategy, the measurement of policymakers' uncertainty (PMU), sentiment and policy stance from FOMC transcripts. In Section V, we analyze the effect of uncertainty and sentiment on policy stance. In Section VI, we study the properties of policymakers' perceptions of uncertainty. Section VII concludes.

II. Uncertainty and Optimal Monetary Policy

II.A. A simple static framework of policy choice

To clarify the impact that uncertainty might have on monetary policy choices, we introduce a simple static framework. Assume that a policymaker has a loss function over deviations of inflation from target and the output gap that has the standard quadratic form:

$$L(\pi, y) = (\tilde{\pi}_i)^2 + \lambda (\tilde{y}_i)^2, \tag{1}$$

where $\tilde{\pi}_i = \pi_i - \pi^*$, $\tilde{y}_i = y_i - y^*$, π^* is the inflation target and y^* is the medium-term potential output. The subscript i indicates that economic outcomes depend on policy.

Consider a policymaker who must choose an interest rate $r \in -1, 0, +1$ to minimise losses.[4] $r_0 \equiv r = 0$ is the interest rate choice corresponding to the baseline economic outlook (such as Alternative B in the FOMC Colorbooks). $r_{-1} (\equiv r = -1)$ corresponds to an easing of monetary policy relative to the baseline (Alternative A) and $r_1 (\equiv r = 1)$ is a tightening (Alternative C). Typically we can think of this choosing between levels of nominal interest rates, but it could also be driven by quantitative easing or tightening, or a change in the communication such as forward guidance.

Let there be uncertainty over economic outcomes, so that $\tilde{\pi} \sim G_\pi$ and $\tilde{y} \sim G_y$. We assume these distributions G are unimodal with finite variance. Let $\overline{x}_i$, $\hat{x}_i$, $\sigma^2_{x,i}$ denote the mean, mode, and variance of the distribution of outcome variable $x \in \{\tilde{\pi}, \tilde{y}\}$ under interest rate $r_i \in \{-1, 0, +1\}$.

Under higher (lower) interest rates, both inflation and output are lower (higher). We assume that the effect of tightening and loosening on inflation and output is symmetric and known. We model these impacts as linear and given by δ and ϕ respectively. That is, we assume that $(\overline{\pi}_1, \overline{y}_1) = (\overline{\pi}_0 - \delta, \overline{y}_0 - \phi)$ and $(\overline{\pi}_{-1}, \overline{y}_{-1}) = (\overline{\pi}_0 + \delta, \overline{y}_0 + \phi)$.

We also allow for the possibility that uncertainty itself is policy induced. That is, we can think about there being a baseline uncertainty about variable x given by σ^2_x, as well as component driven by the policy choice i, $\Delta\sigma_{x,i}$. Overall uncertainty is the policy-specific combination of these two components: $\sigma^2_{x,i} = \sigma^2_x + \Delta\sigma_{x,i}$; we shall assume $\Delta\sigma_{x,0} = 0$ so that baseline uncertainty is the uncertainty under the r_0 ($\sigma^2_{x,0} = \sigma^2_x$).

As is standard in these environments, decisions depend on expected losses. Let $\overline{L}_i$ be the expected loss from choosing r_i. The decision to tighten (loosen) monetary policy follows if $\overline{L}_1 < \overline{L}_0$ ($\overline{L}_{-1} < \overline{L}_0$) which is given by:

[4] It is often the case that policy decisions amount to a comparison of two plausible options (Hansen and McMahon, 2015), but it is also reasonable to think that a comprehensive policymaker would cycle through the possible alternatives comparing losses for each alternative until the lowest possible loss is achieved.

$$\overline{L}_1 < \overline{L}_0 : \delta\overline{\pi}_0 + \lambda\phi\overline{y}_0 > \frac{\delta^2 + \lambda\phi^2}{2} + \frac{\overbrace{(\sigma^2_{\pi,1} - \sigma^2_{\pi,0})}^{\equiv \Delta\sigma^2_{\pi,1}} + \lambda \overbrace{(\sigma^2_{y,1} - \sigma^2_{y,0})}^{\equiv \Delta\sigma^2_{y,1}}}{2} \tag{2}$$

$$\overline{L}_{-1} < \overline{L}_0 : -(\delta\overline{\pi}_0 + \lambda\phi\overline{y}_0) > \frac{\delta^2 + \lambda\phi^2}{2} + \frac{\overbrace{(\sigma^2_{\pi,-1} - \sigma^2_{\pi,0})}^{\equiv \Delta\sigma^2_{\pi,-1}} + \lambda \overbrace{(\sigma^2_{y,-1} - \sigma^2_{y,0})}^{\equiv \Delta\sigma^2_{y,-1}}}{2} \tag{3}$$

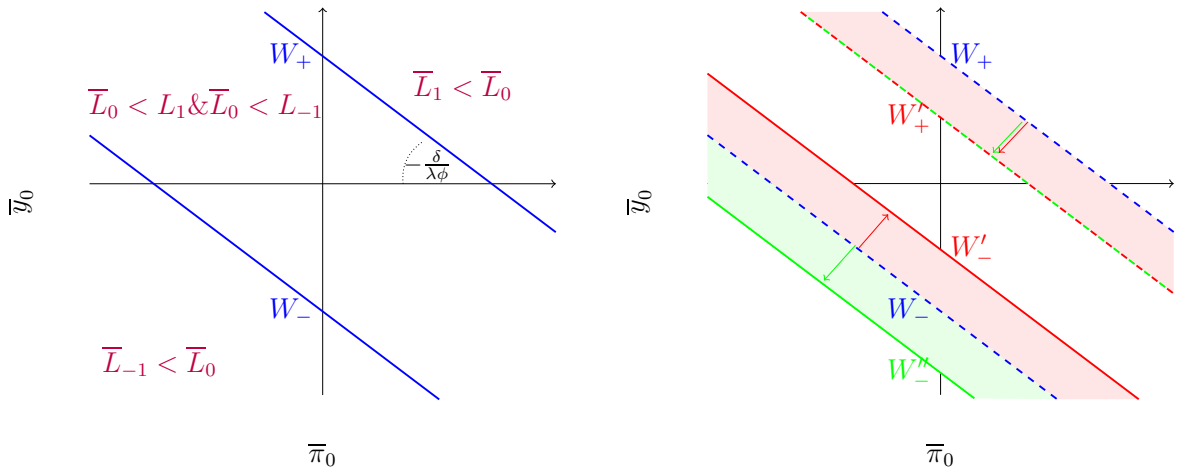
Equation (2) says that when the linear combination of the mean deviation of inflation from target and the deviation of output from its potential level under the accommodative policy r_0 is sufficiently high, the policymaker will choose to tighten monetary policy, r_1. Equation (2) makes clear that tighter policy will be more likely to be pursued as inflation and output are further above their reference values. Given our assumption on baseline uncertainty, the $\Delta\sigma^2_{x,1}$ terms, which measure the extra variance of variable x under r_1 relative to r_0, essentially play the role of shifting the burden of proof of the strength of economic conditions required to tighten policy.

Equation (3), the condition to loosen policy, is similar except the economic conditions term on the left hand side are multiplied by -1 and the extra variance terms compare the choice of r_{-1} relative to r_0 ($\Delta\sigma^2_{x,-1}$).

Figure 1 depicts a graphical representation of the decision rule for both tightening and loosening using an indifference curve. The slope of the decision boundary is determined by the relative sensitivity of output and inflation to the alternative interest rate, as well as the weight λ that the policymaker attaches to output.[5] Consider the blue curves in Panel A for which $\Delta\sigma^2_{\pi,1}$, $\Delta\sigma^2_{y,1}$, $\Delta\sigma^2_{\pi,-1}$, and $\Delta\sigma^2_{y,-1}$ are all zero. Points to the northeast of the upper line (intercept is $W_+ \equiv \frac{\delta^2+\lambda\phi^2}{2}$) represent combinations of inflation and output deviations under the baseline such that the policymaker will choose r_1 (r_0). Points to the southwest of the lower line (intercept is $W_- \equiv -\frac{\delta^2+\lambda\phi^2}{2}$) indicate where the policymaker will choose r_{-1}.

Panel B in figure 1 illustrates the effect of higher moments on the decision rule. When the baseline generates additional uncertainty of outcomes over either alternative ($\Delta\sigma^2_{x,1} < 0 \& \Delta\sigma^2_{x,-1} < 0$), the decision boundaries shift inwards and the policymaker prefers the alternative interest rate for a larger range of forecasts. This is shown as the red shift in the lines to intercepts W'_+ and W'_-; the red shaded area indicates the region in which the FOMC would previously choose no change, but would now choose to raise or lower depending on the value of the baseline economic outlook.

[5] To take an extreme case, suppose that the policymaker cares only about inflation so that $\lambda = 0$. Then, the curve in Figure 1 becomes vertical through $(\frac{\delta}{2}, 0)$, and r_1 is chosen whenever the inflation rate under the baseline is further from its target value than half the effect of changing rates ($(\pi_0 - \pi^*) > \delta/2$).



A: No Policy-Induced Uncertainty B: The Effect of Policy-Induced Uncertainty

Figure 1. Effect of Uncertainty on Decision Boundary These figures present the decision boundaries for a policymaker when the modal forecast is $\overline{\pi}_0$ and $\overline{y}_0$. The left figure is drawn for the case of $\Delta\sigma^2_{\pi,i} = \Delta\sigma^2_{y,i} = 0$. The right figure shows the effect of moving to a situation in which $\Delta\sigma^2_{\pi,i} \neq 0, \Delta\sigma^2_{y,i} \neq 0$.

If, instead, we assume that FOMC members believe that higher rates will reduce the variance ($\Delta\sigma^2_{x,1} < 0$) and lowering them will increase the variance ($\Delta\sigma^2_{x,-1} > 0$), then both curves shift to the southwest. This is captured in Panel B as having the same effect on the upper boundary, but the lower boundary shifts from W'_- to W''_- giving rise to the green line boundary line. In this case, the FOMC member will prefer a tighter policy compared with a situation in which there was no policy induced uncertainty effect.

Of course, there are numerous other possibilities which we don't plot explicitly here. This includes the situation in which the policymaker thinks that the effect of policy has offsetting effects on output volatility and inflation volatility under a particular policy stance. For example, if tightening policy increased the volatility to output ($\Delta\sigma^2_{y,1} > 0$) but reduced the volatility of inflation $\Delta\sigma^2_{\pi,1} < 0$), the net effect is ambiguous on the policy.

II.B. Channels through which uncertainty affects monetary policy

This simple framework admits three broad channels types of uncertainty effects. The first is the situation in which uncertainty has no effect on monetary policy – this is the well-known certainty equivalence result. The second is the case where uncertainty is itself a shock to economic conditions to which policy responds. The third is the case of policy-induced uncertainty whereby the extent of uncertainty is endogenous to the interest rate choice. We now explore each in turn.

II.B.1. No effect: Certainty Equivalence

The starkest prediction from economic theory about the effect of uncertainty on policy is that it does not matter at all. This result, known as certainty equivalence, emerges in many classic monetary models and is a standard property of a linear-quadratic environment: the structure of the economy is linear and the policymaker's loss function is quadratic. As such, the central bank reacts to its assessment of the economy in the same way no matter if policymakers' uncertainty about economic outcomes is high or low (see, e.g., Blinder (1999)).

In our decision rule above, *Certainty Equivalence* is the case when the level of uncertainty in output or inflation does not change the set of economic outcomes for which the policymaker prefers r_1 or r_{-1} over r_0. Since baseline uncertainties, given by $\sigma^2_{\pi,0}$ or $\sigma^2_{y,0}$, do not enter the decision rules above, this is the case $\Delta\sigma^2_{\pi,i} = \Delta\sigma^2_{y,i} = 0$. This leads to our first result:

Proposition 1. *Certainty Equivalence holds when the variance in outcomes is exogenous to the policy choice;* $\Delta\sigma^2_{\pi,i} = \Delta\sigma^2_{y,i} = 0$.

These conditions are typically present in monetary models in which shocks to π and y are exogenous and are independent of the policy choice.[6]

II.B.2. Uncertainty as shocks

Another channel, emphasized by a growing macro literature, pertains to how uncertainty affects economic agents outside the central bank. While specific theoretical mechanisms differ, rising uncertainty tends to act akin to a negative demand shock, causing a rapid drop, rebound, and overshoot in employment, output, and productivity growth (e.g., Bloom, 2009; Basu and Bundick, 2017; Leduc and Liu, 2016). In line with its mandate, the central bank reacts to such an uncertainty shock, as it would to other demand shocks.

This is consistent with the static model presented above. Consider a situation in which baseline uncertainty, such as σ^2_y above, affects economic conditions via a mapping such as $y_{0,t} = f(\sigma^2_y)$ and $f'(\sigma^2_y) < 0$. In other words, a positive uncertainty shock worsens the FOMC's assessment of the economy, y_0, which in turn leads to policy accommodation. This demand shock logic does not overturn the certainty equivalence in that the optimal policy response does not change, but rather, uncertainty now has an effect on policy because it is itself a source economic fluctuations.

[6] In a broader model below, an additional conditional requires the distribution of outcomes to be symmetric. This is also typically the case in our standard models in which we assume that shocks to π and y are normally distributed.

II.B.3. Policy-Induced Uncertainty

Equations (4) and (5) make clear that when monetary policy choices endogenously affect the variance of outcomes, certainty equivalence typically does not hold. We formalize this statement in our next result.

Proposition 2. *Suppose* $\Delta\sigma^2_{\pi,i}, \Delta\sigma^2_{y,i} \geq (\leq) 0$ *with one inequality strict. Then certainty equivalence does not hold.*

It is important to stress that variance only matters where it is induced by policy. Intuitively, when interest rate r_0 generates additional (less) volatility in inflation or output relative to r_1, r_1 becomes more (less) attractive. Hence we talk about policy-induced uncertainty as being the key for driving uncertainty effects on monetary policy. Where there is higher baseline variance of outcomes that does *not* depend on policy, then $\Delta\sigma^2_{\pi,i} = \Delta\sigma^2_{y,i} = 0$ and it is reasonable for policymakers to not adjust their policy choice as a result of this variance (the certainty equivalence result).

II.C. Existing Approaches to Policy under Uncertainty

Our framework makes clear that it is necessary to have some form of policy-induced uncertainty for uncertainty to change the reaction function. There are two specific approaches from the existing literature that model the effects of uncertainty on monetary policymaking which we now map to our framework. A key takeaway is that studying the empirical impact of uncertainy on monetary policy is important because the theoretical literature is not conclusive on the direction of the effect which we should observe.

II.C.1. Parameter Uncertainty ("Brainard-style Uncertainty")

A broad literature emphasises policymakers' incomplete information about model parameters. A classic example is Brainard (1967) in which the policy multiplier, which determines how policy affects the economy, is stochastic and the policymaker only knows the distribution from which it is drawn. In this scenario, optimal policy should be less aggressive relative to policy pursued in a certain world—a result known as the Brainard conservatism principle.

In our framework, we can introduce policymaker uncertainty about the effects of policy by making policymakers unsure about the specific values of the δ and ϕ parameters. Let $\delta \sim G_\delta$ and $\phi \sim G_\phi$, where these distributions G are unimodal, symmetric and have finite variance (this is similar to the original formulation by Brainard). Let the mean of these distributions correspond to the certainty values used so far.

In this environment, the only change in the decision rules in equations (2) and (3) is the presence of $\mathbb{E}[\delta^2] + \lambda\mathbb{E}[\phi^2]$ in place of $\delta^2 + \lambda\phi^2$. By Jensen's Inequality, the burden of proof to change rates is higher.[7] In figure 1, the indifference curves shift outward and the region in which r_0 is favoured gets larger. This means there exist economic conditions that lead to choosing r_1 or r_{-1} under certainty of policy transmission, but lead to choosing r_0 with uncertainty; policymakers are more conservative.

Of course, the scale of the shift in the burden depends on the extent of the uncertainty that policymakers face about the effects of their policy. Moreover, for there to be time-series variation in the effect, the policymaker would need to become more or less uncertain about transmission over time, and the scale of the effect over time would depend on the changing uncertainty.

Söderström (2002) emphasises uncertainty about the parameter of inflation persistence and shows that the effect is the opposite to Brainard (1967), He shows that this induces the policymaker to become *more* aggressive in their policy. When the dynamics of inflation are uncertain, the amount of uncertainty facing policymakers is greater, the further away the inflation rate is from its target. So a policy which brings inflation closer to target, actually reduces the uncertainty around future inflation outcomes. Therefore, the optimal policy is more aggressive and pushes inflation closer to the target more strongly than in the certainty case. This effect is a form of policy-induced uncertainty since the extent of uncertainty faced is dependent on the level of inflation deviation from target, which itself reflects how far inflation is expected to be from target, which itself indirectly reflects the policy actions.

In our framework, we can capture such other forms of parameter uncertainty directly in the uncertainty about the outcomes. We can model the Söderström (2002) case as $r = 1$ ($r = -1$) leading to less inflation variance, $\Delta\sigma^2_{\pi,1} < 0$ ($\Delta\sigma^2_{\pi,-1} < 0$) when the inflation gap is positive (negative). Such effects shift the burden of proof making activist policy more likely which is the opposite of the Brainard conservatism result. Söderström (2002) also shows that uncertainty about other parameters would tend to offset this effect; the net effect of parameter uncertainty in most of his calibrations is consistent with the Brainard conservatism result.

II.C.2. Robust Policymaking

Another class of models emphasises policymakers' desire for robustness: the policymaker is uncertain about their economic model and seeks a policy that is robust to the worst possible form of misspecification (Hansen and Sargent, 2001, 2008; Giordani and Söderlind,

[7] The additional burden of proof to change rates is $\frac{Var(\delta)+\lambda Var(\phi)}{2}$ because $\mathbb{E}[X^2] = \mathbb{E}[X]^2 + Var(X)$.

2004; Giannoni, 2007). Rather than specifying a particular form of uncertainty, the robust policymaker solves for an optimal policy by selecting the minimum loss in the version of the distorted model that causes maximum expected loss (subject to limits on how distorted the alternative model can be). Certainty equivalence fails because, even with a linear-quadratic setup, the coefficients of the optimal policy function depend on the variance of the structural shocks. Generally, uncertainty manifests itself through a more aggressive reaction.

Within our framework, this could capture policymakers worrying about the strength of the transmission of policy. For instance, they might think that δ, the parameter determining the effect of monetary policy on inflation, can take a range of values. A robust policymaker might assume the worst case in which policy is least potent on inflation. In this case, the indifference curves in Figure 1 shift inward (toward the origin), and become flatter. This reduces the area in which the policymaker would choose r_0 becoming more aggressive than under the non-robust preferences.[8]

However, rather than a policy-induced uncertainty that we emphasise, robust control instead reflects an environment in which uncertainty is combined with a desire for robustness and, as a result, the policymaker simply uses a more aggressive reaction function.

II.D. The empirical effect of uncertainty on monetary policy

While the existing literature has posited potential channels through which uncertainty might affect monetary decision making, and policymakers stress its importance in the policy process, there has not been a lot of empirical evaluation of these effects, especially from the point of view of the policymakers themselves. Our framework provides a natural environment for such an exercise. First, our framework is general enough to encompass many possible channels of the effects. Second, the logic that underlies the model matches the deliberation of the FOMC; they first discuss their views about the state of the economy and then they select the policy choice that best achieves their dual mandate. Therefore, in our empirical specifications below, we test whether FOMC members' assessments of uncertainty affect their policy stance above and beyond what Greenbook forecasts explain. Our key source for doing so is the language they use during their deliberations.

II.D.1. Practicalities of FOMC decision making

While the general framework matches standard theoretical analyses of monetary policy, to empirically look at the effects of uncertainty, we must confront some of the practicalities

[8] To see this most easily, consider the case of $\lambda = 0$ in which the decision rule is to tighten (loosen) if $\overline{\pi} > \frac{\delta}{2}$ ($-\overline{\pi} > \frac{\delta}{2}$). If δ is lower, the policymaker tightens or loosens for more values of $\overline{\pi}$.

of FOMC decision making. A major issue is that numeric baseline projections for inflation and output are modal forecasts both in the FOMC context and for other central banks. As Bernanke (2016) describes the FOMC's Summary Economic Projections (SEP), "SEP projections are explicitly of the 'most likely' or modal outcomes rather than the range of possible scenarios." Likewise, the New York Fed forecast "is referred to as the 'modal' forecast in that it is intended to be the most likely of a wide range of potential outcomes" (Alessi et al., 2014).

Given the ubiquity of using modal forecasts, but the optimal decision rule depending on mean outcomes, a natural concern is how this distinction affects the decision making in our simple environment. To address this, we can characterize the policymaker's decision problem in terms of the modes $(\hat{\pi}_0, \hat{y}_0)$. Define $\overline{x}_0 = \hat{x}_0 + s_x$, where s_x represents the difference between the mean and the modal forecast.

Also, in the case of the FOMC, the baseline modal forecast is the staff's Greenbook forecast. This adds an additional dimension to mapping the decision to modal forecasts; the FOMC members' modal forecast may differ from the staff's modal forecast and provide an additional wedge. Let $\hat{x}_0 = \hat{x}_{GB} + d_x$ where $\hat{x}_{GB}$ is the modal Greenbook forecast under alternative B for each key variable.

Taking account of these, we can write $\overline{x}_0 = \hat{x}_{GB} + d_x + s_x$ and the decision rule can be expressed in terms of modal Greenbook forecasts with the addition of wedges. We assume that d_x and s_x terms are constant across policy choices and then simply shift the distribution of outcomes for each variable; this is a simplication and can be relaxed (as it will for s_x below). The reformulated decision rules are:

$$\overline{L}_1 < \overline{L}_0 : \delta(\hat{\pi}_{GB} + d_\pi + s_\pi) + \lambda\phi(\hat{y}_{GB} + d_y + s_y) > \frac{\delta^2 + \lambda\phi^2}{2} + \frac{\Delta\sigma_\pi^2 + \lambda\Delta\sigma_y^2}{2} \quad (4)$$

$$\overline{L}_{-1} < \overline{L}_0 : -\delta(\hat{\pi}_{GB} + d_\pi + s_\pi) - \lambda\phi(\hat{y}_{GB} + d_y + s_y) > \frac{\delta^2 + \lambda\phi^2}{2} + \frac{\Delta\sigma_\pi^2 + \lambda\Delta\sigma_y^2}{2} \quad (5)$$

The main effect of bringing to bear these realities on the decision making is that the LHS of (4) and (5) shows that when using the modal forecasts from the Greenbook to estimate policy reactions, it is important to try to capture the extent that FOMC members differ from the Staff view. We will do this below using language-based measures of views of the economy.

II.D.2. Testing the theoretical predictions

Our general framework above highlights the importance of policy-induced variance. For this reason, we will construct language-based analogues of uncertainty about both inflation and

output, in order to test whether our measures of uncertainty impact policy choices. The reason that market-based or survey-based measures of uncertainty are unlikely to proxy well the uncertainty relevant for policymaking is they already condition on expected FOMC behavior. As we have shown, the effect of uncertainty depends on how outcome distributions compare *across* policy choices, both those made in and out of equilibrium. The language policymakers use as they discuss economic conditions in the context of policy choices is more likely to reflect the important drivers.

If certainty equivalence holds, FOMC members would not even need to discuss their worries, concerns or uncertainty about the economy. Instead they could just express the expected values of economic variables. Of course, they may describe the distribution they perceive in order to explain formation of their expected values and uncertainty language would be a linguistic tool to describe expectations. Or, their beliefs may differ from the Greenbook, and they use language associated with costly scenarios to describe their beliefs. However, such uncertainty should have no role except for explaining their economic beliefs.

With regard to shocks to economic agents uncertainty, it may be natural during the FOMC deliberations for members to discuss the uncertainty as a major source of their outlook on the economy. However, once this outlook were sufficiently controlled for, there should be no additional effect of this uncertainty on policy. Even if the staff's modal forecast does not appropriately model the effects of this shock, FOMC members may incorporate the effects in their own outlook such that it generates a wedge between the Greenbook forecasts and FOMC members' modal forecast (d_x). This should be captured if we can appropriately measure the d_x terms via the FOMC members deliberations.

III. Measuring Policymakers' Uncertainty and Policy Stance with Text

Bringing the decision-making framework in section II to the empirical setting of the FOMC first and foremost requires measuring policymakers' uncertainty (PMU) about the real economy and inflation. Since FOMC members' views on uncertainty are not recorded in structured surveys over our whole sample period, we instead measure them using the text of FOMC meeting transcripts.[9] We also generate text-based measures of policymakers' sentiment towards the real economy and inflation as additional controls.

While the FOMC's policy decision is of course available every meeting, there are several reasons why the language expressed in transcripts is a more appropriate reflection of mem-

[9]Beginning in 2007, individual member views on inflation, output, and employment are recorded in Summary of Economic Projections conducted every other meeting. One role of the SEP is to communicate the FOMC's views to the public, so forecasts have a signaling role. In contrast, transcripts are released with a five-year lag and so also better capture private views.

bers' policy stances. First, policy views expressed in text are related to the future path of interest rates beyond the immediate decision (as we show below).[10] Second, part of the discussion in the transcripts relates to the crafting of public communication, which itself is an increasingly important policy tool. Third, the final years of our sample coincide with the zero lower bound period, and text allows us to construct a consistent measure throughout the sample.

The remainder of the section describes the transcript data in more detail; describes our uncertainty and sentiment measures and their properties; and describes our policy stance measure and its properties. The details of our constructions are in appendix B.

III.A. Transcript data

The main textual source we draw from is the nearly verbatim transcripts of Federal Open Market Committee meetings, available online.[11] These transcripts contain a fully attributed, statement-by-statement account of meetings with very light editing, for example to remove the names of specific banks with which the Fed conducts open market operations. The sample period we consider consists of the 228 meetings from August 1987 (the first meeting of Alan Greenspan's chairmanship) through December 2015 (the last meeting for which a transcript was available at the time of data processing).[12] Regular FOMC meetings occur eight times per year, with occasional special meetings convened via conference call during times of macroeconomic turbulence. Since the format of these calls is somewhat irregular, we only consider regular meetings in our analysis. The typical composition of the FOMC consists of 19 members, of which twelve are regional Fed Presidents and seven are Governors. During our sample, a total of 75 unique FOMC members appear in the transcripts in at least one meeting. A number of Fed staff economists also participate in the meetings.

Importantly, our measurement strategy exploits the regular structure of FOMC meetings. The first core part of the FOMC meetings is the *economy round*, which makes up 43% of the total sentences in the transcripts. The Fed staff economists first present their forecasts of economic activity (contained in Greenbooks/Tealbooks) along with supporting contextual information. Each FOMC member in turn presents his or her views on economic developments, which can differ from the views of the staff. These developments can be discussed in the context of alternative interest rate paths—which our framework shows can be an important part of evaluating uncertainty—but FOMC members do not advocate for particular policy

[10] Meyer (2006) argues that the primary purpose of deliberation in FOMC meetings is to shape future, rather than current, decisions.

[11] See https://www.federalreserve.gov/monetarypolicy/fomc_historical.htm

[12] Only a small part of the May 1988 meeting was transcribed, so we treat it as a missing observation.

choices. It is this part of meeting we use for constructing text-based measures of real economy and inflation distributions as perceived by the FOMC.

The second core part of the meeting is the *policy round*, which accounts for 24% of all sentences.[13] This round begins with the staff laying out different policy alternatives, after which FOMC members debate on which alternative to adopt before proceeding to a final vote. This section also includes a discussion of the public statement released along with the policy announcement. We use this round to derive text-based measures of policy stances.[14]

III.B. Uncertainty and sentiment

III.B.1. Measuring policymakers' uncertainty

At a high level, our measurement of topic-specific uncertainty is based on the local co-occurrence of terms denoting uncertainty and terms denoting the topic of interest.[15] To obtain the terms denoting uncertainty, we begin with the four base terms 'uncertain', 'uncertainty', 'risk', and 'risks'.[16] We then use a word embedding model—specifically the Continuous Bag-of-Words model (Mikolov et al., 2013)—applied to FOMC transcripts to generate an expanded set of terms.[17] A word embedding model represents each unique term in a corpus as a relatively low-dimensional vector in a vector space. Words whose vectors lie close together in the vector space share similar meanings.

Tables A-1 and A-2 display the fifty nearest neighbors for each of the seed words. In general, the neighbors are synonyms of the seeds, such as 'unclear' and 'unsure', or terms reflecting

[13]The remainder of the transcripts, which we do not use, is largely made up of staff discussion of financial market conditions and discussion of special topics in monetary policy. The sectioning of meetings is done manually by us. One outlier in meeting structure is the September 2009 meeting, for which the policy and economic rounds were merged into one round. In this case, we manually classify sentences as either belonging to the economy round or the policy round. For further details on the structure of FOMC meetings and the composition of the committee, see Hansen et al. (2018).

[14]While uncertainty language might appear in the policy round in discussion of economic conditions related to policy stance, it also reflects other factors such as hesitance about the correct policy stance, or how to communicate uncertainty to the public. In practice, separating out these distinct forms of uncertainty is a formidable challenge and, for this reason, we do not use uncertainty language in the policy round to measure uncertainty about economic conditions.

[15]The use of local co-occurrence patterns to build text-based proxies for economic phenomena has been pioneered by Mikael and Blix (2014) in the monetary policy context and by Hassan et al. (2019) to measure specific types of uncertainty in a corporate context. Our innovation is to apply these ideas to analyze the impact of perceived risk and uncertainty on policy preferences.

[16]The motivation for the seeds is that 'risk' and 'risks' capture objective uncertainty, while 'uncertain' and 'uncertainty' capture Knightian uncertainty. Combining both in discussion of economic uncertainty is common. For example, Bloom (2014) writes: "I'll refer to a single concept of uncertainty, but it will typically be a stand-in for a mixture of risk and uncertainty."

[17]This approach follows recent studies such as Hanley and Hoberg (2019), Atalay et al. (2020), Davis et al. (2020), and Bloom et al. (2021).

worries and concerns such as 'threat', 'fear', and 'wary'. This is consistent with uncertainty being discussed in the context of expected utility losses as perceived by FOMC members. At the same time, the nearest neighbors also contain generic terms not obviously related to uncertainty. We therefore further organize the lists using our domain expertise and remove irrelevant terms. Ultimately we obtain 78 terms in total.[18]

The term lists we use to measure topics come from our own judgment.[19] In the analysis below, we focus primarily on inflation and real economy topics, as in the framework above. Since policymakers' concerns about the real economy might be affected by developments in financial markets, we also include financial market uncertainty in some of the analysis below. Finally, although we do not report the results in the main text, we also build a model uncertainty topic in line with the existing theoretical literature on uncertainty. Inflation terms are presented in table A-3; real economy terms are in tables A-4 through A-6; financial and market-related terms are in tables A-7 through A-10; and model-related terms are in table A-11.

Figure 2. Distribution of phrases in topic-specific PMU indices. The figure presents the distribution of terms within topic-specific uncertainty sentences. The size of the term is approximately proportional to its frequency. All topic-specific PMU indices are obtained from the economy round of the FOMC meetings. The sample period is 1987:08–2015:12. Full details of the construction are in appendix B.

Appendix B provides full details of the construction of the topic-specific PMU indices. A sentence in the economy round is assigned to topic-k uncertainty if it contains a term from our uncertainty list and a term from the topic k list. Meeting-level PMU for topic k is then the fraction of total terms in the economy round spoken in topic-k uncertainty sentences. Figure 2 shows the distribution of terms in topic-k uncertainty sentences for the three main topics of interest. The size of the term in each word cloud is approximately proportional to its empirical frequency in topic-k uncertainty sentences.

[18]The separate lists contain substantial overlap, which is another reason for the reduction to 78 terms.

[19]The reason we use a purely manual rather than partially automated approach as for the uncertainty list is that the topical terms are largely made up of phrases, and sequence embeddings are substantially more complex to build than single word embeddings.

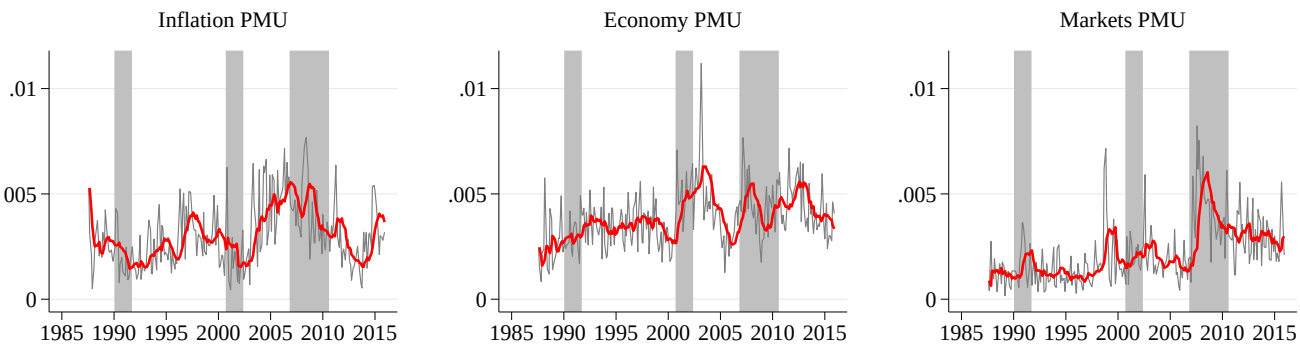


Figure 3. Topic-specific PMU Time Series. This figure displays the time series of the topic-specific PMU measures during the sample period 1987:08–2015:12. The grey curves represent the raw time series. The red curves are moving averages over the last eight meetings. The y-axis is expressed as the fraction of total economy round words contained in topic-k uncertainty sentences. Recessionary periods are shaded.

Figure 3 plots time series for the PMU measures during the sample, where recessionary periods are shaded. The measures contain substantial independent variation: the correlation between the inflation and economy measures is just 0.1, while that between the economy and markets measures is 0.36. Inflation PMU rises most quickly during the 2000s; economy PMU at the onsets of the bursting of the dot-com bubble and of the great financial crisis (GFC); and markets PMU in the early stages of the GFC.

III.B.2. Measuring policymakers' sentiment

As discussed above, uncertainty is not the only potential driver of policy stance, as beliefs on the direction of variables also matter. We therefore construct text-based views on the evolution of inflation, the economy, and financial markets to complement the PMU measures. Following Hassan et al. (2019) and Shapiro and Wilson (2022), we refer to these measures as *sentiment*. As a convention, we label the discussions of falling inflation in meeting t as indication of negative inflation sentiment ($InfNeg_t$), discussions of weakening economic activity as negative sentiment about real economy ($EcoNeg_t$), and discussion of deteriorating financial conditions as negative market sentiment ($MktNeg_t$). We reverse those relations for the positive sentiment ($InfPos_t$, $EcoPos_t$, and $MktPos_t$). As a proxy for the overall sentiment, we define balance measures as the difference between the positive and negative sentiment, e.g., for inflation $InfSent_t = InfPos_t - InfNeg_t$. Increases in the balance indicate a positive tilt in views about a given variable.

Appendix B.2 details the construction of the sentiment indices. The basic idea is to count the frequency with which topic-specific terms (which generally overlap with those used for the topic-specific uncertainty) are preceded or followed by direction words that indicate positive

	(1) $InfPMU_t$	(2) $EcoPMU_t$
$InfPos_t$	0.623***	-0.195***
	(7.17)	(-2.98)
$InfNeg_t$	0.236***	-0.017
	(4.59)	(-0.30)
$EcoPos_t$	-0.154*	0.136*
	(-1.68)	(1.89)
$EcoNeg_t$	-0.063	0.344***
	(-1.10)	(6.22)
N	227	227
$\bar{R}^2$	0.41	0.13

Table I. Relationship between uncertainty and sentiment. This table reports regressions of PMU indices on sentiment. Sentiment proxies are based on sentences that do not contain uncertainty phrases. All measures are derived from the economy round of the FOMC meeting. The coefficients are standardized and HAC t-statistics with eight lags are reported in parentheses. The sample period is 1987:08–2015:12.

or negative sentiment, respectively. In analogy to the PMU, we derive the sentiment proxies from the economy round of the meeting and scale the sentiment count by the number of total words in that round. Importantly, to avoid a mechanical relationship between PMU and sentiment, in sentiment construction we exclude all sentences that we use to obtain the PMU indices.

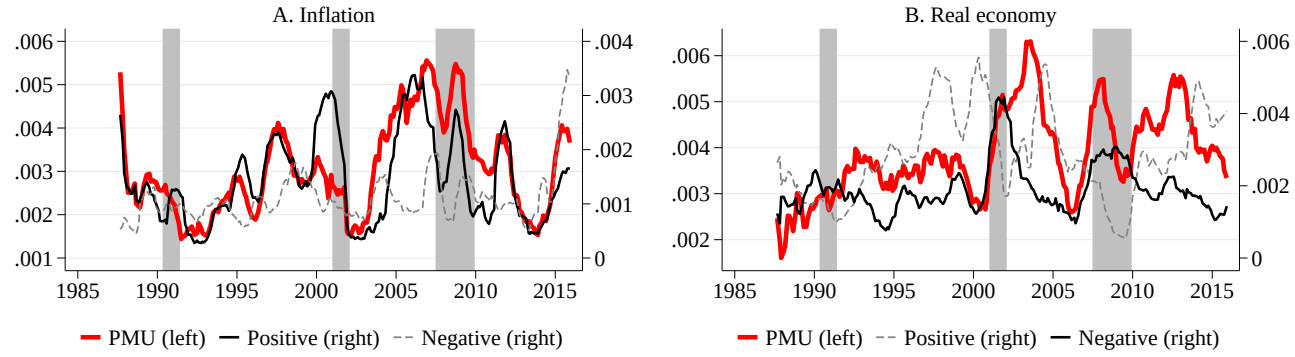


Figure 4. PMU and Sentiment This figure presents inflation and economy PMU indices superimposed against negative and positive sentiment. Positive (negative) sentiment indicates views of rising (declining) inflation or output. All text-based series are smoothed averages over the last eight FOMC meetings.

Figure 4 plots time series for sentiment against those for PMU, and table VIII presents regressions of inflation and economy PMU on sentiment measures. Inflation PMU co-moves positively quite strongly with positive inflation sentiment, indicating the FOMC becomes particularly attentive to inflation uncertainty when inflation is rising. At the

same time, inflation PMU also rises when negative inflation sentiment rises, albeit not as strongly, suggesting that beliefs about disinflation (or potentially deflation) also associate with uncertainty. In terms of economy PMU, it rises most strongly when negative sentiment about the economy increases, which is consistent with the literature on uncertainty and recessions.

IV. Validation of textual measures

In this section, we provide validity checks for our interpretation of the text-based measures developed above as capturing policy stance, policymakers' uncertainty, and the directional views about the economy (sentiment), respectively.

IV.A. HD score as a measure of policy stance

To validate the *HD* score as describing the policy stance, in Table II, we analyze its relationship with proxies in the literature: deviations of the policy rate from a Taylor rule and high-frequency monetary policy surprises obtained from changes in market interest rates around FOMC announcements. All regressions in Table II are estimated at the FOMC meeting frequency.

In Table II, panel A, we first project *HD* on typical variables included in the estimates of a policy rule. This specification, reported in column (1), serves as a benchmark to describe the systematic component of policy reflected in language. The explanatory variables include the Greenbook forecasts and forecast revisions for inflation and the real GDP growth, as well as a trend inflation variable, τ_t, to account for a slow-adjustment in the inflation target over our sample.[20] Most loadings in column (1) are highly significant and have expected signs: higher expected growth and higher expected deviation of inflation from the target predict a more hawkish tilt in the policy language. At the same time, the regression $\bar{R}^2$ of 29% leaves more than two-thirds of the variation in the policy language unexplained by the rule.

Columns (2)–(5) focus on explaining changes in the actual policy instrument—the federal funds rate (FFR) target—with the policy language. Although our textual proxies are available until 2015:12, we estimate these regressions through 2008:12, given that the FFR is

[20]Following Coibion and Gorodnichenko (2012), as Greenbook controls, we use longer-term CPI inflation forecasts (four quarters ahead, $F_t(\pi_4)$), and current quarter real GDP growth forecast (nowcast, $F_t(g_0)$). We also add forecast revisions between meetings ($FR_t(\pi_3), FR_t(g_1)$), following Romer and Romer (2004) to account for changes in forecasts in addition to levels. The trend inflation variable τ_t is constructed as the discounted moving average of past core inflation following Cieslak and Povala (2015). Including trend inflation allows the regression to capture the effect of deviations of expected inflation from the target on the policy rate.

A. FFR target changes and Romer-Romer shocks

	(1) HD_t	(2) ΔFFR_t	(3) ΔFFR_t	(4) ΔFFR_t	(5) ΔFFR_t	(6) RR_t	(7) RR_t	(8) RR_t
$Hawk_t$			0.287***			0.253**		
			(4.07)			(2.54)		
$Dove_t$			-0.316***			-0.359***		
			(-6.42)			(-3.70)		
HD_t				0.497***	0.334***		0.506***	0.601***
				(6.83)	(5.30)		(4.95)	(5.04)
$F_t(\pi_4)$	0.613***	0.684***			0.523***			0.115
	(3.64)	(3.79)			(2.97)			(0.73)
$F_t(g_0)$	0.382***	0.546***			0.456***			-0.085
	(2.99)	(6.60)			(5.75)			(-1.14)
τ_t	-0.695***	-0.374***			-0.226**			0.043
	(-3.81)	(-3.30)			(-2.06)			(0.26)
$FR_t(\pi_3)$	0.073	0.051			0.022			0.088
	(1.43)	(0.86)			(0.39)			(1.30)
$FR_t(g_1)$	0.152***	0.136**			0.092			-0.168**
	(2.79)	(2.30)			(1.32)			(-2.55)
L.FFR_t		0.587	1.807***	1.766***	-0.091			
		(1.14)	(3.35)	(3.18)	(-0.15)			
L2.FFR_t		-0.875*	-1.851***	-1.801***	-0.159			
		(-1.84)	(-3.64)	(-3.40)	(-0.29)			
$\bar{R}^2$	0.29	0.52	0.45	0.45	0.59	0.25	0.25	0.30
N	227	169	169	169	169	163	163	163

B. Market-based measures of monetary policy surprises

	(1) GSS target	(2) GSS path	(3) GK MP0	(4) GK ED12m	(5) NS news
HD_t	0.169	0.178***	0.382***	0.409***	0.290**
	(1.33)	(2.74)	(4.00)	(4.92)	(2.33)
R^2	0.028	0.032	0.15	0.17	0.084
N	196	196	190	199	154

Table II. Validity of textual measures of policy preferences. The table reports regressions of various measures of monetary policy stance on textual *Hawk*, *Dove*, and *HD* variables. The textual measures are derived from the policy round of the FOMC meeting transcripts. Panel A reports regressions of changes in the FFR target and Romer-Romer shocks on the textual proxies, with and without Greenbook controls (forecasts $F_t(\cdot)$ and forecast updates $FR_t(\cdot)$). The τ_t variable controls for the perceived inflation target. Columns (2)–(5) are based on the 1987:08–2008:12 sample, i.e., excluding the zero-lower bound episode. Columns (6)–(8) are based on the 1987:08–2007:12 sample, when Romer-Romer shocks are available from Ramey (2016). HAC t-statistics with eight lags are reported in parentheses. The sample period is 1987:08–2015:12. Panel B reports regressions of monetary policy surprises on the *HD* variable. Columns (1) and (2) contain high-frequency target and path surprises following the approach of Gürkaynak et al. (2005) as updated by Swanson (2018) (1991:07–2015:10 sample). Columns (3) and (4) use shocks from Gertler and Karadi (2015) obtained from the current month fed fund futures (MP0, sample 1988:11–2012:06) and 12-month ahead Eurodollar futures (ED12m, sample 1987:08–2012:06). Column (5) is based on surprises from Nakamura and Steinsson (2018) (sample 1995:02–2014:03). Robust t-statistics are reported in parentheses. All regressions are estimated at the frequency of FOMC meetings. The coefficients are standardized.

at the zero-lower bounds thereafter. The estimates show a strong explanatory power of the policy language. A more hawkish (dovish) language predicts a FFR target increase (decrease) (column (2)). The *HD* variable contains essentially the same information (column (3)) as the *Hawk* and *Dove* scores considered separately. A one standard deviation increase in *HD* is associated with approximately 0.5 standard deviation increase in the FFR target (about 14 basis points) with a t-statistic of 6.8. Given results in column (1), the significance of *HD* could simply reflect the policy rule as opposed to the deviation from it. However, column (5) shows that this is not the case. Also with a full set of controls, the *HD* score remains economically and statistically significant with a one-sigma increase in *HD* corresponding to a 0.3-sigma increase in the target (t-statistic of 5.3).

In columns (6)–(8), we present analogous results using a widely-adopted measure of monetary policy shocks proposed by Romer and Romer (2004).[21] Since Romer-Romer shocks are constructed from changes in the policy rate at each meeting purged of Fed's information (Greenbooks), it is not surprising that the results in column (6)–(8) are very similar to those based on FFR target in columns (3)–(5). The *HD* language alone explains a quarter of variation in Romer-Romer shocks.

In Table II, panel B, we further explore the relationship between language and monetary policy surprises identified from high-frequency changes in interest rates around the FOMC announcements. As these surprises differ in construction details (maturities of interest rates and sample periods), we consider proxies from several recent studies: Swanson (2018) who extends and updates the estimates of target and path factors in Gürkaynak et al. (2005, GSS), Gertler and Karadi (2015, GK), and Nakamura and Steinsson (2018, NS). Across the board, we find a positive relationship with the *HD* score, whereby the relationship is generally stronger for surprises identified from longer-term interest rates. Accordingly, in Table III, we use *HD* to forecast the path of policy rates. The *HD* variable remains a significant predictor of FFR target changes up to eight meetings ahead, controlling for the meeting-t Greenbook forecasts.

In sum, the FOMC deliberations summarized in the *HD* variable reveal to a significant degree the content of policy surprises (deviation of policy stance from a rule). The language in the policy round encompasses forward-looking views by policymakers that pertain not only to the current decision but also to the intended policy path.

[21] We obtain the Romer-Romer shock series from the data set accompanying Valerie Ramey's handbook chapter on propagation of macro shocks (Ramey, 2016). The shocks are available during the pre-zero-lower-bound sample 1987:08–2007:12.

Dependent variable: Change in FFR target over subsequent h meetings, $\Delta FFR_{t+h,t} = FFR_{t+h} - FFR_t$

	(1) $h=1$	(2) $h=2$	(3) $h=3$	(4) $h=4$	(5) $h=5$	(6) $h=6$	(7) $h=7$	(8) $h=8$
HD_t	0.326***	0.311***	0.335***	0.330***	0.290***	0.234***	0.194**	0.188**
	(3.45)	(3.02)	(3.08)	(3.28)	(3.23)	(2.83)	(2.35)	(2.30)
GB controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\bar{R}^2$	0.40	0.40	0.38	0.41	0.44	0.46	0.48	0.50
N	170	170	170	170	170	170	170	170

Table III. Validity of textual measures of policy preferences. The table reports predictive regressions of changes in the FFR target rate over h meetings ahead by the textual measure of policy stance *HD*. The regressions are estimated at the frequency of FOMC meetings, controlling for Greenbook forecasts and trend inflation τ_t and two lags of the FFR target (same controls as in Table II). All explanatory variables (except the lagged FFR target) are measured as of meeting t. The dependent variables (future changes in the FFR target) span the horizon from the next meeting up to eight meetings ahead. The coefficients are standardized. HAC standard errors to account for overlapping data are reported in parentheses. The maximum sample uses data over the 1987:08–2009:12 period.

IV.B. PMU indices as measures of uncertainty

A challenge for empirically identifying the effects of higher-order moments on policy is that they tend to correlate with the current or expected future state of the economy. Additionally, it is possible that when policymakers express views about risk or uncertainty they do not refer to second moments of a distribution, but rather to a particular directional outcome they fear or are concerned about (i.e., skewness).

To verify that our textual measures do not simply capture policymakers' first-moment beliefs about the economy, in Table IV, we study their predictive power for future realization of inflation and real GDP growth. To make sure that the macro realizations are aligned with the schedule of the FOMC meetings, we use the future Greenbook nowcasts for inflation and real GDP growth, $F_{t+h}(\pi_0)$ and $F_{t+h}(g_0)$, up to eight meetings ahead as the dependent variables, for $h = \{1, ..., 8\}$. We project the time-$t+h$ nowcast onto PMU and sentiment observed in meeting t. The regressions control for meeting-t Greenbook forecasts (average of forecasts for horizons between current quarter up to four quarters ahead).

The main observation from Table IV is that PMU does not predict future outcomes at any horizon. This finding holds true both for inflation and real GDP growth forecasts.[22] It is therefore unlikely that PMU proxies for policymakers' first-moment beliefs. The second takeaway is that the sentiment predicts inflation and growth over and above the Greenbook forecasts (growth at all forecast horizons and inflation up to two meetings ahead), implying

[22]The result is not sensitive to whether or not we include sentiment and Greenbook variables in the regression. Univariate predictive regressions with just PMU are in Appendix Table A-13.

A. Dependent variable: Greenbook CPI inflation nowcast h meetings ahead, $F_{t+h}(\pi_0)$

	$h=1$	$h=2$	$h=3$	$h=4$	$h=5$	$h=6$	$h=7$	$h=8$
$InfPMU_t$	0.039	-0.038	-0.042	0.011	-0.107	-0.070	0.038	0.044
	(0.62)	(-0.48)	(-0.38)	(0.08)	(-0.69)	(-0.42)	(0.27)	(0.45)
$InfNeg_t$	-0.260***	-0.164*	0.012	0.093	0.086	0.010	-0.058	-0.025
	(-3.49)	(-1.87)	(0.18)	(1.30)	(1.04)	(0.17)	(-0.98)	(-0.39)
$InfPos_t$	0.173***	0.144***	0.025	-0.131	-0.100	-0.120	-0.169*	-0.138
	(3.81)	(2.67)	(0.38)	(-1.32)	(-0.97)	(-1.42)	(-1.80)	(-1.47)
$\overline{F}_t(\pi)$	0.560***	0.457***	0.378***	0.351***	0.319***	0.321***	0.337***	0.335***
	(8.46)	(6.91)	(4.30)	(3.39)	(2.82)	(2.90)	(3.73)	(4.01)
$\bar{R}^2$	0.50	0.30	0.13	0.11	0.11	0.11	0.12	0.10
N	226	225	224	223	222	221	220	219

B. Dependent variable: Greenbook real GDP growth nowcast h meetings ahead, $F_{t+h}(g_0)$

	$h=1$	$h=2$	$h=3$	$h=4$	$h=5$	$h=6$	$h=7$	$h=8$
$EcoPMU_t$	-0.081	-0.058	0.032	0.069	0.029	-0.001	0.087	0.113
	(-1.60)	(-1.15)	(0.69)	(1.03)	(0.36)	(-0.02)	(1.01)	(1.23)
$EcoNeg_t$	-0.150***	-0.163**	-0.220***	-0.275***	-0.313***	-0.226**	-0.238**	-0.237**
	(-2.92)	(-2.40)	(-2.65)	(-3.00)	(-4.29)	(-2.28)	(-2.05)	(-2.32)
$EcoPos_t$	0.116**	0.127**	0.147**	0.149*	0.151*	0.193**	0.203**	0.190**
	(2.39)	(2.17)	(2.07)	(1.68)	(1.72)	(2.25)	(2.30)	(2.14)
$\overline{F}_t(g)$	0.623***	0.553***	0.401***	0.287***	0.227**	0.174	0.112	0.075
	(7.20)	(5.78)	(5.03)	(3.20)	(2.12)	(1.31)	(0.80)	(0.51)
$\bar{R}^2$	0.56	0.48	0.35	0.28	0.26	0.19	0.16	0.13
N	226	225	224	223	222	221	220	219

Table IV. Predicting macro variables with textual measures of uncertainty and sentiment. The table reports predictive regressions of inflation and real GDP growth by textual PMU and sentiment indices derived from the economy round of the FOMC meeting transcripts. The regressions are estimated at the FOMC meeting frequency with the forecast horizon ranging from the next meeting ($h = 1$) up to eight meetings ahead ($h = 8$). To make sure that the timing of the depend variable is consistent with the timing of the meetings, we use Greenbook nowcasts at future meetings as the dependent variable. The regression is $F_{t+h}(\pi_0) = \beta_0 + \beta_1 InfPos_t + \beta_2 InfNeg_t + \beta_3 InfPMU_t + \beta_4 \overline{F}_t(\pi) + \varepsilon_{t+h}$, where $F_{t+h}(\pi_0)$ is the CPI inflation nowcast at meeting $t+h$, and $\overline{F}_t(\pi)$ is the average forecast (across horizons) given at meeting t. We estimate analogous regressions for the real GDP growth. The coefficients are standardized. HAC standard errors to account for the overlap are reported in parentheses. The sample period is 1987:08–2015:12.

that the deliberations contain information not captured by the staff forecasts. To the extent that the Greenbooks focus on the most likely scenarios (modes), the additional predictive content suggests that the directional language in the meeting reflects policymakers' perceptions of skewed, potentially undesirable, outcomes.

V. (How) Does Uncertainty Affect Policy Stance?

We now explore the relationship between the uncertainty policymakers perceive and their policy stance. Since all PMU and sentiment indices are constructed from the economy round of the FOMC meeting, they are predetermined by the time the policy round begins, and from which we derive policy stance of the FOMC members.

V.A. Meeting-level results

Table V reports the predictability of the policy stance with the PMU and the sentiment in the transcripts, with and without controlling for the Greenbook forecasts. In column (1), we project *HD* on the overall *PMU* index, following much of the literature that focuses on uncertainty in general, without separating the type. More uncertainty expressed in the economy round of the meeting forecasts relatively more dovishness in the policy round. Overall PMU explains about 8% of the variation in the *HD* score. Column (2) illustrates the importance of disaggregating the sources of uncertainty by introducing the topic-specific PMU for inflation and the real economy. As the main empirical fact, inflation and real-economy PMU predict policy stance with opposite signs, both are highly significant, and explain 15% of the *HD* variance. A one-sigma increase in *InfPMU* is associated with a 0.3-sigma increase in the *HD* score (t-statistic = 3.39); in contrast, a one-sigma increase in *EcoPMU* leads to 0.24 sigma decrease in the *HD* score (t-statistic = −3.97).

In columns (3)–(6) we test whether the uncertainty effect on policy stance can be subsumed by the variation in the first-moment beliefs as captured by the Greenbook forecasts or by the sentiment in the meeting. As a first step, columns (3) and (4) establish that the sentiment is strongly predictive for the policy stance beyond the Greenbooks. Importantly, however, *InfPMU* and *EcoPMU* preserve their significance either with the sentiment (column (5)) or the Greenbook controls (column (6)). Of note is the fact that inflation PMU drives out the significance of the inflation sentiment. This suggests that increased inflation PMU correlates with policymakers' discussions of rising inflation. Table IV has already established that inflation sentiment does not predict actual realizations of inflation except at very short horizons. Taken together, the results thus suggest that inflation sentiment is likely to reflect policymakers' worry about inflation getting out of control, but that worry does not materialize in our sample. This evidence is consistent with the inflation scares example in Section **??**, whereby a low-probability but costly event can influence the decision making. We explore this interpretation further in Section VI. In contrast, uncertainty and sentiment about the real economy contain largely independent information: Views of stronger economy

Dependent variable: HD_t policy stance score

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PMU_t	-0.288***							
	(-3.66)							
$InfPMU_t$		0.341***			0.281***	0.184**	0.235***	0.223***
		(3.39)			(3.89)	(2.54)	(3.03)	(3.21)
$EcoPMU_t$		-0.238***			-0.151***	-0.221***	-0.139**	-0.126**
		(-3.97)			(-3.10)	(-3.21)	(-2.26)	(-2.30)
$InfSent_t$			0.204**	0.134***	0.085			0.074
			(2.54)	(2.72)	(1.17)			(1.03)
$EcoSent_t$			0.498***	0.421***	0.471***			0.397***
			(5.71)	(4.79)	(5.91)			(5.00)
$MktPMU_t$							-0.197*	-0.092
							(-1.71)	(-0.86)
$ModPMU_t$							0.155***	0.153***
							(3.35)	(3.87)
$OthPMU_t$							-0.262***	-0.122*
							(-4.21)	(-1.84)
GB controls	No	No	No	Yes	No	Yes	No	No
$\bar{R}^2$	0.079	0.15	0.30	0.40	0.38	0.34	0.28	0.41
N	227	227	227	227	227	227	227	227

Table V. Predicting policy stance with PMU at the meeting-level. The table reports regressions of the policy stance score *HD* on topic-specific PMU indices as well as Greenbook forecasts and textual sentiment controls. The *HD* variable is derived from the statements of FOMC members in the policy round of the FOMC meeting, while the PMU indices are based on the statements by the staff and FOMC members in the economy round of the meeting. All regressions are estimated at the frequency of FOMC meetings. The sentiment measures are defined in Section **??**. The coefficients are standardized. HAC t-statistics with eight lags are reported in parentheses. The sample period is 1987:08–2015:12.

lead to hawkishness, while increased uncertainty about the economy produces a more dovish stance.

Accounting for the remaining uncertainty categories (markets *MktPMU*, models *ModPMU*, and the unclassified category *OthPMU*) in columns (7) and (8) partially reduces the economic significance of inflation and real-economy PMU. This is not surprising in that PMU indices are not orthogonal and can load on common factors. However, the distinct directional effects suggest that uncertainty affects policy via at least two channels. Like *InfPMU*, also model uncertainty (*ModPMU*) predicts more hawkishness. Combined with the fact that *InfPMU* and *ModPMU* are positively correlated, this suggests that inflation PMU stems in part from policymakers' concern with model misspecification. Similar to the real-economy PMU, the market and the residual PMUs, are instead associated with relatively more dovishness. As such, these uncertainty types affect policy akin to a negative demand shock, leading to an easier stance. With a full suite of PMU indices in column (8), *MktPMU* and *OthPMU* become marginally significant, suggesting they have little independent role over and above

inflation and real-economy PMU. Thus, in subsequent analysis, we focus on these two main uncertainty types.

V.B. Individual-level results

The analysis so far focuses on the meeting-level outcomes, where the uncertainty and sentiment aggregate the views of both the FOMC members and the staff in the economy round. One consideration in interpreting the results is that they could arise from a disagreement among members as opposed to the common perceptions on the committee. We thus turn to estimating the language-based reaction functions at the individual FOMC-member level exploiting the granularity of the textual data. The results show that it is the common perception of uncertainty that affects the policy stance.

In Table VI, the dependent variable is the policy stance of member i in meeting t, HD_{it} (using the policy-round statements), and the explanatory variables are the corresponding uncertainty and sentiment scores of that member (using the economy-round statements). The goal is to study how a policymaker's own expression of uncertainty predicts their individual policy stance. All regressions include member fixed effects, and so the estimates represent the within-individual reaction functions. Column (1) shows that, similar to the meeting-level results, also within-member inflation uncertainty is associated with more hawkishness, while real-economy uncertainty with more dovishness (although this effect is weaker than that of inflation). The impact of inflation uncertainty on policy stance is not driven by the member-specific sentiment (column (2)).

To study the role of common perceptions on the committee vis-á-vis heterogeneity, column (3) additionally includes aggregate meeting-level PMU indices, and column (4) includes the time fixed effects. As both specifications render the member-level PMU insignificant, the explanatory power of uncertainty comes entirely from the time-series variation rather than from cross-sectional dispersion of views across members.

Finally, column (5) includes the full set of individual-level PMU indices. Individual member policy views are sensitive to the market uncertainty, with increased $MktPMU_{it}$ associated with an easier stance, supporting the demand-shock interpretation of market uncertainty. However, this effect reflects common rather than member-specific variation and is subsumed by the meeting fixed effects in column (6). Two additional differences from the meeting-level results in Table V are worth highlighting. First, $ModPMU_{it}$ is not significant at the individual level, implying that it stems primarily from the staff discussions of model uncertainty, which then influence inflation uncertainty of the members. Second, $OthPMU_{it}$ predicts easier policy stance even with time fixed effects, suggesting that idiosyncratic uncertainty perceptions do

Dependent variable: Individual FOMC member policy stance at meeting t, HD_{it}

	(1)	(2)	(3)	(4)	(5)	(6)
$InfPMU_{it}$	0.12***	0.12***	-0.0044	-0.011	0.11**	-0.0097
	(2.86)	(2.82)	(-0.10)	(-0.30)	(2.62)	(-0.25)
$EcoPMU_{it}$	-0.074	-0.058	0.014	0.012	-0.041	0.011
	(-1.65)	(-1.43)	(0.36)	(0.30)	(-1.03)	(0.29)
$InfPMU_t$			0.98***			
			(4.70)			
$EcoPMU_t$			-0.84***			
			(-3.86)			
$MktPMU_{it}$					-0.16***	0.011
					(-2.70)	(0.25)
$ModPMU_{it}$					-0.071	-0.15
					(-0.64)	(-1.38)
$OthPMU_{it}$					-0.19***	-0.11**
					(-4.20)	(-2.40)
Sentiment	No	Yes	No	Yes	Yes	Yes
Meeting FE	No	No	No	Yes	No	Yes
Member FE	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.028	0.048	0.055	0.26	0.059	0.26
N	3925	3925	3925	3925	3925	3925

Table VI. Predicting policy stance with PMU at the individual-meeting-level. The table reports regressions of individual FOMC member i policy stance at meeting t, HD_{it}, with individual PMU indices at meeting t. Inflation and real-economy sentiment are also measured at the member-meeting level. $\overline{InfPMU}_t$ and $\overline{EcoPMU}_t$ are the meeting-level PMU indices. Standard errors are double-clustered at the meeting and member level.

influence individual policy views but their effect on the overall policy stance of the committee is weak (given results in Table V column (8)).

V.C. Does uncertainty strengthen or weaken policymakers' reaction to the state of the economy?

The classic approach to introduce a role of uncertainty in policymaking in the literature is by allowing uncertainty to affect the optimal response coefficients in a policy rule. Policy parameters thus become a function of the policymaker's uncertainty. Different models have different predictions as to whether uncertainty induces a more or less aggressive response to economic conditions.[23] Likewise, it remains an open empirical question whether uncertainty strengthens or weakens the policymakers' response, and whether its effects differ across state variables policymakers care about.

To cast light on these questions, we study the role of interactions between macro variables and the PMU indices in explaining policy stance using the following specification estimated

[23]We summarize those models in Section **??** and provide illustrative calibrations in Appendix D.

at the meeting level:

$$
\begin{aligned}
HD_t = \beta_0 + \beta_1 \tau_t + \beta_2 F_t(\pi_4) + \beta_3 F_t(g_0) \\
+ \delta_1 (F_t(\pi_4) \times InfPMU_t) + \delta_2 (F_t(g_0) \times InfPMU_t) \\
+ \delta_3 (F_t(\pi_4) \times EcoPMU_t) + \delta_4 (F_t(g_0) \times EcoPMU_t) \\
+ \gamma_1 InfSent_t + \gamma_2 EcoSent_t + \varepsilon_t.
\end{aligned} \tag{6}
$$

One can interpret equation (6) as a forward-looking policy rule with time-varying loadings that change with the degree of policymakers' uncertainty. The coefficients on the interaction terms describe how the sensitivity of policy stance (measured with the *HD* score as before) to inflation and real growth changes when uncertainty changes.

We report the estimates in Table VII. For reference, column (1) displays results when interactions are not included, only allowing for direct effects of uncertainty, as in Table V. Column (2) adds sentiment. The new results are in columns (3) and (4) which interact each of the Greenbook forecasts with PMU indices, with and without sentiment. All variables are expressed in units of standard deviations. The conditional character of the interaction regressions makes the interpretation of the individual coefficients challenging.[24] Thus, we present the main marginal effects of interest graphically in Figure 5. The estimates, obtained with the delta method, illustrate how the slope coefficient on a given variable changes with the level of another variable. The graph contains 95% confidence bounds for the null hypothesis that each of the coefficients is different from zero.

The main finding is that the policymakers' response to the inflation forecast increases with the level of inflation uncertainty. The interaction term on $F_t(\pi_4) \times InfPMU_t$ is positive and significant. Panel A of Figure 5 shows the change in the HD_t score given one unit change in $F_t(\pi_4)$ at different levels of $InfPMU_t$. The increasing pattern of the slope coefficients shows that policymakers tend to display relatively more hawkishness in reaction to inflation when inflation forecast is accompanied by high uncertainty. When uncertainty is very low, the effect of inflation is not statistically different from zero. This result holds also when we account for the sentiment expressed in the meeting.

The real-economy PMU likewise tends to strengthen the Fed's reaction to real GDP growth, visible in Figure 5 panel B. The positive coefficient on $F_t(g_0) \times EcoPMU_t$ in Table VII means that policy stance becomes relatively more dovish when the economy is doing poorly and uncertainty is high. In contrast to inflation, however, the amplification due to uncertainty weakens when controlling for the sentiment.

[24] With interactions, the direct effect coefficients (βs and γs in equation (6)) capture the effect of a variable when keeping other variables it is interacted with at zero. As such, the direct effects may not be economically interesting or meaningful when considered on their own.

Dependent variable: HD_t policy stance score

	(1)	(2)	(3)	(4)
$F_t(\pi_4)$	0.39***	0.55***	0.090	0.48**
	(2.74)	(3.95)	(0.40)	(2.32)
$F_t(g_0)$	0.38***	0.15**	-0.060	-0.14
	(5.67)	(2.14)	(-0.31)	(-0.80)
τ_t	-0.53***	-0.59***	-0.52***	-0.58***
	(-3.84)	(-4.72)	(-3.64)	(-4.40)
$F_t(\pi_4) \times InfPMU_t$			0.20***	0.15***
			(3.47)	(2.88)
$F_t(g_0) \times InfPMU_t$			-0.016	-0.030
			(-0.33)	(-0.65)
$F_t(g_0) \times EcoPMU_t$			0.18***	0.13**
			(2.99)	(2.49)
$F_t(\pi_4) \times EcoPMU_t$			-0.024	-0.085
			(-0.42)	(-1.55)
$InfPMU_t$	0.19***	0.19***	-0.21	-0.087
	(3.50)	(3.73)	(-1.28)	(-0.59)
$EcoPMU_t$	-0.24***	-0.13**	-0.43***	-0.14
	(-4.11)	(-2.22)	(-2.84)	(-1.02)
$InfSent_t$		0.063		0.090**
		(1.45)		(2.11)
$EcoSent_t$		0.41***		0.39***
		(5.74)		(5.55)
$\bar{R}^2$	0.33	0.43	0.36	0.45
N	227	227	227	227

Table VII. Effect of uncertainty on policy stance. The table reports estimates of regression (6), allowing for interactions between PMU indices and the Greenbook forecasts. The sample period is 1987:08–2015:12. All variables are scaled by their standard deviations. Robust t-statistics are in parentheses.

Complementary to the above results, the bottom panels of Figure 5 depict the impact of uncertainty on policy stance at different levels of expected inflation and growth, respectively. By extending the baseline linear specification in column (1) of Table VII, these estimates help assess when, i.e., in which economic states, the effect of uncertainty on policy is likely to be the strongest. Inflation PMU is associated with a more hawkish stance when inflation forecast is high, while real-economy PMU is associated with a more dovish stance when growth is weak. The cross-effects, i.e., inflation PMU altering the policy response to the real economy, and economy PMU altering the response to inflation, are economically and statistically small (and are not reported in the graph). Thus, while inflation uncertainty tends to amplify the response to inflation, it does not affect the response to growth, and vice-versa.

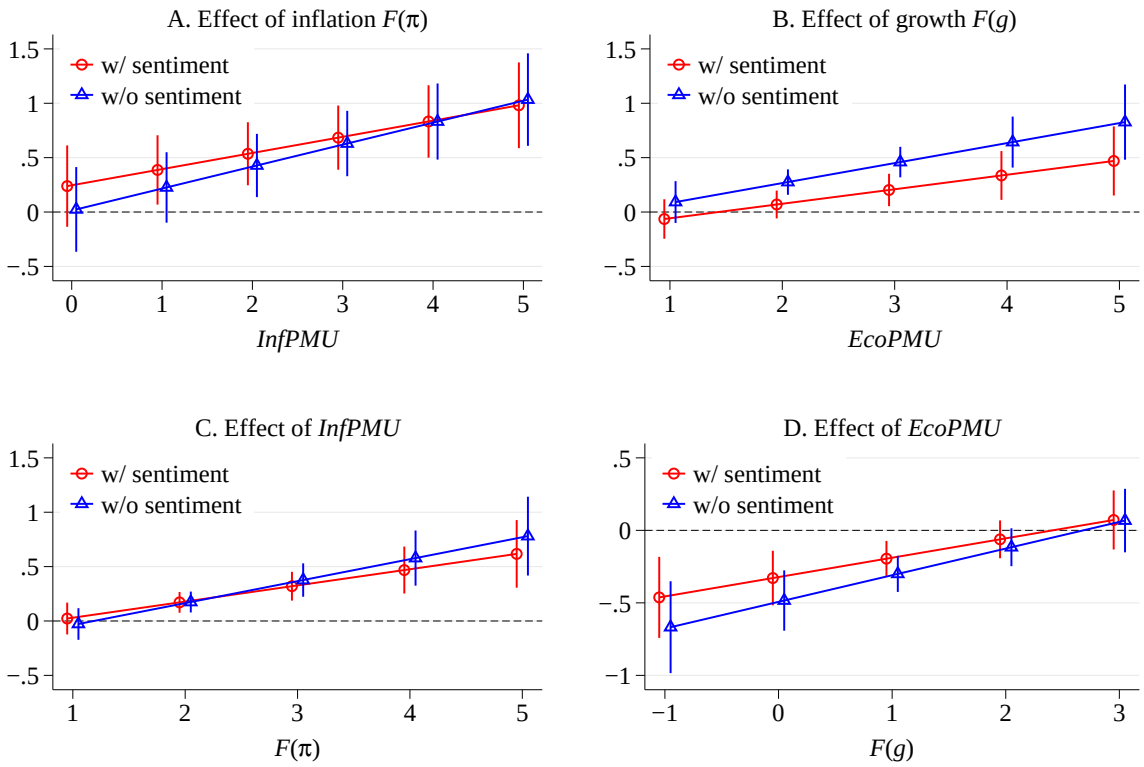


Figure 5. Marginal effects of PMU on policy stance. The figure presents the marginal effects based on the estimates in Table VII, columns (3) and (4). The dependent variable is the *HD* policy stance score. Panel A shows how the *HD* variable changes with a one unit change in Greenbook inflation forecast holding inflation PMU at different values (and all other covariates at their means). Analogous interpretation applies to the other panels. All variables are expressed in units of their standard deviations. The range of values for the variables depicted on the x-axis is constrained between their 5th and the 95th percentile.

V.D. Implications for models of optimal policy choice with uncertainty

Our evidence helps cast light on which theoretical mechanisms discussed in Section **??** are likely to be born out by the actual policymakers' deliberations. The main finding of Table VII—the amplifying effect of uncertainty on the inflation and growth response—goes against the Brainard's conservatism principle, and could arise from uncertainty about inflation persistence and/or desire for decision making to avoid costly outcomes. This interpretation also aligns with view expressed by policymakers themselves, e.g., Bernanke (2007) states: "Indeed, intuition suggests that stronger action by the central bank may be warranted to prevent particularly costly outcomes."[25] However, while the amplification is qualitatively

[25]More recently, Praet (2018) elaborates: "A more aggressive monetary policy response (...) is warranted when there is clear evidence of heightened risks to price stability, i.e. when it is established that the degree of inflation persistence is likely to be high and risks disanchoring inflation expectations. In this case, a forceful, frontloaded monetary policy response to weak or excess inflation may become necessary to signal the central bank's commitment to its objective, and thus nudge inflation expectations towards that objective and make them less backward-looking."

consistent some theoretical specifications, its economic magnitude (visible in Figure 5) is hard to generate in standard settings. We illustrate the different mechanisms proposed in the literature in Appendix D. Using standard calibrations, even very large changes in uncertainty lead to small changes in the coefficients of the reaction function.

Our second set of results pertains to the direct effects, whereby uncertainty may influence policy stance independently of its amplifying impact on the coefficients of the reaction function. Through the lens of the canonical linear-quadratic framework operating under certainty equivalence, additive uncertainty should have no effect on optimal policy. Thus, the fact that the direct effects are present suggests that policymakers systematically deviate from the linear-quadratic paradigm, for example, by overweighing particular outcomes which they view as costly. Likewise, the significance of uncertainty in the presence of the Greenbooks suggests that the staff forecasts customarily used in policy rule estimates do not fully account for the effects of uncertainty on the economy that FOMC members perceive.

VI. Properties of Policymakers' Uncertainty

The evidence so far shows that the uncertainty language in the meetings affects the FOMC's decision making. To further characterize its content, we analyze the variation in PMU over the business cycle, the relationship of the PMU measures with policymakers' skewed beliefs reflected in their sentiment, the Greenbook forecasts, and measures of public perceptions of uncertainty. The balance of evidence shows that policymakers' uncertainty provides new information about decision making that is not subsumed by variables typically used in policy analysis.

VI.A. PMU and sentiment over the business cycle

Figure 6 presents the time-series variation in PMU for inflation and the real economy, juxtaposing them against the positive and negative sentiment. For clarity of the graphs, we smooth all series with a moving average over the last eight meetings. A noteworthy feature of the PMU is a lack of a countercyclical behavior that is usually expected from uncertainty indicators (e.g., Bloom, 2014). Inflation PMU is strongly procyclical, suggesting that policymakers tend to express more uncertainty about inflation when the economy is doing well. Inflation concerns become prevalent from mid-2000s and reach their highest level in the first half of 2008. The procyclical inflation PMU is consistent with policymakers worrying primarily about the demand-driven increases in inflation. Indeed, inflation PMU comoves remarkably closely with the positive inflation sentiment expressed in the meetings (i.e., increasing inflation). Perhaps more surprisingly, the real-economy PMU also fails to

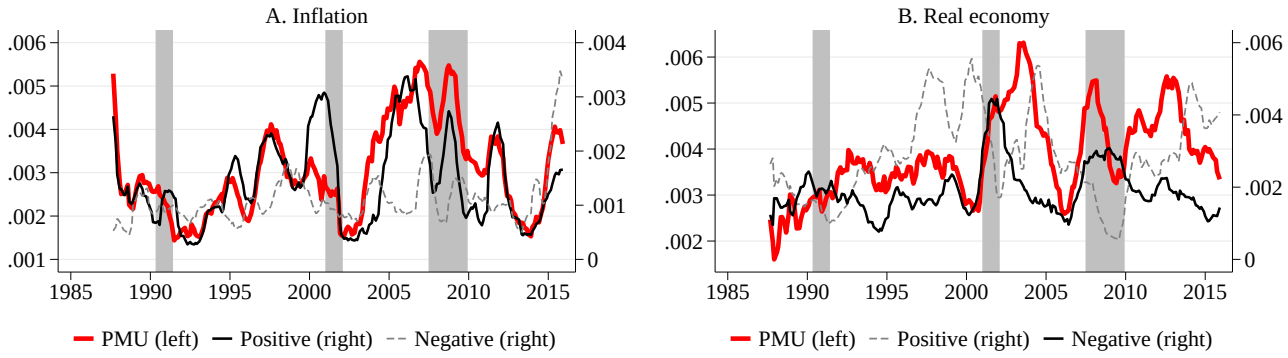


Figure 6. PMU over the business cycle. The figure presents topic-specific PMU indices superimposed against negative and positive sentiment. Positive (negative) sentiment indicates views of rising (declining) inflation or output. All text-based series are smoothed averages over the last eight FOMC meetings.

display obviously countercyclical dynamics.[26] Compared to inflation, the economy PMU however shows a weaker correlation with the sentiment. For example, the economy PMU increases and remains persistently higher through the end of 2013, even when the negative sentiment about the economy subsides.[27]

Figure 6 points to an asymmetry: Elevated PMU coincides with views about the direction of the economy that policymakers would traditionally consider undesirable (rising inflation and weakening growth). To test the asymmetry more formally, in Table VIII, we regress the PMU on the positive and negative sentiment. At the aggregate meeting level, in panel A, a one-sigma increase in positive inflation sentiment *InfPos* (referring to an increasing inflation) is associated with a 0.63-sigma increase in *InfPMU* (t-stat = 7.2); instead, a one-sigma increase in negative inflation sentiment *InfNeg* is associated with just 0.24-sigma increase in *InfPMU* (column (1)). A similarly asymmetric relationship is present for the real-economy PMU (column (2)), with *EcoNeg* (perception of a weakening economy) being about a three times stronger predictor of PMU than *EcoPos* (strengthening economy). The

[26]Its highest reading occurs during the March 18, 2003 meeting, driven by the uncertainty about the timing and extent of the Iraq war and about the underlying economic conditions. In another major episode, real-economy PMU becomes elevated in the first-half of 2007 before the start of the official NBER-dated recession. The transcripts of the March 21, 2007 meeting highlight rising concerns about growth outlook and heightened forecast uncertainty that are not yet associated with a direct downgrade of the economic forecasts. The uncertainty actually declines during the heights of the financial crisis even as the policymakers continue to express negative sentiment about the real economy.

[27]The market PMU is also strongly positively associated with the negative market sentiment expressed during the meetings (not shown in the figure for brevity). The market PMU reaches the highest level already in the early phases of the global financial crisis, in August 2007, preceding spike in the VXO (on October 29, 2008) by more than a year. As such, policymakers' uncertainty increases long before the full extent of the financial crisis can be appreciated.

A. Meeting level

	(1) $InfPMU_t$	(2) $EcoPMU_t$
$InfPos_t$	0.623***	-0.195***
	(7.17)	(-2.98)
$InfNeg_t$	0.236***	-0.017
	(4.59)	(-0.30)
$EcoPos_t$	-0.154*	0.136*
	(-1.68)	(1.89)
$EcoNeg_t$	-0.063	0.344***
	(-1.10)	(6.22)
N	227	227
$\bar{R}^2$	0.41	0.13

B. Meeting-member level

	(1) $InfPMU_{it}$	(2) $InfPMU_{it}$	(3) $EcoPMU_{it}$	(4) $EcoPMU_{it}$
$InfPos_{it}$	0.21***	0.092**	-0.14***	-0.098***
	(5.06)	(2.28)	(-4.32)	(-3.97)
$InfNeg_{it}$	0.15***	0.12**	-0.050	-0.0079
	(3.18)	(2.64)	(-1.06)	(-0.16)
$EcoPos_{it}$	-0.053*	-0.038*	0.022	0.029
	(-1.89)	(-1.78)	(0.81)	(1.27)
$EcoNeg_{it}$	-0.032	-0.011	0.11***	0.062**
	(-1.35)	(-0.41)	(5.16)	(2.48)
Meeting FE	No	Yes	No	Yes
Member FE	Yes	Yes	Yes	Yes
N	3970	3970	3970	3970
R^2	0.15	0.27	0.16	0.25

Table VIII. Relationship between uncertainty and sentiment. The table reports regressions of topic-specific PMU indices on the sentiment. Sentiment proxies are based on sentences that do not contain uncertainty phrases. Panel A presents the regressions at the meeting level, and panel B at the meeting-member level. All measures are derived from the economy round of the FOMC meeting. In panel A, the coefficients are standardized and HAC t-statistics with eight lags are reported in parentheses. In panel B, standard errors are double clustered at the meeting and member level. The sample period is 1987:08–2015:12.

estimates also indicate that the real-economy PMU declines when policymakers place more emphasis on rising inflation.

Panel B of Table VIII presents analogous regressions at the meeting-member level. By including member fixed effects, we study how each a member's perception of uncertainty correlates with his or her directional views about the economy. A comparison of columns with and without time fixed effects indicates that asymmetric relationship between uncertainty and corresponding sentiment arises primarily from the business-cycle variation in policymakers' beliefs.

There are at least two possible interpretations of the correlations between PMU and sentiment. For one, policymakers may downgrade their sentiment in response to an increase in uncertainty they perceive. Thus, negative sentiment in the meeting could reflect policymakers' worry about undesirable developments which may not come true. Alternatively, negative shocks to expectations about the future could lead policymakers to express more uncertainty in the meeting. While in the latter case, one would expect negative sentiment to forecast future outcomes, in the former case, predictability is not warranted. The predictive regressions in Table IV help cast light on these alternative interpretations. There, we establish that sentiment predicts real GDP growth but not inflation (except in a very short run). Thus, the close co-movement between inflation PMU and *InfPos* is likely to encapsulate

policymakers' concerns about increases in inflation that do not come to fruition over our sample period.[28]

VI.B. Past forecast errors

The differences in the properties of inflation and real-economy PMU raise a broader question about the drivers of uncertainty in the meetings. It is natural to expect that uncertainty is affected by the magnitude of forecast errors, or the extent to which economic outcomes have diverged from the Fed's expectations. We therefore explore the relationship between uncertainty expressed in the meeting and the past forecast errors, using the Greenbook forecasts prepared by the Fed staff several days before the meeting. Table IX reports regressions of PMU indices on the absolute and signed forecast errors for inflation and real GDP growth.[29]

The results in Table IX panel A show that past absolute forecast errors (but not signed errors) are predictive of inflation PMU. Policymakers become more uncertain about inflation after experiencing large inflation surprises (in either direction). At the same time, inflation PMU is negatively related with absolute errors about the real GDP growth. The negative relationship is consistent with the procyclical variation in inflation PMU and the fact the real GDP growth errors are most pronounced in recessions. There is much less evidence of a systematic relationship between forecast errors and uncertainty about the real side of the economy. Policymakers tend to emphasize uncertainty about the real economy more when growth turns out lower and inflation higher than expected, but past forecast errors explain at most 4% of variation in the real-economy PMU. In summary, a significant part of PMU variation remains unexplained by the magnitude and direction of past surprises to Fed's macro expectations.

VI.C. Relationship of PMU with public perceptions of (policy) uncertainty

The illustrative framework in Section II indicates that policymakers' uncertainty expressed in the meeting is not equivalent to the objective conditional volatility of the macroeconomic

[28]The predictability results are unlikely to be endogenous to policy, given the known lagged effects of monetary policy on macro variables. The typical effect of policy on inflation takes about 18 months to unfold.

[29]The forecast error is defined as meeting-t nowcast minus meeting-$t-h$ forecast. The forecast errors $|\overline{FE}_t|$ are averages across horizons h from one-quarter-ahead to four-quarters-ahead. All errors are known at the time of the meeting t, but the forecast are formed at different meetings. In this way, we consider lookback period of up to one year. We do not include unemployment forecast errors in the regressions because of their high correlation with the forecast errors about the real GDP growth, making the interpretation of the coefficients less transparent.

A. Absolute forecast errors

	(1) $InfPMU_t$	(2) $EcoPMU_t$
$\lvert\overline{FE}_t(g)\rvert$	-0.308***	-0.013
	(-4.56)	(-0.15)
$\lvert\overline{FE}_t(\pi)\rvert$	0.382***	-0.038
	(4.82)	(-0.53)
$\bar{R}^2$	0.15	-0.0069
N	227	227

B. Forecast errors

	(1) $InfPMU_t$	(2) $EcoPMU_t$
$\overline{FE}_t(g)$	0.058	-0.205**
	(0.54)	(-2.14)
$\overline{FE}_t(\pi)$	0.150	0.144
	(1.26)	(1.60)
$\bar{R}^2$	0.021	0.041
N	227	227

Table IX. Predicting uncertainty with past forecast errors. The table reports regressions of topic-specific PMU indices on past forecast errors in the Greenbooks. The coefficients are standardized. HAC t-statistics with eight lags are reported in parentheses. The sample period is 1987:08–2015:12.

variables. The inflation scares example shows how perceived uncertainty can be intertwined with policymakers' concerns about events that have low probability but are associated with large losses. The empirical properties of the PMU, and the link between PMU and sentiment, indeed suggest that PMU does not measure the objective physical volatility. As such, public perceptions of uncertainty should differ from the uncertainty relevant for policymaking, because they already condition on expected FOMC behavior.

To show this distinction more explicitly it worth connecting the PMU to measures of policy uncertainty proposed by Baker et al. (2016) and Husted et al. (2020).[30] These indices aim to reflect the degree of uncertainty that the public perceives about general economic policy and more specifically Fed's policy actions and/or their consequences. Table X presents regressions of the BBD and HRS indices on the overall PMU, PMU components, and the sentiment in the meeting. Here, in addition to the macro sentiment, we also include policymakers' directional views about financial markets (*MktSent*) given that public uncertainty generally rises at times of financial market stress.

The correlation between public and policymakers' uncertainty is positive (columns (1), (5) and (7)), but the significance of the relationship depends on the proxy. The disaggregated PMU indices reveal differences in signs of loadings across uncertainty types. The positive co-movement between policymakers' and public's uncertainty arises from the discussions of uncertainty about the real economy in the meeting, and in the case of the BBD indices, from

[30]Baker et al. (2016, BBD) develop an index of economic policy uncertainty (EPU) based on the frequency of articles in ten leading newspapers that mention both uncertainty and economic policy. In addition, they also introduce sub-indices tailored for specific policies, including monetary policy. Husted et al. (2020, HRS) adopt a related newspaper-based approach to construct a monetary policy uncertainty index (MPU) specific to the US monetary policy.

	BBD EPU_t				BBD MPU_t		HRS MPU_t	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PMU_t	0.361***				0.372***		0.178	
	(3.35)				(4.35)		(1.51)	
$InfPMU_t$		-0.241***		-0.232***		-0.136**		-0.144
		(-4.46)		(-3.35)		(-2.21)		(-1.52)
$EcoPMU_t$		0.175*		0.196***		0.264***		0.233*
		(1.93)		(2.78)		(2.63)		(1.84)
$MktPMU_t$		0.115		-0.052		-0.091		-0.050
		(1.15)		(-0.57)		(-1.30)		(-0.39)
$ModPMU_t$		-0.036		-0.028		-0.048		0.140**
		(-0.78)		(-0.59)		(-1.21)		(2.05)
$OthPMU_t$		0.409***		0.315***		0.185**		-0.081
		(5.50)		(4.13)		(2.37)		(-0.78)
$InfSent_t$			-0.189**	-0.037		0.048		0.023
			(-2.42)	(-0.60)		(0.95)		(0.29)
$EcoSent_t$			-0.367***	-0.231***		-0.290***		-0.142
			(-4.10)	(-3.03)		(-4.64)		(-1.39)
$MktSent_t$			-0.198**	-0.209***		-0.288***		-0.211**
			(-2.41)	(-3.11)		(-4.02)		(-2.46)
R^2	0.13	0.38	0.27	0.47	0.14	0.41	0.032	0.15
$\bar{R}^2$	0.13	0.37	0.26	0.45	0.13	0.39	0.028	0.12
N	227	227	227	227	227	227	227	227

Table X. Public perceptions of uncertainty. The table reports regressions of measures of public perceptions of policy uncertainty on PMU indices. BBD EPU is the economic policy uncertainty index from Baker et al. (2016), BBD MPU is their subindex for monetary policy uncertainty, and HRS MPU is the monetary policy uncertainty index from Husted et al. (2020). The sample period is 1987:08–2015:12. All variables are scaled by their standard deviations. HAC t-statistics with eight lags are reported in parentheses. The regressions are estimated at the frequency of the FOMC meetings.

other uncertainty (*OthPMU*) not subsumed by our explicit PMU categories.[31] In contrast, inflation PMU is strongly negatively related with the public's uncertainty. The negative loading reflects the fact that inflation PMU is procyclical while public uncertainty proxies are generally countercyclical (Bloom, 2014). Indeed, public uncertainty is high at times when policymakers express negative views about financial markets, as shown by the loadings on the sentiment measures.

Macroeconomic surveys of professional forecasters provide another useful comparison with the PMU. In Figure 7, we superimpose inflation and real-economy PMU with dispersion of forecast about inflation and real GDP growth in two Blue Chip surveys. One would expect the forecast dispersion to correlate with the uncertainty that public has about the path of the macroeconomy. The plots visualize the distinct features of policymakers' uncertainty. Peaks in PMU are not typically accompanied by an elevated dispersion of professional forecasts,

[31] *OthPMU* contains uncertainty mentioned in the context of other (i.e., not monetary) policy. As such, it includes mentions of fiscal policy in the meeting which is an important category in the BBD index.

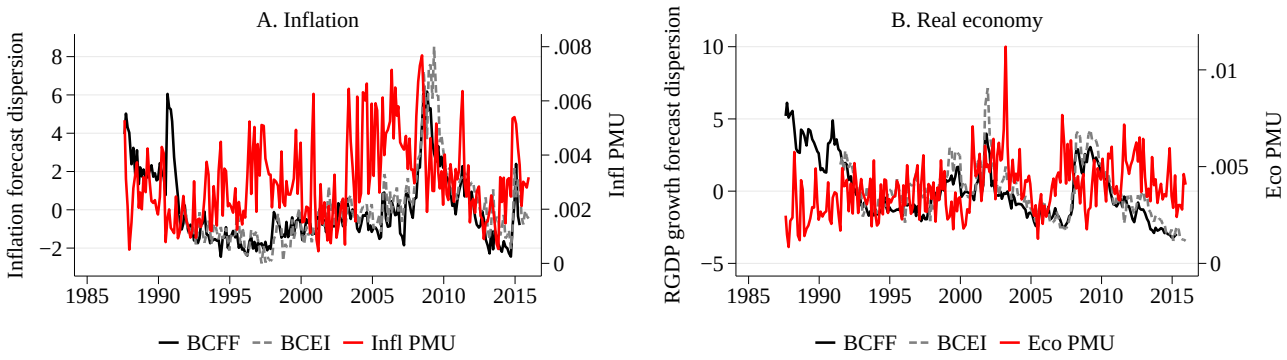


Figure 7. PMU vs. public disagreement. The figure compares PMU with measures of disagreement in survey forecasts of inflation and real GDP growth. The surveys are quarterly forecasts from the Blue Chip Economic Indicators (BCEI) and Blue Chip Financial Forecasts (BCFF). BCFF dispersion is measured as mean absolute deviation of forecasts across individuals. BCEI dispersion is the difference between the top 10th and bottom 10th percentile of forecasts (individual data is not available). We report the first principal component of forecast dispersions across horizons from the current quarter up to four quarters ahead.

and in fact, they precede periods of high dispersion. This supports the notion that uncertainty that is relevant for policymaking differs from public perceptions of macroeconomic uncertainty.

VII. Conclusions

We contribute to the literature by quantifying otherwise hard-to-measure factors driving monetary policymaking using texts of the FOMC deliberations. We show that policymakers' beliefs about the higher-order moments of the economic distributions affect the policy stance at the FOMC meetings during the 1987–2015 sample. Policymakers' perceptions of uncertainty and skewness about inflation and the real-economy drive a wedge between estimated policy rules using Greenbook forecasts and the actual decision-making of the committee. Uncertainty about the real-economy and inflation affect the policy stance in opposite ways. An increase in the real-economy uncertainty works similar to a typical negative demand shock, consistent with the uncertainty channel postulated in recent macro models. Our key new results pertain to the effects of inflation uncertainty. Heightened inflation uncertainty leads to more hawkishness and strengthens the committee's reaction to inflation. We show that the uncertainty relevant for understanding the Fed decision-making deviates significantly from the public perceptions of uncertainty or objective measures of macroeconomic volatility. In particular, policymakers' uncertainty is associated with their skewed beliefs about increasing inflation. Consistent with models of inflation scares, policymakers place weight on low probability but costly and therefore salient events, but those events do not realize in our sample. Our results highlight the central role of policymakers' beliefs in

understanding how deviations from policy rules occur. They also cast light on plausible mechanisms to be incorporated in models of optimal policy choice under uncertainty.

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Internet Appendix for:

Policymakers' Uncertainty

Anna Cieslak Stephen Hansen Michael McMahon Song Xiao[1]

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[1]Cieslak: Duke University, Fuqua School of Business, NBER and CEPR, e-mail: anna.cieslak@duke.edu; Hansen: Imperial College London and CEPR, e-mail: stephen.hansen@imperial.ac.uk; McMahon: University of Oxford, CEPR, CfM (LSE), and CAMA (ANU), email: michael.mcmahon@economics.ox.ac.uk; Xiao: London School of Economics, email: s.xiao2@lse.ac.uk.

A. Dictionaries for Risk, Uncertainty, Topics, and Sentiment

risk			risks		
Term	Similarity	Count in Econ Discussion	Term	Similarity	Count in Econ Discussion
risks	0.691266	3183	downside risk*	0.737511	1118
downside risk*	0.59828	1118	upside risk*	0.704978	585
threat	0.594511	135	risk	0.691266	3236
upside risk*	0.522107	585	threat	0.52743	135
danger	0.502593	121	skewed	0.501801	101
probability	0.484233	524	uncertainties	0.48339	505
possibility	0.475492	1010	~~downside~~	0.449301	707
likelihood	0.469565	224	~~tilted~~	0.448698	119
vulnerability	0.439843	72	danger	0.445836	121
dangers	0.406005	28	dangers	0.439822	28
~~headwind~~	0.402709	38	fatter	0.434411	14
chances	0.386979	65	~~outcomes~~	0.420205	291
fragility	0.374305	106	probability	0.412639	524
~~risktaking~~	0.373512	50	skew	0.40086	29
~~challenges~~	0.348706	174	~~challenges~~	0.395508	174
~~prospect~~	0.347213	242	~~juncture~~	0.393311	114
~~unwelcome~~	0.345361	42	modal	0.391584	131
sensitivity	0.343196	82	~~headwinds~~	0.385167	288
probabilities	0.342825	87	vulnerabilities	0.378889	59
~~breakout~~	0.34249	39	probabilities	0.375555	87
uncertainty	0.341431	2317	concerns	0.374206	628
~~consequences~~	0.339106	367	~~breakout~~	0.372844	39
concern* that	0.33652	678	possibilities	0.369255	98
odds	0.332704	190	uncertainty	0.362784	2317
fatter	0.331849	14	vulnerability	0.355743	72
concern	0.326579	1047	~~directive~~	0.355738	29
potentially	0.322536	275	tensions	0.35208	51
concerns	0.318465	628	~~crosscurrents~~	0.350524	49
tension	0.313301	101	odds	0.343869	190
~~spiral~~	0.312127	69	threats	0.33815	36
possibly	0.309975	290	fragility	0.337531	106
~~costly~~	0.309472	63	~~symmetric~~	0.336238	57
~~challenge~~	0.307298	179	~~asymmetry~~	0.333936	25
~~urgency~~	0.303853	28	~~skews~~	0.33296	14
~~instability~~	0.303578	91	~~urgency~~	0.3309	28
unease	0.303215	25	skewness	0.330203	7
vulnerabilities	0.302247	59	tension	0.325514	101
fear	0.299544	194	~~headwind~~	0.323167	38
skewness	0.298903	7	~~vigilant~~	0.319233	55
~~trap~~	0.297911	58	~~drags~~	0.31894	75
~~overshoot~~	0.296446	53	~~costpush~~	0.318601	4
~~problem~~	0.295296	1221	possibility	0.318443	1010
skew	0.29475	29	~~balanced~~	0.317706	646
worries	0.294228	132	tails	0.31724	28
threats	0.294017	36	~~challenge~~	0.316888	179
~~repercussions~~	0.289451	23	likelihood	0.315145	224
skewed	0.287008	101	imponderables	0.31498	10
volatility	0.284335	360	~~considerations~~	0.311688	184
doubts	0.283668	65	~~consequences~~	0.306922	367
~~juncture~~	0.283524	114	~~leaning~~	0.305052	38

Table A-1. Nearest Neighbors of Risk and Risks in FOMC Word Embeddings. This table shows the fifty nearest neighbors to the terms 'risk' and 'risks' for a word embedding model estimated from the economy round of the FOMC transcripts. For each neighbor term, we report the cosine similarity in the word embedding space and the count of the term in the economy round. We remove certain terms from our final dictionary if they are too generic (struck through).

uncertain			uncertainty		
Term	Similarity	Count in Econ Discussion	Term	Similarity	Count in Econ Discussion
!confident	0.460385	367	uncertainties	0.65845	505
fragile	0.455998	157	anxiety	0.515023	70
!sanguine	0.442406	101	angst	0.433309	24
murky	0.43732	24	skepticism	0.430759	68
unclear	0.436552	57	tension	0.427094	101
wary	0.428437	41	uncertain	0.426752	399
uncertainty	0.426752	2317	~~caution~~	0.423748	445
unsure	0.423955	14	downside risk*	0.418226	1118
~~poor~~	0.411094	194	~~challenges~~	0.414084	174
~~dependent~~	0.406995	119	pessimism	0.411988	179
apprehensive	0.404002	11	fragility	0.401378	106
vulnerable	0.401095	203	gloom	0.380074	65
stressed	0.397458	53	~~conflict~~	0.370107	47
~~challenging~~	0.391555	71	risks	0.362784	3183
~~bullish~~	0.38583	65	volatility	0.359692	360
bleak	0.385454	52	concerns	0.359599	628
skeptical	0.384238	169	!clarity	0.352539	89
~~attuned~~	0.383523	15	sensitivity	0.348326	82
uncertainties	0.383365	505	unease	0.347682	25
~~vigilant~~	0.382641	55	~~publicity~~	0.346734	31
~~cautious~~	0.378045	537	fog	0.343423	20
grim	0.376893	34	~~headwinds~~	0.341591	288
~~jury~~	0.376789	20	risk	0.341431	3236
agnostic	0.375537	31	~~surrounding~~	0.340727	163
!optimistic	0.372549	1249	worries	0.337692	132
~~muted~~	0.365712	87	!certainty	0.332492	91
unsettled	0.362423	22	doubts	0.328778	65
concern* about	0.361507	1634	concern	0.327687	1047
~~buoyant~~	0.360631	70	optimism	0.32465	498
~~disruptive~~	0.359961	50	~~pain~~	0.323275	31
~~depend~~	0.359918	198	ambiguity	0.322258	18
skittish	0.35904	18	error	0.320998	234
jittery	0.358658	11	skittishness	0.319675	9
precarious	0.357391	22	nervousness	0.319648	31
fog	0.357145	20	unknown	0.316516	32
fluid	0.357016	12	tensions	0.314929	51
!convinced	0.354622	173	imponderables	0.314825	10
pessimistic	0.354016	430	upside risk*	0.313048	585
!upbeat	0.352921	217	~~debate~~	0.312722	168
~~destabilizing~~	0.35242	22	~~awareness~~	0.312388	26
precise	0.352262	81	~~uncertaintyin~~	0.310427	3
uncomfortable	0.348358	102	~~disagreement~~	0.304366	57
~~assessing~~	0.345848	110	~~admits~~	0.302832	3
~~damaging~~	0.342869	39	~~science~~	0.29633	31
~~satisfactory~~	0.339921	66	~~apprehension~~	0.292553	16
anxious	0.33839	40	~~headwind~~	0.290777	38
~~worried~~	0.337316	410	~~instability~~	0.290598	91
ambiguous	0.335987	32	~~troubles~~	0.288294	35
problematic	0.33498	78	~~questions~~	0.288182	698
daunting	0.332674	19	~~worry~~	0.286513	402

Table A-2. Nearest Neighbors of Uncertain and Uncertainty in FOMC Word Embeddings. This table shows the fifty nearest neighbors to the terms 'uncertain' and 'uncertainty' for a word embedding model estimated from the economy round of the FOMC transcripts. For each neighbor term, we report the cosine similarity in the word embedding space and the count of the term in the economy round. We remove certain terms from our final dictionary if they are too generic (struck through). An exclamation mark preceding a term indicates it is only associated with the dictionary when it is negated, i.e., when it is immediately preceded by a negation phrase, which is one of {'less', 'no','not', 'little', 'don't', 'doesn't', 'hasn't', 'haven't', 'won't', 'shouldn't', 'didn't'}.

Nouns	Match w/ direction words		Direction words	
	Negative	Positive	Group 1	Group 2
commodity price*	1	2	*abated*	*acceler**
consumer energy price*	1	2	*adjust* downward*	*adjust* upward*
consumer food price*	1	2	*contract**	*advanc**
consumer price index*	1	2	*cool**	*bolster**
consumer price index* cpi	1	2	*deceler**	*boost**
consumer price inflation	1	2	*declin**	*elevat**
consumer price*	1	2	*decreas**	*expand**
core consumer price inflation	1	2	*down*	*fast**
core consumer price*	1	2	*downturn*	*gain**
core cpi	1	2	*downward*	*go* up*
core cpi inflation	1	2	*downward adjust**	*heighten**
core inflation	1	2	*downward revision*	*high**
core pce inflation	1	2	*drop**	*increas**
core pce price inflation	1	2	*eas**	*mov* higher*
core pce price*	1	2	*fall**	*mov* up*
core price inflation	1	2	*fell*	*mov* upward*
core producer price*	1	2	*go* down*	*pick* up*
cost basic material*	1	2	*limit**	*rais**
cost* goods and services	1	2	*low**	*rallied*
cost* health care	1	2	*moderate**	*rally**
cost* labor	1	2	*moderati**	*rebound**
cost* living	1	2	*mov* down*	*recoup**
cost* us goods and services	1	2	*mov* downward*	*revis* up**
crude oil price*	1	2	*mov* lower*	*rise**
disinflation*	2	1	*pullback*	*rising*
disinflation* pressure*	2	1	*reduc**	*rose*
employment cost index*	1	2	*revis* down**	*run up*
energy prices	1	2	*slow**	*runup*
headline inflation	1	2	*slow* down*	*stop decline*
health care cost*	1	2	*soft**	*strength**
inflation*	1	2	*stagnate**	*strong**
inflation compensation	2	1	*stall**	*tick* up*
inflation expectation*	1	2	*subdu**	*up*
inflation level	1	2	*tick* down*	*upward*
inflation outlook	1	2	*tight**	*upward adjust**
inflation rate	1	2	*weak**	*upward revision*
inflation wage*	1	2	*weigh* on*	*went up*
labor compensation	1	2	*went down*	
labor cost pressure*	1	2		
labor cost*	1	2		
long* run inflation expectation*	1	2		
long* term inflation expectation*	1	2		
manufacturing price*	1	2		
material price*	1	2		
near* term inflation expectation*	1	2		
oil price*	1	2		
pce price index*	1	2		
pressure* inflation	1	2		
pressure* wages	1	2		
price index*	1	2		
price inflation	1	2		
price level stability	2	1		
price stability	2	1		
prices of durable goods	1	2		
prices of durables	1	2		
prices of manufacturing	1	2		
prices of material*	1	2		
producer price ind*	1	2		
producer price*	1	2		
real oil price*	1	2		
unit labor cost*	1	2		
wage gains	1	2		
wage inflation	1	2		
wage pressure*	1	2		
wage price pressure*	1	2		
wages	1	2		
inflation* pressure*	1	2		
price pressure*	1	2		
deflation* force*	2	1		
deflation* pressure	2	1		
deflation*	2	1		
prices of durable goods	1	2		
prices of durables	1	2		
prices of manufacturing	1	2		
prices of material*	1	2		

Table A-3. Noun Phrases and Direction Words Related to Inflation and Wages. The first column displays the phrases we associate with inflation and wage discussion in the FOMC transcripts. The second to fifth columns relate to the construction of inflation sentiment. An instance of positive sentiment occurs when a mention of one of the nouns with a 1 (2) recorded in the 'Positive' column is preceded or followed by a phrase from Group 1 (Group 2) within sub-sentences. Negative sentiment is constructed analogously.

Nouns	Match w/ direction words		Direction words	
	Positive	Negative	Group 1	Group 2
aggregate demand	2	1	*adjust* downward*	*acceler**
aggregate inventory sales ratio	1	2	*adverse*	*adjust* upward*
aggregate spending	2	1	*contract**	*advanc**
building activity	2	1	*cool**	*better*
business activity	2	1	*cut**	*bolster**
business capital spending	2	1	*deceler**	*boost**
business confidence	2	1	*declin**	*elevat**
business demand capital equipment	2	1	*decreas**	*encourag**
business equipment investment	2	1	*deteriorat**	*expand**
business equipment spending	2	1	*disappoint**	*fast**
business equipment spending	2	1	*down*	*favor**
business equipment spending and industrial production	2	1	*downturn*	*gain**
business expansion	2	1	*downward*	*go* up*
business expenditure*	2	1	*downward adjust**	*heighten**
business fixed investment	2	1	*downward revision*	*high**
business fixed investment and household spending	2	1	*drag**	*improv**
business inventory investment	2	1	*drop**	*increas**
business investment	2	1	*eas**	*mov* higher*
business investment spending	2	1	*fall**	*mov* up*
business outlay*	2	1	*fell*	*mov* upward*
business outlays capital equipment	2	1	*go* down*	*pick* up*
business output	2	1	*held down*	*rais**
business purchas*	2	1	*hold down*	*rallied*
business purchases of transporation equipment	2	1	*increas* at slow* rate*	*rally**
business sector	2	1	*limit**	*rebound**
business sentiment	2	1	*low**	*recoup**
business spending	2	1	*moderate**	*revis* up**
business spending capital equipment	2	1	*moderati**	*rise**
business spending of transporation equipment	2	1	*mov* down*	*rising*
capacity utilization	2	1	*mov* downward*	*rose*
capital investment	2	1	*mov* lower*	*run up*
capital spending	2	1	*pressur**	*runup*
capital spending plan*	2	1	*pullback*	*stop decline*
civilian unemployment rate	1	2	*reduc**	*strength**
claim* unemployment insurance	1	2	*revis* down**	*strong**
construction activity	2	1	*slow**	*tick* up*
consumer confidence	2	1	*slow* down*	*tight**
consumer sector	2	1	*soft**	*up*
consumer sentiment	2	1	*stagnat**	*upward*
consumer spending	2	1	*stall**	*upward adjust**
consumption	2	1	*strain**	*upward revision*
consumption spending	2	1	*stress**	*went up*
current account deficit			*subdu**	
current account surplus			*take* toll on*	
disposable income	2	1	*tension**	
domestic components of spending	2	1	*tick* down*	
domestic demand	2	1	*took toll on*	
domestic economy	2	1	*weak**	
domestic final demand	2	1	*weigh* down*	
domestic spending	2	1	*weigh* on*	
domestic spending components	2	1	*went down*	
durable equipment	2	1	*worse**	
economic activity	2	1		
economic development*	2	1		
economic expansion	2	1		
economic growth	2	1		
economic outlook	2	1		
economic performance	2	1		
economic recovery	2	1		
economic situation	2	1		
employment	2	1		
employment growth	2	1		
employment rate	2	1		
excess capacity	1	2		
factory output	2	1		

Table A-4. Noun Phrases and Direction Words Related to Economic Growth (1). The first column displays a subset the phrases we associate with economic growth discussion in the FOMC transcripts (see other tables in sequence for other nouns). The second to fifth columns relate to the construction of growth sentiment. An instance of positive sentiment occurs when a mention of one of the nouns with a 1 (2) recorded in the 'Positive' column is preceded or followed by a phrase from Group 1 (Group 2) within sub-sentences. Negative sentiment is constructed analogously. Nouns with no number recorded in the second and third columns are used to contextualize uncertainty language but not for the construction of sentiment.

Nouns	Match w/ direction words		Direction words	
	Positive	Negative	Group 1	Group 2
final demand	2	1	*adjust* downward*	*acceler**
gdp growth	2	1	*adverse*	*adjust* upward*
global economic growth	2	1	*contract**	*advanc**
gross domestic product	2	1	*cool**	*better*
high tech equipment investment	2	1	*cut**	*bolster**
high tech equipment spending	2	1	*deceler**	*boost**
household spending and business fixed investment	2	1	*declin**	*elevat**
household* spending	2	1	*decreas**	*encourag**
housing activity	2	1	*deteriorat**	*expand**
housing construction	2	1	*disappoint**	*fast**
housing demand	2	1	*down*	*favor**
income growth	2	1	*downturn*	*gain**
industrial production	2	1	*downward*	*go* up*
inventories	2	1	*downward adjust**	*heighten**
inventory accumulation	1	2	*downward revision*	*high**
inventory investment	2	1	*drag**	*improv**
inventory liquidation	2	1	*drop**	*increas**
inventory sales ratio	1	2	*eas**	*mov* higher*
investment condition*	2	1	*fall**	*mov* up*
investment demand	2	1	*fell*	*mov* upward*
investment high tech equipment	2	1	*go* down*	*pick* up*
investment manufacturing	2	1	*held down*	*rais**
investment situation	2	1	*hold down*	*rallied*
investment spending	2	1	*increas* at slow* rate*	*rally**
job growth	2	1	*limit**	*rebound**
labor demand	2	1	*low**	*recoup**
labor force participation	2	1	*moderate**	*revis* up**
labor market*	2	1	*moderati**	*rise**
labor market condition*	2	1	*mov* down*	*rising*
labor market indicator*	2	1	*mov* downward*	*rose*
labor market slack	1	2	*mov* lower*	*run up*
labor productivity	2	1	*pressur**	*runup*
manufacturing activity	2	1	*pullback*	*stop decline*
manufacturing capacity utilization	2	1	*reduc**	*strength**
manufacturing output	2	1	*revis* down**	*strong**
manufacturing production	2	1	*slow**	*tick* up*
manufacturing sector	2	1	*slow* down*	*tight**
motor vehicle assembl*	2	1	*soft**	*up*
motor vehicle production	2	1	*stagnat**	*upward*
motor vehicle purchas*	2	1	*stall**	*upward adjust**
motor vehicle sales	2	1	*strain**	*upward revision*
motor vehicle sector	2	1	*stress**	*went up*
new construction	2	1	*subdu**	
new home sales	2	1	*take* toll on*	
new orders	2	1	*tension**	
nominal gdp	2	1	*tick* down*	
nonfarm business sector	2	1	*took toll on*	
nonfarm payroll employment	2	1	*weak**	
nonresidential construction	2	1	*weigh* down*	
nonresidential construction activity	2	1	*weigh* on*	
orders and shipments of nondefense capital goods	2	1	*went down*	
orders of nondefense capital goods	2	1	*worse**	
outlays business equipment	2	1		
outlays high tech equipment	2	1		
outlays transporation equipment	2	1		
outlook economic activity	2	1		
output gap				
output growth	2	1		
payroll employment	2	1		
pce	2	1		
personal consumption expenditure*	2	1		
personal income	2	1		
potential output	2	1		
potential output	2	1		
private expenditures business equipment	2	1		

Table A-5. Noun Phrases and Direction Words Related to Economic Growth (2). The first column displays a subset the phrases we associate with economic growth discussion in the FOMC transcripts (see other tables in sequence for other nouns). The second to fifth columns relate to the construction of growth sentiment. An instance of positive sentiment occurs when a mention of one of the nouns with a 1 (2) recorded in the 'Positive' column is preceded or followed by a phrase from Group 1 (Group 2) within sub-sentences. Negative sentiment is constructed analogously. Nouns with no number recorded in the second and third columns are used to contextualize uncertainty language but not for the construction of sentiment.

Nouns	Match w/ direction words		Direction words	
	Positive	Negative	Group 1	Group 2
private nonfarm employment	2	1	*adjust* downward*	*acceler**
private nonfarm payroll employment	2	1	*adverse*	*adjust* upward*
private sector investment	2	1	*contract**	*advanc**
private spending	2	1	*cool**	*better*
productivity	2	1	*cut**	*bolster**
productivity growth	2	1	*deceler**	*boost**
purchas* of motor vehicle*	2	1	*declin**	*elevat**
real activity	2	1	*decreas**	*encourag**
real business spending	2	1	*deteriorat**	*expand**
real consumer spending	2	1	*disappoint**	*fast**
real disposable income	2	1	*down*	*favor**
real disposable personal income	2	1	*downturn*	*gain**
real gdp	2	1	*downward*	*go* up*
real gdp growth	2	1	*downward adjust**	*heighten**
real gnp	2	1	*downward revision*	*high**
real personal consumption expenditure*	2	1	*drag**	*improv**
real spending	2	1	*drop**	*increas**
residential construction	2	1	*eas**	*mov* higher*
residential construction activity	2	1	*fall**	*mov* up*
residential investment	2	1	*fell*	*mov* upward*
resource use	2	1	*go* down*	*pick* up*
resource utilization	2	1	*held down*	*rais**
retail trade	2	1	*hold down*	*rallied*
shipments of nondefense capital goods	2	1	*increas* at slow* rate*	*rally**
spending and production	2	1	*limit**	*rebound**
spending business equipment	2	1	*low**	*recoup**
spending high tech equipment	2	1	*moderate**	*revis* up**
spending nonresidential structures	2	1	*moderati**	*rise**
spending transporation equipment	2	1	*mov* down*	*rising*
structural productivity	2	1	*mov* downward*	*rose*
total industrial production	2	1	*mov* lower*	*run up*
total nonfarm payroll employment	2	1	*pressur**	*runup*
unemployment	1	2	*pullback*	*stop decline*
unemployment insurance claim*	1	2	*reduc**	*strength**
unemployment level	1	2	*revis* down**	*strong**
unemployment rate	1	2	*slow**	*tick* up*
us economic activity	2	1	*slow* down*	*tight**
us economy	2	1	*soft**	*up*
outlook economy	2	1	*stagnat**	*upward*
inventory level*	1	2	*stall**	*upward adjust**
fiscal			*strain**	*upward revision*
deficit			*stress**	*went up*
surplus			*subdu**	
			take toll on*	
			*tension**	
			tick down*	
			took toll on	
			*weak**	
			weigh down*	
			weigh on*	
			went down	
			*worse**	

Table A-6. Noun Phrases and Direction Words Related to Economic Growth (3). The first column displays a subset the phrases we associate with economic growth discussion in the FOMC transcripts (see other tables in sequence for other nouns). The second to fifth columns relate to the construction of growth sentiment. An instance of positive sentiment occurs when a mention of one of the nouns with a 1 (2) recorded in the 'Positive' column is preceded or followed by a phrase from Group 1 (Group 2) within sub-sentences. Negative sentiment is constructed analogously. Nouns with no number recorded in the second and third columns are used to contextualize uncertainty language but not for the construction of sentiment.

Nouns	Match w/ direction words		Direction words	
	Positive	Negative	Group 1	Group 2
aaa spread*	1	2	*adjust* downward*	*acceler**
baa spread*	1	2	*contract**	*adjust* upward*
corporate bond spread*	1	2	*cool**	*advanc**
corporate spread*	1	2	*deceler**	*adverse*
cost of bank credit	1	2	*declin**	*bolster**
cost of bond financ*	1	2	*decreas**	*boost**
cost of capital	1	2	*down*	*deteriorat**
cost of credit	1	2	*downturn*	*edge* up**
cost of equity	1	2	*downward*	*elevat**
cost of external capital	1	2	*downward adjust**	*expand**
cost of funding	1	2	*drop**	*fast**
cost of raising capital	1	2	*eas**	*gain**
cost of raising capital through equity	1	2	*edge* down*	*go* up*
credit cost*	1	2	*encourag**	*heighten**
credit default swap*	1	2	*fall**	*high**
credit risk spread*	1	2	*favor**	*increas**
credit spread*	1	2	*fell*	*mov* higher*
debt securities spread*	1	2	*go* down*	*mov* up*
equity risk prem*	1	2	*improv**	*mov* upward*
expected real return equit*	1	2	*limit**	*pick* up*
expected return equit*	1	2	*low**	*pressure**
financing cost	1	2	*moderate**	*rais**
funding cost	1	2	*moderati**	*rebound**
risk prem*	1	2	*mov* down*	*recoup**
risk spread*	1	2	*mov* downward*	*revis* up**
risk spread* corporate bonds*	1	2	*mov* lower*	*rise**
spread* corporate bond*	1	2	*narrow**	*rising*
spread* investment grade bond*	1	2	*pullback*	*rose*
spread* speculative grade bond*	1	2	*reduc**	*run up*
			revis down**	*runup*
			*slow**	*stop decline*
			*soft**	*strain**
			*subdu**	*strength**
			take toll on*	*stress**
			tick down*	*strong**
			took toll on	*tension**
			*weak**	*tick* up*
			weigh on*	*up*
			went down	*upward*
				*upward adjust**
				went up
				*widen**
				*worse**

Table A-7. Noun Phrases Related to Financial Markets (1). The first column displays a subset the phrases we associate with financial market discussion in the FOMC transcripts (see other tables in sequence for other nouns). The second to fifth columns relate to the construction of market sentiment. An instance of positive sentiment occurs when a mention of one of the nouns with a 1 (2) recorded in the 'Positive' column is preceded or followed by a phrase from Group 1 (Group 2) within sub-sentences. Negative sentiment is constructed analogously.

Nouns	Match w/ direction words		Direction words	
	Positive	Negative	Group 1	Group 2
appetite* risk taking	2	1	*adjust* downward*	*acceler**
appetite* risk*	2	1	*adverse*	*adjust* upward*
appetite* risk* asset*	2	1	*contract**	*advanc**
appetite* risk* investment*	2	1	*cool**	*bolster**
appetite* taking risk*	2	1	*deceler**	*boost**
condition* credit market*	2	1	*declin**	*eas**
condition* financial market*	2	1	*decreas**	*elevat**
credit condition*	2	1	*deteriorat**	*encourag**
credit growth	2	1	*down*	*expand**
credit market*	2	1	*downturn*	*fast**
credit market condition*	2	1	*downward*	*favor**
credit market demand	2	1	*downward adjust**	*gain**
development financial market*	2	1	*downward revision*	*go* up*
financial condition*	2	1	*drop**	*high**
financial development*	2	1	*fall**	*improv**
financial instabilit*	1	2	*fell*	*increas**
financial market condition*	2	1	*go* down*	*loos**
financial market confidence	2	1	*limit**	*mov* higher*
financial market development*	2	1	*low**	*mov* up*
financial market index*	2	1	*moderate**	*mov* upward*
financial market indic*	2	1	*moderati**	*normaliz**
financial market pressure*	1	2	*mov* down*	*pick* up*
financial market price*	2	1	*mov* downward*	*rais**
financial market sentiment	2	1	*mov* lower*	*rallied*
financial market*	2	1	*pressure**	*rally**
financial situation	2	1	*pullback*	*rebound**
financial stability	2	1	*reduc**	*recoup**
investor* appetite*	2	1	*restrictive*	*revis* up**
investor* appetite* risk*	2	1	*revis* down**	*rise**
investor* confidence	2	1	*slow**	*rising*
investor* risk appetite*	2	1	*soft**	*rose*
investor* sentiment	2	1	*stagnate**	*run up*
investor* sentiment toward risk*	2	1	*stall**	*runup*
investor* sentiment toward risk* asset*	2	1	*strain**	*stop decline*
liquidity	2	1	*stress**	*strength**
pressure* financial market	1	2	*subdu**	*strong**
risk appetite*	2	1	*take a toll on*	*tick* up*
bank credit	2	1	*tension**	*up*
bank lending	2	1	*tick* down*	*upward*
banking supervision			*tight**	*upward adjust**
banking system	2	1	*took toll on*	*upward revision*
consumer credit	2	1	*turbulent*	*went up*
credit availability	2	1	*weak**	
credit quality	2	1	*weigh* on*	
domestic credit	2	1	*went down*	
domestic nonfinancial debt	2	1	*worsen**	
financial outlook	2	1		
financial system	2	1		
foreign exchange				
foreign exchange market*				
foreign exchange valu*				
household balance sheet*	2	1		
market exchange rate*				
market liquidity	2	1		
mortgage refinancing activity	2	1		
non market exchange rate*				
nonfinancial debt	2	1		
private credit	2	1		
private credit market*	2	1		
seasonal borrowing	2	1		
total domestic non financial debt	2	1		
total domestic nonfinancial debt	2	1		
us dollar				

Table A-8. Noun Phrases Related to Financial Markets (2). The first column displays a subset the phrases we associate with financial market discussion in the FOMC transcripts (see other tables in sequence for other nouns). The second to fifth columns relate to the construction of market sentiment. An instance of positive sentiment occurs when a mention of one of the nouns with a 1 (2) recorded in the 'Positive' column is preceded or followed by a phrase from Group 1 (Group 2) within sub-sentences. Negative sentiment is constructed analogously. Nouns with no number recorded in the second and third columns are used to contextualize uncertainty language but not for the construction of sentiment.

Nouns	Match w/ direction words		Direction words	
	Positive	Negative	Group 1	Group 2
aaa yield*	1	2	*adjust* downward*	*acceler**
baa yield*	1	2	*contract**	*adjust* upward*
bond yield*	1	2	*cool**	*advanc**
corporate bond yield*	1	2	*deceler**	*bolster**
corporate debt yield*	1	2	*declin**	*boost**
corporate yield*	1	2	*decreas**	*elevat**
debt yield*	1	2	*down*	*encourag**
high grade corporate bond* yield*	1	2	*downturn*	*expand**
interest rate*	1	2	*downward*	*fast**
investment grade and speculative grade corporate bond* yield*	1	2	*downward adjust**	*gain**
investment grade corporate bond yield*	1	2	*downward movement*	*go* up*
long* term interest rate*	1	2	*downward revision*	*heighten**
long* term rate*	1	2	*drop**	*high**
mortgage interest rate*	1	2	*fall**	*increas**
real long* term interest rate*	1	2	*fell*	*mov* higher*
real long* term rate*	1	2	*go* down*	*mov* up*
speculative grade corporate bond* yield*	1	2	*limit**	*mov* upward*
yield* agency mortgage backed securities mbs	1	2	*low**	*pick* up*
yield* corporate bond*	1	2	*moderate**	*rais**
yield* corporate bonds and agency mbs	1	2	*moderati**	*rallied*
yield* mortgage backed securities	1	2	*mov* down*	*rally**
yield* private sector debt securities	1	2	*mov* downward*	*rebound**
comparable maturity treasury securities			*mov* lower*	*recoup**
discount rate*	1	2	*pullback*	*revis* up*
long* term treasury securities			*reduc**	*revision upward*
nominal treasury securities			*revis* down*	*rise**
real interest rate*	1	2	*slow**	*rising*
short* term interest rate*	1	2	*soft**	*rose*
us government securities			*stagnate**	*run up*
			*stall**	*runup*
			*subdu**	*stop decline*
			take toll on*	*strength**
			tick down*	*strong**
			*tight**	*tick* up*
			took toll on	*up*
			*weak**	*upward*
			weigh on*	*upward adjust**
			went down	*upward movement*
				upward revision
				went up

Table A-9. Noun Phrases Related to Financial Markets (3). The first column displays a subset the phrases we associate with financial market discussion in the FOMC transcripts (see other tables in sequence for other nouns). The second to fifth columns relate to the construction of market sentiment. An instance of positive sentiment occurs when a mention of one of the nouns with a 1 (2) recorded in the 'Positive' column is preceded or followed by a phrase from Group 1 (Group 2) within sub-sentences. Negative sentiment is constructed analogously. Nouns with no number recorded in the second and third columns are used to contextualize uncertainty language but not for the construction of sentiment.

Nouns	Match w/ direction words		Direction words	
	Positive	Negative	Group 1	Group 2
asset index*	2	1	*adjust* downward*	*acceler**
asset indic*	2	1	*adverse*	*adjust* upward*
asset market*	2	1	*burst**	*advanc**
asset price index*	2	1	*contract**	*bolster**
asset price indic*	2	1	*cool**	*boost**
asset price*	2	1	*deceler**	*edge* up*
asset valu*	2	1	*declin**	*elevat**
equities	2	1	*decreas**	*encourag**
equity and home price*	2	1	*deteriorat**	*expand**
equity and home valu*	2	1	*down*	*fast**
equity and house price*	2	1	*downturn*	*favor**
equity and housing price*	2	1	*downward*	*gain**
equity index*	2	1	*downward adjust**	*go* up*
equity indic*	2	1	*downward movement*	*high**
equity market index*	2	1	*downward revision*	*improv**
equity market indic*	2	1	*drop**	*increas**
equity market price*	2	1	*eas**	*mov* high**
equity market valu*	2	1	*edge* down*	*mov* up*
equity market*	2	1	*fall**	*mov* upward*
equity price index*	2	1	*fell*	*pick* up*
equity price indic*	2	1	*go* down*	*rais**
equity price measure*	2	1	*limit**	*rallied*
equity price*	2	1	*low**	*rally**
equity valu*	2	1	*moderate**	*rebound**
equaity wealth	2	1	*moderati**	*recoup**
financial wealth	2	1	*mov* down*	*revis* up**
home and equity price*	2	1	*mov* downward*	*rise**
house and equity price*	2	1	*mov* lower*	*rising*
household wealth	2	1	*plummet**	*rose*
household* net worth	2	1	*pressure**	*run up*
housing and equity price*	2	1	*pull* back*	*runup*
price* of risk* asset*	2	1	*pullback*	*stop decline*
ratio of wealth to income	2	1	*reduc**	*strength**
risk* asset price*	2	1	*revis* down**	*strong**
s p 500 index	2	1	*slow**	*tick* up*
stock index*	2	1	*slow* down*	*up*
stock indic*	2	1	*soft**	*upward*
stock market index*	2	1	*stagnate**	*upward adjust**
stock market price*	2	1	*stall**	*upward movement*
stock market wealth	2	1	*strain**	*upward revision*
stock market*	2	1	*stress**	*went up*
stock price indic*	2	1	*subdu**	
stock price*	2	1	*take* toll on*	
stock prices index*	2	1	*tension**	
stock val*	2	1	*tick* down*	
us stock market price*	2	1	*tight**	
wealth effect*	2	1	*took toll on*	
wealth to income ratio	2	1	*tumbl**	
			*weak**	
			weigh on*	
			went down	
			*worse**	

Table A-10. Noun Phrases Related to Financial Markets (4). The first column displays a subset the phrases we associate with financial market discussion in the FOMC transcripts (see other tables in sequence for other nouns). The second to fifth columns relate to the construction of market sentiment. An instance of positive sentiment occurs when a mention of one of the nouns with a 1 (2) recorded in the 'Positive' column is preceded or followed by a phrase from Group 1 (Group 2) within sub-sentences. Negative sentiment is constructed analogously. Nouns with no number recorded in the second and third columns are used to contextualize uncertainty language but not for the construction of sentiment.

parameter*
model*
measurement*
forecast error*
relationship*
error band*
nairu
trend
confidence interval*
uncertainty band*
confidence band*

Table A-11. Noun Phrases Related to Model. The table contains phrases we associate with model discussion in the FOMC transcripts.

B. Algorithms for Uncertainty, Sentiment, and Policy Stance Construction

In this section, we describe in detail how we construct text-based measures of uncertainty, sentiment, and policy stance. The first step is to preprocess the transcripts by breaking each statement by each speaker into separate sentences using a standard sentence tokenizer. This yields 559,709 total sentences, which form the basic units of linguistic analysis for the algorithms we propose below.

B.1. Uncertainty construction

B.2. Sentiment construction

Here we describe the construction of sentiment for topic k (which corresponds to economic growth, inflation and wages, and financial markets). The algorithm follows closely that in **?** which use a similar approach to build a stock market sentiment index. Here we expand this to additional topics.

Sentiment is built exclusively using economy round language. We first remove any sentence in the economy round that either contains an uncertainty flag word, i.e. a term in the 'Term' columns of tables A-1 or A-2 that is not struck through, as well as sentences that immediately precede or follow such sentences. This ensures that sentiment is constructed using a different set of input words than the uncertainty measures, which avoids a mechanical relationship between the two.

The next step is to break all remaining sentences in the economy round into sub-sentences based on the presence of words in {'and', 'because', 'but',' if', 'or', 'so','that', 'when', 'where', 'while', 'although', 'however', 'though', 'whereas', 'despite'}. Let $\mathbf{p}_{t,s}$ be the sth phrase in meeting t generated by this rule.

As described in the tables above, each topic is associated with a set of nouns. Let $g_{k,m}$ be the mth noun associated with topic k. This noun will be associated with a set of positive words $\text{Pos}_{k,m}$ and a set of negative words $\text{Neg}_{k,m}$ according to the group definitions in the tables. The positive and negative sentiment measures in meeting t begin with the tabulations

$$\tilde{S}^{+}_{t,k} = \sum_{s}\sum_{m}\sum_{n} \mathbb{1}(w_{t,s,n} = g_{k,m}) \left[\mathbb{1}(w_{t,s,n-1} \in \text{Pos}_{k,m}) + \mathbb{1}(w_{t,s,n+1} \in \text{Pos}_{k,m})\right]$$

$$\tilde{S}^{-}_{t,k} = \sum_{s}\sum_{m}\sum_{n} \mathbb{1}(w_{t,s,n} = g_{k,m}) \left[\mathbb{1}\big(w_{t,s,n-1} \in \text{Neg}_{k,m}\big) + \mathbb{1}\big(w_{t,s,n+1} \in \text{Neg}_{k,m}\big)\right]$$

That is, we count the number of times topic-k words are immediately preceded or followed by (word-specific) positive and negative terms.[2] To obtain our final sentiment measure, we scale these counts by the number of total tokens in the economy round.

[2]Since in preprocessing we remove stop words, adjacency in this definition can include separation by stop words.

B.3. Preference construction

We now describe the algorithm for constructing the measures of hawkishness and dovishness used in the main text to capture policy preferences. For all meetings, we measure generic monetary policy preferences using the procedure detailed below. For meetings conducted in 2009 and onwards, we additionally measure preferences over the size of asset purchases as part of the Fed's quantitative easing program. The sentences we consider consist of those in the policy round since that is the section of the meeting pertaining to the articulation of preferences.

B.3.1. Generic monetary policy preferences

First, we exclude from the policy round any sentence in which the term 'increase' appears along with any of {cpi, inflation, yield*, treasury} to ensure we do not include language describing the direction of non-policy-related market prices and interest rates. We classify each remaining sentence as pertaining to monetary policy:

1. If it contains any phrase in the set {federal funds rate, funds rate, target rate, policy rate, interest rate, taylor rule, alternative a, alternative b, alternative c, directive, language, statement, symmetry, asymmetry, hawkish, dovish},
2. OR if 'policy' is in the sentence and NOT any phrase in the set {fiscal policy, supervisory policy, public policy, budget policy, tax policy, housing policy, regulatory policy, ecb policy, economic policy, government policy, inventory policy, health care policy, macro policy, macroeconomic policy, spending policy, legislation, law, regulation}.
3. OR if 'basis point' is found in the sentence AND any phrase in the set {[cut*, hik*, eas*, tight*, action*, moving, move, firming, recommendation, reduction, increase]}.

We define $Hawk'_t$ to be the count of terms in {tight*, hike*, increas*, hawkish, taper, liftoff} in policy sentences; and $Dove'_t$ to be the count of terms in {ease*, easing*, cut*, dovish, reduc*, decrea*} in policy sentences. Here we account for negation, and if any of the hawk (dove) terms is immediately preceded by one of {'less', 'no','not', 'little', 'don't', 'doesn't', 'hasn't', 'haven't', 'won't', 'shouldn't', 'didn't'}, it is counted as belonging to dove (hawk) set.

B.3.2. Quantitative easing preferences

We define policy round sentences beginning in 2009 as relating to quantitative easing whenever they contain the term 'purchase*' immediately preceded by a phrase in {mortgage backed securities, mbs, asset, treasur*, agency debt}.

We then define $Hawk''_t$ to be the count of terms in {reduc*, taper, stop, purchas*} within the set of QE sentences; and $Dove''_t$ to be the count of terms in {more, additional, further} within the set of QE sentences. We again account for negation.

B.3.3. Overall preference measure

Let NP_t be the overall number of terms in the policy round in meeting t. Our hawk measure is

$$Hawk_t = \begin{cases} \frac{Hawk'_t}{\mathrm{NP}_t} & \text{if meeting } t \text{ occurs prior to 2009} \\ \frac{Hawk'_t + Hawk''_t}{\mathrm{NP}_t} & \text{if meeting } t \text{ occurs during or after 2009} \end{cases}$$

and $Dove_t$ is defined analogously.

C. Additional Tables and Figures

C.1. Summary Statistics for PMU

A. Summary statistics for PMU indices

	Mean(%)	Median(%)	St.dev.(%)	P10(%)	P90(%)	AR(1)
PMU_t	1.126	1.078	0.293	0.787	1.529	0.461
$InfPMU_t$	0.302	0.276	0.153	0.131	0.529	0.550
$EcoPMU_t$	0.388	0.386	0.138	0.226	0.566	0.463
$MktPMU_t$	0.222	0.180	0.149	0.071	0.426	0.571
$ModPMU_t$	0.066	0.061	0.044	0.018	0.119	0.107
$OthPMU_t$	0.282	0.260	0.135	0.128	0.456	0.481

B. Correlations of topic-specific PMU indices

	InfPMU	*EcoPMU*	*MktPMU*	*ModPMU*
EcoPMU	0.0735			
MktPMU	0.1218	0.3754		
ModPMU	0.2218	0.1131	0.0957	
OthPMU	-0.3348	0.1319	0.1612	-0.2091

Table A-12. Descriptive statistics for PMU. The table reports summary statistics for the overall PMU and the topic-specific PMU indices. All PMU indices are obtained from the economy round of the FOMC meeting and represent the share of uncertainty-related mentions (by topic) relative to the total number of words in the economy round of the meeting. The sample period is 1987:08–2015:12, covering 227 meetings. Panel A expresses the summary statistics for PMU in percentages (e.g., the number 1.2 for the mean overall PMU implies that on average uncertainty-related mentions constitute 1.2% of all words in the economy round). Column "AR(1)" reports the first order autoregressive coefficient (at the meeting frequency). Panel B reports the pairwise correlations between topic-specific PMU indices.

C.2. Properties of Uncertainty, Sentiment, and Policy Stance Measures

D. Illustrating effects of uncertainty in monetary models

Our empirical findings highlight an amplifying effect of uncertainty on how policy preferences react to the macroeconomy. Especially in the context of the inflation response, several facts are consistent with policymakers behaving as if they are unsure of the model that generates the data they observe. Inflation PMU increases following large forecast errors about inflation in the Greenbook and its predictive power for policy preferences goes in the same direction as the model PMU (more uncertainty about inflation and models is associated with more hawkishness).[3] As such, policymakers are likely to become more uncertain about inflation precisely at the time when their models fail, and concerns about changing economic structure become pertinent.

Below, we expand our discussion in Section V.D and revisit the theoretical literature on parameter uncertainty and preferences for robustness. We show how our empirical findings stand in contrast

[3]As reported in Table A-12, model and inflation PMU have a correlation of 0.22 which is second highest among our measures.

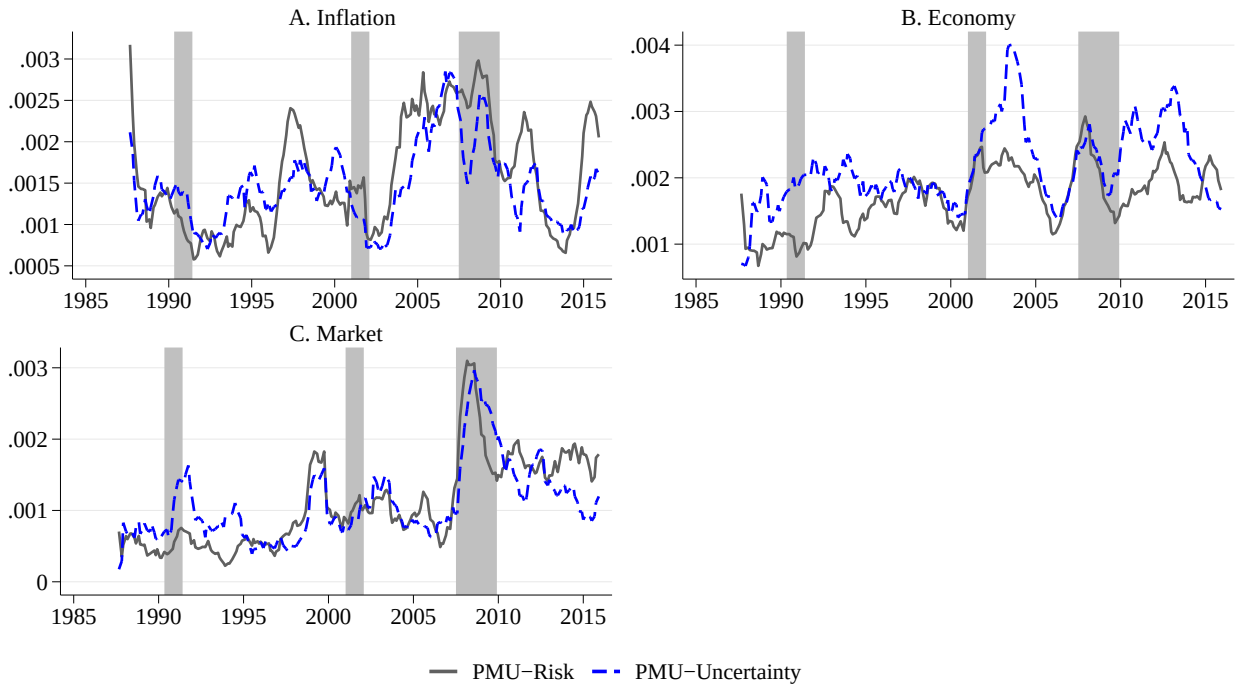

Figure A-1. Risk vs. uncertainty. The figure presents a decomposition of PMU indices (from Figure **??**) into risk and uncertainty components. All text-based series are smoothed averages over the last eight FOMC meetings.

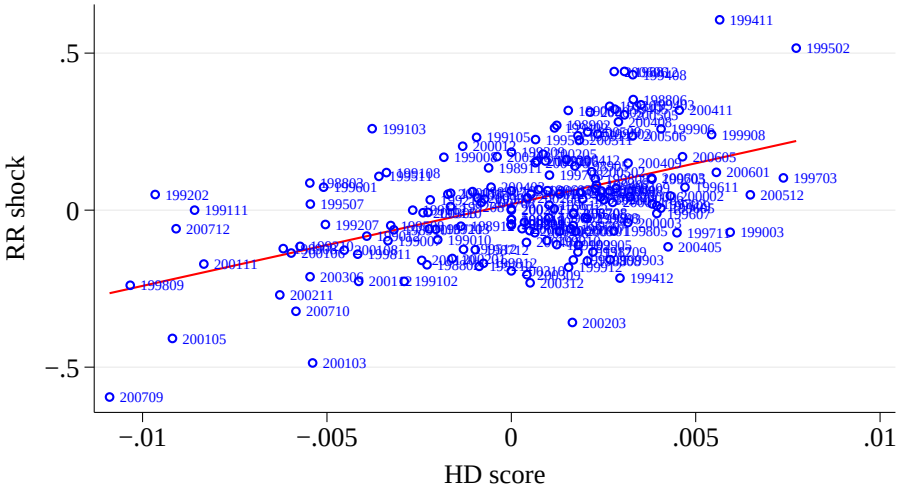

Figure A-2. *HD* measure of policy preferences vs. Romer-Romer shocks. The figure presents a scatter plot of the policy preferences *HD* against the Romer and Romer (2004) shocks. The *HD* measure is derived from the statements of the FOMC members during the policy round of the FOMC meeting.

to the typical models of parameter uncertainty, though they are consistent with settings, in which policymakers face uncertainty about the persistence of inflation. Models with a desire for robustness more easily match the anti-conservatism response we find. However, even though the results are

A. Dependent variable: Greenbook CPI inflation nowcast h meetings ahead, $E_{t+h}(CPI)$

	$h=1$	$h=2$	$h=3$	$h=4$	$h=5$	$h=6$	$h=7$	$h=8$
$InfPMU_t$	0.029	-0.035	-0.063	-0.083	-0.181	-0.173	-0.109	-0.073
	(0.33)	(-0.38)	(-0.63)	(-0.63)	(-1.27)	(-1.16)	(-0.91)	(-0.87)
$\bar{R}^2$	-0.0036	-0.0033	-0.00051	0.0024	0.028	0.025	0.0073	0.00081
N	226	225	224	223	222	221	220	219

B. Dependent variable: Greenbook real GDP growth nowcast h meetings ahead

	$h=1$	$h=2$	$h=3$	$h=4$	$h=5$	$h=6$	$h=7$	$h=8$
$EcoPMU_t$	-0.073	-0.059	-0.002	0.008	-0.050	-0.056	0.023	0.047
	(-0.92)	(-0.76)	(-0.03)	(0.09)	(-0.50)	(-0.52)	(0.21)	(0.39)
$\bar{R}^2$	0.00088	-0.00093	-0.0045	-0.0045	-0.0021	-0.0015	-0.0041	-0.0024
N	226	225	224	223	222	221	220	219

Table A-13. Predicting macro variables with textual measures of uncertainty and sentiment. The table reports predictive regressions of inflation and real GDP growth by textual PMU and sentiment indices derived from the economy round of the FOMC meeting transcripts. The regressions are estimated at the FOMC meeting frequency with the forecast horizon ranging from the next meeting ($h=1$) up to eight meetings ahead ($h=8$). To make sure that the timing of the depend variable is consistent with the timing of the meetings, we use Greenbook nowcasts at future meetings as the dependent variable. The regression is $E_{t+h,0q}(CPI) = \beta_0 + \beta_3 InfPMU_t + E_{t,0q}(CPI)$, and analogously for the real GDP growth. The coefficients are standardized. HAC standard errors to account for the overlap are reported in parentheses. The sample period is 1987:08–2015:12.

qualitatively similar, for standard calibrations the quantitative impact of uncertainty on optimal policy remains economically small relative to the empirical findings.

D.1. Parameter uncertainty

In models where the policymaker lacks knowledge of the precise value of key structural parameters, the ϕ parameters of the policy rule (**??**) become a function of the parameter uncertainty. Typically, greater uncertainty reduces the ϕ loadings. To see this, consider a backward-looking Svensson (1999) type model with perfect knowledge of the parameter values $(\alpha, \beta, \delta, \gamma)$:

$$y_{t+1} = \alpha y_t - \beta (i_t - \pi_t) + \sigma_y \varepsilon^y_{t+1} \tag{A.7}$$

$$\pi_{t+1} = \delta \pi_t + \gamma y_t + \sigma_\pi \varepsilon^\pi_{t+1}, \tag{A.8}$$

where ε^y_{t+1} and ε^π_{t+1} are stochastic shocks. The central bank sets the optimal interest rate i_t by minimizing the following quadratic loss function:

$$\min_{\{i_{t+\tau}\}_{\tau=0}^{\infty}} E_t \sum_{\tau=0}^{\infty} \psi^\tau \left(\pi^2_{t+\tau} + \lambda_y y^2_{t+\tau}\right). \tag{A.9}$$

Optimal policy is a linear function of the current state variables:

$$i_t = \phi_y y_t + \phi_\pi \pi_t. \tag{A.10}$$

The first row of Table A-14 shows the baseline parametrization of the model with the structural parameters known with certainty. The optimal policy coefficients ϕ_y, ϕ_π for $\lambda_y = 0.5$ and $\psi = 0.9$ are shown in the last two columns for the certainty case.

	$\bar{\alpha}$	$\bar{\beta}$	$\bar{\delta}$	$\bar{\gamma}$	σ^2_α	σ^2_β	σ^2_δ	σ^2_γ	ϕ_y	ϕ_π
Certainty	0.645	0.9	1	0.5	0	0	0	0	1.23	2.03
Baseline Uncertainty	0.645	0.9	1	0.5	0.0121	0.01	0.01	0.0169	1.20	1.98

Table A-14. Effect of parameter uncertainty

Uncertainty in this model is introduced following Söderström (2002): The policymaker does not know the specific parameters but is aware that the coefficients $(\alpha_{t+1}, \beta_{t+1}, \delta_{t+1}, \gamma_{t+1})$ are random variables drawn independently each period from normal distributions with known means and variances (e.g., $\alpha_{t+1} \sim N(\bar{\alpha}, \sigma^2_\alpha)$).[4]

Optimal policy remains a linear function of the current state variables as in equation (A.10). The model exhibits certainty equivalence in the sense that increasing volatility of the stochastic shocks (ε^y_{t+1} and ε^π_{t+1}) does not affect the ϕ coefficients. However, certainty equivalence fails in a different sense; the ϕ coefficients are a function of the uncertainty about the parameter values (such as σ_α). The second row of Table A-14 shows that the introduction of uncertainty about all parameters leads the ϕ coefficients to both decrease very slightly in line with the original Brainard's conservatism result. This is because we use the baseline variance of δ from the Söderström (2002) calibration ($\sigma^2_\delta = 0.01$); if we instead use a larger calibrated value considered in Söderström (2002) ($\sigma^2_\delta = 0.1$), the ϕ coefficients increase very slightly overall.

To connect the model predictions to our empirical findings, we explore how different levels of uncertainty about the paramaters (σ_δ, σ_γ, σ_α and σ_β) impact the policy reaction function. We analyze the effect of each of these parameter uncertainty measures varying from 0.4 to 3 times the baseline standard deviation (Table A-14 reports the variances) and present the evolution of the ϕ coefficients in Figure A-3. Two of the parameters directly affect inflation (δ and γ), and two directly affect output (α and β). We, therefore, analyse these together since our empirical measures do not distinguish whether higher uncertainty about inflation derives from uncertainty about δ or γ. The top row of Figure A-3, shows the effect of varying the uncertainty around the inflation parameters,

[4]Specifically:

$$y_{t+1} = \alpha_{t+1} y_t - \beta_{t+1} (i_t - \pi_t) + \sigma_y \varepsilon^y_{t+1}$$
$$\pi_{t+1} = \delta_{t+1} \pi_t + \gamma_{t+1} y_t + \sigma_\pi \varepsilon^\pi_{t+1}$$

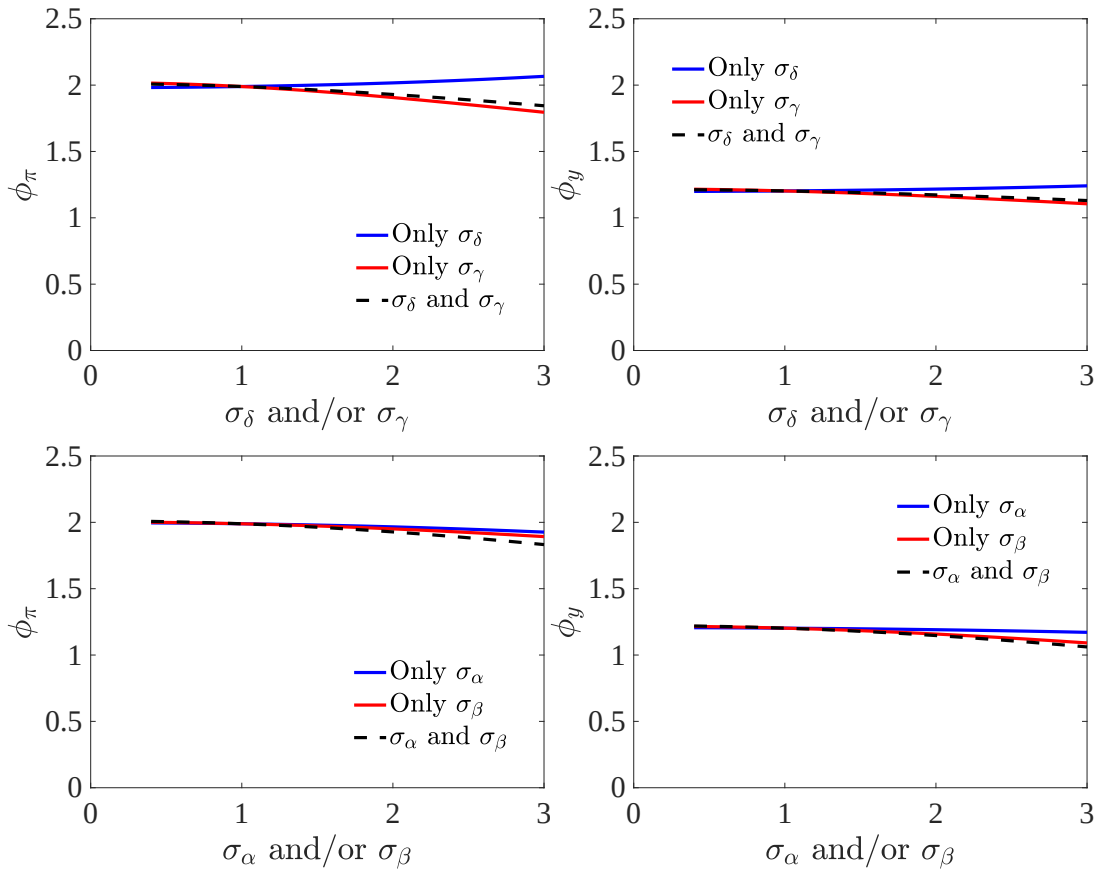

Figure A-3. The effect of parameter uncertainty. The figure presents the effect of parameter uncertainty on the optimal ϕ_π and ϕ_y in the backward looking monetary model. The top row shows the effect of varying uncertainty about the two parameters of the inflation equation (σ_δ and/or σ_γ), and the lower row shows the effect of varying uncertainty about output equation parameters (σ_α and/or σ_β). In each case, the dashed line shows the effect of changing both together.

and the bottom row shows the same for the output parameters. In each case, we consider the effect of uncertainty about each parameter separately as well as jointly with the other parameter.

Uncertainty about inflation can, in principle, drive the ϕ_π coefficient upward so long as it is uncertainty about the persistence of inflation (as in Söderström (2002)). Nonetheless, with a threefold increase in σ_δ, the policy response ϕ_π only rises from 1.98 to 2.07. In the case of the other parameters, greater uncertainty leads to lower ϕ coefficients. Therefore, such a model of policymaker uncertainty has difficulties in explaining the amplifying impact of uncertainty on policy that we document empirically.

D.2. Robust control

As an alternative to parameter uncertainty, a policymaker may display a desire for robustness. That is, in the face of uncertainty about the correct model specification, the policymaker seeks a policy function that is robust to the worst possible form of misspecification (Hansen and Sargent, 2001,

2008; Giordani and Söderlind, 2004). The robust min-max approach to optimal policy involves two stages. First, an imagined evil agent distorts the model in the most damaging possible way (maximize losses); second, the policymaker minimizes losses subject to the distorted model of the economy. Specifically, in the model described above, the evil agent can use shocks, υ_t^y and υ_t^π, to distort the model. The distorted model is:

$$y_{t+1} = \alpha y_t - \beta\left(i_t - \pi_t\right) + \sigma_y(\upsilon_{t+1}^y + \varepsilon_{t+1}^y) \tag{A.11}$$

$$\pi_{t+1} = \delta\pi_t + \gamma y_t + \sigma_\pi(\upsilon_{t+1}^\pi + \varepsilon_{t+1}^\pi) \tag{A.12}$$

The υ shocks can be related to the endogenous variables allowing them to capture broad types of misspecification including the more traditional parameter uncertainty. The evil agent is constrained via a budget in how much they can distort the model and will always exhaust their budget. The parameter θ is inversely related to the budget: $\theta = \infty$ precludes distortions completely and corresponds to the rational expectations solution, while a low value of θ allows the evil agent distort the model in a significant way.[5]

The monetary authority minimizes the loss from inflation deviations and output deviations. The robust control literature finds that the policymaker's preference for interest rate smoothing can be important for model predictions. Therefore, we assume that the policymaker's loss function is given by:

$$L_t = \sum_{\tau=t}^{\infty} \psi^{\tau-t}\left(\pi_t^2 + \lambda_y y_t^2 + \lambda_i i_t^2\right) \tag{A.13}$$

where $\lambda_i > 0$ activates a preference for interest rate smoothing.[6]

Optimal policy is a linear solution of the predetermined state variables. Certainty equivalence fails because the optimal ϕ coefficients change with the variance of the structural shocks (σ_y^2 and σ_π^2). As volatility of the structural shocks increase, it becomes harder for the agent to distinguish their baseline model from the distorted model and they adjust their optimal policy to account for this uncertainty. Therefore, evaluating the effects of uncertainty in the robust control model is now directly related to examining the effect of σ_y^2 and σ_π^2 changing. There is no separate parameter uncertainty in this model.

In Figure A-4, we evaluate the optimal ϕ parameters as σ_π (top row) and σ_y (bottom row) vary. The baseline in this model is $\sigma_\pi^2 = \sigma_y^2 = 1$ and, therefore, the relative volatility increase or decrease is expressed in terms of additional standard deviations. This allows us to compare Figure A-3, Figure A-4, and our empirical results. Each line in Figure A-4 represents the effect of greater uncertainty for different key parameters; the basic calibration is the same as that in Table A-14.

[5]We do not present the evil agents optimisation problem in the interests of space.

[6]The theoretical justification for this welfare function is discussed in Woodford (2003, Chapter 6).

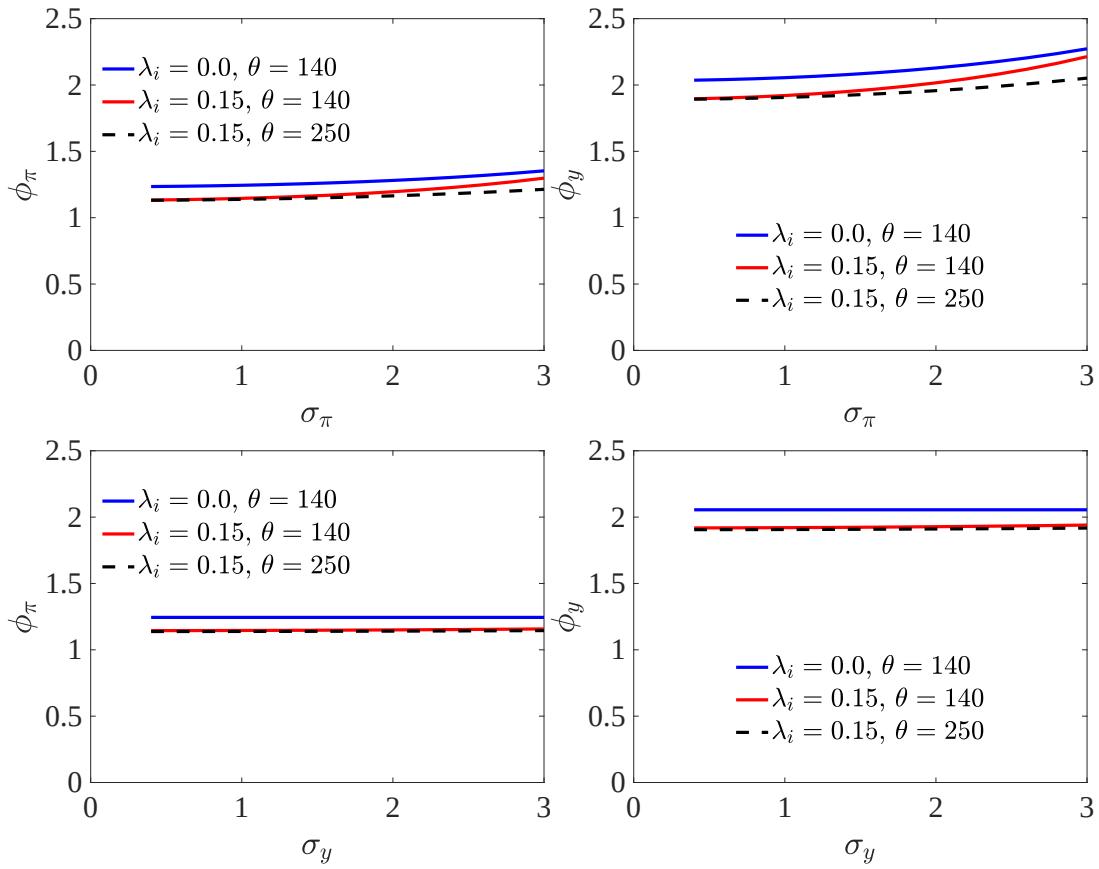

Figure A-4. Backward-looking robust control model. The figure presents the effect on the optimal ϕ_π and ϕ_y of a policymaker who has a preference for robustness in the backward looking monetary model. The top row shows the effect of varying σ_π (volatility of the inflation shocks), and the lower row shows the effect of varying σ_y (output equation shock volatility).

Generally, in this environment, uncertainty manifests itself through a more aggressive reaction function (larger ϕ coefficients). Higher inflation uncertainty σ_π^2, increases both ϕ_π and ϕ_y. The increase is greater when the policymaker has a preference for interest rate smoothing ($\lambda_i = 0.15$), though even this effect is offset if the policymaker's preference for robustness (measured by the inverse of θ) is weaker. In contrast to inflation, the real uncertainty σ_y^2 has a negligible impact on the policy coefficients even when the smoothing motive is substantial.

D.2.1. A forward-looking model with robustness

One concern is that the model presented above is backward-looking and lacks greater persistence, which can be important in generating quantitatively meaningful effects of uncertainty. This simplicity is useful for obtaining tractable solutions for optimal policy. However, to show that the main conclusions persist in richer settings, we now analyze how robustness affects policy in a forward-looking New Keynesian model comprising an IS curve (A.14) and a Phillips curve (A.15) as in Clarida et al. (1999) and Giordani and Söderlind (2004). Both equations are subject to persistent

shocks, g_t and u_t respectively:[7]

$$y_t = E_t y_{t+1} - \gamma \left(i_t - E_t \pi_{t+1}\right) + g_t \tag{A.14}$$

$$\pi_t = \alpha y_t + \beta E_t \pi_{t+1} + u_t \tag{A.15}$$

$$g_t = \rho_g g_{t-1} + \sigma_y \epsilon_t^y \tag{A.16}$$

$$u_t = \rho_u u_{t-1} + \sigma_\pi \epsilon_t^\pi \tag{A.17}$$

where $\epsilon_t^y \sim N(0,1)$ and $\epsilon_t^\pi \sim N(0,1)$ are i.i.d. disturbances. As before, the monetary authority minimizes the loss from inflation deviations, output deviations and, if $\lambda_i > 0$, interest rate level variation. The evil agent can use shocks, υ_t^y and υ_t^π, to distort the model.[8]

We solve this model under the assumption that the central bank cannot commit to a policy rule as in Giordani and Söderlind (2004).[9] This has the advantage that every period, the policymaker can assess uncertainty and choose an optimal response. As such, it is closer in spirit to the comparative statics exercise we perform, in which we change the volatility of structural shocks and solve for the optimal policy. The evil agent is similarly assumed to optimize every period and choose the worst-possible distortion. To simplify the solution, we follow Hansen and Sargent (2008) assuming that the private sector's loss function, reference model, and their degree of robustness are shared with the central bank.

The key parameters are the ρ_u and ρ_g persistence parameters, the degree of interest rate smoothing (λ_i), and the desire for robustness (θ). In Figure A-5, as before, we evaluate the optimal ϕ parameters as σ_π (top row) and σ_y (bottom row) vary for different values of the other key parameters. When the policymaker's utility from interest rate smoothing is low, the impact of uncertainty is imperceptible; the blue line in the figure show the effects for $\rho = \rho_\pi = \rho_x = 0$, but the effect is little changed if $\rho = \rho_\pi = \rho_x = 0.5$ (not shown). Adding a desire for smoothing but no persistence does generate an increasing relationship between the ϕ coefficients and the volatility of the shocks,

[7] Ferrero et al. (2019) present an analysis of optimal policy under parameter uncertainty in a forward-looking model similar to the one we consider. Their main finding is that the optimal response to uncertainty about the slope of the Phillips Curve depends on the the persistence of the cost-push shock. If the shock is not persistent, policy caution is the optimal response; with persistent cost-push shocks, optimal policy is more aggressive.

[8] The distorted model is:

$$y_t = E_t y_{t+1} - \gamma \left(i_t - E_t \pi_{t+1}\right) + \rho_g g_{t-1} + \sigma_y (\upsilon_t^y + \epsilon_t^y)$$
$$\pi_t = \lambda y_t + \beta E_t \pi_{t+1} + \rho_u u_{t-1} + \sigma_\pi (\upsilon_t^\pi + \epsilon_t^\pi)$$

[9] Giannoni (2002) solves a robust-control problem in the same type of model under the assumption of a commitment policy. We did not discuss this distinction when discussing the backward-looking model above as the discretion solution coincides with the commitment solution in that model.

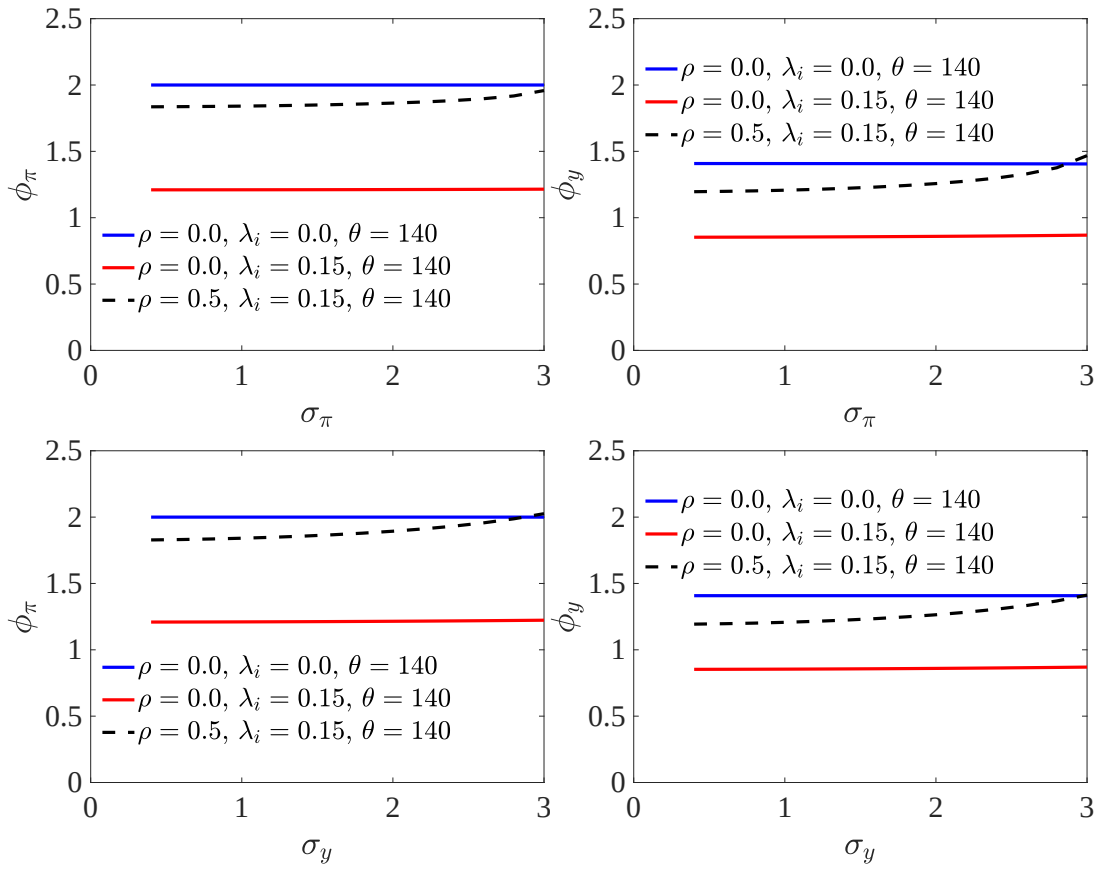

Figure A-5. Forward-looking robust control model. The figure presents the effect on the optimal ϕ_π and ϕ_y of a policymaker who has a preference for robustness in the forward-looking monetary model. The top row shows the effect of varying σ_π (volatility of the inflation shocks), and the lower row shows the effect of varying σ_y (output equation shock volatility).

albeit so slight that it does not appear visible in the graph (red line). It is only when there is a desire for smoothing, alongside persistence, that the upward relationship begins to emerge.[10]

In summary, across the models we consider, while policymakers' parameter uncertainty and preference for robustness can generate amplification of the policy reaction to the state of the macroeconomy, the economic magnitudes of this effect appear quantitatively small and are sensitive to specific model assumptions. This contrasts with the relatively sizeable effects of uncertainty on policy preferences we document empirically.

[10] Although not plotted, increasing θ limits the budget of the evil agent and, as before, has a dampening effect on how higher volatility affects the ϕ coefficients.