DISCUSSION PAPER SERIES

DP13977

CAN MORE PUBLIC INFORMATION RAISE UNCERTAINTY? THE INTERNATIONAL EVIDENCE ON FORWARD GUIDANCE

Michael Ehrmann, Gaetano Gaballo, Peter Hoffmann and Georg Strasser

MONETARY ECONOMICS AND FLUCTUATIONS

ISSN 0265-8003

CAN MORE PUBLIC INFORMATION RAISE UNCERTAINTY? THE INTERNATIONAL EVIDENCE ON FORWARD GUIDANCE

Michael Ehrmann, Gaetano Gaballo, Peter Hoffmann and Georg Strasser

Discussion Paper DP13977
Published 02 September 2019
Submitted 23 August 2019

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

CAN MORE PUBLIC INFORMATION RAISE UNCERTAINTY? THE INTERNATIONAL EVIDENCE ON FORWARD GUIDANCE

Abstract

Central banks have used different types of forward guidance. This paper reports cross-country evidence showing that, in general, forward guidance mutes the response of government bond yields to macroeconomic news. However, calendar-based guidance with a short horizon counter-intuitively raises it. Using a stylized model where agents learn from market signals, it shows that the public release of more precise information about future rates lowers the informativeness of market signals and, as a consequence, may increase uncertainty and amplify the reaction of expectations to macroeconomic news.

JEL Classification: D83, E43, E52, E58

Keywords: central bank communication, heterogeneous beliefs, forward guidance, disagreement, Macroeconomic news

Michael Ehrmann - michael.ehrmann@ecb.europa.eu
European Central Bank

Gaetano Gaballo - gaballo@hec.fr
HEC Paris and CEPR

Peter Hoffmann - peter.hoffmann@ecb.europa.eu
European Central Bank

Georg Strasser - georg.strasser@ecb.europa.eu
European Central Bank

Can more public information raise uncertainty? The international evidence on forward guidance*†

August 23, 2019

Abstract

Central banks have used different types of forward guidance. This paper reports cross-country evidence showing that, in general, forward guidance mutes the response of government bond yields to macroeconomic news. However, calendar-based guidance with a short horizon counter-intuitively raises it. Using a stylized model where agents learn from market signals, it shows that the public release of more precise information about future rates lowers the informativeness of market signals and, as a consequence, may increase uncertainty and amplify the reaction of expectations to macroeconomic news.

Keywords: central bank communication; heterogeneous beliefs, forward guidance, disagreement, macroeconomic news.

JEL: D83, E43, E52, E58.

*Michael Ehrmann (European Central Bank), Gaetano Gaballo (Banque de France, HEC Paris and CEPR), Peter Hoffmann (European Central Bank) and Georg Strasser(European Central Bank). *Email addresses*: michael.ehrmann@ecb.europa.eu; gaetano.gaballo@gmail.com; peter.hoffmann@ecb.europa.eu; georg.strasser@ecb.europa.eu.

†Some of the empirical results of this paper have been contained in ECB Working Paper No. 2080, “Communication of monetary policy in unconventional times”. We thank Jeffrey Campbell, Günter Coenen, Yuriy Gorodnichenko (the editor), Refet Gürkaynak, Luc Laeven, Michele Lenza, Anton Nakov, Stefano Nardelli, Eric Persson and Oreste Tristani as well as seminar participants at the ECB and the DIW, and participants at the conference on “Advances in Applied Macro-Finance” at Bilgi University, the conference on “Challenges in Understanding the Monetary Transmission Mechanism” at Narodowy Bank Polski, the ECB Central Bank Communications Conference, the Bank of Canada conference on “Central Bank Communications”, the Fall 2018 Midwest Macro Meetings at Vanderbilt University, and Annual Research Conference of the National Bank of Ukraine on “Central Bank Communications” for useful comments and suggestions. We also thank Claudio Hantzsche, Jonas Jensen and Alena Wabitsch for their help with the data. The opinions in this paper are those of the authors and do not necessarily reflect the views of the European Central Bank, the Banque de France or the Eurosystem.

1 Introduction

In the aftermath of the global financial crisis, several central banks embarked on an unprecedented easing of monetary policy. As policy rates approached the effective lower bound (ELB), they had to resort to unconventional policies. One such tool, which was employed by several central banks, is forward guidance (FG). With policy rates being constrained, further easing of monetary policy was attempted by managing expectations about the future course of policy, effectively turning communication into a central policy tool.

In practice, central banks have used different types of FG. The literature typically identifies three such types, depending on whether the FG horizon, i.e. the time period over which policy rates are expected to remain at current levels, has been defined by means of i) a state-contingent threshold, ii) a calendar date, or has been iii) left open-ended. In addition, some central banks also provide FG when policy rates are not constrained by the ELB. This type of FG will not be studied in this paper – it will focus exclusively on FG at the ELB.

By means of their FG, central banks provide not only signals about their likely future actions, but also more precise information about their reaction function. The information that is conveyed is typically twofold. On the one hand, FG clarifies that the central bank considers policy rates to be at, or close to, the ELB. On the other hand, it states that an *extended period* of loose policy with no rate hikes is likely to follow.

Effectively, this implies that policy rates will most likely not change for a considerable period of time, regardless of how the economy evolves: In case of negative news, policy rates cannot go any lower. In case of positive news, the central bank will likely not raise rates. As a consequence, market rates should also be less responsive to macroeconomic news Feroli et al. (2017).

However, as shown in this paper, this need not necessarily be the case: By exploiting cross-country data (on Canada, Germany, Italy, Japan, Sweden, the United Kingdom, and the United States) the paper shows that, depending on the form of FG adopted, interest rates can also become *more* responsive to macroeconomic news in comparison to a no-FG benchmark. In line with the earlier literature, the paper finds that some forms of FG (which we consider to be "stronger") reduce the reaction to macroeconomic news. This is the case, in particular, for time-contingent FG with a long horizon (above 1.5 years), which mutes the market responsiveness to macroeconomic news almost completely. State-contingent FG also leads to a reduced responsiveness, but does not fully eliminate it. This is plausible, because markets should remain responsive to news about the macroeconomic indicators to which the FG relates (e.g. unemployment in the case of the Federal Reserve and the Bank of England).[1]

Open-ended FG, in contrast, retains the original market responsiveness, which can be interpreted as markets perceiving no change in the reaction function of the central bank. More surprisingly, time-contingent FG over a short horizon (below or equal to 1.5 years) exhibits a perverse effect, in

[1]These findings are in line with the evidence provided by Femia et al. (2013) and Detmers (2016) for the United States.

that it substantially increases the responsiveness to news.

We furthermore study the effect of FG types on the disagreement among professional forecasters about the future path of interest rates, and report findings that are broadly consistent with those for the responsiveness of bond yields. Long-horizon time-contingent and state-contingent FG effectively reduce disagreement, whereas open-ended and short-horizon time-contingent FG are ineffective in this regard.[2]

The second contribution of this paper is theoretical. In order to rationalize the empirical findings, a stylized model of learning from market signals with endogenous precision is developed. In this setting, the release of more precise public information about future interest rates can perversely increase uncertainty and the sensitivity of bond prices to public information. The key ingredient for generating this effect is learning from market prices.

To understand this, consider a Bayesian model of expectation formation where agents receive exogenous signals, public and private, about the future realization of policy rates, but where there is no learning from market signals. This is the typical framework used recently in the context of the FG debate by, among others, Angeletos and Lian (2018) and Wiederholt (2014). FG can be interpreted as a decrease in prior uncertainty (unconditional volatility) about future rates, where the magnitude of this decrease depends on the strength (or type) of FG. In this setting, FG will unambiguously reduce the responsiveness of expectations to any signal (public or private) and lead to lower disagreement, independently of its strength. Accordingly, a model with exogenous signals, as typically adopted in the literature, cannot replicate the findings of increased macro-news sensitivity under short-horizon time-contingent FG.

In contrast, the introduction of a market signal with endogenous precision can generate a non-monotonic effect of ex-ante uncertainty on the macro-news sensitivity of bond prices. In the model, agents receive noisy signals about the state of the economy, one private and one public. The latter mirrors the flow of macroeconomic news studied in the empirical analysis. In addition, agents observe a noisy market signal which imperfectly aggregates expectations about the realization of the payoff on a bond that depends on the policy rate. It is assumed that the central bank determines the extent to which policy rates co-vary with the state of the economy. In this context, stronger FG corresponds to a lower dependence of policy rates on fundamentals, resulting in lower prior uncertainty about policy rates. In the extreme case of "perfect" FG, policy rates and bond returns are completely detached from economic fluctuations, and thus purely deterministic (no prior uncertainty).

While strengthening FG thus has a direct effect of reducing the prior uncertainty of agents, it also exerts an indirect effect: As more public information is made publicly available, there is less to learn from market prices. This is due to the fact that agents' expectations become relatively less sensitive to their private signals as the precision of public information increases. As expectations react less

[2]Andrade et al. (2019) document a fall in disagreement across professional forecasters at the time of the introduction of time-contingent FG in the United States.

to private information, the price signal loses some of its informativeness.[3] Therefore, ex-post uncertainty can increase even though FG decreases prior uncertainty. The countervailing indirect effect is stronger than the direct beneficial effect when prices are a good source of information. However, if FG is sufficiently strong, the direct effect dominates and the implications are identical to those obtained from a model without price signals.

The model's predictions rationalize the empirical findings. Short-horizon time-contingent FG, i.e. a relatively weak form of FG, only generates a small decrease in prior uncertainty and therefore makes bond prices more reactive to public signals. On the contrary, strong forms of FG such as long-horizon time-contingent FG result in a large decrease in prior uncertainty and therefore imply a lower responsiveness to public news.

The remainder of this paper is organized as follows. The next section provides an overview of the related literature. Section 3 introduces our empirical approach and the underlying data. Section 4 presents the empirical findings, and section 5 the theoretical model, followed by the Conclusion.

2 Literature Review

This paper connects to a long and growing literature covering several aspects of FG from a theoretical and empirical perspective. With regard to *theory*, FG is an essential ingredient of the optimal policy commitment at the ELB advocated by Krugman (1998) and Eggertsson and Woodford (2003). Campbell et al. (2012) refer to this type of FG as *odyssean*, as opposed to *delphic*, where the central bank provides a forecast of its future policy rates and stress the conditionality of the forecast.[4] In this paper, this distinction does not matter to the extent that FG announcements lower the covariance of states of the economy with future rates, independently of whether this guidance relies on a commitment or on a prolonged binding of the ELB.

The seminal work by Morris and Shin (2002) presents a case where a release of public information can reduce welfare. Angeletos and Pavan (2007) clarify that this arises because of misaligned incentives between individuals and the social planner in the use of information. In this class of models, and in contrast to our model, public information unambiguously reduces the ex-post uncertainty of agents; however, the individual use of such enhanced knowledge is socially inefficient.

The paper closest to our theory is Amador and Weill (2010). They model an economy where agents learn from prices and where social welfare is inversely related to agents' ex-post uncertainty. They show that uncertainty can increase as a consequence of more precise prior information because public information crowds out the aggregation of private information. The model in the paper at hand generates the same insight using a much simpler asset pricing model where agents learn from

[3] Note that learning from prices requires the presence of private signals; public signals are observed by everyone, so there is nothing further to learn about them from prices.

[4] *Delphic* FG remains by far the most relevant case in practice. For a nice overview of the FG debate among scholars and practitioners see den Haan (2013). Andrade et al. (2019) present a model where agents are confused about the nature – delphic or odyssean – of public announcements. Jia (2019) develops a model where private agents use interest-rate decisions of a perfectly informed central bank to learn about the state of the economy.

market signals. In our setting, the noisy processing of this endogenous signal captures cognitive limitations or costly information processing, in the vein of a recent literature on rational inattention (see Vives and Yang, 2017; Mackowiak et al., 2018). Our approach allows us to solve analytically for a threshold at which the effect of increasing the prior's precision on agents' uncertainty changes its sign. Moreover, in line with the empirical findings, the focus is on the price sensitivity to public signals, as well as on the disagreement among investors. The international experience on FG represents a useful laboratory to test the effects of public information releases.

Gaballo (2016) studies the link between FG and rational inattention. He presents a dynamic model of learning from prices in which the precision of the *prior* (not only the precision of the market signals, as in the current paper) is endogenous to the use of information. Public announcements both induce agents' information sets to account for a larger share of price volatility and increase the overall level of price volatility. When the latter effect dominates, agents commit larger – rather than smaller – forecast errors.

In standard models, anticipated monetary policy can generate very large changes in prices and activity, a property that has been called the "FG puzzle" (Carlstrom et al., 2015; Del Negro et al., 2015). In response to this, several recent papers [5] introduce motives for discounting in the Euler equation to prevent the explosive forward-looking behaviour predicted by standard models in the absence of monetary stabilization. Other work investigates the role of imperfect information at the ELB.[6] In particular, Wiederholt (2014) argues that FG can be detrimental because it reveals bad news to otherwise imperfectly informed agents. Angeletos and Lian (2018) show that informational frictions can solve the "FG puzzle". The current paper shares the approach of blurring agents' information, but by introducing market signals with endogenous precision shows that FG can amplify the news-sensitivity of asset prices.

The *empirical* evidence on the effectiveness of FG is summarized in Moessner et al. (2017). While FG is overall judged to be an effective tool, not all results are entirely conclusive. For instance, the FG employed by the US Federal Reserve has been judged as effective by Campbell et al. (2012), Moessner (2013, 2015) and Woodford (2013), whereas Filardo and Hofmann (2014) cast a more cautious tone. That different studies come to different conclusions is not too surprising, for at least two reasons. First, identification is not trivial, given that central banks often employed a variety of unconventional tools together with FG. Second, while theory typically assumes that the central bank commits to a future path of policy rates (Eggertsson and Woodford, 2003), FG was in practice probably closer to what Campbell et al. (2012) call "delphic". Such FG has been found to generate smaller effects (Eggertsson and Woodford, 2006; Adam and Billi, 2006, 2007; Nakov, 2008).

Despite the mixed evidence on its effectiveness, FG is generally considered to be an effective tool by central bankers and academic economists alike. The survey by Blinder et al. (2017) shows

[5]For example, Wiederholt (2014); McKay et al. (2016); Gabaix (2016); Angeletos and Lian (2018); Campbell and Weber (2018); Farhi and Werning (2019).

[6]For example Kiley (2016); Michelacci and Paciello (2017); Bianchi and Melosi (2017, 2018).

that more than 70% of central bank governors and more than 85% of academics think that FG should remain an instrument in the central banks' toolkit. This broad agreement on the overall merits of FG between practitioners and academics masks disagreement over the way FG should be implemented. Time-contingent FG is liked least by both groups. State-contingent FG is the preferred type among academics by a large margin. In contrast, the favourite type among central bank heads is open-ended FG. This suggests that more research is warranted into how exactly FG should be implemented, a question that will be analysed in this paper.

3 Forward Guidance, Macroeconomic News and Disagreement

FG has been implemented in many different ways. This section classifies FG used by central banks into three types. It then introduces the data and the methodology used to study the effectiveness of FG.

The first part of the empirical analysis aims to study the causal effect of FG on the responsiveness of bond yields. However, in the vast majority of cases, FG has been implemented by central banks that had reached the ELB, or they had reached what they perceived the ELB to be at the time. If interest rates are at their lower bound, the impact of macroeconomic surprises on bond yields might well be muted – if only because negative news cannot lead to a further downward move in policy rates. To separate the effects of the ELB from those stemming from FG, the analysis is restricted to ELB periods. These are defined as periods where the policy rate is at or below 1%.[7] Column (1) of Table 1 lists the years during which individual countries were at the ELB, i.e. faced policy rates at or below 1%.

3.1 Forward Guidance Types

Central banks have used different types of FG. These can differ in how they affect the expectations of agents about the future course of policy, for example by signalling different degrees of commitment, or by differing in their clarity. We distinguish three types: *Open-ended guidance* (*OG*, i.e. purely qualitative statements about the policy path), *time-contingent guidance* (*TG*, i.e. statements about the policy path with an explicit reference to a calendar date) and *state-contingent guidance* (*SG*, i.e. statements about the policy path that are conditional on economic outcomes). An example of open-ended (or "purely qualitative") FG is the ECB's statement "we expect the key ECB interest rates to remain at present or lower levels for an extended period of time", used between July 2013 and January 2016. While such statements on the expected rate path imply less of a risk for the credibility of the central bank, they might also be less effective because they can easily be interpreted

[7]The restriction to ELB periods does not change the results, as shown in the Online Appendix. Moreover, results are robust to re-classifying the years 2003-04 for the United States as not being at the ELB.

as being vague or not containing any commitment. It can therefore be expected that open-ended FG has only small effects.

Time-contingent (or "calendar-based") FG expresses the likely future path of the policy instrument as a function of calendar time. Within this category, different formulations have been used, varying the degree of commitment. The Bank of Canada, for example, used time-contingent FG from April 2009 until April 2010, with a relatively strong formulation stating that "conditional on the inflation outlook, it *commits* [emphasis added] to hold the current policy rate until the end of the second quarter of 2010". In contrast, in its statements between August and December 2011, the Federal Open Market Committee (FOMC) said "The Committee currently *anticipates* [emphasis added] that economic conditions [...] are likely to warrant exceptionally low levels for the federal funds rate at least through mid-2013". The US example does not explicitly refer to a commitment, whereas the Canadian communication explicitly does. (This commitment, however, is not unconditional). We classify both as time-contingent FG, because there is an explicit reference to a date before which lift-off of policy rates should not be expected.

State-contingent FG states how the policy path depends on economic conditions. For example, in its December 2012 statement the FOMC communicated that its low policy rates were "appropriate at least as long as the unemployment rate remains above 6 1/2 percent, inflation between one and two years ahead is projected to be no more than a half percentage point above the Committee's 2 percent longer-run goal, and longer-term inflation expectations continue to be well anchored." The advantage of this type of FG is that the expected timing of the lift-off responds endogenously to new economic developments. At the same time, this type of FG creates a trade-off between simplicity and accuracy: On the one hand, if the central bank provides a relatively simple state contingency that is easy to communicate, its message might turn out to be too simplistic in the end, requiring the bank to deviate from it.[8] On the other hand, if the central bank lists a multitude of indicators to be considered, accurate and intelligible communication of the contingency might prove impossible, especially if different indicators point in opposite directions.

[Table 1 about here.]

Based on this classification, we collect and classify FG statements from the monetary policy press releases of six major central banks: the Bank of Canada, the Bank of England, the Bank of Japan, the ECB, the Swedish Riksbank, and the US Federal Reserve.[9] Our data covers all

[8]It was widely perceived by the public that this was the case for the FOMC, which did not raise interest rates when the unemployment rate dropped below 6.5% in 2014, but removed the unemployment threshold from its FG. See, e.g., "Fixing forward guidance" (The Economist, February 13, 2014). However, in this context it is important to note that the statement "at least as long as" technically is an inequality, meaning the Federal Reserve never ruled out not to raise rates directly after the threshold breach.

[9]Besides the six central banks listed in Table 1, FG was used by three further central banks at some point in time during the past two decades. Hungary followed open-ended FG, and Chile and Poland time-contingent FG. Because of insufficient expectations data for macroeconomic indicators and lack of high-frequency bond market data, these will not be considered in the empirical study.

available statements made during ELB periods until the end of 2016.[10] The ECB, for example, used open-ended FG starting in July 2013. Since March 2016, the ECB's FG about policy rates has been explicitly linked to the duration of its asset purchase programme (APP). Because the APP itself has an explicitly stated expected minimum duration, we classify the ECB's FG since then as time-contingent.

Table 1 provides a brief overview of the six central banks in the sample and the different types of FG used. Three of them followed state-contingent FG (column 2), four open-ended FG (column 3), and four followed time-contingent FG (column 4). The average (remaining) horizon of time-contingent FG varies considerably across countries (column 5). On the one side of the spectrum are Canada and the euro area with average horizons of between eight and nine months. On the other end of the spectrum is the United States with an average horizon of more than two years. Sweden falls somewhat in-between with an average horizon of slightly more than one year.

[Figure 1 about here.]

Figure 1 plots the remaining guidance horizon of time-contingent FG in the sample. It shows that the remaining guidance horizon is often subject to revisions, which the figure shows as jumps. There are two instances where the guidance horizon was shortened – both in Sweden during its first FG period –, as well as several episodes where the horizon was lengthened, and at times repeatedly so. Many of these extensions appear to reflect a readjustment in order to keep the remaining guidance close to a desired horizon. In the United States, for example, the guidance horizon oscillated around 950 days in 2012 and in Sweden around 400 days during 2013-2015. Furthermore, the chart reveals that the United States abandoned time-contingent FG long before the end of the previously announced guidance horizon.

These frequent revisions might affect the credibility and therefore the effectiveness of FG announcements. A repeated shortening of the FG could imply that agents start expecting further revisions in the future, and therefore expect the FG horizon to be shorter than what the central bank announces. More frequently, the observed revisions implied a lengthening of the FG horizon. This could similarly lead agents to expect FG to be in place longer than announced by the central bank. Unfortunately, this interesting hypothesis cannot be tested in this paper: due to the limited number of observations available, the analysis will not differentiate between announcements before and after a central bank has revised its FG horizon.

Based on the information obtained from the central bank press releases, a binary indicator variable is generated for each of the three types of FG. The indicators for state-contingent FG,

[10] Using data after 2016 complicates the analysis because all additional observations of FG are cases where an asset purchase programme (APP) was in place, which makes identification of FG effects more difficult. Using an extended sample until 2018 and separating the effect of FG with or without an APP shows that the results reported in this paper are in line with the results for FG in the absence of an APP. In the presence of an APP, the difference between long- and short-horizon FG is much smaller, and short-horizon FG no longer raises the responsiveness of bond yields. These findings are rationalized in an extension of the stylized model by introducing a stochastic supply of government bonds, i.e. by interpreting asset purchases as the introduction of a common disturbance to the net supply of the asset. The extended results and the model extension are provided in the Online Appendix.

time-contingent FG, and open-ended FG are denoted by SG_t^c, TG_t^c, and OG_t^c, respectively. Each of these variables is equal to one if the respective FG regime is active in country c at time t, and zero otherwise.

3.2 Data and Methodology

This section describes the key data series, in particular macroeconomic news surprises, bond yields, and forecaster disagreement. It also discusses the econometric models that will be employed.

3.2.1 Macroeconomic News

The macroeconomic news surprise $s_t^{c,i}$ at release time t is defined as the difference between actual and expected values, expressed relative to its standard deviation,

$$s_t^{c,i} \equiv s_t^{c,i,r} = \frac{a_t^{c,i,r} - e_t^{c,i,r}}{\sigma^{c,i,r}} \quad (1)$$

where $a_t^{c,i,r}$ denotes the initially released value of indicator i for country c and release step r, and $e_t^{c,i,r}$ denotes the market expectations at that time. Both are available from Bloomberg. Some macroeconomic indicators are announced in several pre-scheduled steps r. The release of gross domestic product (GDP) figures, for example, typically follows a sequence of data releases based on increasingly comprehensive data. Each of these releases is treated as an announcement event of macroeconomic indicator i, but is standardized using the release-step specific time-series standard deviation $\sigma^{c,i,r}$.[11] Surprises are signed so that positive surprises are good news about the economy, which (via a tighter monetary policy) is likely to imply higher interest rates. For this reason, the sign of the surprise in the unemployment report is inverted.

The dataset covers nine macroeconomic indicators for which market expectations are available for most countries in the sample over a long time span. Indicators without a significant asset price impact in any country during the sample period are excluded.[12] The sample consists of business confidence indices, consumer confidence indices, consumer price indices, GDP growth, industrial production, non-farm payroll employment (available for the United States only), purchasing manager indices, retail sales, and unemployment rates. Column (1) of Table 2 shows that, on average, there are about seven indicators per country.

[Table 2 about here.]

[11] If multiple reference periods are announced simultaneously (e.g. due to delayed reporting after a US government shutdown), the net surprise is taken over all these reference periods.

[12] The criterion is the significance of $\beta^{c,i}$ in the auxiliary regressions $y_t^{c,i} = \alpha^{c,i} + \beta^{c,i} s_t^{c,i} + \varepsilon_t^{c,i}$, where $y_t^{c,i}$ is the yield change of bonds with a residual maturity of two years. An indicator is excluded if $\beta^{c,i}$ is not significant at the 5% level for any country. Based on this criterion, the indicators durable goods orders, housing starts and incoming orders are excluded.

Euro area sovereign bonds are issued by individual euro area countries. Accordingly, they can be expected to respond more to domestic macroeconomic news than to euro area aggregates (also because national statistics are often available first). Two countries are chosen to represent the euro area, namely Germany and Italy, to reflect the diversity of the euro area and to have a similar number of news releases for the euro area as for the United States and Japan.

Because of the ELB requirement, the observations for most countries start at or after the year 2009, with the two exceptions Japan (first observation in the year 2000) and United States (first observation in the year 2003), as shown in columns (3) and (5) of Table 2. The effective sample is further constrained by the limited availability of data on expectations about macroeconomic indicators in some countries. For this reason, the sample of macroeconomic news releases covers the period February 2000 until December 2016. Among all macroeconomic news releases during ELB periods in the sample, 51% occurred at times when the central bank did not provide FG. Open-ended FG was in place for 24% of observations, whereas time-contingent FG and state-contingent FG was in place for to 16% and 9% of observations, respectively.

3.2.2 Bond Yields

The yield changes associated with macroeconomic news releases are calculated from mid quotes for sovereign bonds, based on indicative bid and ask quotes for benchmark bonds with a residual maturity of two years from Thomson Reuters Tick History.[13] The yield changes are computed from these minute-by-minute mid-quotes over a two-hour window from 60 minutes before until 60 minutes after the news release.

3.2.3 Forecaster Disagreement

To assess the disagreement among professional forecasters, three-month-ahead forecasts of three-month interest rates are used, because these are a close proxy for expectations about policy rates. The data are provided by Consensus Economics. Consensus Economics forecast data are particularly suited for the current analysis, as they are available at a monthly frequency for a sufficiently long history in a comparable fashion across countries.[14]

To study disagreement, we follow Ehrmann (2015) and use the interdecile range of forecasts in a given country and month. The advantage of this measure over the standard deviation is that it is insensitive to outliers, which can be important in the analysis of survey data.[15] The individual forecaster data for the construction of the disagreement measure covers the same set of countries as the bond-yield regressions. However, the genuine euro area disagreement measure is used instead

[13] Two years is the shortest maturity for which homogenous tick data is available for all countries in the sample. The focus on two-year yields ensures that the FG used in practice relates to a significant fraction of the residual maturity.

[14] The data have been used in several other studies, such as Crowe (2010), Dovern et al. (2012), Ehrmann et al. (2012), Davis and Presno (2014) or Ehrmann (2015).

[15] Furthermore, using the interdecile range instead of the interquartile range (as in Mankiw et al. (2004) or Dovern et al. (2012)) potentially incorporates a broader range of views while still being robust to outliers.

of separate measures for Germany and Italy. The sample period ends in December 2016, in line with the data for macroeconomic news releases and bond yields. Table 2 shows that this yields a total of 669 observations.

3.2.4 Methodology

If FG was effective in managing expectations about the future course of monetary policy, fixed-income markets would generally be less responsive to macroeconomic news. At the same time, the responsiveness to news might very well depend on the FG specification in place. On the one hand, some types of FG might be less credible than others, therefore leaving markets relatively more responsive than under a highly credible FG. On the other hand, state-contingent FG explicitly conditions the future path of interest rates on economic developments, therefore leaving expectations about future interest rates responsive to macroeconomic developments. In contrast, under credible time-contingent FG, bonds maturing during the FG horizon should in principle not respond to macroeconomic news at all.

To shed light on the effectiveness of the various types of FG, an event-study setup is used, as applied in similar contexts by Swanson and Williams (2014a), Swanson and Williams (2014b) and Feroli et al. (2017).[16] In the baseline specification, it is examined how the three types of FG differ in affecting the impact of macroeconomic surprises $s_t^{c,i}$ on bond yields. The first specification estimates the overall effect of FG on bond yield changes $y_t^{c,i}$:

$$y_t^{c,i} = \alpha^{c,i} + \alpha_{FG} FG_t^c + \beta s_t^{c,i} + \beta_{FG} FG_t^c \times s_t^{c,i} + \varepsilon_t^{c,i}. \tag{2}$$

The binary indicator FG_t^c equals unity whenever some form of FG is provided in country c at time t, and is zero if no FG is provided despite the country being at the ELB. The coefficient β captures the average impact of a macroeconomic surprise on bond yields outside of FG episodes, while α_{FG} captures possible bond market trends specific to the FG period. The coefficient of primary interest is β_{FG}, which captures the differential effect of FG.

Subsequently, this specification is expanded to allow for different types of FG:

$$y_t^{c,i} = \alpha^{c,i} + \Theta_t^c + \beta s_t^{c,i} + \Xi_t^c s_t^{c,i} + \varepsilon_t^{c,i}, \tag{3}$$

with

$$\Theta_t^c = \alpha_{SG} SG_t^c + \alpha_{OG} OG_t^c + \alpha_{TG} TG_t^c \tag{4}$$

and

$$\Xi_t^c = \beta_{SG} SG_t^c + \beta_{OG} OG_t^c + \beta_{TG} TG_t^c. \tag{5}$$

Here the interest rests on β_{SG}, β_{OG} and β_{TG} in equation (5), which are the coefficients on the

[16]Swanson and Williams show that interest rates become less responsive to macroeconomic news when rates are constrained by the ELB. Feroli et al. (2017) apply this methodology to study the Federal Reserves' FG experience.

binary indicators for state-contingent, open-ended, and time-contingent FG, denoted by SG_t^c, OG_t^c, and TG_t^c, respectively.

In addition, we test whether the horizon of time-contingent FG relative to the maturity of the bond is important. For bonds with two years to maturity we define the time-to-maturity coverage ratio as $g_t^c = min(\frac{\tilde{g}_t^c}{365\times 2}, 1)$, where $\tilde{g}_t^c$ is the residual horizon of the time-contingent FG in country c at time t, measured in calendar days. This leads to our third specification, which replaces the term for Θ_t^c in equation (3) by

$$\Theta_t^c = \alpha_{SG} SG_t^c + \alpha_{OG} OG_t^c + (\alpha_{TG} + \rho g_t^c + \rho_2 (g_t^c)^2) TG_t^c \tag{6}$$

and the term for Ξ_t^c by

$$\Xi_t^c = \beta_{SG} SG_t^c + \beta_{OG} OG_t^c + (\beta_{TG} + \gamma g_t^c + \gamma_2 (g_t^c)^2) TG_t^c. \tag{7}$$

If the guidance horizon covers the entire time to maturity, then $\beta_{TG} + \gamma + \gamma_2$ measures the reduction of the asset price impact β.

Finally, two ranges of time-contingent FG horizons are distinguished: a long (residual) horizon more than 550 days (1.5 years), and a short horizon of up to 550 days, captured by the indicator variables LTG_t^c and STG_t^c, respectively.[17] Using these definitions, equations are replaced (4) and (5) by

$$\Theta_t^c = \alpha_{SG} SG_t^c + \alpha_{OG} OG_t^c + \alpha_{STG} STG_t^c + \alpha_{LTG} LTG_t^c \tag{8}$$

and

$$\Xi_t^c = \beta_{SG} SG_t^c + \beta_{OG} OG_t^c + \beta_{STG} STG_t^c + \beta_{LTG} LTG_t^c. \tag{9}$$

Another way to test the effectiveness of FG in managing expectations is to study its impact on forecaster disagreement. Andrade et al. (2019) have shown that under FG, forecaster disagreement about future interest rates is reduced, although disagreement about the future macroeconomic outlook has increased. Their analysis is extended to see whether these effects differ depending on the type of FG. For this purpose, the following model is estimated:

$$\Omega_t^c = \alpha^c + \alpha_t + \alpha_{FG} FG_t^c + \varepsilon_t^c, \tag{10}$$

where Ω_t^c is the interdecile range of three-month-ahead forecasts of three-month interest rates in country c, as provided in the Consensus Economics forecast conducted in month t. α^c and α_t denote country and time fixed effects, respectively. As mentioned previously, the sample is restricted to

[17] This cut-off implies that long-horizon FG covers at least three-quarters of the residual maturity of the bonds. As evident from Figure 1, Sweden and the United States are the only countries that had long-horizon FG in place according to our definition, with the bulk of observations coming from the United States. In this sense, β_{LTG} compares long-horizon time-contingent FG in the United States with FG in other countries. Given the still small set of countries with FG and the even fewer switches between FG types within a given country, it is not possible to fully disentangle country from FG-type effects at this time.

ELB periods. α_{FG} is the parameter of interest, as it informs us how disagreement under FG compares to periods without FG. One would expect $\alpha_{FG} < 0$.

This regression model is extended in an analogous way to the one for bond yields by i) differentiating the different types of FG, and ii) subsequently differentiating between long-horizon and short-horizon time-contingent FG, leading to the final specification

$$\Omega_t^c = \alpha^c + \alpha_t + \Theta_t^c + \varepsilon_t^c, \tag{11}$$

with Θ_t^c given by equations (4) and (8), respectively.

3.3 Endogeneity Concerns

A key assumption underlying the analysis is that the type of FG in place is exogenous to the economic environment. Table 3 presents results from three different tests to verify the validity of this assumption.

[Table 3 about here.]

Column (1) compares the average magnitude (absolute values) of macroeconomic surprises across the different FG regimes. Their magnitudes are similar, but during periods of state-contingent FG absolute surprises were significantly larger than during periods of open-ended FG. Among the remaining five regime-pairs only the difference between open-ended FG and short-horizon time-contingent FG is marginally significant. This suggests that there is no structural difference in the magnitude of news surprises between open-ended FG, short-horizon time-contingent FG and long-horizon time-contingent FG.

The regression results in column (2) show how forecaster disagreement about one-year ahead GDP growth (following equation (11), with disagreement measured by the interdecile range) differs from a benchmark of no FG, and across the different FG types. Disagreement under state-contingent FG and under short-horizon time-contingent FG is smaller than in the absence of FG, but the difference in disagreement across any of the FG types is not statistically significant, again with the exception of a marginally significant difference between open-ended FG and short-horizon time-contingent FG.

Finally, column (3) provides tests whether the tone of central bank statements differs across FG types. In particular, we are interested in whether they refer to the concept of uncertainty more or less often. To do so, we retrieve the text of all monetary policy press releases of the central banks in the sample, and count the number of times words with the stem "uncertain" are mentioned. This number is then put in relation to the total word count of the respective press release, and the resulting ratio is regressed on country fixed effects and dummy variables for each FG regime. Uncertainty is mentioned more often under state-dependent FG than in the absence of FG or under any other type of FG, and somewhat less often under open-ended FG and long-horizon time-contingent FG than in the absence of FG. However, there are no differences across open-ended, long-horizon or short-horizon time-contingent FG.

In sum, we are reasonably confident that the results of this paper, and in particular the core results which relate to the different effects of long-horizon and short-horizon time-contingent FG, are not driven by differences in the economic environment.

4 The Effects of Different Forward Guidance Types

This section analyzes how the effects of FG depend on the specification of FG. It first studies the responsiveness of bond yields to macroeconomic surprises, and then the disagreement among economic forecasters.

4.1 The News-sensitivity of Bond Yields

Table 4 reports the net surprise impact of macroeconomic announcements based on the coefficient estimates of the regression models introduced in section 3.2.4. Driscoll and Kraay (1998) standard errors are reported in parentheses. The first result is the sobering observation that FG overall did not change the impact of a macroeconomic news surprise. This is documented in column (1), which reports the estimates for β and β_{FG} in the baseline regression (2). The bold print for β_{FG} indicates that the coefficient sum $\beta + \beta_{FG}$ is statistically significant at the 1% level. The selected macroeconomic indicators significantly affect bond prices, but the incremental effect of β_{FG} is not statistically significant.

[Table 4 about here.]

Distinguishing the three different types of FG in a regression based on equations (3)-(5) allows us to provide a more nuanced perspective in column (2). Open-ended FG has no effect, as β_{OG} is not statistically different from zero. As expected, state-contingent FG reduces the asset price response significantly, with the sensitivity decreasing by more than three quarters. As the policy path is contingent on macroeconomic indicators, bond prices remain somewhat sensitive to news, but now to a lower (insignificant) degree. Macroeconomic indicators not conditioned on may remain relevant as predictors of the conditioning variable, too, but their relevance decreases and with it the market response to innovations in them (see also Detmers, 2016). Time-contingent FG, in contrast, appears to *amplify* the response of bond yields to macroeconomic news. This begs the question: "How can bond prices become more sensitive to news in presence of guidance that should mute this link?"

As a step towards resolving this puzzle, we allow the effect to vary with the residual FG horizon following equation (7). The estimates in column (3) for γ and γ_2 suggest that responsiveness is non-linear in the guidance horizon. The responsiveness (of bonds with two years to maturity) increases up to a guidance horizon of about 12 months. For longer guidance horizons the responsiveness declines, until it is fully muted under a guidance of about two years.

Finally, column (4) of Table 4 shows the results when subdividing time-contingent FG into short- and long-horizon guidance. There is a marked difference. Long-horizon guidance is very effective in muting the asset price response to macroeconomic news, with the coefficient decreasing by around three quarters. In contrast, short-horizon guidance is not only ineffective, but even yields a counterintuitive increase in the bond price reaction.

In summary, the four types of FG differ systematically in their effectiveness. Long-horizon time-contingent FG largely mutes the market responsiveness to macroeconomic news, while short-horizon time-contingent FG is not only ineffective, but even amplifies the responsiveness. State-contingent FG is effective in limiting bond price responses, while open-ended FG essentially has no effect. Overall, this suggests that time-contingent FG with long horizons has been sufficiently credible to shift market perceptions about the central bank's reaction function, a finding that is in line with the evidence provided by Femia et al. (2013) for the United States. State-dependency appears to have been similarly effective. Open-ended FG, in contrast, retains the original market responsiveness, which can be interpreted as markets perceiving this FG to be delphic (i.e., the regular central bank reaction applies). Finally, the increased market responsiveness under short-horizon time-contingent FG is puzzling: the central bank announces that it will keep short-term rates stable for a while, yet interest rates become more responsive to incoming news about the economy. Section 5 presents a theoretical model that rationalizes this finding.

4.2 Forecaster Disagreement

Next, we study the effects of FG on forecaster disagreement. Column (1) of Table 5 replicates the results of Andrade et al. (2019): in the presence of FG, there is less disagreement across professional forecasters about the future path of interest rates. While only marginally significant, the impact is estimated to be economically important. The bottom row of the table reports the average disagreement that prevails in the sample in the absence of FG, denoted by Ω^*. The estimate of Ω^* of 0.226 is the reference point for the following results. Under FG, this disagreement is reduced by nearly 30%. While this is sizeable, it also implies that professional forecasters still have different views about the future path of interest rates.

[Table 5 about here.]

Splitting up the various types of FG in column (2), it is apparent that the statistical significance does not stem from open-ended FG. Splitting time-contingent FG into short-horizon and long-horizon guidance (column (3)) as done in the previous analysis for the responsiveness of bond yields to macroeconomic news, it is found that long-horizon time-contingent FG effectively cuts the disagreement by half: the average disagreement in the absence of FG of 0.226 is reduced by 0.116. In line with the earlier results on the responsiveness of bond yields, it is found that state-contingent

FG has a substantial, but somewhat smaller effect on disagreement across forecasters – it is reduced by around one third. Finally, open-ended FG and time-contingent FG over a short horizon are found to be ineffective, in the sense that they do not affect disagreement in any meaningful manner: the estimated coefficients are not statistically significant.

To summarise, the empirical findings show that FG can reduce the responsiveness of bond yields to macroeconomic news and the disagreement across forecasters. However, there are certain types of FG where this is not the case, namely open-ended FG and time-contingent FG over a short horizon.

5 A Model of Learning from Market Signals

In our empirical analysis, we have provided evidence that FG can be effective in managing expectations about the future path of policy. However, we have also identified cases where FG does not lead to the intended effect, failing to reduce disagreement across professional forecasters, and counterintuitively raising the responsiveness of yields to macroeconomic news. In this section, we develop a model that rationalizes this pattern as the consequence of a market externality in information aggregation. The model is stylized. It is not designed for quantitative analysis, but as a proof-of-concept device meant to organize ideas..

We present a static asset pricing model where agents trade a bond with a payoff that is related to the state of the economy. While this payoff is unknown to agents at the time of trading, they receive a noisy private signal as well as a noisy public signal about the state of the economy, and also imperfectly observe market prices. We assume that the central bank determines the extent to which the bond payoff co-varies with the state of the economy. More specifically, we interpret FG as generating a lower pass-through of fundamentals to bond payoffs.

We abstract from issues concerning credibility and time-inconsistency. Instead, our focus is on how the central bank affects the way agents form expectations through altering the reaction of returns to fundamentals. Intuitively, FG announcements reduce ex-ante uncertainty because the asset payoff fluctuates less with the state of the economy. More precisely, it is less likely that rates will go down in response to news of a bad state as a FG announcement signals that the ELB is close; it is less likely that rates will go up in response to news of an improved outlook as the FG announcement indicates that rates will be low for some time.

Thus, in principle, FG announcements should reduce the usefulness of private and public information for predicting returns and lead to a lower news-sensitivity of asset prices and lower disagreement. We show that this is indeed always the case when agents do not learn from market signals. However, this is at odds with the empirical evidence above.

These insights change when adding market signals with endogenous precision. Such signals introduce an externality which generates a second, countervailing effect. As before, FG announcements decrease ex-ante uncertainty, so that expectations tend to react less to exogenous signals.

But this implies that the market price aggregates less information and becomes less informative. This loss of information in turn makes agents re-attribute weight from market signals to exogenous signals, exacerbating the response to macroeconomic news. This additional effect dominates when the weight on market signals is sufficiently high to start with.

As a result, a moderate strengthening of FG can lead to an increase, rather than a decrease, of uncertainty about future rates, which exacerbates the news-sensitivity of bond prices. For a sufficiently strong implementation of FG, however, the loss of information from market signals is more than compensated by the decrease in ex-ante uncertainty, so that one always obtains a decrease in sensitivity to news. We derive an analytical expression for the threshold at which the marginal effect of strengthening FG changes sign.

5.1 Setup

Financial market. There is a continuum of agents with mass one, indexed by $i \in (0,1)$. They can invest in bonds with a stochastic final payoff $\tilde{\theta} \sim N\left(\bar{\theta}, \tau_\theta^{-1}\right)$, where τ_θ denotes the precision of $\tilde{\theta}$. Agent i solves the optimization problem

$$\max_{Q_i} \left[\left(E\left[\tilde{\theta}|\Omega_i\right] - P \right) Q_i - \frac{1}{2} Q_i^2 \right]$$

where $E\left[\cdot|\Omega_i\right]$ is the expectations operator conditional on the information set of agent i, Q_i is her investment in the treasury bond, $Q_i^2/2$ represents a quadratic transaction cost, and P denotes the bond price. We assume a fixed supply of treasury bonds so that market clearing implies $\int_i Q_i di = \bar{\kappa}$.[18] The optimal individual demand is

$$Q_i = E\left[\tilde{\theta}|\Omega_i\right] - P,$$

which, combined with market clearing, gives the equilibrium price

$$p = \int E\left[\theta|\Omega_i\right] di,$$

where, $p = P - \bar{\theta} + \bar{\kappa}$ and $\theta = \tilde{\theta} - \bar{\theta}$. As usual, the bond price increases in the expected payoff and decreases in the net supply. Thus, the market price fully reveals the aggregate expectation.

Central Bank. The macroeconomic state $\tilde{\pi}$, which is related to the central bank's mandate, follows the distribution $\tilde{\pi} \sim N\left(\bar{\pi}, \tau_\pi^{-1}\right)$. The surprise component is therefore $\pi = \tilde{\pi} - \bar{\pi}$. We will refer to the inverse of the precision τ_π as the ex-ante uncertainty on the state of the economy. The central bank observes π and sets the bond payoff (i.e. the policy rate) θ according to the rule

$$\theta = \alpha\pi, \tag{12}$$

[18] The case with stochastic supply is explored in the Online Appendix.

where $\alpha \geqslant 0$. The parameter α represents the systematic component of monetary policy and is publicly announced. For instance, the central bank might typically set policy rates according to a Taylor rule, with a Taylor rule coefficient α_{TR}. Under FG, it sets $0 \leqslant \alpha < \alpha_{TR}$, i.e. it reduces its rate response as the state of the economy changes. This diminished reaction can arise as a consequence of two factors emerging during a liquidity trap. First, the perceived costs of going below the ELB make rate cuts in response to a further worsening of the outlook less likely. Second, a desire to create a more accommodative policy stance introduces inertia in the timing of a future rate lift-off.

Information. By varying α, the central bank also affects the ex-ante uncertainty that agents have about θ. In fact, the prior distribution of θ is given by

$$\theta \sim N\left(0, \alpha^2 \tau_\pi^{-1}\right). \tag{13}$$

We interpret announcements of a lower α as stronger forms of FG, as they make rates less dependent on fundamentals. Note that stronger (weaker) forms of FG imply lower (higher) volatility on policy rates because $\tau_\theta = \alpha^{-2}\tau_\pi$.

In contrast to the central bank, the public only observes a noisy signal of π, which is given by

$$y = \pi + \epsilon, \tag{14}$$

with $\epsilon \sim N\left(0, \tau_\epsilon^{-1}\right)$. This signal can be viewed as the surprise component of a macroeconomic news release. Besides this public signal, each agent observes a private signal

$$s_i = \pi + \eta_i, \tag{15}$$

where $\eta_i \sim N\left(0, \tau_\eta^{-1}\right)$ is i.i.d. across agents. Taken together, (13)-(15) constitute the exogenous component of agents' information sets, the precision of which is independent of equilibrium relations.

In addition, agents observe endogenous signals, i.e signals the precision of which depends on equilibrium relations. More specifically, we assume that agents' receive market signals of the form

$$x_i = p + \xi_i = \int E\left[\theta|\Omega_i\right] di + \xi_i, \tag{16}$$

where $\xi_i \sim N\left(0, \tau_\xi^{-1}\right)$ is i.i.d. across agents. This signal provides information about the aggregate expectation, but is subject to an individual-specific noise component. The presence of ξ_i prevents market prices from fully revealing θ. Without such a noise, the model would exhibit the well-known Milgrom and Stokey (1982) no-trade result. It can be interpreted in several ways. For example, agents may interpret the same market evidence differently because they rely on different market indexes. Alternatively, they may suffer from cognitive limitations in processing information. This second interpretation is in the spirit of a growing body of literature on rational inattention.[19]

Finally, we assume that all stochastic variables π, ϵ, η_i and ξ_i are mutually independent. Their probability distributions and corresponding moments are public knowledge.

5.2 Equilibrium

To solve for the equilibrium, we analyse how agents form expectations about the policy rate θ. There are three sources of information, hence agent i forms her expectation according to the linear rule

$$E\left[\theta|\Omega_i\right] = a\alpha s_i + b\alpha y + c x_i, \tag{17}$$

where a, b, and c are equilibrium weights. Aggregating across agents and substituting the various signals yields

$$\int E\left[\theta|\Omega_i\right] di = \frac{a}{1-c}\alpha\pi + \frac{b}{1-c}\alpha\left(\pi + \varepsilon\right), \tag{18}$$

which can be substituted into equation (16) to obtain

$$x_i = \underbrace{\frac{a\alpha}{1-c}\pi + \frac{b\alpha}{1-c}y}_{=p} + \xi_i. \tag{19}$$

The market price is spanned by the realisation of the fundamental and the public information, and the market signal is a noisy private observation of the market price. Because y is publicly observed, the informational content of the market price c can equivalently be represented by $\hat{x}_i = x_i - \frac{b\alpha}{1-c}y$. The precision of this signal about θ, which we denote by τ, is given by

$$\tau = \frac{a^2}{(1-c)^2}\tau_\xi. \tag{20}$$

This expression highlights the dependence of the informational content of the market signal on both a and c. The coefficient a stems from the aggregation of private information in market prices. The stronger agents' expectations respond to private signals, the more information gets incorporated into market signals. In contrast, c captures a complementarity between the reaction to market signals and their precision. As agents react more to market signals, their informational content gets amplified. The latter effect represents an externality. As agents move weights from endogenous to exogenous signals, they do not internalise the weakening of the informativeness of market prices that can result in a net loss of information.

Before proceeding to the equilibrium analysis let us define the news-sensitivity of bond prices

[19] For a recent survey see Mackowiak et al. (2018). See also Vives and Yang (2017) for a similar approach based on a behavioural model of expectation formation.

to public information. From equation (18), this is given by

$$\phi \equiv \frac{b\alpha}{1-c}.$$

Note that this also represents the sensitivity of the average expectation to public information.

The optimal weights a, b and c that characterize the rational expectation equilibrium are such that agents' forecast errors are orthogonal to their signals. They are stated in the following proposition, the proof of which is contained in the Appendix.

Proposition 1. *In equilibrium, we have*

$$a(c) = \frac{\tau_\eta}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}, \tag{21}$$

$$b(c) = \frac{(1-c)\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}, \tag{22}$$

where c is a real root of the fixed-point equation

$$\frac{\frac{1}{1-c}\tau_\eta}{\left(\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi\right)^2}\alpha^2 - \frac{c}{\tau_\xi} = 0. \tag{23}$$

Moreover, the news-sensitivity of bond prices is given by

$$\phi = \frac{\alpha\tau_\epsilon}{\frac{1}{1-c}\tau_\eta + \tau_\epsilon + \tau_\pi}. \tag{24}$$

The fixed-point equation (23) pins down the equilibrium value of c. While there is no closed-form solution, one can prove the following (see the Appendix).

Proposition 2. *In equilibrium, $c \in (0,1)$; in particular $c \to 0^+$ as $\alpha \to 0^+$ or $\tau_\eta \to 0^+$. Moreover, for*

$$\frac{\tau_\eta}{\tau_\epsilon + \tau_\pi} > \frac{1}{8}, \tag{25}$$

the equilibrium is unique for any $\tau_\xi > 0$ and $\alpha > 0$. Otherwise, there exists a compact set of values for α for which three equilibria exist.

The intuition for why c approaches zero as α declines towards zero is straightforward. A decrease in α reduces the uncertainty on the asset payoff, and thus the usefulness of any information. In particular, for $\alpha = 0$, any information is useless. As α marginally increases above zero, the sensitivity to any signal must increase.

Explaining why $c \to 0^+$ as $\tau_\eta \to 0^+$ is slightly more subtle. Notice that the price signal is informative about the aggregate expectation, but not about θ directly. Therefore, as the private signal becomes uninformative, the only informative signal is the public one. Hence, the market signal can only be a noisy version of that public signal, and thus becomes redundant. In this case, a regression of bond payoffs on public information becomes colinear.

5.3 The Case of No Market Signals

In this subsection, we briefly study the case where market signals are absent. This corresponds to $\tau_\xi \to 0$, i.e. to a situation in which agents are cognitively incapable of inferring anything about bond payoffs from prices. We will show that our two empirical findings established in the previous section cannot be rationalized in a typical Bayesian model of expectation formation in the absence of market signals.

Notice that the optimal weights that agents attach to the private and the public exogenous signals in Proposition 1 are expressed as a function of the weight on the market signal c. This is particularly convenient because the case $\tau_\xi \to 0$ is equivalent to a setting with no market signals, i.e. $c = 0$.

From (21) and (22), we deduce that $a(0)$ and $b(0)$ are equal to the precision of public and private signals, respectively, divided by the total precision (i.e. the sum of the precisions of the prior τ_π, of the public signals τ_ϵ and of the private signals τ_η). In particular, note that $E[\pi|s_i, y] = a(0)s_i + b(0)y$ is the conditional expectation about π given s_i and y and that $E[\theta|s_i, y] = \alpha E[\pi|s_i, y]$. Moreover, equation (24) directly implies the following.

Corollary 3. *In the absence of informative market signals (for $\tau_\xi \to 0$ or $c = 0$), ϕ is strictly increasing in α.*

This result establishes an important benchmark in which agents do not observe any price signal and can only access information with exogenous precision. In this case, stronger FG (lower α) always dampens the sensitivity of prices (and expectations) to public information. We have thus established that, in the absence of endogenous market signals, a standard model of Bayesian updating cannot replicate our empirical finding that short-term FG leads to an increase in the news-sensitivity of bond yields.

5.4 The Case with Market Signals

We now return to the full model with market signals. While it is not possible to obtain a closed-form solution for the equilibrium coefficients, it is still possible to make additional statements about the evolution of ϕ. More specifically, in the Appendix we prove the following result.

Proposition 4. *ϕ is a non-monotonic function of α. In particular, it achieves a maximum at $c = 1/2$ which corresponds to*

$$\alpha^* = \sqrt{\frac{\tau_\eta}{\tau_\xi}} + \frac{1}{2}\frac{\tau_\varepsilon + \tau_\pi}{\sqrt{\tau_\eta \tau_\xi}},$$

independently of the number of equilibria.

The proposition states that the bond price sensitivity to public information is decreasing in α for $\alpha > \alpha^*$. The range of values of α, for which the sensitivity $\phi(\alpha)$ counterintuitively decreases, grows larger as the market signal becomes less distorted by private noise, i.e. as τ_ξ grows large.

Intuitively, a decrease in α implies lower ex-ante uncertainty about the bond payoff θ. This should normally decrease agents' reliance on other sources of information, including public ones. However, when agents react less to private signals, market signals become less informative as less information is aggregated in prices. It is exactly when market signals are powerful aggregators of information – i.e. when τ_ξ large – that this second effect can dominate and agents can become overall more (rather than less) uncertain about θ.

[Figure 2 about here.]

To gain some intuition of the mechanism at work, it is instructive to look at Figure 2, which is based on a parameter combination that yields a unique equilibrium. In the upper row, we plot a, the agent's weight on her normalized private signal αs_i, and c, the weight on her endogenous price signal. In the bottom-left panel, we plot the precision of the market signal τ as a solid line, which – as shown in equation (20) – depends on the ratio $a/(1-c)$.

Panel (b) highlights that c is increasing in α, reflecting that agents are increasing the weight on the price signal. This means that more private information is effectively shared across agents through prices. In contrast, a is decreasing in α because private signals are becoming more noisy and thus less useful in making inference. Accordingly, the shape of τ depends on the net effect of these two forces. Panel (c) reveals that the learning externality always dominates. The precision of the market signal (solid line) always increases in α.

As α grows large, the weight c converges to one, because then all other sources of information become useless.[20] Panel (c) illustrates this by showing for comparison the precision of the private signal $\alpha^{-2}\tau_\eta$ as dashed line and the overall precision of public information, i.e. the prior precision plus the precision of the public signal $\alpha^{-2}(\tau_\pi + \tau_\epsilon)$, as dotted line. Both curves are strictly decreasing in α and tend to zero as α grows large.[21] Thus, the key feature generating non-monotonicity of ϕ in our model is the ability of market signals to aggregate information and retain some precision irrespectively of the level of α.

Panel (d) of Figure 2 plots ϕ as a function of α. To gain some further intuition, first note that ϕ is equal to zero for $\alpha = 0$. This is intuitive: there is no ex-ante uncertainty about θ, and thus no further information to be extracted from any signal. Moreover, notice that ϕ converges to zero as α grows very large because the public signal becomes less and less informative.[22] This second effect depends exclusively on the presence of the market signal. In fact, as α increases, all sources of information except the market signal become completely uninformative in the limit. Therefore, the weights allocated to them when making inference converge to zero. However, for intermediate

[20]Formally we have $\lim_{\alpha\to\infty} \tau = \tau_\xi$ from (21) and the fact that $\lim_{\alpha\to\infty} c = 1$.

[21]Notice that at α^* the market signal has exactly the same precision as the private signal.

[22]This can be seen formally by noting that (23) implies $\phi^2 = c(1-c)/\tau_\xi$ which goes to zero as c goes to one.

ranges of α the reaction coefficient ϕ must be different from zero because away from extreme values exogenous signals are useful sources of information.

[Figure 3 about here.]

Figure 3 illustrates the role of market signals with endogenous precision for generating our results. Panel (a) plots the price-sensitivity to public information, ϕ, as a function of α for four values of τ_ξ. As the market signal becomes less informative (lower values of τ_ξ), ϕ converges in the limit to a linearly increasing function, in line with Corollary 3. It is only in this limiting case that FG announcements always lead to a lower news-sensitivity of bond prices. The two other panels plot ex-post uncertainty and disagreement, i.e. the dispersion of individual beliefs. Uncertainty is defined as the posterior variance

$$Uncertainty \equiv Var(\theta|x_i, s_i, y) = \frac{\alpha^2}{\frac{1}{1-c}\tau_\eta + \tau_\epsilon + \tau_\pi}, \tag{26}$$

where $\frac{1}{1-c}\tau_\eta + \tau_\epsilon$ captures the joint precision of private signals and price signals. Disagreement is defined as

$$Disagreement \equiv Var(E[\theta|x_i, s_i, y] - \int E[\theta|x_i, s_i, y]di) = a^2\alpha^2\tau_\eta^{-1} + c^2\tau_\xi^{-1}. \tag{27}$$

The first term of this sum measures the dispersion in beliefs generated by the idiosyncratic noise in private signals, and the second term captures the one from idiosyncratic noise in price signals.

We see in the middle panel of Figure 3 that the pattern for uncertainty qualitatively follows the one for ϕ, which is natural as both are at least in part linked to how agents trade off the weights they allocate to various signals. In contrast, the bottom panel shows that disagreement is always monotonically increasing is α. This stems from the different behavior of the two components of disagreement. The first term $a^2\alpha^2\tau_\eta^{-1}$ is non-monotonic with a peak at α^*, whereas the second term $c^2\tau_\xi^{-1}$ is always increasing in α. Although disagreement is monotonic in α, under certain parameter conditions small changes in FG can lead to large changes in disagreement, which is highlighted by Figure 3. This is consistent with the findings in Section 4 that disagreement never increases, even for weak FG, and that only strong FG has a significant effect on forecaster disagreement.

6 Conclusion

Intuitively, one would expect FG to reduce uncertainty about the future path of interest rates. However, this paper shows that this crucially depends on the type of guidance adopted. It studies the impact of different types of FG on the responsiveness of bond yields to macroeconomic news, and on forecaster disagreement about the future path of interest rates. Time-contingent FG over long horizons eliminates both the asset price response to incoming news and substantially reduces disagreement across forecasters. State-contingent FG works in the same direction, but preserves some responsiveness and disagreement, because future policy continues to depend on a subset of macroeconomic information. In contrast, time-contingent FG over short horizons counterintuitively increases the news-sensitivity of bond yields and is ineffective in reducing forecaster disagreement. Finally, open-ended FG is largely ineffective.

A rational expectations model with noisy market information can explain these findings. In particular, public information by the central bank can hamper the aggregation of private information in prices. Thus, when the market is an important source of information, FG can increase, instead of decrease, uncertainty and can amplify, instead of reduce, the reaction of expectations to macroeconomic news.

References

Adam, K., Billi, R.M., 2006. Optimal monetary policy under commitment with a zero bound on nominal interest rates. Journal of Money, Credit and Banking 38, 1877–1905.

Adam, K., Billi, R.M., 2007. Discretionary monetary policy and the zero lower bound on nominal interest rates. Journal of Monetary Economics 54, 728–752.

Amador, M., Weill, P.O., 2010. Learning from prices: Public communication and welfare. Journal of Political Economy 118, 866–907.

Andrade, P., Gaballo, G., Mengus, E., Mojon, B., 2019. Forward guidance and heterogeneous beliefs. American Economic Journal: Macroeconomics 11, 1–29.

Angeletos, G.M., Lian, C., 2018. Forward guidance without common knowledge. American Economic Review 108, 2477–2512.

Angeletos, G.M., Pavan, A., 2007. Efficient use of information and social value of information. Econometrica 75, 1103–1142.

Bianchi, F., Melosi, L., 2017. Escaping the great recession. American Economic Review 107, 1030–1058.

Bianchi, F., Melosi, L., 2018. Constrained discretion and central bank transparency. Review of Economics and Statistics 100, 187–202.

Blinder, A., Ehrmann, M., de Haan, J., Jansen, D.J., 2017. Necessity as the mother of invention: Monetary policy after the crisis. Economic Policy 32, 707–755.

Campbell, J.R., Evans, C.L., Fisher, J.D.M., Justiniano, A., 2012. Macroeconomic effects of Federal Reserve forward guidance. Brookings Papers on Economic Activity 43, 1–80.

Campbell, J.R., Weber, J., 2018. Open mouth operations. Working Paper WP-2018-3. Federal Reserve Bank of Chicago.

Carlstrom, C.T., Fuerst, T.S., Paustian, M., 2015. Inflation and output in new Keynesian models with a transient interest rate peg. Journal of Monetary Economics 76, 230–243.

Crowe, C., 2010. Testing the transparency benefits of inflation targeting: Evidence from private sector forecasts. Journal of Monetary Economics 57, 226–232.

Davis, J.S., Presno, I., 2014. Inflation targeting and the anchoring of inflation expectations: Cross-country evidence from consensus forecasts. Globalization and Monetary Policy Institute Working Paper 174. Federal Reserve Bank of Dallas.

Del Negro, M., Giannoni, M., Patterson, C., 2015. The forward guidance puzzle. Staff Reports 574. Federal Reserve Bank of New York.

Detmers, G.A., 2016. Forward guidance under disagreement – evidence from the Fed's dot projections. Annual Conference 2016 (Augsburg): Demographic Change 145768. Verein für Socialpolitik.

Dovern, J., Fritsche, U., Slacalek, J., 2012. Disagreement among forecasters in G7 countries. Review of Economics and Statistics 94, 1081–1096.

Driscoll, J.C., Kraay, A.C., 1998. Consistent covariance matrix estimation with spatially dependent panel data. Review of Economics and Statistics 80, 549–560.

Eggertsson, G.B., Woodford, M., 2003. The zero bound on interest rates and optimal monetary policy. Brookings Papers on Economic Activity 34, 139–235.

Eggertsson, G.B., Woodford, M., 2006. Optimal monetary and fiscal policy in a liquidity trap, in: Clarida, R.H., Frankel, J., Giavazzi, F., West, K.D. (Eds.), NBER International Seminar on Macroeconomics 2004. MIT Press. chapter 2, pp. 75–144.

Ehrmann, M., 2015. Targeting inflation from below: How do inflation expectations behave? International Journal of Central Banking 11, 213–249.

Ehrmann, M., Eijffinger, S., Fratzscher, M., 2012. The role of central bank transparency for guiding private sector forecasts. Scandinavian Journal of Economics 114, 1018–1052.

Farhi, E., Werning, I., 2019. Monetary policy, bounded rationality, and incomplete markets. American Economic Review – forthcoming.

Femia, K., Friedman, S., Sack, B.P., 2013. The effects of policy guidance on perceptions of the Fed's reaction function. Staff Report 652. Federal Reserve Bank of New York.

Feroli, M., Greenlaw, D., Hooper, P., Mishkin, F.S., Sufi, A., 2017. Language after liftoff: Fed communication away from the zero lower bound. Research in Economics 71, 452–490.

Filardo, A., Hofmann, B., 2014. Forward guidance at the zero lower bound. BIS Quarterly Review , 37–53.

Gabaix, X., 2016. A behavioral new Keynesian model. Discussion Paper 11729. Centre for Economic Policy Research.

Gaballo, G., 2016. Rational inattention to news: The perils of forward guidance. American Economic Journal: Macroeconomics 8, 42–97.

den Haan, W. (Ed.), 2013. Forward guidance – perspectives from central bankers, scholars and market participants. VoxEU.org eBooks, Centre for Economic Policy Research.

Jia, C., 2019. The informational effect of monetary policy and the case for policy commitment. Working Paper 19-07. Federal Reserve Bank of Cleveland.

Kiley, M., 2016. Policy paradoxes in the New-Keynesian model. Review of Economic Dynamics 21, 1–15.

Krugman, P.R., 1998. It's baaack: Japan's slump and the return of the liquidity trap. Brookings Papers on Economic Activity 29, 137–206.

Mackowiak, B.A., Matejka, F., Wiederholt, M., 2018. Survey: Rational inattention, a disciplined behavioral model. Discussion Paper 13243. Centre for Economic Policy Research.

Mankiw, N.G., Reis, R., Wolfers, J., 2004. Disagreement about inflation expectations, in: Gertler, M., Rogoff, K. (Eds.), NBER Macroeconomics Annual 2003. MIT Press. volume 18. chapter 4, pp. 209–270.

McKay, A., Nakamura, E., Steinsson, J., 2016. The power of forward guidance revisited. American Economic Review 106, 3133–3158.

Michelacci, C., Paciello, L., 2017. Ambiguous policy announcements. Discussion Paper 11754. Centre for Economic Policy Research.

Milgrom, P., Stokey, N., 1982. Information, trade and common knowledge. Journal of Economic Theory 26, 17–27.

Moessner, R., 2013. Effects of explicit FOMC policy rate guidance on interest rate expectations. Economics Letters 121, 170–173.

Moessner, R., 2015. Reactions of real yields and inflation expectations to forward guidance in the United States. Applied Economics 47, 2671–2682.

Moessner, R., Jansen, D.J., de Haan, J., 2017. Communication about future policy rates in theory and practice: A survey. Journal of Economic Surveys 31, 678–711.

Morris, S., Shin, H.S., 2002. Social value of public information. American Economic Review 92, 1521–1534.

Nakov, A., 2008. Optimal and simple monetary policy rules with zero floor on the nominal interest rate. International Journal of Central Banking 4, 73–127.

Swanson, E.T., Williams, J.C., 2014a. Measuring the effect of the zero lower bound on medium- and longer-term interest rates. American Economic Review 104, 3154–3185.

Swanson, E.T., Williams, J.C., 2014b. Measuring the effect of the zero lower bound on yields and exchange rates in the U.K. and Germany. Journal of International Economics 92, Supplement 1, S2–S21.

Vives, X., Yang, L., 2017. Costly interpretation of asset prices. Discussion Paper 12360. Centre for Economic Policy Research.

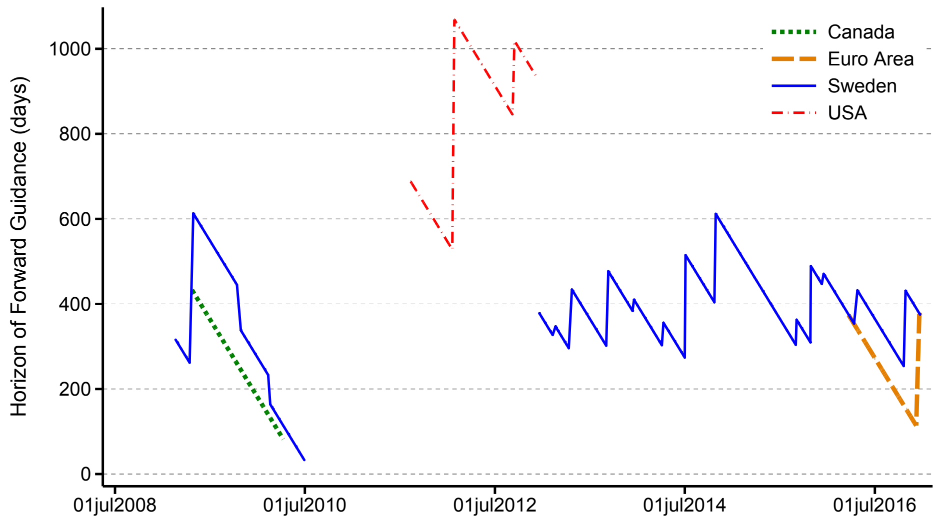
Wiederholt, M., 2014. Empirical properties of inflation expectations at the zero lower bound. Goethe University Frankfurt.

Woodford, M., 2013. Forward guidance by inflation-targeting central banks. Discussion Paper 9722. Centre for Economic Policy Research.

List of Figures

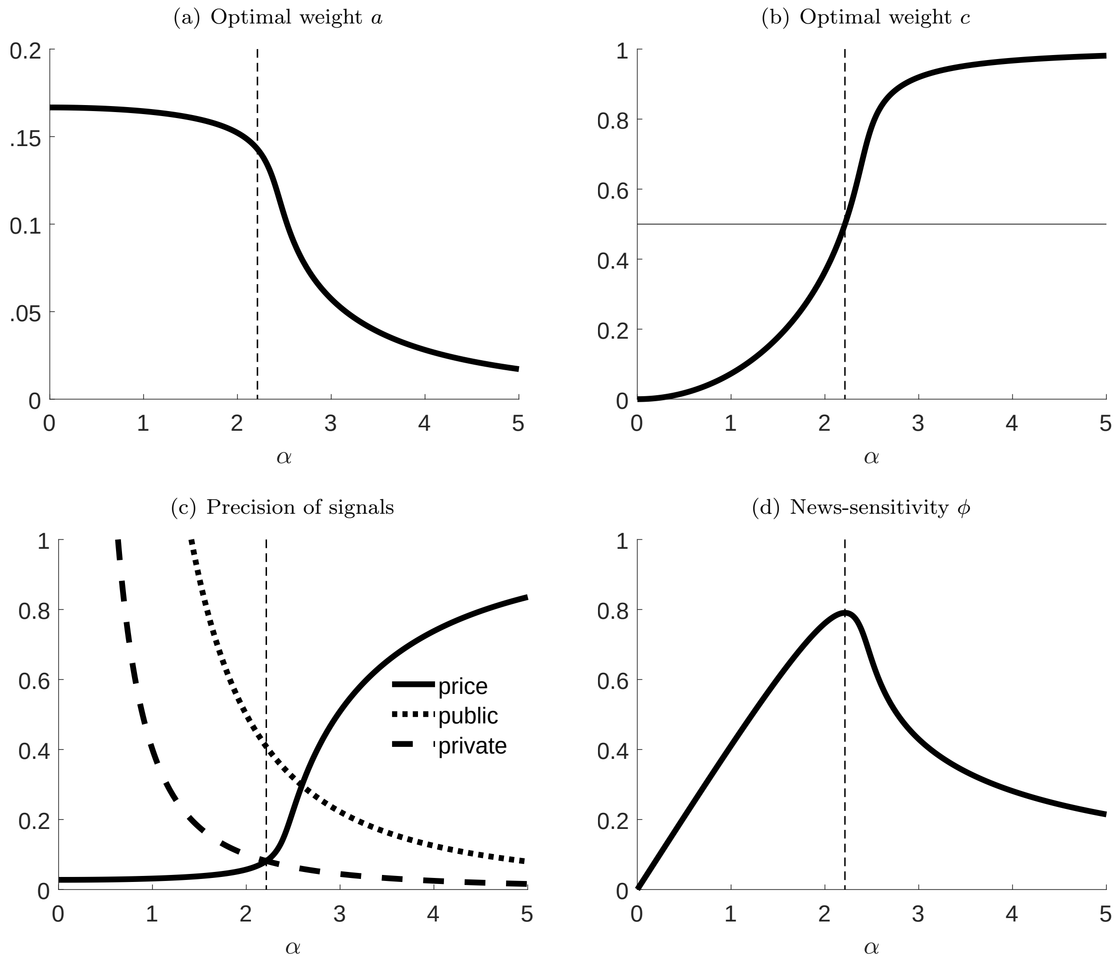
1 Remaining guidance horizon of time-contingent forward guidance 28
2 Optimal weights, precision, and news-sensitivity as function of α 29
3 The importance of market signals 30

Figure 1: Remaining guidance horizon of time-contingent forward guidance



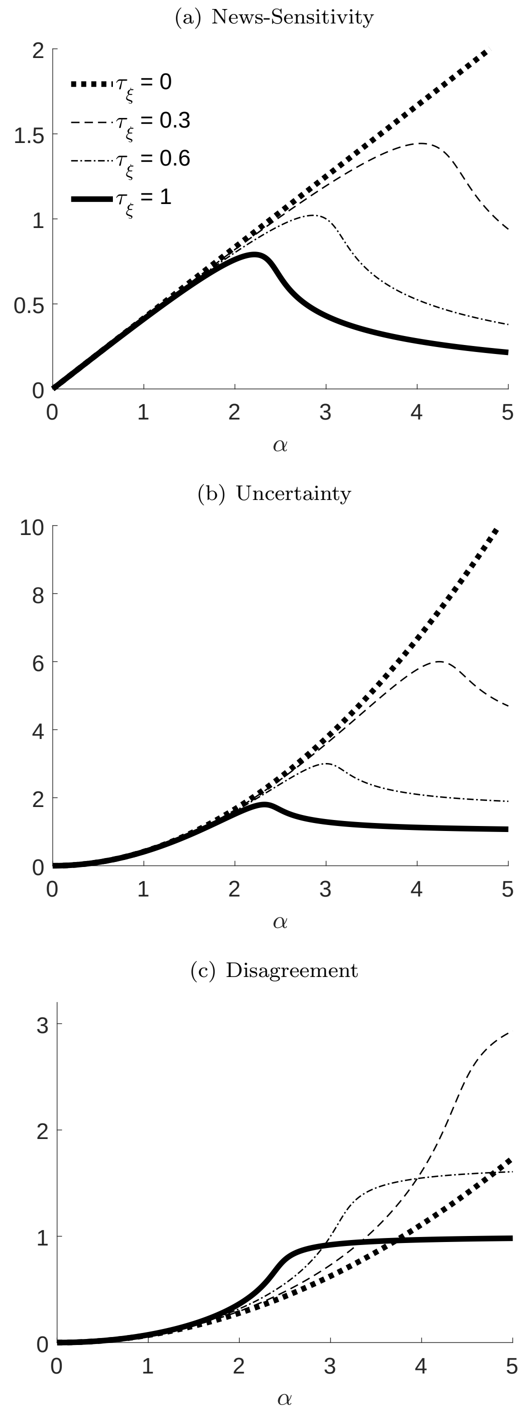
Notes: This figure graphs the remaining horizon of the announced time contingency over time, measured in days. In the absence of time-contingent forward guidance, no line is shown.

Figure 2: Optimal weights, precision, and news-sensitivity as function of α



Notes: This figure illustrates how key elements of the model vary with the strength of forward guidance measured by α. The parameters are set to $\tau_\eta = 0.4$, $\tau_\epsilon = \tau_\pi = \tau_\xi = 1$. This implies that the sensitivity of bond prices to public information is highest at $\alpha^* = 2.2$, which is marked by the dashed vertical lines. Panel (a) plots the weight on the normalized private signal αs_i, and panel (b) the weight on the endogenous price signal. Panel (c) shows the precision of the price signal as solid line, of the private signal as dashed line, and of public information as dotted line. Panel (d) shows the sensitivity of bond prices to public information.

Figure 3: The importance of market signals



Notes: This figure illustrates how the presence of a market signal affects the news-sensitivity of asset prices, uncertainty, and disagreement. Panel (a) shows the news-sensitivity, given by equation (24). Panel (b) shows the ex-post uncertainty, given by equation (26), and panel (c) disagreement, given by equation (27). All three are plotted as functions of α for four different precision levels τ_ξ. The other parameters are set to $\tau_\eta = 0.4$ and $\tau_\epsilon = \tau_\pi = 1$.

List of Tables

1 Effective lower bound and forward guidance episodes, 1995 - 2016 32
2 Summary statistics 33
3 Differences in the economic environment across forward guidance regimes 34
4 The responsiveness of yields to macroeconomic surprises 35
5 Forward guidance and forecaster disagreement 36

Table 1: Effective lower bound and forward guidance episodes, 1995 - 2016

	(1) Effective lower bound periods	(2) State-contingent FG periods	(3) Open-ended FG periods	(4) Time-contingent FG periods	(5) Time-contingent FG ∅ horizon (days)
Canada	20.01.09 –	-	-	21.04.09 – 19.04.10	258
Euro area	07.05.09 – 06.04.11 08.12.11 –	-	04.07.13 – 09.03.16	10.03.16 –	247
Japan	01.04.95 –	05.10.10 – 03.04.13 29.01.16 –	12.02.99 – 10.08.00	-	-
Sweden	11.02.09 – 14.12.10 18.12.12 –	-	-	30.10.07 – 30.06.10 20.12.11 –	383
UK	05.02.09 –	07.08.13 – 11.02.14	12.02.14 – 12.08.14	-	-
USA	25.06.2003 – 29.06.2004 29.10.2008 –	12.12.12 – 18.03.14	06.12.08 – 08.08.11 19.03.14 –	09.08.11 – 11.12.12	843

Notes: The first column reports the periods during which a central bank was at the effective lower bound (ELB), defined as a policy rate at or below 1%. Columns (2), (3) and (4) report the periods during which a country was subject to one of the three forward guidance (FG) types. Column (5) reports the average horizon of time-contingent FG in days during the periods that time-contingent FG was active at the ELB in the respective country. A "–" without a date following indicates that the ELB or the respective FG regime was still active on 31 December 2016, i.e. at the end of the sampling period. A "-" reflects that the respective type of FG was not observed for the respective country before 31 December 2016.

Table 2: Summary statistics

Dependent variable		(1)	(2) Bond Yield	(3)	(4) Disagreement	(5)
		macro indicators (count)	obs. at ELB (count)	first obs. (year)	obs. at ELB (count)	first obs. (year)
Canada		6	406	2009	95	2009
Euro area	Germany	8	583	2009	83	2009
	Italy	8	654	2009		
Japan		8	1023	2000	216	1999
Sweden		8	487	2009	70	2009
UK		7	664	2009	95	2009
USA		9	1102	2003	110	2003
Total			4919		669	

Notes: Column (1) reports the number of macroeconomic indicators in each country used in the bond-yield regressions (2)-(9). Columns (2) and (3) report the number of observations during the effective lower bound (ELB) sample period and the year of the first observation in these regressions. Analogously, columns (4) and (5) report the number of observations during the ELB sample period and the year of the first observation underlying the disagreement regressions (10) and (11). Both samples end on 31 December 2016.

Table 3: Differences in the economic environment across forward guidance regimes

	(1) Mean Absolute Surprise	(2) Forecaster Disagreement	(3) Mentions of "uncertain"
State-contingent FG	0.809***	−0.136**	0.069***
(SG)	*(0.034)*	*(0.057)*	*(0.014)*
Open-ended FG	0.700***	−0.011	−0.032***
(OG)	*(0.018)*	*(0.082)*	*(0.007)*
Short-horizon time-	0.758***	−0.117*	−0.008
contingent FG (STG)	*(0.023)*	*(0.069)*	*(0.030)*
Long-horizon time-	0.713***	−0.068	−0.057**
contingent FG (LTG)	*(0.048)*	*(0.077)*	*(0.023)*
Difference between FG types (p-values)			
SG vs. OG	0.00	0.14	0.00
SG vs. STG	0.21	0.81	0.02
SG vs. LTG	0.10	0.49	0.00
OG vs. STG	0.05	0.06	0.42
OG vs. LTG	0.81	0.48	0.22
STG vs. LTG	0.40	0.61	0.18

Notes: The upper part of column (1) of this table reports the mean absolute macroeconomic surprises and their standard errors (in parentheses) for different FG regimes. Column (2) reports differences in forecaster disagreement about one-year-ahead GDP growth across Consensus Economics forecasters relative to the no-FG case. Column (3) reports differences in the frequency with which central bank press releases refer to uncertainty relative to the no-FG case. For all columns, the lower part tests for differences across FG types. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

Table 4: The responsiveness of yields to macroeconomic surprises

	(1)	(2)	(3)	(4)
No FG (β)	0.443***	0.443***	0.443***	0.443***
	(0.097)	*(0.097)*	*(0.097)*	*(0.097)*
FG (β_{FG})	**0.042**			
	(0.116)			
SG (β_{SG})		-0.340***	-0.341***	-0.342***
		(0.108)	*(0.108)*	*(0.108)*
OG (β_{OG})		**0.049**	**0.047**	**0.047**
		(0.141)	*(0.141)*	*(0.141)*
TG (β_{TG})		**0.304****	-0.383	
		(0.153)	*(0.632)*	
g (γ)			3.624*	
			(2.091)	
g^2 (γ_2)			-3.607**	
			(1.556)	
STG (β_{STG})				**0.496*****
				(0.189)
LTG (β_{LTG})				-0.317**
				(0.131)
# observations	4919	4919	4919	4919
within-R^2	0.02	0.03	0.03	0.03

Notes: This table shows how the responsiveness of bond yields to macroeconomic surprises depends on the type of forward guidance (FG) in place. The dependent variable is the 120-minute window change in two-year sovereign bond yields in basis points. Column (1) reports the results for the fixed effects specification (2). Column (2) uses the specification given by equations (3), (4) and (5). Column (3) combines (3) with (6) and (7), and column (4) combines (3) with (8) and (9). Country-indicator fixed effects and FG fixed effects not reported. SG denotes state-contingent FG, OG open-ended FG, TG time-contingent FG, STG time-contingent FG with a remaining guidance horizon of up to 1.5 years, and LTG time-contingent FG with a remaining horizon of more than 1.5 years. g measures the horizon of time-contingent FG relative a two-year benchmark, g^2 is the squared value thereof. Driscoll-Kraay standard errors with business week sampling are given in parentheses. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level. Bold coefficients indicate the significance of the response of yields at the 1% level. The sample covers the effective-lower-bound periods from February 2000 until December 2016.

Table 5: Forward guidance and forecaster disagreement

	(1)	(2)	(3)
FG (α_{FG})	-0.062*		
	(0.037)		
SG (α_{SG})		-0.067*	-0.070**
		(0.036)	*(0.033)*
OG (α_{OG})		-0.026	-0.029
		(0.051)	*(0.048)*
TG (α_{TG})		-0.097**	
		(0.047)	
STG (α_{STG})			-0.090
			(0.056)
LTG (α_{LTG})			-0.116**
			(0.049)
# observations	669	669	669
R^2	0.63	0.64	0.64
Ω*	0.226	0.226	0.226

Notes: This table shows the effect of forward guidance (FG) on forecaster disagreement regarding three-month-ahead forecasts for 3-month interest rates, as measured by the interdecile range and as estimated by equations (10) and (11). Country and time fixed effects not reported. SG denotes state-contingent FG, OG open-ended FG, TG time-contingent FG, STG time-contingent FG with a remaining guidance horizon of up to 1.5 years, and LTG time-contingent FG with a remaining horizon of more than 1.5 years. Ω* measures the sample average of the interdecile range in the absence of FG. Driscoll-Kraay standard errors are given in parentheses. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level. The sample covers the effective-lower-bound periods from January 1999 until December 2016.

A Proofs

A.1 Proof of Proposition 1

Formally, the weights in equation (17) have to satisfy the following three orthogonality conditions:

$$\begin{aligned} E\left[\alpha s_i\left(\theta - E\left[\theta|\Omega_i\right]\right)\right] &= 0, \quad (28)\\ E\left[\alpha y\left(\theta - E\left[\theta|\Omega_i\right]\right)\right] &= 0, \quad (29)\\ E\left[x_i\left(\theta - E\left[\theta|\Omega_i\right]\right)\right] &= 0. \quad (30)\end{aligned}$$

Substituting from equation (17), condition (28) yields

$$\sigma_\theta^2 - a\alpha^2\sigma_\eta^2 - \frac{a+b}{1-c}\sigma_\theta^2 = 0$$

and

$$a\left(c,b\right) = \frac{(1-c)\sigma_\theta^2 - b\sigma_\theta^2}{\sigma_\theta^2 + (1-c)\alpha^2\sigma_\eta^2}. \quad (31)$$

Similarly, equation (29) yields

$$\sigma_\theta^2 - \frac{a+b}{1-c}\sigma_\theta^2 - \frac{b}{1-c}\alpha^2\sigma_\varepsilon^2 = 0$$

and

$$b\left(a,c\right) = \frac{(1-c)\sigma_\theta^2 - a\sigma_\theta^2}{\sigma_\theta^2 + \alpha^2\sigma_\varepsilon^2}. \quad (32)$$

Combining (31) and (32), we get

$$\begin{aligned} a\left(c\right) &= \frac{\tau_\eta}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}, \quad (33)\\ b\left(c\right) &= \frac{(1-c)\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}. \quad (34)\end{aligned}$$

Substituting (33) and (34) into the endogenous signal x_i and the individual expectation $E\left[\theta|\Omega_i\right]$ yields

$$x_i = \left(\frac{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}\alpha\pi + \frac{\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}\alpha\varepsilon + \xi_i\right)$$

and

$$
\begin{aligned}
E\left[\theta|\Omega_i\right] &= \frac{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}\alpha\pi + \frac{\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\theta}\alpha\varepsilon \\
&+ \frac{\frac{1}{1-c}\tau_\eta}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}\alpha\eta_i + c\xi_i.
\end{aligned}
$$

Using these two expressions, the third orthogonality condition (30) can be written as

$$
\begin{aligned}
&\frac{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}\alpha^2\tau_\pi^{-1} - \left(\frac{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}\right)^2 \alpha^2\tau_\pi^{-1} \\
&- \left(\frac{\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}\right)^2 \alpha^2\tau_\varepsilon^{-1} - c\tau_\xi^{-1} = 0.
\end{aligned}
$$

Simplifying this yields the fixed-point equation stated in Proposition 1.

A.2 Proof of Proposition 2

The first statement of the proposition follows from the fact that, in equilibrium, we have

$$
\alpha^2 = (1-c)c\tau_\eta^{-1}\left(\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi\right)^2 \tau_\xi^{-1},
$$

with $\tau_\eta, \tau_\varepsilon, \tau_\pi, \tau_\xi$ being all positive.

Let us now check the condition for the uniqueness of the equilibrium. The fixed-point equation (23) implies that, in equilibrium,

$$
\alpha = \underbrace{\left(\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi\right)\sqrt{\frac{(1-c)c}{\tau_\eta\tau_\xi}}}_{\equiv f(c)},
$$

where $\alpha > 0$ and $c \in (0,1)$. Note that the sign of the derivative of $f(c)'$,

$$
\frac{\partial f(c)}{\partial c} = \frac{1}{2c\left(1-c\right)^2}\sqrt{\frac{(1-c)c}{\tau_\eta\tau_\xi}}\left(\tau_\eta + \left(1-2c\right)\left(1-c\right)\left(\tau_\varepsilon + \tau_\pi\right)\right)
$$

depends on the sign of $(\tau_\eta + (1-2c)(1-c)(\tau_\varepsilon + \tau_\pi))$. It is easy to show that $f(c)' > 0$ for any $\alpha > 0$ and any $c \in (0,1)$ if and only if

$$
\frac{\tau_\eta}{\tau_\epsilon + \tau_\pi} > \frac{1}{8}. \tag{35}
$$

If instead (35) does not hold, $f(c)'$ is negative in a compact interval $(\underline{c}, \bar{c}) \subset (0,1)$ and it is positive otherwise. In particular, we have

$$\underline{c} = \frac{3}{4} - \sqrt{\frac{1}{2}\left(\frac{1}{8} - \frac{\tau_\eta}{\tau_\epsilon + \tau_\pi}\right)} \quad \text{and} \quad \bar{c} = \frac{3}{4} + \sqrt{\frac{1}{2}\left(\frac{1}{8} - \frac{\tau_\eta}{\tau_\epsilon + \tau_\pi}\right)}$$

with

$$\lim_{\frac{\tau_\eta}{\tau_\epsilon + \tau_\pi} \to 0} (\underline{c}, \bar{c}) = (0.5, 1).$$

Therefore, we conclude that, whenever condition (35) does not hold, multiple equilibria must exist in an interval of α.

A.3 Proof of Proposition 4

The fixed-point equation (23) implies that, in equilibrium,

$$\alpha(c) = \left(\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi\right)\sqrt{\frac{(1-c)c}{\tau_\eta \tau_\xi}}.$$

Note that

$$\frac{\partial \alpha}{\partial c} = \frac{1}{2c(1-c)^2}\sqrt{\frac{(1-c)c}{\tau_\eta \tau_\xi}}\left(\tau_\eta + (1-2c)(1-c)(\tau_\varepsilon + \tau_\pi)\right)$$

and that $\partial c / \partial \alpha = (\partial \alpha / \partial c)^{-1}$. Therefore we get

$$\begin{aligned}
\frac{\partial \phi}{\partial \alpha} &= \alpha \frac{\partial \left(\frac{\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi}\right)}{\partial c}\frac{\partial c}{\partial \alpha} + \frac{\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi} \\
&= \frac{\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi} - \frac{\alpha \tau_\varepsilon \tau_\eta}{\left(\tau_\eta + (1-c)(\tau_\pi + \tau_\varepsilon)\right)^2} \\
&\times \left(\frac{1}{2c(1-c)^2}\sqrt{\frac{(1-c)c}{\tau_\eta \tau_\xi}}\left(\tau_\eta + (1-2c)(1-c)(\tau_\varepsilon + \tau_\pi)\right)\right)^{-1},
\end{aligned}$$

which is **weakly negative** if and only if

$$\begin{aligned}
&\frac{\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta + \tau_\varepsilon + \tau_\pi} \\
\leqslant\ &\frac{\alpha \tau_\varepsilon \tau_\eta}{\left(\tau_\eta + (1-c)(\tau_\pi + \tau_\varepsilon)\right)^2}\left(\frac{1}{2c(1-c)^2}\sqrt{\frac{(1-c)c}{\tau_\eta \tau_\xi}}\left(\tau_\eta + (1-2c)(1-c)(\tau_\varepsilon + \tau_\pi)\right)\right)^{-1}.
\end{aligned}$$

By using again the fixed-point equation, we obtain

$$\begin{aligned}
&\frac{\tau_\varepsilon}{\frac{1}{1-c}\tau_\eta+\tau_\varepsilon+\tau_\pi} \\
&\quad \leqslant \quad \frac{\tau_\eta}{(1-c)^2}\frac{\alpha\tau_\varepsilon}{\left(\frac{1}{1-c}\tau_\eta+(\tau_\pi+\tau_\varepsilon)\right)^2}\left(\frac{1}{2c(1-c)^2}\sqrt{\frac{(1-c)c}{\tau_\eta\tau_\xi}}\left(\tau_\eta+(1-2c)(1-c)(\tau_\varepsilon+\tau_\pi)\right)\right)^{-1} \\
1 &\quad \leqslant \quad \frac{\tau_\eta}{(1-c)^2}\frac{\alpha}{\frac{1}{1-c}\tau_\eta+\tau_\pi+\tau_\varepsilon}\left(\frac{1}{2c(1-c)^2}\sqrt{\frac{(1-c)c}{\tau_\eta\tau_\xi}}\left(\tau_\eta+(1-2c)(1-c)(\tau_\varepsilon+\tau_\pi)\right)\right)^{-1} \\
1 &\quad \leqslant \quad \frac{\tau_\eta}{(1-c)^2}\sqrt{\frac{(1-c)c}{\tau_\eta\tau_\xi}}\left(\frac{1}{2c(1-c)^2}\sqrt{\frac{(1-c)c}{\tau_\eta\tau_\xi}}\left(\tau_\eta+(1-2c)(1-c)(\tau_\varepsilon+\tau_\pi)\right)\right)^{-1} \\
1 &\quad \leqslant \quad \frac{2c\tau_\eta}{\tau_\eta+(1-2c)(1-c)(\tau_\varepsilon+\tau_\pi)},
\end{aligned}$$

which requires, first,

$$\tau_\eta \geqslant -(1-2c)(1-c)(\tau_\varepsilon+\tau_\pi),$$

and second,

$$\begin{aligned}
\tau_\eta+(1-2c)(1-c)(\tau_\varepsilon+\tau_\pi) &\leqslant 2c\tau_\eta, \\
(1-2c)(1-c)(\tau_\varepsilon+\tau_\pi) &\leqslant -(1-2c)\tau_\eta.
\end{aligned}$$

This is satisfied for

$$\frac{1}{2} \leqslant c \leqslant 1+\frac{\tau_\eta}{\tau_\varepsilon+\tau_\pi}.$$

We thus conclude that a maximum for ϕ obtains for $c = 1/2$, which corresponds to

$$\alpha^* \equiv \alpha(1/2) = \sqrt{\frac{\tau_\eta}{\tau_\xi}}+\frac{1}{2}\frac{\tau_\varepsilon+\tau_\pi}{\sqrt{\tau_\eta\tau_\xi}}.$$