BANK OF ENGLAND

Staff Working Paper No. 672

Central bank information and the effects of monetary shocks

Paul Hubert

August 2017

BANK OF ENGLAND

Staff Working Paper No. 672

Central bank information and the effects of monetary shocks

Paul Hubert[(1)]

Abstract

Does the effect of monetary policy depend on the macroeconomic information released by the central bank? Because differences between central bank's and private agents' information sets affect private agents' interpretation of policy decisions, this paper aims to investigate whether the publication of macroeconomic information by the central bank modifies private responses to monetary policy. We assess the non-linear effects of monetary shocks conditional on the Bank of England's macroeconomic projections on UK private inflation expectations. We find that inflation projections modify the impact of monetary shocks. When contractionary monetary shocks are interacted with positive (negative) projections, the negative effect of policy on inflation expectations is amplified (reduced). This suggests that providing guidance about central bank future expected inflation helps private agents' information processing, and therefore changes their response to policy decisions.

Key words: Monetary policy, information processing, signal extraction, market-based inflation expectations, central bank projections, real-time forecasts.

JEL classification: E52, E58.

(1) Sciences Po — OFCE. Email: paul.hubert@sciencespo.fr

The views expressed in this paper are those of the author, and not necessarily those of the Bank of England or its committees. I thank Philippe Andrade, Christophe Blot, Ambrogio Cesa-Bianchi, James Cloyne, Camille Cornand, Jérôme Creel, Martin Ellison, Stephen Hansen, Michael McMahon, Becky Maule, Roland Meeks, Francesca Monti and Giovanni Ricco, and seminar participants at the Bank of England, Deutsche Bundesbank, CEPII, Banque de France, the 2016 CFE and the 2017 VUB workshop for helpful discussions and comments at different stages of this project. I am grateful to the Bank of England for its hospitality during my time on secondment to the Monetary Assessment and Strategy Division. Any remaining errors are my own responsibility.

Information on the Bank's working paper series can be found at
www.bankofengland.co.uk/research/Pages/workingpapers/default.aspx

Publications and Design Team, Bank of England, Threadneedle Street, London, EC2R 8AH
Telephone +44 (0)20 7601 4030 email publications@bankofengland.co.uk

ISSN 1749-9135 (on-line)

1. Introduction

Expectations matter in determining current and future macroeconomic outcomes. Hence, the management of private expectations has become a central feature of monetary policy, as private agents' interpretation of central bank decisions and communication is central to the formation of their beliefs (Woodford, 2005). One way in which some central banks communicate is by publishing macroeconomic projections. While there is variation in terms of the variables forecasted, and how those projections are published, a number of central banks – including the Bank of England, Federal Reserve, European Central Bank, Riksbank, Norges Bank and Reserve Bank of New Zealand – release projections on a regular basis.

In the meantime, and despite a considerable empirical literature, there is still uncertainty about the effects of monetary shocks.[1] The sign and magnitude of the responses of private beliefs and economic variables to monetary policy may depend on the identification strategy, the state of the economy, the specification of the model considered, and the relative information sets of policymakers and private agents. This paper aims at assessing, in the presence of information frictions, the effect of monetary shocks when accounting for the publication of central bank macroeconomic projections.

In a framework with perfect information, private agents are able to infer the pure monetary innovation from the central bank's policy decision based on their knowledge of its reaction function. However, in a set-up with information frictions and more particularly non-nested information sets, private agents cannot infer the pure monetary shock from the policy decision without central bank macroeconomic projections. When the central bank and private agents have different information sets, the policy decision can convey information about the central bank's view of macroeconomic developments, influencing private beliefs about the future economic outlook.[2] The reaction of private expectations to the policy decision may therefore reflect a mix of the responses to the pure monetary innovation and to the macroeconomic information conveyed by the policy instrument. In that case, an increase in the policy rate could signal to private agents that an inflationary shock will hit the economy in the future, causing higher private inflation expectations and so higher inflation.[3] Yet, the same increase in the policy rate may be interpreted as a contractionary monetary shock, which will lower private inflation expectations and so inflation.

Private agents' interpretation of changes in the policy rate is therefore crucial in determining the sign and magnitude of the effect of monetary policy actions. Because this interpretation of policy decisions in turn depend on the differences between information sets of policymakers and private agents, the publication of central bank macroeconomic projections may affect the impact of the policy decision. This paper aims to assess the extent to which the effect of monetary shocks depends on the information

[1] See Sims (1972), Bernanke and Blinder (1992), Romer and Romer (2004), Coibion (2012), Gertler and Karadi (2015), Miranda-Agrippino (2016), and Miranda-Agrippino and Ricco (2017).
[2] Melosi (2017) and Nakamura and Steinsson (2017) study this signalling channel of monetary policy.
[3] The signalling channel of monetary policy might then be one explanation for the positive response of inflation to monetary shocks documented in the VAR literature as the "price puzzle" (Sims 1992) and would be consistent with Castelnuovo and Surico (2010) that including inflation expectations in VARs captures this price puzzle.

disclosed by central bank macroeconomic projections. In other words, do central bank macroeconomic projections help private agents to infer the true monetary shock?

This paper investigates, for the United Kingdom (UK), whether and how the term structure of market-based inflation expectations, measured with inflation swaps, responds to the Bank of England's (BoE) policy decisions and to their interaction with BoE macroeconomic projections. If the publication of macroeconomic projections, by facilitating information processing and signal extraction, helps private agents to infer the true monetary innovation, then the usual negative effect of contractionary monetary policy on private inflation expectations should not be mitigated by the signalling channel of monetary policy, and should therefore be amplified.

This paper makes use of a specific feature of the BoE data to overcome the main empirical challenge of this paper. The research question requires that the central bank projections are not a function of the current policy decision so both the monetary shocks and the projection surprises can be separately identified. In this particular dataset, BoE projections are conditioned on the market interest rate instead of the policy rate, so BoE projections are orthogonal to contemporary policy decisions, a necessary feature for identification issues.

Two additional features of this paper are worth stressing. First, its focus is on the effects of the release of central bank macroeconomic information, not on policy announcements, communication about the future path of policy, the Forward Guidance policy (see e.g. Andrade et al. 2015; Campbell et al. 2016) or whether communication is relatively more hawkish or dovish (see e.g. Ehrmann and Fratzscher, 2007; Rosa and Verga, 2007). Second, this paper focuses on quantitative communication and abstracts from quantification issues of qualitative communication like statements, minutes and speeches (see Blinder et al., 2008, for a review and Hubert, 2017, for a comparison of the effects of both types of communication).

The contribution of this paper to the literature is to analyse whether the publication of central bank macroeconomic projections modifies the effect of monetary shocks. Given that facilitating private agents' information processing has been put forward as one reason why central banks complement their actions with communication, we document this interdependence and assess its impact on the term structure of private inflation expectations.

Our empirical analysis proceeds in two steps. First, we deal with the issue of endogeneity by extracting series of exogenous shocks to the BoE's policy rate and to its inflation and output projections by removing their systematic component, following the identification methodology of Romer and Romer (2004) applied to UK data by Cloyne and Huertgen (2016).[4] Blanchard et al. (2013) and Miranda-Agrippino and Ricco (2017) discuss how information frictions modify the econometric identification problem. To account for potential non-nested information sets, we augment the Romer and Romer (2004) approach so that monetary shocks are not only orthogonal to the central bank's

[4] Because the policy rate is at its effective lower bound during a significant part of our sample and monetary policy has taken many different dimensions over the last years, we use a shadow rate to capture all dimensions of monetary policy into a single variable of the monetary stance.

information set but also to private agents' information set. Second, we estimate the effects of monetary shocks on private inflation expectations conditional on BoE projection surprises in a framework derived from the information frictions literature and controlling for news shocks.[5]

We find that private inflation expectations on average respond negatively to contractionary monetary shocks, as would be expected given the transmission mechanism of monetary policy. Our main result however is that BoE inflation projections do modify the effect of monetary shocks on inflation expectations. First, contractionary monetary shocks have more negative effects in months when the central bank publishes its macroeconomic projections, especially since the conventional policy instrument has approached the Zero Lower Bound (ZLB) and the central bank has turned to unconventional instruments. In quantitative terms, a 100 basis points exogenous increase in the policy rate would reduce on impact 1-year inflation expectations by 0.08 basis points when no projections are published and by 0.11 basis points when central bank projections are published. Second, during months when the central bank publishes its macroeconomic projections, a positive shock to the shadow policy rate – i.e. a contractionary monetary shock – has a more negative effect on inflation expectations when interacted with a positive surprise to the Bank's inflation projections (a 100 basis point increase in the policy rate reduces 1-year inflation expectations by 18 basis points on impact in this case). In contrast, when a contractionary monetary shock is interacted with a negative surprise to the Bank's inflation projections, there is no effect on private inflation expectations.

This finding suggests that when monetary shocks and projection surprises corroborate each other, monetary shocks have more impact on private inflation expectations, possibly because private agents are able to infer the true policy innovation and to uncover the stance of monetary policy. When monetary shocks and projection surprises contradict each other, monetary shocks have no (or less) impact, possibly because private agents receive opposite signals and are not able to infer the true policy innovation. So they respond to the macroeconomic information disclosed, as described by the "signalling channel of monetary policy". Finally, the same is not true of output projection surprises, although that might be consistent with the remit of an inflation targeting central bank, such as the Bank of England.

These findings show that the publication of central bank inflation projections provides information that private agents view as useful, helps private agents' information processing and signal extraction and therefore changes their response to policy decisions. They give policymakers insights on how private agents interpret and use central bank macroeconomic information. The coordination of policy decisions and macroeconomic projections appears important for the management of private inflation expectations and for the transmission and effectiveness of monetary policy.[6]

---

[5] The use of market-based inflation expectation measured by inflation swaps as our dependent variables calls for correcting for term, liquidity and inflation risk premia. We use the regression based approach following the methodology used by Gürkaynak et al. (2010a, 2010b) and Soderlind (2011).

[6] This paper refers to a large literature focusing on the expectation formation process departing from the full-information rational expectations accounting for the persistence of private expectations (sticky and noisy information models or adaptive learning models, and models with heterogeneity in beliefs or in loss functions) led by Evans and Honkapohja (2001), Bullard and Mitra (2002), Mankiw and Reis (2002), Sims

This paper suggests that providing guidance about future projections of inflation rather than future projections of interest rates – the Forward Guidance (FG) policy – may actually enhance the effectiveness of monetary policy by better allowing private agents to distinguish between the information set of the central bank and the appropriateness of its policy setting.[7] This paper also suggests that the release of macroeconomic projections may be able to reduce the contractionary effects of the zero-lower bound constraint. The latter has been modelled as news about a sequence of future contractionary shocks (Campbell et al., 2012, and Campbell et al., 2016) and the publication of negative inflation surprises during this period may have mitigated the negative effect of these monetary shocks on private inflation expectations.

The literature has focused extensively, both theoretically and empirically, on the classical transmission mechanism of monetary policy. In contrast, the signalling issue has received less attention, most of the analyses being theoretical in nature. Morris and Shin (2002) show that public signals – e.g. from a central bank – affect private agents' actions. Angeletos et al. (2006) study the signalling effects of policy in coordination games. Walsh (2007) studies optimal transparency when the central bank provides public information by setting its policy instrument. In Baeriswyl and Cornand (2010), the policy instrument discloses information about policymakers' assessment of shocks which are imperfectly observed by firms. Kohlhas (2014) shows how central bank information disclosure may increase the information content of public signals about the state of the economy. Tang (2015) show that policy actions can signal information about the macro outlook when policymakers are more informed than private agents. Hubert and Maule (2016) assess empirically the importance of such signalling channels in the UK while Melosi (2017) estimate a model in which the policy rate has signalling effects about the macro outlook as aggregate variables are not observed by firms.

The present paper therefore bridges the signalling literature with the literature about the non-linear effects of monetary policy shocks. Weise (1999), Garcia (2002), Lo and Piger (2005), Angrist et al. (2013), Santoro et al. (2014) and Tenreyro and Thwaites (2016) assess their state-dependence and Barnichon and Matthes (2015) also their size-dependence. This paper is then also linked to the finding documented by Romer and Romer (2000), Campbell et al. (2012) and Nakamura and Steinsson (2017) that contractionary United States' federal fund rate surprises can have, under certain conditions, positive effects on private inflation or output expectations.[8]

(2003), Orphanides and Williams (2005) and Branch (2004, 2007). Another strand of the literature tries to explain macroeconomic outcomes with expectations (see e.g. Nunes 2010 and Adam and Padula 2011), while another strand focuses on the characteristics, responsiveness to news, dispersion or anchoring of expectations (see e.g. Swanson 2006, Capistran and Timmermann 2009, Crowe 2010, Gürkaynak et al. 2010a, Beechey et al. 2011, Coibion and Gorodnichenko 2012, 2015, Hubert 2014, 2015, Ehrmann 2015, Siklos 2017).

[7] The problem with the FG policy is that it may be unclear whether the central bank makes a commitment about policy to stimulate the economy ("Odyssean FG" in the terms of Campbell et al., 2012) or simply represents its views about the future outlook of the economy ("Delphic FG"). Andrade et al. (2015) and Michelacci and Paciello (2017) find that FG may have adverse effects if signalling a weak future expected state of the economy.

[8] In parallel, there is an ample literature on the role of central bank communication in policymaking (see e.g. Woodford, 2005; Reis, 2013), its effects on inflation expectations (see e.g. Gürkaynak et al. 2005; Blinder et al., 2008; King, Lu and Pasten, 2008), or how it may help predicting future policy decisions (see e.g. Jansen and De Haan, 2009; Hayo and Neuenkirch, 2010; Sturm and De Haan, 2011).

The rest of the paper is organised as follows. Section 2 describes our framework, section 3 the data, section 4 the first stage regressions to identify causality, and section 5 the estimates. Section 6 concludes.

2. Framework

This section sets out our approach. First, we derive predictions about how private inflation expectations might react to monetary shocks under different assumptions about the central bank's and private agents' information sets. Second, we present the empirical specification which allows us to test these predictions.

2.1. Theoretical predictions

First, we derive predictions for the expected effects of monetary shocks on private inflation expectations based on a standard macroeconomic framework with perfect information, such as a New-Keynesian model. In such a framework where the central bank and private agents have similar information sets, contractionary monetary shocks have a negative effect on private expectations, through the usual transmission channels. Private agents are able to infer the monetary shock from the policy rule, and there is no room for a "signalling channel of monetary policy" and for central bank projections to modify the effect of monetary shocks.

Second, we derive predictions for the expected effects of monetary shocks in a framework with information frictions. That assumption is consistent with empirical evidence by Coibion and Gorodnichenko (2015) and Andrade and Le Bihan (2013).[9] In a framework with non-nested information sets, we assume the central bank sets its interest rate i_t as a function of its own inflation, $\pi_{t,h}^{CB}$, and output, $x_{t,h}^{CB}$, projections, and potentially other macro variables, ω_t:

$$i_t = f(\pi_{t,h}^{CB}, x_{t,h}^{CB}, \omega_t) + \varepsilon_t^i \qquad (1)$$

where ε_t^i is the monetary shock, capturing policymakers' deviations from their policy rule, and which is orthogonal to central bank inflation and output projections. The central bank's inflation and output projections depend on the central bank's information set, Ω_t, and are formed prior to policy decision meetings, so do not contain the effect of the policy decision (i.e. they are uncorrelated with the error term ε_t^i). They are defined by:

$$\begin{aligned} \pi_{t,h}^{CB} &= g(\Omega_t) + \varepsilon_t^{\pi_{CB}} \text{ with } \pi_{t,h}^{CB} \perp \varepsilon_t^i \mid \Omega_t \\ x_{t,h}^{CB} &= g'(\Omega_t) + \varepsilon_t^{x_{CB}} \text{ with } x_{t,h}^{CB} \perp \varepsilon_t^i \mid \Omega_t \end{aligned} \qquad (2)$$

It is a crucial assumption that central bank projections do not already contain the effect of the policy decision, so private agents can infer the monetary innovation (ε_t^i) from the central bank reaction function (equation 1). In that set-up, when the central bank does

[9] In addition, recent works on information frictions such as Woodford (2001), Mankiw and Reis (2002), and Sims (2003) highlight how departing from the full information assumption can account for empirical patterns of expectations and lead to policy recommendations different from those with full information.

not publish projections, if the observed policy rate differs from private agents' policy expectations, private agents face a signal processing issue as they cannot infer whether the central bank has changed its own view of future inflation and output, or whether there has been a monetary shock. So policy decisions may convey signals about both future macroeconomic developments and the policy stance to private agents (see e.g. Melosi, 2017), so the response of private expectations would be a mix of the responses to both signals. Alternatively, when the central bank publishes its macroeconomic projections, private agents are able to solve their signal extraction issue and infer the true monetary shock, so the central bank projections would modify the effect policy decisions have on private expectations compared to the previous case.

In the situation where the central bank publishes its macroeconomic projections and private agents are able to infer the monetary innovation, the sign of the projection surprises may also play a role in the response of private agents. When the central bank publishes a projection surprise that corroborates the monetary shock, these two pieces of information validate private agents' signal extraction. Alternatively, when the central bank projection surprise contradicts the monetary shock, then the signal extraction remains unclear, so the policy decision would have less impact on private expectations. Another way of looking at this issue is to consider that positive (negative) inflation projection surprises would probably raise (lower) private agents' expected policy rate. In this case, the contractionary effect of a positive monetary shock would be magnified (mitigated) by the increase (decrease) in private policy rate expectations.

The rest of the paper aims to investigate which predictions the data appear to support by testing whether the publication of central bank projections and the sign of projection surprises modify the effects of monetary shocks, so whether central bank projections are used by private agents to infer the part of the interest rate change that is due to policy only.

We make use of three features of the UK data to test our research question. First, we exploit the fact that the Bank of England publishes macroeconomic projections that are conditioned on the path for the policy instrument implied by financial market interest rates prior to the policy meeting, rather than a preferred interest rate path of the Monetary Policy Committee (MPC).[10] As these projections are not conditioned on the BoE's policy decision, it enables us to separately identify projection surprises and monetary shocks. Second, policy decisions at the Bank of England have happened every month, whereas the Bank's projections are published quarterly.[11] That means that private agents do not observe up-to-date central bank projections for each policy decision, but only for one over three. Third, in order to nest our empirical analysis, we provide suggestive evidence of information rigidities for UK inflation expectations, as proposed in Coibion and Gorodnichenko (2015) who regress ex-post forecast errors $(\pi_{t+h} - \pi_{t,h}^{PF})$ on forecast revisions $(\pi_{t,h}^{PF} - \pi_{t-1,h}^{PF})$:

[10] For comparison, FOMC projections are conditioned on FOMC members' views of "appropriate monetary policy" which corresponds to the future interest rate path that best satisfies the Fed's dual objectives of maximum employment and price stability.
[11] Until September 2016, the Bank's Monetary Policy Committee held policy meetings every month, with 12 per year. After that point, the number of meetings has been lowered to 8 per year.

$$(\pi_{t+h} - \pi_{t,h}^{PF}) = \gamma_0 + \gamma_1(\pi_{t,h}^{PF} - \pi_{t-1,h}^{PF}) \quad (3)$$

Under the null hypothesis of existing information rigidities, we expect $\gamma_1 > 0$ and $\gamma_1 = 0$ under full information. For 1-year ahead inflation swaps, α_1 equals 0.84 and is significantly different from zero in months when the BoE does not publish its macroeconomic projections whereas it equals 0.72 and is not significant anymore in months when the BoE do publish them, suggesting that UK data are relevant for testing the predictions for the expected effects of monetary shocks in a set-up with non-nested information sets.

2.2. Empirical strategy

Our empirical setup is motivated by two theoretical models with rational expectations and information frictions. In the sticky information model of Mankiw and Reis (2002) and Carroll (2003), private agents update their information set infrequently as they face costs of absorbing and processing information. However, if private agents update their information set, they gain perfect information. In the noisy information models of Woodford (2001) and Sims (2003), private agents continuously update their information set but observe only noisy signals about the true state of the economy. Their observed inertial reaction arises from the inability to pay attention to all the information available. Internalising their information processing capacity constraint, they remain inattentive to a part of the available information because incorporating all noisy signals is impossible (Moscarini, 2004).[12]

We can bridge the two different strands of the literature in a simple and general specification by modelling private forecasts as a linear combination of past forecasts $\pi_{t-1,h}^{PF}$ and a vector Λ_t, which captures new information between *t-1* and *t*.[13] To do that, we explicitly assume private agents have homogeneous inflation forecasts in the case of sticky information models, which allows us to match the point forecasts nature of the data used hereafter:[14]

$$\pi_{t,h}^{PF} = \beta_0 + \beta_L \, \pi_{t-1,h}^{PF} + \beta_\Lambda \, \Lambda_t + \varepsilon_t \quad (4)$$

The value of the β_L parameter, which we expect to be positive and significant, should shed light on whether the limited adjustment mechanism in which information is only partially absorbed over time is at work in the data.[15] The vector Λ_t would include any variable that is likely to affect inflation and therefore to be used by private forecasters to predict future inflation. We decompose this vector into three subgroups. The first one

[12] Another interpretation of this reduced-form equation is that private agents have an initial belief about future inflation (their past inflation expectations) at the beginning of each period, and during each period, they incorporate relevant - but potentially noisy - information about future inflation.

[13] This specification can be interpreted through the lens of either noisy information models or augmented sticky-information models where rational or professional forecasts are substituted with the vector Λ_t which captures information relevant to forecast inflation.

[14] We acknowledge that point forecasts may suffer an aggregation bias because agents may have heterogeneous beliefs due to differences in their own information sets, but we abstract from this issue in this paper.

[15] This specification allows us to be agnostic about whether information is imperfect or not, and about the nature of information frictions. We show in section 5.4 that including more lags does not alter our main results.

includes our variables of interest: the monetary shock and the Bank's inflation and output projection surprises. The second one, represented by the vector X_t, aims to capture news shocks and surprises to macro developments that are contemporaneous to central bank projections. It comprises a news variable capturing the set of macroeconomic data released between *t-1* and *t* based on the announcement literature (see Andersen et al., 2003), the three indices of Scotti (2016): the real activity index, capturing the state of economic conditions, the surprise index, summarizing economic data surprises, and the uncertainty index, measuring uncertainty related to the state of the economy, as well as two high-frequency financial indices: the UK move and the FTSE. The third group, represented by the vector Z_t, includes macroeconomic variables that are likely to affect inflation and so inflation expectations: Consumer Price Index (CPI) inflation, industrial production, oil prices, the sterling effective exchange rate, net lending, and housing prices. These two vectors X_t and Z_t aim to capture other shocks that could occur at the same time than the publication of central bank projections and that would bias the response of private inflation expectations. Thus, equation (4) can be written as:

$$\pi_{t,h}^{PF} = \beta_0 + \beta_2\, \varepsilon_t^{i} + \beta_3\, \varepsilon_t^{\pi_{CB}} + \beta_4\, \varepsilon_t^{x_{CB}} + \beta_L\, \pi_{t-1,h}^{PF} + \beta_X\, X_t + \beta_Z\, Z_t + \varepsilon_t \qquad (5)$$

where ε_t^{i}, $\varepsilon_t^{\pi_{CB}}$ and $\varepsilon_t^{x_{CB}}$ are the monetary shock and projection surprises (from equations 1 and 2) that we explicitly incorporate in private agents' forecasting function.[16] Equation (5) can then be augmented to include an interaction term of the monetary shock with either a dummy for the publication of central bank projections, or as represented by equation (6), the interaction of the monetary shock with inflation projection surprises:

$$\pi_{t,h}^{PF} = \beta_0 + \beta_1\, \varepsilon_t^{i} \cdot \varepsilon_t^{\pi_{CB}} + \beta_2\, \varepsilon_t^{i} + \beta_3\, \varepsilon_t^{\pi_{CB}} + \beta_4\, \varepsilon_t^{x_{CB}} + \beta_L\, \pi_{t-1,h}^{PF} + \beta_X\, X_t + \beta_Z\, Z_t + \varepsilon_t \qquad (6)$$

After having corrected our dependent variables for term, liquidity and inflation risk premia, and extracted exogenous shocks from our three variables of interest to circumvent a potential endogeneity issue, we estimate equation (6) with OLS.[17] We do so for different horizons of the term structure of inflation expectations.[18] Because our dependent variables are financial market variables that are likely to introduce heteroskedasticity and autocorrelation, we compute heteroskedasticity and autocorrelation robust Newey-West standard errors assuming that the autocorrelation

[16] The timing of policy decisions and Bank projection releases - detailed in the next section - which are made public in the early days of the given months should ensure that their information content is not already contained in private inflation expectations and that inflation expectation dynamics are not responsible for these shocks. We test the robustness of this assumption by considering only the last daily observation of each month for our left-hand side variable so as to remove any potential endogeneity issue.
[17] Our econometric specification resembles the smooth transition model of Teräsvirta (1994) but abstract from defining a specific transition function.
[18] Estimating the equation along the term structure allows us to assess whether shocks have different effects at different horizons. This could happen for a number of reasons. One might relate to lags in the transmission of policy. For example, the term structure could be thought of as being split into three groups: (i) the short term (i.e. 1 year ahead), which, given the transmission lags of monetary policy, should be unaffected by changes in Bank Rate, (ii) the medium term (i.e. 2-4 years ahead), when interest rates are generally thought to affect the economy, and (iii) the long term (i.e. ≥ 5 years ahead), when the impact of any monetary shocks should have died out.

dies out after three lags.[19] The sign of the β_1 parameter should shed light on the hypothesis that the effects of monetary shocks depend on central bank projection surprises.

3. Data

Our dependent variable, π^{PF}, is derived from inflation swaps. These instruments are financial market contracts to transfer inflation risk from one counterparty to another. We consider instantaneous forwards at different maturities that measure expected inflation at the date of the maturity of the contract. In the UK, they are linked to the Retail Price Index (RPI) measure of inflation, rather than CPI, which is the measure the Bank's inflation target is currently based on. In general, the advantage of financial market expectations over survey measures of expectations is that they are directly related to payoff decisions, so there is no strategic response bias or no difference between stated and actual beliefs. Although one disadvantage is that financial market variables do not provide a direct measure of inflation expectations as they are affected by term, liquidity and inflation risk premia.[20] We correct inflation compensation, the raw measure extracted from inflation swaps, for term, liquidity and inflation risk premia using the regression based approach following the methodology used by Gürkaynak et al. (2010a, 2010b) and Soderlind (2011).This procedure is detailed the section A of the Appendix.

Another advantage of market-based measures is that they are available for all horizons from 1 to 10 years ahead. We perform our empirical analysis at the monthly frequency and take the average of all the working day observations in each month.[21] For robustness purposes, we also consider the last observation of the month.[22] These are available since October 2004, which determines the starting date of our sample. For robustness purposes, we also use survey data from Citigroup/YouGov and the Survey of External Forecasters.

Because the policy rate is at its effective lower bound during a significant part of our sample and monetary policy has taken many different dimensions over the last years, we use a shadow rate measure, labeled i, that translates unconventional policies into a

[19] This correction also enables to circumvent the "generated regressor" bias that our explanatory variables of interest (monetary shocks and projection surprises) might introduce in the estimation of standard errors.
[20] Swaps tend to be a better market measure for deriving inflation expectations than index-linked gilts because they are generally less sensitive to term and liquidity premia.
[21] Given that we are interested in the interaction of monetary shocks and projection surprises, and that policy decisions and projections were released on different days in a given month (the Inflation Report started to be published at the same time as policy decisions in August 2015 following the Warsh's report "Transparency and the Bank of England's Monetary Policy Committee"), we cannot perform an event-study analysis at a daily frequency and need to work at the monthly frequency. Moreover, since we take advantage of the fact that policy decisions happen every month whereas projections are published quarterly, working at the monthly frequency does not weaken the estimation of the interaction of monetary shocks and projection surprises. Finally, because most of the macroeconomic variables are reported at a monthly frequency at best, we are interested in the lower-frequency effects of monetary shocks on inflation expectations, not their daily reactions.
[22] This frequency transformation is more extreme as it discards all inflation expectation data points before the last observation. However, by doing so, we make sure that all shocks or information happening during a month are available to private agents and potentially incorporated in the last observation of the month; and (ii) that there is no endogeneity issue between our left-hand side variable and its potential explanatory variables.

single variable expressed in interest rate space to measure the overall stance of monetary policy. We consider three different measures of the BoE shadow rate. We use as a baseline a BoE shadow rate measure that augments Bank Rate to include a BoE in-house estimate of the effect of QE.[23] In addition, we use for robustness purposes the shadow rate computed by Wu and Xia (2016) as well as the one estimated by Krippner (2013, 2014). Finally, we also use the BoE's policy interest rate, called Bank Rate, which is the intended policy target rate, and was referred previously to as the Minimum Lending Rate, Repo Rate, or Official Bank Rate.

We also focus on the Bank's inflation and output projections, π^{CB} and x^{CB} respectively. They are available from the quarterly Inflation Report (IR) for each quarter up to three years ahead. They are released in February, May, August and November. These forecasts are published with fan charts capturing the uncertainty and skewness of the forecasts.[24] Two sets of forecasts are published: one set is conditioned on a constant interest rate path which ex-post includes the effect of the Monetary Policy Committee's (MPC) most recent Bank Rate decision. The other set is conditioned on the path for Bank Rate implied by market interest rates just prior to the previous policy meeting. A crucial assumption to ensure identification is that forecasts do not already contain the effect of the policy decision (in other words, they are uncorrelated with the monetary policy innovation ε_t^i) as if the forecasts included the effect of the policy change, the regression results would be biased. We therefore use the latter set of forecasts.

For the identification of monetary shocks and projection surprises, we also use private output expectations obtained from Consensus Forecasts for horizons from 1 to 6 quarters ahead (monthly constant-interpolated from surveys in March, June, September and December) and from the Bank's Survey of External Forecasters for horizons from 2 to 3 years ahead (monthly constant-interpolated from surveys in February, May, August and November); and 3-month market interest rate expectations 1 to 3 years ahead. This market interest rate curve is the one used as conditioning path for BoE's macroeconomic projections.

The vector X_t includes a news variable π^s which represents inflation surprises: the information set of macroeconomic data released between *t-1* and *t* having an impact on the inflation outcome. Following the announcement and news literature (Andersen et al., 2003, and references within), this variable is defined as the difference between the actual value of CPI inflation in *t* and the private inflation forecast, measured by the Bloomberg Consensus, formed at date *t-1* for the quarter *t* ($\pi^s = \pi_t - E_{t-1}\pi_t$). This is equivalent to the private inflation forecast error and captures the news published between the two dates. Bloomberg provides the market average expected one month ahead CPI inflation outturn at a monthly frequency. We also capture the presence of news by using the three indices (real activity, surprise and uncertainty) estimated by

[23] The shadow rate is derived by computing a sequence of unanticipated monetary policy shocks to match the time series for the estimated effect of QE on GDP using estimates from Joyce, Tong and Woods (2011) – see also Section 8.4 of Burgess et al. (2013). The underlying assumption that underpins this approach is that QE is a close substitute as a monetary policy instrument to Bank Rate such that the zero lower bound was not an effective constraint on monetary policy over the period in question.

[24] Analyzing whether the uncertainty and skewness matter for the responses of inflation expectations is beyond the scope of this paper and left for future research. Moreover, our intuition is that it should not matter that much as the variance of these measures is extremely small.

Scotti (2016) for the UK, and two financial indices, the UK move and FTSE, that are supposed to react in real-time and promptly to information flows.

The vector Z_t comprises various macroeconomic controls that are likely to capture expected inflation dynamics: CPI inflation, industrial production, oil prices, net lending, the sterling ERI, and housing prices (all included as 12-month percentage changes). Our overall sample period is 2004m10-2015m03. Data sources and descriptive statistics are presented in Tables A1 and A2 in the Appendix.

4. Identification of Monetary Shocks and Projection Surprises

When estimating the effects of monetary policy and central bank inflation and output projections, we need to overcome one major econometric challenge. Our three variables of interest are likely to be endogenous to private inflation expectations. To correct for this, we perform a first-stage regression to isolate the unpredictable and exogenous innovations to i, π^{CB}, and x^{CB}, orthogonal to their systematic component. So the contribution of the endogenous factors that underlies the evolution of these three variables would be removed.[25]

Blanchard et al. (2013) and Miranda-Agrippino and Ricco (2017) have shown how information frictions modify the econometric identification problem. In order to cope with the presence of non-nested information sets, we augment Romer and Romer (2004)'s approach so that exogenous innovations are not only orthogonal to the central bank's information set but also to private agents' information set. We aim to remove the contribution of *lagged* macroeconomic variables and private forecasts (so that innovations can have contemporaneous effects on these) and the contribution of *contemporaneous* Bank variables (so as to remove the information set of policymakers).

4.1. Monetary shocks

Starting with the identification of monetary shocks from a shadow rate measure i_t and based on equation (1), we estimate the following equation:

$$\Delta i_t = \alpha_0 + \alpha_1\, i_{t-1} + \sum_{h=1}^{3} \alpha_{2,h}\, \pi_{t,h}^{CB} + \sum_{h=1}^{3} \alpha_{3,h}\, x_{t,h}^{CB} + \sum_{h=1}^{3} \alpha_{4,h}\, \Delta\pi_{t,h}^{CB} + \sum_{h=1}^{3} \alpha_{5,h}\, \Delta x_{t,h}^{CB} + \alpha_6\, \Psi_{t-1} + \alpha_7\, IR_t + \varepsilon_t^{i} \qquad (7)$$

We assume that changes in i_t are driven by the policymakers' response to the level and change in its own inflation ($\pi_{t,h}^{CB}$ and $\Delta\pi_{t,h}^{CB}$) and output ($x_{t,h}^{CB}$ and $\Delta x_{t,h}^{CB}$) projections at horizons h = 1, 2 and 3 years ahead, to a vector Ψ_{t-1} which includes lagged private inflation and output expectations and lagged macro variables (the vector Z_t comprising CPI, industrial production, oil prices, sterling effective exchange rate, net lending, and housing prices), and to a dummy IR_t that takes the value 1 in months when the BoE

[25] The main advantage of this approach over a VAR estimation is that the identification of innovations does not rely on short-run timing restrictions in a recursive set-up, while only one restriction is needed (and justifiable): projections are not a function of the policy rate and cannot react contemporaneously to it whereas the opposite is true. Moreover, estimating a VAR might also raise the issue of the number of degrees of freedom. Because there is no obvious instrument for these variables, an instrumental variable strategy does not appear relevant.

publishes its *Inflation Report* (IR). $f(\cdot)$ is the function capturing its systematic reaction and the error term ε_t^i reflects monetary shocks. More precisely, private inflation and output expectations are introduced in equation (7) through the first principal components (from a Principal Component Analysis, PCA) of six private inflation expectation series from 1 to 10 years ahead, and five private output expectation series from 1-quarter to 2 years ahead.[26]

The inclusion of both private and central bank forecasts in the regression model enables us to deal with three concerns. First, forecasts encompass rich information sets. Private agents and policymakers' information sets include a large number of variables. Bernanke et al. (2005) show that a data-rich environment approach modifies the identification of monetary shocks. Forecasts work as a FAVAR model as they summarise a large variety of macroeconomic variables as well as their expected evolutions. Second, forecasts are real-time data. Private agents and policymakers base their decisions on their information set in real-time, not on ex-post revised data. Orphanides (2001, 2003) show that Taylor (1993) rule-type reaction functions estimated on revised data produce different outcomes when using real-time data. Third, private agents and policymakers are mechanically incorporating information about the current state of the economy and anticipate future macroeconomic conditions in their forecasts and we need to correct for their forward-looking information set when estimating the exogenous part of their respective forecasts.

We assess the robustness of this method for estimating exogenous monetary shocks in various ways. First, we estimate monetary shocks with two alternative shadow rate measures: the ones estimated by Wu and Xia (2016) and Krippner (2013, 2014). Second, because private agents may expect the central bank to update its policy more frequently during IR months when it updates its published assessment of the current and future state of the economy, expectations of policy changes may be different in IR and non-IR months.[27] We therefore estimate equation (7) on IR months only but extract residuals for all months. We also proceed to two estimations for IR and non-IR months and extract series of residuals for each that we combine in a unique time series. Third, because the period during which the policy rate approaches the ZLB may affect macroeconomic dynamics, the transmission of macroeconomic shocks and the way private agents form their expectations, we estimate equation (7) on two subsamples pre and post ZLB. The former estimation features the Bank Rate while the latter features the shadow rate. Fourth, we estimate a forward-looking Taylor rule with one lag of interest rate smoothing and the 1 year, 2 years and 3 years ahead inflation and output projections. Fifth, we reproduce the monetary shock measure of Cloyne and Huertgen (2016).[28] Sixth,

---

[26] We use the first principal component of a given forecast variable at various horizons so as not to include all horizons into the estimated model and then avoid multicollinearity or losing too many degrees of freedom. The first principal component intends to capture the forward-looking information set of forecasters for all horizons together. The first principal component of private inflation expectations captures 76% of the variance of the underlying series, while the first principal component of private output forecasts captures 85% of variance. For robustness purposes, we provide estimates when not using the first principal components but all forecast series.

[27] While Bean and Jenkinson (2001) report that the BoE is more likely to change interest rates in Inflation Report months, our sample includes 7 interest rate changes in IR months and 8 changes in non-IR months.

[28] Cloyne and Huertgen (2016) regresses the change in Bank Rate on the level of past Bank Rate (together with the Bank's projections and macro variables; equation (2) in their paper), and then cumulates the series of residuals to obtain their monetary shock series. Their series stops in 2007 just before Bank Rate converged

we replace the first principal components of private inflation and output expectations in the vector Ψ_{t-1} by all individual series of private inflation and output expectations at different horizons.

The correlation of the baseline monetary shock series is 0.16 with the one using the shadow rate of Wu and Xia (2016), 0.22 with the one of Krippner (2013, 2014), 0.89 with the series obtained from the estimation on IR months only, 0.97 with the series from two estimations for IR and non-IR months, 0.45 with the series estimated from two subsamples pre and post ZLB, 0.81 with the series from a Taylor rule, 0.17 with the series from Cloyne and Huertgen (2016), and 0.80 with the series without the first principal components. We present in section 5.4 estimates of our coefficient of interest using these alternative monetary shock series.

4.2. Central bank projection surprises

Central bank inflation and output projection surprises should be seen as the unpredictable component of these projections, conditional on the information available to private agents at the date when the projections are published. We estimate these surprises by using the Bank's inflation and output projections conditioned on the path for Bank Rate implied by market interest rates prior to the policy meeting, so independent from the policy decision, using the following equation (for inflation projections, as an example):

$$\pi_{t,h}^{CB} = \phi_0 + \phi_1 i_{t-1} + \sum_{h=1}^{3} \phi_{2,h} \pi_{t-1,h}^{CB} + \sum_{h=1}^{3} \phi_{3,h} x_{t-1,h}^{CB} + \phi_4 mc_{t,h} + \phi_5 \Psi_{t-1} + \varepsilon_t^{\pi_{CB}} \quad (8)$$

where the level of lagged inflation ($\pi_{t-1,h}^{CB}$) and output ($x_{t-1,h}^{CB}$) projections at horizons h = 1, 2 and 3 years ahead is included, $mc_{t,h}$ is the market interest rate curve used as conditioning path for BoE's macroeconomic projections at horizons h = 1, 2 and 3 years ahead, the vector Ψ_{t-1} includes a lag of the first principal components of private inflation and output expectations and a lag of the vector Z of macro variables. Equation (8) is estimated on IR months only since no projections are published during non-IR months (during which, by construction, projection surprises are zero). Figure 1 plots the estimated monetary shocks and projection surprises, while Table A4 shows the estimated parameters of equations (7)-(8), and the properties and correlation of exogenous innovations.

Because the Bank's inflation and output projections are published quarterly, the estimation of equation (8) for these two variables is performed for the specific months when the Bank's projections are released but without affecting the lag structure (for instance, the surprise to February projections takes January values for the lagged macro variables). The estimated surprises therefore have non-zero values during the months when the Bank's projections are published and zeros otherwise, which is consistent with the fact that no re-assessment or releases of the Bank's projections happen during these months. A potential alternative would be to proceed to a constant-interpolation of the Bank projection surprises for the following two months during each quarter to fill these gaps as one could argue that the projections are still available during the following two

towards the effective lower bound. Using their methodology and the Bank of England's shadow rate, we compute an equivalent to their monetary shock series.

months. We choose to focus on the most conservative choice and keep all zeros for the months with no *Inflation Report*.

It is worth stressing that the timing of the variables in equations (7)-(8) is driven by the assumption that monetary shocks and projection surprises can affect macro and financial variables and private expectations contemporaneously (so these variables enter with a lag in equations 7-8). Monetary shocks being orthogonal to the policymakers' information set, central bank projections enter contemporaneously in equation (7), whereas the formation of projections preceding the policy decision, the shadow rate enters with a lag in equation (8).

Finally, if these estimated series of exogenous innovations are relevant, they should be unpredictable from movements in data. So we assess the predictability of the estimated innovation series with Granger-causality type tests and regress these series on a set of variables from a standard macro VAR including inflation, industrial production, oil prices, the sterling effective exchange rate and net lending growth. The bottom panel of Table A4 in the Appendix shows the F-stats of this test. The null hypothesis that these estimated series of exogenous innovations are unpredictable cannot be rejected and that they are relevant to be used in second stage estimations to assess their effects on private inflation expectations.

5. The Non-Linear Effects of Monetary Shocks

We now investigate whether private agents process monetary shocks differently when they receive central bank information. Given that facilitating private agents' information processing is one reason why central banks complement their actions with communication to the public (see Adam, 2009, or Baeriswyl and Cornand, 2010), we test that the effects of monetary shocks vary when central bank macroeconomic projections are published at the same time.

5.1. The effect of monetary shocks in IR and non-IR months

We first test the hypothesis that the *publication* of central bank projections, not their *content*, modifies private agents' interpretation of policy decisions, so the effects of monetary shocks. Indeed, the monetary shock series is reported at a monthly frequency, whereas surprises to the Bank's projections can happen only in months in which the quarterly IR is published. In the months in which projections are published, the impact of monetary shocks might be different because private agents are provided with more information.

Table 1 shows, for 1 to 10 years ahead inflation expectations, estimates of an alternative equation (6) in which monetary shocks are interacted with a dummy for the publication of Bank's projections, and the two BoE's inflation and output projection variables are replaced by this publication dummy. In months when no central bank information is published, contractionary monetary shocks have a significant negative effect on inflation expectations at the 1-year horizon only. More precisely, a 1 S.D. increase in the shadow rate would decrease inflation expectations by 0.08 percentage points. This negative response of private inflation expectations to contractionary monetary shocks is consistent with the usual transmission mechanism. Although the difference (the interaction term) is not significant at conventional levels, in months when the BoE publishes its IR and macroeconomic projections, contractionary monetary shocks have a more negative effect on inflation expectations at the 1-year horizon (-0.11 percentage points) and have a significant negative effect on inflation expectations from 2 years to 5 years ahead. In addition, we find that monetary shocks during non-IR months account for 8% of the variance of 1-year ahead inflation expectations whereas they account for 10% at the same horizon during IR months.[29] Finally, the magnitude of the effect of monetary shocks during IR months decreases with the horizon, consistent with waning effects of monetary policy on inflation. The transmission lags of monetary policy are often estimated to be around 12 to 24 months for inflation (see e.g. Bernanke and Blinder, 1992, or Bernanke and Mihov, 1998). Negative effects at longer horizons than the transmission lags could be interpreted as a signalling effect going through the expectations channel.

This finding suggests that the information conveyed when the BoE publishes its IR and macroeconomic projections modifies private agents' interpretation of the policy decision, and so the effects of monetary shocks. However, this result is not a sufficient condition to demonstrate that the publication of central bank macroeconomic information affects the transmission of monetary shocks. Indeed, the effect evidenced here might be due to the disclosure of information about policymakers' preferences or guidance about the future likely stance of policy rather than about policymakers' macroeconomic information set.

5.2. The interaction of monetary shocks and projection surprises

We second test the hypothesis that the central bank projections *per se* (their information *content*) modifies private agents' inference of the part of interest rate changes that is due to policy specifically (i.e. the ability of private agents to uncover the pure monetary innovation), so the effect of monetary shocks. We then assess whether monetary shocks are given a different interpretation by private agents depending on Bank's projection surprises. We might expect that, when there is a positive projection shock, the negative effect of a contractionary monetary shock is amplified, because both the policy decision and the macroeconomic surprise are consistent and the effect of the monetary innovation can be inferred in a Taylor-type rule setting, so can be the effect on future inflation. At the opposite, we might expect a contractionary monetary shock to have a more muted effect when accompanied by a negative inflation projection surprise, since the policy decision and the macroeconomic surprise are not consistent, so the monetary shock cannot be inferred and so is less effective.

Our baseline analysis is realised for BoE's inflation projections 1 year ahead. This horizon falls before interest rates are generally estimated to have their peak effect on inflation - around 18 months ahead - and therefore enables us to minimise the control issue,[30] but

[29] We compute this variance decomposition using partial R^2 that indicates the fraction of the improvement in R^2 that is contributed by the excluded covariate.

[30] The interest rate instrument gives the central bank some control over the forecasted variables, and this issue is circumvented when the horizon of forecasts is shorter than the transmission lag of monetary policy.

should also convey information about inflation at the 1 year horizon, the shortest horizon of the term structure of private inflation expectations studied here.

We are primarily interested in the sign of the parameter (β_1) associated with the interaction variable that enables rejecting or not our null hypothesis. Table 2 shows, for 1 to 10 years ahead inflation expectations, estimates of equation (6) in which monetary shocks are interacted with BoE's inflation projection surprises.[31] The main result is that the coefficient of the interaction variable is significant and negative for the 1 to 5 years horizon inflation expectations. This means that the negative effect of contractionary monetary shocks is amplified when policymakers' surprise private agents with higher inflation projections than expected whereas contractionary monetary shocks have no impact on inflation expectations when interacted with a negative surprise to the BoE's inflation projections. More precisely, a 1 S.D. increase in the shadow rate reduces inflation expectations by 0.18 percentage points at the 1-year horizon when accompanied by positive projection surprises, but does not impact inflation expectations when accompanied by negative projection surprises. The monetary shock alone (i.e. independently of BoE's inflation projection surprises) has a significant negative effect on inflation expectations at the 1 and 2 years horizons (-0.09 and -0.05 percentage points respectively). We find that monetary shocks alone account for 10% of the variance of 1-year ahead inflation expectations while monetary shocks interacted with projection surprises account for 13% at the same horizon.

This finding suggests that central bank projections give private agents the possibility to infer the pure monetary innovation and therefore determinate its effects on private inflation expectations. Thus, when contractionary monetary shocks are not corroborated by a positive surprise to the Bank's inflation projections, the inference of the pure monetary innovation is made more difficult so the negative effect of monetary shocks is smaller; while when contractionary monetary shocks are contradicted by a negative surprise to the Bank's inflation projections, the inference of the pure monetary innovation is problematic so the effect of monetary shocks vanishes. This result therefore suggests that providing guidance about future projections of inflation rather than future projections of interest rates – the Forward Guidance policy – may actually enhance the effectiveness of monetary policy by better allowing private agents to distinguish between the information set of the central bank and the appropriateness of its policy setting.

It is worth stressing that central bank projection surprises itself, in this set-up accounting for non-linearities, do not impact private inflation expectations, at least at conventional significance levels. The value added of central bank projections goes through their contribution to the inference of monetary shocks. This finding is consistent with Hubert and Maule (2016). They find in a linear set-up that central bank projections may convey policy signals as policy decisions may convey macro signals. An increase in central bank inflation projections could signal that an inflationary shock will hit the economy in the future, causing higher inflation; alternatively, a similar increase in central bank inflation projections may be interpreted as a signal about a future policy tightening, leading to lower expected inflation.

[31] The results show that β_L is positive and significant, consistent with inertia in inflation expectations, suggesting that the information frictions framework is likely to be appropriate for this analysis.

Table A5 in the Appendix shows estimates of specifications of equation (6) with 2-years ahead BoE's projections and BoE's output projections. The monetary shocks alone always have a negative effect on 1 and 2 years ahead inflation expectations. However, the interaction is never significant. First, it seems that private forecasters better understand the link between the policy instrument and inflation than with output, which is consistent with a central bank pursing an inflation targeting strategy, like the Bank of England. Second, it seems that only inflation projection surprises at the 1-year horizon matters. A potential reason for such an effect may be that the central bank tends to publish inflation projections that converge to its inflation target around the 2 years horizon (and even more so at the policy horizon, i.e. 3 years), so the information content of these is smaller.[32] Private agents would therefore use inflation projections at the 1-year to understand the policymakers' information set and uncover the pure monetary innovation.

The non-linearity evidenced above should not be confused with a non-linear effect of monetary policy with the business cycle. Evidence on this matter is mixed so far. On the one hand, Barnichon and Matthes (2016), for instance, find that monetary policy is more potent during recessions. So if one assumes that positive (resp. negative) inflation projection surprises are a proxy for a future positive (resp. negative) output gap, then the effect we find (a muted effect of monetary shocks when interacted with negative inflation projection surprises) is the opposite of theirs. On the other hand, Tenreyro and Thwaites (2016), for instance, find that monetary policy is less powerful during recessions. Under the same assumption about what projection surprises may capture, one may conclude that the more negative effect of monetary shocks with positive inflation projection surprises captures the more negative effect of monetary policy on inflation during expansions. However, the assumption underlying this argument is not consistent with the data: the correlation between inflation projection surprises and a contemporaneous (resp. 1-year forward) output gap measure (the Hodrick-Prescott trend/cycle decomposition of real GDP growth) is 0.04 (resp. -0.02) and non-significant. This suggests that the non-linear effect of monetary policy evidenced in this paper is specific to central bank projections.

Finally, Table 3 shows estimates pre and post ZLB of the non-linear effects of monetary shocks when interacted with inflation projection surprises. The interaction variable is negative on the post-ZLB subsample but less than in the pre-ZLB subsample. So the negative effect of monetary shocks when interacted with positive inflation surprises is weaker than in the pre-ZLB subsample. This difference suggests that the release of macroeconomic projections may have been able to reduce the contractionary effects of the zero-lower bound constraint. The latter has been modelled as news about a sequence of future contractionary shocks (Campbell et al., 2012, and Campbell et al., 2016) and the publication of inflation surprises during this period may have mitigated the negative effect of these monetary shocks on private inflation expectations.

[32] Table A2 in the Appendix shows the distribution of the absolute value of deviation of inflation projections to the inflation target. It shows that the mode is much smaller for the 2-year horizon than for the 1-year horizon.

5.3. Local projections

This section investigates the dynamic effects of monetary shocks and assesses how persistent is the contemporaneous effect evidenced in section 6.2. Our preferred approach is to use the local projections method of Jordà (2005). Impulse response functions obtained from VARs may be imposing excessive restrictions on the endogenous dynamics, while the local projection method is more flexible and may easily account for non-linearities in the transmission of monetary policy. Another advantage is the robustness of local projections to model misspecification to estimate dynamic responses to exogenous shocks.[33]

Jordà (2005) suggests estimating a set of k regressions representing the impulse response of the dependent variable at the horizon k to a given exogenous shock at time t. We therefore modify equation (6) in that respect:

$$\pi^{PF}_{t+k,h} = \beta_{0,k} + \beta_{1,k}\, \varepsilon^{i}_{t} \cdot \varepsilon^{\pi_{CB}}_{t} + \beta_{2,k}\, \varepsilon^{i}_{t} + \beta_{3,k}\, \varepsilon^{\pi_{CB}}_{t} + \beta_{4,k}\, \varepsilon^{x_{CB}}_{t} + \beta_{L,k}\, \pi^{PF}_{t-1,h} + \beta_{X,k}\, X_t + \beta_{Z,k}\, Z_t + \varepsilon_{t+k} \quad (9)$$

where $\pi^{PF}_{t+k,h}$ is our dependent variable, private inflation expectations h-year ahead, at the horizon k, ε^{i}_{t} is the monetary shock, $\varepsilon^{\pi_{CB}}_{t}$ is the BoE's inflation projection surprise, and $\varepsilon^{i}_{t} \cdot \varepsilon^{\pi_{CB}}_{t}$ is the interaction of both. X_t and Z_t are vectors of news and macroeconomic controls respectively. Equation (9) is estimated with OLS until k = 6.

Figure 2 plots the results from estimating the dynamic effects, over 6 months, of monetary shocks when interacted with positive and negative inflation projection surprises on private inflation expectations from 1 to 10 years ahead. Each panel plots the $\beta_{1,k}$ coefficient for each of the 6 horizons. Monetary shocks have statistically different effects on inflation expectations depending on whether they corroborated or contradicted by inflation projection surprises at least during 2 months after the policy decision. This is true for inflation expectations 1 to 5 years ahead.

It is interesting to note that the response of inflation expectations, from 1 to 5 years ahead, to a contractionary monetary shock interacted with a negative inflation projection surprise is not only different from the response with a positive inflation projection surprise, but is also positive and significantly different from zero after 2 months. This finding is consistent with one of the results of Melosi (2017) which finds that inflation expectations may respond positively to contractionary monetary shocks under certain calibrated parameters. When the quality of private information is poor relative to that of central bank information (private agents' signal-to-noise ratio is low), and/or if the policy rate is more informative about non-monetary shocks than about monetary shocks (the variance of monetary shocks is low or the central bank's estimates of inflation and the output gap are relatively accurate), then the macro outlook signalling channel may be at work. Similarly, Tang (2015) finds a positive effect when prior uncertainty about inflation is high.

[33] Another alternative is to estimate the effect of monetary shocks in a simple autoregressive distributed lag (ADL) model. One potential drawback of this approach for our specification is the differencing of the dependent variable over the long run.

It is also worth stressing that the non-linear effect is not reversed afterwards: responses to monetary shocks are not statistically different 3 or 4 months after the policy decisions, so the difference in the cumulated effects of the initial impact and of the first two months is not offset. These dynamic estimates show that the differentiated effects of monetary shocks when interacted with projection surprises are persistent and tend to suggest that the disclosure of central bank macroeconomic information and helping private agents to infer monetary innovations has tangible effects.

5.4. Sensitivity analysis

We run several tests to ensure the robustness of the baseline non-linear results. They are decomposed into tests about the identification of monetary shocks and projection surprises, the left-hand side variable, additional right-hand side variables and subsample estimates.

The robustness tests about the identification of monetary shocks are presented in the subsection 4.1. Monetary shocks are estimated with two alternative shadow rate measures. Parameters of equation (7) are estimated on IR months only but residuals extracted for all months, or using two distinct estimations for IR and non-IR months. Equation (7) is estimated on two subsamples pre and post ZLB. A forward-looking Taylor rule is estimated and the monetary shock measure of Cloyne and Huertgen (2016) is reproduced. The first principal components of private inflation and output expectations in the vector Ψ_{t-1} in equation (7) is replaced by all individual series of private inflation and output expectations at all different horizons. The differentiated effects of large and small monetary shocks are estimated. Tables A6 and A7 in the Appendix show that the marginal effect of inflation projection surprises on the impact of monetary shocks is always negative.

Turning to private inflation expectation measures, we first consider a more extreme information assumption, replacing the monthly average of all observations of market-based (daily) inflation expectations by the last observation of the month. While we discard all inflation expectation data points before the last observation by doing so, we ensure that: (i) all shocks or information happening during a month are available to private agents and potentially incorporated in the last observation of the month; and (ii) that there is no endogeneity issue between our left-hand side variable and its potential explanatory variables. Second, we replace the swap-based inflation expectation measures by the break-even inflation rates obtained from the difference between inflation-indexed and nominal gilts. Because of liquidity issues on short maturities, inflation-indexed bonds are only considered from the 4-years horizon. Third, we replace the level of inflation expectations by their first difference. Fourth, we replace the level of private expectations by their deviation from the Bank's inflation target (corrected for the sample mean of the wedge between RPI and CPI).[34]

Fifth, we correct inflation compensation measures for term, liquidity, inflation risk premia by estimating equation (A2) in the Appendix on the full sample, therefore

[34] The wedge is computed as the difference between RPI and CPI inflation corrected for the contribution of a dummy capturing the uncertainty created by the announcement by the Office for National Statistics' Consumer Prices Advisory Committee (CPAC) of a potential revision in the RPI calculation methodology, between May 2012 and January 2013.

assuming a constant pricing of these premia. By doing so, we assess the impact of the assumption that the ZLB may affect the transmission of shocks and macro and financial dynamics, so that the pricing relationship of premia may change pre and post ZLB. Sixth, because the proxies we use to correct inflation compensation for the different premia might be correlated with the business cycle, we turn to an alternative methodology using survey expectation measures that do not contain these various premia. We regress market-based expectations on survey expectations and consider the predicted value as our left-hand side variables. Seventh, because the central bank may intend to affect the inflation risk premium as well as inflation expectations, we also compute adjusted series for term and liquidity premia only. Eighth, we use raw inflation compensation rather than our derived inflation expectation measure, so as to assess the impact of the correction for term, liquidity, and inflation risk premia. Tables A8 and A9 in the Appendix show that the non-linear effect of monetary shocks when interacted with inflation projection surprises does not depend on the variables or corrections used to measure private inflation expectations.[35]

We then assess the impact of estimating the non-linear effects on two different subsamples ending in March 2009, when Bank Rate reached its lower bound, and in July 2013, when the forward guidance policy was introduced. We therefore check that our results are robust to sub-samples when Bank Rate was considered the main policy instrument and when the central bank did not disclose information about the future likely path of policy. We also use a constant-interpolated measure of the projection surprises, so during the two months after the publication of the Inflation Report, they take the value of the surprise happening in the first month instead of zeros. In addition, we use a constant-interpolated measure of the projections, so during the two months after the publication of the Inflation Report, they take the value of the projections published and we estimate equation (8) on all dates. We finally assess whether the non-linear result holds when considering raw inflation projections rather than inflation projection surprises, so the main result is not driven by our identification of these surprises. Table A10 in the Appendix confirms the negative coefficient of the interaction term between monetary shocks and inflation projection surprises.[36]

In addition, we assess the robustness of the non-linear effect to additional right-hand side variables. First, we estimate equation (6) without the vectors X_t and Z_t to examine potential over-identification issues and further check the orthogonality condition of our estimated shocks and surprises. Second, we estimate equation (6) without output projection surprises, so as to control that the non-linear effects do not depend on their inclusion together with inflation projection surprises.[37] We augment the vector of macro controls with a Value Added Tax (VAT) dummy which takes the value of one in

[35] We also performed quantile regressions to assess whether estimates approximating the conditional mean of the dependent variable were similar across its entire distribution. Estimates of the conditional median or of other quantiles are similar to the OLS estimates. These outcomes are available from the authors upon request.

[36] It is interesting to note that the effect of inflation projection surprises on monetary shocks is sometimes reversed and positive on very long-term inflation expectations (at the 10-years horizon) suggesting that a different interpretation is given to the same policy decision depending on the horizon. However, the lack of range of this effect does not enable drawing sound conclusions about it.

[37] As the BoE is an inflation targeting central bank, one could argue that only inflation projections should matter.

December 2008, January 2010 and January 2011 when the UK government raised the VAT causing inflation to rise. Then we test a specification in which we introduce a dummy for the dates of the announcements of explicit forward guidance on future policy rates in August 2013 and February 2014.[38] Table A11 in the Appendix shows that the non-linear effect evidenced does not stem from an omitted variable bias and inflation projection surprises capturing the presence of news.

Finally, because news shock at time t may raise private inflation expectations as well as central bank inflation projections, the estimation requires controlling for as many news shocks as possible. In our benchmark analysis, we control for a news variable *à la* Andersen et al. (2003), the real activity, surprise and uncertainty indices of Scotti (2016) and two high-frequency financial indices: the UK move and the FTSE. To further control that central bank projections do not capture the presence of potential news shocks, we augment the X_t with the three European Commission (EC)'s UK sentiment measures for the industry, services and consumers. We also include the change between $t-1$ and t in private output and interest rate forecasts, to control for their link with private inflation forecasts as evidenced by Fendel et al. (2011), Dräger et al. (2016) and Paloviita and Viren (2013).[39] That allows us to control for the changes in private inflation expectations which are related to changes in private beliefs about other macro variables. We also test a specification in which we include various other macroeconomic, financial and expectation variables to further control that our result is not driven by some omitted variable bias. We add to equation (6) the growth rate of retail prices, input producer prices, output producer prices, wages, import prices, the level of unemployment, capacity constraints, capacity utilisation, the cycle component of an HP filter of real GDP, the change in the VIX and the Saint-Louis Financial Stress Index, and private output expectations at the 2 and 3-years horizon. Finally, we include five more lags of the dependent variable (so up to 6 lags) in equation (6). Table A12 in the Appendix shows that the non-linear effect evidenced does not stem from the omission of variables enabling private agents to forecast future inflation.

6. Conclusion

This paper investigates the extent to which the effects of monetary shocks on inflation expectations depend on the macroeconomic information released by the central bank. We assess the non-linear effects of monetary shocks conditional on the Bank of England's macroeconomic projections on UK private inflation expectations. After having corrected our dependent variables, UK market-based inflation expectation measures, for term, liquidity and inflation risk premia, and extracted exogenous innovations following Romer and Romer (2004)'s identification approach, we estimate the interacted effects of these innovations in an empirical framework derived from the information frictions literature. We find that private inflation expectations respond negatively to contractionary monetary shocks, as would be expected given the transmission

[38] The Monetary Policy Committee has provided guidance on the setting of future monetary policy since 7 August 2013 (http://www.bankofengland.co.uk/monetarypolicy/Pages/forwardguidance.aspx). Because this policy is supposed to affect the private agents' expected future policy path via a commitment device, it may affect private inflation expectations, and we need to control for this potential effect at the end of our sample.

[39] We use Consensus Forecasts and the market curve used by the BoE as conditioning path for its projections for private output and interest rate expectations.

mechanism of monetary policy. However, we also find that inflation projections modify the impact of monetary shocks. When contractionary monetary shocks are corroborated by positive projections, the negative effect of policy on inflation expectations is amplified. Whereas when contractionary monetary shocks are contradicted by negative projections, the negative effect of policy on inflation expectations is reduced. This suggests that providing guidance about central bank future expected inflation helps private agents' information processing, and therefore changes their response to policy decisions. The coordination of policy decisions and macroeconomic projections appears important for the management of private inflation expectations.

References

Adam, Klaus (2009). "Monetary policy and aggregate volatility", *Journal of Monetary Economics,* 56, S1–S18.

Adam, Klaus, and Mario Padula (2011). "Inflation Dynamics and Subjective Expectations in the United States", *Economic Inquiry*, 49(1), 13–25.

Andersen, Torben, Tim Bollerslev, Francis Diebold, and Clara Vega (2003). "Micro Effects of Macro Announcements: Real-Time Price Discovery in Foreign Exchange." *American Economic Review*, 93(1), 38-62.

Andrade, Philippe, Gaballo Gaetano, Eric Mengus and Benoit Mojon (2015). "Forward Guidance and Heterogeneous Beliefs", Banque de France Working Paper, No. 573.

Andrade, Philippe, and Hervé Le Bihan (2013). "Inattentive professional forecasters", *Journal of Monetary Economics*, 60(8), 967-982.

Angeletos, George-Marios, Christian Hellwig, and Alessandro Pavan (2006). "Signaling in a Global Game: Coordination and Policy Traps", *Journal of Political Economy*, 114, 452–484.

Angrist, Joshua, Òscar Jordà and Guido Kuersteiner (2013). "Semiparametric estimates of monetary policy effects: string theory revisited", *NBER Working Paper*, No. 19355.

Baeriswyl, Romain, and Camille Cornand (2010). "The signaling role of policy actions", *Journal of Monetary Economics*, 57(6), 682–695.

Barnichon, Regis, and Christian Matthes (2015). "Measuring the Non-Linear Effects of Monetary Policy", *mimeo*, Federal Reserve Bank of Richmond.

Bean, Charles, and Nigel Jenkinson (2001). "The formulation of monetary policy at the Bank of England", *Bank of England Quarterly Bulletin*, Winter.

Beechey, Meredith, Benjamin Johannsen, and Andrew Levin (2011). "Are long-run inflation expectations anchored more firmly in the Euro area than in the United States?", *American Economic Journal: Macroeconomics*, 3(2), 104-129.

Bernanke, Ben, and Alan Blinder (1992). "The Federal Funds Rate and the channels of monetary transmission", *American Economic Review,* 82(4), 901–921.

Bernanke, Ben, and Ilian Mihov (1998). "Measuring monetary policy", *Quarterly Journal of Economics,* 113(3), 869–902.

Bernanke, Ben, Jean Boivin, and Piotr Eliasz (2005). "Measuring the Effects of Monetary Policy: A Factor-augmented Vector Autoregressive (FAVAR) Approach", *Quarterly Journal of Economics*, 120(1), 387–422.

Blanchard, Olivier, Jean-Paul L'Huillier, and Guido Lorenzoni (2013). "News, Noise, and Fluctuations: An Empirical Exploration," *American Economic Review*, 103(7), 3045–70.

Blinder, Alan, Michael Ehrmann, Marcel Fratzscher, Jakob De Haan, and David-Jan Jansen (2008). "Central Bank Communication and Monetary Policy: A Survey of Theory and Evidence", *Journal of Economic Literature*, 46(4), 910-45.

Branch, William (2004). "The Theory of Rationally Heterogeneous Expectations: Evidence from Survey Data on Inflation Expectations", *Economic Journal,* 114, 592–621.

Branch, William (2007). "Sticky Information and Model Uncertainty in Survey Data on Inflation Expectations", *Journal of Economic Dynamics and Control*, 31, 245–76.

Bullard, James, and Kaushik Mitra (2002). "Learning about monetary policy rules" *Journal of Monetary Economics* 49, 1105-1129.

Burgess, Stephen, Emilio Fernandez-Corugedo, Charlotta Groth, Richard Harrison, Francesca Monti, Konstantinos Theodoridis and Matt Waldron (2013). "The Bank of England's forecasting platform: COMPASS, MAPS, EASE and the suite of models", *Bank of England Working Paper*, No. 471.

Campbell, Jeffrey, Charles Evans, Jonas Fisher and Alejandro Justiniano (2012). "Macroeconomic Effects of Federal Reserve Forward Guidance", *Brookings Papers on Economic Activity,* Spring 2012, 1-80.

Campbell, Jeffrey, Jonas Fisher, Alejandro Justiniano and Leonardo Melosi (2016). "Forward Guidance and Macroeconomic Outcomes Since the Financial Crisis", In *NBER Macroeconomics Annual 2016*, Volume 31. University of Chicago Press.

Capistran, Carlos and Allan Timmermann (2009). "Disagreement and Biases in Inflation Expectations," *Journal of Money, Credit and Banking*, 41, 365–396.

Carroll, Christopher (2003). "Macroeconomic expectations of households and professional forecasters", *Quarterly Journal of Economics*, 118, 269-298.

Castelnuovo, Efrem, and Paolo Surico (2010). "Monetary Policy, Inflation Expectations and the Price Puzzle", *Economic Journal*, 120(549), 1262-1283.

Cloyne, James, and Patrick Huertgen (2016). "The macroeconomic effects of monetary policy: a new measure for the United Kingdom", *American Economic Journal: Macroeconomics,* 8(4), 75-102.

Coibion, Olivier, and Yuriy Gorodnichenko (2012). "What Can Survey Forecasts Tell Us about Informational Rigidities?" *Journal of Political Economy*, 120(1), 116–59.

Coibion, Olivier, and Yuriy Gorodnichenko (2015). "Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts", *American Economic Review*, 105(8), 2644-2678.

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

Dräger, Lena, Michael Lamla and Damjan Pfajfar (2016). "Are Survey Expectations Theory-Consistent? The Role of Central Bank Communication and News", *European Economic Review*, 85, 84-111.

Ehrmann , Michael (2015). "Targeting Inflation from Below - How Do Inflation Expectations Behave?", *International Journal of Central Banking*, 11(S1), 213-249.

Ehrmann, Michael and Marcel Fratzscher (2007). "Communication by central bank committee members: Different strategies, same effectiveness", *Journal of Money, Credit, and Banking*, 39(2–3), 509–541.

Evans, George, and Seppo Honkapohja (2001). Learning and Expectations in Macroeconomics. Princeton University Press.

Fendel, Ralf, Eliza Lis, and Jan-Christoph Rülke (2011). "Do professional forecasters believe in the Phillips curve? Evidence from G7 countries", *Journal of Forecasting*, 30(2), 268-87.

Garcia, René (2002). "Are the Effects of Monetary Policy Asymmetric?", *Economic Inquiry*, 40(1), 102-119.

Gertler, Mark and Peter Karadi (2015). "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 7(1), 44-76.

Gürkaynak, Refet, Brian Sack, and Eric Swanson (2005). "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements", *International Journal of Central Banking*, 1(1), 55–93.

Gürkaynak, Refet, Andrew Levin, and Eric Swanson (2010a). "Does Inflation Targeting Anchor Long-Run Inflation Expectations? Evidence from Long-Term Bond Yields in the US, UK, and Sweden", *Journal of the European Economic Association*, 8(6), 1208-42.

Gürkaynak, Refet, Brian Sack and John Wright (2010b). "The TIPS yield curve and inflation compensation", *American Economic Journal: Macroeconomics*, 2(1), 70–92.

Hayo, Bernd, and Matthias Neuenkirch (2010). "Do Federal Reserve communications help predict federal funds target rate decisions?", *Journal of Macroeconomics*, 32(4), 1014-1024.

Hubert, Paul (2014). "FOMC Forecasts as a Focal Point for Private Expectations", *Journal of Money, Credit and Banking*, 46(7), 1381-1420.

Hubert, Paul (2015). "Do Central Bank Forecasts Influence Private Agents? Forecasting Performance vs. Signals", *Journal of Money, Credit and Banking*, 47(4), 771-789.

Hubert, Paul (2017). "Qualitative and Quantitative Central Bank Communication and Inflation Expectations", *B.E. Journal of Macroeconomics*, 7(1), 1-41.

Hubert, Paul and Becky Maule (2016). "Policy and macro signals as inputs to inflation expectation formation", *Bank of England Working Paper*, No. 581.

Jansen, David-Jan, and Jakob De Haan (2009). "Does ECB communication help in predicting its interest rate decisions?", *Applied Economics*, 41(16), 1995-2003.

Jordà, Oscar (2005). "Estimation and Inference of Impulse Responses by Local Projections", *American Economic Review*, 95(1), 161–182.

Joyce, Michael, Matthew Tong and Robert Woods (2011). "The United Kingdom's quantitative easing policy: design, operation and impact", *Bank of England Quarterly Bulletin*, 51, 200–212.

King, Robert, Yang Lu, and Ernesto Pasten (2008). "Managing Expectations", *Journal of Money, Credit and Banking*, 40(8), 1625-1666.

Kohlhas, Alexandre (2014). "Learning-by-sharing: Monetary policy and the information content of public signals", manuscript.

Krippner, Leo (2013). "Measuring the stance of monetary policy in zero lower bound environments", Economics Letters, 118(1), 135-138.

Krippner, Leo (2014). "Measuring the Stance of Monetary Policy in Conventional and Unconventional Environments", Centre for Applied Macroeconomic Analysis Working Paper, No. 6/2014.

Lo, Ming, and Jeremy Piger (2005). "Is the Response of Output to Monetary Policy Asymmetric? Evidence from a Regime-Switching Coefficients Model", *Journal of Money, Credit and Banking*, 37(5), 865-86.

Mankiw, Gregory, and Ricardo Reis (2002). "Sticky information versus sticky prices: A proposal to replace the new Keynesian Phillips curve", *Quarterly Journal of Economics*, 117(4), 1295-1328.

Melosi, Leonardo (2017). "Signaling effects of monetary policy", *Review of Economic Studies*, 84(2), 853-884.

Michelacci, Claudio, and Luigi Paciello (2017). "Ambiguous Policy Announcements", *mimeo*.
Miranda-Agrippino, Silvia (2016). "Unsurprising Shocks: Information, Premia, and the Monetary Transmission", Bank of England Staff Working Paper No. 626.
Miranda-Agrippino, Silvia, and Giovanni Ricco (2017). "The Transmission of Monetary Policy Shocks", Bank of England Staff Working Paper No. 657.
Morris, Stephen, and Hyun Shin (2002). "Social Value of Public Information", *American Economic Review*, 92(5), 1521–1534.
Moscarini, Giuseppe (2004). "Limited Information Capacity as a Source of Inertia", *Journal of Economic Dynamics and Control*, 28(10), 2003–2035.
Nakamura, Emi, and Jón Steinsson (2017). "High Frequency Identification of Monetary Non-Neutrality: The Information Effect", *Quarterly Journal of Economics*, forthcoming.
Nunes, Ricardo (2010). "Inflation Dynamics: The Role of Expectations", *Journal of Money, Credit and Banking*, 42(6), 1161–1172.
Orphanides, Athanasios (2001). "Monetary Policy Rules Based on Real-Time Data", *American Economic Review*, 91, 964–985.
Orphanides, Athanasios (2003). 'Historical monetary policy analysis and the Taylor rule', *Journal of Monetary Economics*, 50, 983–1022.
Orphanides, Athanasios, and John Williams (2005). "The decline of activist stabilization policy: Natural rate misperceptions, learning, and expectations", *Journal of Economic Dynamics and Control*, 29(11), 1927-1950.
Paloviita, Maritta, and Matti Viren (2013). "Are individual survey expectations internally consistent?", *National Bank of Poland Working Paper*, No. 140.
Reis, Ricardo (2013). "Central Bank Design", *Journal of Economic Perspectives*, 27(4), 17-44.
Rosa, Carlo, and Giovanni Verga (2007). "On the consistency and effectiveness of central bank communication: Evidence from the ECB", *European Journal of Political Economy*, 23(1), 146-175.
Romer, Christina, and David Romer (2000). "Federal Reserve Information and the Behavior of Interest Rates", *American Economic Review*, 90, 429-457.
Romer, Christina, and David Romer (2004). "A New Measure of Monetary Shocks: Derivation and Implications", *American Economic Review*, 94, 1055–1084.
Santoro, Emiliano, Ivan Petrella, Damjan Pfajfar and Edoardo Gaffeo (2014). "Loss aversion and the asymmetric transmission of monetary policy", *Journal of Monetary Economics*, 68, 19-36.
Scotti, Chiara (2016). "Surprise and Uncertainty Indexes: Real-Time Aggregation of Real-Activity Macro Surprises", *Journal of Monetary Economics*, 82, 1-19.
Siklos, Pierre (2017). "What has publishing inflation forecasts accomplished? Central banks and their competitors", *CAMA Working Paper*, No. 33.
Sims, Christopher (1972). "Money, Income, and Causality," *American Economic Review*, 62(4), 540–552.
Sims, Christopher (1992). "Interpreting the macroeconomic time series facts: the effects of monetary policy", *European Economic Review*, 36(5), 975-1000.
Sims, Christopher (2003). "Implications of Rational Inattention", *Journal of Monetary Economics*, 50, 665–690.
Soderlind, Paul (2011). "Inflation Risk Premia and Survey Evidence on Macroeconomic Uncertainty", *International Journal of Central Banking*, 7(2), 113-133.

Sturm, Jan-Egbert, and Jakob De Haan (2011). "Does central bank communication really lead to better forecasts of policy decisions? New evidence based on a Taylor rule model for the ECB", *Review of World Economics*, 147(1), 41-58.

Swanson, Eric (2006). "Have increases in Federal Reserve transparency improved private sector interest rate forecasts." *Journal of Money, Credit and Banking*, 38, 792-819.

Tang, Jenny (2015). "Uncertainty and the signaling channel of monetary policy", *FRB Boston Working Paper*, No. 15-8.

Taylor, John (1993). "Discretion versus policy rules in practice". *Carnegie-Rochester Conference Series on Public Policy*, 39, 195-214. North-Holland.

Teräsvirta, Timo (1994). "Specification, estimation, and evaluation of smooth transition autoregressive models", *Journal of the American Statistical Association*, 89(425), 208–218.

Tenreyro, Silvana and Gregory Thwaites (2016). "Pushing on a string: US monetary policy is less powerful in recessions", *American Economic Journal: Macroeconomics*, 8(4), 43-74.

Walsh, Carl (2007). "Optimal economic transparency", *International Journal of Central Banking*, 3(1), 5-36.

Weise, Charles (1999). "The Asymmetric Effects of Monetary Policy: A Nonlinear Vector Autoregression Approach", *Journal of Money, Credit and Banking*, 31(1), 85-108.

Woodford, Michael (2001). "Imperfect Common Knowledge and the Effects of Monetary Policy," *NBER Working Paper*, No. 8673.

Woodford, Michael (2005). "Central-bank communication and policy effectiveness", In: The Greenspan era: Lessons for the future, 399–474. Kansas City: Federal Reserve Bank of Kansas City.

Wu, Cynthia and Fan Xia (2016). "Measuring the macroeconomic impact of monetary policy at the Zero lower bound", *Journal of Money Credit and Banking*, 48(2-3), 253-291.

Table 1 - The effect of monetary shocks in IR and non-IR months

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
BoE_ShadowRate * Dummy for the publication of BoE's projections						
BoE_ShadowRate * Dummy IR	-0.025	-0.045	-0.045	-0.037	-0.024	0.050
	[0.07]	[0.06]	[0.05]	[0.04]	[0.03]	[0.05]
BoE_ShadowRate	-0.084**	-0.046	-0.025	-0.016	-0.014	-0.032
	[0.04]	[0.03]	[0.03]	[0.02]	[0.02]	[0.02]
Dummy IR	0.023	-0.018	-0.027	-0.022	-0.013	0.004
	[0.04]	[0.03]	[0.02]	[0.02]	[0.02]	[0.02]
Lag dep var	0.644***	0.637***	0.669***	0.737***	0.790***	0.688***
	[0.10]	[0.10]	[0.10]	[0.08]	[0.06]	[0.10]
Constant	0.972**	0.995**	0.932***	0.802***	0.712***	1.245***
	[0.45]	[0.38]	[0.33]	[0.28]	[0.24]	[0.36]
Controls: X_t & Z_t	Yes	Yes	Yes	Yes	Yes	Yes
N	125	125	125	125	125	125
R^2	0.59	0.57	0.58	0.71	0.84	0.94
BoE_ShadowRate coefficient when:						
Dummy IR = 1	-0.109*	-0.091**	-0.070**	-0.053**	-0.038*	0.018
	[0.06]	[0.04]	[0.03]	[0.03]	[0.02]	[0.03]
Partial R^2 - Variance decomposition						
BoE_ShadowRate when IR = 0	0.08	0.05	0.02	0.01	0.01	0.06
BoE_ShadowRate when IR = 1	0.10	0.09	0.06	0.04	0.03	0.06

Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * p < 0.10, ** p < 0.05, *** p < 0.01. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the key coefficients are reported. Complete tables are available from the authors upon request. X_t includes a news variable capturing the information flow between *t-1* and *t* of macro data releases related to inflation, the real activity, uncertainty and news indices of Scotti (2016), the changes in the FTSE and UK move indices. Z_t includes CPI, industrial production, oil prices, the sterling effective exchange rate, net lending, housing prices. To facilitate the reading of the interacted effects, we compute the coefficient associated with the monetary shock when the dummy equals 1.

Table 2 - The effect of monetary shocks when interacted with inflation projection surprises

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
BoE_ShadowRate * 4-quarter BoE projection surprises						
BoE_ShadowRate * BoE_cpi_4	-0.434**	-0.272**	-0.195*	-0.163*	-0.133**	0.062
	[0.21]	[0.13]	[0.10]	[0.09]	[0.07]	[0.14]
BoE_ShadowRate	-0.086**	-0.053**	-0.032	-0.023	-0.018	-0.024
	[0.03]	[0.03]	[0.02]	[0.02]	[0.01]	[0.02]
BoE_cpi_4	0.119	0.053	0.019	-0.006	-0.026	-0.078
	[0.10]	[0.07]	[0.07]	[0.06]	[0.05]	[0.06]
BoE_gdp_4	0.145	0.104	0.087	0.082	0.075	0.007
	[0.16]	[0.11]	[0.10]	[0.09]	[0.07]	[0.07]
Lag dep var	0.640***	0.627***	0.655***	0.725***	0.783***	0.683***
	[0.10]	[0.10]	[0.10]	[0.08]	[0.06]	[0.10]
Constant	0.962**	1.000***	0.951***	0.822***	0.726***	1.269***
	[0.44]	[0.37]	[0.32]	[0.28]	[0.24]	[0.38]
Controls: X_t & Z_t	Yes	Yes	Yes	Yes	Yes	Yes
N	125	125	125	125	125	125
R^2	0.61	0.58	0.58	0.71	0.84	0.94
BoE_ShadowRate coefficient when:						
Δ+ BoE_cpi_4	-0.182***	-0.113***	-0.075**	-0.058**	-0.048**	-0.011
	[0.06]	[0.04]	[0.03]	[0.03]	[0.02]	[0.03]
Δ- BoE_cpi_4	0.009	0.007	0.011	0.013	0.011	-0.038
	[0.05]	[0.04]	[0.03]	[0.03]	[0.02]	[0.05]
Partial R^2 - Variance decomposition						
BoE_ShadowRate alone	0.10	0.08	0.04	0.03	0.03	0.04
BoE_ShadowRate interacted	0.13	0.10	0.06	0.04	0.04	0.04

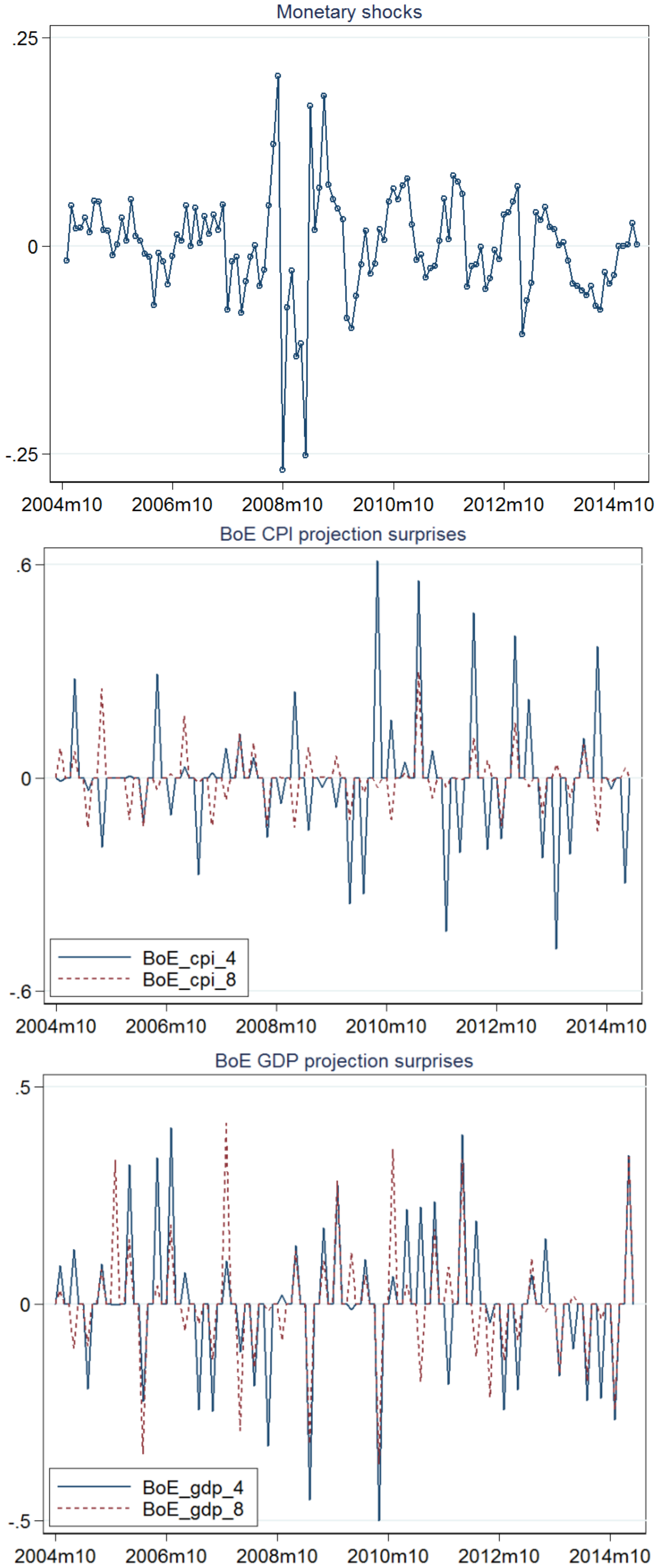
Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the key coefficients are reported. Complete tables are available from the authors upon request. X_t includes a news variable capturing the information flow between *t-1* and *t* of macro data releases related to inflation, the real activity, uncertainty and news indices of Scotti (2016), the changes in the FTSE and UK move indices. Z_t includes CPI, industrial production, oil prices, the sterling effective exchange rate, net lending, housing prices. To facilitate the reading of the interacted effects, we compute the coefficient associated with the monetary shock for positive (mean + 1.5 S.D.) or negative (mean - 1.5 S.D.) projection surprises.

Table 3 - Subsample estimations: pre and post ZLB

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
Pre ZLB						
BoE_ShadowRate * BoE_cpi_4	-1.176**	-0.695*	-0.492*	-0.411*	-0.345*	0.043
	[0.58]	[0.36]	[0.28]	[0.23]	[0.18]	[0.17]
BoE_ShadowRate coefficient when:						
Δ+ BoE_cpi_4	-0.383**	-0.247**	-0.187**	-0.156**	-0.130**	0.005
	[0.17]	[0.10]	[0.08]	[0.07]	[0.05]	[0.03]
Δ- BoE_cpi_4	0.134	0.059	0.030	0.024	0.022	-0.014
	[0.13]	[0.08]	[0.06]	[0.05]	[0.04]	[0.05]
Post ZLB						
BoE_ShadowRate * BoE_cpi_4	-0.299**	-0.191*	-0.131	-0.107	-0.088	-0.001
	[0.12]	[0.11]	[0.12]	[0.11]	[0.09]	[0.07]
BoE_ShadowRate coefficient when:						
Δ+ BoE_cpi_4	-0.120***	-0.051	-0.015	-0.007	-0.011	-0.040
	[0.05]	[0.04]	[0.04]	[0.03]	[0.03]	[0.02]
Δ- BoE_cpi_4	0.011	0.033	0.043*	0.040*	0.028	-0.040
	[0.04]	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]

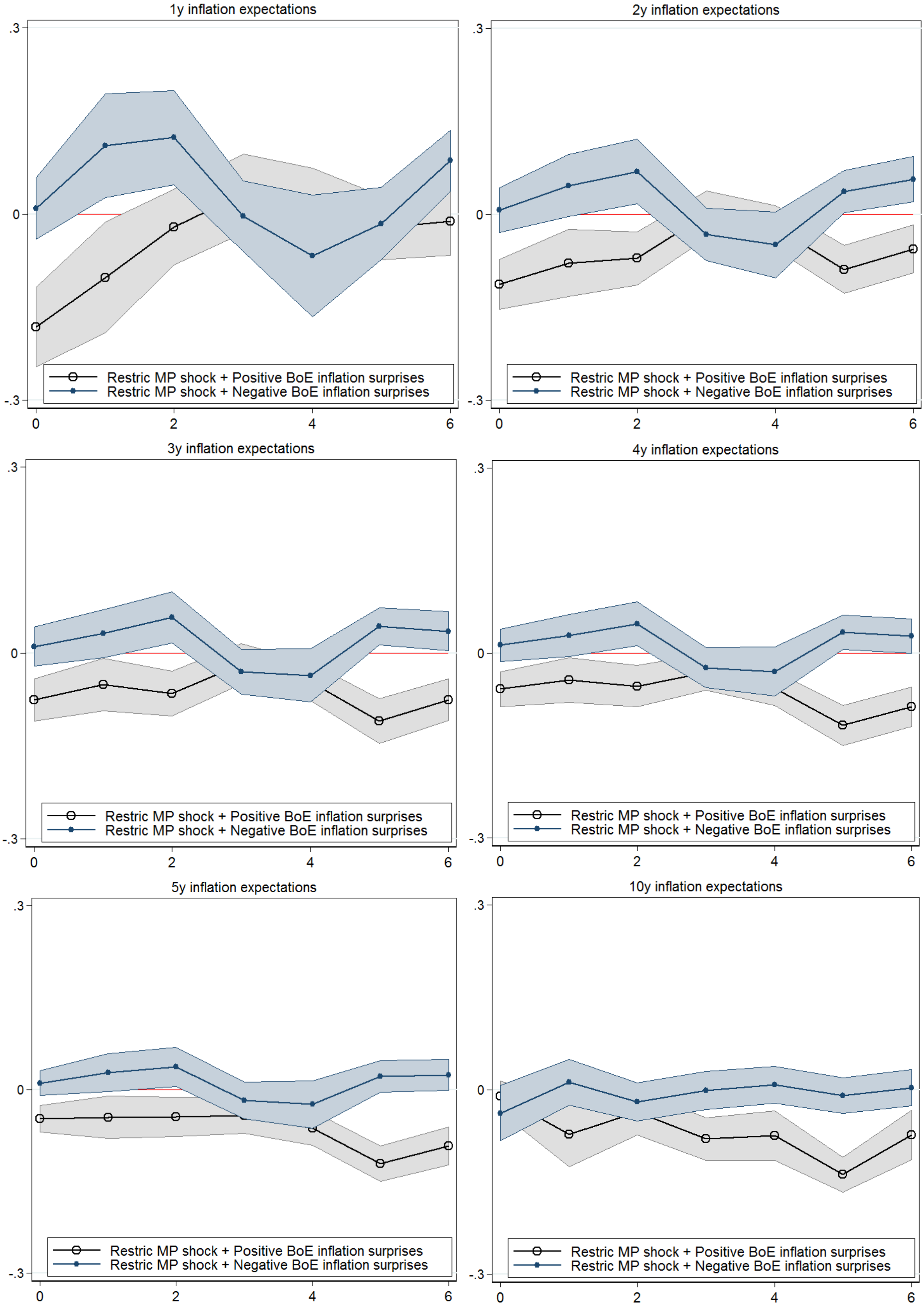
Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the key coefficients are reported. Complete tables are available from the authors upon request.

Figure 1 – Exogenous shocks
for the Bank of England's shadow rate, and inflation and output projections



Note: The shocks plotted on these panels are estimated from equations (7)-(8). Parameters are presented in Table 1.

Figure 2 – Local projections



Note: Impulse responses to a monetary shock when interacted with positive (black line) or negative (blue line) projection surprises, over 6 months, estimated with equation (6) using local projections as described in equation (9) with one standard error confidence intervals. The coefficient associated with the monetary shock is computed for positive (mean + 1.5 S.D.) or negative (mean - 1.5 S.D.) projection surprises.

APPENDIX

A. Correcting Market-based Expectation Measures

We aim to derive accurate estimates of market-based measures of inflation expectations by correcting inflation compensation, as measured by inflation swaps, for term, liquidity and inflation risk premia. Market-based measures of inflation compensation are an appropriate indicator of inflation expectations if investors are risk neutral and there is no liquidity premium. However, that is unlikely to be the case, and these premia might have sizable values and be time-varying. We use a model-free regression approach to correct our compensation measure, rather than a no arbitrage approach based on term-structure models.

Gürkaynak et al. (2010a, 2010b) and Soderlind (2011) decompose inflation compensation, $\pi_{t,h}^{COMP}$, obtained from financial swaps into: expected inflation, $\pi_{t,h}^{PF}$, a liquidity premium, $\varphi_{t,h}^{l}$, that investors demand to encourage them to hold these assets when they are illiquid, and an inflation uncertainty premium, $\varphi_{t,h}^{ir}$, that compensates investors for bearing inflation risk.[1] We also include a term premium, $\varphi_{t,h}^{risk}$, compensating investors for holding a risky asset.[2] Assuming t is the time subscript and h is the horizon of inflation expectations, this breakdown can be written:

$$\pi_{t,h}^{COMP} = \pi_{t,h}^{PF} + \varphi_{t,h}^{risk} + \varphi_{t,h}^{l} + \varphi_{t,h}^{ir} \qquad \text{(A1)}$$

We estimate a linear regression model of inflation compensation on proxy measures capturing the different premia. In the spirit of Chen, Lesmond and Wei (2007) who control for risk premium using bond ratings, the credit risk premium is proxied by the Libor-OIS spread and by the average of UK major banks' CDS premia. Those measures should capture the riskiness of holding financial instruments, especially during the global financial crisis. The liquidity premium is proxied by the FTSE Volatility index (the UK-equivalent of the VIX), following Gürkaynak et al. (2010b) and Soderlind (2011).[3] For the inflation risk premium, we use the implied volatility from swaptions – options on short-term interest rate swaps – maturing in 20 years which captures inflation uncertainty, following Soderlind (2011).[4] This leads us to estimate the following equation:

$$\pi_{t,h}^{COMP} = \alpha + \beta_h^s\, spread + \beta_h^{cds}\, cds + \beta_h^f\, ftsev + \beta_h^i\, impvol + \varepsilon_{t,h}^{COMP} \qquad \text{(A2)}$$

[1] Because the central bank may intend to affect the inflation risk premium as well as inflation expectations, we also compute adjusted series for term and liquidity premia only and assess the effect of this alternative in table A4.

[2] The term premium has been neglected in most of the literature so far for two reasons. First, most of the studies focus on US treasury bonds and TIPS, and therefore implicitly assume there is no credit risk, those bonds being considered as risk-free (see Gürkaynak et al. 2010b). Second, when considering swap contracts to derive inflation expectations, the collateral is supposed to remove any potential credit risk. However, in a post-Great Recession sample in which sovereign bonds have been shown to be not as risk-free as previously thought and collateral value may have changed rapidly, we explicitly assess whether proxies for credit risk correlate with supposedly risk-free inflation compensation rather than assuming ex ante the absence of a term premium.

[3] An extension would be to correct for the micro liquidity premium affecting investors' appetite for inflation hedging instruments compared to nominal instruments and for the maturity-specific liquidity premium affecting investors' appetite for each maturity differently. One option would be to use maturity-specific residuals from a fitted term structure model as a proxy for maturity-specific liquidity premia (Garcia and Fontaine 2009, Hu, Pan and Wang 2013) and the average of all yield curve fitting errors for indexed bonds over the average of all yield curve fitting errors for nominal bonds to capture the micro liquidity premium.

[4] An alternative indicator to measure inflation uncertainty more precisely would be the standard deviation of the probability density function of inflation options maturing in 10 years, which are available for the UK only since 2007. Over the same sample, the correlation between this measure and our proxy is 0.76.

We estimate equation (A2) using OLS. We use monthly observations – calculated simply as the average of daily observations. And we estimate it separately for each horizon of inflation compensation from 1 year ahead to 5 years ahead and 10 years ahead. The term, liquidity and inflation risk premia – directly related to inflation uncertainty – should all push inflation compensation up.[5] So we expect the coefficients on the LIBOR-OIS spread, CDS premia, the FTSE Volatility index (*ftsev*) and implied volatility (*impvol*) variables to be positive.[6] We also expect the term and inflation risk premia to increase with the maturity of the swap. We estimate equation (A2) on the full sample and on two subsamples pre and post ZLB. Because the ZLB may affect the transmission of shocks and macro and financial dynamics, the pricing relationship of premia may also change pre and post ZLB. Table A3 in the Appendix shows the estimated coefficients for each maturity of the term structure of inflation expectations.

Using these estimated parameters, we adjust the inflation compensation series by subtracting the fitted values of the contributions of the term, liquidity and inflation risk premia to obtain corrected inflation expectation series. Figure A1 in the Appendix shows on the left-hand side the raw inflation compensation series and the corrected inflation expectations series (either with constant pricing or pre/post ZLB pricing), and on the right-hand side the evolution of the estimated term premium (in blue), the liquidity premium (in red) and the inflation risk premium (in green) in the constant pricing estimation.[7] While the risk proxies started to become non-null and positive in mid-2007, they had effects of different signs for short and long maturities during the financial turmoil of late 2008: they had a negative contribution to inflation compensation when financial stress was most acute after Lehman Brothers' collapse for maturities under 6-years, pushing inflation compensation to negative values, whereas their effects remained positive for longer maturities. After this episode of severe financial stress, the term premium had a positive contribution for all maturities of around 20-50 basis points. The liquidity premium spiked at almost 120 basis points for longer maturities in the second half of 2008 and remained elevated at around 40-50 basis points after that. The inflation risk premium has declined over time, particularly at longer maturities, and became negative during 2011 (moving from +20 basis points to -10 basis points), which might be associated with the implementation of QE. Overall, the correction results in flatter series for inflation expectations and in lower inflation expectations at the longer horizons for which the difference between the unadjusted and adjusted series is larger.

Overall, for compensation measures ten-years ahead, we estimate that the total combined premium has averaged about 60 basis points since 2004, and has varied between around 30 and 160 basis points. For comparison, D'Amico, Kim and Wei (2010) find that the liquidity premium on US TIPS has varied between 0 and 130 basis points. Gürkaynak et al. (2010b) find that the liquidity premium has varied between 0 and 140 basis points. Risa (2001) finds an inflation risk premium in the UK of around 170 basis points, and Joyce et al. (2010) estimate it to be between 75 and 100 basis points. Ang et al. (2008) find an inflation risk premium of between 10 and 140 basis points in the US over the last two decades. Finally, using Gaussian affine dynamic term structure models, Guimarães (2012) finds a total combined premium of

[5] This is in contrast to inflation compensation derived from inflation indexed bonds, for which we would expect the liquidity proxy to have a negative coefficient, because they are generally less liquid than nominal bonds.
[6] Because these proxies might be correlated with the business cycle, we use an alternative methodology based on survey expectation measures that do not contain these various premia by construction. We consider the predicted value of market-based expectations when regressed on survey expectations, which we use as instruments.
[7] The constant in equation (A2) may include other constants related to term, liquidity or inflation risk. This does not invalidate the main result since the mean of inflation expectations is not needed when estimating equation (6). However, the series on the left-hand side of Figure A1 should be considered cautiously and is only indicative.

190 basis points over 1985-1992 and of 30 basis points over 1997-2002 for 10-years inflation compensation derived from UK gilts.

The correlation between the original and (constant pricing) corrected series is 0.74, 0.84, 0.94, 0.97, 0.91 and 0.69 for each maturity from 1-year to 5-years and 10-years respectively. The correlation between the original and (pre/post ZLB pricing) corrected series is 0.73, 0.75, 0.80, 0.79, 0.67 and 0.46 for each maturity from 1-year to 5-years and 10-years respectively. We use the pre/post ZLB pricing corrected series in our benchmark analysis and provide estimates using the constant pricing corrected series in the robustness section.

We also assess the robustness of our main result using the original raw market-based measures –inflation compensation–, so as to observe the impact of the correction for the term, liquidity, and inflation risk premia. In addition, because the central bank may intend to affect the inflation risk premium as well as inflation expectations, we also compute adjusted series for term and liquidity premia only. Finally, because the proxies we use to correct inflation compensation for the different premia might be correlated with the business cycle, we turn to an alternative methodology using survey expectation measures that do not contain these various premia. We regress market-based expectations on their 1-year trend and survey expectations and consider the predicted value as our adjusted series. Table A9 provides estimates of these alternative specifications and shows that our main result is robust to the correction of premia.

References

Ang, Andrew, Geert Bekaert and Min Wei (2008). "The term structure of real rates and inflation expectations", *Journal of Finance*, 63(2), 797–849.

Chen, Long, David Lesmond, and Jason Wei (2007). 'Corporate Yield Spreads and Bond Liquidity', *Journal of Finance*, 62(1), 119-149.

D'Amico, Stefania, Don Kim, and Min Wei (2010). 'Tips from TIPS: the information content of Treasury inflation-protected security prices', *Finance and Economics Discussion Series Working Paper* 2010-19, Federal Reserve Board.

Garcia, René, and Jean-Sébastien Fontaine (2009). "Bond Liquidity Premia", *Review of Financial Studies*, 25(4), 1207-1205.

Guimarães, Rodrigo (2012). "What accounts for the fall in UK ten-year government bond yields?", *Bank of England Quarterly Bulletin*, 52(3), 213-223.

Gürkaynak, Refet, Andrew Levin, and Eric Swanson (2010a). "Does Inflation Targeting Anchor Long-Run Inflation Expectations? Evidence from Long-Term Bond Yields in the US, UK, and Sweden", *Journal of the European Economic Association*, 8(6), 1208-42.

Gürkaynak, Refet, Brian Sack and John Wright (2010b). "The TIPS yield curve and inflation compensation", *American Economic Journal: Macroeconomics*, 2(1), 70–92.

Hu, Grace Xing, Jun Pan, and Jiang Wang (2013). "Noise as Information for Illiquidity", *Journal of Finance*, 18(6).

Joyce, Michael, Peter Lildholdt and Steffen Sorensen (2010). "Extracting inflation expectations and inflation risk premia from the term structure: a joint model of the UK nominal and real yield curves", *Journal of Banking and Finance*, 34(2), 281–94.

Risa, Stefano (2001). "Nominal and inflation indexed yields: separating expected inflation and inflation risk premia", *Working Paper*, Columbia University.

Soderlind, Paul (2011). "Inflation Risk Premia and Survey Evidence on Macroeconomic Uncertainty", *International Journal of Central Banking*, 7(2), 113-133.

Table A1 - Data description

Variable	Source	Description
PF_h	Bloomberg and Bank of England calculations	Inflation expectation measures derived from inflation swaps. Instantaneous forward inflation rates for annual RPI inflation h years ahead. Monthly average of daily observations.
BoE_ShadowRate	Bank of England	Bank Rate adjusted for internal estimates of the impact of QE.
BoE_ShadowRate1	Wu and Xia (2016)	UK shadow rate estimated using a nonlinear term structure model.
BoE_ShadowRate2	Krippner (2013, 2014)	UK shadow rate estimated using a two state-variable yield curve model.
Bank Rate	Bank of England	Bank of England's policy interest rate.
BoE_cpi_h	Bank of England	Bank of England's modal projections for annual CPI inflation h quarters ahead, based on market interest rate expectations.
BoE_gdp_h	Bank of England	Bank of England's modal projections for annual GDP growth h quarters ahead, based on market interest rate expectations.
FG	Authors' computation	Dummy that equals 1 during the period for which Forward Guidance on policy is in place.
ZLB	Authors' computation	Dummy that equals 1 during the period Ban Rate is at its effective lower bound of 0.5%.
mc_h	Bank of England	Market interest rate curve used as conditioning path for BoE's macroeconomic projections.
PF_gdp_h	Consensus Forecasts / Survey of External Forecasters	Consensus Forecasts' average projections for annual GDP growth h quarters ahead, for h=1 to 6. Survey of External Forecasters' average projections for annual GDP growth h quarters ahead, for h=8 and 12. Monthly constant interpolation from quarterly frequency.
Oil	FRED	Crude oil spot prices, Brent - Europe. Annual % change.
Sterling	Bank of England	Effective exchange rate index, January 2005 = 100. Annual % change.
CPI	ONS	Annual % change in the Consumer Price Index.
Indpro	ONS	Annual real Industrial Production growth seasonally adjusted.
Netlending	Bank of England	12 month growth rate of monetary financial institutions' sterling net lending to private non-financial corporations (excluding the effects of securitisations and loan transfers) (SA).
Housing	Halifax and Nationwide	Average of (SA) Halifax and Nationwide measures of average house prices. Annual % change.
RPI surprises	ONS and Bloomberg	Difference between the outturn for annual RPI inflation in a given month and the market median forecast 1 month before.
scottiactiv	Scotti (2016)	UK real-time real activity index, capturing the state of economic conditions.
scottinews	Scotti (2016)	UK real-time surprise index, summarizing economic data surprises.
scottiuncert	Scotti (2016)	UK real-time uncertainty index, measuring uncertainty related to the state of the economy.
FTSE	Bloomberg	FTSE all-share index. Annual change.
UKmove	Bank of England	The Merrill lynch Option Volatility Estimate (MOVE) Index is a yield curve weighted index of the normalized implied volatility on 1-month UK gilt options which are weighted on the 2, 5, 10, and 30 year contracts. It is the bond market's equivalent of the VIX.
LIBOR-OIS	FRED and Thomson DataStream	3-Month London Interbank Offered Rate and 3-Month Overnight Indexed Swap rates. Monthly average of daily observations.
CDS	Markit Group Limited and BoE calculations	Unweighted average of the five-year CDS premia for the major UK lenders. Monthly average of daily observations.
FTSE-Vol	Bloomberg	FTSE 100 Implied Volatility Index, 3 months constant maturity. Monthly average of daily obs.
ImpVol20	Barclays Live	At-the-money implied volatility of 1 year LIBOR swaptions, 20 years constant maturity. Monthly average of daily observations.

Table A2 - Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
PF_1y	126	3.13	0.38	1.50	4.15
PF_2y	126	3.07	0.26	2.04	3.72
PF_3y	126	3.02	0.22	2.19	3.57
PF_4y	126	3.02	0.23	2.23	3.42
PF_5y	126	3.05	0.27	2.26	3.50
PF_10y	126	3.25	0.45	2.50	3.91
BoE_ShadowRate	125	0.00	0.06	-0.27	0.20
BoE_ShadowRate1	125	0.00	0.29	-0.84	1.82
BoE_ShadowRate2	125	0.00	0.46	-1.35	2.36
Bank Rate	125	0.00	0.12	-0.51	0.34
BoE_cpi_4	126	0.00	0.15	-0.48	0.61
BoE_cpi_8	126	0.00	0.06	-0.15	0.30
BoE_gdp_4	126	0.00	0.13	-0.50	0.41
BoE_gdp_8	126	0.00	0.11	-0.37	0.42
mc_1y	125	2.42	2.02	0.22	5.93
mc_2y	125	2.88	1.81	0.28	5.89
mc_3y	125	3.22	1.61	0.56	5.79
PF_gdp_1	126	1.42	1.67	-3.90	3.10
PF_gdp_4	126	1.81	0.73	-0.70	2.60
PF_gdp_8	126	2.30	0.24	1.82	2.63
Oil	126	14.88	35.21	-56.10	86.40
Sterling	126	-1.07	6.49	-21.60	11.00
CPI	126	2.62	1.04	0.00	5.20
Indpro	126	-0.98	3.44	-11.10	5.10
Netlending	126	4.65	8.77	-4.40	19.60
Housing	126	2.71	7.27	-17.10	17.60
RPI surprises	126	0.03	0.17	-0.50	0.70
scottiactiv	126	-0.17	0.62	-2.44	0.51
scottinews	126	-0.08	0.28	-0.96	0.53
scottiuncert	126	0.92	0.32	0.41	1.98
FTSE	126	6.04	15.50	-36.20	51.20
UKmove	126	90.32	32.55	52.59	220.01
LIBOR-OIS	126	0.34	0.41	0.09	2.21
CDS	126	0.97	0.73	0.06	2.61
FTSE-Vol	126	17.59	7.53	8.85	48.68
ImpVol20	126	-1.42	5.48	-12.93	7.16

Table A3 - Correction of raw market-based measures for premia

	1	2	3	4	5	6
	swap_1y	swap_2y	swap_3y	swap_4y	swap_5y	swap_10y
			Pre ZLB sample			
LIBOR-OIS	-0.867**	-0.732**	-0.597**	-0.465**	-0.347*	0.034
	[0.42]	[0.30]	[0.25]	[0.21]	[0.19]	[0.13]
CDS	0.996***	0.963***	0.846***	0.733***	0.637***	0.393***
	[0.29]	[0.21]	[0.17]	[0.15]	[0.13]	[0.09]
FTSE-Vol	-0.044*	-0.030*	-0.019	-0.009	-0.001	0.017**
	[0.02]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]
ImpVol20	-0.037*	-0.028*	-0.027**	-0.027**	-0.027***	-0.026***
	[0.02]	[0.02]	[0.01]	[0.01]	[0.01]	[0.01]
Constant	3.064***	3.031***	2.965***	2.889***	2.825***	2.748***
	[0.25]	[0.18]	[0.15]	[0.13]	[0.11]	[0.08]
N	53	53	53	53	53	53
R^2	0.53	0.51	0.45	0.44	0.55	0.91
			Post ZLB sample			
LIBOR-OIS	-1.183***	-0.174	0.138	0.304**	0.396***	0.289**
	[0.26]	[0.17]	[0.15]	[0.14]	[0.14]	[0.14]
CDS	0.219**	-0.08	-0.167***	-0.207***	-0.232***	-0.253***
	[0.09]	[0.05]	[0.05]	[0.05]	[0.05]	[0.05]
FTSE-Vol	-0.017	-0.003	0.006	0.009	0.011	0.016**
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
ImpVol20	-0.030**	0.006	0.011	0.006	0.000	-0.014**
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Constant	3.186***	3.099***	3.054***	3.121***	3.217***	3.611***
	[0.18]	[0.12]	[0.10]	[0.10]	[0.10]	[0.10]
N	73	73	73	73	73	73
R^2	0.40	0.22	0.16	0.26	0.40	0.55
			No subsample			
LIBOR-OIS	-0.881***	-0.412***	-0.263*	-0.166	-0.096	0.038
	[0.20]	[0.15]	[0.14]	[0.13]	[0.12]	[0.13]
CDS	0.349***	0.170***	0.117**	0.095**	0.084*	0.065
	[0.07]	[0.06]	[0.05]	[0.05]	[0.04]	[0.05]
FTSE-Vol	-0.021*	-0.013	-0.004	0.004	0.011	0.030***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
ImpVol20	-0.030***	-0.014*	-0.01	-0.009	-0.009	0.001
	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]	[0.01]
Constant	2.982***	3.005***	2.952***	2.906***	2.875***	2.882***
	[0.13]	[0.10]	[0.09]	[0.08]	[0.08]	[0.08]
N	126	126	126	126	126	126
R^2	0.46	0.29	0.12	0.06	0.17	0.53

Standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (A2) for a different horizon and estimated with OLS.

Table A4 - Extracting Exogenous Shocks

	1		2	3	4	5
	Δ BoE_ShadowRate		BoE_cpi_4	BoE_cpi_8	BoE_gdp_4	BoE_gdp_8
L.BoE_ShadowRate	-0.019	L.BoE_ShadowRate	-0.397**	-0.284***	-0.757***	-0.158
	[0.01]		[0.15]	[0.07]	[0.14]	[0.12]
L.PCA_PF_cpi	0.015***	L.PCA_PF_cpi	-0.059	-0.013	-0.133***	-0.085**
	[0.00]		[0.05]	[0.02]	[0.04]	[0.04]
L.PCA_PF_gdp	0.017*	L.PCA_PF_gdp	0.097	0.142***	0.016	-0.071
	[0.01]		[0.11]	[0.05]	[0.10]	[0.08]
BoE_cpi_4	0.014	L.BoE_cpi_4	-0.172	-0.04	-0.374*	0.117
	[0.03]		[0.23]	[0.10]	[0.21]	[0.18]
BoE_cpi_8	0.143	L.BoE_cpi_8	0.503	0.507	0.904	-0.54
	[0.10]		[0.85]	[0.36]	[0.77]	[0.66]
BoE_cpi_12	-0.056	L.BoE_cpi_12	-0.869	-0.638	-0.758	0.771
	[0.12]		[1.01]	[0.43]	[0.91]	[0.78]
BoE_gdp_4	0.042	L.BoE_gdp_4	0.095	-0.406***	0.312	0.226
	[0.03]		[0.26]	[0.11]	[0.23]	[0.20]
BoE_gdp_8	-0.019	L.BoE_gdp_8	-0.472	0.359**	0.059	-0.359
	[0.05]		[0.40]	[0.17]	[0.37]	[0.32]
BoE_gdp_12	-0.001	L.BoE_gdp_12	-0.145	-0.409**	0.586	0.848**
	[0.05]		[0.40]	[0.17]	[0.36]	[0.31]
Δ BoE_cpi_4	-0.007	mc_1y	1.925***	1.132***	0.468	-1.157**
	[0.03]		[0.57]	[0.24]	[0.52]	[0.45]
Δ BoE_cpi_8	0.153	mc_2y	-2.908*	-1.545**	0.174	2.601**
	[0.11]		[1.47]	[0.62]	[1.33]	[1.14]
Δ BoE_cpi_12	-0.117	mc_3y	1.727	0.900*	0.084	-1.500*
	[0.13]		[1.05]	[0.45]	[0.96]	[0.82]
Δ BoE_gdp_4	-0.019	.	.	.	.	.
	[0.04]					
Δ BoE_gdp_8	-0.015	.	.	.	.	.
	[0.06]					
Δ BoE_gdp_12	0.059	.	.	.	.	.
	[0.07]					
Constant	-0.264	Constant	3.999**	3.455***	-0.900	-0.984
	[0.19]		[1.49]	[0.63]	[1.36]	[1.16]
Controls: Z_{t-1} & IR_t	Yes	Controls: Z_{t-1}	Yes	Yes	Yes	Yes
N	125	N	42	42	42	42
R^2	0.85	R^2	0.80	0.92	0.92	0.79

Properties of exogenous shock series

	Mean	SD	Min	Max	AR(1)	AR(3)
BoE_ShadowRate	0.00	0.06	-0.27	0.20	0.29***	0.07
BoE_cpi_4	0.00	0.15	-0.48	0.61	0.00	0.04
BoE_cpi_8	0.00	0.06	-0.15	0.30	0.00	-0.18*
BoE_gdp_4	0.00	0.13	-0.50	0.41	0.00	0.02
BoE_gdp_8	0.00	0.11	-0.37	0.42	0.00	-0.21*

Correlation of monetary shock and projection surprises

	BoE_ShadowRate	BoE_cpi_4	BoE_cpi_8	BoE_gdp_4	BoE_gdp_8
BoE_ShadowRate	1				
BoE_cpi_4	-0.12	1			
BoE_cpi_8	-0.09	0.22	1		
BoE_gdp_4	-0.04	0.02	0.15	1	
BoE_gdp_8	0.06	-0.20	-0.20	0.66	1

Predictability of exogenous shock series

	BoE_ShadowRate	BoE_cpi_4	BoE_cpi_8	BoE_gdp_4	BoE_gdp_8
VAR(3) - F-stat	0.31	0.98	0.59	0.77	0.78
VAR(3) - *p* -value	0.99	0.48	0.88	0.71	0.70
VAR(6) - F-stat	0.54	0.60	0.45	0.67	0.44
VAR(6) - p-value	0.97	0.94	0.99	0.90	0.99

Standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. L is the lag operator and Δ the first difference operator. Column 1 and columns 2 to 5 correspond to the OLS estimation of equation (7) and (8) respectively. The Z vector of controls includes CPI, industrial production, net lending, housing prices as well as oil prices and the sterling effective exchange rate.

Table A5 - Interaction of monetary shocks with longer-horizons BoE projection surprises

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
BoE_ShadowRate * BoE_cpi_8						
BoE_ShadowRate * BoE_cpi_8	0.584	0.393	0.287	0.220	0.135	-0.479
	[0.62]	[0.43]	[0.35]	[0.29]	[0.23]	[0.35]
BoE_ShadowRate	-0.088**	-0.052*	-0.031	-0.021	-0.017	-0.025
	[0.03]	[0.03]	[0.02]	[0.02]	[0.01]	[0.02]
BoE_cpi_8	-0.227	-0.049	0.028	0.059	0.069	0.065
	[0.37]	[0.27]	[0.22]	[0.18]	[0.15]	[0.16]
BoE_gdp_8	0.046	0.036	0.03	0.029	0.034	0.041
	[0.17]	[0.14]	[0.12]	[0.10]	[0.08]	[0.08]
BoE_ShadowRate * BoE_gdp_4						
BoE_ShadowRate * BoE_gdp_4	0.044	0.236	0.257	0.238	0.211	0.204
	[0.41]	[0.26]	[0.20]	[0.16]	[0.13]	[0.16]
BoE_ShadowRate	-0.085**	-0.050*	-0.029	-0.02	-0.016	-0.022
	[0.03]	[0.03]	[0.02]	[0.02]	[0.01]	[0.02]
BoE_cpi_4	0.170	0.058	0.012	-0.015	-0.035	-0.111
	[0.15]	[0.10]	[0.08]	[0.07]	[0.06]	[0.08]
BoE_gdp_4	0.066	0.032	0.026	0.028	0.03	-0.004
	[0.16]	[0.11]	[0.09]	[0.08]	[0.07]	[0.06]
BoE_ShadowRate * BoE_gdp_8						
BoE_ShadowRate * BoE_gdp_8	-0.246	-0.097	-0.065	-0.021	0.040	0.413
	[0.38]	[0.26]	[0.20]	[0.16]	[0.12]	[0.24]
BoE_ShadowRate	-0.089***	-0.054**	-0.033	-0.023	-0.018	-0.025
	[0.03]	[0.03]	[0.02]	[0.02]	[0.01]	[0.02]
BoE_cpi_8	-0.218	-0.066	0.013	0.038	0.039	-0.008
	[0.37]	[0.27]	[0.22]	[0.18]	[0.14]	[0.14]
BoE_gdp_8	0.096	0.069	0.054	0.046	0.042	-0.008
	[0.18]	[0.15]	[0.13]	[0.10]	[0.08]	[0.08]

Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the key coefficients are reported. Complete tables are available from the authors upon request.

Table A6 - Robustness: Policy variables and identification of monetary shocks

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
Benchmark identification						
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.342***	-0.295***	-0.248***	-0.194***	-0.135***	0.082
	[0.12]	[0.08]	[0.07]	[0.06]	[0.04]	[0.06]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.293**	-0.260**	-0.228**	-0.194***	-0.152**	0.062
	[0.13]	[0.10]	[0.09]	[0.07]	[0.06]	[0.12]
Estimation on IR months only / Shocks prediction on all months						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.261	-0.158	-0.095	-0.070	-0.047	0.092
	[0.22]	[0.16]	[0.13]	[0.11]	[0.09]	[0.10]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.379***	-0.327***	-0.279***	-0.220***	-0.156***	0.084
	[0.14]	[0.09]	[0.07]	[0.06]	[0.05]	[0.08]
Krippner (2015)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.362*	-0.335***	-0.286***	-0.239***	-0.184***	0.084
	[0.18]	[0.12]	[0.10]	[0.08]	[0.07]	[0.15]
Two estimations (IR and non-IR months)						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.224	-0.136	-0.083	-0.061	-0.042	0.078
	[0.20]	[0.14]	[0.11]	[0.09]	[0.08]	[0.09]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.310**	-0.278***	-0.241***	-0.191***	-0.136***	0.069
	[0.13]	[0.08]	[0.07]	[0.05]	[0.04]	[0.07]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.356**	-0.302***	-0.250***	-0.209***	-0.162**	0.072
	[0.14]	[0.10]	[0.09]	[0.08]	[0.06]	[0.13]
Two estimations (Pre/Post ZLB)						
Bank Rate + BoE's UK shadow rate						
BoE_BR/SR * BoE_cpi_4	-0.002	-0.017	-0.041	-0.066	-0.091	-0.200*
	[0.21]	[0.16]	[0.14]	[0.11]	[0.09]	[0.10]
Bank Rate + Wu and Xia (2016)'s UK shadow rate						
BoE_BR/SR1 * BoE_cpi_4	-0.592***	-0.432**	-0.328*	-0.263	-0.207*	0.008
	[0.20]	[0.20]	[0.19]	[0.16]	[0.12]	[0.11]
Bank Rate + Krippner (2013, 2014)'s UK shadow rate						
BoE_BR/SR2 * BoE_cpi_4	-0.085	-0.121	-0.115	-0.101	-0.077	0.031
	[0.17]	[0.10]	[0.09]	[0.07]	[0.07]	[0.08]

Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the coefficient of the interaction variable is reported. Complete tables are available from the authors upon request.

Table A7 - Robustness: Identification of monetary shocks

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
Taylor rule						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.301	-0.189*	-0.123	-0.099	-0.077	0.127
	[0.19]	[0.11]	[0.09]	[0.07]	[0.05]	[0.14]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.283**	-0.250***	-0.219***	-0.171***	-0.115***	0.095**
	[0.13]	[0.07]	[0.05]	[0.04]	[0.04]	[0.04]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.275	-0.257*	-0.240*	-0.202**	-0.152*	0.048
	[0.20]	[0.14]	[0.13]	[0.10]	[0.08]	[0.12]
Cloyne-Huertgen (2016)						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.117	0.052	0.052	0.020	-0.014	-0.066
	[0.25]	[0.15]	[0.11]	[0.09]	[0.08]	[0.09]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.263*	-0.221**	-0.200**	-0.165**	-0.119**	0.081
	[0.14]	[0.10]	[0.08]	[0.06]	[0.05]	[0.10]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.144	-0.168**	-0.167**	-0.154**	-0.134**	-0.119**
	[0.11]	[0.08]	[0.07]	[0.06]	[0.05]	[0.05]
No PCA variables in identification						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.289	-0.140	-0.078	-0.061	-0.055	0.009
	[0.20]	[0.13]	[0.10]	[0.08]	[0.06]	[0.06]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.378***	-0.330***	-0.277***	-0.219***	-0.156***	0.089
	[0.11]	[0.07]	[0.06]	[0.05]	[0.04]	[0.07]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.208**	-0.197***	-0.162**	-0.129**	-0.094*	0.068
	[0.09]	[0.07]	[0.07]	[0.06]	[0.05]	[0.09]
Disentangling small and big monetary shocks						
BoE's UK shadow rate						
BoE_SR * BoE_cpi_4 * Dummy Big	-0.199	-0.196	-0.154	-0.103	-0.044	0.356
	[0.39]	[0.22]	[0.18]	[0.15]	[0.14]	[0.31]
Wu and Xia (2016)'s UK shadow rate						
BoE_SR1 * BoE_cpi_4 * Dummy Big	-0.898**	-0.782***	-0.617***	-0.446***	-0.270*	0.322
	[0.37]	[0.22]	[0.18]	[0.16]	[0.14]	[0.26]
Krippner (2013, 2014)'s UK shadow rate						
BoE_SR2 * BoE_cpi_4 * Dummy Big	-0.45	-0.460**	-0.428**	-0.343**	-0.246**	0.019
	[0.28]	[0.20]	[0.17]	[0.13]	[0.10]	[0.18]

Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the coefficient of the interaction variable is reported. Complete tables are available from the authors upon request.

Table A8 - Robustness: Alternative dependent variables

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
Last observation of the month						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.169	-0.152	-0.141	-0.126	-0.12	-0.136
	[0.19]	[0.16]	[0.13]	[0.11]	[0.10]	[0.08]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.570**	-0.469**	-0.352*	-0.243*	-0.170*	-0.113
	[0.25]	[0.21]	[0.18]	[0.13]	[0.10]	[0.07]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.384*	-0.216	-0.114	-0.065	-0.038	-0.019
	[0.19]	[0.16]	[0.14]	[0.11]	[0.08]	[0.10]
Gilts						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	.	.	.	-0.294**	-0.366***	-0.198
				[0.12]	[0.12]	[0.16]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	.	.	.	-0.221**	-0.12	0.256*
				[0.10]	[0.07]	[0.15]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	.	.	.	-0.277**	-0.260***	0.028
				[0.12]	[0.09]	[0.21]
First difference						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.495	-0.296	-0.227	-0.18	-0.135	0.048
	[0.31]	[0.21]	[0.17]	[0.13]	[0.10]	[0.13]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.579***	-0.448***	-0.348***	-0.264***	-0.185***	0.06
	[0.17]	[0.14]	[0.11]	[0.07]	[0.05]	[0.08]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.538***	-0.411***	-0.321***	-0.253***	-0.192***	-0.014
	[0.19]	[0.14]	[0.12]	[0.09]	[0.06]	[0.12]
Deviation from target						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.434**	-0.272**	-0.195*	-0.163*	-0.133**	0.062
	[0.21]	[0.13]	[0.10]	[0.09]	[0.07]	[0.14]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.342***	-0.295***	-0.248***	-0.194***	-0.135***	0.082
	[0.12]	[0.08]	[0.07]	[0.06]	[0.04]	[0.06]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.293**	-0.260**	-0.228**	-0.194***	-0.152**	0.062
	[0.13]	[0.10]	[0.09]	[0.07]	[0.06]	[0.12]

Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the coefficient of the interaction variable is reported. Complete tables are available from the authors upon request.

Table A9 - Robustness: Alternative dependent variables

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
Constant pricing of premia						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.789***	-0.542***	-0.403***	-0.333***	-0.279***	-0.006
	[0.30]	[0.19]	[0.15]	[0.12]	[0.10]	[0.09]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.365***	-0.312***	-0.255***	-0.191***	-0.131***	0.071
	[0.11]	[0.08]	[0.07]	[0.05]	[0.04]	[0.06]
Krippner (2015)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.365***	-0.319***	-0.265**	-0.216**	-0.171**	0.008
	[0.14]	[0.12]	[0.10]	[0.08]	[0.07]	[0.10]
Survey expectations-based correction of premia						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.170*	-0.04	-0.066*	-0.037***	-0.071***	-0.032*
	[0.09]	[0.09]	[0.03]	[0.01]	[0.02]	[0.02]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.183***	-0.041	-0.011	-0.004	0.016	0.028
	[0.07]	[0.04]	[0.02]	[0.01]	[0.02]	[0.02]
Krippner (2015)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.035	0.025	0.012	-0.006	0.033	0.048
	[0.12]	[0.08]	[0.04]	[0.02]	[0.03]	[0.03]
Without correction for the inflation risk premium						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.797**	-0.543***	-0.405***	-0.337***	-0.283***	-0.01
	[0.31]	[0.20]	[0.15]	[0.12]	[0.10]	[0.09]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.396***	-0.324***	-0.262***	-0.196***	-0.134***	0.072
	[0.10]	[0.07]	[0.07]	[0.05]	[0.04]	[0.07]
Krippner (2015)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.383**	-0.315**	-0.261**	-0.215**	-0.171**	0.003
	[0.15]	[0.12]	[0.11]	[0.09]	[0.07]	[0.10]
Inflation compensation (no correction for risk, liquidity and inflation risk premia)						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.969***	-0.658***	-0.467***	-0.361***	-0.279***	0.085
	[0.33]	[0.21]	[0.15]	[0.12]	[0.09]	[0.09]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.413***	-0.329***	-0.266***	-0.205***	-0.151***	0.035
	[0.08]	[0.07]	[0.07]	[0.06]	[0.05]	[0.05]
Krippner (2015)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.381**	-0.302**	-0.257**	-0.219**	-0.185***	-0.037
	[0.15]	[0.13]	[0.11]	[0.09]	[0.06]	[0.08]

Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the coefficient of the interaction variable is reported. Complete tables are available from the authors upon request.

Table A10 - Robustness: Alternative sample and specifications

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
Estimation subsample ending in February 2009						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-1.176**	-0.695*	-0.492*	-0.411*	-0.345*	0.043
	[0.58]	[0.36]	[0.28]	[0.23]	[0.18]	[0.17]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.144	-0.278	-0.270*	-0.195	-0.109	0.132**
	[0.36]	[0.20]	[0.15]	[0.12]	[0.10]	[0.05]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.633	-0.586*	-0.515**	-0.409**	-0.290**	0.211**
	[0.45]	[0.31]	[0.24]	[0.18]	[0.13]	[0.10]
Estimation subsample ending in July 2013						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.349	-0.226	-0.176	-0.157	-0.132*	0.095
	[0.22]	[0.14]	[0.12]	[0.10]	[0.08]	[0.18]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.406**	-0.368***	-0.315***	-0.248***	-0.175***	0.091
	[0.20]	[0.11]	[0.08]	[0.06]	[0.06]	[0.08]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.404***	-0.354***	-0.305***	-0.259***	-0.203***	0.044
	[0.15]	[0.10]	[0.08]	[0.06]	[0.05]	[0.13]
Projection surprises interpolated						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.075	-0.001	0.034	0.032	0.012	-0.123**
	[0.12]	[0.09]	[0.09]	[0.07]	[0.05]	[0.06]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.224***	-0.179**	-0.148**	-0.122**	-0.094**	0.043*
	[0.08]	[0.07]	[0.07]	[0.06]	[0.04]	[0.03]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.039	-0.119	-0.136*	-0.121**	-0.097**	0.009
	[0.12]	[0.08]	[0.07]	[0.05]	[0.04]	[0.04]
Projections interpolated						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.341***	-0.194**	-0.131	-0.108	-0.096*	-0.074
	[0.08]	[0.09]	[0.10]	[0.08]	[0.05]	[0.08]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.191***	-0.158***	-0.133***	-0.104**	-0.071**	0.060**
	[0.06]	[0.05]	[0.05]	[0.04]	[0.03]	[0.03]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.253**	-0.236**	-0.213**	-0.177**	-0.139**	0.017
	[0.10]	[0.10]	[0.09]	[0.08]	[0.06]	[0.06]
Raw projections						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.058	-0.085***	-0.081***	-0.061***	-0.038***	0.035**
	[0.04]	[0.02]	[0.02]	[0.02]	[0.01]	[0.02]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.134*	-0.109**	-0.089*	-0.070*	-0.050*	0.036**
	[0.07]	[0.05]	[0.05]	[0.04]	[0.03]	[0.02]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.130**	-0.100*	-0.088*	-0.071*	-0.054*	-0.021
	[0.06]	[0.05]	[0.05]	[0.04]	[0.03]	[0.03]

Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the coefficient of the interaction variable is reported. Complete tables are available from the authors upon request.

Table A11 - Robustness: Alternative specifications

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
No controls						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.374**	-0.239**	-0.187*	-0.177*	-0.168*	-0.014
	[0.17]	[0.11]	[0.10]	[0.10]	[0.09]	[0.13]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.336***	-0.274***	-0.235***	-0.198***	-0.153***	0.026
	[0.10]	[0.09]	[0.08]	[0.07]	[0.05]	[0.06]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.348***	-0.285**	-0.257**	-0.237**	-0.206***	-0.043
	[0.13]	[0.12]	[0.11]	[0.09]	[0.08]	[0.10]
No output projections						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.397*	-0.246*	-0.173*	-0.142	-0.113	0.064
	[0.21]	[0.13]	[0.10]	[0.09]	[0.07]	[0.14]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.353***	-0.305***	-0.258***	-0.203***	-0.144***	0.079
	[0.12]	[0.08]	[0.07]	[0.06]	[0.04]	[0.06]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.279**	-0.250**	-0.221**	-0.188**	-0.148**	0.064
	[0.14]	[0.11]	[0.10]	[0.08]	[0.06]	[0.11]
Including a VAT dummy						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.428**	-0.270**	-0.193*	-0.161*	-0.131*	0.063
	[0.20]	[0.12]	[0.10]	[0.09]	[0.07]	[0.15]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.368***	-0.306***	-0.256***	-0.201***	-0.143***	0.078
	[0.10]	[0.08]	[0.08]	[0.06]	[0.04]	[0.06]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.338**	-0.280**	-0.243**	-0.208**	-0.167***	0.054
	[0.14]	[0.11]	[0.10]	[0.08]	[0.06]	[0.11]
Including dummies for FG dates						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.433**	-0.272**	-0.195*	-0.162*	-0.132**	0.062
	[0.21]	[0.13]	[0.10]	[0.09]	[0.07]	[0.15]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.341***	-0.295***	-0.249***	-0.194***	-0.135***	0.082
	[0.12]	[0.08]	[0.07]	[0.06]	[0.04]	[0.07]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.301**	-0.266***	-0.233***	-0.199***	-0.156***	0.062
	[0.13]	[0.10]	[0.09]	[0.07]	[0.06]	[0.12]

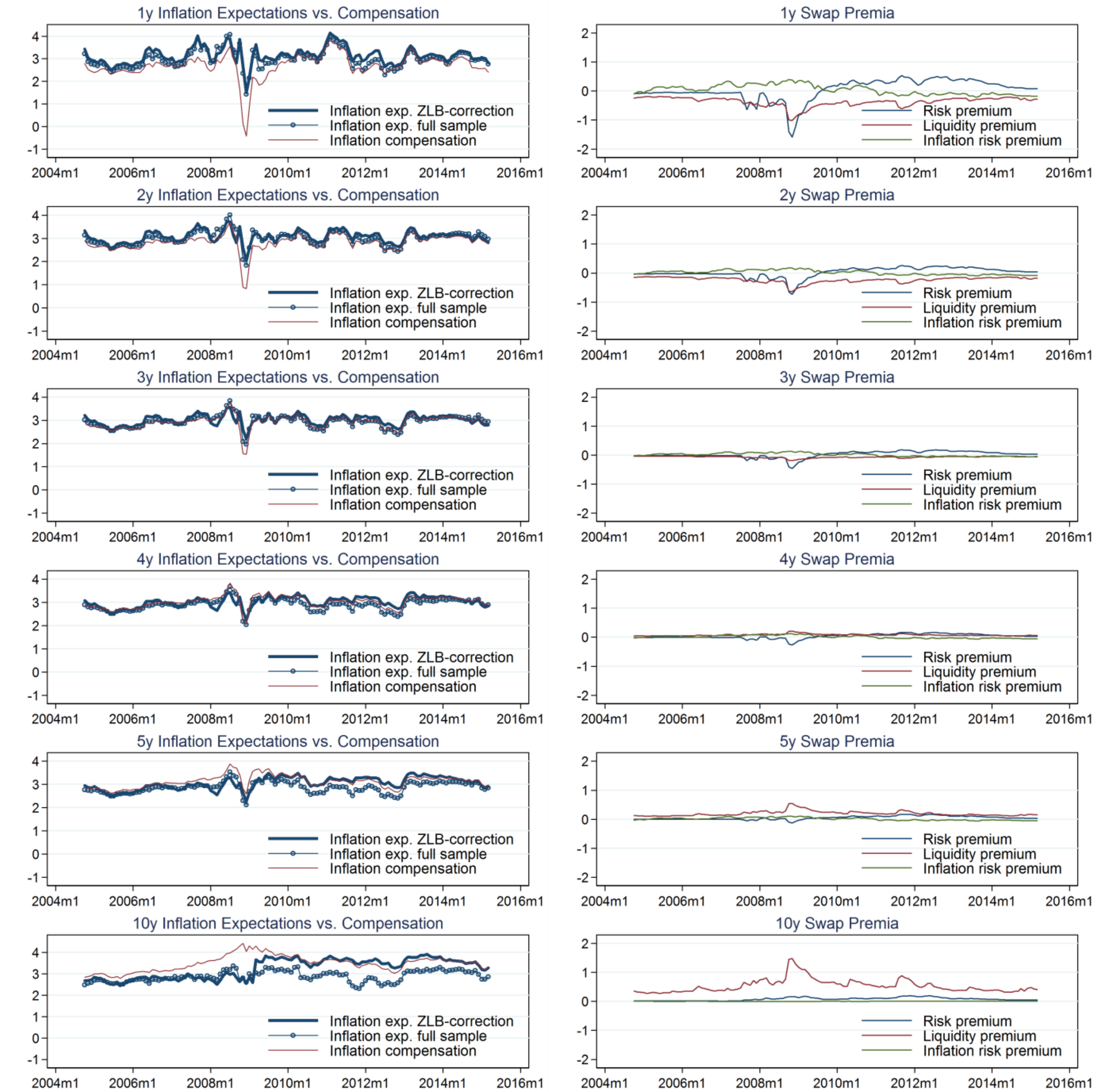
Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the coefficient of the interaction variable is reported. Complete tables are available from the authors upon request.

Table A12 - Robustness: Miscellaneous

	1	2	3	4	5	6
	PF_1y	PF_2y	PF_3y	PF_4y	PF_5y	PF_10y
Including EC sentiment measures						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.396*	-0.251*	-0.179*	-0.152*	-0.126*	0.078
	[0.22]	[0.13]	[0.10]	[0.08]	[0.07]	[0.15]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.305**	-0.286***	-0.247***	-0.194***	-0.135***	0.086
	[0.12]	[0.08]	[0.07]	[0.06]	[0.04]	[0.06]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.277**	-0.258***	-0.229***	-0.193***	-0.149***	0.048
	[0.13]	[0.09]	[0.08]	[0.07]	[0.05]	[0.11]
Change in private output and interest rate forecasts between *t-1* and *t*						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.473*	-0.304*	-0.223*	-0.185*	-0.152*	0.038
	[0.25]	[0.16]	[0.13]	[0.10]	[0.08]	[0.11]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.448***	-0.329***	-0.259***	-0.200***	-0.138***	0.136
	[0.12]	[0.10]	[0.09]	[0.07]	[0.05]	[0.09]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.325***	-0.263**	-0.223**	-0.190**	-0.150**	0.08
	[0.12]	[0.10]	[0.09]	[0.07]	[0.06]	[0.12]
More controls						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.327*	-0.231*	-0.16	-0.121	-0.085	0.112
	[0.19]	[0.13]	[0.11]	[0.09]	[0.08]	[0.16]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.222*	-0.189**	-0.137**	-0.096	-0.055	0.136*
	[0.12]	[0.08]	[0.07]	[0.06]	[0.06]	[0.07]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.254*	-0.173*	-0.122	-0.102	-0.085	0.048
	[0.15]	[0.10]	[0.08]	[0.07]	[0.06]	[0.10]
More lags of the dependent variable						
BoE's UK shadow rate						
BoE_ShadowRate * BoE_cpi_4	-0.349	-0.201	-0.150	-0.108	-0.067	0.025
	[0.21]	[0.17]	[0.14]	[0.12]	[0.08]	[0.12]
Wu and Xia (2016)'s UK shadow rate						
BoE_ShadowRate1 * BoE_cpi_4	-0.488***	-0.352***	-0.267**	-0.216**	-0.157***	0.08
	[0.16]	[0.12]	[0.10]	[0.08]	[0.05]	[0.07]
Krippner (2013, 2014)'s UK shadow rate						
BoE_ShadowRate2 * BoE_cpi_4	-0.262	-0.265**	-0.258**	-0.212**	-0.150***	0.027
	[0.19]	[0.13]	[0.10]	[0.08]	[0.06]	[0.12]

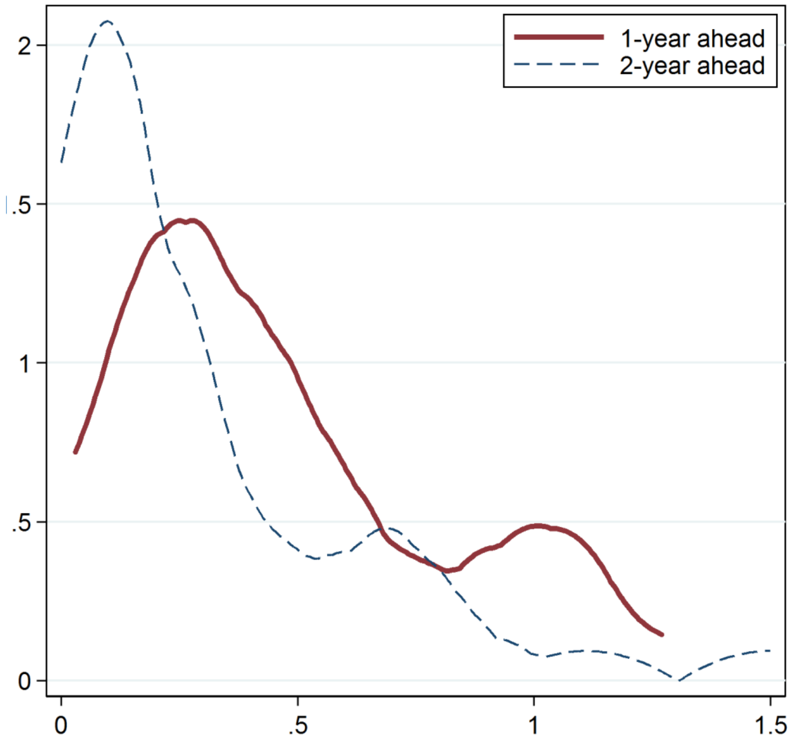
Heteroskedasticity and autocorrelation robust Newey-West standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Each column corresponds to equation (6) estimated for a different horizon with OLS. For parsimony, only the coefficient of the interaction variable is reported. Complete tables are available from the authors upon request.

Figure A1 – Raw and corrected inflation expectations (in %) and the predicted values of the three premia (in pp)



Note: The first row is for 1-year ahead inflation expectations, the second for 2-years ahead, and so on. Inflation expectations with the ZLB correction correspond to the upper two panels of Table A3 whereas inflation expectations estimated on the full sample correspond to the lower panel of Table A3. The different premia on the right-hand are the full sample ones.

Figure A2 – Kernel densities of the absolute value of deviations of BoE's inflation projections from the BoE's inflation target



Note: A kernel density produces a smoothed estimate of the probability density function. The y-axis unit of the probability density function is the reciprocal of the x-axis unit of the variable considered: the absolute value of the deviation of BoE's inflation projections at a given horizon to the BoE's inflation target: 2%.