Conformism and Inflation Expectations Surveys

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Abstract

We investigate the implications of strategic behaviour among professional forecasters when responding to surveys about their inflation expectations. We posit the existence of a desire for conformism among the survey respondents and show that its presence affects the signal about future inflation that monetary authorities extract from survey responses.

Keywords: conformism, inflation rate, central bank, information

JEL classification: D82, E31, E37, E58

1. Introduction

Inflation expectations are central to modern macro-economic theory and monetary policy (Gali, 2008; Sims, 2009). How economic agents form these expectations has long been one of the most fundamental, and most debated, questions in macroeconomics. Indeed, national surveys of public inflation expectations are conducted in multiple countries[1] by central banks to ascertain the nature of the expectations formation process. For firms, inflation expectations have an impact on wage negotiations, price setting and financial contracting for investment; for households, expectations affect consumption and savings decisions. For example, if workers expect an increase in the prices they currently face, they will ask for wage adjustments now, and entrepreneurs will ask for adjustments of the prices of their goods or services. Given the importance of inflation expectations for central banks and for all decision makers in the economy, it is not surprising that much research has been done to shed light on how agents form their inflation expectations (Keane and Runkle, 1990; Roberts,

[1]US: Reuters/University of Michigan Survey of Consumers, the Livingston Survey, the Conference Board's Consumer Confidence Survey and the Survey of Professional Forecasters. Other central banks also have survey of public inflation expectations: Bank of England, the European Central Bank, the Bank of Japan, the Reserve Bank of India, the Sveriges Riksbank, the Bank of Canada.

1997; Croushore, 1997; Thomas, 1999; Mehra, 2002; Mankiw et al., 2003; Andolfatto et al., 2008; Castelnuovo, 2010; Adam and Padula, 2011; Del Negro and Eusepi, 2011; Fuhrer, 2011; Coibion and Gorodnichenko, 2012).

This line of research concentrates on some characteristics of inflation expectations, such as how much expectations matter, whether they are adaptive or rational, and how quickly they respond to economic shocks. For example, Mankiw et al. (2003), Mehra (2002), Thomas (1999), Roberts (1997), and Croushore (1997) consider whether measured inflation expectations are rational, i.e whether economic agents make systematic errors when forecasting inflation. They focus on a key characteristic of rationality, namely, rational expectations should be unbiased.

While the economic and statistical properties of inflation expectations have been widely discussed in the literature, little is known about a potential strategic behavior among professional forecasters and how it may affect inflation expectations data. It is generally understood that economic forecasters may have incentives to act strategically in the sense of seeking to enhance their reputations (Ehrbeck and Waldmann, 1996; Laster et al., 1999; Lamont, 2002). For example, Croushore (1997) argued that some survey respondents might direct their forecasts more toward the consensus to avoid unfavorable publicity when wrong, while others might make unusually bold forecasts, hoping to stand out from the crowd. Laster et al. (1999) postulate that forecasters' wages are based on two criteria: their accuracy and their ability to generate publicity for their firms, while Ehrbeck and Waldmann (1996) suppose that forecasters compromise between minimizing errors and mimicking predictions patterns typical for able forecasters. There are some studies that have statistically tested the existence of conformism among professional forecasters (Clements, 2015; Pierdzioch et al., 2016). For example, Clements (2015) uses a herding test developed by Bernhardt et al. (2006) to show that the US Survey of Professional Forecasters (SPF) tend to herd at the shortest horizons (one quarter ahead), but tend to exaggerate in their differences for the longer forecast horizons.

In this paper, we investigate the implications of strategic behavior among forecasters for the evaluation and use of inflation expectations data. The specific strategic behavior that we focus on is conformism among forecasters. Conformism arises when forecasters rely not only on private information when forming their inflation forecasts, but also on the forecasts of other forecasters, (Pierdzioch et al., 2016). For this purpose, we address the question: How does a conformism behavior among forecasters affect the signal about future inflation that monetary authorities extract from survey responses?

We develop a model where a finite number of experts are asked to make point predictions about the rate of inflation. The experts' payoff is a function of their prediction's accuracy, but it also affected by their desire not to deviate too much from the prediction of the other experts. The expert's information set consists of two signals, one publicly and commonly observed by all the experts and another privately observed. Assuming a setting with bayesian static game, we solve for the expert's predictions, as a function of the model's fundamentals. Three main results emerge from the analysis. First, the experts' reported predictions are a convex combination of the public signal and their private one, with degree of conformism leading to increases in the weight of the public signal in reported predictions. Second, the mean of prediction is not affected by conformism but the variance of the predictions, however, decreases as conformism increases, which implies that the presence of conformism leads to forecasts with lower mean-squared deviations. This is particularly true in period of high volatility. Third, we show that conditional of having observed all reported experts' predictions, the posterior distribution of inflation is a normal distribution whose mean is very sensitive to the gap between the average prediction and the public signal. Under high level of conformism, the desire to coordinate on a common prediction will imply that experts report a value close to the public signal even if their private signals depart significantly from it. A central bank that ignores conformism could therefore incorrectly infer that the experts' signals are close to the public one.

The paper contributes to the literature on inflation expectations by introducing strategic behavior among respondents in expectations formation process. We analyze the impact of conformism on experts' expectations and on central bank interpretation of these expectations. It is also related to the literature on strategic behavior in the spirit of the Keynes (1996) "beauty contest". The papers closest in spirit to ours are that of Morris and Shin (2002) and Desgranges and Rochon (2008). Morris and Shin (2002) examine the impact of public information in a setting where agents take actions appropriate to the underlying fundamentals, but they also have a coordination motive arising from a strategic complementarity in their actions. Here, we focus on the effect of conformism on expectations and on their interpretation by the central bank, while Morris and Shin (2002) concentrate on the impact of strategic behavior on the welfare. Desgranges and Rochon (2008) analyze the implications of conformism among analysts in a CARA Gaussian model of the market for a risky asset, where a trader's information is a message sent by an analyst. In our paper, as in theirs, the results are driven by an overweighing of the public signal under conformism.

The rest of the paper is structured as follows. Surveys design and data are describe in 2. In Section 3, we present our conformism model and derive some theoretical results. Section 4 presents an empirical evidence and Section 5 concludes.

2. Data

We analyze two sources of data on inflation expectations: the Livingston Survey and the Survey of Professional Forecasters (SPF), both conducted by Federal Reserve of Philadelphia. The Livingston Survey was initiated by Joseph Livingston in june 1946, and reports the forecasts of 18 different variables describing national output, prices, unemployment, and other macroeconomic variables. The population of the survey is made of economists from Nonfinancial Businesses, Investment Banking, Academic Institution, Insurance companies, and Government. In this paper, we focus on inflation expectations on a 12-month horizon. The SPF is very similar to the Livingston Survey. Its specificity is that the population of SPF is economists for whom forecasting is major part of their job. SPF was begun in 1968, but CPI inflation was added to the questionnaire during the 3^{rd} quarter of 1981.

The Livingston survey is conducted twice a year, in june and december. The questionnaires are sent to the forecasters in may and november, after the release of CPI data for april and october and are due back in early june and december before the release of CPI data for may and november. As forecasters do not yet know the inflation in may (for the june survey) and the november (for december survey), we will assume, following Carlson (1977), that they base their forecasts on information available in april and october. This assumption implies that forecasts cover a fourteen-month span, from may of year in which the survey is conducted to june for the following year and from november to december (for two surveys respectively). Then, even if the forecast is called twelve-month forecast, it covers fourteen months. In the questionnaire, participants are requested to forecast CPI level rather than inflation rates. We then calculate the change in the CPI over the forecasts horizon using the formula :

$$\mathbb{E}_{t-14}(\pi_t) = 100 \left\{ \left[\frac{\mathbb{E}_{t-14}(CPI_t)}{CPI_t} \right]^{\frac{12}{14}} - 1 \right\} \tag{1}$$

where π_t is annualized rate of inflation, $\mathbb{E}_{t-14}(\pi_t)$ is the inflation rate expected for date t based on information available at $t-14$. $t-14$ represents april for the june survey and october for the december survey. This is geometric average, taking 14^{th} root provides an estimated of the expected monthly rate of inflation, and raising to the 12^{th} power expresses expected inflation rate at an annual rate.

SPF is performed quarterly and questionnaires go out at the end of the first month of each quarter after the government's release of quarterly data. Unlike Livingston Survey, SPF asks directly the CPI inflation rate rather than CPI level. Forecasters know the value of inflation rate for the quarter prior to the quarter in which survey is conducted when they submit their projections. They are asked to forecast inflation rate for current quarter (quarter in which survey is conducted) and for the four following quarters. This means that their provides forecasts for five quarters, at each quarter. For our analysis, we will use the one-year-ahead expectations, which are annual averages, in annualized percentage points, over the four quarters following the quarter of the survey. The formula is given by:

$$\mathbb{E}_{t-3}(\pi_{t+9,t-3}) = 100\left\{\left[\left(1+\frac{\mathbb{E}_{t-3}(\pi_t)}{100}\right)\left(1+\frac{\mathbb{E}_{t-3}(\pi_{t+3})}{100}\right)\left(1+\frac{\mathbb{E}_{t-3}(\pi_{t+6})}{100}\right)\left(1+\frac{\mathbb{E}_{t-3}(\pi_{t+9})}{100}\right)\right]^{\frac{1}{4}} - 1\right\} \tag{2}$$

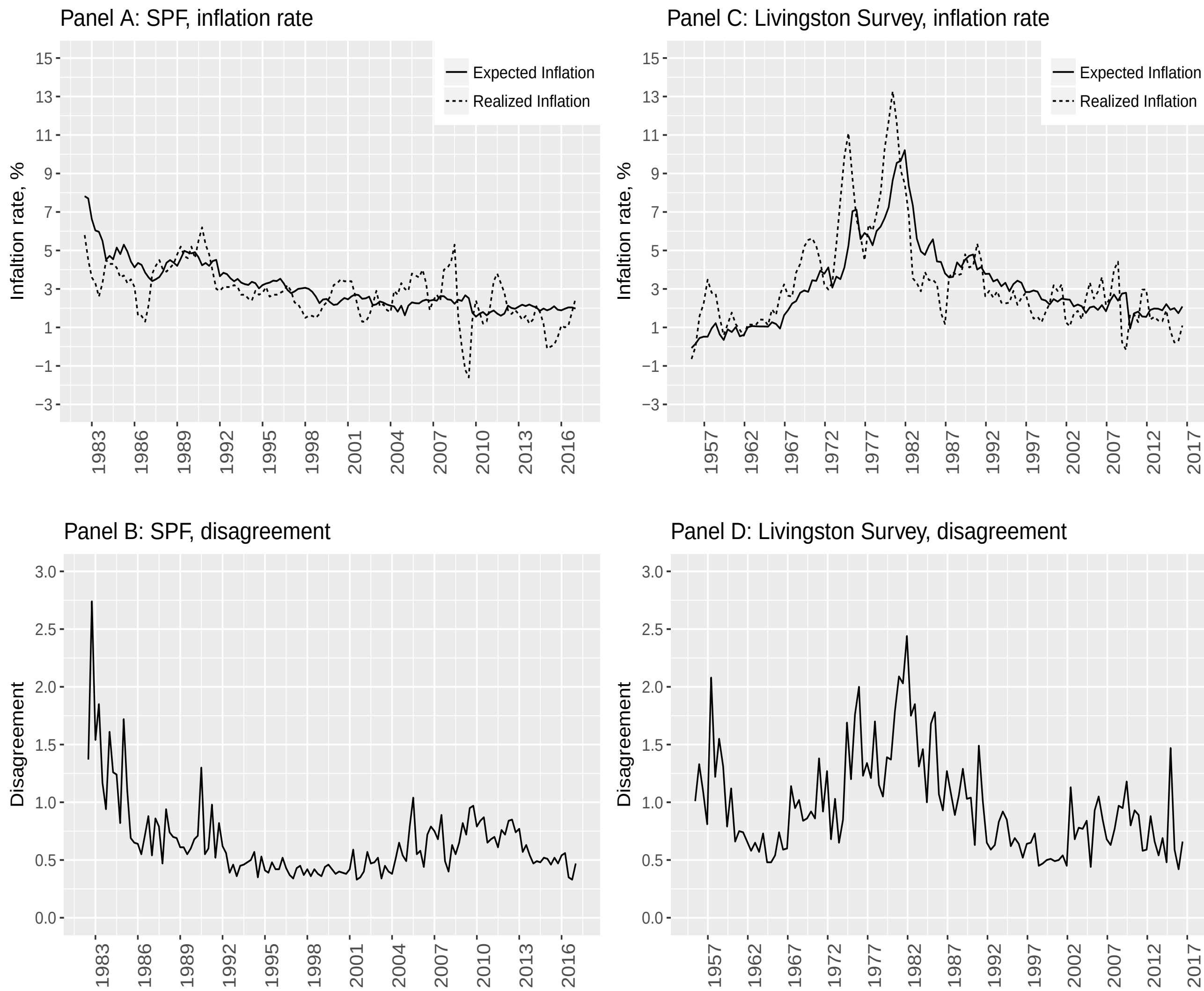
where $\mathbb{E}_{t-3}(\pi_t)$, $\mathbb{E}_{t-3}(\pi_{t+3})$, $\mathbb{E}_{t-3}(\pi_{t+6})$, and $\mathbb{E}_{t-3}(\pi_{t+9})$ are the inflation rate expected for the four quarters following the quarter in which the survey is conducted.

Panels A and C in figure 1 present time series of realized inflation and median expected inflation for SPF and the Livingston survey. The realized inflation rate is calculated using the formula (1) (for Livingston survey) and (2) (for SPF) on the real-time CPI data[2]. The horizontal axis refers to expectations at the endpoint of the relevant forecast horizon rather than the time the forecast was made. We observe that both the SPF and the Livingston survey appear to predict inflation reasonably well, although they often fail to match periods of low inflation. The difference between realized and forecast inflation is fairly persistent for two series. Panels B and D show the disagreement within respondents for our inflation expectations series. The disagreement is measured as in Coibion and Gorodnichenko (2012) by standard deviation. The extent of disagreement within each of these surveys varies dramatically over time.

Forecast disagreement is high at the beginning of the sample for SPF participants (between 1982 and 1985), and becomes low by 1892, but it stays relatively the same for the rest of sample. The level of disagreement is higher for Livingston survey than SPF. This may be due to the cross-sectional heterogeneity in Livingston survey participants. In fact, the participants of Livingston survey are composed of all categories of economist (banking, government, academic); while the SPF participants are economists for whom forecasting is major part of their job. Then, SPF respondents are more homogeneous.

[2]We use real time CPI data from Saint Louis FED

Figure 1: Time series: Inflation rate



3. The Model

We present a model where a finite number of experts are asked to make point predictions about the rate of inflation. Experts are concerned about giving accurate predictions, but do not want to deviate too much from the other experts' predictions. The game goes as follows:

1. At each period t, nature chooses next period's inflation rate s^{t+1} from a distribution S. We assume that S is common knowledge and that $\mathbb{E}|s^{t+1}|^2 < \infty$. In essence, S represents the prior

information about the true inflation rate and can be a function of the current inflation rate.

2. Each expert independently receives a signal θ_i^t from a distribution $\Theta(s^{t+1})$ where $\mathbb{E}\theta_i^t = s^{t+1}$ and that $\mathbb{E}|\theta_i^t|^2 < \infty$ for all i. We assume that Θ is common knowledge (conditional on s^{t+1}, which is unobserved). Note that $\mathbb{E}\theta_i^t = s^{t+1}$ reflects the fact that the experts are non-biased.

3. Experts are simultaneously asked to provide a prediction p_i^t of s^{t+1} given their private information θ_i^t.

Restricting the message space to a single prediction p_i^t allows for a better representation of the reality and simplify the analysis by abstracting from strategic concerns between the principal and the experts (as for instance in Ottaviani and Sørensen (2006a)). We assume that the experts' payoff is given by:

$$U(p_i^t, p_{-i}^t, \theta_i^t) = \mathbb{E}_s \mathbb{E}_{\theta_{-i}} \frac{-(1-\alpha)}{2} \left[p_i^t(\theta_i^t) - s^{t+1}\right]^2 + \frac{-\alpha}{2(n-1)} \sum_{j \neq i} \left[p_i^t(\theta_i^t) - p_j^t(\theta_j^t)\right]^2 |\theta_i^t \tag{3}$$

for $\alpha \in [0,1]$. The first part of the payoff function reflects the fact that experts want to report a prediction that is as close as possible to their true (posterior) beliefs about next period's inflation rate. The second part of the payoff function reflects the fact that experts do not want to deviate too much from the predictions of the other experts.

We now turn to the analysis of the game. We assume that the predictions (i.e. the players' strategies) $p_i^t(\theta_i^t)$ are in $\mathcal{L}^2$ for all i[3] We have the following:

Proposition 1.

1. *If $\alpha = 1$, there is an infinity of Bayesian Nash equilibria. In particular, any solution of the form $p_i^t(\theta_i^t) = p_j^t(\theta_j^t) = p^*$ for all i, j is an equilibrium.*

2. *If $\alpha \in [0,1)$, there exists a unique Bayesian Nash equilibrium. Moreover, it is symmetric in the sense that $p_i^*(\theta_i^t) = p^*(\theta_i^t)$ for all i and such that:*

$$p^t(\theta_i^t) = (1-\alpha)\mathbb{E}s^{t+1}|\theta_i^t + \alpha \mathbb{E}p^t(\theta_j^t)|\theta_i^t \tag{4}$$

If experts do not care at all about the true inflation rate and only want to report the same thing as the other experts, then any prediction (predicted by all experts) is an equilibrium. However, if experts do care about the true inflation rate, the (expected) inflation rate acts as a coordination device, and there is a unique equilibrium.

The fact that there is a unique equilibrium for $\alpha \in [0,1)$ is important for the predictive power of the model. However, there is *a priori* no guarantee that this equilibrium is unbiased. It turns out that

[3]This assumption, together with the moment restrictions on S and Θ ensure that the payoff function (3) is well defined.

it is the case, although is a very specific way. Since experts coordinate around the expected inflation rate, they, together, provide an unbiased prediction. Formally:

Proposition 2. *Assume that* $\alpha \in [0, 1)$*, we have*

1. $\mathbb{E}p^*(\theta_i^t) = \mathbb{E}s^{t+1}$

2. $Var(p^*(\theta_i^t)) \leq Var(\mathbb{E}s^{t+1}|\theta_i^t)$

Note that in the first part of proposition 2, the first expectation is taken over prediction: *ex ante*, the expected prediction is equal to the expected inflation rate. The second part of proposition 2 is typical of conformism games: conformism reduces the variance of the predictions. Indeed, recall that when $\alpha = 0$, we have $p^*(\theta_i^t) = \mathbb{E}s^{t+1}|\theta_i^t$. It is also worth noting that the inequality in this second part of proposition 2 is strict whenever $\alpha \in (0, 1)$ and the distribution of θ_i^t is not degenerated and informative about s^t.

Propositions 1 and 2 hold for any distributions. In the next section, we make additional distributional assumptions in order to obtain closed-form solutions and proceed to the empirical implementation.

3.1. An Empirical Application - Normal Disturbances

We now put a little more structure on the model. Let $\mathbf{x}^t$ be a series of observables at time t and $\mathbf{s}^{t-1} = \{s^\tau\}_{\tau=-\infty}^{t-1}$ be the previous inflation rates. The inflation rate at time t is given by

$$s^{t+1} = \phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right) + \varepsilon^{t+1} \tag{5}$$

where

$$\varepsilon^{t+1} \sim \mathcal{N}(0, \sigma_\varepsilon^2).$$

For example, ϕ can be an AR (1), or an AR (2), or any specification giving a good prediction of inflation rate.

Equation (5) can be interpreted as the model used by the central bank to predict inflation rate. We also assume that it represent the public information known by experts before receiving their private signal.

We assume that the experts' signal is given by

$$\theta_i^t = s^{t+1} + \nu_i^t \tag{6}$$

where $\nu_i^t \sim \mathcal{N}(0, \sigma_\nu^2)$. All signals have the same precision, but every expert observes a different signal. The use of normal disturbances is convenient since they are conjugate distributions and admit a normally distributed posterior distribution. Moreover, assuming normally distributed inflation rates and signals, we can find the experts'predictions, as an explicit function of the model's fundamentals. Specifically, can compute $s^{t+1}|\theta_i^t$ using Bayes' rule:

$$f(s^{t+1}|\theta_i^t) \sim \mathcal{N}\left(\gamma\theta_i^t + (1-\gamma)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right), \sigma_T^2\right)$$

where $\gamma = \dfrac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \sigma_\nu^2}$ and $\sigma_T^2 = \left(\dfrac{1}{\sigma_\varepsilon^2} + \dfrac{1}{\sigma_\nu^2}\right)^{-1}$

We can also find the experts' prediction function (4) in close form. Using a "guess and verify" approach, we have (see Appendix for details):

$$p^*(\theta_i^t) = \frac{\sigma_\varepsilon^2(1-\alpha)}{\sigma_\varepsilon^2(1-\alpha)+\sigma_\nu^2}\theta_i^t + \frac{\sigma_\nu^2}{\sigma_\varepsilon^2(1-\alpha)+\sigma_\nu^2}\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right) \tag{7}$$

An expert's prediction is therefore a convex combination between his private signal and the public signal. Note that the weight on the private signal decreases as the conformism increases. This means that as conformism increases, the experts put more weight of the public signal, and less on their private signal. Under extreme conformism ($\alpha = 1$), all experts predict the public signal ϕ. Any decrease in σ_ε^2 (or any increase of the precision of the public signal) reinforces the conformist behavior of experts: the weight on public signal increases and the weight on private signal decreases (the opposite holds for a decrease in σ_ν^2). The higher the variance of the public signal (σ_ε^2) relative to the variance of the private signal (σ_ν^2) the higher is the weight experts put on the private signal.

As stated in Proposition 2, conformism reduces the variance of the predictions. Here, we can easily compute:

$$Var(p^*(\theta_i^t)) = \left(\frac{(1-\alpha)\sigma_\varepsilon^2}{\sigma_\nu^2 + (1-\alpha)\sigma_\varepsilon^2}\right)^2 \sigma_\nu^2 \tag{8}$$

We obtain a stronger result than the one in Proposition 2 which is that $Var(p^*(\theta_i^t))$ is strictly decreasing in $\alpha \in (0,1)$. Then, since conformism reduces the variance of predictions, it prevents the bank from observing extreme values. This is particularly true in period of high volatility, i.e. when σ_ε^2 or σ_ν^2 are larger.[4] Then, the conformism has more impact on the predictions in periods of high volatility than in times of stability.

3.1.1. The Bank's Posterior Beliefs

We now investigate the properties of the information revealed by expert to the central bank, in particular, the influence of the degree of conformism α.

[4] Indeed, $\dfrac{\partial}{\partial\alpha}\left[\dfrac{\partial Var(p^*(\theta_i^{t-1}))}{\partial\sigma_\varepsilon^2}\right] < 0$.

Since we focus on normal disturbances, we can obtain the Bank's posterior in closed form. The posterior distribution of inflation rate given the experts' predictions $\{p_i\}_i$ and assuming a known conformism level α is $\mathcal{N}(\mu_{s^{t+1}}, \sigma^2_{s^{t+1}})$ (see Appendix), where

$$\mu_{s^{t+1}} = \frac{N\sigma_\varepsilon^2 \left[(1-\alpha)\sigma_\varepsilon^2 + \sigma_\nu^2\right] \left[\bar{p} - \phi(\mathbf{s}^t, \boldsymbol{x}^t)\right]}{\sigma_\varepsilon^2(1-\alpha)(N\sigma_\varepsilon^2 + \sigma_\nu^2)} + \phi(\mathbf{s}^t, \boldsymbol{x}^t) \tag{9}$$

and

$$\sigma^2_{s^{t+1}} = \frac{\sigma_\nu^2 \sigma_\varepsilon^2}{N\sigma_\varepsilon^2 + \sigma_\nu^2}$$

The variance of inflation $\sigma^2_{s^{t+1}}$ is not affected by the degree of conformism α. Indeed, if the Bank knows the level of conformism, it can back out the value of the experts' private signals using (7). Similarly, using (7), one can rewrite $\mu_{s^{t+1}}$ as a function of the private signals.[5]

That being said, the specification in (9) allows to see the impact of conformism on the Bank's posterior beliefs. Indeed, the posterior mean depends on the difference between the average prediction of experts and the public signal (i.e. $\bar{p} - \phi(\mathbf{s}^{t-1}, \boldsymbol{x}^t)$). If this difference is positive (negative), the posterior mean is higher (lower) than the public signal.

The level of conformism α impacts how much the Bank should weight the difference between the average experts' prediction and the public signal.[6] When conformism is high, small difference between $\bar{p}$ and $\phi(\mathbf{s}^t, \boldsymbol{x}^t)$ are more important. Indeed, conformism reduces probability of receiving predictions that differ too much from the public signal. Then, when the average prediction do differs from the public signal, it implies that some of the experts received extreme private signals. *Then, if the Bank suspects a high level of conformism from the experts, it should be very wary when the experts' average prediction differs from their in-house prediction.*

4. Empirical evidence

In the previous section, we show that conditional of having observed all reported experts' predictions, the posterior distribution of inflation is a normal of mean $\mu_{s^{t+1}}$ and variance $\sigma^2_{s^{t+1}}$. In this section, we find the level of conformism α and the variance of private signal σ_ν^2 that maximize the performance of bank posterior distribution using the SPF and the Livingston survey. The density function of inflation given experts'predictions is given by:

$$f(s^1, \ldots, s^T | p^{1:T}_{i=1:N}) = \prod_t^T f(s^{t+1} | p^t_{i=1:N})$$

[5] That is: $\mu_{s^{t+1}} = \frac{N\sigma_\varepsilon^2\bar{\theta} + \sigma_\nu^2\phi(\mathbf{s}^t, \boldsymbol{x}^t)}{N\sigma_\varepsilon^2 + \sigma_\nu^2}$

[6] Note that: $\frac{\partial}{\partial\alpha} \frac{N\sigma_\varepsilon^2\left[(1-\alpha)\sigma_\varepsilon^2 + \sigma_\nu^2\right]}{\sigma_\varepsilon^2(1-\alpha)(N\sigma_\varepsilon^2} > 0$.

The log-likelihood is given by:

$$L(s^1,\dots,s^T,\alpha,\sigma_\nu) = -\frac{T}{2}\log(2\pi\sigma^2_{s^{t+1}}) - \frac{1}{2\sigma^2_{s^{t+1}}}\sum_t^T (s^{t+1}-\mu_{s^{t+1}})^2 \tag{10}$$

4.1. Estimation of public signal

Before estimation of the parameters of interest, we need to specify an explicit form for $\phi(\mathbf{s}^t, \boldsymbol{x}^t)$, our inflation forecasting model. Stock and Watson (2008) distinguishes four groups of single-equation inflation forecasting models: (1) forecasts based solely on past inflation; (2) forecasts based on activity measures (Phillips curve forecasts); (3) forecasts based on the forecasts of others; and (4) forecasts based on other predictors. They show that the performance of these forecasting models is episodic, each of them does sometimes better than and sometimes worse than others. To illustrate our theoretical model, we will focus on the first group, especially ARIMA models which are generalizations of the simple auto regressive (AR). We compute out-of-sample forecasts using the whole set of ARIMA models with AR lags ranging from 1 to 4 and MA terms ranging from 0 to 4. The criteria to select the models are Bayesian Information Criteria (BIC). Ljung-Box autocorrelation test for ARIMA residuals is done to ensure that residuals are independent.

The question about CPI inflation was introduced in the SPF in 3^{rd} 1981. We then suppose that experts observed past inflation rate until Q3 1981 when forming their forecast in Q3 1981. The first estimation sample starts in Q1 1960 and ends in Q3 1981 in order to produce forecasts for Q3 1982[7], as in the survey. The next estimation sample is extended for one quarter up to Q4 1981 in order forecast for Q4 1982. This rolling procedure continues until the last observation of the survey. We do the same thing with the Livingston Survey by using monthly data. The forecasts obtained from this procedure represent our $\phi(\mathbf{s}^t, \boldsymbol{x}^t)$. We compare them with expectations from both surveys on figure (2).

We also compute two measures of forecast accuracy: the square root of the average squared error (RMSE) and the mean absolute error (MAE). Table 1 reports the accuracy of the median expectations in each survey, both over their maximal samples, and for a common sample (1982-2015). It also reports the RMSE and MAE of forecasts from the previous estimations. Inflation expectations are relatively accurate in the two surveys compare to the ARIMA model. As expected, for the common sample, SPF forecasts are the most accurate.

[7]We use real data from Federal Reserve of St Louis: Consumer Price Index: Total All Items , Growth Rate Same Period Previous Year, Quarterly, Not Seasonally Adjusted

Figure 2: Time series: Forecasts errors

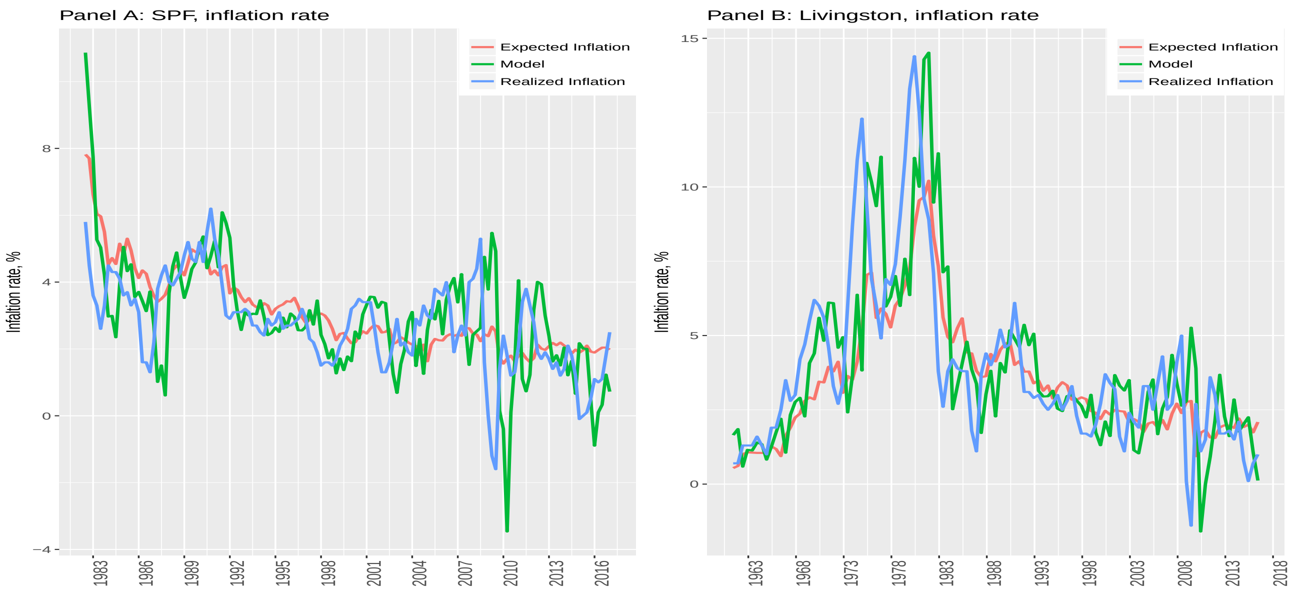


Table 1: Forecast errors

	SPF(1982-2015)	Livingston survey(1982-2015)	Livingston survey(1955-2016)	ARIMA model(1982-2015)
RMSE	1.26	1.28	1.63	1.76
MAE	0.96	1.03	1.2	1.26

4.2. Maximization of the central bank posterior distribution

We find the level of conformism α and the variance of experts' public signal that maximize the performance of bank posterior distribution using the SPF and the Livingston survey. Note that the likelihood is not based in the data, but on the posterior distribution of inflation. So, the estimated α is not the level of conformism in the data. Table 2 reports the coefficients estimates. The reported σ_{ε}^2 represent the residuals variance obtained from the last estimation fo the rolling procedure, which is interpreted as the variance of public signal. For the SPF, this variance is larger than the variance of experts' private signal σ_{ν}^2, meaning that the professional private signal is more informative than the public one. This is not the case for the Livingston survey where $\sigma_\nu^2 > \sigma_\varepsilon^2$. Aslo note that, the private signal of profesional is more precise than those of Livingston participants. This finding is not surprising given that the major part of profesional job is forecasting, so, they are more attentive to macroeconomc aggregate. This is reflected in their predictions which are very close to the realized inflation.

Table 2: Maximization of posterior distribution

	SPF	Livingston survey
α	0.00	0.00
σ_ν^2	0.22***	0.38***
n	134	111
σ_ε^2	0.28	0.29

***p<0.01

5. Conclusion

A crucial aspect of monetary policy is managing inflation expectations. Despite the resurgent focus on the nature of expectation formation process, there is no consensus among economists on how economic agents form their inflation expectations. This paper, focusing on inflation expectations by professional forecasters (SPF) and economists in general (Livingston survey), attempt to contribute to this literature by addressing a new aspect of inflation expectation: the behaviour of respondents. We investigate the implications of conformism among forecasters for the evaluation and use of inflation expectations data in static bayesian game framework. We find that the experts' reported predictions are a convex combination of the public signal and their private one, with degree of conformism leading to increases in the weight of the public signal in reported predictions. We also find that conformism does not affect the mean of experts'predictions, but it reduces their variance. This means that the presence of conformism leads to forecasts with lower mean-squared deviations. This is particularly true in the periods of high inflation volatility. Computing the central bank posterior distribution about inflation, we show that conformism reduces probability of receiving predictions that differ too much from the public signal. Then, when the average prediction do differs from the public signal, it implies that some of the experts received extreme private signals.

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Appendix

PROOF (OF PROPOSITION 1). Since U is strictly concave in p_i^t, the first order conditions are sufficient (conditional on the existence of a maximum, which follows directly from the quadratic shape of the payoff function). They lead to:

$$p_i^t(\theta_i^t) = (1-\alpha)\mathbb{E}s|\theta_i + \frac{\alpha}{n-1}\sum_{j\neq i}\mathbb{E}p_j^t(\theta_j^t)|\theta_i^t \tag{11}$$

If $\alpha = 1$, this reduces to:

$$p_i^t(\theta_i^t) = \frac{1}{(n-1)}\sum_{j\neq i}\mathbb{E}p_j^t(\theta_j^t)|\theta_i^t$$

from which part 1 of the proposition follows trivially.

Assume now that $\alpha \in [0,1)$. Let $\mathcal{P}$ denote the set of functions $P : \mathbb{R}^n \to \mathbb{R}^n$ such that $(\theta_1, ..., \theta_n) \mapsto P(\theta_1, ..., \theta_n)$ and that $P^i(\theta, t)$ is in $\mathcal{L}^2$ for all i. Let $T : \mathcal{P} \to \mathcal{P}$ be such that $T^i(P)$ is given by (11) for all i. Let also $\|P\| = \max_i |p_i(\theta)|_2$, where $|\cdot|_2$ is the $\mathcal{L}^2$-norm.

We first show that T is a contraction on $(\mathcal{P}, \|\cdot\|)$.

We have

$$|T^i(P) - T^i(\tilde{P})|_2 = \frac{\alpha}{(n-1)}|\sum_{j\neq i}\mathbb{E}[p_j(\theta_j) - \tilde{p}_j(\theta_j)|\theta_i]|_2$$

We have then that (from Minkowski's inequality):

$$|T^i(P) - T^i(\tilde{P})|_2 \leq \frac{\alpha}{(n-1)}\sum_{j\neq i}|\mathbb{E}[p_j(\theta_j) - \tilde{p}_j(\theta_j)|\theta_i]|_2$$

which, in turns, implies that (again using Minkowski's (integral) inequality):

$$|T^i(P) - T^i(\tilde{P})|_2 \leq \frac{\alpha}{(n-1)}\sum_{j\neq i}|p_j - \tilde{p}_j|_2$$

and

$$|T^i(P) - T^i(\tilde{P})| \leq \alpha\|P - \tilde{P}\|$$

Finally, since it holds for all i, we have:

$$\|T(P) - T(\tilde{P})\| \leq \alpha\|P - \tilde{P}\|$$

Then, T is a contraction.

This implies that there exist a unique Bayesian Nash equilibrium $P(\theta)$. It remains to show that P is such that $P^i(\theta, t) = p(\theta_i)$ for all i. Assuming that this is true, we can rewrite (11) as:

$$p^t(\theta_i^t) = (1-\alpha)\mathbb{E}s^{t+1}|\theta_i^t + \frac{\alpha}{(n-1)}\sum_{j\neq i}\mathbb{E}p(\theta_j^t)|\theta_i^t \tag{12}$$

Since the problem is symmetric for all $j \neq i$, we have:

$$p^t(\theta_i^t) = (1-\alpha)\mathbb{E}s^{t+1}|\theta_i^t + \alpha\mathbb{E}p^t(\theta_j^t)|\theta_i^t \tag{13}$$

Using the same argument as above, it is easy to see that p is a contraction, so p is also a Bayesian Nash equilibrium of the game. Since there is a unique equilibrium so they must be the same. This completes the proof.

Proof (of Proposition 2). From the proof of proposition 1, we have:

$$p^t(\theta_i^t) = (1-\alpha)\mathbb{E}s^{t+1}|\theta_i^t + \alpha\mathbb{E}p^t(\theta_j^t)|\theta_i^t \tag{14}$$

The first part of the proposition then follows directly from the law of iterated expectations.

For the second part of the proposition, we first establish the following claim:

Claim: For two random variables x and y such that $\mathbb{E}x = \mathbb{E}y = \mu$, we have: $Var((1-\alpha)x + \alpha y) \leq (1-\alpha)Var(x) + \alpha Var(y)$.

Proof: To see this, remark that $Var((1-\alpha)x + \alpha y) = \mathbb{E}((1-\alpha)x + \alpha y)^2 - \mu^2$, which (from Jensen's inequality) implies that $Var((1-\alpha)x + \alpha y) \leq (1-\alpha)\mathbb{E}x^2 + \alpha\mathbb{E}y^2 - \mu^2$. Rewriting, using $\mu^2 = (1-\alpha)\mu^2 + \alpha\mu^2$ completes the proof. □

Using the first part of the proposition, we can apply that claim to (14) so we have:

$$Var[p^t(\theta_i^t)] \leq (1-\alpha)Var[\mathbb{E}s^t|\theta_i^t] + \alpha Var[\mathbb{E}p(\theta_j^t)|\theta_i^t] \tag{15}$$

From the law of total covariance, we have $Var[p^t(\theta_i^t)] \geq Var[\mathbb{E}p^t(\theta_j^t)|\theta_i^t]$, so we also have

$$Var[p^t(\theta_i^t)] \leq (1-\alpha)Var[\mathbb{E}s^t|\theta_i^t] + \alpha Var[p^t(\theta_i^t)] \tag{16}$$

which completes the proof.

Derivation of p_i^t

From equation(4):

$$\begin{aligned} p(\theta_i^t) &= (1-\alpha)\mathbb{E}s^{t+1}|\theta_i^t + \alpha\mathbb{E}\left[A\theta_j^t + B\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)\right]|\theta_i^t \\ &= (1-\alpha)\gamma\theta_i^t + (1-\alpha)(1-\gamma)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right) + A\alpha\mathbb{E}\left(\theta_j^t|\theta_i^t\right) \end{aligned}$$

standard computations show that:

$$f(\theta_j^t|\theta_i^t) \sim \mathcal{N}\left(\gamma\theta_i^t + (1-\gamma)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right), \sigma_T^2 + \sigma_\nu^2\right)$$

after replacing $\mathbb{E}\left(\theta_j^t|\theta_i^t\right)$ and grouping the terms in θ_i^t and in $\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)$, we find A and B such that:

$$p^*(\theta_i^t) = \frac{\sigma_\varepsilon^2(1-\alpha)}{\sigma_\varepsilon^2(1-\alpha) + \sigma_\nu^2}\theta_i^t + \frac{\sigma_\nu^2}{\sigma_\varepsilon^2(1-\alpha) + \sigma_\nu^2}\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)$$

Derivation of posterior distribution of inflation rate given the predictions

$$f(s^{t+1}|p_1^t, p_2^t, \ldots, p_N^t, \alpha, \gamma, \sigma_\varepsilon^2, \sigma_\nu^2) \quad \propto \quad f(s^{t+1})f(p_1^t, p_2^t, \ldots, p_N^t|s^t, x^t, \alpha, \gamma, \sigma_\varepsilon^2, \sigma_\nu^2)$$

where $f(s^{t+1})$ is the prior distribution of central bank about inflation, and $f(p_1^t, p_2^t, \ldots, p_N^t|s^t, x^t, \alpha, \gamma, \sigma_\varepsilon^2, \sigma_\nu^2)$ is the likelihood of predictions. Using equations (6) and (7), we have:

$$p(\theta_i^t) = \frac{(1-\alpha)\gamma}{1-\alpha\gamma}s^{t+1} + \frac{1-\gamma}{1-\alpha\gamma}\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right) + \frac{(1-\alpha)\gamma}{1-\alpha\gamma}\nu_i^t = \delta s^{t+1} + (1-\delta)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right) + \delta\nu_i^t$$

$$p^t(\theta_i^t) \sim \mathcal{N}\left(\delta s^{t+1} + (1-\delta)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right), \sigma_p^2\right) \tag{17}$$

with $\delta = \frac{(1-\alpha)\gamma}{1-\alpha\gamma}$, and σ_p^2 given by equation (8). The likelihood can be written as:

$$\begin{aligned} f(p_1^t, p_2^t, \ldots, p_N^t | s^t, x^t, \alpha, \gamma, \sigma_\varepsilon^2, \sigma_\nu^2) &\propto \exp\left\{-\frac{1}{2\sigma_p^2}\sum_{i=1}^N \left[p_i - \delta s^{t+1} - (1-\delta)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)\right]^2\right\} \\ &\propto \exp\left\{-\frac{1}{2\sigma_p^2}\left[N\delta^2(s^{t+1})^2 - 2N\delta s^{t+1}\left(\bar{p} - (1-\delta)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)\right)\right]\right\} \end{aligned}$$

The prior distribution is derive from equation (5):

$$f(s^{t+1}) \quad \propto \quad \exp\left\{-\frac{1}{2\sigma_\varepsilon^2}\left(s^{t+1} - \phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)\right)^2\right\}$$

Hence the posterior distribution can be derive with some simple computations:

We have:

$$\begin{aligned} f(s^{t+1} | p_1, p_2, \ldots, p_N, \alpha, \sigma_\varepsilon^2, \sigma_\nu^2) &\propto \exp\left\{-\frac{1}{2\sigma_p^2}\left[N\delta^2(s^{t+1})^2 - 2N\delta s^{t+1}\left(\bar{p} - (1-\delta)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)\right)\right]\right\} \\ &\times \exp\left\{-\frac{1}{2\sigma_\varepsilon^2}\left(s^{t+1} - \phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)\right)^2\right\} \\ &\propto \exp\left\{(s^{t+1})^2\left(-\frac{N\delta^2}{2\sigma_p^2} - \frac{1}{2\sigma_\varepsilon^2}\right) - s^{t+1}\left[-\frac{N\delta\left(\bar{p} - (1-\delta)\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)\right)}{\sigma_p^2} - \frac{\phi\left(\mathbf{s}^t, \boldsymbol{x}^t\right)}{\sigma_\varepsilon^2}\right]\right\} \end{aligned}$$

Completing the square, we obtain the result.