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Disagreement in consumer inflation expectations

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Abstract

We posit that consumers form expectations about inflation by combining two sources of information: their beliefs from shopping experience and news about inflation they learn from experts. Disagreement among consumers in our model comes from four sources: (i) consumers' divergent prior beliefs, (ii) heterogeneity in their propensities to learn from experts, (iii) experts' different views about future inflation, and (iv) difference in mean expectations between consumers and experts. By carefully matching the datasets from the Michigan Survey of Consumers with the Survey of Professional Forecasters, we find that inflation expectations between households and experts differ substantially and persistently from each other, and households pay close attention to salient price changes, while experts respond more to monetary policy and macro indicators. Our empirical estimates imply economically significant degrees of information rigidity and these estimates vary substantially across households. This significant heterogeneity poses a great challenge for the canonical sticky-information model that assumes a single rate of information acquisition and for noisy-information model in which all agents place the same weight on new information received.

JEL classification: E32; E52

Keywords: Consumers, Disagreement, Inflation Expectation, Noisy Information, Sticky Information

1 Introduction

Disagreement about expectations is itself an interesting variable for students of monetary policy and the business cycle. [...] Disagreement may be a key to macroeconomic dynamics.
N. Gregory Mankiw, Ricardo Reis, and Justin Wolfers, NBER Macroeconomics Annual 2003.

Disagreement about expectations of the public matters. Recent work on macroeconomics has emphasized the role of disagreement in signaling upcoming structural changes in the economy (Mankiw, Reis and Wolfers, 2004), and as a proxy for uncertainty in driving business cycle fluctuations (Bachmann, Elstner and Sims, 2013). Yet why ordinary people disagree in their expectations, and how best to model this heterogeneity, remains an open question. We answer this question by matching household and expert inflation expectations and by building a theory of consumer expectation updating.

Our theory has three key elements. First, consumers hold different beliefs about price levels, gained from personal experiences on shopping and the previous inflation rates experienced in their lifetime. Second, consumers obtain public information from experts via newspapers and social media about the trends in future inflation. Third, households have different propensities to learn from experts. Consumers then combine public and private information in forming their inflation expectations. Disagreement among consumers in our model comes from four sources: (i) consumers' divergent prior beliefs, (ii) heterogeneity in their propensities to learn from experts, (iii) experts' different views about future inflation, and (iv) deviation of consumer mean expectation from that of experts.

The ingredients of our theory are motivated by the empirical findings. Our primary database of household forecasts comes from the Michigan Survey of Consumers that contains both quantitative and qualitative inflation expectations. We use both forms of expectations to estimate the central tendency and dispersion among consumers and in particular, quantify the qualitative responses following the probability method. By carefully matching the database of consumer expectations with those of experts from U.S. Survey of Professional Forecasters, we find that inflation expectations between laymen and experts differ substantially and persistently from each other. We also observe substantially higher levels of disagreement among the public than among professional forecasters. Finally, we see that households pay close attention to salient price changes, such as oil and food prices; see, e.g. Coibion and Gorodnichenko (2015b), Berge (2017) and Binder (2017b). By contrast, experts respond more to monetary policy and macro indicators.

Our model is closely related to the theoretical literature on expectations formation with information frictions. For instance, Mankiw and Reis (2002) propose the sticky information model that explains agents' rational inattention in terms of limited resources and the cost of updating information sets. Carroll (2003) develops an epidemiological model of expectations formation that can be viewed as providing microfoundations for the Mankiw-Reis model. Our model differs from the sticky-information model in an important aspect. Disagreement in Carroll (2003)'s model, or in sticky-information model in general, arises only from different generations of consumers using different information vintages and there is no disagreement within a generation. In contrast, our model generates disagreement within a generation due to consumers' exposure to different expert views about inflation even under full information updating. Sims (2003), Woodford (2003) and Maćkowiak and Wiederholt (2009) advocate the noisy information model that emphasizes the limited ability of economic agents to process new information from noisy signals. In contrast to the noisy-information model where agents always solve a signal extraction problem, households in our model observe different views of experts and use these views as direct inputs in their expectation formation process. The intuition is straightforward. Ordinary people do not know the latest economic statistics, nor understand basic economic theory to interpret the data. Observing views of different experts via newspaper and social media is therefore an important public source of information about inflation in the future.

Our empirical estimates show that, on average, the propensity for consumers to learn from experts is about 0.15, implying economically significant degrees of information rigidity among the public. This magnitude is broadly similar to those reported in the literature on expectation formation with information frictions. For example, the average estimate of information rigidity in our dataset, 0.85, is close to the 0.82 value estimated by Coibion and Gorodnichenko (2012) but is slightly higher than the 0.75 value assumed by Mankiw and Reis (2002), the 0.75 value calibrated by Hur and Kim (2017) and the 0.73 value estimated by Carroll (2003). In contrast to all these papers, we also find substantial variations in the estimated degrees of information rigidity, with attentive consumers revising forecasts very often, while inattentive consumers making revisions only infrequently. As long as there is no substantial evidence that would dramatically surprise those inattentive consumers, they will not revise their previous forecasts, consistent with the so-called predisposition effects (Branch, 2004). This significant heterogeneity is consistent with the findings in Pfajfar and Santoro (2013) that consumers split in the two categories – those adjusting their forecasts toward and away from the professional forecasters' mean expectation. However, this notable heterogeneity cannot be explained by the canonical sticky-information model that assumes a single rate of information acquisition for all agents, nor by the classical noisy-information model in which all agents place the same weight on new information received.[1]

Finally, our paper builds on the burgeoning literature exploring cross-sectional distribution of forecasts. One strand of the literature examines the disagreement among professional forecasters; see, e.g. Lahiri and Sheng (2008), Capistran and Timmermann (2009), Patton and Timmermann (2010), Dovern, Fritsche and Slacalek (2012), Andrade and Le Bihan

[1] Mankiw and Reis (2007) and Hur and Kim (2017) generalize the partial equilibrium model with sticky information to a general equilibrium model and find that information stickiness is present in all markets, and is especially pronounced for consumers. Coibion and Gorodnichenko (2015a) extend the noisy information model by allowing agents to have different signal-noise ratios and therefore placing different weights on the new information.

(2013), Dovern (2015) and Andrade, et al. (2016).[2] In contrast to these studies, our paper focuses on the disagreement among household expectations and is more closely related to a second strand of literature relying on consumer and business surveys to explore heterogeneity in expectations. For example, household inflation expectations from the Michigan Survey of Consumers are found to vary by gender, education levels, or age cohorts (Souleles, 2004; Bruine de Bruin, et al., 2010; Malmendier and Nagel, 2016). Branch (2004, 2007) estimate a model in which consumers rationally choose from a set of predictors by evaluating costs and benefits of each predictor and find that such a model is consistent with the response behavior of consumers. Lamla and Maag (2012) build a Bayesian learning model and find that disagreement among consumers (but not professionals) is governed by the amount, the heterogeneity, and the tone of media reports about consumer price inflation. Dräger and Lamla (2017) explore disagreement among the general pubic in a multivariate context and find that disagreement on the interest rate is mainly driven by disagreement on inflation. The basic structure of our model is similar to Lamla and Maag (2012), but differs in two important aspects. (i) Consumers in our model observe and directly use experts' views about inflation in forming their expectations, rather than proactively estimating the rational forecast of inflation from noisy signals reported in the media. This assumption is supported by the evidence collected from dozens of surveys from the 1950s to 2014 in Binder (2017a) that exposes a lack of public awareness of the Federal Reserve and its objectives, a decline

[2] Using expert forecasts from Consensus Economics, Lahiri and Sheng (2008) find that differential interpretation of public information explains most of forecast disagreement as forecast horizon gets shorter; Patton and Timmermann (2010) emphasize the role of heterogeneity in priors in explaining disagreement; and Dovern, Fritsche and Slacalek (2012) investigate determinants of disagreement about six key economic indicators in G7 countries. Using inflation forecasts from U.S. Survey of Professional Forecasters (SPF), Capistran and Timmermann (2009) offer a simple explanation of disagreement based on asymmetries in the forecasters' costs of over- and underpredicting inflation. Using the ECB SPF forecasts at the micro level, Andrade and Le Bihan (2013) document two new facts – forecasters fail to systematically update their forecasts and disagree even when updating and accordingly build a hybrid sticky-noisy information model aimed at matching these facts. However, they find that their model cannot quantitatively replicate the error and disagreement observed in the data. Dovern (2015) and Andrade, et al. (2016) analyze forecast disagreement in a multivariate context.

in public opinion of central bankers, and reasons for consumers' inattention to monetary policy. (ii) Rather than the reduced-form estimation of model implications, we perform the structural estimation that allows us to gauge the relative importance of each channel in explaining household disagreement in their inflation expectations.

The rest of the paper is organized as follows. Section 2 discusses the dataset from U.S. Survey of Professional Forecasters and Michigan Survey of Consumers and presents the stylized facts about consumer inflation expectations. Section 3 proposes a model of consumer expectation updating. Section 4 provides empirical estimation of the model and section 5 concludes.

2 Data and Stylized Facts

2.1 Data

In our study we analyze short-term inflation expectations of consumers and professional forecasters in the United States, formed in a one-year horizon. As far as professional forecasters are concerned, we use their inflation forecasts reported in the Survey of Professional Forecasters (SPF), conducted by the Philadelphia Fed. As the measure of central tendency we use medians of individual forecasts, while cross-sectional variance is the measure of disagreement among professional experts.[3]

In the case of consumers, we make use of two sets of measures of their inflation expectations based on Michigan Survey of Consumers (MSC) data. The first set relies on quantitative assessments of consumers concerning expected price developments. Average expectations are proxied with the median of individual declarations, while the dispersion is represented by the implied variance transformed on the basis of interquartile range (IQR):

[3]The mean and median forecasts are almost the same for professional forecasters. Our choice of using the median is driven by household' forecasts.

$$\sigma_t^{imp} = \left(\frac{IQR}{1.35}\right)^2. \tag{1}$$

The above measure of dispersion is less sensitive to outlier observations than a direct cross-sectional variance of individual responses.

The second set of measures, including the mean and variance of expected inflation, is based on quantification of qualitative survey data.[4] Given percentages of consumers declaring expected increase of prices (a), stabilization (b) and reduction (c), we use the Carlson-Parkin (1975) probability method in order to convert qualitative responses into the distribution of expected inflation. We assume that the expected inflation is normally distributed in the population, with unknown mean μ and standard deviation σ. In addition, we assume that expectations of the respondents stating that prices will not change are located around zero, within the sensitivity interval $(-l, l)$. Consequently, we can express the observed fractions of respondents a, b and c as the functions of cumulative standard normal distribution F, the limit of the sensitivity interval l and the mean and standard deviation of the distribution of expected inflation rate, i.e.:

$$a_t = 1 - F\left(\frac{l - \mu_t}{\sigma_t}\right), \tag{2}$$

$$b_t = F\left(\frac{l - \mu_t}{\sigma_t}\right) - F\left(\frac{-l - \mu_t}{\sigma_t}\right), \tag{3}$$

$$c_t = F\left(\frac{l - \mu_t}{\sigma_t}\right). \tag{4}$$

The above equations can be solved simultaneously, yielding the following formulas for the

[4]Drawing on relevant studies from economics, statistics, sociology and psychology, Mokinski, Sheng and Yang (2015) provide a detailed review of the literature on measuring disagreement in qualitative survey data.

parameters of the distribution of expected inflation:

$$\mu_t = l \frac{F^{-1}(c_t) + F^{-1}(1 - a_t)}{F^{-1}(c_t) - F^{-1}(1 - a_t)}, \tag{5}$$

$$\sigma_t = -l \frac{2}{F^{-1}(c_t) - F^{-1}(1 - a_t)}. \tag{6}$$

As can be noticed, both parameters depend on the unknown width of the sensitivity interval surrounding zero. To estimate the parameter l, we make an additional assumption. Instead of assuming unbiasedness of inflation expectations, as Carlson and Parkin (1975) did, we follow Mankiw, Reis and Wolfers (2004). We make use of quantitative measures of consumer inflation expectations assuming that, on average, the quantified mean of expected inflation should equal the quantitative declarations, μ^q:

$$\sum_{t=1}^{T} \frac{\mu_t}{T} = \sum_{t=1}^{T} \frac{\mu_t^q}{T}. \tag{7}$$

The above condition implies that:

$$l = \frac{\sum_{t=1}^{T} \mu_t^q}{\sum_{t=1}^{T} \frac{F^{-1}(c_t)+F^{-1}(1-a_t)}{F^{-1}(c_t)-F^{-1}(1-a_t)}}. \tag{8}$$

The sensitivity interval calculated in this way using the sample 1995-2016 gives an estimate of $l = 1.1\%$. It suggests that, on average, the expectations of respondents declaring no change in prices were located in the interval $(-1.1\%, 1.1\%)$.

2.2 Stylized Facts

Fact 1: Consumers' inflation expectations differ substantially and persistently from those of experts.

Figure 1 plots the median MSC consumer and SPF expert inflation expectations. Expert expectations are only weakly correlated with those of households, correlation of about 0.40 with quantitative expectation and of 0.20 with the quantified measure.[5] Furthermore, they show substantial differences – household inflation expectations are lower than those of experts before 1996, but become larger and more volatile afterwards.

Fact 2: Disagreement among the general public is substantially higher than that among professional forecasters.

Figure 2 plots the disagreement among consumers and experts. The former is measured either with the implied cross-sectional variance of individual responses in the quantitative survey or with the variance of distribution of expected inflation quantified on the basis of qualitative survey. The latter is measured as the cross-sectional variance in SPF inflation expectations. There are much larger levels of disagreement among consumers than exists among experts. The contemporaneous correlation between consumer and professional disagreement ranges from 0.24 to 0.30, depending on the measure of consumer disagreement used, implying different drivers for layman and expert disagreement. Indeed, Lamla and Maag (2012) find that disagreement among consumers, but not professionals, is governed by the amount, heterogeneity, and tone of media reports about consumer price inflation. Ehrmann, Eijffinger and Fratzscher (2012) and Binder (2017a) find evidence for a significant and sizeable effect of central bank transparency on forecast disagreement among professionals, but not on disagreement among the general public.

Fact 3: Households pay more attention to salient price changes, while experts respond more to macro indicators.

To see this, we run regressions of household and expert expectations on a battery of variables. In both regressions, we add the lagged dependent variable to control for the persistence of inflation expectations. We include the following five variables, all from FRED

[5] The two series of consumer inflation expectations, i.e. quantitative and quantified, tend to move together, with a correlation of 0.76.

database: non-farm employment, Federal Funds rate, Consumer Price Index (CPI), CPI food price away from home (CPI-food-away) and west Texas intermediate spot crude oil price. Monthly data are converted to quarterly by computing the average level of the variable within each quarter. For employment, CPI and CPI-food-away, we then calculate the annualized quarter-over-quarter change as $400 * log(\frac{X_t}{X_{t-1}})$. To make sure that all those variables are available to economic agents when they make forecasts, we lag all variables by one period in the regression. Table 1 reports the regression results. Households pay close attention to salient price changes, such as oil and food prices, while experts respond more to macro indicators, such as employment and price level in general. In addition, expert inflation expectations are much more persistent than those of households, as indicated by the large and highly significant coefficient in the lagged dependent variable for experts. Notably, this small set of variables can explain the volatility in expert inflation expectations very well ($R^2 = 0.948$), but only modestly for households, implying the difficulty in explaining and modeling expectations formation process of ordinary people.

3 A Model of Consumer Inflation Expectation

Imagine that a consumer forms his expectation about inflation in the future. He has access to two sources of information: (i) private sources of information gained from personal experiences on shopping and pumping at gas stations and (ii) public information gathered from countless advertisements, news media report and expectations of experts. He then combines these two types of information to form his inflation expectation. To fix ideas, let C_{it} be consumer i's inflation expectation based on the information available at time t, P_{it} be expert i's inflation expectation at time t, and $\lambda_i \in (0, 1)$ be consumer i's propensity to learn from experts. We consider three different cases.

Case 1: For the moment, we assume that all consumers learn the same news from experts, mimicking the "common source" story in epidemiology where people get sick because of their common exposure to the polluted air in Washington, DC. Consumers have different propensities to learning and this heterogeneity might reflect democratic characteristics, such as gender, education levels and age cohorts. In this case, consumer i's inflation expectation is the weighted average of the common expert view, P_t and his prior belief, $C_{i,t-1}$ as in equation (9):

$$C_{it} = \lambda_i P_t + (1 - \lambda_i) C_{i,t-1}. \tag{9}$$

For convenience, we denote $\bar{x}_t$ as the cross-sectional average of x_{it}, i.e. $\bar{x}_t = E_i(x_{it})$, and σ^2_{xt} as the cross-sectional variance of x_{it}, i.e. $\sigma^2_{xt} = Var_i(x_{it})$. Then consumers' forecast disagreement, measured by σ^2_{ct}, evolves as follows:

$$\sigma^2_{ct} = \left[\sigma^2_\lambda + (1 - \bar{\lambda})^2\right] \sigma^2_{c,t-1} + \sigma^2_\lambda (\bar{p}_t - \bar{c}_{t-1})^2. \tag{10}$$

Equation (10) decomposes consumer inflation forecast disagreement into three sources: (i) heterogeneity in consumers' prior beliefs, $\sigma^2_{c,t-1}$, (ii) heterogeneity in their propensities to learn from experts, σ^2_λ and (iii) deviation of consumer mean expectation from that of experts, $(\bar{p}_t - \bar{c}_{t-1})^2$.

Case 2: Now we allow for the possibility that consumers might learn different views about inflation from different newspapers and social media. Sometimes, even the same newspaper contains different views about future inflation. In line with Carroll (2003), we assume that consumers have the same propensity to learn from experts. In this case, consumer i's inflation expectation can be described as follows

$$C_{it} = \lambda P_{it} + (1 - \lambda) C_{i,t-1}. \tag{11}$$

Equation (11) allows for a simple variance decomposition where the covariance term between P_{it} and $C_{i,t-1}$ is zero:

$$\sigma_{ct}^2 = (1-\lambda)^2\sigma_{c,t-1}^2 + \lambda^2\sigma_{pt}^2. \tag{12}$$

Forecast disagreement in this case arises from the heterogeneity in consumers' prior beliefs and in experts' divergent views about future inflation. Before we present a more general model of consumer expectation formation, we need to point out the key differences between our model and Carroll (2003)'s model. Carroll (2003) assumes that each consumer faces a constant probability λ of encountering and absorbing the contents of an article on inflation and that consumers who do not encounter an article simply continue to believe the last forecast they read about. As such, disagreement in his model arises only from different generations of consumers using different information vintages and there is no disagreement within a generation. In contrast, our model generates disagreement within a generation due to consumers' exposure to different expert views about inflation even under full information updating $\lambda = 1$.

Case 3: Finally, we relax both assumptions and present a general model of consumer inflation expectation. In this model, consumers are allowed to have different propensities to learn from experts who might have different views about future inflation. Consumer i's inflation expectation at time t evolves according to the following equation

$$C_{it} = \lambda_i P_{it} + (1-\lambda_i)C_{i,t-1}. \tag{13}$$

Under the assumption that $C_{i,t-1}$, λ_i and P_{it} are orthogonal to each other, we derive the dynamics of consumer forecast disagreement as follows[6]

[6] The appendix contains details for the derivation.

$$\sigma_{ct}^2 = \left[\sigma_\lambda^2 + (1-\bar{\lambda})^2\right]\sigma_{c,t-1}^2 + (\sigma_\lambda^2 + \bar{\lambda}^2)\sigma_{pt}^2 + \sigma_\lambda^2(\bar{p}_t - \bar{c}_{t-1})^2. \tag{14}$$

Equation (14) posits that disagreement among consumer inflation expectations comes from four sources: (i) consumers' divergent prior beliefs, $\sigma_{c,t-1}^2$, (ii) heterogeneity in their propensities to learn from experts, σ_λ^2, (iii) experts' different views about future inflation, σ_{pt}^2 and (iv) deviation of consumer mean expectation from that of experts, $(\bar{p}_t - \bar{c}_{t-1})^2$. Clearly, this case nests the previous two where equation (14) reduces to (10) when all newspaper and social media contain the identical news about future inflation; and to (12) when consumers have the same propensity to learn from experts.

Finally, all three cases impose the same restriction regarding the dynamics of mean inflation expectation, $\bar{c}_t$, as follows

$$\bar{c}_t = \bar{\lambda}\bar{p}_t + (1-\bar{\lambda})\bar{c}_{t-1}. \tag{15}$$

These additional restrictions, in turn, can be employed to test the validity of different model specifications in the empirical study of consumer inflation expectation process.

4 Empirical Estimation

In order to estimate the model parameters of consumer inflation expectation formation, we use three sets of equations. Each of them contains two equations. The first, equation (15), governs the dynamics of mean expectations and has the same specification in all estimated systems. The second equation explains the disagreement in consumer inflation expectations. In the first system (Sys_1), it is assumed that propensities to learn by consumers from experts are different among individuals, but consumers update to the same central SPF forecast, hence we use equation (10) to model disagreement. In the second system (Sys_2), we apply equation (12), according to which propensities to learn do not differ among consumers, but consumers update their views to different SPF forecasts. Finally, the third system (Sys_3) exploits equation (14) for disagreement, which reflects the case, in which parameters λ differ among individuals and consumers update to different SPF forecasts. To allow for correleted error terms across both equations, we conduct the estmation with the use of seemingly unrelated regressions (SUR) method. Systems are estimated either with the use of the outcomes from quantitative survey questions or exploiting the distribution of expected inflation quantified on the basis of qualitative survey data.

In our estimations we use two sample periods. Both of them start in 1985Q1. The whole sample ends in 2016Q3, while the shorter sample ends in 2007Q4. Estimation results based on the whole sample period allow assessing which model for disagreement of consumer inflation expectations displays the best statistical fit. To make this analysis more robust, the systems estimated till the end of 2007 are then used to forecast the level and dispersion of consumer inflation expectations in the 2008-2016. Table 2 presents the estimation results.

We find that the third system of equations (Sys_3) is the only one, in which the estimated parameters are significant in both sample periods, independently of the measures of consumer inflation expectations. The models for the level of consumer inflation expectations display a better empirical fit ($adj.R^2$) if the measures of inflation expectations quantified with the probability method are used instead of quantitative expectations. The opposite conclusion concerns the models of disagreement in consumer expectations – in this case the measures based on the responses to the quantitative MSC question are preferred to qualitative ones. A comparison of empirical fit of individual models does not indicate a single best model for disagreement. The above mixed results hold both in systems estimated in the whole sample and in the short sample.

Even if a comparison of coefficients of determination does not indicate the preferred model, assessment of out-of-sample forecasting accuracy offers more robust conclusions. It shows that the third estimated system (Sys_3) produces the most accurate forecasts, especially in the case of forecasted disagreement. Another observation supporting this choice is that in the remaining models, especially in the second one (Sys_2), the estimated propensity to learn is very low – much lower than in the existing empirical studies, in which epidemiological models have been used (e.g. Carroll, 2003). Finally, taking the short sample period into consideration, only the third system (Sys_3) produces statistically significant estimates of λ and σ^2_λ.

Therefore, we can safely conclude that the formation of inflation expectations by U.S. consumers is more complex than assumed in the sticky-information model so far. In particular, consumers are heterogeneous in terms of their propensities to learn. In addition, they take into account not only expert consensus forecasts, but update their expectations to different expert forecasts.[7]

The average propensity to learning in our preferred models is 0.12-0.13 in the whole sample, depending on the consumer expectations' measure vs. 0.10-0.11 in the shorter sample. These estimates correspond to the structural parameter "the degree of attention" in the sticky-information model and imply economically significant degrees of information rigidity among the public. This magnitude is broadly consistent with estimates reported in the literature, e.g. Coibion and Gorodnichenko (2012). The standard deviation of the propensity to learn is estimated to be relatively high (approximately 0.4). This finding confirms the results in Pfajfar and Santoro (2013) that some consumers revise their forecasts in the direction opposite to the direction in which SPF forecasters move, and complements the results in Madeira and Zafar (2015) that women and less educated consumers are slower to update their expectations.

[7] Replacing the implied variance of consumer inflation expectations based on interquartile range with the variance of individual responses worsens estimation results. However, these results confirm that consumers update to different expert forecasts.

5 Conclusion

By matching the datasets from the Michigan Survey of Consumers with the Survey of Professional Forecasters, we find that inflation expectations between households and experts differ substantially and persistently from each other, and households pay close attention to salient price changes, while experts responding more to monetary policy and macro indicators. We then build a theory of consumer expectation updating. Our theory has three key elements. First, consumers hold different beliefs about price levels, gained from personal experiences on shopping and pumping at gas stations. Second, consumers obtain public information from experts via newspapers and social media about the trends in future inflation. Third, households have different propensities to learn from experts. Disagreement among consumers in our model comes from four sources: (i) consumers' divergent prior beliefs, (ii) heterogeneity in their propensities to learn from experts, (iii) experts' different views about future inflation, and (iv) deviation of consumer mean expectation from that of experts.

Estimation results suggest that consumers form their inflation expectations in a more complex manner than assumed in the sticky-information model so far. Propensities to learning from experts differ among individuals, who update their expectations to forecasts of different professionals. Therefore all ingredients of our theory seem important in explaining households inflation expectations.

Our empirical estimates imply economically significant degrees of information rigidity and these estimates vary substantially across households. This significant heterogeneity poses a great challenge for the canonical sticky-information model that assumes a single rate of information acquisition and for noisy-information model in which all agents place the same weight on new information received. Future research is warranted by incorporating this notable heterogeneity in information updating into expectations formation process.

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Appendix

This appendix shows how to derive the dynamics of forecast disagreement among the general public in equation (14) from equation (13). Let C_{it} be consumer i's inflation expectation based on the information available at time t, P_{it} be expert i's inflation expectation at time t, and $\lambda_i \in (0,1)$ be consumer i's propensity to learn from experts. For convenience, we denote $\bar{x}_t$ as the cross-sectional average of x_{it}, i.e. $\bar{x}_t = E_i(x_{it})$, and σ^2_{xt} as the cross-sectional variance of x_{it}, i.e. $\sigma^2_{xt} = Var_i(x_{it})$. Equation (13) states that

$$C_{it} = \lambda_i P_{it} + (1-\lambda_i)C_{i,t-1}.$$

Taking cross-sectional variance on both sides of equation (13) yields

$$\sigma^2_{ct} = Var_i(\lambda_i P_{it}) + Var_i\Big[(1-\lambda_i)C_{i,t-1}\Big] + 2Cov\Big[\lambda_i P_{it}, (1-\lambda_i)C_{i,t-1}\Big]. \tag{16}$$

To simplify algebra, we assume that $C_{i,t-1}$, λ_i and P_{it} are orthogonal to each other. Under this assumption, the items on the RHS of equation (16) can be expressed as

$$\begin{aligned}
&Var_i(\lambda_i P_{it}) = \sigma^2_\lambda \sigma^2_{pt} + \sigma^2_\lambda \bar{p}^2_t + \sigma^2_{pt}\bar{\lambda}^2,\\
&Var_i\Big[(1-\lambda_i)C_{i,t-1}\Big] = \sigma^2_\lambda \sigma^2_{c,t-1} + \sigma^2_\lambda \bar{c}^2_{t-1} + \sigma^2_{c,t-1}(1-\bar{\lambda})^2,\\
&2Cov\Big[\lambda_i P_{it}, (1-\lambda_i)C_{i,t-1}\Big] = -2\sigma^2_\lambda \bar{p}_t \bar{c}_{t-1}.
\end{aligned}$$

Plugging in these expressions into equation (16) yields the dynamics of forecast disagreement among the general public (i.e. equation (14)):

$$\sigma^2_{ct} = \Big[\sigma^2_\lambda + (1-\bar{\lambda})^2\Big]\sigma^2_{c,t-1} + (\sigma^2_\lambda + \bar{\lambda}^2)\sigma^2_{pt} + \sigma^2_\lambda(\bar{p}_t - \bar{c}_{t-1})^2.$$

Table 1: Inflation Expectations and Macro Variables

	Consumer		Expert
Variable	Quantitative	Qualitative	
Lagged Dependent Variable	0.275***	0.413***	0.908***
	(0.087)	(0.116)	(0.034)
Oil Price	0.006***	0.008*	-0.002***
	(0.002)	(0.004)	(0.001)
Consumer Price Index	0.239***	0.085	0.034*
	(0.033)	(0.067)	(0.019)
Federal Funds Rate	0.034*	0.031	-0.011
	(0.019)	(0.043)	(0.012)
CPI-Food-Away	0.148*	0.285	0.069
	(0.082)	(0.228)	(0.073)
Employment	0.041	0.285***	0.056**
	(0.048)	(0.079)	(0.026)
Constant	1.340***	0.724**	0.210*
	(0.195)	(0.278)	(0.110)
R-squared	0.640	0.520	0.948
Number of observations	126	126	126

Note: The results are obtained from regressions of consumer and expert median inflation expectations on the lagged dependent variable and a set of independent variables. Newey-West HAC standard errors are reported in the parentheses. *, ** and *** represent statistical significance at the 10%, 5% and 1% levels, respectively.

Table 2: Estimation results based on the whole sample: 1985Q1-2016Q3

Variable	Quantitative expectations			Qualitative expectations		
	Sys_1	Sys_2	Sys_3	Sys_1	Sys_2	Sys_3
Whole sample: 1985Q1-2016Q3						
λ	0.123***	0.017***	0.128***	0.114***	0.011	0.119***
	(0.041)	(0.006)	(0.040)	(0.038)	(0.011)	(0.039)
σ^2_λ	0.449***	NA	0.449***	0.445***	NA	0.439***
	(0.080)		(0.075)	(0.074)		(0.071)
adj. R^2 – eq. for C	0.446	0.417	0.446	0.569	0.551	0.569
adj. R^2 – eq. for σ^2_c	0.828	0.829	0.829	0.573	0.577	0.577
Short sample: 1985Q1-2007Q4						
λ	0.091*	0.012*	0.103*	0.137**	0.009	0.108**
	(0.054)	(0.007)	(0.054)	(0.065)	(0.011)	(0.047)
σ^2_λ	0.391***	NA	0.411***	0.474***	NA	0.431***
	(0.128)		(0.114)	(0.112)		(0.095)
adj. R^2 – eq. for C	0.465	0.453	0.465	0.493	0.471	0.492
adj. R^2 – eq. for σ^2_c	0.659	0.663	0.662	0.393	0.190	0.185
$RMSE$ of C forecasts	0.523	0.533	0.523	1.033	1.068	1.031
$RMSE$ of σ^2_c forecasts	3.569	3.565	3.544	3.934	3.905	3.910

Note: We use median of quantitative inflation expectations declared by individual consumers and the median (=mean) of the distribution of expected inflation quantified on the basis of qualitative survey data. In the former case we use the variance based on interquartile range as the measure of disagreement among consumers, in the latter case we use the variance of the distribution of expected inflation. To allow for correleted error terms across both equations we apply SUR estimator. Standard errors in the parentheses. *, ** and *** represent statistical significance at the 10%, 5% and 1% levels, respectively.

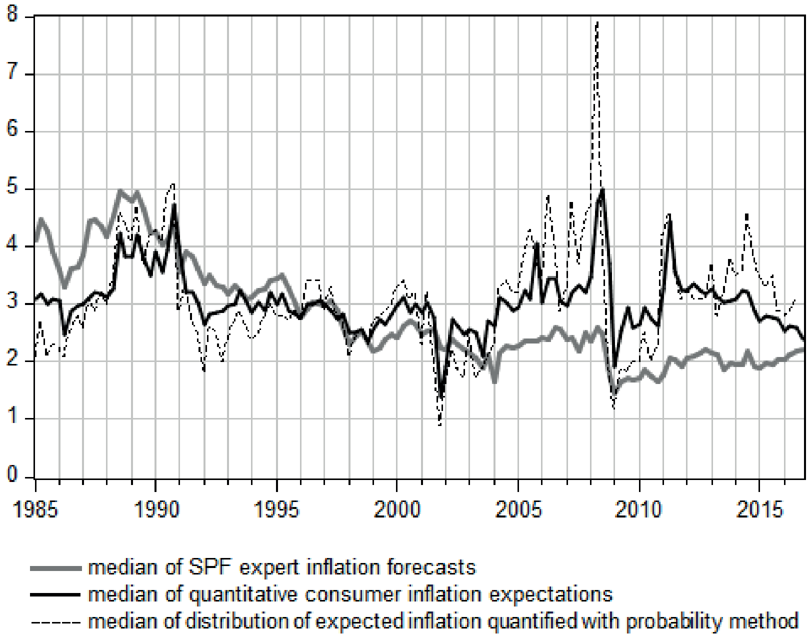

Figure 1: Median Inflation Expectations: MSC Consumers vs. SPF Experts

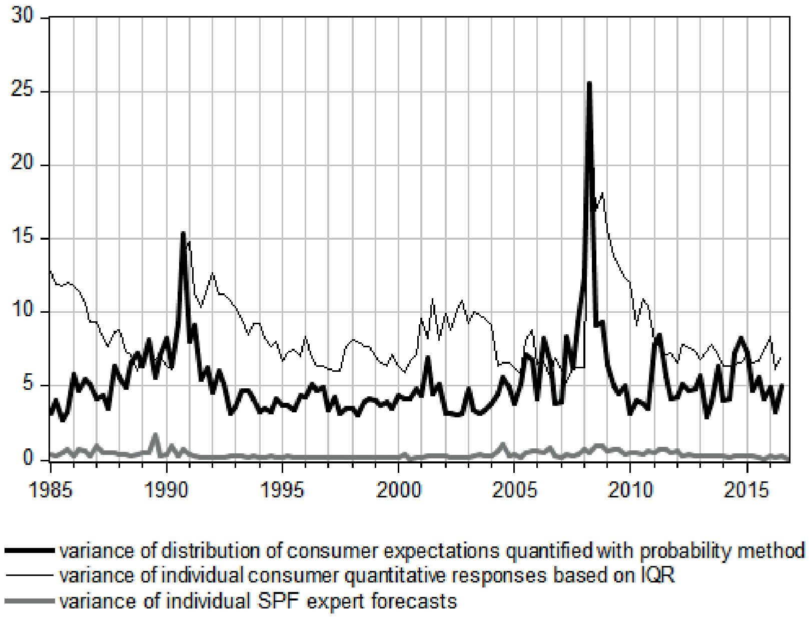

Figure 2: Disagreement among consumers and forecasters

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