

**Finance and Economics Discussion Series
Divisions of Research & Statistics and Monetary Affairs
Federal Reserve Board, Washington, D.C.**

**Inflation Experience and Inflation Expectations: Dispersion and
Disagreement Within Demographic Groups**

Benjamin K. Johannsen

2014-89

NOTE: Staff working papers in the Finance and Economics Discussion Series (FEDS) are preliminary materials circulated to stimulate discussion and critical comment. The analysis and conclusions set forth are those of the authors and do not indicate concurrence by other members of the research staff or the Board of Governors. References in publications to the Finance and Economics Discussion Series (other than acknowledgement) should be cleared with the author(s) to protect the tentative character of these papers.

Inflation Experience and Inflation Expectations: Dispersion and Disagreement Within Demographic Groups

Benjamin K. Johannsen*

Board of Governors[†]

October 22, 2014

Abstract

Using consumption data from the Consumer Expenditure Survey, I document persistent differences across demographic groups in the dispersion of household-specific rates of inflation. Using survey data on inflation expectations, I show that demographic groups with greater dispersion in experienced inflation also disagree more about future inflation. I argue that these results can be rationalized from the perspective of an imperfect information model in which idiosyncratic inflation experience serves as a signal about aggregate inflation. These empirical regularities pose a challenge to several other popular models of the expectations formation process of households.

*benjamin.k.johannsen@frb.gov. This is a revised version of material that appeared in the second chapter of my dissertation. I would like to thank Martin Eichenbaum, Lawrence Christiano, Sergio Rebelo, and Giorgio Primiceri for their comments and support. I would also like to thank seminar participants at Northwestern and the Board of Governors for useful feedback. Will Gamber provided excellent research assistance. All errors are my own.

[†]The views expressed here are solely those of the author and do not necessarily reflect the views of the Board of Governors or any other member of the Federal Reserve System.

1 Introduction

This paper establishes an empirical connection between dispersion in experienced inflation and disagreement about future inflation within demographic groups. I construct a measure of inflation for individual households and examine the dispersion in experienced inflation within groups and over time. I then use survey data on expectations about future price changes to show that the same demographic groups with relatively high levels of dispersion in experienced inflation also disagree more about future inflation.

By using within-group dispersion in experienced inflation—rather than mean or median experienced inflation—to study the expectation formation process, I highlight a novel way in which inflation experience can differ across groups to affect the expectation formation process. My approach requires departing from a representative consumer for each demographic group, and instead focuses attention on the diversity of experienced inflation. To calculate household-specific rates of inflation, I construct consumption bundles for households in the Consumer Expenditure Survey (CES), conducted by the Bureau of Labor Statistics (BLS). I match the expenditure categories of those bundles to sub-indexes of the consumer price index (CPI) to create household-specific rates of inflation. I find that consumers with lower levels of expenditure (education) have more dispersed inflation experiences than consumers with higher levels of expenditure (education). I document that households with low levels of expenditure (education) have more heterogeneous expenditure weights on food and energy, two of the most volatile components of the CPI, which leads to the more dispersed inflation experience. It is not surprising that I find similar results for groups based on expenditure and education because there is considerable overlap among these groupings.

This paper offers new evidence that can be used to discriminate among models of the expectation formation process of households by establishing an empirical connection between the dispersion in experienced inflation and disagreement about future inflation. After constructing within-group distributions over experienced inflation, I analyze the distribution over expected inflation within similar groups. Using survey data on household inflation expectations from the Thompson Reuters/University of Michigan Survey of Consumers (MSC), I document that consumers with lower levels of income (education) disagree more about future inflation than consumers with higher

levels of income (education).

I also study groups formed based on age and find no persistent differences in the dispersion of experienced inflation or disagreement about future inflation. I show that these groups have similar levels of dispersion in the expenditure weights on food and energy, which causes the similarly dispersed distributions of experienced inflation. I interpret the finding that these groups do not display persistent differences in disagreement about future inflation as consistent with the connection between dispersion in experienced inflation and disagreement about future inflation that I document for groups based on expenditure and education.

To connect my empirical findings to a model of expectation formation, I show that a model of imperfect information in which household-specific rates of inflation serve as signals about aggregate inflation can rationalize the results that I document. Additionally, I argue that the sticky information model of Mankiw et al. (2003) and the epidemiological model of Carroll (2003) cannot on their own generate the empirical connection between dispersion in experienced inflation and disagreement about future inflation.

This study is related to works by Hameed (2006), Cage et al. (2002), and Hobijn and Lagakos (2004) that have have constructed household-specific rates of inflation using data from the CES. My paper adds to this literature by investigating the dispersion of inflation experience across demographic groups and linking differences in dispersion with disagreement about future inflation. This paper is also related to works by Meyer and Venkatu (2011), Bryan and Venkatu (2001b), Bryan and Venkatu (2001a), and Bruine De Bruin et al. (2010) that study the demographic differences in inflation expectations. My work contributes to this literature by relating features the distribution of inflation expectations that differ by demographic group to the inflation experience within those groups.

This paper is also closely related to a growing literature that tests the predictions of models of the expectation formation process using forecast data from surveys. Mankiw et al. (2003) show that the sticky information model matches several key features of survey data. Carroll (2003) argues that an epidemiological model in which household forecasts are derived from those of professional forecasters gives micro-foundations to the work of Mankiw and Reis (2002) and fits certain properties of survey

data well. Branch (2007) studies the dispersion in forecast data from the perspective of the sticky information model and interprets this as model uncertainty. Coibion and Gorodnichenko (2010) and Coibion and Gorodnichenko (2012) study common predictions of the imperfect information model and the sticky information model. My work contributes to this literature by offering another empirical connection between dispersion in inflation experience and beliefs about future inflation for these models to confront. Malmendier and Nagel (2013) show that a learning model using lifetime experienced inflation for cohorts matches certain features of the MSC data well and Madeira and Zafar (2014) consider a learning model with heterogeneous information using the MSC data. My paper offers an explanation as to why households in similar cohorts might disagree about future inflation and can be thought of as providing a microfoundation for the heterogeneous information sets of those households.

I structure the rest of the paper in the following way. Section 2 documents that different demographic groups have persistently different dispersion in experienced inflation. Section 3 documents persistent differences in disagreement in survey data on household inflation expectations. Section 4 connects dispersion in experienced inflation and disagreement about future inflation in a model of imperfect information. Section 5 explores the connection between inflation experience and inflation expectations using forecast performance as a metric. Section 6 concludes.

2 Dispersed Inflation Experience

In this section, I construct a measure of household-specific rates of inflation using consumption data from the CES. I document that consumers with higher levels of expenditure (education) have less dispersion in experienced inflation than consumers with lower levels of expenditure (education).

2.1 Consumption Data

To construct consumption bundles, I use publicly available microdata from the CES. The CES is comprised of an interview survey and a diary survey. In the diary survey, households are asked to report expenditures at a very fine level of detail for two consecutive weeks. In the interview survey, households are interviewed once every three months, at which time they provide information about

their expenditure in the previous three months. The interview survey also gathers a variety of demographic information about each household, including the age and levels of education of heads of households.¹

For the purposes of this study, I use data from the interview survey, which includes approximately 7,500 survey participants in each quarter.² A household can appear in the data from the interview survey for up to one year. Expenditures are recorded at the level of the consumer unit (CU) and are classified by Universal Classification Codes (UCC's).³ There are hundreds of UCC's in the interview survey, which offer a comprehensive view of each survey participant's spending habits.

I group a household's spending into 22 categories, which are enumerated in Appendix A. I aggregate the UCC's into these categories for each survey year using definitions found in the CES program files. Calculating consumption spending on a homeowner's housing services presents special challenges because payments for an owned home include an investment component that is not easy to separate from housing services. The BLS asks participants in the CES

If someone were to rent your home today, how much do you think it would rent for monthly, unfurnished and without utilities?

The BLS uses this question to establish the expenditure weight on housing in the CPI (see Poole et al. (2005) for a detailed discussion). In a similar way, I subtract a homeowners payments on an owned dwelling from their expenditure on shelter and add the rental equivalence of that owned dwelling.

¹The CES also includes a measure of income, which other studies have found to be noisy. I instead compare households base on total expenditure.

²Before 1999 the number of survey participants was approximately 5,000.

³I use the word "household" interchangeably for "consumer unit," which is the relevant unit of measure in the CES. The BLS defines a consumer unit as

A consumer unit consists of any of the following: (1) All members of a particular household who are related by blood, marriage, adoption, or other legal arrangements; (2) a person living alone or sharing a household with others or living as a roomer in a private home or lodging house or in permanent living quarters in a hotel or motel, but who is financially independent; or (3) two or more persons living together who use their incomes to make joint expenditure decisions. Financial independence is determined by spending behavior with regard to the three major expense categories: Housing, food, and other living expenses. To be considered financially independent, the respondent must provide at least two of the three major expenditure categories, either entirely or in part.

<http://www.bls.gov/cex/faq.htm#q3>

Expenditure on new and used vehicles also poses a challenge in my data. In any given year, the purchase of a vehicle could dominate expenditure in other categories that would not be representative of the regular pattern of purchases for a given household. To alleviate the associated problems, I exclude expenditure on new and used vehicles from my calculations.

2.2 Price Indexes and Household-Specific Inflation

I match components of each household's consumption bundle to sub-indexes of the CPI. The BLS releases numerous category-specific indexes, a weighted average of which forms the CPI. The mapping between the UCC categories and the price indexes can be found in Appendix A. Due to the availability of public data on prices, my sample starts in 1999.

To construct a household-specific rate of inflation, I first construct a price index for each household in my sample.⁴ I assume that consumption goods and services can be categorized into J categories. Each household, i , has a household-specific percentage of income spent on category j , which I denote w_j^i . These percentages are analogous to the aggregate expenditure weights used in the construction of the CPI. Let the price index for household i at time t be an index defined as

$$I_t^i \equiv \sum_{j \in J} w_j^i \frac{P_{j,t}}{P_{j,b}}, \quad (1)$$

where $P_{j,t}$ is the price of goods and service in category j at time t and b stands for the base year. Define the k period rate of inflation for household i at time t as

$$\pi_{t-k,t}^i \equiv \frac{I_t^i}{I_{t-k}^i} - 1. \quad (2)$$

As in Hobbijn and Lagakos (2004), I set the base period to $t - k$, meaning

$$\pi_{t-k,t}^i = \sum_{j \in J} w_j^i \frac{P_{j,t}}{P_{j,t-k}} - 1 = \sum_{j \in J} w_j^i \frac{P_{j,t} - P_{j,t-k}}{P_{j,t-k}} = \sum_{j \in J} w_j^i \pi_{j,t-k,t} \quad (3)$$

where $\pi_{j,t-k,t}$ is the k period percentage change in prices in category j at time t . When formulated

⁴My methodology for constructing household-specific rates of inflation is very similar to Hameed (2006), Hobbijn and Lagakos (2004), and Cage et al. (2002).

in this way, the inflation rate of a household is a weighted average of category-specific rates of inflation.

When constructing household-specific price indexes, I am implicitly assuming that all households face the same prices. Clearly, households that shop in different locations will face different prices, however I do not have information about the exact set of prices that each household faces. I use aggregate category-specific inflation as a stand-in for the prices consumers actually pay. Because I use price indexes for urban consumers, I only include in my sample households that live in urban areas, as defined by the BLS. The price data display seasonality, however I calculate yearly inflation rates to alleviate the issue.

2.3 Household-Specific Expenditure Weights

With well-defined expenditure categories, I calculate household-specific expenditure weights for each household in the CES. Denote the amount of good or service j consumed by household i in time period t by $c_{j,t}^i$. Total spending by household i in time period t is then

$$\sum_{j \in J} P_{j,t} c_{j,t}^i. \quad (4)$$

Expenditure weights at time t are defined as the percentage of income spent on goods and services in category j ,

$$w_j^i = \frac{P_{j,t} c_{j,t}^i}{\sum_{j \in J} P_{j,t} c_{j,t}^i}. \quad (5)$$

Calculating consumption weights based only one month of consumption data can over-state or under-state the weight on goods and services that households do not buy on a monthly basis. A wide variety of goods that economists would normally classify as non-durable are durable at the monthly frequency, e.g. canned goods and clothing. Thus, I construct expenditure weights using all of each household's reported spending in the CES, meaning that a household has up to one

year’s worth of expenditure information. Expenditure weights are constructed so that

$$w_j^i = \frac{\sum_{k=0}^{11} P_{j,t-k} c_{j,k}^i}{\sum_{k=0}^{11} \sum_{j \in J} P_{j,t-k} c_{j,t-k}^i}. \quad (6)$$

Though it is still possible that a household will make a large durable purchase over the course of a year that is not representative of its normal buying habits, averaging over the span of a year yields expenditure weights closer to the household’s typical consumption bundle.

Households sometimes exit the CES before they have completed all of the scheduled interviews. To make households comparable, I limit the sample to households with at least nine months of consumption data.⁵ This ensures that a large purchase does not dominate a household’s consumption and also alleviates problems associated with the seasonality of consumption spending.

2.4 Producing a Distribution Over Inflation

The expenditure weights from each household relate to spending in a particular period in my sample. Slow-moving relative price changes are likely to cause households to substitute from one consumption category to another. To accommodate these changes, I date the expenditure weights for a household as the last month for which I have data about that household. My procedure leaves me with approximately 400 households in each month. I then use inflation over the previous twelve months to construct the household-specific rate of inflation.⁶

As a check to ensure that I am producing household-specific measures of inflation that are close in spirit to CPI inflation, Figure 1 shows the median of the calculated household-specific rates of inflation, as well as the inflation rate implied by the CPI. I focus on the median of the distribution so that outliers do not have undue influence on the calculations. The results are very similar for the mean of the distribution. Notably the median of the distribution of household-specific rates of inflation closely tracks the headline value of CPI inflation. Both Hameed (2006) and Hobijn and Lagakos (2004) find similarly sized deviations of the median inflation rate from CPI inflation.

There are several periods during my sample in which the median of the distribution of household-

⁵Hameed (2006) also uses the nine-month cutoff for inclusion in his data.

⁶The results are robust to calculating inflation rates using changes in prices over the year after the weights are measured.

specific rates of inflation is slightly higher than headline CPI inflation. These differences are largely driven by changes in food and energy prices. Food and energy are relatively inelastic components of a typical household's consumption bundle, and there have been several large and sustained increases in food and energy prices since the turn of the century. There is no reason to expect that the median (or mean) inflation rate will correspond exactly to the CPI inflation rate because the CPI is quantity weighted and the distribution over experienced inflation is not. In the data, consumers with relatively low levels expenditure tend to spend more of their income on food and energy than consumers with high levels of expenditure. Expenditure inequality then may make the median (or mean) of the distribution somewhat sensitive to changes in food and energy prices.

2.5 Differences Among Demographic Groups

I group households based on age, education, and expenditure in order to study across-group differences in the distribution of experienced inflation. In each month, I compare households in the top third of reported expenditure to those in the bottom third. I also compare households in which the a head of household has a college degree to those in which no head of household attended college. Finally, I compare households with a head of household over the age of 54 to those with only members under 35. The CES top-codes expenditure, and I excluded any household with top-coded values, meaning that very highest spenders are not included in my sample.

As a check to ensure that the data are consistent with previous studies of the median of the distributions, the three panels of Figure 2 show the median of the inflation rate in groups based on expenditure, education, and age, along with CPI inflation. Similar to the results reported in Hameed (2006) and Hobijn and Lagakos (2004), differences among groups are small in magnitude and are not persistent over time. Previous studies (see Stewart (2008)) have found persistent differences in the rate of inflation across demographic groups based on age due to persistently high health care cost inflation. However, in my sample health care cost inflation has not been uniformly higher than overall CPI inflation, especially in the most recent data, which attenuates the differences.

While the medians of the distribution are similar across groups, I find persistent differences

in the dispersion of experienced inflation. To measure within-group dispersion in experienced inflation, I use the interquartile range,⁷ which is shown for each group in Figure 3. For groups based on expenditure and education, the top two panels of the figure show that households with lower levels of expenditure (education) have higher levels of dispersion in experienced inflation than households with higher levels of expenditure (education). The bottom panel reveals no consistent differences for groups based on age.

To make the comparisons clearer, the top two panels of Figure 4 show the difference of the interquartile ranges between the groups with low levels of expenditure and education and high levels of expenditure and education, along with 95 percent bootstrap confidence intervals. The third panel shows the same information for groups based on age. For groups based on expenditure, the difference of the interquartile ranges is greater than zero in 92 percent of the months in my sample, and the 95 percent confidence interval is strictly above zero in 51 percent of the months. The average difference of the interquartile ranges over time is 0.40 with a bootstrap 95 percent confidence interval of (0.36, 0.43). For groups based on education, the differences between groups are somewhat less stark on a month-by-month basis but still similar. The difference of the interquartile ranges is greater than zero in 88 percent of the months in my sample, and the 95 percent confidence interval is strictly above zero in 31 percent of the months. Over time, the average difference of interquartile ranges is 0.29 with a bootstrap confidence interval of (0.26, 0.32). While the groups based on expenditure and education display persistent differences in the dispersion of experienced inflation, the bottom panel of Figure 4 shows that the differences in dispersion between groups based on age are much less pronounced. On a monthly basis, zero is contained in the 95 percent confidence interval in 94 percent of the months in my sample. Over time, the average difference is 0.03 with a 95 percent bootstrap confidence interval of (0, 0.06). The estimate is not statistically different from zero and the magnitude of the estimate is notably smaller than for groups based on expenditure and education.

The reasons for the persistent difference in the dispersion household-specific inflation experience across demographic groups can be seen in Figures 5 and 6, which show the interquartile range of

⁷I use the interquartile range rather than the standard deviation because it is robust to outliers. Results using the standard deviation are very similar.

the household-specific expenditure weights on food and energy, respectively. Households with lower levels of expenditure (education) have a more dispersed expenditure weights on food and energy. The greater within-group heterogeneity in expenditure weights leads to the greater dispersion in experienced inflation because food and energy prices are two of the most volatile components of the CPI.⁸ The bottom panel of each figure shows the same information for groups based on age. Unlike for groups based on expenditure and education, there is no persistent ordering of the interquartile range among groups based on age, which helps explain why the dispersion in experienced inflation is not persistently different for groups based on age.

3 Disagreement in Inflation Expectations

In this section, I use survey data from the MSC to document that demographic groups with lower levels of income (education) have persistently higher levels of disagreement about future inflation than demographic groups with higher levels of income (education). I also show that there are not persistent differences in disagreement among groups based on age.

3.1 Data

To measure household expectations about future inflation, I use data on expected price changes from the MSC. Each month, the MSC surveys approximately 500 consumers who are meant to be a random sample from the population of the United States. In any given month, about 40 percent of survey participants are re-interviewed after a 6 month lag. Survey participants are included in the data set at most two times. The MSC records a variety of demographic information about survey participants, including information about education, income, and age, which allows me to create demographic groups comparable to those in previous section. While the MSC does not have expenditure information, I assume that expenditure is roughly monotone in income, and thus compare expenditure groups with similarly formed groups based on income. Demographic groups based on education and age are formed based on the survey participant in the same way as they

⁸The interquartile range of household-specific expenditure weights on energy display a slight upward trend for each demographic group in the first 8 years of my sample. The reason is because of a level shift in the average level of expenditure weights on energy over this period as energy prices rose.

were for heads of households in the previous section.

The MSC asks each survey participant a variety of questions about the current condition of the United States economy. Among those questions, consumers are asked:

By about what percent do you expect prices to go (up/down) on average during the next 12 months?

I interpret the answers to this question to be the consumer’s beliefs about CPI inflation over the next year. The MSC records a numeric response to this question if a consumer is willing to provide one.⁹ Numeric responses are restricted to the integers, and the MSC imputes a smooth distribution over responses. Given my interpretation of the survey question, this smooth distribution is a probability density function of the distribution of expected rates of inflation.

There is considerable debate about the meaning of the responses to the MSC’s question about prices over the next year. Though it has been common practice to assume that respondents provide their best guess about CPI inflation,¹⁰ recent work has investigated what people have in mind when they answer the question posed by the MSC. Beginning in 2007, the Federal Reserve Bank of New York began surveying consumers to ask about “inflation” explicitly, rather than prices in general. Survey design and preliminary findings are documented in van der Klaauw et al. (2008), Bruine de Bruin et al. (2010), Bruine de Bruin et al. (2011), Bruine De Bruin et al. (2010), who show that the wording of the question, among other things, can greatly affect people’s responses.

Despite the limitations of the data from the MSC, I use the microdata on consumer expectations to investigate disagreement across demographic groups. To buttress my findings, I report suggestive evidence from other studies that used surveys of consumers that were designed to overcome some shortcomings of the MSC’s question about expected price changes.

3.2 Disagreement Within Income Groups

To measure within-group disagreement about future inflation, I focus on the interquartile range of responses to the MSC question about prices over the next year. I chose the interquartile range

⁹About 95% of survey participants provide a numeric answer to this question.

¹⁰See, for example, Coibion and Gorodnichenko (2012).

because the standard deviation is sensitive to a small number of outliers in the data from the MSC. Curtin (1996) documents that before 1995 the standard deviation was much larger than the interquartile range due to a small number of consumers who answer the question with unrealistically high inflation expectations. My my main conclusions are unchanged if the standard deviations are used.

The three panels in Figure 7 show the interquartile ranges from the smoothed distribution of inflation expectations for groups based on income, education, and age. Apparent in the top two panels, survey participants who report lower levels of income (education) disagree more about future inflation more than survey participants who report higher levels of income (education). However, no such consistent pattern of disagreement arises from the groups based on age. That is, the same groups for which I document persistent differences in the dispersion of experienced inflation also have persistent differences in disagreement about future inflation, and the differences go in the same direction. However, for groups based on age, which do not display persistent differences in the dispersion of experienced inflation, there is also no persistent difference in disagreement about future inflation.

While conclusions drawn from the MSC must be tempered by the limitations of the data, surveys of consumers' inflation expectations by the Federal Reserve Bank of New York and the Federal Reserve Bank of Cleveland provide supporting evidence. In the Federal Reserve Bank of New York's survey on inflation expectations, van der Klaauw et al. (2008) document that measures disagreement are lower those with higher income and levels of education as well. Additionally, Bryan and Venkatu (2001b) and Bryan and Venkatu (2001a) report similar results in a survey conducted by the Federal Reserve Bank of Cleveland on the inflation expectations of Ohioans from 1998-2001. In both of these surveys, consumers were asked about inflation explicit, rather than about prices in general, as in the MSC. Given the constancy of the results across multiple surveys and over time, I take the persistently higher disagreement about future inflation among demographic groups with low levels of income and education to be a feature of inflation expectations.

4 Models of Disagreement

In this section I describe an imperfect information model that can generate consistently higher disagreement within demographic groups that experience consistently higher dispersion in experienced inflation. Hence, the model connects inflation experience and inflation expectations in a way consistent with the empirical findings of this paper.

4.1 Imperfect Information

Recent work by Coibion and Gorodnichenko (2010) and Coibion and Gorodnichenko (2012) has drawn attention to the empirical successes of simple imperfect information models when applied to survey data. In the version of the model I study here, agents observe noisy signals about aggregate inflation and form expectations conditional on the information available to them. The model generates dispersion in expectations because agents have access to different sets of information.

To be concrete, I assume that annual aggregate inflation evolves so that

$$\pi_t = \pi_{t-1} + \sigma_\epsilon \epsilon_t, \quad (7)$$

where $\epsilon_t \sim N(0, 1)$, and that a continuum of agents, indexed by $i \in (0, 1)$, observe their individual rates of inflation, π_t^i . This time series representation of inflation has enjoyed empirical success, as documented by Atkeson and Ohanian (2001) and Stock and Watson (2007). Further, I assume that each agent's rate of inflation is related to aggregate inflation such that

$$\pi_t^i = \pi_t + \sigma_\psi \psi_t^i, \quad (8)$$

where $\psi_t^i \sim N(0, 1)$ and $\psi_t^i \perp \psi_t^j$ for $j \neq i$ and $\psi_t^i \perp \epsilon_t$. The idiosyncratic inflation rate of each agent acts as an imperfect signal about the aggregate rate of inflation. In each period, I assume that consumers learn $\pi_{t-\ell}$ for some $\ell > 0$. Let $\pi_{t|s}^i$ be the expectation of π_t formed by agent i using information available up to time s . Define $\bar{\pi}_{t|s} = \int_i \pi_{t|s}^i di$. I measure disagreement as the variance

of household expectations, which is given by

$$V_{t|s} = \int_i (\pi_{t|s}^i - \bar{\pi}_{t|s})^2 di \quad (9)$$

Since the model is linear and the shocks have a Gaussian distribution, agents optimally form beliefs using the properties of multivariate normal distributions. Consider the particularly simple case where $\ell = 1$. Expectations are formed so that

$$\pi_{t|t}^i = \pi_{t-1} + \frac{\sigma_\epsilon^2}{\sigma_\epsilon^2 + \sigma_\psi^2} (\pi_t^i - \pi_{t-1}). \quad (10)$$

Given the time series properties of π_t , we have that $\pi_{t+h|t}^i = \pi_{t|t}^i$ for $h \geq 0$ and a closed form expression for disagreement given by

$$V_{t+h|t} = \left(\frac{\sigma_\epsilon^2}{\sigma_\epsilon^2 + \sigma_\psi^2} \right)^2 \sigma_\psi^2 \quad (11)$$

Notice that the level of disagreement is not monotone in σ_ψ . The reason is that if the signal were perfectly informative ($\sigma_\psi = 0$), then there would be no disagreement since every household would have the same information set. However, there would also be no disagreement if the signal were perfectly uninformative ($\sigma_\psi = \infty$), since every household would forecast using only the past realizations of inflation. The function $V_{t+h|t}$ is a smooth function of σ_ψ so, $V_{t+h|t}$ is increasing and decreasing on some parts of the parameter space.

To connect the model to the data, I interpret σ_ψ as the within-group standard-deviation in experienced inflation. The interquartile ranges imply that the values of σ_ψ for groups in my sample are between 0.5 and 1.5, on average. I fit the time series model of four-quarter average CPI inflation to the US data during my sample and estimate a value of $\sigma_\epsilon^2 = 3.92$. I set $\ell = 1$ and plot the resulting level of disagreement, as a function of σ_ψ in Figure 8. Clearly, $\frac{\partial V_{t|t}}{\partial \sigma_\psi} > 0$ for σ_ψ in the relevant region, meaning that an increase in the dispersion of experienced inflation also increases disagreement about future inflation. In this sense, the model is consistent with the empirical regularities I document in the previous sections. Notably, the result is general in the

sense that the range of σ_ψ for which the model generates $\frac{\partial V_{t|t}}{\partial \sigma_\psi} > 0$ in increasing in ℓ . Thus, this simple version of the imperfect information model is able to capture a link between dispersion in experienced inflation and disagreement about future inflation.

4.2 Other Models of Expectation Formation

Mankiw and Reis (2002) develop a model of sticky information that has been used by Mankiw et al. (2003) to explain features of disagreement in survey data on inflation expectations. To make the model comparable to the imperfect information model studied above, assume that inflation follows the same time series process. Following Mankiw and Reis (2002), I assume that in every period agents update their information with probability $1 - \lambda$. If an agent updates his or her information, he or she becomes fully informed about the entire history of aggregate inflation. Agents who do not update their information set remain ignorant of the inflation path since they last acquired new information.

The expected level of one-period-ahead inflation for a person who last updated his or her information k periods ago is π_{t-k} . Define $\bar{\pi}_t$ to be the average expected rate of inflation at time t , which is given by

$$\bar{\pi}_t = (1 - \lambda) \sum_{k=0}^{\infty} \lambda^k \pi_{t-k}. \quad (12)$$

The variance of beliefs about one period ahead inflation is given by

$$(1 - \lambda) \sum_{k=0}^{\infty} \lambda^k (\pi_{t-k} - \bar{\pi}_t)^2. \quad (13)$$

Notice that, unlike in the imperfect information model, disagreement is necessarily state dependent; the history of the level of inflation determines the dispersion in the distribution of expectations. A large change in the level of inflation will cause the beliefs of those with stale information to be very different from the beliefs of those with updated information, and disagreement increases. If inflation remains at the same value for many periods, disagreement will converge to zero.

Endowing groups with different values of λ introduces heterogeneity in the sticky information

model. However, because disagreement is state-dependent, different values of λ do not result in predictably different levels of disagreement. To understand why, consider two groups. In group one, agents update their information with probability 0.5 ($\lambda = 0.5$). In group two, agents update their information with probability 0.1 ($\lambda = 0.9$). Also assume that inflation had been constant for many periods. In this case, we would initially observe (almost) no disagreement within both groups. Now consider a shock that increases inflation by two percentage points on an annualized basis. In the period of the shock, half of the people in group one will report expectations based on the current information and half will use the old value. In group two, only ten percent will use the new information and ninety percent of agents will use the old information, meaning that disagreement will be lower in group two than in group one. However, because information is acquired relatively quickly by agents in group one, disagreement in group one will fall quickly. In group two, it takes longer for agents to become fully informed, meaning that disagreement will rise and fall relatively slowly. Figure 9 shows these dynamics. Since levels of disagreement are state contingent and rise and fall at different rates, different groups (defined by different values of λ) will at different times display more or less disagreement.

Carroll (2003) studies an epidemiological model of belief formation that takes a similar form to the sticky information model, except that agents update their information sets with forecasts of inflation from professional forecasters rather than past inflation. Disagreement evolves in much the same way as in the sticky information model in that it is state contingent and is not consistently different across groups. While the simple imperfect information model studied above certainly does not capture the entirety of the expectation formation process—for example, it does not produce the level of disagreement seen in the data on household inflation expectations—it does provide a key link between inflation expectations and inflation experience that can result in consistently different levels of disagreement among demographic groups. My empirical results suggest that this is a connection other models of the expectation formation process need to confront. Thus, even in models that generate disagreement from statistical uncertainty, like in Branch (2007), my results suggest that the information sets of households should be linked to household-specific inflation experience.

5 Implications for Forecasting Performance

A empirical connection between a household's consumption bundle its expectations about future inflation has implications for the forecasting performance of different households. From the perspective of the imperfect information model, households that receive less noisy signals about inflation would have lower absolute forecast errors. To see if this prediction holds in the data, I calculate the mean squared forecast error (MSFE) for demographic groups based on income, education, and age, using the median of the imputed distribution from the forecasts from the MSC as the group forecast. The results are reported in Table 1. Notably, the MSFE is higher for groups with low levels of income (education) than for groups with high levels, but there is no pattern for groups based on age. The estimated difference in the MSFE between groups with low levels of income and groups with high levels of income is 1.49 and the GMM standard error of the difference is 0.55, making it statistically significant at standard levels of confidence.¹¹ Similarly, the estimated difference in the MSFE between groups with low levels of education and groups with high levels of education is 0.80 and the GMM standard error of the difference is 0.35, again making the difference statistically significant.

Table 1: Mean Squared Forecast Errors by Group

Group	MSFE
Age < 35	3.25
$35 \leq \text{Age} < 55$	3.18
Age > 55	3.22
Income: Bottom $\frac{1}{3}$	4.40
Income: Middle $\frac{1}{3}$	3.31
Income: Top $\frac{1}{3}$	2.91
Education: High School	3.77
Education: Some College	3.51
Education: College Degree	2.97

¹¹The weighting matrix is calculated to take into account serial correlation using the method of Newey and West (1987).

Bruine De Bruin et al. (2010) have emphasized the role of financial literacy for inflation expectations of households. If the same households that have relatively high levels of education and income also have relatively high levels of financial literacy, the relatively good forecasting performance of these groups is not surprising. To further investigate the relationship between these groups' inflation experience and their forecasting performance, I weight one-year ahead inflation expectation from the MSC by each characteristic. For income and age, I use the value reported by the survey respondent as the weight. To produce the weights for education, I assign a value of 10 if the person has less than a high-school degree, 12 if the person has a high-school degree, 14 if the person has some college, and 16 if the person has a college degree. The numbers are chosen to roughly correspond to the number of years of school the respondent has completed.

Table 2 reports the MSFE over my sample period of the weighted one-year ahead average inflation expectations from the MSC.¹² Notably, weighting survey responses by income results in the lowest MSFE and weighting by age results in the highest. The final row of Table 1 reports the MSFE for forecasts using an alternative weighting for education where I raise the original weights to the fourth power so that respondents with a college degree have about three times more weight than respondents with a high-school degree. While this alternative weighting improves the MSFE, weighting by income still results in the best forecasting performance.¹³ If financial literacy is at least as correlated with years of education as it is with income, then one would expect that weighting inflation forecasts by education would result in the best predictor. Instead, the income weights produce the lowest MSFE. Groups delineated by expenditure have the sharpest differences in inflation dispersion, meaning that the low MSFE produce by the income weights is consistent with the predictions of the imperfect information model which implies a link between within-group inflation dispersion and a group's forecasting performance.

¹²The MSFE's in Table 2 are not directly comparable to those reported in Table 1 because I am using a version of a mean expectation in Table 2, not a median.

¹³I have tried raising the education weights to many different powers, and none produced a lower MSFE than the income weights.

Table 2: Mean Squared Forecast Errors, Weighted Forecasts

Weighting	MSFE
Income	3.71
Age	4.51
Education	4.37
Education (Alternative)	4.11

6 Conclusion

In this paper, I empirically established that demographic groups that have greater dispersion in experienced inflation also disagree more about future inflation. I showed that the imperfect information model can generate these features of the data if signals about aggregate inflation are interpreted as household-specific rates of inflation. Furthermore, I showed that the model’s predictions about the relative forecasting performance of different groups holds in the data from the MSC, which further sheds light on a connection between inflation experience and inflation expectations in the expectation formation process of households.

While I interpret the empirical regularities I document as implying that the imperfect information model captures salient features of the expectation formation process of households about future inflation, I do not mean to conclude that the expectation formation process of households is fully characterized by that simple model. The way that households formulate their responses to the MSC (and other surveys) is more complicated than the simple models studied here can capture. Almost surely issues of financial literacy, as emphasized by Bruine De Bruin et al. (2010), play an important role in the way that households form expectations and respond to surveys. Furthermore, the models presented in Carroll (2006) and Mankiw et al. (2003) are successful along other dimensions than those studied here. The purpose of this study is to document certain empirical regularities between inflation expectations and inflation experience that any model of the expectation formation process of households must address.

References

- Atkeson, A. and L. E. Ohanian (2001). Are Phillips Curves Useful for Forecasting Inflation? *Federal Reserve Bank of Minneapolis Quarterly Review* 1(25), 2–11.
- Branch, W. A. (2007, January). Sticky information and model uncertainty in survey data on inflation expectations. *Journal of Economic Dynamics and Control* 31(1), 245–276.
- Bruine de Bruin, W., C. F. Manksi, G. Topa, and W. van der Klaauw (2011). Measuring Consumer Uncertainty about Future Inflation. *Journal of Applied Econometrics* 26, 454–478.
- Bruine de Bruin, W., S. Potter, R. Rich, G. Topa, and W. van der Klaauw (2010, August). Improving Survey Measures of Household Inflation Expectations. *Federal Reserve Bank of New York Current Issues in Economics and Finance* 16(7), 1–7.
- Bruine De Bruin, W., W. van der Klaauw, J. S. Downs, B. Fischhoff, G. Topa, and O. Armantier (2010, June). Expectations of Inflation: The Role of Demographic Variables, Expectation Formation, and Financial Literacy. *Journal of Consumer Affairs* 44(2), 381–402.
- Bryan, M. F. and G. Venkatu (2001a, November). The Curiously Different Inflation Perspectives of Men and Women. *Federal Reserve Bank of Cleveland Economic Commentary Series*.
- Bryan, M. F. and G. Venkatu (2001b, October). The Demographics of Inflation Opinion Surveys. *Federal Reserve Bank of Cleveland Economic Commentary Series*.
- Cage, R. A., T. I. Garner, and J. Ruiz-Castillo (2002). Constructing Household Specific Consumer Price Indexes: An Analysis of Different Techniques and Methods. *BLS Working Papers* (354).
- Carroll, C. (2003, February). Macroeconomic Expectations of Households and Professional Forecasters. *The Quarterly Journal of Economics* 118(1), 269–298.
- Carroll, C. D. (2006). The Epidemiology of Macroeconomic Expectations. In L. Blume and S. Durlauf (Eds.), *The Economy as an Evolving Complex System, III*. Oxford: Oxford University Press.
- Coibion, O. and Y. Gorodnichenko (2010). Information Rigidity and the Expectations Formation Process: A Simple Framework and New Facts. *NBER Working Paper 16537*.
- Coibion, O. and Y. Gorodnichenko (2012, February). What Can Survey Forecasts Tell Us about Information Rigidities? *Journal of Political Economy* 120(1), 116–159.
- Curtin, R. T. (1996, May). Procedure to Estimate Price Expectations. *University of Michigan Survey Research Center Manuscript*, 1–56.
- Hameed, F. (2006). Essays on Fiscal Transparency and Inflation Expectations. *PhD Dissertation, Johns Hopkins University*.

- Hobijn, B. and D. Lagakos (2004). Inflation Inequality in the United States. *Review of Income and Wealth* 51(4).
- Madeira, C. and B. Zafar (2014). Heterogeneous Inflation Expectations and Learning. *FRBNY Staff Reports* (536).
- Malmendier, U. and S. Nagel (2013). Learning from Inflation Experiences. *mimeo*.
- Mankiw, N. G. and R. Reis (2002, November). Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve. *The Quarterly Journal of Economics* 117(4), 1295–1328.
- Mankiw, N. G., R. Reis, and J. Wolfers (2003, June). Disagreement about Inflation Expectations. *NBER Working Paper Series 9796*.
- Meyer, B. and G. Venkatu (2011, May). Demographic Differences in Inflation Expectations: What Do They Really Mean. *Federal Reserve Bank of Cleveland Economic Commentary Series*.
- Newey, W. K. and K. D. West (1987). A Simple Positive Semi-Definite Heteroskedasticity and Autocorrelation Consistent Covariance Matrix. *Econometrica* 55, 967–976.
- Poole, R., F. Ptacek, and R. Verbrugge (2005). Treatment of owner-occupied housing in the cpi. *mimeo*.
- Stewart, K. J. (2008, April). The Experimental Consumer Price Index for Elderly Americans (CPI-E): 1982-2007. *Monthly Labor Review, Bureau of Labor Statistics*.
- Stock, J. H. and M. W. Watson (2007). Why Has U.S. Inflation Become Harder to Forecast? *Journal of Money, Credit, and Banking* 39(1).
- van der Klaauw, W., W. Bruine de Bruin, G. Topa, S. Potter, and M. F. Bryan (2008). Rethinking the Measurement of Household Inflation Expectations: Preliminary Findings. *Federal Reserve Bank of New York Staff Reports December*(no. 359).

A Consumption Categories and Price Indexes

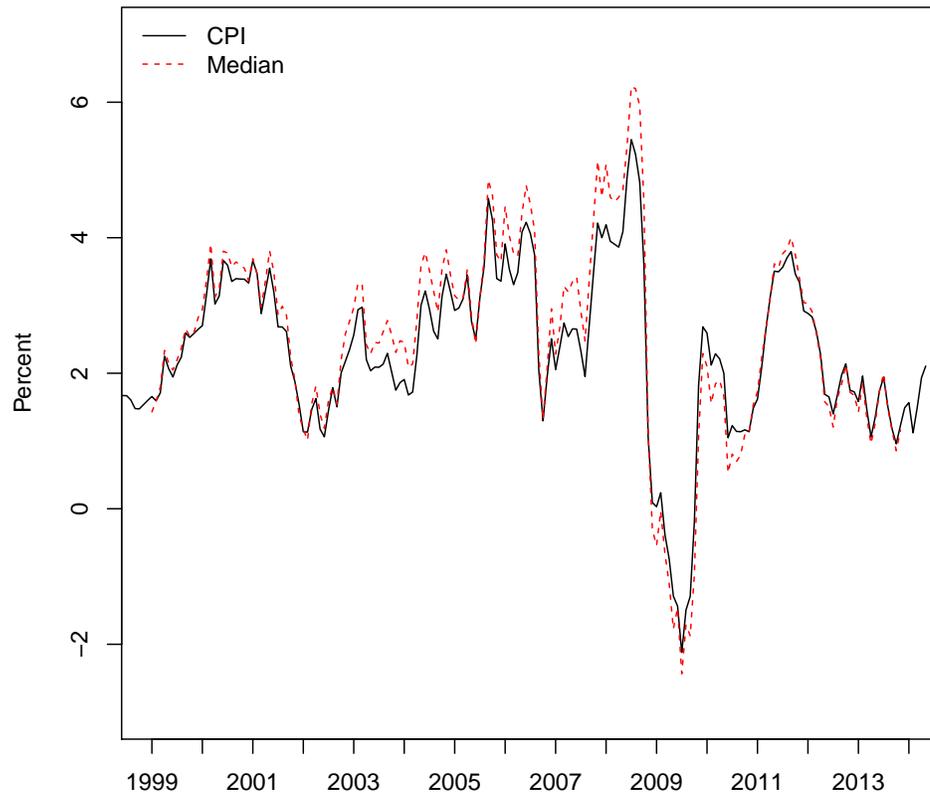
The 22 consumption categories I use to construct consumption bundles are listed below with the associated price indexes.

Table 3: Consumption Categories and Price Indexes

Category	Price Index (CUUR0000)
Food at Home	SAF11
Food Away from Home	SEFV
Alcoholic Beverages	SAF116
Shelter	SAH1
Natural Gas	SEHF02
Electricity	SEHF01
Other Fuel	SEHE
Phone	SEED
Water	SEHG
Household Operations	SEHP
Household Furnishings	SEHL
Apparel	SAA
Other Vehicles	SETA
Gasoline and Motor Oil	SETB
Other Vehicle Expenses	SETD
Public Transportation	SETG
Health	SAM
Entertainment	SAR
Personal Care	SAG1
Reading Material	SERG
Education	SAE
Miscellaneous	SAG

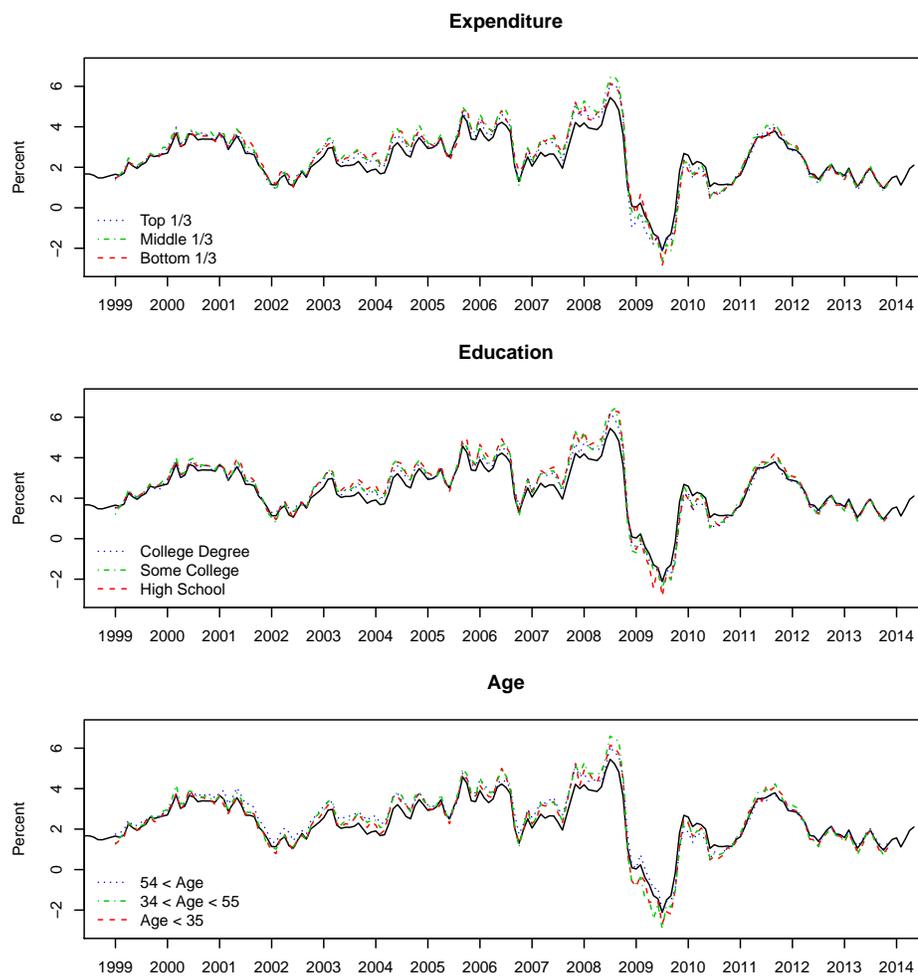
B Figures

Figure 1: Headline and Median Consumer Price Inflation



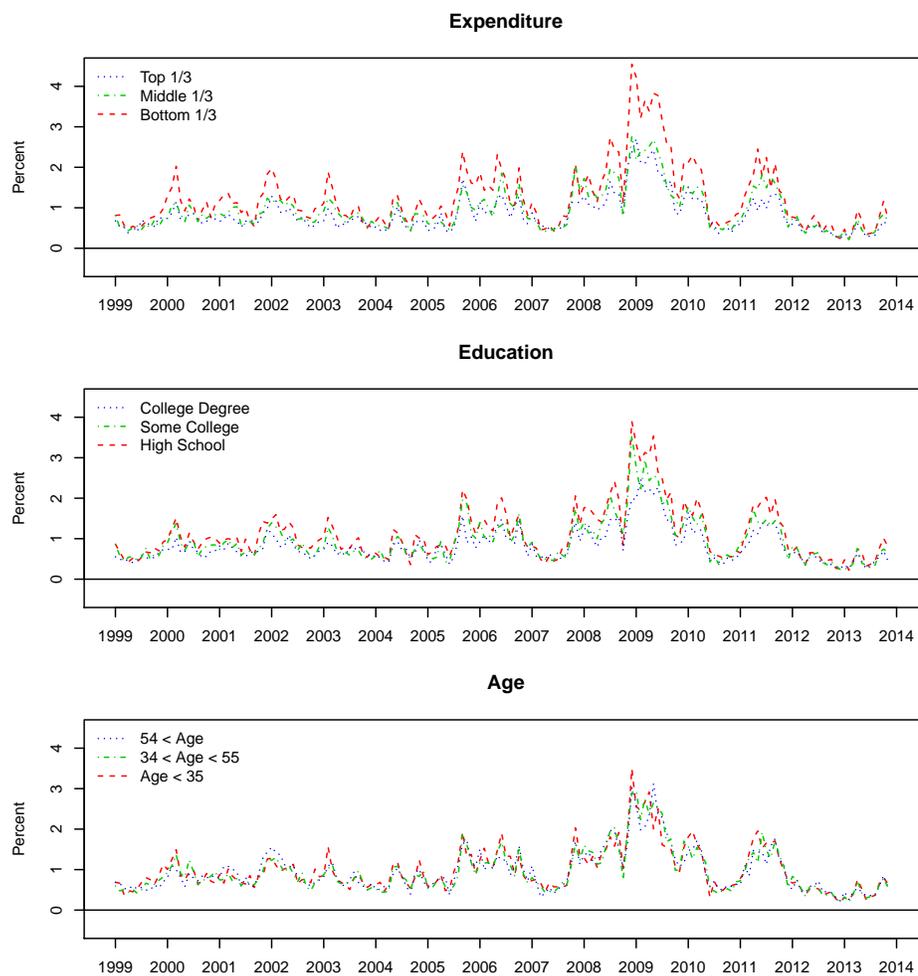
Source: Bureau of Labor Statistics and author's calculations.

Figure 2: Median Household-Specific Inflation by Group



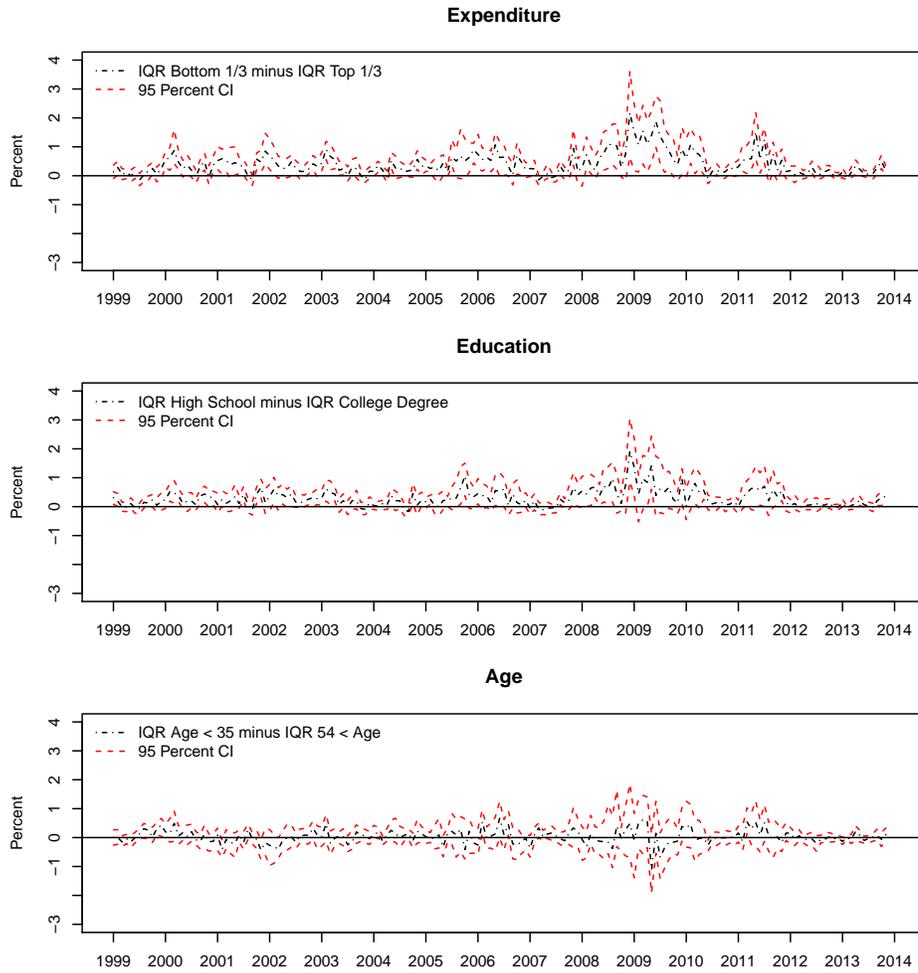
Source: Bureau of Labor Statistics and author's calculations. The black solid line is CPI inflation.

Figure 3: Interquartile Range of Household-Specific Inflation by Group



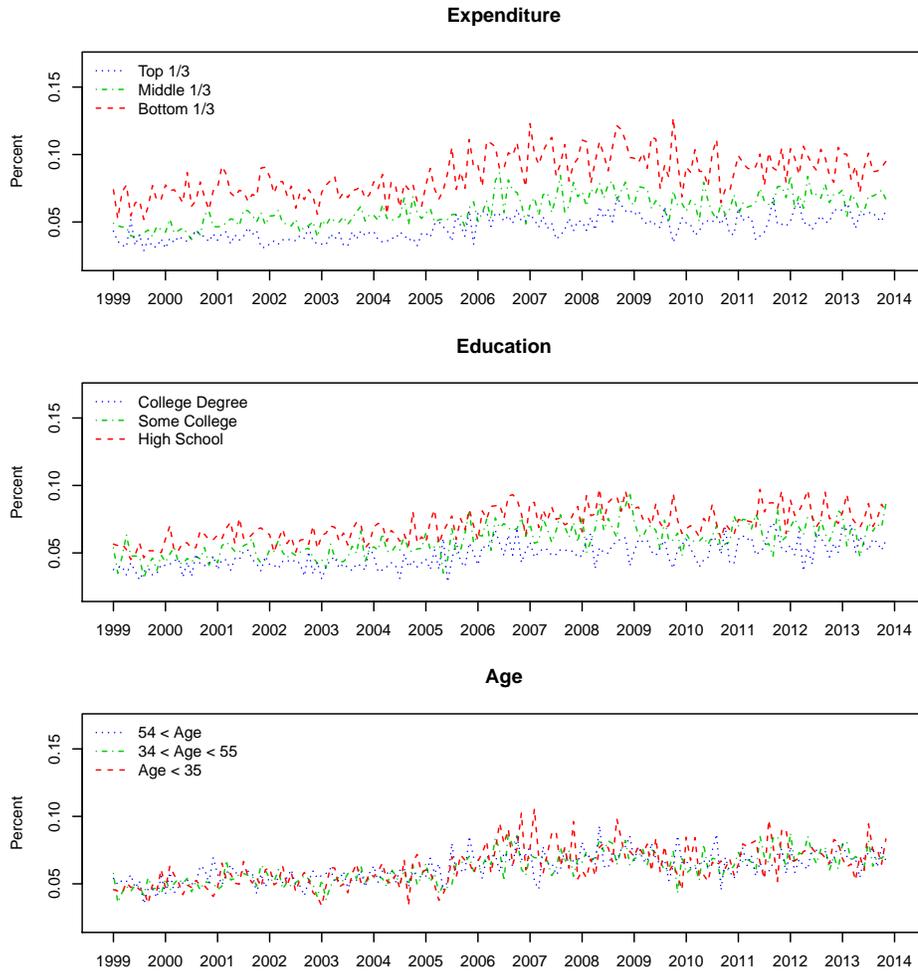
Source: Bureau of Labor Statistics and author's calculations.

Figure 4: Difference of Interquartile Ranges of Household-Specific Inflation



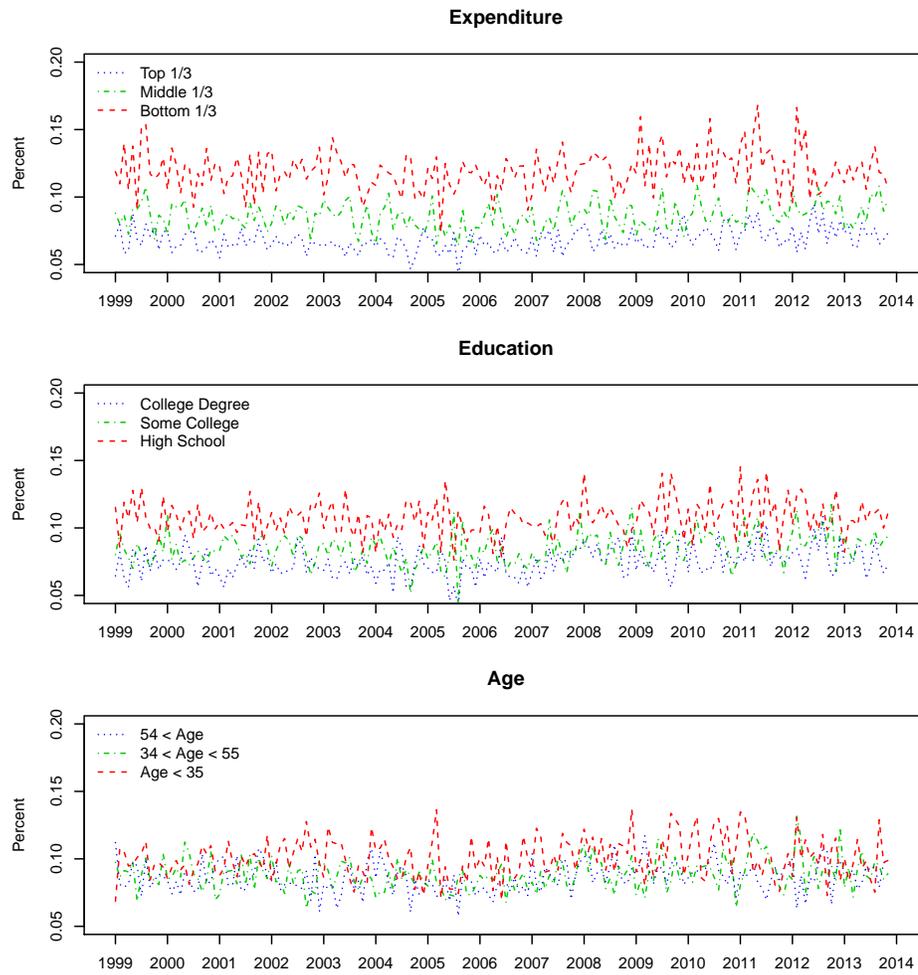
Source: Bureau of Labor Statistics and author's calculations.

Figure 5: Interquartile Ranges of Household Weights on Energy by Group



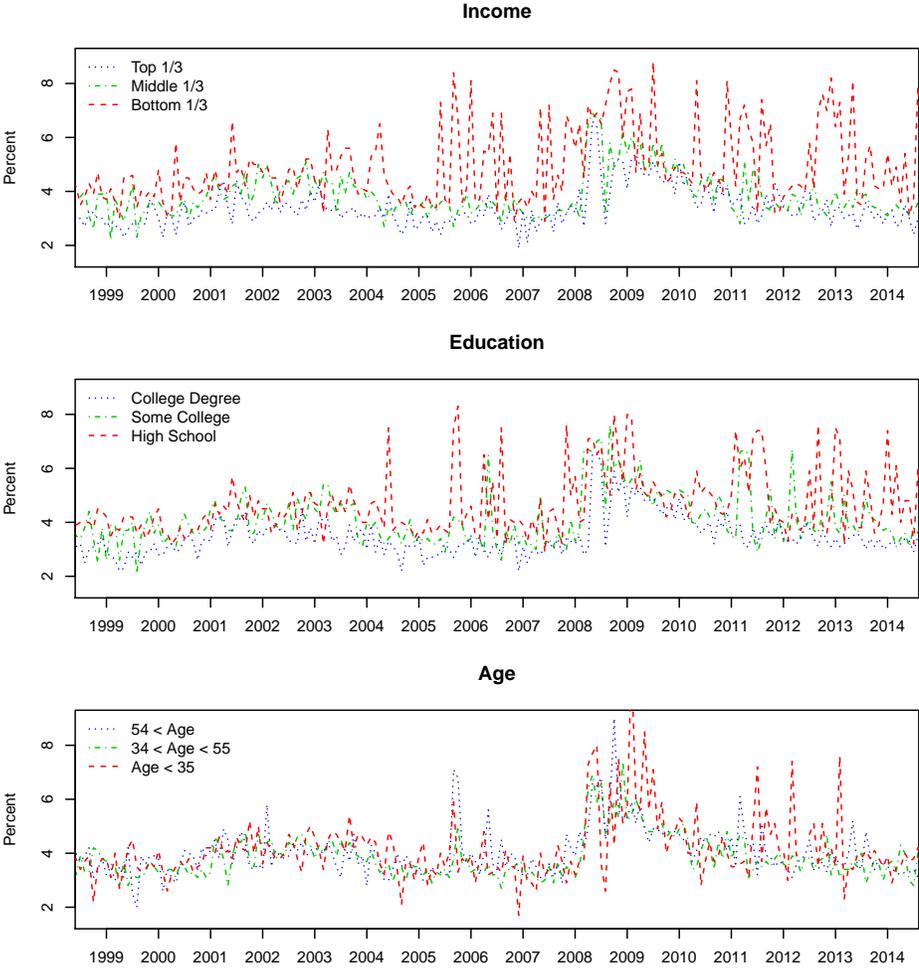
Source: Bureau of Labor Statistics and author's calculations.

Figure 6: Interquartile Ranges of Household Weights on Food by Group



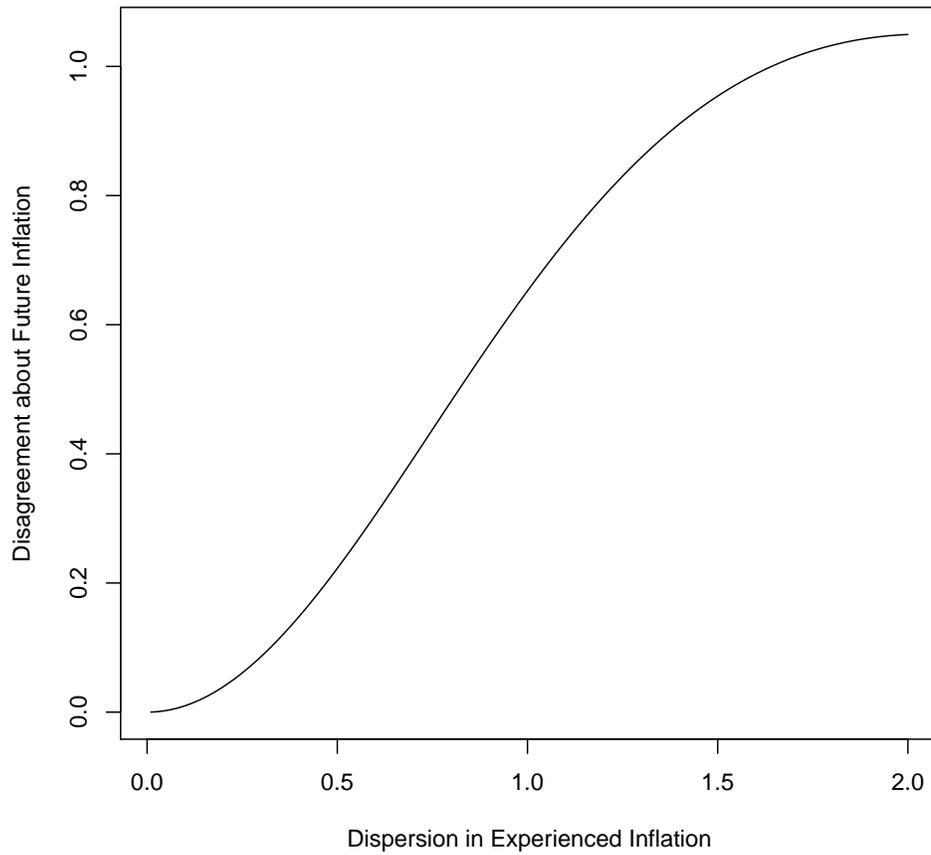
Source: Bureau of Labor Statistics and author's calculations.

Figure 7: Disagreement about Future Inflation, by Group



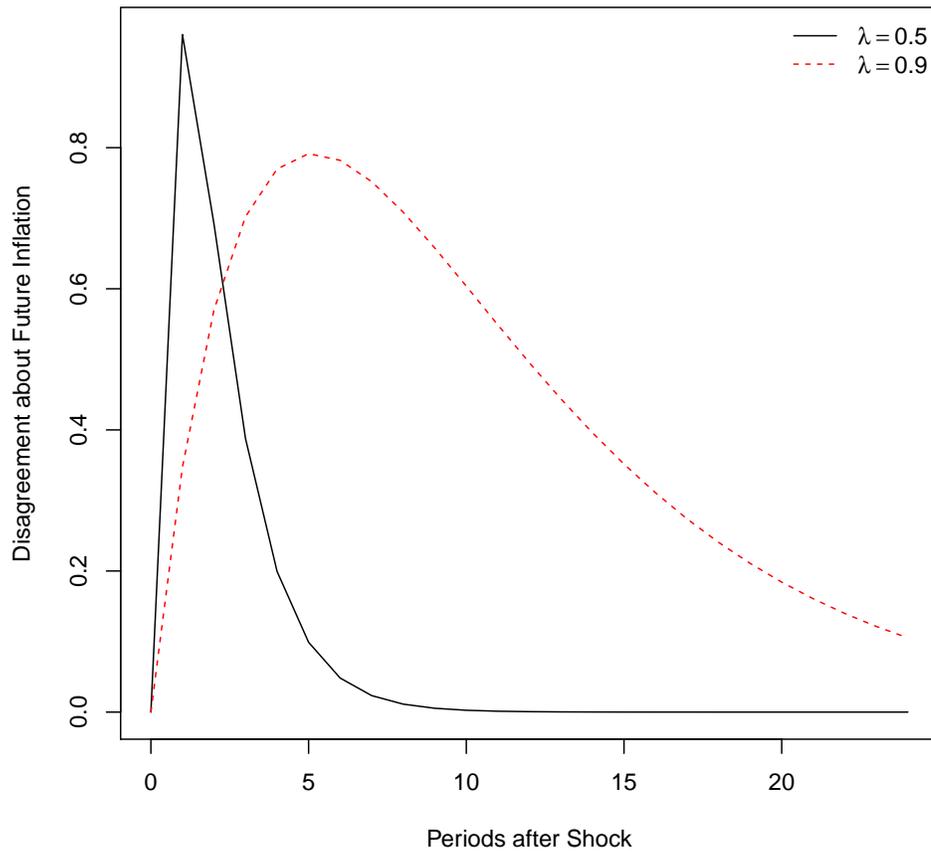
Source: Thompson-Reuters/University of Michigan Survey of Consumers.

Figure 8: Disagreement in the Imperfect Information Model



Source: Author's calculations.

Figure 9: Disagreement in the Sticky Information Model After a 2 Percent Inflation Shock



Source: Author's calculations.