INFLATION EXPECTATIONS AND INFLATION FORECASTING: CONSUMERS VERSUS PROFESSIONAL FORECASTERS

by

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To my parents,
for their selfless love.

To my love, Xue Qi,
without whom this thesis would have been completed earlier :)

Table of Contents

List of Tables

List of Figures

Abstract

By using Michigan and SPF surveys, this thesis compares the group-level inflation-forecast performance as well as information transmission between two main market-participation groups, consumers and professional forecasters. Group-level performance are in terms of forecasting different U.S. inflation indexes and evaluated using forecast accuracy measured by RMSE as well as predictive power tested by a linear model. In addition, consumers are decomposed into three sub-groups based on educational attainment and income distribution to explore within-group heterogeneity. The results indicate that both consumer groups and professionals show poor forecast performance for all the inflation measures, except professionals' performance for CPI-Core. Further, gathering downward-biased inflation forecasts from professionals is a possible reason that contributes to highly educated consumers' inflation-forecast performance for price changes of expenditure categories they care.

Keywords: Michigan survey; SPF survey; group-level; heterogeneity

List of Abbreviations and Symbols Used

Michigan Survey	Surveys of Consumers Conducted by Michigan University
SPF	Survey of Professional Forecasters Conducted by Federal Reserve Bank of Philadelphia
CPI–U	Consumer Price Index for All Urban Consumers, All Items
CPI–Core	Consumer Price Index for All Urban Consumers, All Items Less Food and Energy
CPI–Nondu	Nondurables Index of Consumer Price Index for All Urban Consumers
CPI–A	Apparel Index of Consumer Price Index for All Urban Consumers
CPI–Fb	Food and Beverages Index of Consumer Price Index for All Urban Consumers
CPI–H	Housing Index of Consumer Price Index for All Urban Consumers
CPI–T	Transportation Index of Consumer Price Index for All Urban Consumers
CPI–E	Energy Index of Consumer Price Index for All Urban Consumers
PCE	Personal Consumption Expenditure Index
Gdpurchase	Gross Domestic Purchase Index
BLS	Bureau of Labor Statistics
BEA	Bureau of Economic Analysis
C-all	General Michigan Consumer Group
C-hi	Michigan Consumer Group with Relatively Higher Income
C-he	Michigan Consumer Group with Relatively Higher Education
Pro	SPF Professional Group

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Chapter 1

Introduction

Ever since the fundamental theory of macroeconomics of Keynes (1936), economists have long emphasized the key role of private agents' expectations in determining macroeconomic outcomes.[1] In particular, in recent decades, private agents' inflation expectations has attracted significant attention. For instance Bernanke (2007) argues that expectations of inflation greatly influence actual inflation, and thus the central bank's ability to maintain price stability, low unemployment, and sustained economic growth. Therefore, most central banks around the world strive for well anchored inflation expectations (Pfajfar and Santoro, 2010).

Given the importance of understanding the determinants of inflation expectations, a large literature has focused on theoretical models, in particular modeling the formation of private agents' inflation expectations. Main theoretical models including backward-looking adaptive expectations (Cagan, 1956; Friedman, 1957), forward-looking rational expectations (Muth, 1961; Lucas Jr, 1976; Sargent and Wallace, 1975), the adaptive-learning model (Evans and Honkapohja, 2001), as well as bounded-rational expectations with sticky information and rational inattention (Mankiw, Reis, and Wolfers, 2003; Carroll, 2003).

Given the proliferation of theoretical models, it is also useful to study private agents' inflation expectations from a more "practical" prospective. This thesis thus uses a variety of empirical models to understand the processes that underlie inflation expectations. Specifically, by using time-series survey measures of inflation expectations from Michigan Survey of Consumers (Michigan Survey) and Survey of Professional Forecasters (SPF), we comprehensively compare the U.S. inflation-forecasting

[1] Keynes (1936), for instance, argued that due to the time gap between the incurring of costs for production by the producer and the purchase of output by the ultimate consumer, producers' expectations regarding the price of "finished" goods at the time of decision making had a significant influence on employment and output.

behavior between two main market participants: consumers and professional forecasters.[2] In addition, consumers are decomposed into three sub-groups based on educational attainment and income distribution to explore within-group heterogeneity: a "all" group which is defined as the entire Michigan consumer sample, a "high-education" group which is defined as the group of Michigan consumers with college or higher degree, and a "high-income" group as the group of consumers with top 33% sample-income.[3]

Three objectives are pursued in this thesis. Our first and primary objective is to compare and contrast the forecast performance between different groups of consumers and professional forecasters, in terms of forecasting the U.S. inflation rate gauged by various different measures of price indexes. Group-level performance are evaluated using forecast accuracy measured by RMSE as well as predictive power tested by a linear model. Second, information transmission between consumers and professional forecasters is examined to see whether consumers gather information from professionals before reporting their forecasts. Further, we examine for possible heterogeneity in consumers' inflation forecasting in two dimensions: forecast performance and efficiency of information usage. Specifically, we examine whether consumers with relatively high education or income outperform the general public or even professional forecasters, and whether they are more likely to gather forecast information from professionals than the general public if it is the case that professionals outperform the public (including those with high education or income).

This thesis makes three contributions. First, to our knowledge, our analysis is the first to comprehensively use various measures of U.S. inflation rate to measure the forecast performance between consumers and professionals at group-level, including different components of the Consumer Price Index (CPI), Personal Consumption Expenditure (PCE) Deflator, and Deflator for Gross Domestic Product (Gdpurchase).

The previous literature has mainly concentrated on using overall CPI as the

[2]The professional forecasters who conduct the SPF survey worked in several industries including financial service, manufacturing, consulting, etc., therefore can be treated as the representatives of firms in terms of their inflation expectations. For more details of industry classifications, see SPF documentation: http://www.philadelphiafed.org/research-and-data/real-time-center/survey-of-professional-forecasters/spf-documentation.pdf.

[3]Ideally, consumer group with both high education and income should be explored jointly. But due to the restriction of the survey data, we examine them separately. Also, top 33% as well as college or higher degree is the finest categories publicly available from monthly Michigan Survey.

benchmark, which is also called CPI for all urban consumers, all items (CPI-U). For example, by comparing the mean survey responses between Michigan Survey and Livingston Survey for economists, Gramlich (1983) shows that in general consumers surprisingly do a slightly better job than economists in forecasting U.S. inflation rate measured by CPI-U. However, both groups fail a test based on the rational expectation hypothesis, appearing to be biased and inefficient.[4] In addition, Thomas (1999) finds that the median consumer forecasts of year-ahead CPI inflation rate from Michigan Survey outperform forecasts from both Livingston and SPF surveys in terms of accuracy, as well as unbiasedness in the 1981-1997 period. Mehra (2002) also finds Michigan consumers outperform professional economists and forecasters in the period covering the 1980s and 1990s: He concludes that "Michigan consumers are more accurate, unbiased, have predictive content for future inflation."

Yet, the most comprehensive study to date, Ang, Bekaert, and Wei (2007), finds a different result. Using three CPI measures and PCE deflator as the benchmark, they compare the forecasting performance between four alternative inflation forecast methods: time-series forecasts, forecasts based on the Phillips curve, forecasts from the yield curve, and surveys (the Livingston, Michigan, and SPF surveys). They find survey measures consistently deliver better forecasts than other three methods, while SPF and Livingston surveys conducted among professionals, do even better than the consumers in the Michigan Survey. However, Ang et al. (2007) do not consider various components of the CPI index that capture the price changes of those commodities that may be more relevant for consumers' daily purchases like food, transportation, etc., as well as the GDP deflator. Also, they do not examine high-education or high-income consumer groups separately, and compare them with the general public as well as professionals.

The lack of a proper benchmark price index implies that there is no well-accepted set of findings regarding which inflation rate is the most appropriate to use to model or examine private agents' (especially, consumers') inflation expectations. Here, instead of only using CPI-U, testing inflation-forecast performance using a variety of

[4]Michigan Survey data on inflation expectations of consumers has been routinely used to test the rational expectations hypothesis. See Lott and Miller (1982); Grant and Thomas (1999); Roberts (1997); Baghestani (1992); Noble and Fields (1982); Batchelor (1986). The existing data has rarely given clear support to the rational expectations hypothesis, with the principle failing being the lack of efficient use of all available information (Curtin, 2010).

inflation measures acknowledges the fact that different groups pay attention to different components of price in forming their inflation expectations. As mentioned by Curtin (2010), it would make no sense for ordinary people to take into account future prices that they will not face when making their forecasts.

In terms of examining the information transmission from professionals to different groups of consumers, we follow and extend the epidemiological sticky-information model proposed by Carroll (2003). Specifically, in order to capture the substantial disagreement about expected future inflation that is observed in the U.S. survey data for both consumers and professionals and that can not be explained by the traditional rational expectations framework, Mankiw et al. (2003) propose a sticky-information model in which agents update expectations only periodically because of costs of collecting and processing information. Carroll (2003) provides a simple and testable micro-foundation for sticky-information model, assuming consumers update inflation expectations probabilistically toward the views of professional forecasters — a model inspired by the epidemiology literature. Carroll (2003) argues that this model does a good job of capturing much of the variation in the Michigan Survey's measures of consumers' inflation expectations.

However, in Carroll's model, the probability of updating information is constant and the same for all consumers . Here, we relax this assumption to account for the possibility that consumers with relatively high education or income might update expectations or gather information from professionals more frequently than general consumers. To our knowledge, this thesis is the first to consider cross-sectional heterogeneity in sticky-information model, associating information-updating probability with consumers' observed demographic characteristics.

In fact, several papers have already provided empirical evidence on the heterogeneity of information-updating in sticky-information models, but these papers primarily focus on the time-series variations. For example, Mankiw and Reis (2002) suggest that agents update information more frequently when inflation matters (relatively high or low). Pfajfar and Santoro (2010) uses percentile time series analysis as well as a sticky-information model and find that consumers in the Michigan Survey are more likely to update their expectations during periods of high inflation.

The third contribution of this thesis is that, we pay considerable attention to the

comparability issue between Michigan and SPF surveys regarding their forecast horizons. This issue is particularly relevant to compare inflation-forecast performance of consumers and professionals. Specifically, we argue that consumers respond to monthly Michigan Survey interviews and their responses in the third month of every quarter are the best observations to be employed to compare their inflation-forecast performance with those professional forecasters who respond to the SPF Survey quarterly. This allows us to condition these forecasts using same forecast horizon and similar information set. To our knowledge, this is the first time "such consistency is considered" in the literature.

In addition, in term of examining the possibility of information transmission from professionals to consumers, the consumers surveyed in the third month of every quarter are also the best choices since they have the same-quarter professionals' inflation-forecast information in their information set for sure. Therefore, in this thesis, Michigan consumers' inflation forecast data from third month of each quarter is first used to compare forecast performance as well as information transmission with quarterly SPF professionals' forecasts.[5]

Our major empirical results can be summarized as follows. First, in general, the professionals in the SPF show relatively better inflation-forecast performance for all broad inflation measures (e.g., CPI-U, CPI-Core and PCE) except for the GDP deflator. By contrast, Michigan consumer groups perform relatively well in forecasting sub-index CPI measures. However, from the standpoint of absolute forecast accuracy, none of the groups shows notable forecast performance and RMSEs by all groups exceed the standard deviations of the corresponding inflation series, except SPF professionals' forecast performance for CPI-Core. In addition, we do not find evidence that high-income or high-education consumer groups necessarily outperform the entire Michigan Survey consumers (the "all" group) in terms of inflation-forecast performance.

Second, in terms of information transmission, the baseline model of epidemiological sticky-information (Carroll, 2003) is not an accurate description how the consumers in the Michigan Survey sample form inflation expectations. And only high-income and high-education consumer groups, especially highly educated Michigan

[5]Fore more details, see Section 2.1 below.

consumers, tend to possibly gather inflation-forecast information from professionals. Further, when making inflation forecasts, both the "all" and high-income consumer groups have systematic forecast errors and heavily rely on their previous forecasts, which contribute to their poor inflation-forecast performance. While for highly educated consumers, this group use inflation-forecast information in a relatively efficient and timely manner. On the other hand, gathering downward-biased SPF forecasts is a possible reason that contributes to high-education group's poor forecast performance for inflation series they care (e.g., CPI-Fb and CPI-H).

The reminder of this thesis is structured as follows. Chapter 2 describes the data sets, including the various U.S. inflation indexes we considered as well as the Michigan and SPF surveys. Chapter 3 introduces the models we used to examine inflation forecast performance as well as information transmission between different groups of consumers and professional forecasters. Chapter 4 contains the empirical results. Chapter 5 concludes.

Chapter 2

Data

2.1 Survey Measures of Inflation Expectations

We begin by discussing the details and differences between Michigan and SPF surveys, two major and consistent U.S. surveys that contain extensive information on expectations for consumers and professional forecasters respectively.

Specifically, initiated in 1946 by Survey Research Center of University of Michigan, Michigan Survey has been collecting information about consumers' expectations for economic growth, inflation, unemployment, and other macroeconomic factors for almost 50 years. On the other hand, as one of the oldest quarterly survey of macroeconomic forecasts of U.S., SPF has been providing professionals' forecasts of various economic variables since 1968.

While the survey information this thesis mainly focuses on are different consumers and professionals' survey forecasts for one-year-ahead average inflation rate, treated as proxies for their inflation expectations over the next year. Table 2.1 provides the basic details and differences for the two surveys with this focus.[1]

There are two crucial differences between the Michigan and SPF surveys that affect the group-level comparability between the consumers' and professional forecasters' one-year-ahead average inflation-forecast performance. First, compared with SPF that is conducted quarterly, Michigan survey has a monthly frequency. Although Michigan survey provides recalculated quarterly data for consumers' aggregate-level forecasts (e.g., mean, median and other statistical variables), which is applied by most previous literature that compare group-level inflation-forecast performance between consumers and professionals, but the methodology for recalculation remain unclear.[2]

[1]For further details on Michigan survey, see survey website: http://www.sca.isr.umich.edu/ For SPF, see: http://www.phil.frb.org/research-and-data/real-time-center/survey-of-professional-forecasters/index.cfm.

[2]We could not find documentation regarding the recalculated method at Michigan Survey's website: http://www.sca.isr.umich.edu/, it is also not discussed by any previous scholars who applied the recalculated quarterly data, see Gramlich (1983); Thomas (1999); Mehra (2002); Carroll (2003).

Table 2.1: Michigan Survey and Survey of Professional Forecasters

	Michigan Survey	SPF Survey
Survey population	Cross-section of general public ("consumers")	Professional forecasters in various industries
Mean number of respondents	Minimum 500 per survey Varies from 500–700	Roughly 40 per survey Varies from 9–83
Periodicity	Monthly	Quarterly
Interview period	Across the month until few days before release	Around the first two weeks of the middle month of the quarter
Release period	End of the month	Late in the second week of the middle month of the quarter
Questions related to Inflation Expectations	Expected general price change over the next 12 months	CPI-U,CPI-Core PCE,PCE-Core GDP Deflator (Quarterly, five quarters)
Starting date	Qualitative: 1946:Q1 Quantitative: 1978,January	GDP Deflator 1968:Q4 CPI-U 1981:Q3 CPI-Core PCE PCE-Core 2007:Q1

Note: Professionals are asked to predict annualized quarter-over-quarter percentage change for specific seasonal-adjusted quarterly-average inflation indexes (e.g., CPI-U and PCE), for current quarter and next four quarter. Then SPF reports professionals' implied group-level prediction for one-year-ahead annual rate by calculating geometric average of median forecasts of annualized quarterly percentage change of the next four quarter (see chapter 5 of SPF documentation for more details: http://www.phil.frb.org/research-and-data/real-time-center/survey-of-professional-forecasters/spf-documentation.pdf). we only consider SPF forecasts for CPI-U and GDP deflator in our thesis, due to short sample periods for other measures (e.g., CPI-Core, PCE and PCE-Core that started until 2007:Q1).

Table 2.2: Forecast horizon comparison between two surveys: an example

Survey Type	Interview Date	Forecast Horizon
Michigan Survey	2014-01-25	2014-02-01 to 2015-01-31
Michigan Survey	2014-02-05	2014-03-01 to 2015-02-28
Michigan Survey	2014-03-10	2014-04-01 to 2015-03-31
SPF	2014-02-05	2014:Q2 to 2015:Q1 or 2014-04-01 to 2015-03-31

Note: Date display format follows YYYY-MM-DD.

Further, our thesis argues that it might be inappropriate to directly compare quarterly adjusted data of Michigan consumers' annual inflation forecasts to that of SPF professionals. This is due to the fact that a large portion of the consumers do not share the same forecast horizon with professional forecasters even within the same quarter.

Table 2.2 provides an example to demonstrate the issue. During the first quarter of 2014, Michigan consumers' forecast horizons vary from month to month, and only those consumers who are interviewed in March share the same forecast horizon with the professionals. Therefore, instead of using recalculated quarterly data, this thesis first employs Michigan consumers' one-year-ahead inflation-forecast data from the last month of each quarter and compares them with the forecast performance of the SPF professionals who are interviewed with quarterly frequency.

Moreover, as shown in Table 2.1, the release period of SPF is late in the second week of the middle month of every quarter. Thus, theoretically, consumers who respond to Michigan survey interviews during the last month of each quarter is the only group that in particular can have the same quarter's one-year-ahead inflation forecasts of professionals in their information set.[3] Combined with the fact that these two groups also share the same forecast horizon, we thus argue that using Michigan's third month forecast data of each quarter is also the best option to examine information transmission from professionals to consumers.

[3]For detail survey deadlines and release dates, of SPF see http://www.phil.frb.org/research-and-data/real-time-center/survey-of-professional-forecasters/spf-release-dates.txt, and of Michigan Survey see http://www.sca.isr.umich.edu/survey-info.php.

The top panel of Figure 2.1 shows the quarterly-frequency one-year-ahead inflation forecasts of SPF professionals as well as different groups of Michigan consumers (all, high-education or high-income) over the last three decades, where we use consumers' forecasts during the third month of each quarter. For all groups, we use the median forecasts as the group forecast.[4] The common sample period is 1981:Q3 – 2012:Q3.[5]

In general, different groups of Michigan consumers show quite similar inflation expectation trends over these three decades. While professionals' forecasts had moved relatively closely with those of the consumers until the early 2000s, they differ significantly in recent years.[6] Therefore, at this informal level, there is little evidence of information transmission from professionals to consumers. However, the group of consumers with high education are different, by the fact that their inflation expectations exhibit a relatively similar trend with that of the professionals, and a different trend compared with the all and high-income groups, during the early periods of the sample. Besides, despite the similar trends, there are disagreements about inflation expectations among different consumer groups across the whole sample period, with high-education or high-income groups often expecting lower inflation rate than general consumers, especially during the last twenty years. We argue that one of the reasons that contribute to the divergence of inflation expectations over groups (different consumer groups and the professional group) is the difference in questions asked by Michigan and SPF surveys, and the difference between two surveys turn out to lead to economically significant differences in forecasting performance.

Specifically, SPF explicitly asks professionals to predict inflation rates measured by specific inflation indexes (e.g., CPI-U inflation and GDP deflator). By contrast, the Michigan Survey asks consumers' opinions of future price changes in general.[7] This

[4]Michigan Survey director Curtin (1996) argues that, compared with sample mean, sample median is a more reliable indicator of month-to-month changes in consumers' price expectations , due to the sensitivity of sample mean to extreme survey respondents. Also, SPF use median forecasts of quarterly inflation rate of next four quarter to calculate the implied future annual rate.

[5]This thesis examines median Michigan forecast from different groups of consumers as well as median SPF forecast for CPI-U and GDP deflator, starting from 1981:Q3. This is the first data that CPI-U inflation rate forecast by SPF professionals is available. CPI-Core, PCE and PCE-Core forecasts that started in 2007:Q1 are not considered here due to the short sample period.

[6]One of the reasons that contributes to the similar trends of different consumer groups is that high-income and high-education groups are two significant sub-samples of the entire Michigan consumer sample (the "all" group). However as mentioned, top 33% as well as college or higher degree are the finest categories that are publicly available from the monthly Michigan Survey.

[7]Consumers are asked ":During the next 12 months, do you think that prices in general will go

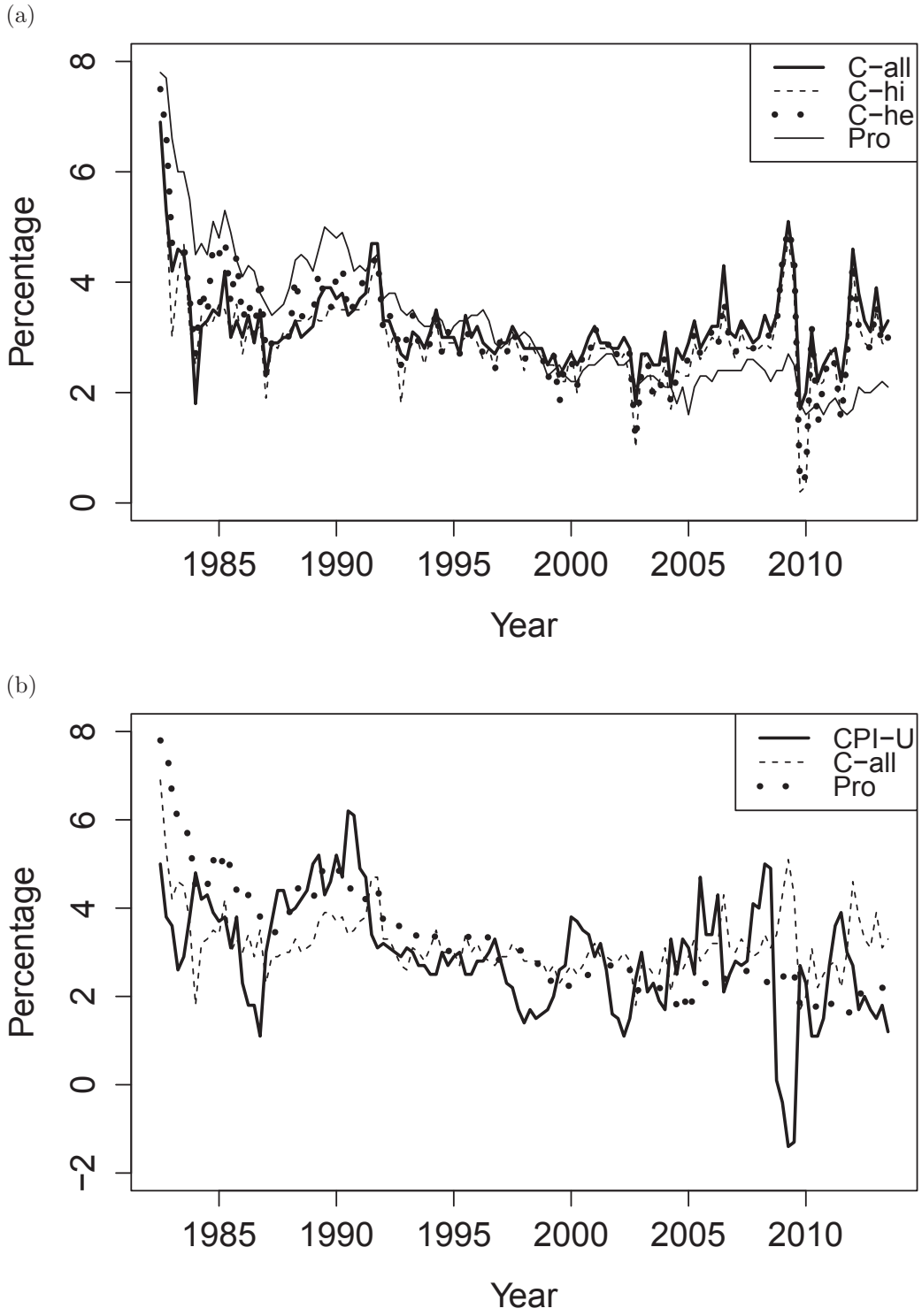

Figure 2.1: Annual CPI inflation and survey forecasts

Note: The top panel plots quarterly-frequency one-year-ahead median inflation forecasts from all survey groups, from 1981:Q3 to 2012:Q3. C-all, C-hi, C-he and Pro stand for the entire Michigan consumer group (the "all" group), high-income group, high-education group and SPF professional group respectively. The bottom panel plots forecasts from the "all" group and professionals, together with corresponding realized quarterly frequency annual CPI-U inflation series ex-post, from 1982:Q3 to 2013:Q3. The survey forecasts are lagged one year, so that forecasts overlap with the realized inflation.

difference matters because consumers' interpretation of price changes in general is not immediate: Do consumers indeed equate general price change to overall inflation rate measures like CPI-U, or instead only track specific price indexes that they care about? Also, do high-education or high-income consumers differ from general consumers in their interpretations?

The bottom panel of Figure 2.1 plots median forecasts of one-year-ahead inflation rate by Michigan consumers (the "all" group) and professionals for the full sample, together with the corresponding quarterly-frequency annual CPI-U inflation rate.[8] The survey forecasts are lagged one year for direct comparison, so that forecasts overlap with the realized inflation. In general, neither consumers nor professionals appears to predict this inflation series. Michigan consumers seem to track the CPI-U inflation but with persistent "delay", as the real-time series appears to consistently lead the median forecast of the consumers for around one year. In other words, assuming that the consumers in the Michigan Survey actually equate general price change to the CPI-U inflation rate, they appear to heavily base their inflation expectations on the past release of actual CPI-U inflation and do not seem to use all available information as efficiently as possible (backward-looking manner). This contributes to their systematic forecast errors and "delay". In terms of professionals, who are explicitly asked to forecast CPI-U inflation series, their forecasts are also poor, not only showing backward-looking manner similar to the consumers in the Michigan Survey, but also exhibiting downward bias, persistently underestimating the changes (fluctuations) in the CPI-U inflation rate series.[9]

Overall, these observations support that only considering CPI-U inflation as the benchmark may not be satisfactory for two reasons: it ignores the differences in survey questions and it ignores the possibility that different populations care about different price series in responding to questions about expected price changes and inflation. Therefore, we apply various different inflation indexes as benchmark when comparing

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up, or go down, or stay where they are now?" and "By about what percent do you expect prices to go (up/down), on the average, during the next 12 months?"

[8]Noted here, for the rest of the thesis, SPF professionals' median one-year-ahead inflation forecasts refer to median forecasts for CPI-U. We only use median forecast for GDP deflator in terms of Gdpurcahse.

[9]Backward-looking manner for professionals may be arising from their inflation forecasting techniques, for example time-series forecasts, forecasts based on the Phillips curve, forecasts from the yield curve, for which professionals heavily use historical data to do out-of-sample forecasts.

inflation-forecast performance between groups of consumers and professional forecasters.

2.2 Inflation Indexes

We use a variety of U.S. inflation indexes that measure price changes from different perspectives, including the different components of CPI series, PCE, and GDP deflator. Specifically, CPI series focus on the price of goods and services consumers actually face and pay, while PCE deflator measures the price of anything consumers consumed, but not necessarily paid by consumers (McCully, Moyer, and Stewart, 2007). Compared with CPI and PCE that only concentrate on consumers, GDP deflator broadly gauges the price changes for the economy as a whole (Baumohl, 2005).

In terms of CPI measures, we consider CPI for all urban consumers, all items (CPI-U), CPI for all urban consumers, all items less food and energy (CPI-Core) and several CPI sub-indexes that capture consumers' major expenditure categories including nondurables (CPI-Nondu), food and beverages (CPI-Fb), apparel (CPI-A), housing (CPI-H), transportation (CPI-T), and energy (CPI-E).

The CPI series are obtained from the Bureau of Labor Statistics (BLS) website while PCE and GDP deflator are gathered from the Bureau of Economic Analysis (BEA).[10] All price indexes are seasonally adjusted, except for those CPI series for which seasonally non-adjusted data is also available and considered. These are used to further examine the link between consumers' forecasts and the prices consumers actually pay. The sample period is 1982:Q3 – 2013:Q3 for all measures (realized inflation series for survey forecasts).

This thesis focuses on annual inflation rate sampled at quarterly frequency, which match up the forecast periodicity of our survey samples. We define the annual inflation rate, $\pi_{t-4,t}$, from $t-4$ to t as

$$\pi_{t-4,t} = \left(\frac{P_t}{P_{t-4}} - 1 \right) \times 100\%, \tag{1}$$

where P_t is a certain price index level of quarter t.[11] This simple annual average

[10]For more details related to CPI inflation series, see BLS webiste: http://www.bls.gov/cpi/. For PCE and GDP defalotr, see BEA website: http://www.bea.gov/.

[11]For monthly collected CPI series, we use two methods to measure quarterly CPI index. First is

Table 2.3: Summary statistics for different inflation measures

	Mean	Standard deviation	Autocorrelation
CPI-U	2.94	1.26	0.81
CPI-Core	2.99	1.23	0.92
CPI-Nondu	2.78	2.61	0.72
CPI-A	0.90	2.13	0.91
CPI-Fb	2.95	1.33	0.87
CPI-H	2.84	1.17	0.88
CPI-T	2.77	4.29	0.70
CPI-E	3.39	9.61	0.74
PCE deflator	2.52	1.15	0.87
GDP deflator	2.42	1.06	0.88

Note: This table reports summary statistics for different measures of U.S. annual inflation rate sampled at a quarterly frequency. Inflation measures are in percentage terms with sample period 1982:Q3 – 2013:Q3. For CPI series, seasonally adjusted quarterly average level is used to calculate annual percentage change, in order to maintain consistency with the PCE and GDP deflator. The autocorrelation reported is the fist-order autocorrelation, $corr(\pi_{t-4,t}, \pi_{t-5,t-1})$.

percentage change measure is consistent with the survey questions.[12]

Table 2.3 reports summary statistics for all the annual inflation measures we considered. Overall, U.S. inflation is persistent, with the mean of all general inflation measures (CPI-U, CPI-Core, PCE and GDP deflator) above 2%, as well as autocorrelation coefficients all above 0.8. GDP deflator has the lowest volatility of 1.06%, followed by the PCE deflator and CPI-Core inflation, with 1.15% and 1.23%, respectively. The CPI-U inflation series is more variable than the CPI-Core and PCE, arising from the fact that CPI-Core does not include relatively volatile food and energy indexes and PCE accounts for the ability of consumers to substitute item categories in response to changes in relative prices.

In terms of inflation measured by annual percentage change of specific CPI subindexes that capture price changes in consumers' major expenditure categories, in general they are more volatile than general inflation measures, except Housing index

the usual quarterly average of monthly CPI that favor SPF professionals (explicitly being asked to predict), second is the CPI level of the last month of one quarter that may favor Michigan consumers (being asked about opinions of 12-month percentage change of general price).

[12]The more familiar $log(p_t/p_{t-4})$ method differs from survey measures by a Jensens inequality term.

of CPI. Food index of CPI is not highly volatile, with inflation volatility of 1.33%, which is slightly higher than CPI-U. By contrast nondurables, transportation, and energy index of CPI experience the most variability over the full sample, in particular, energy inflation series has the highest mean 3.39% with a standard deviation of 9.61%.

Chapter 3

Methodology

3.1 Forecasting Performance Comparison Models

This section describes the models we use to compare one-year-ahead inflation-forecast performance between different groups of Michigan consumers and SPF professionals. We consider two complementary perspectives, forecast accuracy as well as predictive power.

Specifically, in Section 3.1.1, we describe the method of root mean squared errors (RMSE) we use to examine inflation forecast accuracy for different groups. In Section 3.1.2, we introduce a linear model to test the predictive power of each group's inflation forecast, after controlling the most recent realized inflation data available at the time of forecasts.

3.1.1 RMSE for Forecast Accuracy Comparison

We assess forecast accuracy for any inflation measure with the RMSE of the forecasts produced by each group. Also the ratio of different consumer groups' RMSEs relative to SPF professionals' is reported for comparison purposes, treating the RMSEs of the forecasts made by professional group as the baseline. The inflation forecast RMSE is calculated as

$$RMSE = \sqrt{\frac{\sum_{t=1}^{n}(M_t[\pi_{t,t+4}] - \pi_{t,t+4})^2}{n}}, \tag{2}$$

where $M_t[\pi_{t,t+4}]$ is a particular group's median forecast of one-year-ahead inflation rate at quarter t, $\pi_{t,t+4}$ is the corresponding realized annual inflation rate defined in Equation (1), n is the number of quarters in our full sample.[1]

[1] As mentioned in Chapter 2, for different groups of Michigan consumers we employ the median one-year-ahead inflation forecast from the last month of quarter t. For realized annual inflation series, we use various different inflation indexes.

3.1.2 Predictive Power Comparison Model

Table 2.3 shows that all U.S. inflation measures we consider have some degree of "memory", with high first-order autocorrelation (all above 0.7) over the entire sample period. High serial correlation means that future levels of the inflation rate will be highly predictable based on the recent past history of inflation.

Therefore, besides forecast accuracy comparison, we also compare forecast performance by examining whether the forecasts made by different groups have predictive power for the future inflation rate beyond what could be predicted based on the publicly available inflation data. We perform a simple linear model following Carroll (2003):

$$\pi_{t,t+4} = \beta_0 + \beta_1 \pi_{t-5,t-1} + \beta_2 M_t[\pi_{t,t+4}] + \epsilon_{t+4}, \tag{3}$$

where $M_t[\pi_{t,t+4}]$ and $\pi_{t,t+4}$ is as defined in Equation (2), and $\pi_{t-5,t-1}$ is the most recently realized quarterly-frequency annual inflation data that is also available for all groups (in all groups' information set) at quarter t.

3.2 Models for Testing Information Transmission

In section 3.2.1, we introduce an epidemiological sticky-information model (Carroll, 2003) to examine the information transmission from SPF professionals to different groups of Michigan consumers, as well as our extension to this model accounting for (and testing) the possibility that groups of consumers with relatively high education or income update inflation-forecast information from professionals more frequently than general consumers.[2]

Further in Section 3.2.2, we move beyond inflation forecasts, and describe a model which tests the relationship between forecast errors made by professionals and different consumer groups. This provides robustness check on our conclusions about information transmission.

[2]We do not test information transmission from consumers to professionals for two reasons. First, for each quarter, professionals do not have consumers' forecasts in their information set, as we use consumers' data from last month of each quarter. Also, consumers' survey reports for the most recent six months are not publicly available. Second, the one-year-ahead SPF inflation forecast are implied, calculated and reported by SPF, professionals participate in these interviews only forecast 5 quarters' annualized quarterly rates.

3.2.1 Epidemiological Sticky Information model

In general, in Carroll's model consumers instead of continuously forming inflation expectations as would be the case under rational expectation hypothesis, derive their views about future inflation periodically from the forecasts of professionals on the new media.[3] Further, every consumer is assumed to face the same and constant probability λ of absorbing the inflation-forecasting news in any given period. Individuals who do not absorb the news simply continue to believe the last forecast they read about. This epidemiological sticky-information structure leads to the following equation for the population mean of consumers' one-year-ahead inflation expectations:

$$\mathbb{C}_t[\pi_{t,t+4}] = \lambda N_t[\pi_{t,t+4}] + (1-\lambda)\{\lambda N_{t-1}[\pi_{t,t+4}] + (1-\lambda)(\lambda N_{t-2}[\pi_{t,t+4}] + \dots)\}, \quad (4)$$

where $\mathbb{C}_t$ is an operator that yields the population-mean value of consumers' inflation expectations of next year at quarter t, $\pi_{t,t+4}$ is the realized inflation rate over the next year defined in Equation (1) and $N_t[\pi_{t,t+4}]$ is the media's forecast of $\pi_{t,t+4}$ reported in quarter t.

Specifically, the idea behind the derivation of Equation (4) is as follows. In quarter t a fraction λ of the consumer population will have absorbed and updated the current-quarter media forecast of one-year-ahead inflation rate, $N_t[\pi_{t,t+4}]$. While the $(1-\lambda)$ fraction of the consumers retain the views that they held in quarter $t-1$ for $\pi_{t,t+4}$. Further, by the same logic, those period $t-1$ views can also be decomposed into a fraction λ of people who obtained media's forecast for $\pi_{t,t+4}$ in period $t-1$, $N_{t-1}[\pi_{t,t+4}]$ and a fraction $(1-\lambda)$ who retained their quarter $t-2$ views about $\pi_{t,t+4}$. Recursion leads to the remainder of the equation.

However, additional assumptions related to consumers need to be involved, else Equation (4) is not suitable for empirical work.[4] In particular, consumers are assumed to believe that inflation follows a random walk. They also believe that media professionals hold the same opinion but have some ability to directly estimate the shocks to inflation (through a deeper economic knowledge or private information, but only for the shock over the next year and not beyond).[5]

[3] In Carroll's model, all media are assumed to report the same forecast for inflation.

[4] In real world, it is not possible to obtain from media a complete forecast of the inflation rates for infinite future.

[5] Carroll (2003) claims this assumption is in line with the near-unit-root behavior of the inflation rate.

Thus, from the consumers' point of view, the Equation (5) holds, by the assumption that consumers believe that changes in inflation rate beyond one year is unforecastable:

$$\begin{aligned} N_{t-1}[\pi_{t-1,t+3}] &= N_{t-1}[\pi_{t,t+4}], \\ N_{t-2}[\pi_{t-2,t+2}] &= N_{t-2}[\pi_{t,t+4}]. \end{aligned} \tag{5}$$

Therefore, after substituting Equation (5) into Equation (4) we obtain

$$\begin{aligned} \mathbb{C}_t[\pi_{t,t+4}] &= \lambda N_t[\pi_{t,t+4}] + (1-\lambda)\{\lambda N_{t-1}[\pi_{t-1,t+3}] + (1-\lambda)(\dots)\} \\ &= \lambda N_t[\pi_{t,t+4}] + (1-\lambda)\mathbb{C}_{t-1}[\pi_{t-1,t+3}], \end{aligned} \tag{6}$$

where consumers' population-mean inflation expectations for the next year at quarter t should be a weighted average of current-quarter media forecast and last quarter's mean measured inflation expectations.

Carroll (2003) claims that the strength of Equation (6) is that it can be directly estimable through empirical data. Specifically, Carroll uses recalculated quarterly sample mean of Michigan consumers' one-year-ahead inflation forecast as the proxy for $\mathbb{C}_t[\pi_{t,t+4}]$ and mean four-quarter inflation forecast from quarterly SPF professionals as the proxy for $N_t[\pi_{t,t+4}]$. He shows that the variation in Michigan consumers' inflation expectations is well explained by this equation.

While in this thesis, both Michigan consumers' mean and median forecast from the third month of each quarter are employed as the proxies for $\mathbb{C}_t[\pi_{t,t+4}]$ separately, and the median rather than mean four-quarter inflation forecast from SPF professionals is used as the proxy for $N_t[\pi_{t,t+4}]$.

Specifically, first, compared with recalculated quarterly data, Michigan Survey's third month data of each quarter is a better option to examine information transmission from SPF professionals to Michigan consumers.[6] Second, it is median rather than mean four-quarter inflation forecast that being reported by SPF as professional forecasters' group-level forecast over the next year.[7] Therefore, if consumers derive inflation forecast view from SPF professionals, median four-quarter forecast would

[6] As mentioned in Section 2.1, consumers interviewed in last month of each quarter is the only group not only for sure have same quarter's professionals' forecast in their information set but also share same forecast horizon with them.

[7] See Chapter 5 of SPF documentation for more details: http://www.phil.frb.org/research-and-data/real-time-center/survey-of-professional-forecasters/spf-documentation.pdf.

be the one available and used by consumers. Third, although theoretically Equation (6) delivers a prediction for the sample-mean, we also consider Michigan consumers' median forecast to see whether the results are sensitive to different measures of $\mathbb{C}_t[\pi_{t,t+4}]$.[8]

Further, to test whether groups of Michigan consumers with relatively high education or high income gathering inflation-forecasting views from professionals more likely and frequently than consumers in all, we use forecasts of these three sub-groups (all, high-education or high-income) separately in Equation (6) to examine whether information updating probability λ differs across groups both statistically and economically.[9]

3.2.2 Robustness

We implement a robustness check for information transmission from SPF professionals to different groups of Michigan consumers by examining the explanatory power of forecast errors made by professionals for relative mistakes made by different consumer groups:

$$\begin{aligned} \mathcal{X}_t &= (C_t[\pi_{t,t+4}] - \pi_{t,t+4}), \\ \mathcal{Y}_t &= (Pro_t[\pi_{t,t+4}] - \pi_{t,t+4}). \end{aligned} \tag{7}$$

In Equation (7), $\pi_{t,t+4}$ is as in Equation (1), the realized annual inflation, $C_t[\pi_{t,t+4}]$ is Michigan consumers' median forecast for $\pi_{t,t+4}$ during the third month of quarter t, and $Pro_t[\pi_{t,t+4}]$ is the SPF professionals' median forecast in quarter t. We write, $C_t^{all}[\pi_{t,t+4}]$, $C_t^{he}[\pi_{t,t+4}]$ and $C_t^{hi}[\pi_{t,t+4}]$ for all, high-education and high-income groups. Thus, $\mathcal{X}_t$ ($\mathcal{X}_t^{all}$, $\mathcal{X}_t^{he}$ and $\mathcal{X}_t^{hi}$) and $\mathcal{Y}_t$ are quarterly frequency one-year-ahead inflation forecast error series for different Michigan consumer groups and SPF professionals, respectively. In addition, we use forecast error series here for all groups rather than square or absolute value of forecast error, arising from the fact that from our point of view the sign of forecast errors matters in terms of examining information transmission between groups.

[8] As mentioned in Section 2.1, Curtin (1996) argues that sample median is a more reliable indicator of month-to-month changes in consumers' price expectations compared with sample mean, due to the sensitivity of sample mean to extreme survey respondents.

[9] For all three consumer groups, we assume that they all believe that the inflation process follows a random walk. They only differ in terms of the frequency of absorbing inflation forecasting information from the SPF professionals.

The specific linear model we employ is:

$$\mathcal{X}_t = \beta_0 + \beta_1 \pi_{t-5,t-1} + \sum_{i=1}^{p} \phi_i \mathbf{B}^i \mathcal{X}_t + \sum_{j=0}^{q} \psi_j \mathbf{B}^j \mathcal{Y}_t + \epsilon_{t+4}, \tag{8}$$

where $\pi_{t-5,t-1}$ is as in Equation (3), the most recent realized annual inflation (in all groups' information set) available at quarter t, $\mathbf{B}$ is the backward operator that yields $\mathbf{B}^i \mathcal{X}_t = \mathcal{X}_{t-i}$ and $\mathbf{B}^i \mathcal{Y}_t = \mathcal{Y}_{t-i}$, while the order of lags p and q are selected through Bayesian information criteria (BIC) (Schwarz et al., 1978).

Chapter 4

Empirical Results

4.1 Forecast Performance Comparison

4.1.1 Forecast Accuracy

Table 4.1 reports RMSE statistics of all groups' one-year-ahead annual average forecast for different U.S. inflation rate series measured by various price indexes.[1] The RMSEs from the SPF professionals are chosen as the benchmark for comparison purposes.

Specifically, in terms of forecast accuracy for general inflation measures (CPI-U, CPI-Core, PCE and Gdpurchase), SPF professionals perform better than all Michigan consumer groups, except for annual inflation measured by Gdpurchase where high-income consumers perform slightly better. However, from the standpoint of absolute forecast accuracy, none of the groups has good forecasting performance for CPI-U, PCE, and Gdpurchase. In particular, the SPF professionals who are explicitly asked to target CPI-U inflation and GDP deflator have large RMSEs, and RMSEs by all groups even exceed the standard deviations of the corresponding inflation series (see Table 2.3).

One notable finding can be seen in terms of the forecast accuracy for CPI-Core inflation, where the most significant forecast accuracy difference across groups exists. The SPF professional group, who are specifically asked to predict the CPI-U inflation, perform relatively well in forecasting one-year-ahead inflation rate measured by CPI-core (with RMSE 0.648, also the lowest RMSE over all) — not only compared with

[1]For Table 4.1, all realized annual CPI inflation rates used to measure RMSEs are calculated using the quarterly average of seasonally adjusted CPI indexes, which are consistent with quarterly-frequency PCE and Gdpurchase series that only have officially-reported seasonally adjusted data. While, in terms of RMSEs calculated using annual CPI inflation rates measured by seasonally non-adjusted data or 12-month percentage change that may favor Michigan consumers' forecasts, the complete RMSE statistics can be found in Table A.1. However, as shown in Table A.1, our forecast accuracy comparison results are not sensitive to the methods chosen to measure annual CPI inflation rates.

Table 4.1: Forecast accuracy measured by RMSE – I

		RMSE	Pro=1
Gdpurchase	Pro	1.257	1.000
	C-all	1.319	1.049
	C-he	1.314	1.045
	C-hi*	1.198	0.953
PCE	Pro*	1.102	1.000
	C-all	1.321	1.199
	C-he	1.288	1.168
	C-hi	1.214	1.101
CPI-U	Pro*	1.276	1.000
	C-all	1.360	1.066
	C-he	1.368	1.072
	C-hi	1.320	1.035
CPI-Core	Pro*	0.648	1.000
	C-all	1.109	1.712
	C-he	0.967	1.494
	C-hi	1.034	1.597
CPI-H	Pro	1.162	1.000
	C-all	1.193	1.026
	C-he	1.137	0.978
	C-hi*	1.088	0.936
CPI-Fb	Pro	1.540	1.000
	C-all	1.377	0.894
	C-he	1.397	0.907
	C-hi*	1.311	0.851
CPI-A	Pro	2.947	1.000
	C-all	3.000	1.018
	C-he	2.937	0.996
	C-hi*	2.822	0.958
CPI-Nondu	Pro	2.950	1.000
	C-all*	2.843	0.964
	C-he	2.943	0.998
	C-hi	2.845	0.964
CPI-T	Pro	4.559	1.000
	C-all*	4.524	0.992
	C-he	4.625	1.041
	C-hi	4.549	0.998
CPI-E	Pro	9.954	1.000
	C-all*	9.739	0.978
	C-he	9.868	0.991
	C-hi	9.800	0.984

Note: This table reports in percentage-term the RMSE statistics of all groups' one-year-ahead annual average forecasts for different U.S. inflation rate series measured by various price indexes (1982:Q3–2013:Q3). The column labeled PRO=1 reports the ratio of the RMSE relative to professional group. The smallest RMSEs for each inflation measure are marked with an asterisk.

different groups of consumers but also compared to the standard deviation of CPI-Core series (0.648 versus 1.23).

In terms of inflation rates measured by CPI sub-indexes that capture price changes of consumers' major expenditure categories, overall none of the groups distinctly outperform others, with RMSEs by all groups larger than relative standard deviations for all sub-index measures. High-income Michigan consumer group perform slightly better in predicting CPI-H, CPI-Fb and CPI-A inflation, while for forecasting price changes of most volatile CPI indexes (nondurables, transportation and energy), consumers in all outperform other groups. Besides, annual inflation rates measured by CPI-Fb, CPI-Nondu and CPI-E are the three that all Michigan consumer groups outperform their SPF counterparts. However, for all CPI sub-index measures, the forecast accuracy differences across groups are relatively quite small compared with the overall RMSEs they contain.

In sum, the forecast accuracy of SPF professionals for CPI-U inflation and GDP deflator that they explicitly target are relatively poor. However, they perform relatively well in forecasting CPI-Core inflation, a measure that they are not even asked to predict.[2] This phenomenon indicates the possibility that even being asked to predict annual CPI-U inflation, SPF professionals may in fact forecast CPI-Core inflation instead, which is consistent with our finding in Figure 2.1 that their prediction for CPI-U inflation tend to be biased downward, persistently underestimating fluctuations in the realized series.

In terms of different groups of Michigan consumers, in general there are no obvious evidences that groups of consumers with relatively high education or income fully outperform consumers as a whole in terms of inflation forecast accuracy. Also, although consumers tend to have better forecast accuracy than SPF professionals for inflation rates measured by CPI sub-indexes, it is too strong to say that consumers are actually tracking specific indexes that they care instead of CPI-U, arising from the fact that the forecast accuracy differences across groups for these measures are relatively small given the fact that SPF professionals are not directly asked to predict these series.

[2]Remember that for our sample, we do no include SPF professionals' median forecast for CPI-Core inflation that did not start until 2007:Q1.

Therefore, in the following Section 4.1.2, different groups' forecast performance evaluated through alternative predictive power channel are examined to check whether the results are consistent with our findings here.

4.1.2 Predictive Power

Tables 4.2–4.4 present the regression results for Equation (3), examining the predictive power of all groups' predictions for future inflation rates, controlling for the most recent realized annual inflation statistics available at the time the SPF and Michigan forecasts were made.[3]

Table 4.2 reports the predictive power comparison results for general inflation measures (CPI-U, CPI-Core and PCE). These are the inflation measures on which SPF professionals show better forecast accuracy (see Table 4.1). In general, professionals consistently have highly statistically significant predictive power for all these three measures of future inflation, even controlling for the most recent inflation rates. By contrast, Michigan consumer groups' forecasts have statistically insignificant predictive power.

Specifically, for the one-year-ahead CPI-U inflation that professionals target, the coefficient estimate on their inflation forecast is statistically significant at the 1% level, while the three consumer groups' forecasts do not show statistical significance. However, the low adjusted R-square value (0.26) and the highly statistically and economically significant constant term consistently indicate that SPF professionals' forecast performance for CPI-U is still poor and biased.

In terms of the CPI-Core inflation, professionals have significant forecast accuracy but this is not a measure that they are directly asked to predict: In fact, professional group's predictive power is also sparkled, has a high adjusted R-square (0.80) and the constant term is not statistically significant. Also, once professionals' forecasts are included, the most recent realized CPI-Core, that originally had highly significant predictive power in both statistical and economic term (originally explains 54% of the variation of ex-post CPI-Core) becomes statistically insignificant at the 5% level.

[3]For consistency, in Tables 4.2–4.4, all annual CPI inflation rates are calculated using the quarterly average of seasonally adjusted CPI indexes. Regression estimates that use annual CPI inflation rates measured by 12-month percentage change of monthly seasonally non-adjusted CPI indexes can be found in Tables A.3–A.2. The regression results are not sensitive to the methods chosen to measure the annual CPI inflation rates, except for CPI-Core inflation (more details below).

Table 4.2: Forecast power comparisons – CPI-U, CPI-Core and PCE

Dependent Variable: $\pi_{t,t+4}$ (CPI-U)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
2.346**	0.221**	−0.038				0.38	0.07
(0.900)	(0.099)	(0.392)					
1.860***	0.138		0.202			0.44	0.08
(0.541)	(0.101)		(0.269)				
1.917***	0.170*			0.161		0.42	0.08
(0.611)	(0.090)			(0.282)			
1.257**	−0.179				0.704***	0.55	0.26
(0.568)	(0.180)				(0.261)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-Core)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
0.934	0.468***	0.160				0.27	0.54
(0.661)	(0.175)	(0.158)					
0.640	0.380**		0.348*			0.38	0.58
(0.456)	(0.177)		(0.179)				
0.654	0.427**			0.314*		0.34	0.57
(0.460)	(0.178)			(0.174)			
−0.133	−0.340*				1.322***	0.60	0.80
(0.214)	(0.177)				(0.184)		
−0.031	−0.350*		−0.086		1.385***	0.57	0.80
(0.240)	(0.182)		(0.098)		(0.212)		
0.002	−0.351*			−0.088	1.372***	0.58	0.80
(0.254)	(0.193)			(0.100)	(0.213)		
Dependent Variable: $\pi_{t,t+4}$ (PCE)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
1.677***	0.479***	−0.152				0.37	0.32
(0.614)	(0.101)	0.283)					
1.188***	0.401***		0.070			0.37	0.31
(0.390)	(0.126)		(0.228)				
1.280***	0.427***			0.020		0.36	0.31
(0.405)	(0.103)			(0.218)			
0.519	−0.001				0.622**	0.44	0.44
(0.603)	(0.233)				(0.314)		

Note: $C_t^{all}[\pi_{t,t+4}]$, $C_t^{he}[\pi_{t,t+4}]$, $C_t^{hi}[\pi_{t,t+4}]$ and $Pro_t[\pi_{t,t+4}]$ for all, high-education, high-income and professional groups' one-year-ahead median inflation forecasts respectively. $\pi_{t,t+4}$ (CPI-U, CPI-Core and PCE) are the corresponding realized annual CPI-U, CPI-Core and PCE inflation series, respectively (measured by 4-quarter percentage change of seasonal-adjusted quarter-average CPI-U, CPI-Core, and PCE index respectively). $\pi_{t-5,t-1}$ is the relative most recent available annual inflation data available at quarter t. The column labeled "DW-stat." reports the Durbin-Watson statistic. Errors are corrected for heteroskedasticity and autocorrelation using a Newey-West (Newey and West, 1986) procedure (a Bartlett-modified kernel) with four lags. Results are not sensitive to alternative lag length choices. One, two, and three stars indicate, respectively, statistical significance at the 10, 5, and 1 percent levels.

As for Michigan consumers, an interesting finding is that while the entire consumer group has no predictive power, high-income as well as high-education consumer groups show limited predictive power beyond the historical data for CPI-Core inflation, both with statistically significant coefficient but only at the 10% level. Further, the "horse race" regressions with professional group indicate that forecasts by these two consumer groups contain no additional valuable information that is also not included in the SPF professionals' forecasts. This phenomenon may point to the possibility that consumers with high education or high income are more likely than entire group to gather inflation-forecast information from professional forecasters, especially for high-education group that has forecast trend relatively more similar to that of professionals' (see top panel of Figure 2.1).[4]

In terms of inflation rates measured by CPI sub-indexes that capture price changes of consumers' major expenditure categories, for which consumers tend to have slightly better forecast accuracy than SPF professionals, the predictive power comparison results are mixed.

Table 4.3 presents the regression results for the most variable CPI sub-indexes (nondurables, transportation and energy). In general, no group show meaningful predictive power for these three volatile inflation measures, including entire consumer group that beat others in terms of the forecast accuracy (see Table 4.1).

Specifically, for the CPI-Nondu and CPI-T, after controlling for the most recent available inflation series, none of the groups has statistically significant predictive coefficient even at the 10% level. While for energy index of CPI, although professionals as well as consumer groups with high education or income show statistically significant coefficients, but signs of the coefficients are all negative. Combined with the facts of extremely low R-square value and statistically and economically significant constant terms, we conclude that the predictive power of these groups' predictions for CPI-E is economically insignificant. Therefore, overall no group shows distinctly better forecast performance for price changes of consumers' most variable expenditure categories. This is true for both forecast accuracy (RMSEs larger than relative

[4]However, the evidence of this possibility is not strong enough and deserves further examination, arising from the fact that these two groups' significant predictive power for annual CPI-Core disappears after using 12-month percentage change of monthly seasonally non-adjusted CPI-Core index as the annual measure (see Table A.3)

Table 4.3: Forecast power comparisons – CPI-Nondu, CPI-T and CPI-E

Dependent Variable: $\pi_{t,t+4}$ (CPI-Nondu)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
4.671***	−0.056	−0.543				0.52	0.02
(1.649)	(0.155)	(0.504)					
4.227***	−0.068		−0.396			0.53	0.02
(1.113)	(0.173)		(0.313)				
4.379***	−0.073			−0.470		0.52	0.02
(1.272)	(0.168)			(0.384)			
3.153***	−0.121				−0.003	0.56	0.00
(1.172)	(0.196)				(0.397)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-T)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
6.923**	−0.147	−1.165				0.59	0.07
(3.423)	(0.130)	(1.135)					
6.083***	−0.154		−0.904			0.59	0.07
(2.266)	(0.138)		(0.761)				
6.757***	−0.153			−1.195		0.59	0.08
(2.570)	(0.134)			(0.897)			
3.690*	−0.216				−0.077	0.64	0.04
(1.992)	(0.175)				(0.571)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-E)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
10.721*	−0.138	−2.142				0.53	0.04
(5.799)	(0.149)	(1.561)					
11.428***	−0.141		−2.389***			0.54	0.07
(3.826)	(0.153)		(0.945)				
11.772***	−0.147			−2.660**		0.53	0.06
(4.431)	(0.153)			(1.148)			
10.477**	−0.188				−1.980*	0.55	0.08
(4.390)	(0.157)				(1.034)		

Note: $C_t^{all}[\pi_{t,t+4}]$, $C_t^{he}[\pi_{t,t+4}]$, $C_t^{hi}[\pi_{t,t+4}]$ and $Pro_t[\pi_{t,t+4}]$ for all, high-education, high-income and professional groups' one-year-ahead median inflation forecasts respectively. $\pi_{t,t+4}$ (CPI-Nondu, CPI-T and CPI-E) are the corresponding realized annual CPI-Nondu, CPI-T, and CPI-E inflation series, respectively (measured by 4-quarter percentage change of seasonal-adjusted quarter-average CPI-Nondu, CPI-T, and CPI-E index respectively). $\pi_{t-5,t-1}$ is the most recently available annual data available at quarter t. The column labeled "DW-stat." reports the Durbin-Watson statistic. Errors are corrected for heteroskedasticity and autocorrelation using a Newey-West (Newey and West, 1986) procedure (a Bartlett-modified kernel) with four lags. Results are not sensitive to alternative lag length choices. One, two, and three stars indicate, respectively, statistical significance at the 10, 5, and 1 percent levels.

series' standard deviations for all groups) and predictive power, which indicate that Michigan consumers do not seem to track more closely specific volatile price indexes like energy price or these series are highly unpredictable.

In terms of predictive power comparison for future inflation rates measured by relatively less volatile CPI sub-indexes (CPI-H, CPI-A and CPI-Fb), the results differ from their volatile counterparts (see Table 4.4).

In general, high-income or high-education Michigan consumers are the only two groups that show predictive power for all these three less volatile sub-index inflation measures, having statistically significant coefficients with positive sign. Together with the fact that these two groups also outperform others in terms of forecast accuracy (high-income consumer group outperform others for all three measures, followed by high-education group), it is possible that consumers with relatively high education or income track more closely the price changes of specific daily expenditure categories that they not only care about but are also less volatile and relatively predictable.

Nevertheless, these two groups' forecast performance for these relatively less variable CPI sub-indexes are still far from good. In terms of predictive power, compared with predictions made by consumers in all as well as professionals, the improvements in the adjusted R-square value achieved by high-education or high-income consumer groups' predictions are quite modest. While from the forecast accuracy view, although these two groups outperform others, but RMSEs made by their forecasts are still larger than standard deviations of corresponding sub-index inflation rates (see Table 4.1).

4.1.3 Summary

In conclusion, in terms of SPF professionals' forecast performance, the results are mixed. For annual inflation series measured by CPI-U and Gdpurchase that professionals explicitly being requested to forecast, their forecast performance is rather poor. While for CPI-Core inflation that not being directly asked to predict, their performance are notable.

Specifically, although professionals show some predictive power for CPI-U inflation beyond what can be learned from historical data, on average their forecasts only explain about 26% of the variation in the CPI-U series, along with significant

Table 4.4: Forecast power comparisons − Gdpurchase, CPI-Fb, CPI-A and CPI-H

Dependent Variable: $\pi_{t,t+4}$ (Gdpurchase)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
1.706***	0.412***	−0.123				0.28	0.27
(0.539)	(0.091)	(0.224)					
1.264***	0.338***		0.079			0.27	0.27
(0.446)	(0.096)		(0.149)				
1.307***	0.357***			0.053		0.27	0.27
(0.474)	(0.087)			(0.152)			
1.119	0.163				0.294	0.27	0.31
(0.748)	(0.317)				(0.424)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-Fb)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
1.611**	−0.062	−0.123				0.32	0.04
(0.785)	(0.319)	(0.365)					
1.720***	−0.091		0.482**			0.35	0.08
(0.659)	(0.122)		(0.223)				
1.439**	−0.084			0.602**		0.36	0.09
(0.716)	(0.101)			(0.232)			
2.037	−0.115				0.395	0.28	0.09
(1.328)	(0.352)				(0.563)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-A)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
−1.047	0.546***	0.444				0.38	0.40
(0.814)	(0.148)	(0.283)					
−0.747	0.527***		0.359**			0.39	0.40
(0.579)	(0.144)		(0.177)				
−0.755	0.547***			0.380*		0.39	0.40
(0.540)	(0.139)			(0.225)			
−0.508	0.500***				0.285	0.35	0.40
(1.417)	(0.131)				(0.360)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-H)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW-stat.	$\bar{R}^2$
1.372	0.198	0.265				0.24	0.17
(0.986)	(0.173)	(0.231)					
1.074	0.121		0.441**			0.35	0.24
(0.702)	(0.159)		(0.170)				
0.978	0.160			0.462**		0.33	0.23
(0.912)	(0.141)			(0.208)			
1.070	−0.049				0.601	0.26	0.33
(1.370)	(0.187)				(0.400)		

Note: $\pi_{t,t+4}$ (Gdpurchase, CPI-Fb, CPI-A and CPI-H) are the realized annual Gdpurchase, CPI-Fb, CPI-A, and CPI-H inflation series, respectively. See also Table 4.2.

RMSE that is even larger than the standard deviation of CPI-U series. While for the GDP deflator, their performance are even worse, despite the fact that inflation rate measured by Gdpurchase has the lowest volatility over all inflation measures we considered (see Table 2.3). Professionals not only have no predictive power over recent realized inflation data, but also show bad forecast accuracy that is worse than both corresponding standard deviation of GDP deflator and high-income Michigan consumer group's prediction.

Further, given the phenomenon that none of the groups shows valuable forecast performance for GDP deflator that concerning the price changes of the economy as a whole (none of the groups has valuable predictive power beyond history, combined with larger than standard deviation RMSEs for all), it confirms the possibility that agents actually do not take into account future prices that they will not necessarily face when making forecasts.

In terms of professional forecasters' notable forecast performance for CPI-Core inflation series from both channels (meaningful predictive power with lower RMSE than the standard deviation of realized series), it confirms the possibility that professionals track CPI-Core inflation instead of CPI-U that they are being asked. Figure 4.1 plots SPF professionals' median one-year-ahead inflation forecasts, together with both corresponding realized CPI-U and CPI-Core inflation series. Looking over these three series, it is the case that SPF professionals predict the CPI-Core inflation significantly better than the CPI-U, given professionals' forecast trend is extremely similar to CPI-Core series but relatively quite different from CPI-U series.

We give two possible reasons from our point of view: First, SPF professionals care more about CPI-Core than CPI-U (e.g., professionals may think CPI-Core is a more important indicator for tracking government's possible monetary policy actions). Second, professionals ignore the price changes in food and energy index. (e.g., they may think these two indexes are too volatile to predict or the benefit of more effortful prediction is lower than the cost).[5]

In terms of the group of all Michigan consumers, this group does not show better forecast performance than others for all the inflation series included in our sample,

[5]However, this phenomenon (professionals may predict CPI-Core series instead of CPI-U that they are asked to predict) may tend to disappear after CPI-Core inflation forecast was included in SPF separately in 2007:Q1.

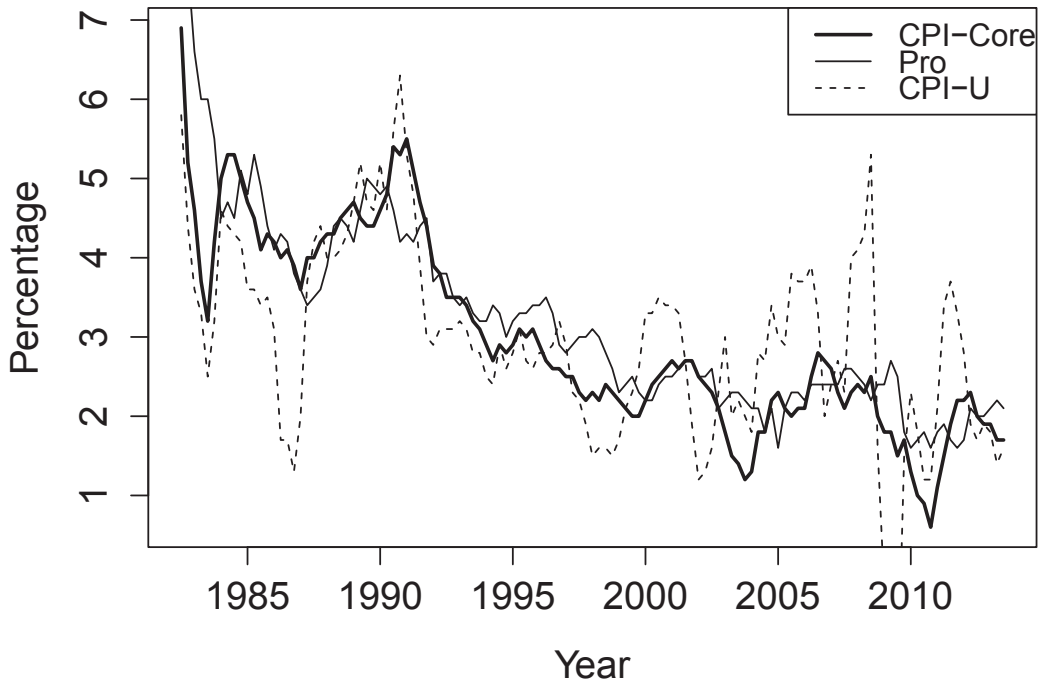

Figure 4.1: Annual CPI-U, CPI-Core inflation and SPF forecasts

Note: We plot quarterly frequency median one-year-ahead inflation forecasts from SPF professionals (Pro), from 1981:Q3 to 2012:Q3, together with corresponding realized annual CPI-U and CPI-Core inflation series (measured by 4-quarter percentage change of seasonal-adjusted quarter-average CPI-U and CPI-Core index, respectively). Professionals' forecasts are lagged one year, so that forecasts are mapping with realized inflation.

no matter whether we are considering general inflation measures or specific sub-index CPI inflation measures that concerning the price changes of their certain major expenditure categories. For all the inflation measures, their forecasts have no predictive power and with RMSEs larger than corresponding standard deviations of series. Although their forecast accuracy for the most volatile sub-index CPI inflation series (CPI-Nondu, CPI-T and CPI-E) is not as poor as other groups (see Table 4.1), but given their corresponding poor predictive power performance (see Table 4.3) it is still difficult to argue with any certainty that they actually care and consistently make efforts to track future price changes of the most volatile expenditure categories. Therefore, we believe that, instead of tracking specific price indexes, the entire Michigan consumer group is still more likely to follow the CPI-U inflation series. While on the other hand, their forecasts exhibit persistent "delay" and "bias" compared with the realized CPI-U series (see bottom panel of Figure 2.1), contributing to their poor

inflation-forecast performance for CPI-U inflation.

In terms of Michigan consumers with high education or high income, we do not find strong support for the hypothesis that their inflation-forecast performance significantly outperform those of all consumers, from both forecast accuracy and predictive power perspectives.[6] While, different from the entire consumer group that have poor performance for all the inflation measures we considered, these two groups show better forecast performance than others for inflation rates measured by relatively less volatile CPI sub-indexes (CPI-H, CPI-A and CPI-Fb) by both metrics (best forecast accuracy with significant predictive power beyond history). However, as mentioned, their performance are still quite "limited", given the fact that RMSEs made by their forecasts are still larger than standard deviations of corresponding sub-index inflation rates (see Table 4.1), as well as improvements of adjusted R-square value achieved through high-education or high-income consumer groups' predictions are quite weak (see Table 4.4).

Figures 4.2 – 4.3 plot these two groups' median one-year-ahead inflation forecasts, together with the corresponding realized annual inflation rates measured by CPI-A, CPI-H and CPI-Fb index, respectively.

In general, for these three less volatile sub-index CPI inflation measures, both high-income or high-education Michigan consumer groups' forecasts also exhibit persistent "delay" to the corresponding realized series (persistently lag the realized series) that is similar to the entire consumer group, which contributes to their' "limited" forecast performance for these inflation measures. This is not surprising as Michigan consumer groups' forecast trends are quite similar (see top panel of Figure 2.1) and sub-index CPI inflation series are weighted components of CPI-U inflation.[7]

However, compared with CPI-Fb and CPI-H inflation series, these two groups' forecasts are quite different from the realized CPI-A series (see Figures 4.2 and 4.3). In addition, the coefficients of the available past value of CPI-A inflation are highly

[6]One of the reasons that contribute to this is that high-income and high-education groups are two significant sub-samples of the "all" group. But top 33% income as well as college or higher degree are the finest categories that are publicly available from monthly Michigan Survey.

[7]High-income and high-education Michigan groups' forecasts tend to coincide in this decade, may arising from the fact that over time consumers with college degree or higher tend to account for most portion of top 33% income group, or vice-versa. But as mentioned, forecasts for consumer group with both high education and income are not available in Michigan Survey.

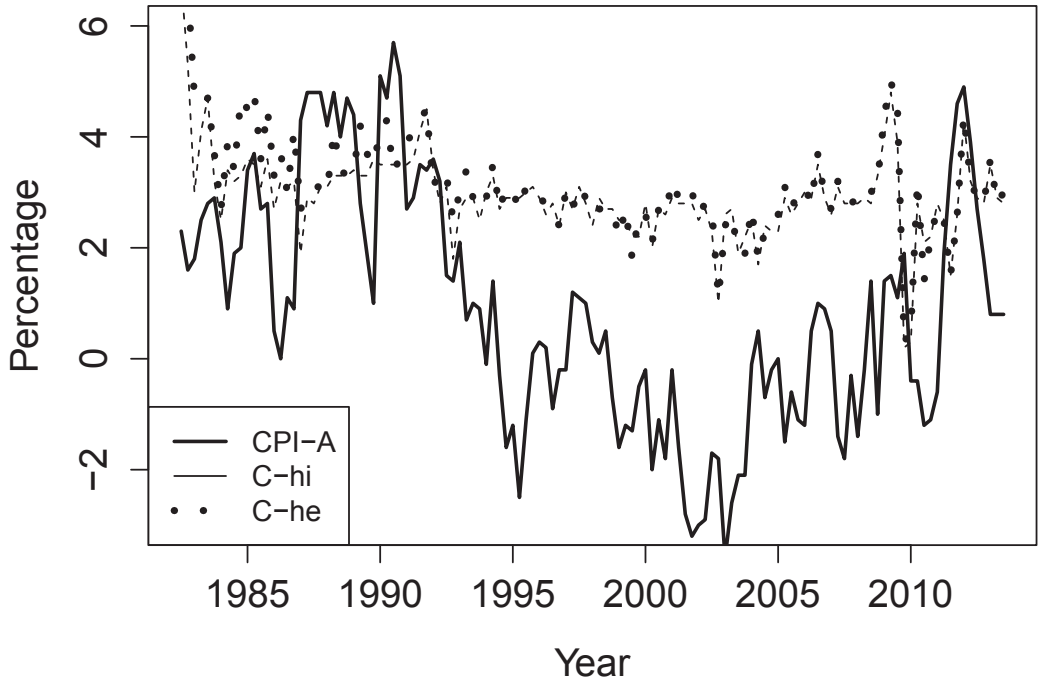

Figure 4.2: Annual CPI-A inflation and forecasts from consumer groups

Note: This figure plots quarterly-frequency median one-year-ahead inflation forecasts from high-income (C-hi) and high-education (C-he) Michigan consumer groups that are interviewed in the last month of every quarter, from 1981:Q3 to 2012:Q3, together with corresponding realized annual CPI-A inflation series (measured by 12-month percentage change of non seasonally-adjusted monthly CPI-A index).

statistically and economically significant at the 1% level in predictive power regressions for both two groups (see Table 4.4). This indicates that these two groups' forecasts do not seem to correctly incorporate the "valuable" historical data of CPI-A that is also publicly available. Therefore, there is little evidence to suggest that high-income or high-education Michigan consumer groups track price changes of Apparel index, although these two groups show better forecast performance over all. Besides, CPI-A inflation is also relatively volatile relative to the other less volatile CPI sub-indexes (see Table 2.3), which may suggest that consumers tend to ignore the price changes of expenditure categories that they think being relatively unpredictable when making inflation forecasts.

On the other hand, given the comparatively similar trends (see Figure 4.3) as well as "acceptable" (better than other groups but still "limited") forecast performance for CPI-H and CPI-Fb inflation series (the least volatile sub-index CPI inflation series in

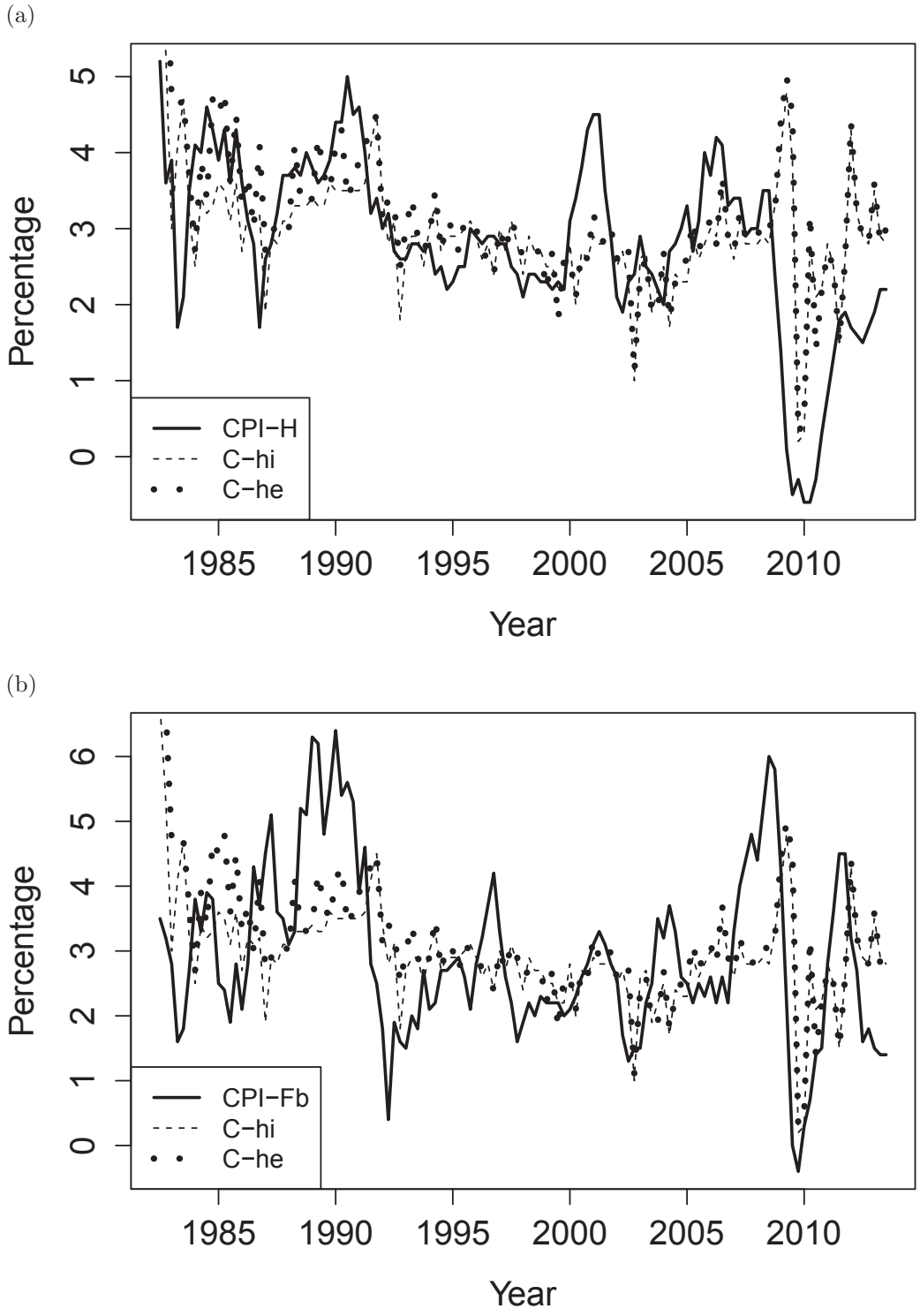

Figure 4.3: Annual CPI-H, CPI-Fb inflation and forecasts from consumer groups

Note: This figure plots quarterly-frequency median one-year-ahead inflation forecasts from high-income (C-hi) and high-education (C-he) Michigan consumer groups, from 1981:Q3 to 2012:Q3, together with corresponding realized annual CPI-H and CPI-Fb inflation series (measured by 12-month percentage change of non seasonally-adjusted monthly CPI-H and CPI-Fb indexes, respectively).

our sample), it confirms the possibility that consumers with high education or income make efforts to track price changes of expenditure categories that they not only care but also consider being predictable (worth to take cost to predict).

In sum, for all Michigan consumer groups, given their inflation forecasts for the inflation indexes they care about are consistently lagging the corresponding realized series, they do not efficiently use all the available information and seem to form their inflation expectations more rely on what has happened in the past, which contributes to their poor inflation-forecast performance. Therefore, the key problem seem to be whether these phenomenon more likely arises from consumers basing inflation expectations heavily on past release of actual inflation or from incorporating downward-biased and "incorrect" (professionals are asked to predict CPI-U, but may actually predict CPI-Core) SPF forecasts that also show lagging relationship with realized CPI-U inflation series. This is especially the case for high-income or education groups that show heterogeneous information gathering phenomenons. These consumers may treat professionals' inflation forecasts for CPI-U as an indicator of future "fundamental" rate (or price level) and make predictions for price changes of specific expenditure categories (they care about and think being predictable) based on this indicator.

Thus, in the following Section 4.2, the information transmission from SPF professionals to different groups of Michigan consumers are examined in detail.

4.2 Information Transmission

4.2.1 Sticky Information Model

Table 4.5 presents the regression results for examining the information transmission from SPF professionals to different groups of Michigan consumers, employing the epidemiological sticky-information model (Carroll, 2003).[8]

We begin by examining the explanatory power of Equation (6) for explaining the variations in different consumer groups' group-level inflation forecasts in the Michigan data sample. Equation (6) is the baseline model of epidemiological sticky information

[8]For the purpose of consistency, in Table 4.5, we use different groups of Michigan consumers' median instead of mean inflation forecasts as proxies for $\mathbb{C}_t[\pi_{t,t+4}]$. For the results based on sample means, see Table A.4.

(Carroll, 2003) that is empirically testable. We use only the consumers' forecasts from third month of each quarter data. This ensures that the same quarters' SPF professional group's forecasts are in Michigan consumers' information set.

Model 1 in Table 4.5 ($\mathbb{C}_t[\pi_{t,t+4}] = \beta_1 Pro_t[\pi_{t,t+4}] + \beta_2 \mathbb{C}_{t-1}[\pi_{t-1,t+3}]$) presents the estimation results for Equation (6). For all consumer groups (all, high-income or high-education), the point estimates of coefficients for SPF professional group's median forecasts (β_1) and consumers' median forecasts from last quarter (β_2) are highly statistically significant at the 1% level. Besides, the sum of these estimated coefficients ($\beta_1 + \beta_2$) approach to one for all groups, suggesting the assumption of Equation 6 is possible to holding true for our sample, where consumers' median inflation expectations for the next year at quarter t is a weighted average between current-quarter SPF professional group's median forecast and consumers' median one-year-ahead inflation expectations from the previous quarter.

Furthermore, the coefficient estimate for information-updating frequency λ (β_1) differs across consumer groups, with high-education group exhibiting the highest updating frequency from SPF professionals, followed by high-income and the entire consumer group. These results suggest that groups of consumers with relatively high-education or income gather inflation-forecasting information from professionals more frequently than consumers in all. This is consistent with our previous findings: high-education group having forecasts the most similar to professionals (top panel of Figure 2.1) and both high-education or high-income groups exhibiting the phenomenon of possible information gathering from professionals (Table 4.2 for CPI-Core).[9]

However, at the same time, there are reasons to believe that Michigan consumer groups in our sample do not follow the behavior described in epidemiological sticky-information model. First, for all consumer groups, the adjusted R-square values are extremely low, especially for "all" and high-income groups with 0.02 and 0.08 respectively, indicating the weak explanatory power of Equation (6).[10]

Second, when we include a constant term in the regression (Model 2 in Table 4.5),

[9]The same results hold if we use consumer groups' mean one-year-ahead inflation forecasts, though the differences across groups become smaller, see Table A.4.

[10]In Table A.4, after using Michigan consumers' sample-mean that Equation 6 theoretically deliver, the R-square values for all consumer groups increase but is still quite low.

Table 4.5: Information transmission – sticky information model – median measure

Estimating Equation: $\mathbb{C}_t[\pi_{t,t+4}] = \beta_0 + \beta_1 Pro_t[\pi_{t,t+4}] + \beta_2 \mathbb{C}_{t-1}[\pi_{t-1,t+3}] + \beta_3 \pi_{t-5,t-1} + \epsilon_{t+4}$

Dependent Variable: $C_t^{all}[\pi_{t,t+4}]$						
Model	β_0	β_1	β_2	β_3	$\bar{R}^2$	DW-stat.
1.		0.180***	0.803***		0.02	2.17
		(0.055)	(0.056)			
2.	1.511***	0.123**	0.388***		0.26	1.86
	(0.247)	(0.057)	(0.097)			
3.	1.649***	0.092	0.316***	0.061	0.26	1.84
	(0.279)	(0.057)	(0.108)	(0.057)		
Dependent Variable: $C_t^{hi}[\pi_{t,t+4}]$						
Model	β_0	β_1	β_2	β_3	$\bar{R}^2$	DW-stat.
1.		0.295***	0.657***		0.08	1.89
		(0.066)	(0.071)			
2.	1.362***	0.220***	0.286***		0.30	1.73
	(0.213)	(0.067)	(0.083)			
3.	1.431***	0.197**	0.230**	0.054	0.29	1.70
	(0.250)	(0.076)	(0.102)	(0.057)		
Dependent Variable: $C_t^{he}[\pi_{t,t+4}]$						
Model	β_0	β_1	β_2	β_3	$\bar{R}^2$	DW-stat.
1.		0.475***	0.492***		0.23	1.96
		(0.079)	(0.081)			
2.	1.272***	0.390***	0.185**		0.39	1.81
	(0.226)	(0.072)	(0.090)			
3.	1.380***	0.354***	0.065	0.124***	0.40	1.73
	(0.226)	(0.098)	(0.120)	(0.045)		

Note: $C_t^{all}[\pi_{t,t+4}]$, $C_t^{he}[\pi_{t,t+4}]$, $C_t^{hi}[\pi_{t,t+4}]$ and $Pro_t[\pi_{t,t+4}]$ for general, high-education, high-income and professional groups' one-year-ahead median inflation forecasts respectively, from 1981:Q3 to 2012:Q3. $\pi_{t-5,t-1}$ is the most recently available annual CPI-U inflation (measured by 12-month percentage change of non seasonally-adjusted monthly CPI-U index) available at quarter t. The column labeled DW-stat. reports the Durbin-Watson statistic. Errors with heteroskedasticity and autocorrelation are corrected using a Newey-West (Newey and West, 1986) procedure (a Bartlett-modified kernel) with four lags. Results are not sensitive to alternative lag length choices. One, two, and three stars indicate, respectively, statistical significance at the 10, 5, and 1 percent levels.

for all consumer groups, the constant terms are statistically and economically significant at the 1% level with positive signs, and this inclusion increase the corresponding adjusted R-square dramatically.[11] The significant non-zero constant terms violate consumer behavior implied by the epidemiological sticky-information model (Carroll, 2003). Because, for example, if professionals' forecasts for inflation were to go to zero forever, people would still continue to expect a positive inflation rate forever, instead of epidemiologically expecting zero inflation over time.

Therefore, we conclude that the baseline model of epidemiological sticky information (Equation (6)) is not an accurate description of consumers' inflation expectation formation process for the monthly Michigan Survey sample, even if we use Michigan consumers' forecasts from last month of each quarter that ensuring the professionals' forecasts are available.

Further, Model 3 in Table 4.5 includes the most recently realized quarterly-frequency annual CPI-U inflation rate available at the time that Michigan forecasts were made ($\pi_{t-5,t-1}$), allowing for the possibility that consumers update their expectations using the most recently available inflation rate rather than using SPF professional group's forecast. This is intended to test: among these two potential inflation-information sources, which one is more likely being used by the Michigan consumers? And thus which one is more likely contributing to the phenomenon that Michigan consumers' forecasts for the inflation indexes they care are consistently lagging the corresponding realized series ?

In general, the regression results (Model 3 in Table 4.5) differ across different Michigan consumer groups (all, high-income, or high-education). Specifically, for the group of Michigan consumers in all, once the most recent CPI-U inflation rate is included, this group's previous-quarter one-year-ahead inflation forecast becomes the only regressor that show statistically significant explanatory power for its current-quarter forecast. The coefficient estimates for the current-quarter professionals' forecasts as well as the most recent CPI-U inflation rate are both statistically insignificant.[12] Therefore, Michigan consumers as a whole use neither professionals' forecasts

[11] The same results hold for using consumer groups' mean one-year-ahead inflation forecasts, see Table A.4.

[12] The regression results are sensitive to the measure we choose as the proxy for $\mathbb{C}_t[\pi_{t,t+4}]$. For the group of Michigan consumers in all, the coefficient on professionals' forecasts remain statistically significant using consumers' sample-mean forecast data (see Table A.4).

nor publicly available CPI-U inflation data when making forecasts for one-year-ahead CPI-U inflation they care, and seem to simply rely on their previous inflation forecasts. This confirms the fact that they do not use all available inflation-forecast information efficiently. Because, the most recently available CPI-U inflation rate ($\pi_{t-5,t-1}$) show "valuable" predictive power for the future CPI-U inflation (see Table 4.2). Also, although professionals' forecasts for CPI-U inflation series are downward-biased and "incorrect", their forecast performance for CPI-U are still better than all Michigan consumer groups from two channels (best forecast accuracy with significant predictive power beyond history).

Different from the entire consumer group, the estimates of the coefficients on current-quarter SPF forecast remain statistically and economically significant for both high-income or high-education Michigan consumer groups. This is consistent with our previous findings and indicates that high-education or high-income groups are more likely to gather inflation forecast views from SPF professionals.

On the other hand, among these three consumer groups, high-education group is the only group that have statistically significant coefficient on recent release of CPI-U inflation rate ($\pi_{t-5,t-1}$), as well as the only group that have statistically insignificant coefficient on previous-quarter forecasts by themselves. Therefore, when forecasting CPI-U inflation rate (treated as the "fundamental" inflation rate by both high-education and high-income groups), high-education Michigan consumer group not only use most recent release of CPI-U inflation that is "valuable", but also incorporate current-quarter professionals' forecasts for CPI-U.[13] In addition, they do not rely on their previous inflation forecasts, updating inflation-forecast information in time.

In term of high-income consumer group, although they incorporate professionals' forecasts for CPI-U inflation, they do not use most recent release of CPI-U inflation rate efficiently. Also, similar to the entire consumer group, they do not timely update inflation-forecast information and still rely on their previous inflation forecasts. Therefore, compared with the "all" and high-income groups, high-education group use inflation-forecast information in a relatively efficient and timely manner.

[13]The regression results are sensitive to the measure we choose as the proxy for $\mathbb{C}_t[\pi_{t,t+4}]$. For high-education Michigan consumer group, the significance of the coefficient of $\pi_{t-5,t-1}$ disappears when using sample-mean forecast data (see Table A.4).

However, for all Michigan consumer groups, the statistically and economically significant constant terms, as well as the relatively low adjusted R-square values (Model 3, Table 4.5) indicate that the model is not well-suite to describe different consumer groups' inflation forecasting behaviors in our sample. Therefore, in the following Section 4.2.2, instead of focusing on inflation forecasts themselves, we introduce a robustness check which examines the explanatory power of CPI-U forecast errors made by SPF professional group for relative mistakes made by different Michigan consumer groups.

4.2.2 Robustness Checks for Information Transmission

In Figure 4.4, we plot forecast errors for realized quarterly-frequency annual CPI-U inflation series made by SPF professional group as well as different Michigan consumer groups over the whole sample period (1982:Q3 –2013:Q3). In general, the CPI-U forecast errors by all groups are similar, especially during the middle two decades of the sample, showing prediction mistakes with the same sign over time (all groups tend to simultaneously underestimate or overestimate the realized CPI-U inflation rate except during several instances in the first decade in our sample).

In addition, compared with the entire consumer group, high-education and high-income consumer groups, especially high-education group, show more similar CPI-U forecast errors with that of the professionals over time. This is consistent with our findings from groups' forecasts themselves before, where consumers with relatively high education or high income especially highly educated consumers, are relatively more likely to gather inflation-forecast information from SPF professionals. Overall, the correlations for CPI-U forecast errors between different consumer groups (all, high-income or high-education) and professional group are 0.74, 0.76, and 0.83 respectively.

Besides, for all consumer groups, there is no leading or lagging relationship between specific consumer group's CPI-U forecast errors and that of SPF professional group. In other words, Michigan consumers' forecast errors at specific quarter are correlated with same-quarter professionals' forecast mistakes. This is another indicator that epidemiological sticky information model (Carroll, 2003) is not suitable for our sample where Michigan consumers for sure having same quarter's professionals'

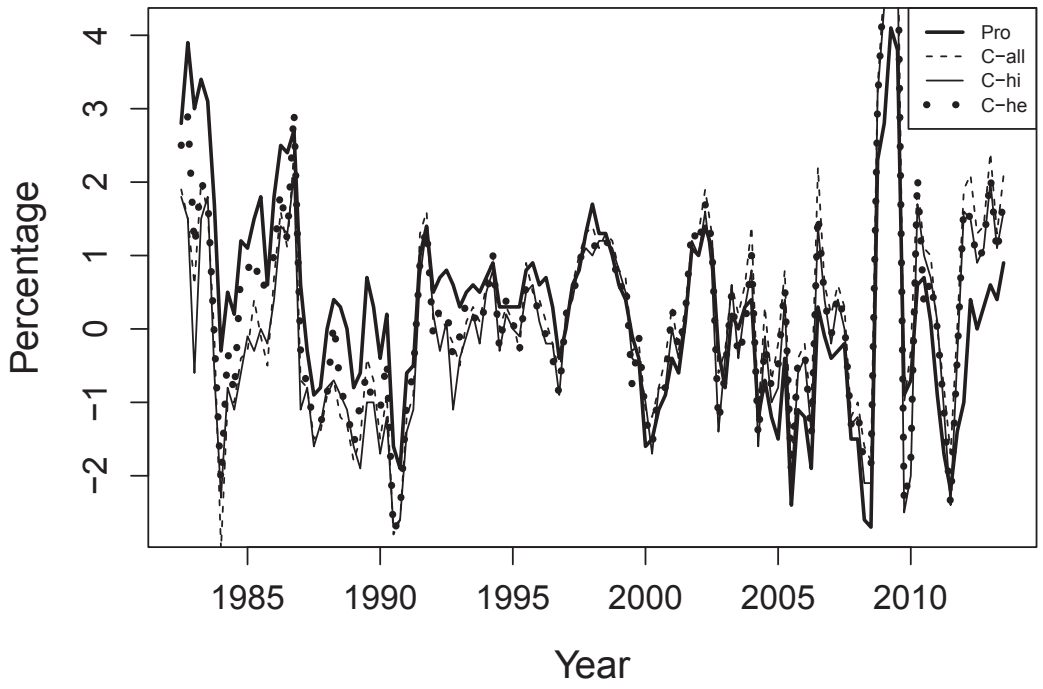

Figure 4.4: CPI-U Forecast errors made by all groups

Note: This figure plots quarterly-frequency annual CPI-U forecast errors by all groups, from 1982:Q3 to 2013:Q3, where annual CPI-U inflation rate is measured by 12-month percentage change of non seasonally-adjusted monthly data. C-all, C-hi, C-he and Pro stand for the entire Michigan consumer group, high-income group, high-education group and SPF professional group respectively.

forecasts in their information set.

Further, Table 4.6 shows the regression results for Equation (7). It examines the explanatory power of CPI-U forecast errors made by SPF professionals for relative mistakes made by different Michigan consumer groups, after controlling for the historical mistakes of consumers as well as the most recent CPI-U inflation rate publicly available at the time that Michigan forecasts were made ($\pi_{t-5,t-1}$). [14]

Specifically, for all consumer groups, after controlling for their historical mistakes for predicting CPI-U inflation series, the estimates of the coefficients on $\pi_{t-5,t-1}$ are not in general statistically significant and have negative signs (when significant only

[14]We do not include previous-quarter forecast errors of professional group in the regression model to explain the current-quarter forecast errors of consumers for two reasons. First, as mentioned there is no leading or lagging relationship between specific consumer group's CPI-U forecast errors and that of SPF professional group in Figure 4.4. Michigan consumers' forecast errors at specific quarter are correlated with same-quarter professionals' forecast mistakes. Second, the correlation between same-quarter forecast errors by professionals and different consumer groups ($Corr(\mathcal{X}_t, \mathcal{Y}_t)$) are all above 0.74, including both $\mathcal{X}_{t-1}$ and $\mathcal{Y}_{t-1}$ as regressors in the regression result in Multicollinearity.

Table 4.6: Information transmission – robustness check

Estimating equation: $\mathcal{X}_t = \beta_0 + \beta_1 \pi_{t-5,t-1} + \sum_{i=1}^{p} \phi_i \mathbf{B}^i \mathcal{X}_t + \psi_0 \mathcal{Y}_t + \epsilon_{t+4}$

Dependent Variable: $\mathcal{X}_t^{all}$

β_0	β_1	ϕ_1	ϕ_2	ψ_0	$\bar{R}^2$	BIC	DW-stat.
0.08		0.61***			0.36	387.75	1.82
(0.11)		(0.07)					
0.09		0.69***	−0.13		0.37	390.50	1.99
(0.11)		(0.09)	(0.09)				
0.44**	−0.12*	0.62***			0.37	390.24	1.79
(0.20)	(0.07)	(0.10)					
0.02		0.31**		0.72***	0.64	323.85	0.98
(0.13)		(0.09)		(0.15)			

Dependent Variable: $\mathcal{X}_t^{hi}$

β_0	β_1	ϕ_1	ϕ_2	ψ_0	$\bar{R}^2$	BIC	DW-stat.
−0.02		0.56***			0.31	393.04	1.73
(0.11)		(0.08)					
−0.02		0.68***	−0.21		0.33	393.62	1.96
(0.11)		(0.15)	(0.11)				
0.34*	−0.12*	0.58***			0.32	395.78	1.71
(0.20)	(0.07)	(0.08)					
−0.15		0.21**		0.80***	0.64	318.99	0.91
(0.12)		(0.10)		(0.17)			

Dependent Variable: $\mathcal{X}_t^{he}$

β_0	β_1	ϕ_1	ϕ_2	ψ_0	$\bar{R}^2$	BIC	DW-stat.
0.06		0.52***			0.26	405.07	1.82
(0.10)		(0.12)					
0.07		0.60***	−0.15		0.27	407.09	1.98
(0.11)		(0.17)	(0.11)				
0.27	−0.07	0.54***			0.26	409.22	1.82
(0.20)	(0.06)	(0.12)					
−0.03		0.08		0.94***	0.69	305.93	0.98
(0.12)		(0.07)		(0.16)			

Note: $\mathcal{X}_t$ ($\mathcal{X}_t^{all}$, $\mathcal{X}_t^{hi}$ and $\mathcal{X}_t^{he}$) and $\mathcal{Y}_t$ are quarterly frequency one-year-ahead CPI-U inflation forecast error series for different Michigan consumer groups and SPF professionals respectively. The column labeled "DW-stat." reports the Durbin-Watson statistic, BIC reports the Bayesian information criteria (BIC) statistics (Schwarz et al., 1978). Noted here, we do not include previous-quarter forecast errors of professional group in the regression model to explain the current-quarter forecast errors of consumers for two reasons. First, as mentioned there is no leading or lagging relationship between specific consumer group's CPI-U forecast errors and that of SPF professional group in Figure 4.4. Michigan consumers' forecast errors at specific quarter are correlated with same-quarter professionals' forecast mistakes. Second, the correlation between same-quarter forecast errors by professionals and different consumer groups ($Corr(\mathcal{X}_t, \mathcal{Y}_t)$) are all above 0.74, including both $\mathcal{X}_{t-1}$ and $\mathcal{Y}_{t-1}$ as regressors in the regression result in Multicollinearity.

at the 10% level for "all" and high-income consumer group, insignificant for high-education group). Combined with the small improvement of adjusted R-square as well as a increase in the Bayesian information criteria (BIC) statistics, the explanatory power of the most recent release of CPI-U inflation rate ($\pi_{t-5,t-1}$) for CPI-U forecast errors by Michigan consumers is not economically significant. Therefore, $\pi_{t-5,t-1}$ is not correlated with the CPI-U forecast errors by all consumer groups. This is consistent with our previous findings that the "all" and high-income Michigan consumer groups do not use the most recent release of CPI-U that is "valuable" for forecasting future CPI-U inflation rate. While for high-education group who use $\pi_{t-5,t-1}$ when making inflation forecasts, it indicates that they seem to use this inflation-forecast information correctly and it is not the reason that contributes to their poor forecast performance for CPI-U.

On the other hand, the current-quarter SPF professionals' CPI-U forecast errors keep explain the variations in all consumer groups' relative inflation-forecast mistakes: the coefficient on professionals' current-quarter forecast errors is statistically and economically significant and this variable improves the relative R-square by a large amount for all consumer groups. This is consistent with the previous finding that CPI-U forecast errors by all groups are similar over the whole sample period (see Figure 4.4). One of the reasons that contributes to this phenomenon is that all groups, no matter different consumer groups or professionals, experience similar external inflation shocks over time. This is especially the case for the entire consumer group that in general do not incorporate professionals' forecasts when forecasting one-year-ahead CPI-U inflation rate. While, in terms of high-income and high-education consumer groups, gathering professionals' downward-biased and "incorrect" forecasts for CPI-U inflation may contribute to these two groups' poor inflation-forecast performance.

In addition, after the inclusion of professionals' current-quarter forecast errors, the coefficient on Michigan consumers' previous-quarter CPI-U forecast errors remains statistically significant for both "all" and high-income consumer groups, while that of high-education group becomes statistically insignificant. This indicates that, after controlling for professionals' forecast errors, "all" and high-income Michigan consumer groups still have systematic forecast errors for forecasting CPI-U inflation rate. This is consistent with the previous finding that, different from high-education group,

these two groups do not timely update inflation-forecast information and heavily rely on their previous inflation forecasts, which contributes to their poor inflation-forecast performance. While, for high-education group who uses inflation-forecast information in a relatively efficient and timely manner, it confirms the possibility that gathering downward-biased and "incorrect" CPI-U inflation forecasts from professionals is one of the reasons that contributes to their poor forecast performance for price changes of expenditure categories they care (e.g.,CPI-Fb and CPI-H).

Chapter 5

Conclusion

5.1 Summary and Conclusion

This thesis studied private agents' inflation expectations using Michigan and SPF Survey data. We considered consumers as well as professional forecasters' forecasts for one-year-head U.S. inflation rate measured by various price indexes. We studied these two main market participants' inflation forecasts from two perspectives: forecast performance and information transmission. We also decomposed Michigan consumers into three groups: all, high-income or high-education and examined possible heterogeneity in consumers' inflation expectations.

In terms of inflation-forecast performance, we examined and compared the group-level forecast performance using forecast accuracy as measured by RMSE as well as predictive power tested by a linear model.

We found that, SPF professionals show relatively better inflation-forecast performance for all general inflation measures (e.g., CPI-U, CPI-Core and PCE) except the GDP deflator, while Michigan consumer groups do relatively well in forecasting sub-index CPI measures. However, none of the groups shows notable forecast performance from the standpoint of absolute forecast accuracy and RMSEs by all groups exceed the standard deviations of the corresponding inflation series, except SPF professionals' forecast performance for CPI-Core. Also, their inflation forecasts are persistently lagging the realized series.

For SPF professionals, their forecasts of CPI-U and Gdpurchase that they are explicitly asked to forecast are quite poor. Yet, their forecasts of CPI-Core inflation are notable, with lowest RMSE over all and is significantly smaller than the standard deviation of CPI-Core series. This indicates that, SPF professionals tend to track CPI-Core series instead of CPI-U and GDP deflator, perhaps because they care more about CPI-Core and treat it as an indicator for possible monetary policy actions.

Among consumers, high-income or high-education consumer groups do not necessarily outperform the entire Michigan Survey consumers (the "all" group) in terms of inflation-forecast performance. In any case, consumers show poor forecast performance for all the inflation series we considered. While those with high-education or high-income show marginally better forecast performance for inflation rates measured by relatively least volatile CPI sub-indexes (CPI-H and CPI-Fb), possibly because they track relatively predictable price changes of expenditure categories that they consume.

We also examined information transmission from SPF professional group to different groups of Michigan consumers, following the epidemiological sticky information model (Carroll, 2003). We found that the baseline model of epidemiological sticky-information is not an accurate description of consumers' inflation expectation formation process for our Michigan Survey sample, and that only high-income and high-education consumer groups, especially tend to possibly gather inflation-forecast information from professionals.

Further, we introduced a robustness check and studied the inflation-forecast errors of all groups. We found that CPI-U forecast errors by all groups are similar and highly correlated over time, perhaps because they experience similar external inflation shocks. This is especially the case for the "all" group that in general do not incorporate professionals' forecasts. Also, we found that when making CPI-U inflation forecasts, both the "all" and high-income consumer groups have systematic forecast errors and heavily rely on their previous forecasts, which contribute to their poor forecast performance for CPI-U. While for highly educated consumers, this group use inflation-forecast information in a relatively efficient and timely manner. Therefore, gathering downward-biased and "incorrect" SPF forecasts for CPI-U (treated as a "fundamental" inflation rate by high-education group) is a possible reason that contributes to their poor forecast performance for inflation series they care (e.g., CPI-Fb and CPI-H).

5.2 Future Research

Ideally, heterogeneity in economic agents' expectations should be examined using individual-level data, instead of group-level aggregate data. Aggregate data like

mean and median overlook heterogeneity in the data. Therefore, consistent long-time individual-level panel data with demographic information would be the best option.

In our case, the major restriction of our data is that high-education as well as high-income consumer groups are two significant sub-sample of the Michigan Survey. In addition, even group-level aggregate data that combines several unique demographic information is not publicly available. For example, we do not have data on consumers with both high education and income. This restricted group-level Michigan Survey data contributes to the fact that median inflation forecasts from different consumer groups share similar trends and do not significantly differ across groups.

Moreover, even though Michigan Survey has a short rotating panel design, with around 40% respondents contacted a second time six months after the initial survey, it is impossible to construct a consistent individual-level panel data given the high "turnover" rate. Therefore, the Michigan Survey may not be ideal to examine heterogeneity in consumers' inflation expectations. Further research in this field can be done more properly if one had access to an individual-level panel data containing inflation expectations as well as demographic information.

Despite these limitations, the framework outlined in this thesis was still able to examine group-level heterogeneity in inflation expectations and found some evidence supporting of heterogeneity. One could also consider such as male versus female, elder versus young. These possibilities are left for future research.

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Appendix A

Tables for complete regression results

Table A.1: Forecast accuracy measured by RMSE – II

		Seasonal Adjusted		Non-seasonal Adjusted	
		M/M	Q/Q	M/M	Q/Q
CPI-U	C-all	1.467	1.360	1.461	1.358
	C-he	1.489	1.368	1.482	1.366
	C-hi	1.430	1.320	1.423	1.320
	Pro	1.359	1.276	1.353	1.275
CPI-Core	C-all	1.124	1.109	1.124	1.103
	C-he	0.998	0.967	0.995	0.963
	C-hi	1.045	1.034	1.044	1.027
	Pro	0.700	0.648	0.705	0.648
CPI-Fb	C-all	1.432	1.377	1.433	1.382
	C-he	1.461	1.397	1.462	1.401
	C-hi	1.366	1.311	1.368	1.316
	Pro	1.574	1.540	1.573	1.543
CPI-E	C-all	10.368	9.739	10.382	9.804
	C-he	10.506	9.868	10.519	9.931
	C-hi	10.445	9.800	10.460	9.863
	Pro	10.555	9.954	10.571	10.016
CPI-H	C-all	1.252	1.193	1.243	1.200
	C-he	1.214	1.137	1.204	1.142
	C-hi	1.150	1.088	1.140	1.097
	Pro	1.221	1.162	1.213	1.168
CPI-T	C-all	5.002	4.524	4.994	4.541
	C-he	5.110	4.625	5.100	4.640
	C-hi	5.031	4.549	5.022	4.566
	Pro	4.990	4.559	4.979	4.575
CPI-A	C-all	3.046	3.000	3.051	3.001
	C-he	2.981	2.937	2.983	2.935
	C-hi	2.873	2.822	2.876	2.823
	Pro	2.995	2.947	3.001	2.946
CPI-Nondu	C-all	3.111	2.843	3.105	2.843
	C-he	3.216	2.943	3.208	2.942
	C-hi	3.116	2.845	3.109	2.845
	Pro	3.166	2.950	3.154	2.948
Gdpurchase	C-all		1.319		
	C-he		1.314		
	C-hi		1.198		
	Pro		1.257		
PCE	C-all		1.321		
	C-he		1.288		
	C-hi		1.214		
	Pro		1.102		

Note: Same as Table 4.1, except that annual CPI inflation rate is also measured by seasonally non-adjusted data or 12-month percentage change. M/M and Q/Q stand for 12-month and 4-quarter percentage change, respectively.

Table A.2: Forecast power comparisons – CPI-Nondu, CPI-T and CPI-E – 12-month percentage change

Dependent Variable: $\pi_{t,t+4}$ (CPI-Non)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW stat	$\bar{R}^2$
6.284***	0.059	−1.160**				0.71	0.06
(1.782)	(0.115)	(0.557)					
5.145***	0.032		−0.786**			0.73	0.05
(1.266)	(0.133)		(0.388)				
5.529***	0.033			−0.970**		0.73	0.05
(1.425)	(0.132)			(0.466)			
3.238***	−0.065				−0.083	0.83	0.00
(1.065)	(0.148)				(0.359)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-T)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW stat	$\bar{R}^2$
9.622***	−0.032	−2.127*				0.79	0.10
(3.527)	(0.094)	(1.146)					
7.764***	−0.044		−1.548*			0.80	0.10
(2.578)	(0.102)		(0.873)				
8.794***	−0.038			−2.009*		0.81	0.11
(2.952)	(0.098)			(1.050)			
3.943**	−0.148				−0.221	0.92	0.01
(1.722)	(0.131)				(0.487)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-E)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW stat	$\bar{R}^2$
13.611**	−0.077	−3.107				0.76	0.05
(6.704)	(0.117)	(1.997)					
13.461***	−0.084		−3.089*			0.79	0.08
(4.330)	(0.119)		(1.306)				
14.653***	−0.085			−3.700**		0.77	0.08
(4.945)	(0.120)			(1.565)			
10.826***	−0.141				−2.127**	0.78	0.07
(3.599)	(0.122)				(0.849)		

Note: The notations of Table A.2 are consistently defined with Table 4.2, 4.3 and 4.4, except all annual CPI inflation rates are measured by 12-month percentage change of monthly seasonally non-adjusted CPI indexes.

Table A.3: Forecast power comparisons – CPI-U, CPI-Core, CPI-Fb and CPI-A – 12-month percentage change

Dependent Variable: $\pi_{t,t+4}$ (CPI-U)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW stat	$\bar{R}^2$
3.176***	0.286***	−0.368				0.46	0.07
(0.901)	(0.103)	(0.385)					
2.369***	0.196*		−0.023			0.50	0.05
(0.582)	(0.112)		(0.297)				
2.529***	0.214**			−0.100		0.48	0.05
(0.642)	(0.097)			(0.304)			
1.388**	−0.170				0.648***	0.72	0.21
(0.553)	(0.154)				(0.229)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-Core)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW stat	$\bar{R}^2$
1.258*	0.468***	0.055				0.31	0.49
(0.637)	(0.153)	(0.161)					
0.861*	0.378**		0.276			0.37	0.52
(0.436)	(0.150)		(0.187)				
0.910**	0.422***			0.229		0.36	0.51
(0.438)	(0.146)			(0.169)			
−0.093	−0.436***				1.398***	0.60	0.78
(0.205)	(0.144)				(0.164)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-Fb)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW stat	$\bar{R}^2$
2.052**	−0.020	0.300				0.34	0.01
(0.792)	(0.310)	(0.363)					
1.896***	−0.053		0.387***			0.39	0.04
(0.600)	(0.104)		(0.121)				
1.677**	−0.034			0.467***		0.39	0.05
(0.674)	(0.090)			(0.151)			
2.114∗	−0.095				0.349	0.33	0.07
(1.192)	(0.325)				(0.510)		
Dependent Variable: $\pi_{t,t+4}$ (CPI-A)							
Constant	$\pi_{t-5,t-1}$	$C_t^{all}[\pi_{t,t+4}]$	$C_t^{he}[\pi_{t,t+4}]$	$C_t^{hi}[\pi_{t,t+4}]$	$Pro_t[\pi_{t,t+4}]$	DW stat	$\bar{R}^2$
−1.174	0.494***	0.498*				0.49	0.35
(0.862)	(0.134)	(0.267)					
−0.886	0.470***		0.420**			0.49	0.35
(0.588)	(0.082)		(0.193)				
−0.774	0.498***			0.400*		0.49	0.34
(0.575)	(0.129)			(0.208)			
−0.726	0.430***				0.373	0.45	0.35
(1.315)	(0.121)				(0.336)		

Note: Same as Table A.2.

Table A.4: Information transmission − sticky information model − mean measure

Estimating Equation: $\mathbb{C}_t[\pi_{t,t+4}] = \beta_0 + \beta_1 Pro_t[\pi_{t,t+4}] + \beta_2 \mathbb{C}_{t-1}[\pi_{t-1,t+3}] + \beta_3 \pi_{t-5,t-1} + \epsilon_{t+4}$

Dependent Variable: $C_t^{all}[\pi_{t,t+4}]$						
Equation	β_0	β_1	β_2	β_3	$\bar{R}^2$	DW stat
1		0.327***	0.727***		0.20	2.26
		(0.084)	(0.066)			
2	1.718***	0.302**	0.331***		0.38	1.91
	(0.289)	(0.074)	(0.089)			
3	1.750***	0.294***	0.313***	0.022	0.38	1.90
	(0.309)	(0.078)	(0.107)	(0.071)		
Dependent Variable: $C_t^{hi}[\pi_{t,t+4}]$						
Equation	β_0	β_1	β_2	β_3	$\bar{R}^2$	DW stat
1		0.338***	0.654***		0.18	2.02
		(0.076)	(0.073)			
2	1.343***	0.255***	0.339***		0.34	1.82
	(0.249)	(0.070)	(0.088)			
3	1.335***	0.258***	0.350***	−0.008	0.34	1.82
	(0.260)	(0.075)	(0.106)	(0.069)		
Dependent Variable: $C_t^{he}[\pi_{t,t+4}]$						
Equation	β_0	β_1	β_2	β_3	$\bar{R}^2$	DW stat
1		0.417***	0.598***		0.21	2.00
		(0.081)	(0.075)			
2	1.367***	0.325***	0.301***		0.36	1.82
	(0.261)	(0.075)	(0.088)			
3	1.387***	0.316***	0.284***	−0.008	0.36	1.81
	(0.271)	(0.081)	(0.107)	(0.062)		

Note: $C_t^{all}[\pi_{t,t+4}]$, $C_t^{he}[\pi_{t,t+4}]$, $C_t^{hi}[\pi_{t,t+4}]$ and $Pro_t[\pi_{t,t+4}]$ for general, high-education, high-income and professional groups' one-year-ahead mean inflation forecasts respectively, from 1981:Q3 to 2012:Q3. $\pi_{t-5,t-1}$ is the most recently available annual CPI-U inflation (measured by 12-month percentage change of non seasonally-adjusted monthly CPI-U index) available at quarter t. The column labeled DW stat reports the Durbin-Watson statistic. Errors with heteroskedasticity and autocorrelation are corrected using a Newey-West (Newey and West, 1986) procedure (a Bartlett-modified kernel) with four lags. Results were not sensitive to alternative lag length choices. One, two, and three stars indicate, respectively, statistical significance at the 10, 5, and 1 percent levels.