Inflation Expectations and the Price at the Pump

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Abstract

Gas prices are visible, volatile, and salient. The optimal monetary policy response to energy price changes depends on whether inflation expectations are "overly sensitive" to gas prices. I find that they are not, despite a positive correlation between oil prices and median inflation expectations. I use multi-horizon, rotating panel microdata from the Michigan Survey of Consumers to study the joint dynamics of consumers' gas price and inflation expectations. Consumers neither over-weight gas price changes in their perception of overall inflation nor expect gas price inflation to feed into core inflation. Thus, large movements in oil and gas prices have negligible impact on longer-run headline inflation expectations. In particular, the rise in household inflation expectations from 2009 to 2011 is not attributable to rising oil prices.

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Introduction

In recent decades, despite the high volatility of energy inflation, headline inflation has remained relatively stable. This represents a stark contrast to the 1970s and early 1980s, when oil price shocks were accompanied by stagflation (Hamilton, 1983; Clark and Terry, 2010). A popular hypothesis is that well-anchored inflation expectations, resulting from credible monetary policy, have limited the pass-through of energy prices to the prices of other goods and services (Hooker, 2002; Cavallo, 2008; Chen, 2009; Liu and Weidner, 2011; Celasun et al., 2012). However, other recent studies find that inflation expectations react strongly to energy and gas prices (Trehan, 2011; Neely, 2015). In fact, Coibion and Gorodnichenko (2015) argue that the high sensitivity of consumers' inflation expectations to gas prices helps explain the absence of more significant disinflation from 2009 to 2011.

These seemingly contradictory findings are central to the debate over how monetary policymakers should react to core and non-core inflation (Thornton, 2011). The Federal

Reserve tends to focus on measures of core inflation that exclude changes in the prices of energy and other volatile commodities (Bodenstein et al., 2008). Chicago Federal Reserve President Charles Evans explains that "if commodity and energy prices were to lead to a general expectation of a broader increase in inflation, more substantial policy rate increases would be justified. But assuming there is a generally high degree of central bank credibility, there is no reason for such expectations to develop—in fact, in the post-Volcker period, there have been no signs that they typically do" (Evans and Fisher, 2011).

In contrast, St. Louis Federal Reserve President James Bullard (2011) argues that "With trips to the gas station and the grocery store being some of the most frequent shopping experiences for many Americans, it is hardly helpful for Fed credibility to appear to exclude all those prices from consideration in the formation of monetary policy."

In this paper, I emphasize that the response of consumers' inflation expectations to changes in gas prices[1] depends, in an accounting sense, on three main factors. First, if gas prices are rising today, does that lead consumers to expect them to rise tomorrow? In other words, what do consumers believe about the *persistence* of gas price inflation? The answer is not obvious. An increase in gas price inflation could plausibly lead to either a rise or a fall in expectations of future gas price inflation.[2]

Second, how heavily do consumers weigh gas price inflation in their perception of overall inflation? Gasoline accounts for about 4 to 5% of consumer expenditures (Figure A.1), but since gas is purchased frequently, the high salience of the "price at the pump" may lead consumers to weigh gas more heavily when thinking about overall price changes (Georganas et al., 2014). People also tend to notice and remember extreme price changes and use them to form expectations of the future (Morewedge et al., 2005; Bruine de Bruin et al., 2011). Thus, since gas prices are more volatile than prices in general (see Figure A.3), they may have a disproportionately large influence on inflation expectations.

Third, to what extent do consumers expect changes in gas prices to lead to changes in the price of other items? Among other things, this will be influenced by beliefs about how monetary policy responds to core and non-core inflation. If inflation expectations are "well-anchored," then increases in gas prices should not lead to expectations of a broader increase in inflation.

These three factors interact to determine the effect of current gas price inflation on expected future core and headline inflation. If consumers believe that gas price inflation

[1] I focus specifically on gas prices, rather than energy or oil prices. Killian (2008) notes that for U.S. consumers, gasoline is by far the most important form of energy consumed in the US and the one with the most volatile price, so it is most useful to examine consumers' response to gas prices rather than energy prices in general. Oil prices and gas prices are strongly correlated, with a correlation coefficient of 0.97 since 2000.

[2] Blinder and Reis (2005) find that oil price shocks from 1970 to 2004 tend to be reversed. If consumers believe that the level of gas prices is roughly mean-reverting, then rising prices would lead consumers to expect falling prices to follow. If consumers believe that gas prices follow a random-walk, then an increase in gas price inflation today will not alter the expectation of gas price inflation tomorrow. The literature on automobile demand and fuel economy typically assumes that the expected future real price of gasoline equals the current price (Busse et al., 2013). Anderson et al. (2013) find that this assumption is a reasonable description of the mean gas price forecast on the Michigan Survey of Consumers.

is persistent and also weigh it heavily in their perception of headline inflation or believe it will pass through into core inflation, then a change in gas price inflation will have an especially large effect on expected headline inflation. Regressions of inflation expectations on energy prices confound these three factors. If inflation expectations respond very little to a sharp increase in gas prices, it could mean that gas prices are not weighted very heavily in consumers' perceptions of overall prices, that consumers do not view gas price inflation as persistent, or that gas price inflation is not expected to feed into inflation of other prices. To disentangle these factors, I build a model that reflects each of them distinctly, and use rotating panel microdata from the MSC to estimate the parameters of the model.

In the model, consumers differ in their perceptions of current inflation and in their beliefs about the mean of the inflation process for gas prices and core CPI. Consumer i's perception of headline inflation, $\pi^{e}_{it,0}$, is a weighted average of her perceptions of gas price inflation ($\pi^{ge}_{it,0}$) and core (i.e. excluding gas) inflation ($\pi^{ce}_{it,0}$), where the weight α on gas price inflation may not necessarily correspond to the expenditure share on gasoline. Each consumer uses her perceptions of current core and gas price inflation to form expectations of future core and gas price inflation ($\pi^{ce}_{it,1}$ and $\pi^{ge}_{it,1}$):

$$\pi^{ce}_{it,1} = a_{cc}\pi^{ce}_{it,0} + a_{cg}\pi^{ge}_{it,0} + \gamma_{ic},$$
$$\pi^{ge}_{it,1} = a_{gc}\pi^{ce}_{it,0} + a_{gg}\pi^{ge}_{it,0} + \gamma_{ig}.$$

The derivative of expected headline inflation with respect to gas price inflation is $\alpha a_{gg} + (1-\alpha)a_{cg}$. The coefficient a_{gg} corresponds to consumers' perception about the persistence of gas price inflation (factor 1). The weight α corresponds to the weight on gas price inflation in consumers' perception of overall inflation (factor 2), and the coefficient a_{cg} corresponds to beliefs about the pass-through of gas price inflation to core inflation (factor 3). The derivative of expected headline inflation at longer horizons with respect to gas price inflation is a similar but slightly more complicated function of α, a_{cc}, a_{cg}, a_{gc}, and a_{gg}. The MSC asks consumers about their expectations of gas price changes and inflation at two time horizons since 2006. Some of the respondents take the survey twice with a six-month gap. Using this rotating panel microdata, I estimate the parameters of the model, α, a_{cc}, a_{cg}, a_{gc}, and a_{gg}.

The estimate of α is 4.2%, which is very similar to the actual expenditure share on gasoline, and does not indicate that headline inflation perceptions are excessively sensitive to gas prices. Moreover, a_{cg} is near zero, indicating that consumers do not expect gas price inflation to lead to an increase in core inflation in the future. The estimate of the persistence parameter for gas price inflation exectations is (a_{gg}) is 0.17, compared to a persistence parameter of just $a_{cc} = 0.03$ for core inflation expectations. These estimates imply that if gas price inflation increases by one percentage point, then one-year-ahead headline inflation expectations increase by about 0.012 percentage points and five-year-ahead inflation expectations increase by less than 10^{-5} percentage points.

These relatively small estimates have implications for monetary policy and for the interpretation of inflation dynamics since the Great Recession. Rising gas prices from 2009 to 2011 and rising median household inflation expectations over the same period may be only spuriously correlated. Coibion and Gorodnichenko (2015) find that the inflation expectations of highest-income households, who spend the largest total amount on gas, rose more than those of other households as oil prices rose. However, I do not find that α varies across demographic groups.

I supplement this empirical work with the New York Federal Reserve's new Survey of Consumer Expectations, which asks consumers not only about gas price and inflation expectations, but also about expected price changes in other categories. This survey also tests respondents' numeracy. Even though the questions on this survey are worded differently than the MSC questions, I still find that changes in gas price inflation expectations have little to no effect on longer-run inflation expectations for highly-numerate or less-numerate consumers. Food and rent prices appear to be more salient for some consumers.

The paper is organized as follows. Section 1 discusses the literature on core and headline inflation, and in particular on a central bank's choice of which price index to target when credibility is a concern. Section 2 describes the microdata on gas price expectations from the MSC and shows that, while time series of inflation expectations and gas prices are strongly positively correlated, there is no obvious strong relationship between individuals' gas price expectations and inflation expectations in the cross section. Section 3 models an expectations formation process, and Section 4 estimates the parameters of the model using the MSC data. Section 5 uses the results to re-examine Coibion and Gorodnichenko's hypothesis about the role of gas prices in the "missing disinflation" puzzle. Section 6 concludes.

1 Gas Prices, Core Inflation, and Expectations

In the 1970s and early 1980s, rising gas prices were accompanied by high overall inflation in many developed countries. The desire to avoid recurrence of this experience has motivated efforts by the Federal Reserve and other central banks to establish credible price stability objectives and to anchor inflation expectations (Yellen, 2013). Towards this end, many central banks have adopted explicit or implicit inflation targets.[3]

An inflation-targeting central bank must decide which price index to target, and in particular on how it will react to food and energy prices. Under Alan Greenspan, the Fed began to focus on core inflation, the more persistent and less volatile component of inflation (Blinder and Reis, 2005; Cavallo, 2008). In contrast, the Bank of England and the European Central Bank are more concerned with headline inflation (Bodenstein et al., 2008). Goodfriend and King (1997) and King and Wolman (1998) argue that a focus on core inflation is appropriate because a central bank should stabilize the components of the price index that are sticky. Aoki (2001) formally derives the same result in a model with flexible price and sticky price sectors with nominal rigidities in the form of Calvo staggered price setting.

Mankiw and Reis (2003) model an economy in which sectors differ in their cyclical sensitivity, proclivity to experience idiosyncratic shocks, speed of price adjustment, and share in consumers' budget sets. They derive several propositions about the optimal weight on each sector in a "stability price index" that, if used as the inflation target, would minimize

[3]See Bernanke (2003) for a discussion of how the Federal Reserve, while not adopting the inflation targeting label, has adopted "hallmarks of the inflation targeting approach."

output volatility. One proposition is similar to Aoki's result: more flexibly-priced price sectors should receive less weight. Since energy prices are flexible, this implies a relatively low weight on energy prices in a stability price index. Two other propositions have to do with the usefulness of a sector's price from a signal-extraction perspective. First, the more cyclically sensitive a sector is, the greater weight that sector's price should receive. Second, the greater the magnitude of idiosyncratic shocks in a sector, the less weight that sector's price should receive. Although energy prices are procyclical, the energy sector is subject to large sector-specific shocks, and movements in energy prices send an especially noisy signal about trends in underlying inflation (Wynne, 1999). Figure A.3 plots the consumer price index (CPI) for all items and the CPI for gasoline since 1980. Movements in the CPI for gasoline are more often large and reversed than movements in the CPI for all items. The core CPI has typically performed better than headline CPI as a predictor of headline CPI (Khettry and Mester, 2006). These results provide several rationales for the Federal Reserve's low emphasis on responding to energy prices.

Other models have focused on optimal monetary policy response to oil or energy prices in particular. Dhawan and Jeske (2007) find that if a central bank follows a Taylor rule with core inflation, the output drop following an energy price shock is less severe than if the Taylor rule uses headline inflation. In a similar model to that of Aoki (2001), Bodenstein et al. (2008) also introduce energy as an input into the demand functions of firms and households, and find that policies that respond to forecasts of core inflation exhibit better stabilization properties than policies that respond to forecasts of headline inflation.

In the models of Aoki, Mankiw and Reis, and Bodenstein et al., the monetary policymaker can commit to a time-invariant rule, and the inflation target is known and fully credible. Departing from this assumption may alter results about the optimality of targeting core inflation, particularly if the more volatile components of headline inflation have excessive impact on inflation expectations (Harris et al., 2009). If the central bank lacks credibility, rising oil and energy prices can feed into higher core inflation by raising inflation expectations (Cavallo, 2008). Blanchard and Gali (2010) study a New Keynesian model in which the nature and credibility of monetary policy affect impact of an oil price increase. They find that a more credible commitment to low and stable inflation can improve the policy tradeoff, so that an oil price shock has a smaller impact on both inflation and output.

Several studies find little evidence of a pass-through effect from energy prices to core inflation since the late 1970s or early 1980s (LeBlanc and Chinn, 2004; van den Noord and Andre, 2007; Gregorio et al., 2007; Cavallo, 2008; Chen, 2009; Clark and Terry, 2010; Evans and Fisher, 2011; Chen and Wen, 2011).[4] Hooker (2002) hypothesizes that since monetary policy became significantly less accommodative of energy price shocks under Volcker, such shocks stopped triggering expectations of higher inflation, reducing the pass-through to core inflation. The reduced pass-through seems to have persisted even though monetary policy has been less responsive to energy inflation since around 1985 (Clark and Terry, 2010).

Oil prices rose from around $20 per barrel in 2001 to $140 per barrel in mid-2008. Gas

[4]Cavallo (2008) finds that in the U.S., the U.K., and Canada, rising oil prices did not lead to higher core inflation in the 2000s, though they did in the euro area.

prices, which have a correlation coefficient of 0.97 with oil prices since 2000,[5] rose in line with oil prices. From 2004 to 2006, although rising energy prices contributed to higher levels of headline inflation, the Fed maintained its focus on core inflation, which remained near 2%, and thus raised rates only slowly (Harris et al., 2009). As oil prices continued to climb in the years leading up to 2008, policymakers closely watched for signs that inflation expectations would become unanchored. Yellen (2009) interprets evidence that forecasters' inflation expectations were minimally responsive to relative price changes in those years as a sign of strong Federal Reserve credibility. Mishkin (2007, p. 329) concurs that better-anchored inflation expectations "implies some very good news: potentially inflationary shocks, like a sharp rise in energy prices, are less likely to spill over into expected and actual core inflation. Therefore, the Fed does not have to respond as aggressively as would be necessary if inflation expectations were unanchored, as they were during the Great Inflation era."

However, consumers' expectations differ from those of professional forecasters, and may be more sensitive to energy prices (Trehan, 2011). Coibion and Gorodnichenko (2015) suggest that "Because gasoline prices are among the most visible prices to consumers, a natural explanation could be that households pay particular attention to them when formulating their expectations of other prices." Harris et al. (2009) note that the median inflation expectations of households rose with oil prices and headline inflation in the mid-2000s.

Figure A.4 plots median one-year-ahead inflation expectations from the Michigan Survey of Consumers (MSC) and Philadelphia Federal Reserve's Survey of Professional Forecasters. Professional forecasters' expectations have remained near 2% since the early 2000s. Consumers' expectations are both higher and more volatile than those of professional forecasters over that time period. Figure A.5 plots gas prices and median one-year-ahead inflation expectations from the MSC. The correlation coefficient between the two series is 0.65 after 2000. This strong correlation is striking, though it is not clear what type of expectations formation process would lead to a correlation between the *level* of gas prices and the expected *rate of change* in overall prices.

Should monetary policymakers be concerned if household inflation expectations are sensitive to oil and gas prices even if professional forecasters' expectations are firmly anchored? Coibion and Gorodnichenko (2015) argue that households' inflation expectations are crucial for explaining inflation dynamics since the Great Recession. The "missing disinflation" puzzle refers to the absence of a more significant disinflation from 2009 to 2011 compared to the predictions of the standard Phillips Curve framework. Coibion and Gorodnichenko note that while the Phillips Curve is typically estimated using the expectations of professional forecasters, households' expectations may be a better proxy for price-setters' expectations. Median U.S. household inflation expectations grew from a low of 1.7% in December 2008 to 4.6% in March 2011, and have hovered near or above 3% since then. Using these expectations to estimate the Phillips Curve can account for the lack of strong disinflationary pressures since 2009. They attribute the rise in households' inflation expectations to the rise in oil

[5]The correlation coefficient of 0.97 refers to monthly data on West Texas Intermediate Crude Oil Prices and All Grades of Gasoline, U.S. City Average Retail Price (both series from the US. Energy Information Administration).

prices over the same time period.

Previous studies use time series measures of energy or gas prices to examine their role in inflation expectations. For example, Coibion and Gorodnichenko show that consumers revise their inflation expectations upward when oil prices are rising.[6] This does not tell us, however, address the "accounting framework" described in the introduction. Do consumers extrapolate that if gas prices have been rising, they will continue to rise? Do they weigh gas prices heavily in their perception of current inflation? Do they expect gas price inflation to feed into future core inflation? This paper uses micro-level data on households' expectations of gas prices at two horizons to relate individual-specific changes in inflation expectations to individual-specific changes in gas price expectations, providing a clearer picture of the role of gas prices in inflation expectations formation. The next section describes the data and documents the lack of an immediately obvious cross-sectional relationship between gas price and headline inflation expectations.

2 Data

The Michigan Survey of Consumers (MSC) surveys about 500 households per month by telephone about their economic attitudes and expectations, including inflation and gas price expectations. Respondents are asked: "About how many cents per gallon do you think gasoline prices will (increase/decrease) during the next five years compared to now?" and similarly for the next 12 months. I use actual gas prices[7] to convert the expected cents per gallon changes to expected gas price inflation over the next year, $\pi^{ge}_{it,1}$, and expected average gas price inflation over the next five years, $\bar{\pi}^{ge}_{it,5}$.

Respondents are also asked about their expectations of the percent change of prices in general,[8] which I interpret as headline inflation expectations, $\pi^{e}_{it,1}$ and $\pi^{e}_{it,5}$. While the inflation expectation survey data has been used in countless studies, the gas price expectation data has only rarely been used.[9] Table B.1 summarizes the MSC variables used in this paper.

A 40% rotating panel of respondents takes the survey twice with a six-month gap. For these respondents, let Δ denote the change in a response between the first and second survey. Questions about gas price expectations at the one-year horizon were asked from 1982 to 1992, with gaps, and from October 2005 to the present with the exception of January 2006.

[6] See Section 5 for more details.

[7] I use the "All Grades of Gasoline, U.S. City Average Retail Price" series from the US Energy Information Administration May 2015 Monthly Energy Review.

[8] The wording is, "By about what percent do you expect prices to go (up/down) on the average, during the next 12 months?" and "By about what percent per year do you expect prices to go (up/down) on the average, during the next 5 to 10 years?"

[9] Anderson et al. (2011, 2013) examine the average gas price expectation data and find that in normal times, the average consumer expects future real gas prices to equal current prices, but in the 2008 financial crisis, the average consumer correctly expected gas prices to rebound from their fall. They also note substantial heterogeneity across consumers in expected future gas prices. Aladangady and Sahm (2015) show that changes in expected gas price changes are informative of actual changes in gas prices and that consumers who expect gas prices to go down have more favorable spending attitudes and are more optimistic about their real income.

Questions about the five-year horizon were asked sporadically in the early 1980s, and from 1992 to the present, with gaps. The dates for which we have rotating panel data on gas price expectations and inflation expectations at both horizons are April 2006 through August 2014 (101 months and 14,903 observations).

Figure A.6 plots actual changes in gas prices over the past 12 months with expected changes in gas prices over the next year and five years. Notice that the average consumer always expects gas prices to rise, even when gas prices have fallen over the previous year.

Table B.2 summarizes the correlations between individual consumers' headline and gas price inflation expectations at the shorter and longer horizon. Long-run headline inflation expectations are only slightly correlated with short-run gas inflation expectations ($\rho = 0.07$) and with long-run gas inflation expectations ($\rho = 0.11$). Table B.3 reports correlations between *changes* in individual consumers' headline and gas price inflation expectations at each horizon, using the rotating panel of respondents. These correlation coefficients are even smaller, though still statistically significant.

Figure A.8 and A.9 plot short-run gas price inflation expectations against short-run headline inflation expectations and long-run gas price inflation expectations against long-run headline inflation expectations, respectively, in a recent month. Figure A.10 plots changes in long-run headline inflation expectations against changes in short-run gas price inflation expectations in the same month using the rotating panel. The key feature to notice in all three scatter plots, in addition to the substantial heterogeneity of expectations across consumers, is the lack of strong correlation between gas price inflation expectations and headline inflation expectations in the cross section. This rotating panel microdata allows me to estimate the model of expectations formation described in the next section.

3 Model of Gas Price and Inflation Expectations

Let π, π^c, and π^g denote headline, core, and gas price inflation, respectively, and let $\Pi_t = \begin{bmatrix} \pi_t^c \\ \pi_t^g \end{bmatrix}$. Here "core" refers to non-gas price inflation, and headline inflation is a weighted average of π^c and π^g:

$$\pi_t = \phi\pi_t^g + (1-\phi)\pi_t^c = \begin{bmatrix} 1-\phi \\ \phi \end{bmatrix}' \Pi_t \tag{1}$$

Let $\pi_{it,h}^e$, $\pi_{it,h}^{ge}$, and $\pi_{it,h}^{ce}$ denote consumer i's expectation at time t of π_{t+h},π_{t+h}^g and π_{i+h}^c, and $\Pi_{it,h} = \begin{bmatrix} \pi_{it,h}^{ce} \\ \pi_{it,h}^{ge} \end{bmatrix}$. She may observe current gas price and core inflation with some error, so her perceptions of current gas price and core inflation, $\pi_{it,0}^{ge}$ and $\pi_{it,0}^{ce}$ are given by:

$$\Pi_{it,0} = \begin{bmatrix} \pi_{it,0}^{ce} \\ \pi_{it,0}^{ge} \end{bmatrix} = \begin{bmatrix} \pi_t^c + e_{it}^c \\ \pi_t^g + e_{it}^g \end{bmatrix} = \Pi_t + \mathbf{e_{it}}. \tag{2}$$

Her perception of current headline inflation, $\pi_{it,0}^e$, is a weighted average of her perceptions of gas price inflation and core inflation, where the weight $\alpha \in [0, 1]$ on gas price inflation expectations may differ from ϕ:

$$\pi^e_{it,0} = \alpha\pi^{ge}_{it,0} + (1-\alpha)\pi^{ce}_{it,0} = \begin{bmatrix} 1-\alpha \\ \alpha \end{bmatrix}' (\Pi_t + \mathbf{e_{it}}). \tag{3}$$

Suppose that consumers use perceptions of current gas price inflation and core inflation to forecast next-period gas price inflation and core inflation as follows:

$$\pi^{ce}_{it,1} = a_{cc}\pi^{ce}_{it,0} + a_{cg}\pi^{ge}_{it,0} + \gamma_{ic}, \tag{4}$$
$$\pi^{ge}_{it,1} = a_{gc}\pi^{ce}_{it,0} + a_{gg}\pi^{ge}_{it,0} + \gamma_{ig}. \tag{5}$$

The i subscript on γ_{ic} and γ_{ig} allows for consumers to have heterogeneous views about the unconditional mean of Π. In matrix notation,

$$\Pi_{it,1} = A\Pi_{it,0} + \Gamma_i, \tag{6}$$

where $A = \begin{bmatrix} a_{cc} & a_{cg} \\ a_{gc} & a_{gg} \end{bmatrix}$ and $\Gamma_i = \begin{bmatrix} \gamma_{ic} \\ \gamma_{ig} \end{bmatrix}$. Expectations of core and gas price inflation at time $t+h$ are given by:

$$\Pi_{it,h} = A^h\Pi_{it,0} + S_h\Gamma_i, \text{ where } S_h = \sum_{j=0}^{h-1} A^j = (I-A)^{-1}(I-A^h). \tag{7}$$

Expectations of headline inflation at horizon h are:

$$\pi^e_{it,h} = \begin{bmatrix} 1-\alpha \\ \alpha \end{bmatrix}' \Pi_{it,h} = \begin{bmatrix} 1-\alpha \\ \alpha \end{bmatrix}' (A^h\Pi_{it,0} + S_h\Gamma_i). \tag{8}$$

Denote the elements of A^h by $A^h = \begin{bmatrix} \hat{a}^h_{cc} & \hat{a}^h_{cg} \\ \hat{a}^h_{gc} & \hat{a}^h_{gg} \end{bmatrix}$. Then

$$\pi^e_{it,h} = (\alpha\hat{a}^h_{gg} + (1-\alpha)\hat{a}^h_{cg})(\pi^g_t + e^g_{it}) + (\alpha\hat{a}^h_{gc} + (1-\alpha)\hat{a}^h_{cc})(\pi^c_t + e^c_{it}) + \begin{bmatrix} 1-\alpha \\ \alpha \end{bmatrix}' S_h\Gamma_i \tag{9}$$

To examine the effects of gas price inflation on headline inflation expectations at different horizons, let X_h be the derivative of $\pi^e_{it,h}$ with respect to π^g_g:

$$X_h = \frac{d\pi^e_{it,h}}{d\pi^g_t} = \alpha\hat{a}^h_{gg} + (1-\alpha)\hat{a}^h_{cg}. \tag{10}$$

At the one-year horizon, $X_1 = \alpha a_{gg} + (1-\alpha)a_{cg}$. In other words, a one percentage point increase in π^g_t results in a $(\alpha a_{gg}+(1-\alpha)a_{cg})$ percentage point increase in $\pi^e_{it,1}$. The parameters a_{gg}, α, and a_{cg} correspond to the three factors discussed in the introduction that jointly account for the effect of changes in gas prices on headline inflation expectations. The term αa_{gg} is the weight the consumer puts on gas price inflation multiplied by her belief about the persistence of gas price inflation. The term $(1-\alpha)a_{cg}$ represents the indirect effects of gas price inflation on headline inflation expectations through core inflation expectations. The effect is increasing in α if $a_{gg} > a_{cg}$, increasing in a_{gg} if $\alpha \neq 0$, and increasing in a_{cg} if $\alpha \neq 1$.

At longer horizons, the interpretation is similar. This is easier to see in the case where a_{gc} is near zero.[10] Then the effect of a change in π_t^g on $\pi_{it,h}^e$ is:

$$X_h \approx \alpha a_{gg}^h + (1-\alpha)\frac{a_{cg}(a_{gg}^h - a_{cc}^h)}{a_{gg} - a_{cc}}. \tag{11}$$

Again, the first term tells us that effect of gas price inflation on headline inflation expectations depends on the weight α that the consumer puts on gas price inflation multiplied by her belief about the persistence a_{gg} of gas price inflation. As the horizon h increases, the term αa_{gg}^h decreases if $0 < a_{gg} < 1$ and $\alpha > 0$. The second term represents indirect effects of gas price inflation on expectations of future core inflation. In the next section I detail how the survey data allow me to estimate α and the elements of A, which allows me to calculate the components of X_h to account for the effects of gas price inflation on inflation expectations.

4 Estimation and Results

The previous section derived a relationship between a consumer's perception of core and gas price inflation and her expectations about longer-horizon inflation. The system of equations in (7) also implies a relationship between short-horizon and long-horizon expectations:

$$\Pi_{it,h}^e = A^{h-1}\Pi_{it,1}^e + S_{h-1}\Gamma_i, \;\; h > 1 \tag{12}$$

As described in Section 2, the Michigan Survey of Consumers asks consumers about their expectations of inflation and gas prices at both short and long horizons. The data does not correspond perfectly to observations of $\Pi_{it,1}^e$ and $\Pi_{it,h}^e$, however. In particular, the long-horizon questions refer to the expected *average* inflation rate over the longer horizon. To correspond to the survey data, I define $\bar{\pi}_{it,h} \equiv \frac{1}{h}\sum_{j=1}^h \pi_{it,j}$, and similarly:

$$\bar{\Pi}_{it,h} \equiv \begin{bmatrix} \bar{\pi}_{it,h}^c \\ \bar{\pi}_{it,h}^g \end{bmatrix} \equiv \begin{bmatrix} h^-1\sum_{j=1}^h \pi_{it,j}^{ce} \\ h^{-1}\sum_{j=1}^h \pi_{it,h}^{ge} \end{bmatrix} = \frac{1}{h}\sum_{j=1}^h \Pi_{it,j}^e, \tag{13}$$

I substitute Equation (12) into Equation (13) and obtain:

$$\bar{\Pi}_{it,h} = \frac{1}{h}\sum_{j=1}^h (A^{j-1}\Pi_{it,t+1}^e + S_{j-1}\Gamma_i) = \frac{1}{h}S_h\Pi_{it,1}^e + \frac{1}{h}\sum_{j=0}^{h-1} S_j\Gamma_i \tag{14}$$

[10]If $a_{gc}=0$, then A is upper triangular, so the eigenvalues of A are a_{cc} and a_{gg}. We can write $A = PDP^{-1}$, where $D = \begin{bmatrix} a_{cc} & 0 \\ 0 & a_{gg} \end{bmatrix}$ and $P = \begin{bmatrix} 1 & a_{cg}/(a_{gg}-a_{cc}) \\ 0 & 1 \end{bmatrix}$. Then $A^h = PD^hP^{-1} = \begin{bmatrix} a_{cc}^h & \frac{a_{cg}(a_{cc}^h - a_{gg}^h)}{a_{cc}-a_{gg}} \\ 0 & a_{gg}^h \end{bmatrix}$.

Even (14) does not correspond perfectly to the MSC data. I observe $\pi_{it,1}$, $\bar{\pi}_{it,5}$, $\pi^g_{it,1}$, and $\bar{\pi}^g_{it,5}$, but not $\bar{\pi}^c_{it,5}$ or $\bar{\pi}^c_{it,1}$. To rewrite (14) in terms of my observations, I multiply the first row of (14) by $(1-\alpha)$ and replacing $(1-\alpha)\bar{\pi}^c_{it,h}$ with $\bar{\pi}_{it,h} - \alpha\bar{\pi}_{it,h}$:

$$\begin{bmatrix} \bar{\pi}_{it,5} \\ \bar{\pi}^g_{it,5} \end{bmatrix} = \frac{1}{5} S_5 \begin{bmatrix} 1 & -\alpha \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \bar{\pi}_{it,1} \\ \bar{\pi}^g_{it,1} \end{bmatrix} + \frac{1}{h} \sum_{j=0}^{h-1} S_j \begin{bmatrix} (1-\alpha)\gamma_{ic} \\ \gamma_{ig} \end{bmatrix} - \alpha \begin{bmatrix} \bar{\pi}^g_{it,5} \\ 0 \end{bmatrix} \tag{15}$$

The system has the form:

$$\begin{aligned} \bar{\pi}_{it,5} &= \alpha\bar{\pi}^g_{it,5} + \beta_{cc}\bar{\pi}^c_{it,1} + \beta_{cg}\bar{\pi}^g_{it,1} + \gamma_{ic}, \\ \bar{\pi}^g_{it,5} &= \beta_{gc}\bar{\pi}^c_{it,1} + \beta_{gg}\bar{\pi}^g_{it,1} + \gamma_{ig}. \end{aligned} \tag{16}$$

Estimating (16) by ordinary least squares could result in omitted variable bias because γ_{ic} and γ_{ig} are not observed.[11] Fortunately, the rotating panel structure of the dataset means that I observe $\Delta\pi_{it,1}$, $\Delta\bar{\pi}_{it,5}$, $\Delta\pi^g_{it,1}$, and $\Delta\bar{\pi}^g_{it,5}$, so I can take first differences and estimate the following system of equations via seemingly unrelated regression:

$$\begin{aligned} \Delta\bar{\pi}_{it,5} &= \alpha\Delta\bar{\pi}^g_{it,5} + \beta_{cc}\Delta\bar{\pi}^c_{it,1} + \beta_{cg}\Delta\bar{\pi}^g_{it,1} + u_{it1}, \\ \Delta\bar{\pi}^g_{it,5} &= \beta_{gc}\Delta\bar{\pi}^c_{it,1} + \beta_{gg}\Delta\bar{\pi}^g_{it,1} + u_{it2}. \end{aligned} \tag{17}$$

From estimates of $\beta_{cc}, \beta_{cg}, \beta_{gc}$, and β_{gg}, I recover the elements of S_{5t}. These allow me to solve for A_t using the relationship $S_{5t} = (I - A_t)^{-1}(I - A_t^5)$. Table 1 displays the results of the regression in (17). Estimates correspond to values of $\alpha = 0.05$, $a_{cc} = 0.05$ $a_{cg} = 0.01$, $a_{gc} = -0.02$, $a_{gg} = 0.02$.

The estimate $\alpha = 0.05$ is remarkably similar to the consumer expenditure share on gasoline. The estimate $a_{gg} = 0.02$ implies low perceived persistence of gas price inflation. The near-zero estimates of a_{cc} and a_{cg} imply that consumers do not believe that current core or gas price inflation is a strong predictor of future core inflation. Using Equation (10), I calculate X_{1t}, the derivative of $\pi^e_{it,t+1}$ with respect to π^g_t, and X_{5t}, the derivative of $\pi^e_{it,t+5}$ with respect to π^g_t. The value of X_1 of 0.01 means that if gas price inflation increases by one percentage point, then one-year-ahead headline inflation expectations increase by about 0.01 percentage points. The value of X_5 is less than 10^{-5}. A one percentage point increase in gas price inflation has an indetectable effect on five-year-ahead headline inflation expectations. Since Trehan (2011) finds that changes in current noncore inflation do not have a statistically significant effect on next year's headline inflation, these consumer beliefs are not unreasonable.

[11]Specifically, let γ_c and γ_g be the mean of γ_{ic} and γ_{ig}, respectively, and let $\nu_{ic} = \gamma_{ic} - \gamma_c$ and $\nu_{ig} = \gamma_{ig} - \gamma_g$. It is possible, and seems likely, that ν_{ic} and ν_{ig} are correlated with each other and with $\mathbf{e_{it}}$. That is, a consumer who overestimates the unconditional mean of core inflation may also overstate the unconditional mean of gas price inflation and may also believe that current core inflation is higher than it actually is. Since $\bar{\pi}^c_{it,1} = a_{cc}\pi^{ce}_{it,0} + a_{cg}\pi^{ge}_{it,0} + \gamma_{ic} = a_{cc}(\pi^c_t + e^c_{it}) + a_{cg}(\pi^g_t + e^g_{it}) + \gamma + \nu_{ic}$, regressing $\bar{\pi}_{it,5}$ on $\bar{\pi}^g_{it,5}$, $\beta_{cc}\bar{\pi}^c_{it,1}$, $\bar{\pi}^g_{it,1}$, and a constant would result in correlation between the error term (ν_{ic}) and the regressors. If the correlation is positive, we would expect estimates of α and β_{cc} to be biased up. Similarly, estimates of β_{gg} would be biased up.

Table 1: Regression results from baseline specification

	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$
$\Delta\bar{\pi}^{ge}_{it,5}$	0.050***	
	(0.007)	
$\Delta\pi^{e}_{it,1}$	0.211***	-0.013*
	(0.006)	(0.007)
$\Delta\bar{\pi}^{ge}_{it,1}$	0.004	0.203***
	(0.004)	(0.004)
Observations	13985	
R^2	0.09	0.13

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Seemingly-unrelated regression results correspond to equation (17). Dependent variable in column (1) is change in long-run inflation expectations. Dependent variable in column (2) is change in long-run gas price inflation expectations. Standard errors in parentheses.

4.1 Robustness Checks and Alternative Specifications

Table B.4 includes several alternative specifications as robustness checks. The first specification includes changes in other expectations reported by the consumer. The second specification includes these changes in expectations and also changes in the unemployment and CPI inflation rates. The third specification includes time fixed effects. The time fixed effects control for any events at time t that might lead respondents to revise both gas price and core inflation expectations.

Table B.6 shows the results of running the regressions of Table 1 in levels instead of first differences. The estimate of α is greater, 0.08 instead of 0.04, reflecting omitted variable bias from not including γ_{ic} and γ_{ig} as regressors.[12] Including demographic control variables does not remove this bias. As another robustness check, in Table B.5, I use regional instead of national data on gas prices to convert expected cents per gallon changes to expected gas price inflation. I re-estimate Equations (17) using these measures of gas price inflation expectations, and find similar estimates of α and A.

Categorical responses:

I define dummy variables $RevGasUp^{s}_{it}$ and $RevGasDown^{s}_{it}$ that indicate whether respondent i revised her short-horizon gas price change forecast up or down, respectively. Variables $RevGasUp^{l}_{it}$ and $RevGasDown^{l}_{it}$ are analogous for the longer horizon.

4.2 Survey of Consumer Expectations

The New York Federal Reserve launched the Survey of Consumer Expectations (SCE) in 2013. The SCE asks about expected inflation at the one- and three-year horizon and about one-year expected percent changes in gas, food, medical, college, rent, and gold prices. A benefit of this data is that we have up to 11 repeated observations on respondent. Another

[12] See footnote 11.

benefit is that the wording of the questions differs substantially from the wording in the Michigan Survey,[13] so we can check that results from the previous sections do not simply result from consumers being confused by the Michigan Survey wording. Figure A.7 plots mean expected gas price inflation from both surveys. They are similar over the short time sample of the SCE, despite the different wording.

Since the gas inflation expectation question is only available for one time horizon, I cannot exactly replicate the analysis from the previous sections using this data. However, if we return to the model of Section 3, we can generalize Equation 1 to allow headline inflation to be a weighted average of the inflation rates of K categories of products:

$$\pi_t = \sum_{k=1}^{K} \phi_k \pi_t^k, \tag{18}$$

where the Kth category is core (i.e. excluding the other $K-1$ categories) inflation, ϕ_k is the expenditure share on category k, and $\sum_{k=1}^{K} \phi_k$.

As in Equation 3, a consumer's perception of current headline inflation is a weighted average of her perceptions of category-specific inflation rates, where the weights α_k sum to 1 but may differ from the expenditure weights ϕ_k:

$$\pi_{it,0}^e = \sum_{k=1}^{K} \alpha_k \pi_{it,0}^{ke}. \tag{19}$$

Then her expectation of future headline inflation is also a weighted average of her expectations of category-specific inflation rates:

$$\pi_{it,j}^e = \sum_{k=1}^{K} \alpha_k \pi_{it,j}^{ke}. \tag{20}$$

More generally, the α_k may also vary across individuals. I estimate a random effects panel regression of one-year-ahead inflation expectations on expected percent changes in gas, food, medical, college, rent, and gold prices. Table B.7 displays results. The first two columns include all consumers, with and without demographic controls. Notice that the coefficients on gas inflation expectations and food inflation expectations are 0.02 and 0.12, respectively. Food accounts for about 13% of consumers' expenditures, similar to the 0.12 coefficient. The coefficient on rent is 0.1. Shelter accounts for 20% of consumer expenditures, while shelter specific to rented housing is 7%. Although healthcare accounts for 8% of consumer expenditures, the coefficient on expected medical price inflation is not statistically significant. The third column only includes highly numerate consumers—those who correctly answered several numeracy test questions on the survey—while the fourth column only includes low numeracy consumers. The biggest difference between the groups is that the coefficient on

[13] The SCE uses the word "inflation," while the MSC asks about "percent change in prices." The SCE asks about gas price changes in terms of percent changes, while the MSC asks about changes in cents per gallon.

gas price inflation expectations is larger for the low-numeracy group (0.06 compared to 0.01) while the coefficient on food price inflation is larger for the high-numeracy group (0.14 compared to 0.08).

Table B.8 is similar to Table B.7, but the dependent variable is three-year-ahead expected inflation instead of one-year-ahead, and one-year-ahead headline inflation expectations are included as an independent variable. Here, the coefficient on expected gas price inflation is no longer statistically significant, so gas price inflation expectations have no effect on long-run headline inflation expectations beyond their effect on short-run headline inflation expectations. However, the coefficient on food price inflation is 0.15 and on rent is 0.06, and both are statistically significant.

5 Gas Prices and the "Missing Disinflation"?

The United States experienced very little decline in inflation following the financial crisis and Great Recession. A standard Phillips curve framework predicts that, given the severity of the decline in economic activity, the U.S. economy should have experienced more significant disinflation. Several candidate explanations for this "missing disinflation" puzzle involve inflation expectations. Bernanke (2010), Simon et al. (2013), and Ball and Mazumder (2014) suggest that firmly-anchored inflation expectations contribute to greater inflation stability. In contrast, Coibion and Gorodnichenko (2015) posit that *household* inflation expectations are not well-anchored, but in fact are highly sensitive to gas prices. As oil and gas prices rose from 2009 to 2011, rising household inflation expectations prevented deep declines in inflation. In this section, I first summarize Coibion and Gorodnichenko's tests of the sensitivity of household inflation expectations to gas prices, then compare their method and results to those of this paper.

To test if households' expectations are sensitive to oil prices, Coibion and Gorodnichenko regress changes in households' one-year-ahead inflation expectations from the MSC on changes in the price of oil:

$$\Delta\pi^e_{it,1} = \beta_0 + \beta_1 \log \frac{\text{OilP}_t}{\text{OilP}_{t-6}} * 100 + error_{it} \tag{21}$$

One might expect cross-sectional differences in sensitivity to gas prices to depend on individuals' spending patterns. Coibion and Gorodnichenko raise two possibilities: first, that sensitivity increases with the *share* of income that an individual spends on gas, and second, that sensitivity increases with the *total amount* that an individual spends on gas (because individuals who spend more on gas probably purchase gas more frequently). The MSC does not ask about individuals' consumption of gas, so Coibion and Gorodnichenko use data from the Bureau of Labor Statistics Consumer Expenditure Survey to assign gasoline expenditure levels and shares to individuals based on their income quintile or age group. Let $Spend_{it}$ be the yearly spending on gasoline (in dollars) of an individual in i's demographic group (age or income quintile) relative to the spending on gasoline for a baseline group (the bottom income quintile or age group 18-24). Let $Share_{it}$ be the budget share spent on gasoline of an individual in i's demographic group relative to the budget share spent on gasoline for the baseline group. Coibion and Gorodnichenko modify (21) to include an interaction of $Spend_{it}$ or $Share_{it}$ with the percent change in oil price:

$$\Delta\pi^e_{it,1} = \beta_0 + \beta_1 \log\frac{\text{OilP}_t}{\text{OilP}_{t-6}} * 100 + \beta_2 Spend_{it} \log\frac{\text{OilP}_t}{\text{OilP}_{t-6}} * 100 + error_{it} \tag{22}$$

$$\Delta\pi^e_{it,1} = \beta_0 + \beta_1 \log\frac{\text{OilP}_t}{\text{OilP}_{t-6}} * 100 + \beta_2 Share_{it} \log\frac{\text{OilP}_t}{\text{OilP}_{t-6}} * 100 + error_{it} \tag{23}$$

The main result is that β_1 is positive in (21), (22), and (23). They also find a positive coefficient on the $Spend_{it}$ interaction term when using income quintiles, a positive but not statistically significant coefficient on the $Spend_{it}$ interaction term when using age groups, and negative but not statistically significant coefficients on the $Share_{it}$ interaction term in both cases. Thus, they conclude that consumer inflation expectations are very sensitive to oil prices, especially for consumers who spend most on gas in absolute terms.

Table B.9 includes a replication of the Coibion and Gorodnichenko's regression in (21) and several modifications. The first column replicates the regression in (21). The estimate of the coefficient on the percent change in oil prices is $\beta_1 = 0.016$. (In the paper, the coefficient is instead listed as $\beta_1 = 1.6$, and the authors interpret this to mean that households revise their inflation expectations upwards by 1.6% in response to an increase in oil prices. I have confirmed with the authors that this should be 100 times smaller.) The second column includes the changes in inflation and core inflation as control variables, since household expectations may also respond to these variables (Trehan, 2011). The coefficient on each is positive, and the coefficient on the percent change in oil price is reduced to just 0.012.

In the third and fourth columns, the dependent variable is change in expected one-year-ahead gas price inflation ($\Delta\pi^{ge}_{it,1}$ instead of $\Delta\pi^e_{it,1}$). If increases in oil prices cause consumers to revise their headline inflation expectations upward, we might expect even larger upward revisions in expectations in gas price inflation. However, the coefficient on $\Delta\pi^{ge}_{it,1}$ is negative and not statistically significant, with or without the inclusion of changes in inflation and core inflation as regressors. Increases in oil prices are *not* associated with increased expectations of future gas price inflation. This raises suspicion that the association between increases in oil prices and increased expectations of future headline inflation is spurious.

The primary difference between Coibion and Gorodnichenko's regression in (21) and my main regression (17) is that, while both use the rotating panel data on the left hand side, their right hand side variable is a time series variable, the percent change in oil prices. My right hand side variables are from the rotating panel data. I also use expectations at both horizons, in order to be able to account for the role of gas prices in the inflation expectations formation process. My results cast doubt on whether the rise in oil and gas prices can explain the rise in household inflation expectations after 2009.

In the spirit of equations (22) and (23), to test whether α varies by $Spend_{it}$ or $Share_{it}$, I modify the regression equations in (17) so the first equation takes one of the following forms:

$$\Delta\bar{\pi}_{it,5} = \alpha\Delta\bar{\pi}^g_{it,5} + \alpha_2\Delta\bar{\pi}^g_{it,5} * Spend_{it} + \beta_{cc}\Delta\bar{\pi}^c_{it,1} + \beta_{cg}\Delta\bar{\pi}^g_{it,1} \tag{24}$$

$$\Delta\bar{\pi}_{it,5} = \alpha\Delta\bar{\pi}^g_{it,5} + \alpha_2\Delta\bar{\pi}^g_{it,5} * Share_{it} + \beta_{cc}\Delta\bar{\pi}^c_{it,1} + \beta_{cg}\Delta\bar{\pi}^g_{it,1}. \tag{25}$$

Figures A.1 and A.2 plot gasoline expenditure levels and budget shares by income quintile and age group, respectively. The highest income households spend the most on gasoline in absolute terms, but the least as a share of their total budget. Thus, if sensitivity to gas prices increases with total amount spent on gas, high income households should be most sensitive, but if sensitivity increases with budget share, they should be the least sensitive. Table B.10 summarizes $Spend_{it}$ and $Share_{it}$ by income quintile and age group.[14] For example, consumers age 45 to 54 spend 1.71 times as much on gas as consumers under 25, but as a share of income they spend just 0.85 times as much.[15]

Table B.11 reports estimates of equations (24) and (25) where spending and budget shares are assigned based on income quintile. Table B.12 reports estimates by age category. In neither table are the coefficients on the interactions between $\Delta\pi_{it}^{ge}$ and $Share_{it}$ or $Spend_{it}$ statistically significant.

Recall that Coibion and Gorodnichenko find that high-income households' inflation expectations increased more than low-income households' inflation expectations as oil prices rose from 2009 to 2011. But I fail to find a difference in the weight that high and low-income households place on gas prices in their perceptions of inflation. Instead, I suggest an alternative explanation for the differential rise in higher income households' inflation expectations from 2009 to 2011. In Binder (2015a), I show that households who are highly uncertain about future inflation tend to round their inflation forecasts to a multiple of five percent when responding to the Michigan Survey. Lower-income consumers typically have higher uncertainty than higher-income consumers, and more frequently report 5% and 10% inflation forecasts. Their median forecast tends to be higher, primarily because of the preponderance of 5 and 10% forecasts. Inflation uncertainty grew sharply following the Great Recession. And this led to upward forecast revisions: in 2009, 16% of consumers chose a 5% forecast and 9% chose a 10% forecast. But for consumers who revised forecasts upward, 21% chose a 5% forecast and 13% chose a 10% forecast.

The increase in inflation uncertainty was highest for high-income consumers, mostly because their uncertainty was lower to begin with. Figure A.11 plots the inflation uncertainty measure for consumers in the lowest and highest income quintiles from 2006-2014. Uncertainty for high-income consumers was initially much lower than for low-income consumers, but rose much more sharply in 2009. This differential increase in uncertainty was reflected in a greater rise in the share of high-income consumers choosing 5 or 10% inflation forecasts (common responses for highly uncertain consumers) and a greater decline in the share of high-income consumers choosing 2 or 3% forecasts in 2009. Figure A.12 plots the share of 5 and 10% forecasts and the share of 2 and 3% forecasts for the top and bottom income quintiles from 2006-2014. Notice that these shares are steadier for the low-income quintile. The reason high-income consumers' inflation expectations rose more than low-income consumers'

[14] Consumer expenditure survey data is annual. In the results I present, I use the spending or budget share of the baseline group in year t. Results that follow are virtually unchanged if I use the spending or budget share of the baseline group in a fixed year.

[15] It would be interesting to examine results by car ownership. About 92% of the surveyed consumers own a car. Unfortunately, the question about car ownership was removed from the survey after 2003.The question was asked in 2005 and 2008, but in 2008 100% of respondents owned a car.

inflation expectations has to do with this greater increase in uncertainty among high-income consumers, which resulted in more 5 and 10% forecasts.

What does this tell us about the degree to which consumers' inflation expectations are anchored? On one hand, expectations do not appear overly reactive to gas prices, which should be reassuring to the Fed. Reacting to core, rather than headline, inflation is unlikely to damage the Fed's credibility and unanchor expectations. On the other hand, expectations may not be so well-anchored to begin with. Uncertainty about inflation rises when times are bad, and the share of consumers forecasting inflation near 2% at either horizon is quite low.[16]

5.1 Regional Evidence

Note that, while Coibion and Gorodnichenko find a correlation between inflation expectations and the *rate of change* in oil prices, there is also a positive correlation between average consumer inflation expectations and the *level* of gas prices (recall Figure A.5). Over the years included in this study, the correlation coefficient between mean year-ahead inflation expectations and the price of gas is 0.72. Inflation itself is also correlated with the level of gas prices in recent years. The correlation between gas prices and CPI inflation is 0.50 since 2006. After 2008, the correlation is 0.71. This should not be too surprising; since gas prices display almost no time trend over this period, the level of gas prices is correlated with the rate of change in gas prices.[17]

However, it is still worth considering whether consumers might actually use the *level* of gas prices to forecast the future *rate of change* in prices. For this purpose, I exploit regional variations in gas prices.

Table B.13 summarizes gas prices and inflation expectations by region since 2006, and Figure A.13 plots gas prices by region over time. Gas prices are highest in the West and lowest in the South. The volatility of gas prices is similar across regions, with standard deviation ranging from 0.54 in the South to 0.57 in the North Central region. However, the South has both the highest mean inflation expectation and the lowest mean gas price; the West has the lowest mean inflation expectation and the highest mean gas price. Moreover, inflation expectations in each region are most strongly correlated with gas prices in the South, rather than gas prices in the respondents' region of residence. Mean inflation expectations nationwide have a correlation coefficient of 0.75 with gas prices in the South, slightly higher than the correlation with national gas prices. Since gas prices in the South are very unlikely to have a causal influence on inflation expectations in other regions, the average level of gas prices nationwide is also unlikely to directly cause movements in inflation expectations.

[16]See Binder (2015b) for a more extensive discussion of the degree to which consumers' inflation expectations are anchored.

[17]Interestingly, this is quite similar to an explanation of the Gibson paradox, a once puzzling correlation between the price level and nominal interest rates (and hence, expected inflation) during the classical gold standard (**?**Coulombe, 1998).

6 Conclusion

Large fluctuations in gasoline and other energy prices are common and present a challenge to monetary policymakers. The Federal Reserve tends to respond to core inflation, rather than headline inflation, as a better indicator of underlying inflation trends. However, if major shifts in non-core prices like gasoline cause inflation expectations to become unanchored, then a greater emphasis on headline inflation would be warranted. The response of consumer inflation expectations to gas price fluctuations depends both on how heavily consumers weight changes in gas prices in their perception of inflation and on what consumers believe about the dynamics of gas price inflation and core inflation.

This paper has used panel microdata from the Michigan Survey of Consumers on gas price expectations and inflation expectations to study the dynamics of gas price, core, and headline inflation. A result is that consumers' perceptions of inflation are a weighted average of gas price inflation and core inflation, where the weight on gas price inflation is quite similar to consumers' expenditure share on gasoline. That is, consumers do not overweight gas prices when forming inflation expectations. Consumers expect negligible feedback between gas price and core inflation. Thus, increases in gas price inflation have negligible effects on long-run headline inflation expectations.

These results shed light on the role of gas prices in the inflation expectations formation process of consumers. Although the price at the pump may be highly salient, it does not appear to be the main driver of consumers' inflation expectations. This makes it unlikely that rising oil prices from 2009 to 2011 can explain the "missing disinflation" puzzle in those years. These results also suggest that transitory fluctuations in oil prices are unlikely to lead to unanchored inflation expectations as long as core inflation remains stable.

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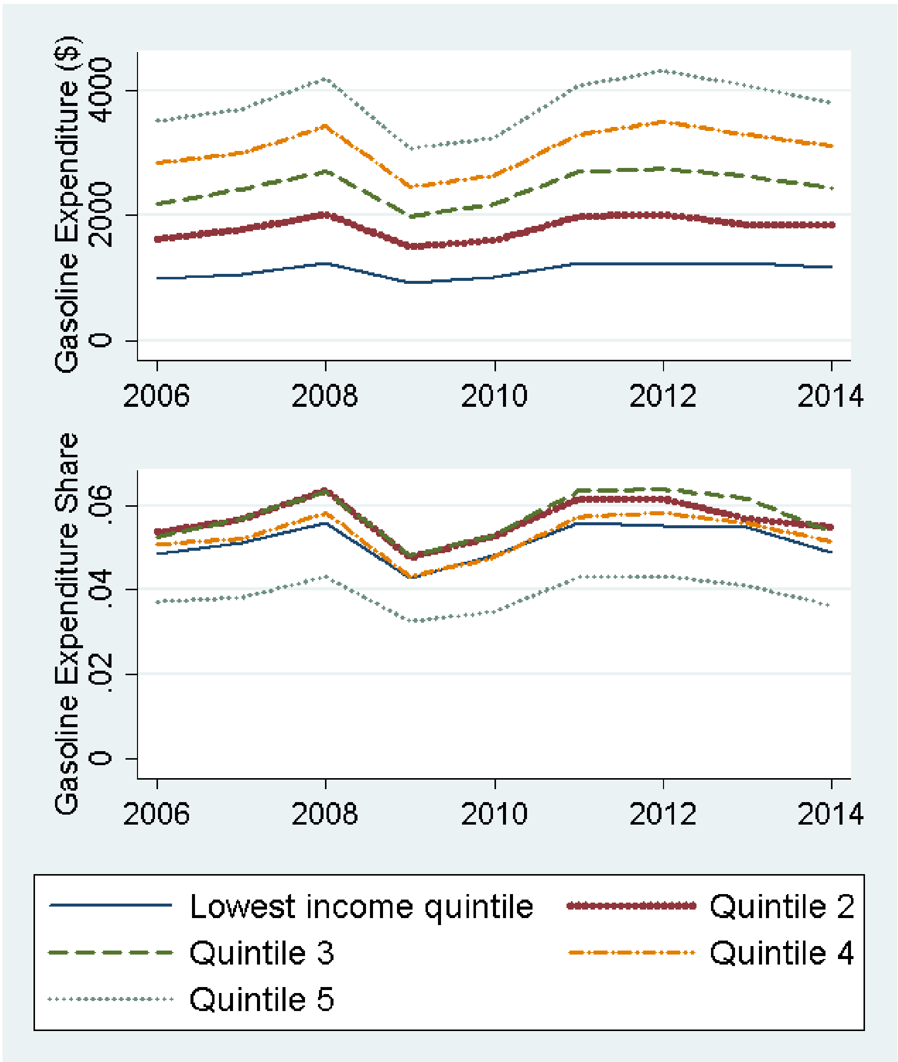
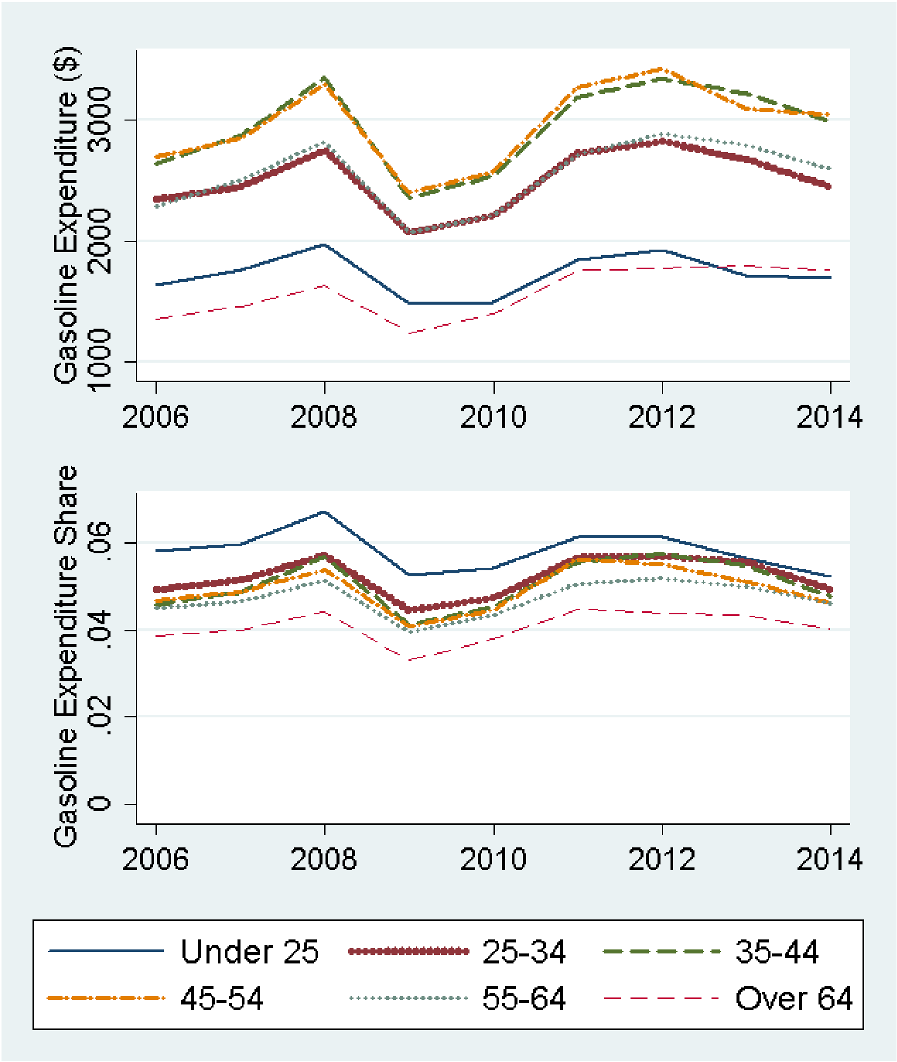
Appendix A Figures

Figure A.1: Spending on Gasoline by Income Quintile



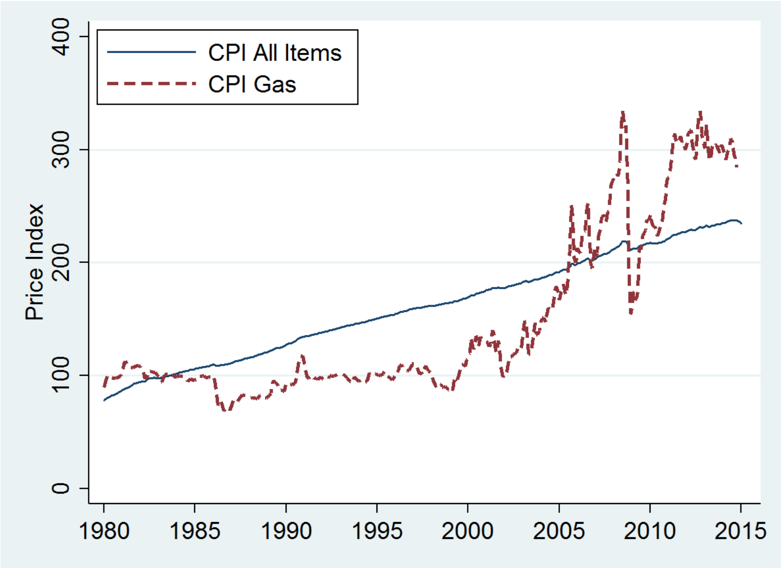
Notes: Data from the Bureau of Labor Statistics Consumer Expenditure Survey.

Figure A.2: Spending on Gasoline by Age



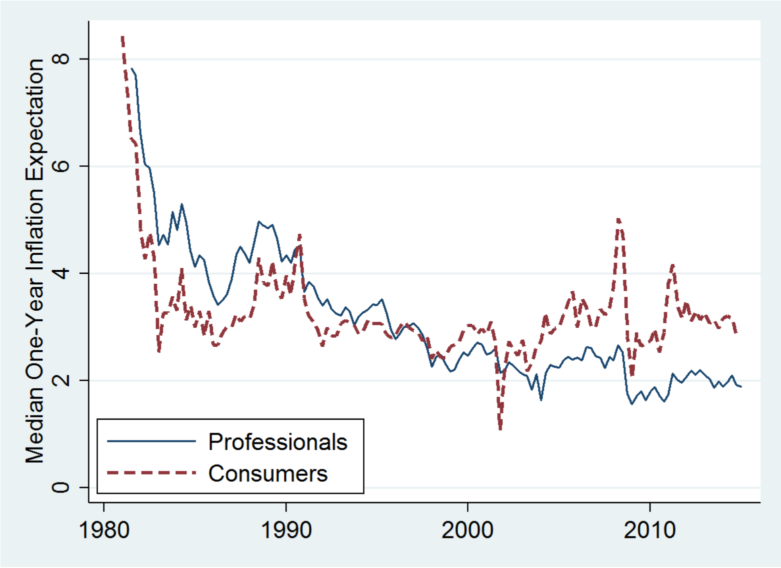
Notes: Data from the Bureau of Labor Statistics Consumer Expenditure Survey.

Figure A.3: Gas Prices are More Volatile than Overall Price Index



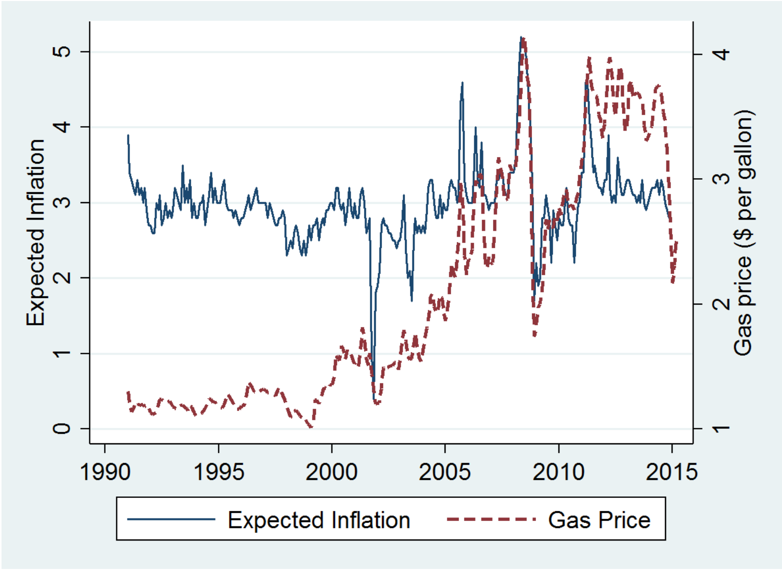
Notes: Data from U.S. Bureau of Labor Statistics.

Figure A.4: Median Inflation Expectations of Consumers and Professional Forecasters



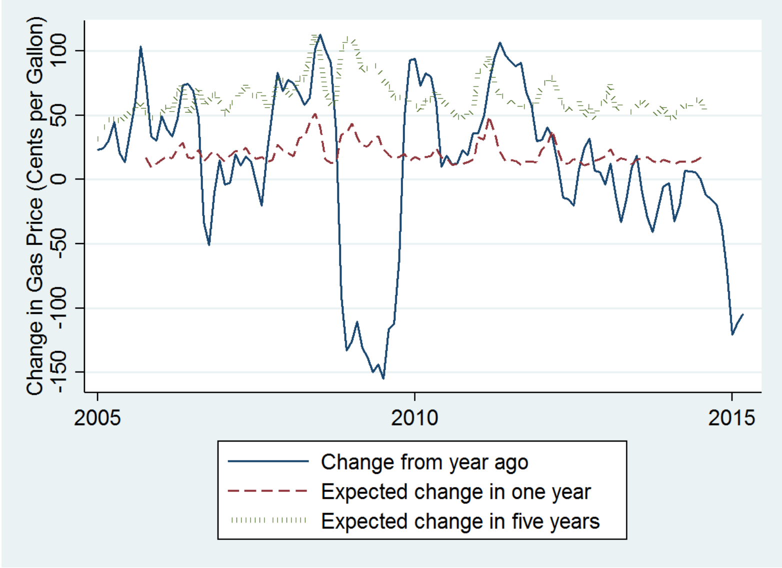
Notes: Professional forecasters' expectations come from the Philadelphia Federal Reserve's Survey of Professional Forecasters for CPI. Consumer expectations come from the Michigan Survey of Consumers, aggregated to quarterly frequency for comparability.

Figure A.5: Consumer Inflation Expectations and Gas Prices



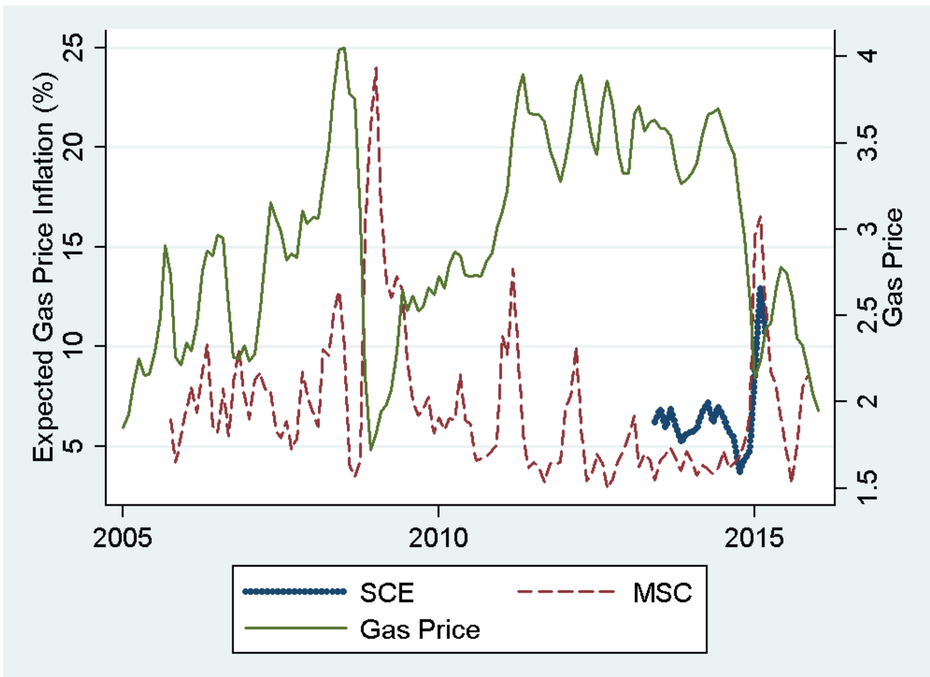
Notes: Consumer one-year-ahead inflation expectations come from the Michigan Survey of Consumers. Gas prices are the "All Grades of Gasoline, U.S. City Average Retail Price" series from the US Energy Information Administration May 2015 Monthly Energy Review.

Figure A.6: Actual and Expected Changes in Gas Prices



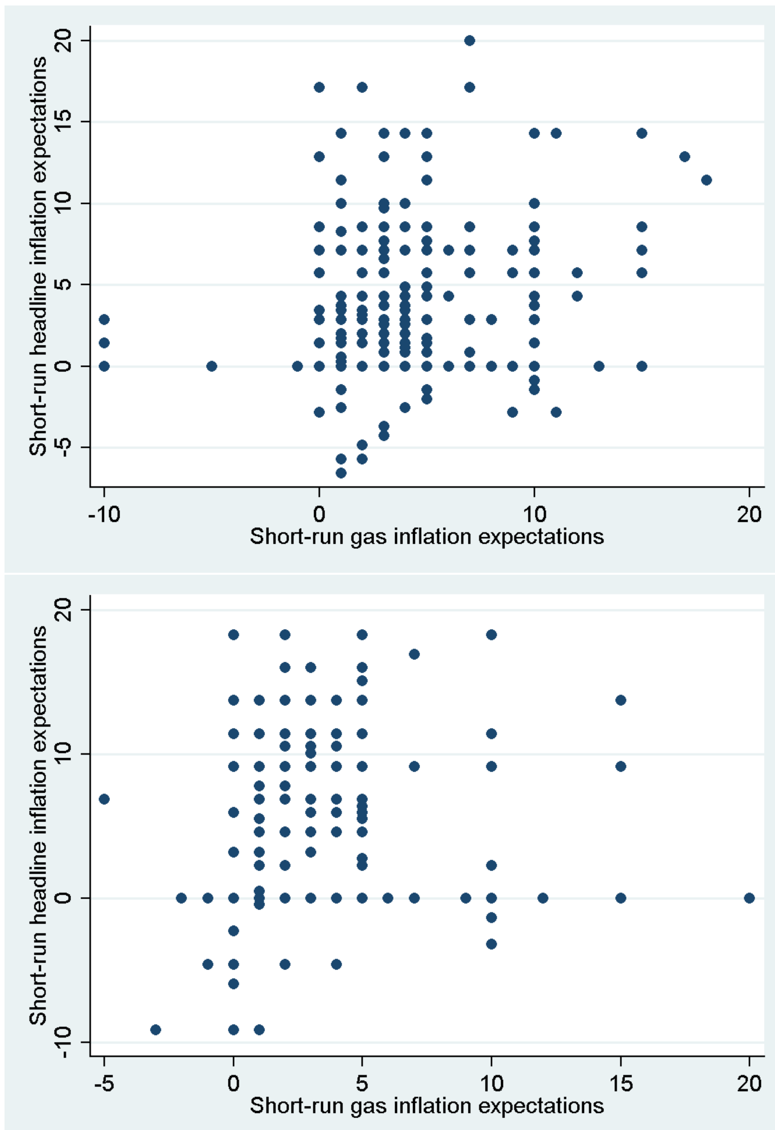
Notes: Change from year ago is the actual change in gas prices over the past 12 months, in cents per gallon, from the "All Grades of Gasoline, U.S. City Average Retail Price" series from the US Energy Information Administration. Expected change in one year and five years are the mean expected gas price increases, in cents per gallon, from the Michigan Survey of Consumers.

Figure A.7: Gas Prices and Expected Gas Price Inflation



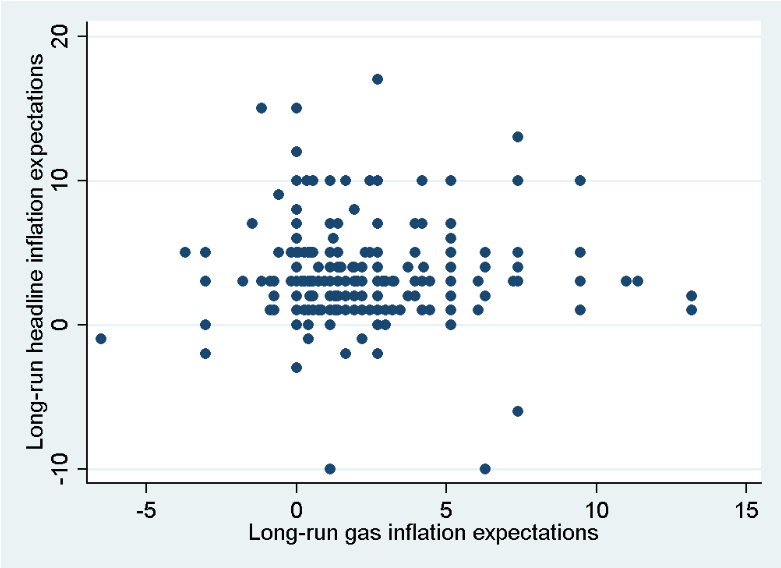
Notes: Expected gas price inflation from the Michigan Survey of Consumers and Survey of Consumer Expectations.

Figure A.8: Short-Run Gas Price and Headline Inflation Expectations in August 2014 and November 2015



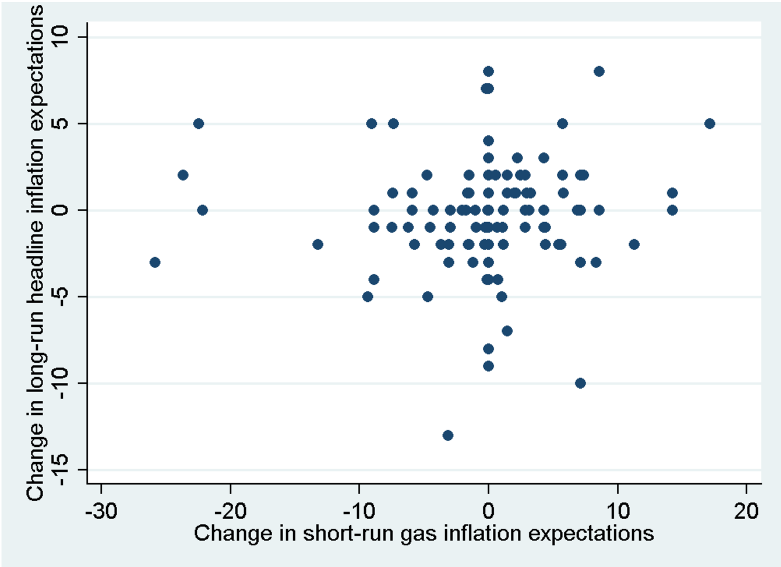
Notes: Data from Michigan Survey of Consumers. One-year-horizon expectations of gas price inflation and headline inflation.

Figure A.9: Long-Run Gas Price and Headline Inflation Expectations in August 2014



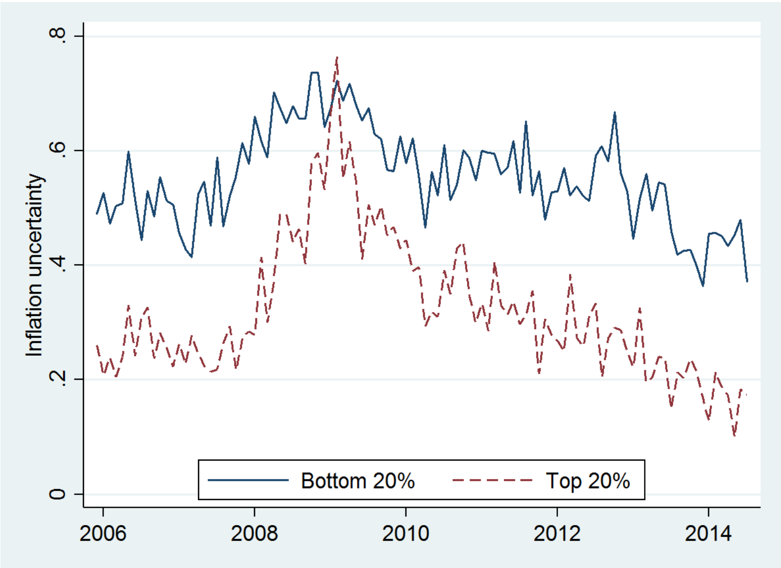
Notes: Data from August 2014 Michigan Survey of Consumers. Long-horizon expectations of gas price inflation and headline inflation.

Figure A.10: Changes in Gas Price and Headline Inflation Expectations in August 2014



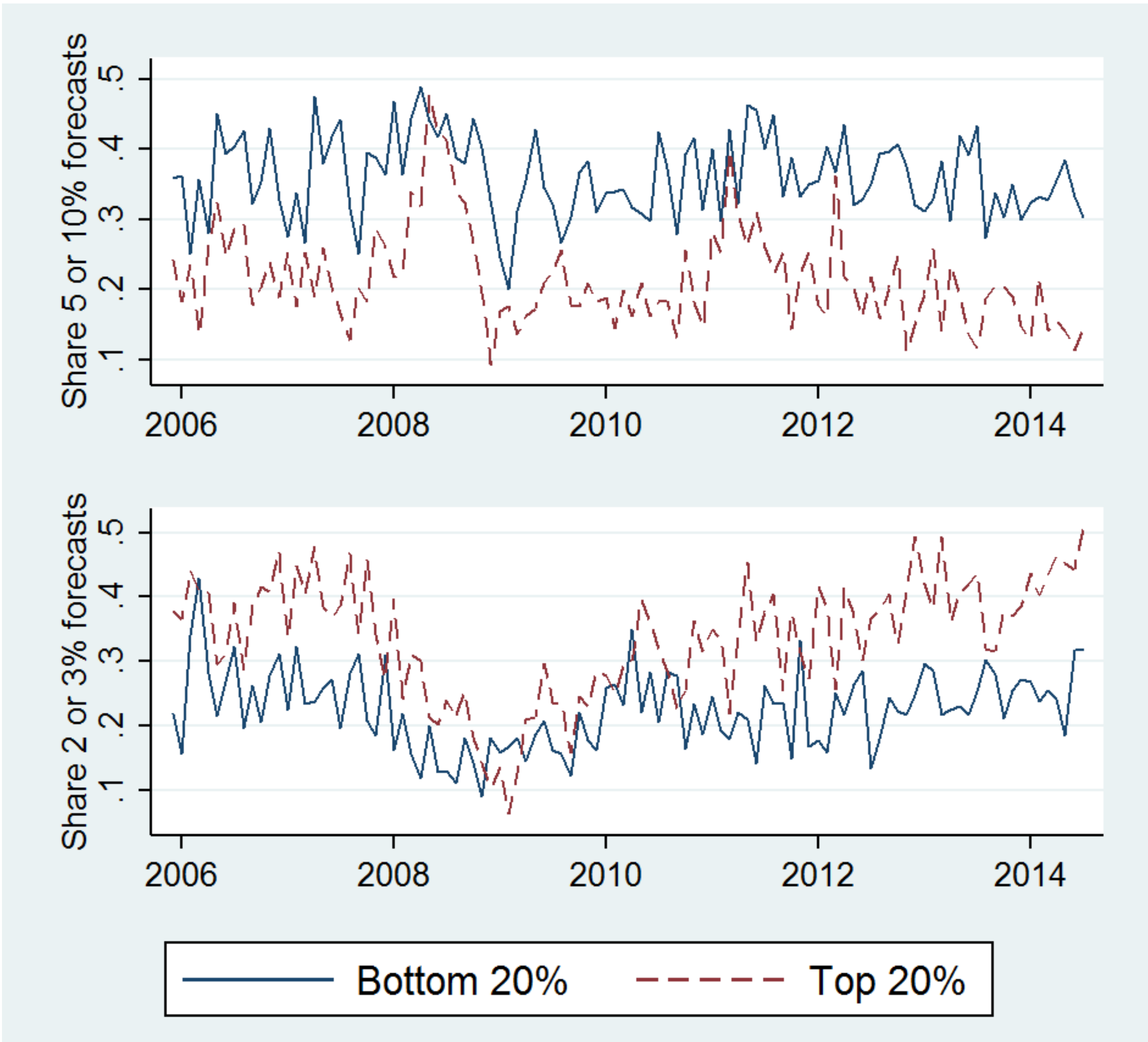
Notes: Data from rotating panel of Michigan Survey of Consumers. Respondents took survey in February and August 2014. Change in short-horizon expectations of gas price inflation and change in long-horizon expectations of headline inflation.

Figure A.11: Inflation Uncertainty for Bottom and Top Income Quintiles



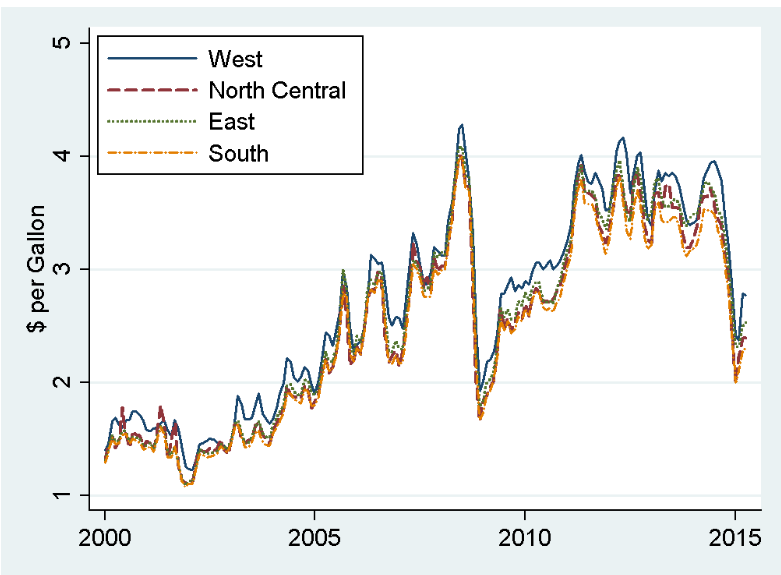
Notes: The inflation uncertainty measure was constructed by Binder (2015a) using Michigan Survey of Consumers data.

Figure A.12: Year-ahead Inflation Forecasts for Bottom and Top Income Quintiles



Notes: Data from Michigan Survey of Consumers. Top panel shows the fraction of respondents by income quintile who choose 5% or 10% inflation forecasts at the one-year horizon. Bottom panel shows the fraction who choose 2 or 3% forecasts.

Figure A.13: Gas Prices by Region



Notes: All-grades conventional gas price.

Appendix B Tables

Table B.1: Variable Descriptions

Variable	**Description**
Demographic Variables from Michigan Survey of Consumers	
Income	Income quintile from 1 (lowest) to 5 (highest)
Education	Highest grade of education completed
Female	Dummy: Female
Married	Dummy: Married
Married*Female	Dummy: Interaction of Female and Married
Age	Age in years
Age Squared	Age in years, squared
Region	Dummies: West, Northeast, and South
Race	Dummies: White, African-American, and Hispanic
Expectation Variables from Michigan Survey of Consumers	
U_{it}^e	A10 Expect unemployment rate to rise (1), stay same (0), or fall (-1)
$B_{it,1}^e$	A10 Expect economy next year to have bad times (1),...,good times (5)
$B_{it,5}^e$	A10 Expect economy next 5 years to have bad times (1),...,good times (5)
R_{it}^e	A11 Expect interest rates next year to rise (1), stay same (0), or fall (-1)
π_{it}^e	A12b Expected % change in prices in next 12 mos.
GAS	A20c Expected change in gas prices in next 12 mos. (cents)
Macroeconomic Variables	
U_t	Civilian unemployment rate
π_t	CPI inflation rate, year-over-year
GasPrice_t	All Grades of Gasoline, U.S. City Average Retail Price

Notes: MSC data are provided by the University of Michigan and Thomson Reuters. Variable codes are provided for expectation variables.

Table B.2: Correlation between headline and gas price inflation expectations

Variables	Short-run headline	Long-run headline	Short-run gas	Long-run gas
Short-run headline	1.00			
Long-run headline	0.43	1.00		
Short-run gas	0.13	0.11	1.00	
Long-run gas	0.07	0.16	0.57	1.00

Notes: Data from Michigan Survey of Consumers.

Table B.3: Correlation between changes in headline inflation expectations and changes in gas price inflation expectations

Variables	Short-run headline	Long-run headline	Short-run gas	Long-run gas
Short-run headline	1.00			
Long-run headline	0.28	1.00		
Short-run gas	0.06	0.05	1.00	
Long-run gas	0.01	0.07	0.48	1.00

Notes: Data from rotating panel of Michigan Survey of Consumers.

Table B.4: Regression results

	(1)		(2)		(3)	
	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$
$\Delta\bar{\pi}^{ge}_{it,5}$	0.056***		0.055***		0.047***	
	(0.007)		(0.007)		(0.007)	
$\Delta\bar{\pi}^{e}_{it,1}$	0.214***	-0.021**	0.216***	-0.012	0.213***	0.007
	(0.006)	(0.008)	(0.006)	(0.008)	(0.006)	(0.007)
$\Delta\bar{\pi}^{ge}_{it,1}$	0.004	0.206***	0.005	0.204***	0.003	0.196***
	(0.004)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)
$\Delta U^{e}_{it,1}$	-0.022	0.056	-0.021	0.057		
	(0.039)	(0.050)	(0.039)	(0.049)		
$\Delta B^{e}_{it,1}$	-0.018	0.004	-0.018	-0.006		
	(0.015)	(0.019)	(0.015)	(0.019)		
$\Delta B^{e}_{it,5}$	-0.069***	-0.036*	-0.068***	-0.041*		
	(0.016)	(0.021)	(0.016)	(0.021)		
$\Delta R^{e}_{it,1}$	-0.011	-0.077*	-0.008	-0.057		
	(0.035)	(0.044)	(0.035)	(0.044)		
ΔU_t			0.087**	-0.100*		
			(0.042)	(0.054)		
$\Delta \pi_t$			-0.039**	-0.240***		
			(0.018)	(0.023)		
Observations	11471		11471		13985	
R^2	0.100	0.135	0.101	0.143	0.102	0.172
Time Fixed Effects	No		No		Yes	

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Table contains modifications of regression in Table 1. Specification (1) includes changes in expectations of unemployment, short and long-run business conditions, and interest rates as control variables. Specification (2) also includes changes in unemployment rate and inflation as control variables. Specification (3) includes time fixed effects. Seemingly-unrelated regression standard errors in parentheses.

Table B.5: Regressions with regional gasoline prices

	$\Delta\pi^{e}_{it,5}$	$\Delta\pi^{ge}_{it,5}$
$\Delta\pi^{ge}_{it,5}$	0.049***	
	(0.007)	
$\Delta\pi^{e}_{it,1}$	0.211***	-0.013*
	(0.006)	(0.007)
$\Delta\pi^{ge}_{it,1}$	0.004	0.204***
	(0.004)	(0.004)
Observations	13985	
R^2	0.093	0.132

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Seemingly-unrelated regression standard errors in parentheses. Expected gas price inflation for respondent i is expected cents per gallon increase divided by price of gas in i's geographic region (in dollars per gallon.) Regional gas price data was downloaded from Federal Reserve Bank of St. Louis FRED with codes GASALLCOVWCM, GASALLCOVMWM, GASALLCOVECM, and GASALLCOVGCM. Estimates correspond to the following values for the matrix A: $a_{cc} = 0.025, a_{cg} = -0.028, a_{gc} = -0.044, a_{gg} = 0.17$.

Table B.6: Regression results using levels instead of first differences

	(1)		(2)		(3)	
	$\bar{\pi}^{e}_{it,5}$	$\bar{\pi}^{ge}_{it,5}$	$\bar{\pi}^{e}_{it,5}$	$\bar{\pi}^{ge}_{it,5}$	$\bar{\pi}^{e}_{it,5}$	$\bar{\pi}^{ge}_{it,5}$
$\bar{\pi}^{ge}_{it,5}$	0.087***		0.090***		0.089***	
	(0.004)		(0.006)		(0.007)	
$\bar{\pi}^{e}_{it,1}$	0.327***	-0.001	0.339***	-0.011	0.335***	0.009
	(0.003)	(0.004)	(0.006)	(0.007)	(0.006)	(0.007)
$\bar{\pi}^{ge}_{it,1}$	-0.003	0.313***	-0.006	0.331***	-0.007*	0.321***
	(0.002)	(0.003)	(0.004)	(0.005)	(0.004)	(0.005)
Income Quintile					-0.035*	0.040*
					(0.019)	(0.024)
Education					-0.009	0.085***
					(0.010)	(0.013)
Female					0.150***	-0.625***
					(0.041)	(0.053)
Married					0.034	0.053
					(0.047)	(0.062)
Age					0.014*	0.054***
					(0.007)	(0.010)
Age Squared					-0.000***	-0.001***
					(0.000)	(0.000)
West					0.146**	0.224***
					(0.059)	(0.077)
Northeast					0.049	-0.187**
					(0.060)	(0.078)
South					0.102**	-0.079
					(0.051)	(0.067)
Constant	1.724***	1.926***	1.619***	1.759***	1.527***	-0.249
	(0.020)	(0.024)	(0.032)	(0.040)	(0.224)	(0.295)
Observations	44462		13985		13631	
R^2	0.214	0.230	0.229	0.267	0.230	0.287

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Regression results correspond to equation (16). Variable descriptions in Table B.1. Specification (1) includes all available data. Specification (2) includes same sample as Table 1 (rotating panel participants). Specification (3) includes same sample as Table 1 and demographic controls. Seemingly-unrelated regression standard errors in parentheses.

Table B.7: Panel regression of inflation expectations on categories of price change expectations

	(1)	(2)	(3)	(4)
Gas	0.019**	0.023**	0.008	0.064**
	(0.009)	(0.009)	(0.007)	(0.027)
Food	0.125***	0.116***	0.138***	0.080*
	(0.023)	(0.023)	(0.025)	(0.043)
Medical	0.009	0.010	0.017*	0.002
	(0.010)	(0.010)	(0.010)	(0.020)
College	0.059***	0.051***	0.036**	0.065**
	(0.016)	(0.016)	(0.015)	(0.030)
Rent	0.101***	0.097***	0.055**	0.139***
	(0.022)	(0.022)	(0.022)	(0.040)
Gold	0.012	0.007	0.016	-0.009
	(0.012)	(0.012)	(0.012)	(0.023)
Female		0.993***	1.142***	0.700
		(0.235)	(0.213)	(0.660)
CollegeEducation		-1.230***	-1.042***	-1.748***
		(0.238)	(0.227)	(0.637)
Income>100k		-0.288	-0.320	-0.722
		(0.231)	(0.207)	(0.902)
Income< 50k		1.070***	0.714***	1.684**
		(0.296)	(0.274)	(0.712)
Age		-0.002	0.015*	-0.132
		(0.009)	(0.008)	(0.166)
AgeSquared		0.000	-0.000*	0.001
		(0.000)	(0.000)	(0.002)
HighlyNumerate		-1.256***		
		(0.344)		
Constant	2.776***	3.852***	2.042***	7.691*
	(0.186)	(0.611)	(0.451)	(4.132)
Observations	25246	24850	18233	6617
Sample	All	All	High Numeracy	Low Numeracy

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Random effects panel regression using data from the New York Federal Reserve Survey of Consumer Expectations. Dependent variable is one-year-ahead expected inflation. Gas, food, etc. refer to one-year-ahead expected changes in gas prices, food prices, etc.

Table B.8: Panel regression of three-year-ahead inflation expectations on categories of price change expectations

	(1)	(2)	(3)	(4)
Short-run Headline	0.396***	0.392***	0.404***	0.386***
	(0.025)	(0.025)	(0.036)	(0.034)
Gas	-0.002	-0.000	-0.005	0.017
	(0.010)	(0.010)	(0.008)	(0.031)
Food	0.153***	0.151***	0.131***	0.162***
	(0.027)	(0.027)	(0.028)	(0.050)
Medical	0.009	0.009	-0.001	0.023
	(0.011)	(0.011)	(0.012)	(0.021)
College	0.025	0.022	0.061**	-0.029
	(0.019)	(0.019)	(0.024)	(0.029)
Rent	0.059**	0.053**	-0.018	0.133***
	(0.026)	(0.026)	(0.031)	(0.041)
Gold	0.002	0.001	0.008	-0.013
	(0.011)	(0.011)	(0.011)	(0.024)
Female		0.208	0.115	0.381
		(0.188)	(0.170)	(0.523)
CollegeEducation		-0.621***	-0.474**	-1.110**
		(0.196)	(0.191)	(0.518)
Income>100k		0.170	0.113	0.073
		(0.167)	(0.163)	(0.600)
Income< 50k		0.679***	0.675***	0.590
		(0.244)	(0.228)	(0.583)
Age		-0.004	0.005	-0.023
		(0.008)	(0.007)	(0.127)
AgeSquared		0.000	-0.000	-0.000
		(0.000)	(0.000)	(0.001)
HighlyNumerate		-0.760***		
		(0.284)		
Constant	1.444***	2.248***	1.337***	2.918
	(0.171)	(0.500)	(0.387)	(3.166)
Observations	25198	24804	18205	6599
Sample	All	All	High Numeracy	Low Numeracy

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses. Random effects panel regression using data from the New York Federal Reserve Survey of Consumer Expectations. Dependent variable is three-year-ahead expected inflation. Gas, food, etc. refer to one-year-ahead expected changes in gas prices, food prices, etc.

Table B.9: Regressions of changes in headline and gas price expectations on percent change in oil price

	(1)	(2)	(3)	(4)
	$\Delta\pi^{e}_{it,1}$	$\Delta\pi^{e}_{it,1}$	$\Delta\pi^{ge}_{it,1}$	$\Delta\pi^{ge}_{it,1}$
$100\log(OilP_t/OilP_{t-6})$	0.016***	0.012***	-0.025	-0.015
	(0.002)	(0.002)	(0.021)	(0.024)
$\Delta\pi_t$		0.110***		-0.321
		(0.032)		(0.324)
$\Delta\pi^{c}_t$		0.172**		-0.188
		(0.074)		(0.814)
Constant	-0.263***	-0.217***	-0.357	-0.408
	(0.028)	(0.027)	(0.327)	(0.317)
Observations	75149	75149	32122	32122
R^2	0.009	0.011	0.003	0.004

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Regression results correspond to equation (21). Standard errors clustered by time in parentheses.

Table B.10: Spending on gasoline by age and income groups, 2006-2014

Demographic group	Gas expenditures ($/year)	Gas budget share (%)	Spend (ratio relative to baseline group)	Share (ratio relative to baseline group)
Age				
Under 25	1725	5.8	1.00	1.00
25-34	2500	5.2	1.45	0.89
35-44	2943	5.0	1.70	0.87
45-54	2960	4.9	1.71	0.85
55-64	2543	4.7	1.47	0.81
Over 64	1575	4.1	0.91	0.70
Income				
Lowest quintile	1117	5.1	1.00	1.00
Quintile 2	1799	5.7	1.61	1.11
Quintile 3	2440	5.7	2.18	1.12
Quintile 4	3057	5.3	2.74	1.03
Top quintile	3771	3.9	3.38	0.76

Notes: Data from BLS Consumer Expenditure Survey.

Table B.11: Regressions with income quintile relative expenditure levels and shares on gasoline

	(1)		(2)	
	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$
$\Delta\bar{\pi}^{ge}_{it,5}$	0.078***		0.048	
	(0.020)		(0.039)	
$\Delta\bar{\pi}^{ge}_{it,5}$*Spend	-0.009			
	(0.007)			
$\Delta\bar{\pi}^{ge}_{it,5}$*Share			0.007	
			(0.037)	
$\Delta\bar{\pi}^{e}_{it,1}$	0.205***	-0.011	0.205***	-0.011
	(0.006)	(0.008)	(0.006)	(0.008)
$\Delta\bar{\pi}^{ge}_{it,1}$	0.003	0.199***	0.003	0.199***
	(0.004)	(0.005)	(0.004)	(0.005)
Observations	12623		12623	
R^2	0.091	0.128	0.091	0.128

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Regression results correspond to system of equations (17), where first equation is replaced by (24) in specification (1) and (25) in specification (2). Variable descriptions in Table B.1. Seemingly-unrelated regression standard errors in parentheses.

Table B.12: Regressions with age group relative expenditure levels and shares on gasoline

	(1)		(2)	
	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$
$\Delta\bar{\pi}^{ge}_{it,5}$	0.040		0.032	
	(0.026)		(0.048)	
$\Delta\bar{\pi}^{ge}_{it,5}$*Spend	0.011			
	(0.017)			
$\Delta\bar{\pi}^{ge}_{it,5}$*Share			0.030	
			(0.059)	
$\Delta\bar{\pi}^{e}_{it,1}$	0.207***	-0.010	0.206***	-0.010
	(0.006)	(0.007)	(0.006)	(0.007)
$\Delta\bar{\pi}^{ge}_{it,1}$	0.003	0.201***	0.003	0.201***
	(0.004)	(0.005)	(0.004)	(0.005)
Observations	12916		12916	
R^2	0.092	0.130	0.092	0.130

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Regression results correspond to system of equations (17), where first equation is replaced by (24) in specification (1) and (25) in specification (2). Variable descriptions in Table B.1. Seemingly-unrelated regression standard errors in parentheses.

Table B.13: Regional inflation expectations and gas prices

Region	π^e (%)	Gas Price ($/gallon)
West	3.69	3.29
	(0.98)	(0.56)
North Central	3.90	3.07
	(0.84)	(0.57)
Northeast	3.77	3.14
	(1.01)	(0.56)
South	3.99	3.00
	(0.88)	(0.54)

Notes: Means and standard devations (in parentheses.) All-grades conventional gas price.