Inflation Expectations and the Price at the Pump

Carola Conces Binder*

July 22, 2017

Abstract

Consumer inflation expectations are positively correlated with gas prices. The optimal monetary policy response to energy price fluctuations depends on whether inflation expectations are excessively sensitive to gas prices, perhaps due to their high volatility and salience. I use multi-horizon microdata to study the dynamics of consumers' gas price and inflation expectations. Consumers do not "overweight" gas prices in their perception of inflation, relative to the expenditure share of gas. They believe gas price inflation is negatively autocorrelated and feeds into core inflation moderately. The impact of gas prices on inflation expectations fades quickly with forecast horizon.

Keywords: Gas prices, energy prices, inflation expectations, core inflation, consumers, monetary policy

JEL codes: E31, E52, D84, Q43

Acknowledgments: I thank Yuriy Gorodnichenko and participants at the Federal Reserve Bank of Cleveland seminar series, the Federal Reserve Bank of New York Workshop on Subjective Expectations, and seminar participants at American University, Lafayette College, and Haverford College for valuable feedback and suggestions.

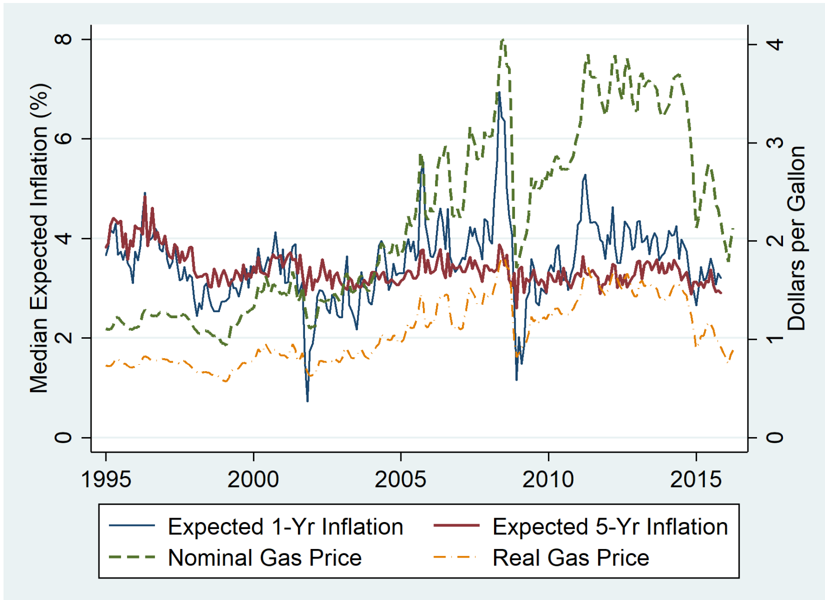
*Assistant Professor, Haverford College, Department of Economics, 370 Lancaster Avenue Haverford, PA 19041. Email: cbinder1@haverford.edu.

Introduction

Consumers' long-run inflation expectations reached historical lows in 2016, following a marked decline in gasoline prices. The Wall Street Journal reported that "inflation expectations as surveyed by the University of Michigan are highly correlated to gasoline. The drop in this measure should be no surprise given the epic collapse in pump prices since 2014" (Ip, 2016). A typical explanation for this often-noted correlation between gas prices and inflation expectations, visible in Figure 1, is the "frequency hypothesis": since gas is purchased frequently, its price is highly salient (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). Since gas prices are volatile, although gas accounts for around 5% of consumer expenditures, its price may have a disproportionately large influence on inflation expectations. Indeed, Trehan (2011) claims that consumer inflation expectations are *excessively* sensitive to energy prices.

The response of inflation expectations to energy prices is important for monetary policy. Goodfriend and King (1997) and King and Wolman (1998) argue that a central bank with a known inflation target and perfect credibility should target core inflation, which excludes more volatile prices like gas. But if energy prices have excessive impact on inflation expectations, larger monetary policy responses to energy price changes may be warranted (Cavallo, 2008; Harris et al., 2009). St. Louis Fed President James Bullard (2011) appeals to the frequency hypothesis when he 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." Conversely, Evans and Fisher (2011) posits 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

Figure 1: Consumer Inflation Expectations and Gas Prices



Notes: Consumer inflation expectations come from the Michigan Survey of Consumers and gas prices from the US Energy Information Administration.

high degree of central bank credibility, there is no reason for such expectations to develop."

In this paper, I re-examine the sensitivity of consumers' inflation expectations to gas prices[1] using data from the Michigan Survey of Consumers (MSC). Frequency or saliency bias theories posit that consumers over-weight gas prices relative to the expenditure share on gas when forming *perceptions* of inflation, but the observed correlation is between gas prices and *expectations* of inflation. Moreover, as the correlation referenced by the Wall Street Journal and also frequently in the literature is between the *level* of gas prices and the expected *rate of change* of overall prices, its interpretation is not obvious.

I show that this puzzle of mismatched units is resolved by noting that gas prices are mean-reverting, so the level of gas prices is correlated with its rate of change. Thus, expected

[1] I focus specifically on gas prices, rather than energy or oil prices. Kilian (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 general energy prices. Oil and gas prices are strongly correlated, with a correlation coefficient of 0.97 since 2000.

inflation is also correlated with gas price inflation. This correlation alone, however, does not necessarily imply that consumer inflation expectations are *excessively* sensitive to gas prices or that any behavioral biases are present.

To delve further into this issue, I use MSC rotating panel data on both inflation expectations and gas price expectations at the one- and five-to-ten-year horizons to help clarify the propagation of gas prices into inflation expectations. The key insight is to use data on expecions for horizons $t+1$ and $t+1+h$ to infer the relationship between expectations for horizon t (the current perception) and $t+1$. This allows me to examine how heavily consumers weigh gas price inflation in their perception of overall inflation—whether consumers indeed weight gas prices significantly more than the roughly five percent expenditure share on gasoline. Using data on expectations of both gas and headline inflation also allows me to investigate consumers' beliefs about their joint dynamics: what do consumers believe about the dynamics of gas price inflation and to what extent do consumers expect changes in gas prices to lead to changes in the prices of other items? Previous work finds that the average consumer typically expects the future real price of gasoline to equal its current price, though forecasts vary substantially across consumers (Anderson et al., 2013). Beliefs about feedback into core inflation may depend on beliefs about the monetary policy reaction function and the degree to which core inflation expectations are well-anchored.

To disentangle these aspects of perception and expectation formation, I build a parsimonious model in which consumers differ in their perceptions of current gas and non-gas inflation and in their beliefs about the mean of the inflation process for gas and non-gas prices. A consumer's perception of headline inflation is a weighted average of her perceptions of gas price inflation and non-gas inflation, where the weight ω on gas price inflation may not necessarily correspond to the expenditure share on gasoline. Each consumer forms expectations of future inflation using her perceptions of current gas and non-gas price inflation and her model of their bivariate dynamics. The multi-horizon, rotating panel structure of the MSC data on both expected inflation and expected gas price changes allows me to estimate ω and the other parameters describing consumers' beliefs about gas and inflation dynamics, even though the MSC does not ask about inflation perceptions directly.

I find that if gas price inflation increases by one percentage point, then one-year-ahead headline inflation expectations increase by about 0.01 percentage points and five-year-ahead inflation expectations increase by under 0.003 percentage points. The parameter estimates allow me to account for these changes. First, my estimate of ω is 4%, which is similar to the actual expenditure share on gasoline and does not indicate that headline inflation perceptions are excessively sensitive to gas prices. In other words, headline inflation and consumers' perceptions of headline inflation rise by about the same amount in response to a rise in gas price inflation. Other parameter estimates indicate that consumers believe that gas price inflation is slightly *negatively* autocorrelated (which is realistic). If gas price inflation increases by one percentage point, expected one-year-ahead gas price inflation decreases by 0.16 percentage points. Moreover, consumers believe that the pass-through of current gas price inflation to future non-gas inflation is somewhat larger than in reality, but of the same order of magnitude. If gas price inflation increases by one percentage point, non-gas inflation expectations rise by about 0.02 percentage points. The 0.01 percentage point rise in headline inflation expectations is the weighted sum of the 0.16 percentage point fall in expected gas price inflation and the 0.02 percentage point rise in non-gas inflation, where the weights are 4% and 96%, respectively.

Since gas price fluctuations can be very large, even a 0.01 percentage point increase in expected inflation in response to a one percentage point increase in gas price inflation is not trivial. This is similar to the estimate found by Coibion and Gorodnichenko (2015), who note that this effect is large enough to account for much of the variation in one-year-ahead inflation expectations from 2009 to 2011. However, the magnitude of the effect is consistent with consumers using a fairly reasonable model of inflation dynamics, in which the weight on gas price inflation in headline inflation is similar to the expenditure share on gas, and shocks to gas price inflation are not expected to persist. Since the effects of gas prices on inflation expectations fade quickly with forecast horizon, gas price fluctuations seem unlikely to unanchor consumers' longer-run inflation expectations. My parameter estimates also indicate that gas price fluctuations are unlikely to unanchor medium- to longer-run *core* inflation expectations and do not provide support for the frequency hypothesis.

Section 1 provides an overview of existing evidence on gas price and inflation dynamics and expectations. Section 2 describes the MSC data on inflation and gas price expectations and presents correlations and reduced form analysis. Section 3 describes and estimates a model of expectations formation, and section 4 concludes.

1 Gas Prices, Inflation, and Expectations

In the 1970s and early 1980s, the US economy experienced rising gas prices and high overall inflation. In recent decades, despite the high volatility of energy inflation, headline inflation has remained relatively stable (Hamilton, 1983; Blanchard and Gali, 2010; Clark and Terry, 2010; Chen and Wen, 2011). 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). In fact, an oil price shock can act as both an adverse aggregate supply shock, by raising the costs of producing domestic output, and as an adverse aggregate demand shock, by reducing household purchasing power. Since the latter effect tends to dominate (Kilian, 2008), exogenous oil price shocks may be minimally inflationary or even deflationary.[2]

The pass-through of energy prices to inflation depends on the monetary policy reaction

[2]See Barsky and Kilian (2002) for an argument that oil price shocks did not cause the Great Stagflation.

function and on expectations (Hamilton, 2012). The monetary policy response to oil price shocks has changed over time and may take into account the underlying causes of the shocks; the Fed appears to have responded directly to oil price shocks in the 1970s and early 1980s, for example, but not since the late 1980s (Kilian and Lewis, 2011).

Another aspect of the monetary reaction function is whether the Fed responds to headline inflation or to core inflation, the less volatile component of inflation that excludes gas prices. When a central bank can commit to a fully known and credible inflation target, Goodfriend and King (1997) and King and Wolman (1998) argue that the bank should target core inflation in order to stabilize the sticky components of the price index. Aoki (2001) formally derives this result in a model with both flexible and sticky price sectors with nominal rigidities in the form of Calvo staggered price setting. In a similar model, Bodenstein et al. (2008) 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. 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 includes headline inflation.

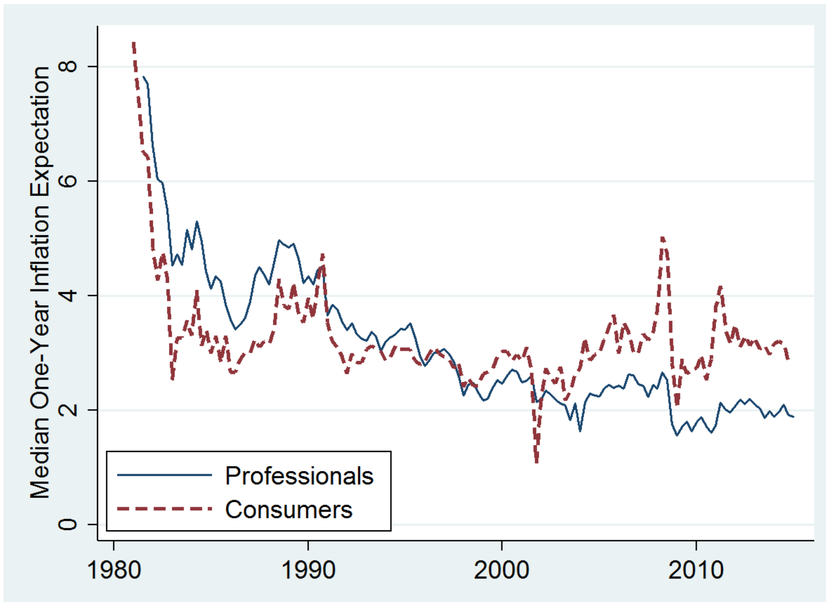
Mankiw and Reis (2003) model an economy in which sectors differ in cyclical sensitivity, proclivity to experience idiosyncratic shocks, speed of price adjustment, and share in consumers' budget sets. They derive several propositions about the optimal weight on each sector in a "stability price index" that, if used as the inflation target, would minimize output volatility. One proposition is similar to Aoki's result: more flexibly-priced sectors should receive less weight; this implies a relatively low weight on energy prices. Two other propositions concern 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). The core consumer price index (CPI) has typically performed better than headline CPI as a predictor of headline CPI (Khettry and Mester, 2006).

Departing from the assumption that the monetary policymaker can commit to a time-invariant rule with a known and credible inflation target 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 credibility of monetary policy affects the 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.

The Greenspan Fed reacted primarily to core inflation (Blinder and Reis, 2005; Cavallo, 2008). But in 2012, the Federal Reserve's Federal Open Market Committee (FOMC) adopted a long-run 2% objective for headline Personal Consumption Expenditures (PCE) inflation. Thus, like the Bank of England and the European Central Bank, the Fed officially targets headline rather than core inflation, though it monitors core inflation carefully (Bodenstein et al., 2008).

The announcement of a 2% target was part of an effort to anchor inflation expectations (Yellen, 2013). Expectations are well-anchored if they respond minimally to shocks (Bernanke, 2007), and in particular should not react strongly to changes in oil or gas prices. Yellen (2009) interprets the stability of *professional forecasters'* expectations (see Figure 2) as a sign of strong Fed credibility. Similarly, Celasun et al. (2012) find that oil price shocks have a statistically significant but economically small impact on inflation compensation in Treasury bonds. Mishkin (2007, p. 329) claims that better-anchored inflation expectations

Figure 2: 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.

"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, households' expectations are less strongly the anchored than professional forecasters' (Binder, 2017a). The median inflation expectations of households rose in the mid-2000s, and also fell with energy prices in 2008 and rose with energy prices from 2009 to 2011. Coibion and Gorodnichenko (2015) argue that this movement of households' inflation expectations deserves monetary policymakers' attention, and is in fact crucial for explaining inflation dynamics since the Great Recession. They 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. Using household expectations to estimate the Phillips Curve can account for the "missing disinflation" puzzle, or lack of strong disinflationary pressures despite a weak labor market from 2009 to 2011. While Coibion and Gorodnichenko (p. 226) attribute the movement in households' short-run inflation expectations to a "remarkably high sensitivity" to energy prices, Verbrugge and Higgins (2015) find that energy price shocks have a statistically significant but very small impact on consumers' long-run inflation expectations using a structural vector autoregression (SVAR). Wong (2015), also using an SVAR, finds that consumers' inflation expectations do react to oil prices, but that these inflation expectations do not propagate real oil price shocks into inflation.

The response of inflation expectations to oil or gas prices depends in part on beliefs about oil or gas price dynamics. The stochastic properties of oil and gas prices are the subject of a large literature (Gibson and Schwartz, 1990; Pindyck, 2001). Celasun et al. (2012) argues that it is unlikely that a shock to oil prices will lead to expectations of a sustained commodity price rise since oil prices follow a random walk rather than being autocorrelated.[3] Indeed, the no-change forecast was, until recently, considered the best possible forecast for oil prices (Alquist et al., 2013; Baumeister et al., 2017). 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 MSC. Baumeister et al. (2017) suggest that MSC respondents use simple, suboptimal rules of thumb to forecast gas prices.

[3]Bessembinder et al. (1995) use the term structure of futures prices to test whether investors anticipate mean reversion in spot asset prices and estimate that 44 percent of a spot oil price shock is expected to be reversed over the subsequent eight months. Blinder and Reis (2005) find that oil price shocks from 1970 to 2004 tend to be reversed. Also see Roache and Reichsfeld (2011).

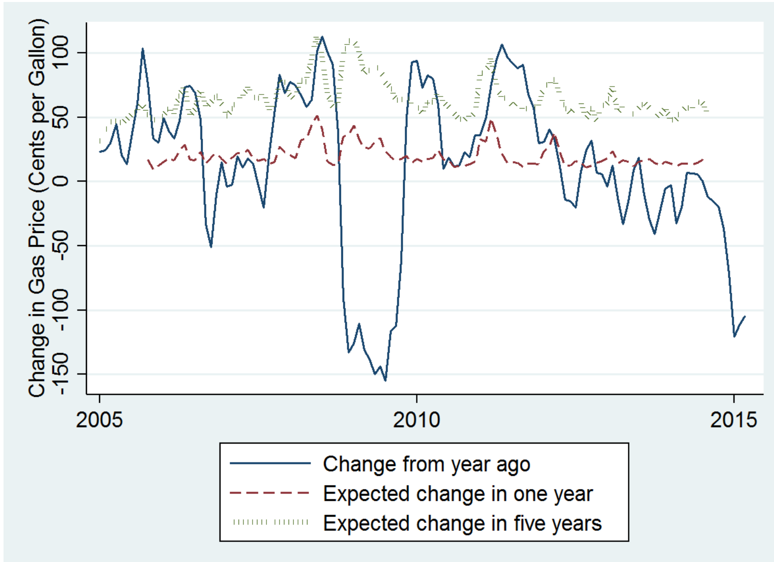
2 Correlational Evidence

The Michigan Survey of Consumers (MSC) surveys about 500 households per month by telephone about their 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. Figure 3 plots actual changes in gas prices over the past 12 months with expected changes in gas prices over the next year and five years. The average consumer always expects gas prices to rise, even when gas prices have fallen over the previous year. I use the US All Grades Conventional Gas Price series from the US Energy Information Administration 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, $\bar{\pi}^{ge}_{it,5}$. Figure 4 plots gas prices and average expected gas price inflation from both the MSC and the New York Federal Reserve's Survey of Consumer Expectations (SCE). Though the SCE question asks directly for the percent change in gas prices, rather than the cents per gallon change, the mean expectations implied by the two surveys are similar.

Michigan Survey respondents are also asked about the expected percent change in prices over both horizons.[4] I use the notation $\pi^{e}_{it,1}$ and $\bar{\pi}^{e}_{it,5}$ to denote these year-ahead and average long-run inflation expectations. 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. 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

[4]The exact 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?" Since the gas price question asks about the next 5 years, I interpret both questions as being about the average over the next 5 years.

Figure 3: 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.

rotating panel data on gas price expectations and inflation expectations at both horizons are April 2006 through November 2015.

2.1 Expectations and Gas Prices

While the inflation expectation survey data has been used in countless studies, the gas price expectation data is rarely used.[5] Most studies and commentary compare expected inflation to actual, rather than expected, oil or gas prices (recall Figure 1). In particular, Coibion

[5]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. 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.

and Gorodnichenko run a regression of the form:

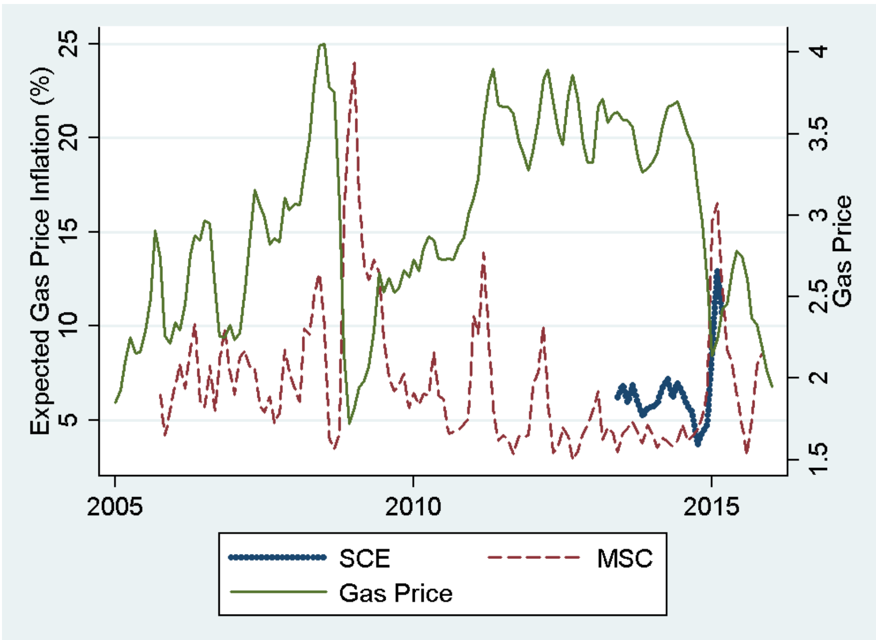
$$\Delta\pi^e_{it,1} = \beta_0 + \beta_1 \pi^{oil}_t + \epsilon_{it} \tag{1}$$

where $\Delta\pi^e_{it,1}$ is the change in respondent i's expectation of one-year ahead inflation from six months prior, $\pi^{oil}_t = \log(P^{oil}_t / P^{oil}_{t-6}) * 100\%$, and P^{oil}_t is the price of oil at time t. They find a positive coefficient on π^{oil}_t and 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." The left-hand-side variable $\Delta\pi^e_{it,1}$ is a cross-sectional variable, but the independent variable π^{oil}_t does not vary in the cross section. Their results imply that the *average* change in expected inflation is positively correlated with the change in oil prices. Notice that this implies a correlation between expected inflation and the *level* of oil prices.

This correlation between a price level and the expected rate of change in prices may seem surprising (and curiously reminiscent of the Gibson paradox[6]), but note that oil and gas prices are mean-reverting, at least over certain time samples (Blinder and Reis, 2005). Thus, the level of gas prices is correlated with its rate of change, simply reflecting the fact that gas prices tend to be above average when they have recently risen. Table 1 verifies this positive correlation between the level and rate of change of gas prices, which is 0.17 over the full time sample and over 0.5 for 1994-2005 and 2006-2016 subsamples. The table shows that mean consumer inflation expectations are correlated not only with the level of gas prices, but also with their rate of change. For shorter horizon inflation expectations, the two

[6]In the U.S. and Great Britain from the 1700s to the early 1900s, nominal interest rates (and hence, according to the Fisher (1930) hypothesis, expected inflation) were correlated with the price *level* (and hence, with gold prices, since the general price level was the reciprocal of the price of gold in terms of goods (Barsky and Summers, 1988)). Keynes (1930, p. 198) called this "one of the most completely established empirical facts in the whole field of quantitative economics," and it puzzled monetary theorists for decades (Benjamin and Kochin, 1984). Under the gold standard, the price level is stationary (Coulombe, 1998). Therefore, the price level is highly correlated with an average of past rates of inflation, which can resolve the Gibson paradox if inflation expectations are formed with long lags (Summers, 1983).

Figure 4: Gas Prices and Expected Gas Price Inflation



Notes: Expected gas price inflation from the Michigan Survey of Consumers and Survey of Consumer Expectations. All-grades conventional gas price in dollars per gallon from the U.S. Energy Information Administration.

correlation coefficients are approximately equal. For longer horizon inflation expectations, the correlation between expected inflation and the level of gas prices is actually negative. The correlations between inflation expectations and real, as opposed to nominal, gas prices and gas price inflation are very similar.

In light of this discussion, in Table 2 I replicate and then modify the analysis of Coibion and Gorodnichenko. The first column estimates Equation (1). The estimate of the coefficient β_1 on π_t^{oil} is 0.016, as found by Coibion and Gorodnichenko. Column 2 replaces π_t^{oil} with $\Delta\pi_t^{oil}$, so both the dependent and independent variables are a change in a rate of change. The coefficient is of similar magnitude, 0.009, and statistically significant. Define $\pi_t^g = \log(P_t^{gas}/P_{t-6}^{gas}) * 100\%$ and $\pi_t^c = \log(P_t^c/P_{t-6}^c) * 100\%$, where P_t^{gas} is the price of gas and P_t^c is the consumer price index for all items less energy. Column 3 replaces $\Delta\pi_t^{oil}$ with $\Delta\pi_t^g$ and includes $\Delta\pi_t^c$ as a control variable. The coefficient on $\Delta\pi_t^g$ is 0.016, similar to

Table 1: Correlation between gas price level, gas price inflation, and inflation expectations

	Gas Price	Gas Price Inflation	Short-Run Expected Inflation
Gas Price Inflation	0.17		
Short-Run Expected Inflation	0.56	0.52	
Long-Run Expected Inflation	-0.24	0.18	0.40

Notes: Monthly data from Michigan Survey of Consumers and U.S. Energy Information Administration, 1994-2016. All correlation coefficients are statistically significant with $p < 0.05$. Gas price inflation is the year-over-year percent change in gas prices.

previous columns, and inflation expectations also rise significantly with non-energy inflation on average.

Columns 4, 5, and 6 replace the dependent variable of column 3 with the change in the respondent's expectation of longer-run inflation, short-run gas price inflation, and long-run gas price inflation, respectively. The average revision in long-run expected inflation is positive and small (0.003 percentage points) in response to a one percentage point increase in gas price inflation. This is one-fifth the response of short-run expected inflation. Since $\bar{\pi}^e_{it,5} = \frac{1}{5}\sum_{h=1}^{5} \pi^e_{it,h}$, all of the revision in $\bar{\pi}^e_{it,5}$ is attributable to the revision in $\pi^e_{it,1}$. The average revisions in gas price inflation expectations in response to an increase in gas price inflation are *negative* and statistically significant. If the change in expected gas price inflation at either horizon is regressed on π^{oil}_t, the coefficient estimate is also negative. The fact that inflation expectations and gas price inflation expectations have opposite-signed responses raises questions about how gas price inflation translates into inflation expectations. If high or rising gas prices lead people to expect slower gas price inflation, why do they also expect faster overall inflation? A starting point is to look at the microdata on both gas price and inflation expectations.

Table 2: Replication and modifications of Coibion and Gorodnichenko (2015)

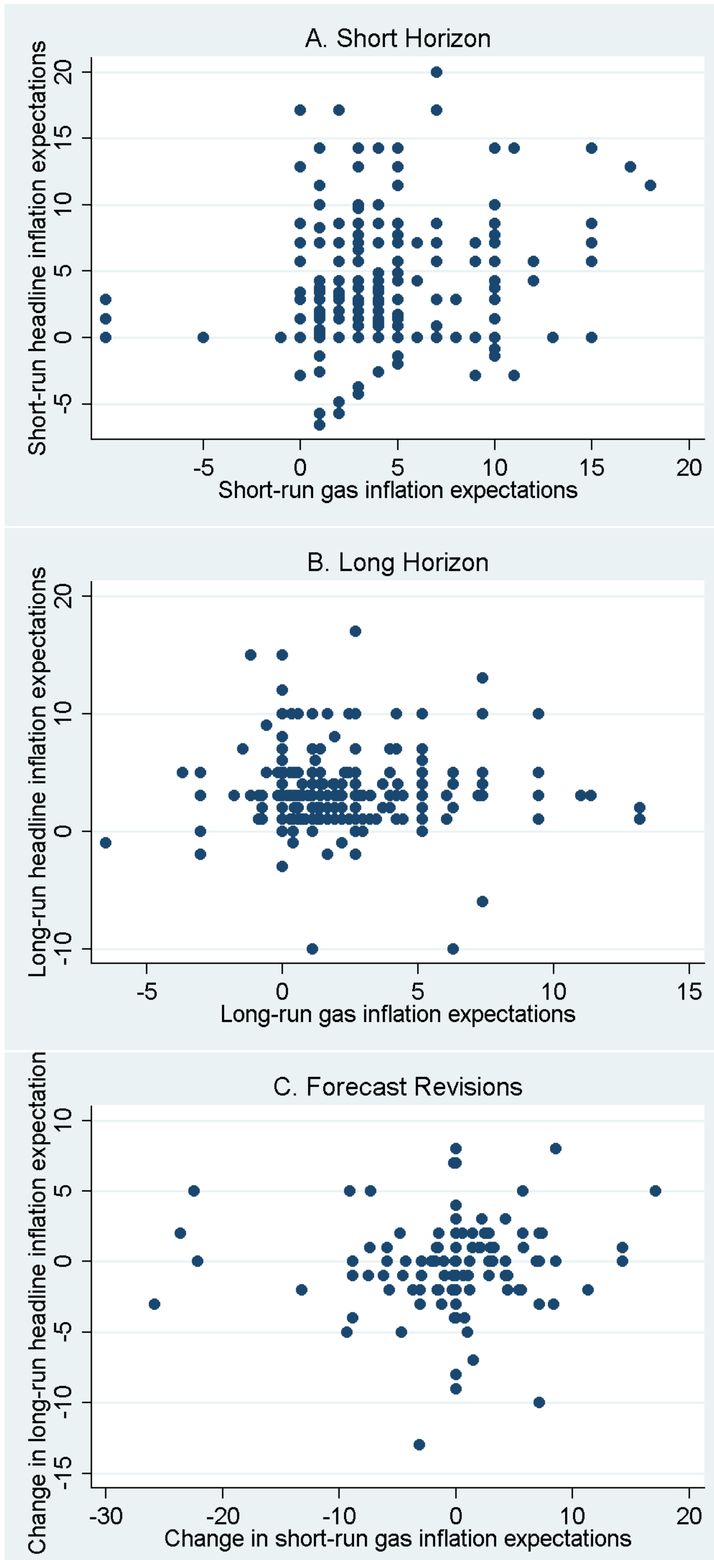
	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta\pi^e_{it,1}$	$\Delta\pi^e_{it,1}$	$\Delta\pi^e_{it,1}$	$\Delta\pi^e_{it,5}$	$\Delta\pi^{ge}_{it,1}$	$\Delta\pi^{ge}_{it,5}$
π^{oil}	0.016***					
	(0.002)					
$\Delta\pi^{oil}$		0.009***				
		(0.001)				
$\Delta\pi^g$			0.016***	0.003***	-0.068***	-0.027***
			(0.002)	(0.001)	(0.011)	(0.003)
$\Delta\pi^c$			0.549***	0.088	-1.251	-0.355
			(0.147)	(0.072)	(1.570)	(0.274)
Constant	-0.255***	-0.252***	-0.173***	-0.126***	-0.502	-0.182***
	(0.027)	(0.028)	(0.033)	(0.020)	(0.396)	(0.066)
Observations	77371	77371	39613	36557	18188	34119
R^2	0.009	0.006	0.017	0.001	0.036	0.032

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Time-clustered standard errors in parentheses. Following Coibion and Gorodnichenko (2015), I drop observations for which $|\Delta\pi^e_{it,1}| > 15$, and use Δ to denote the change over a 6-month period.

2.2 Cross-Sectional Correlations

Figure 5 plots short-run gas price inflation expectations against short-run headline inflation expectations, long-run gas price inflation expectations against long-run headline inflation expectations, and changes in long-run headline inflation expectations against changes in short-run gas price inflation expectations in a recent month. The striking feature in all three scatter plots, in addition to the heterogeneity of expectations across consumers, is the weak correlation between gas price inflation expectations and headline inflation expectations in the cross section. This is not unique to the Michigan Survey data; Table 3 summarizes the correlations between an individual's inflation and gas price expectations using data from both the MSC and the New York Fed Survey of Consumer Expectations. For repeat respondents, the table also summarizes the correlations between changes in an individual's inflation and gas price expectations. The correlation coefficients are similarly small across the two surveys.

Figure 5: Gas Price and Headline Inflation Expectations in August 2014



Notes: Data from Michigan Survey of Consumers.

Table 3: Correlation between headline and gas price inflation expectations

Variables	MSC	SCE
Short-run expected inflation and short-run expected gas inflation	0.13	0.18
Longer-run expected inflation and short-run expected gas inflation	0.12	0.16
Change in short-run expected inflation and change in short-run expected gas inflation	0.05	0.05
Change in longer-run expected inflation and change in short-run expected gas inflation	0.05	0.02

Notes: Data from Michigan Survey of Consumers (MSC) and New York Fed Survey of Consumer Expectations (SCE). Changes in expectations come from rotating panel component of survey. The short horizon is one year for both surveys. The longer horizon is 5-10 years for the MSC and 3 years for the SCE.

2.3 Geographical Disaggregation

The microdata includes each respondent's geographic region of residence (West, North Central, Northeast, or South). If the high visibility or salience of the price at the pump leads consumers to overweight gas prices in their inflation expectations formation, then we might expect a stronger relationship between a consumers' inflation forecast and gas prices in her own region than gas prices in other regions. In particular, if consumers use the level of gas prices to forecast the future rate of change in prices, we might expect consumers in regions with higher gas prices to have higher inflation expectations. Table 4 summarizes gas prices and inflation expectations by region since 2006. 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.

Let R_{itj} be a dummy variable equal to 1 if respondent i lives in region j at time t. Let $\pi_t^{g,j}$ denote the percent change in gas prices in region j from month $t-6$ to t. I modify the regression in Equation (1) to consider own-region and other-region gas prices as follows.

$$\Delta\pi^e_{it,1} = \beta_0 + \sum_{j=1}^{4} \beta_j \pi_t^{g,j} + \beta_5 \sum_{j=1}^{4} \pi_t^{g,j} R_{itj} + \epsilon_{it} \tag{2}$$

(3)

If a respondent's expectations depend most strongly on the level of gas prices in her own region, then β_5 should be positive. In the first column of Table 5, the coefficient on gas price inflation in the Northeast is statistically significant and positive, while the coefficient β_5 on own-region gas price inflation is not. The second column limits the sample to more recent years, with similar findings. The third and fourth columns include own-region gas price inflation and nationwide gas price inflation, and find a statistically significant positive coefficient only on nationwide gas price inflation for the full sample and more recent years. Results are similar if I replace $\pi_t^{g,j}$ by $\Delta\pi_t^{g,j}$ (omitted to save space). These results do not necessarily demonstrate that consumers do not heavily weight gas prices in their inflation expectations. They could, for instance, be more influenced by media reporting on gas prices, which may focus most on nationwide trends or on the Northeast, rather than by their own shopping experiences. However, this is distinct from the hypothesis that the prices of goods that are purchased more frequently are weighted more heavily (Georganas et al., 2014).

The evidence in this section points to the need for a more formal framework for analyzing the role of gas prices in household inflation expectations. The next section presents a model of expectations formation with parameters that can be estimated using the multi-horizon, rotating panel microdata on gas price and inflation expectations.

Table 4: 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 deviations (in parentheses). Monthly data from 2006 to 2016. Gas price is the all-grades conventional gas price and π^e is the mean one-year inflation expectation on the Michigan Survey of Consumers.

Table 5: Regressions of changes in inflation expectations on regional gas price changes

	(1)	(2)	(3)	(4)
	$\Delta\pi^e_{it,1}$	$\Delta\pi^e_{it,1}$	$\Delta\pi^e_{it,1}$	$\Delta\pi^e_{it,1}$
π^g_t West	-0.003	0.001		
	(0.004)	(0.008)		
π^g_t North Central	0.014*	0.016		
	(0.009)	(0.016)		
π^g_t Northeast	0.059***	0.079***		
	(0.014)	(0.021)		
π^g_t South	-0.013	-0.050		
	(0.017)	(0.032)		
π^g_t Own Region	-0.014	0.002	-0.016	-0.003
	(0.010)	(0.017)	(0.010)	(0.018)
π^g_t National			0.058***	0.045**
			(0.011)	(0.018)
Constant	-0.532***	-0.566***	-0.528***	-0.554***
	(0.028)	(0.042)	(0.027)	(0.040)
Observations	40815	19390	40957	19390
R^2	0.030	0.046	0.029	0.045
Time sample	All	Since 2006	All	Since 2006

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors clustered by time and region in parentheses

3 Expectations Formation Model and Estimation

It is often assumed that if expectations of future inflation are excessively sensitive to gas prices, then this is because perceptions of *current* inflation are excessively sensitive to gas prices. The MSC does not ask consumers about their perceptions of current inflation, so we cannot directly observe whether consumers put an overly large weight on gas, relative to its expenditure share, when recalling price changes they have recently observed. The availability of multi-horizon expectations data can help overcome this issue. The idea is that, if we have data on expections for horizons $t + 1$ and $t + 1 + h$, we can use it to infer the relationship between expectations for horizon t (the current perception) and $t + 1$. We can also examine what consumers believe about the dynamics of gas prices and inflation.

Given the persistence of the inflation process, researchers commonly model inflation expectations as if consumers believed that headline inflation follows a first-order autoregressive (AR(1)) process (Fuhrer, 2009; Coibion and Gorodnichenko, 2015). That is, if π_t denotes headline inflation and $\pi^e_{it,h}$ denotes consumer i's expectation at time t for π_{t+h}, then:

$$\pi^e_{it,1} = \rho\pi^e_{it,0} \tag{4}$$

Note that $\pi^e_{it,0}$ is i's perception of inflation at time t, which may equal π_t if perceptions are accurate. Coibion and Gorodnichenko (2015) show that results generated from this analytically tractable model can be generalized to much more general data generating processes. I follow this parsimonious approach, modifying it slightly to allow consumers to form expectations of both gas price inflation (π^g_t) and non-gas price inflation (π^c_t)—for convenience, I use "core" and the subscript c to refer to all items less gasoline— where next-period forecasts

$\pi^{ge}_{it,1}$ and $\pi^{ce}_{it,1}$ depend on perceptions of both variables:

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

$$\pi^{ge}_{it,1} = a_{gc}\pi^{ce}_{it,0} + a_{gg}\pi^{ge}_{it,0} + \gamma_{ig} \tag{6}$$

The terms γ_{ic} and γ_{ig} are included to allow consumers to have heterogeneous views about the unconditional means of inflation and its components (see Coibion and Gorodnichenko (2015) and Patton and Timmermann (2010)). Let $\Pi_t = \begin{bmatrix} \pi^c_t \\ \pi^g_t \end{bmatrix}$ and $\Pi_{it,h} = \begin{bmatrix} \pi^{ce}_{it,h} \\ \pi^{ge}_{it,h} \end{bmatrix}$. She may observe current gas price and core inflation with some error, so her perceptions of current gas price and core inflation, $\pi^{ge}_{it,0}$ and $\pi^{ce}_{it,0}$ are given by:

$$\Pi_{it,0} = \begin{bmatrix} \pi^{ce}_{it,0} \\ \pi^{ge}_{it,0} \end{bmatrix} = \begin{bmatrix} \pi^c_t + e^c_{it} \\ \pi^g_t + e^g_{it} \end{bmatrix} \equiv \Pi_t + \mathbf{e_{it}} \tag{7}$$

Then in matrix notation, Equations 6 and 6 can be written:

$$\Pi^e_{it,1} = A\Pi^e_{it,0} + \Gamma_i, \tag{8}$$

where $A = \begin{bmatrix} a_{cc} & a_{cg} \\ a_{gc} & a_{gg} \end{bmatrix}$ and $\Gamma_i = \begin{bmatrix} \gamma_{ic} \\ \gamma_{ig} \end{bmatrix}$. This is analogous to Equation (4); consumers form expectations as if they believe gas and non-gas price inflation follow a first order vector autoregressive process. I remain neutral as to *how* they form their beliefs about the parameters of the process, and simply attempt to estimate them empirically.

Note that headline inflation π_t is a weighted average of gas price inflation and non-gas price inflation where the weight ϕ corresponds to the expenditure share on gasoline (see

Georganas et al. (2014)):

$$\pi_t = \phi \pi_t^g + (1-\phi)\pi_t^c, \tag{9}$$

or $\pi_t = \begin{bmatrix} 1-\phi \\ \phi \end{bmatrix}' \Pi_t$.

Suppose that i's perception of current headline inflation, $\pi_{it,0}^e$, is a weighted average of her perceptions of gas price inflation and core inflation, where, as in Georganas et al. (2014), the weight $\omega \in [0,1]$ on gas price inflation expectations may differ from ϕ:

$$\pi_{it,0}^e = \omega \pi_{it,0}^{ge} + (1-\omega)\pi_{it,0}^{ce} = \begin{bmatrix} 1-\omega \\ \omega \end{bmatrix}' (\Pi_t + \mathbf{e_{it}}) \tag{10}$$

Equation (10) implies that her expectation of future headline inflation, $\pi_{it,h}^e$, is a weighted average of her expectations of future gas price and core inflation:

$$\pi_{it,h}^e = \omega \pi_{it,h}^{ge} + (1-\omega)\pi_{it,h}^{ce}. \tag{11}$$

Iterating Equation (8) forward, expectations of core and gas price inflation at time $t+h$ are given by:

$$\Pi_{it,h}^e = A^h \Pi_{it,0}^e + S_h \Gamma_i, \text{ where } S_h = \sum_{j=0}^{h-1} A^j = (I-A)^{-1}(I-A^h). \tag{12}$$

The system of equations in (12) also implies a relationship between short-horizon and long-horizon expectations:

$$\Pi_{it,h}^e = A^{h-1}\Pi_{it,1}^e + S_{h-1}\Gamma_i, \;\; h > 1 \tag{13}$$

A few manipulations are required so that the system of equations in (13) corresponds to our observations in the MSC data. First, the MSC data does not correspond exactly to observations of $\Pi^e_{it,h}$. Instead, the long-horizon questions refer to the expected *average* rate over the longer horizon. Thus, I define $\bar{\pi}^e_{it,h} \equiv \frac{1}{h}\sum_{j=1}^{h} \pi^e_{it,j}$, and similarly:

$$\bar{\Pi}^e_{it,h} \equiv \begin{bmatrix} \bar{\pi}^{ce}_{it,h} \\ \bar{\pi}^{ge}_{it,h} \end{bmatrix} \equiv \begin{bmatrix} \frac{1}{h}\sum_{j=1}^{h} \pi^{ce}_{it,j} \\ \frac{1}{h}\sum_{j=1}^{h} \pi^{ge}_{it,h} \end{bmatrix} = \frac{1}{h}\sum_{j=1}^{h} \Pi^e_{it,j} \tag{14}$$

I substitute Equation (13) into Equation (14) and obtain:

$$\bar{\Pi}^e_{it,h} = \frac{1}{h}\sum_{j=1}^{h}(A^{j-1}\Pi^e_{it,t+1} + S_{j-1}\Gamma_i) = \frac{1}{h}S_h\Pi^e_{it,1} + \frac{1}{h}\sum_{j=0}^{h-1} S_j\Gamma_i \tag{15}$$

In the MSC data, Γ_i is not observed, but because a rotating panel of respondents takes the survey twice, I can take differences in (15), using Δ to denote the difference from six months prior:

$$\Delta\bar{\Pi}^e_{it,h} = \frac{1}{h}S_h\Delta\Pi^e_{it,1}, \text{ or } \begin{bmatrix} \Delta\bar{\pi}^{ce}_{it,h} \\ \Delta\bar{\pi}^{ge}_{it,h} \end{bmatrix} = \frac{1}{h}S_h \begin{bmatrix} \Delta\pi^{ce}_{it,1} \\ \Delta\pi^{ge}_{it,1} \end{bmatrix} \tag{16}$$

This first differencing allows Γ_i to drop out.[7] Equation (16) does not correspond perfectly to the MSC data because it is written in terms of core and gas price inflation expectations, while I observe headline and gas price inflation expectations. To rewrite (16) in terms of my

[7] Note that in Equation (12), the perception error terms e^c_{it} and e^g_{it} may be correlated with γ_{ic} and γ_{ig}. For instance, a consumer who believes that the long-run mean of π^g_t is very high may also overestimate current gas price inflation. This also suggests that e^g_{it} and e^g_{it+1} may be positively correlated; a consumer may systematically over- or under-perceive current gas price inflation (and similarly for non-gas price inflation.) To account for these possibilities, I assume that $e^c_{it} = \nu^c_i + \nu^c_{it}$ and $e^g_{it} = \nu^g_i + \nu^g_{it}$, where ν^c_{it} and ν^g_{it} are i.i.d. with mean zero, but $E[\nu^c_i|\Gamma_i]$, $E[\nu^g_i|\Gamma_i]$, $E[\nu^c_i|\nu^g_i]$, and $E[\nu^g_i|\nu^c_i]$ are not necessarily zero. The first differencing also allows ν^c_i and ν^g_i to drop out, facilitating estimation.

observations, first I premultiply both sides by $\begin{bmatrix} 1-\omega & 0 \\ 0 & 1 \end{bmatrix}$, and let $s_{ij,h}$ denote the (i,j) element of S_h:

$$\begin{bmatrix} 1-\omega & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \Delta\bar{\pi}^{ce}_{it,h} \\ \Delta\bar{\pi}^{ge}_{it,h} \end{bmatrix} = \begin{bmatrix} 1-\omega & 0 \\ 0 & 1 \end{bmatrix} \frac{1}{h} S_h \begin{bmatrix} \Delta\pi^{ce}_{it,1} \\ \Delta\pi^{ge}_{it,1} \end{bmatrix} \tag{17}$$

$$\Rightarrow \begin{bmatrix} (1-\omega)\Delta\bar{\pi}^{ce}_{it,h} \\ \Delta\bar{\pi}^{ge}_{it,h} \end{bmatrix} = \frac{1}{h} \begin{bmatrix} (1-\omega)s_{11,h}\Delta\pi^{ce}_{it,1} + (1-\omega)s_{12,h}\Delta\pi^{ge}_{it,1} \\ s_{21,h}\Delta\pi^{ce}_{it,1} + s_{22,h}\Delta\pi^{ge}_{it,1} \end{bmatrix} \tag{18}$$

Using Equation (11), I replace $(1-\omega)\Delta\bar{\pi}^{ce}_{it,h}$ with $\Delta\bar{\pi}^{e}_{it,h} - \omega\Delta\bar{\pi}^{ge}_{it,h}$ and $(1-\omega)\Delta\pi^{ce}_{it,1}$ with $\Delta\pi^{e}_{it,1} - \omega\Delta\pi^{ge}_{it,1}$:

$$\begin{bmatrix} \Delta\bar{\pi}^{e}_{it,h} - \omega\Delta\bar{\pi}^{g}_{it,h} \\ \Delta\bar{\pi}^{ge}_{it,h} \end{bmatrix} = \frac{1}{h} \begin{bmatrix} s_{11,h}\Delta\pi^{e}_{it,1} + (s_{12,h}(1-\omega) - s_{11,h}\omega)\Delta\pi^{ge}_{it,1} \\ \frac{s_{21,h}}{1-\omega}\Delta\pi^{e}_{it,1} + (s_{22,h} - \frac{\omega}{1-\omega}s_{21,h})\Delta\pi^{ge}_{it,1} \end{bmatrix} \tag{19}$$

Rearranging, and using $h = 5$, I obtain the following system of equations:

$$\begin{aligned} \Delta\bar{\pi}^{e}_{it,5} &= \frac{s_{11,5}}{5}\Delta\pi^{e}_{it,1} + \frac{-\omega s_{11,5} + (1-\omega)s_{12,5}}{5}\Delta\pi^{ge}_{it,1} + \omega\Delta\bar{\pi}^{ge}_{it,5}, \\ \Delta\bar{\pi}^{ge}_{it,5} &= \frac{s_{21,5}}{5(1-\omega)}\Delta\pi^{e}_{it,1} + \frac{s_{22,5}(1-\omega) - \omega s_{21,5}}{5(1-\omega)}\Delta\pi^{ge}_{it,1} \end{aligned} \tag{20}$$

Notice that in the above system of equations, only the first row (the equation for $\Delta\bar{\pi}^{e}_{it,h}$) includes a $\Delta\bar{\pi}^{ge}_{it,h}$ term on the right hand side. Both rows include $\Delta\pi^{ge}_{it,1}$ and $\Delta\pi^{ce}_{it,1}$ terms.

3.1 Estimates and Interpretation

I estimate the system of equations in (20) via seemingly unrelated regression, with results in Table 6.[8] The coefficient on $\Delta\bar{\pi}^{ge}_{it,5}$ in the first equation is an estimate of ω: 0.04 with

[8]Following Coibion and Gorodnichenko (2015), I drop observations for which the absolute value of the change in expected inflation at either horizon is greater than 15. This corresponds to the approximately

standard error 0.006. From the other four coefficients it is straightforward to recover the elements of S_5. The estimates I obtain (with bootstrapped standard errors in parentheses) are $S_5 = \begin{bmatrix} 1.09\ (0.002) & 0.04\ (0.0006) \\ -.08\ (0.002) & 0.86\ (0.001) \end{bmatrix}$. I solve for A numerically using the relationship $S_5 = (I - A)^{-1}(I - A^5)$, and obtain $a_{cc} = 0.08$, $a_{cg} = 0.02$, $a_{gc} = -0.11$, $a_{gg} = -0.16$. The bootstrapped standard errors for a_{cc}, a_{cg}, a_{gc}, and a_{gg} are 0.005, 0.01, 0.01, and 0.02, respectively.

Table 6: Regression results from baseline specification

	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$
$\Delta\bar{\pi}^{ge}_{it,5}$	0.041***	
	(0.006)	
$\Delta\pi^{e}_{it,1}$	0.217***	-0.016**
	(0.005)	(0.008)
$\Delta\bar{\pi}^{ge}_{it,1}$	-0.000	0.173***
	(0.002)	(0.003)
Observations	16423	16423
R^2	0.094	0.224

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Seemingly-unrelated regression results correspond to equation (20). Dependent variable in column (1) is change in long-run inflation expectations. The dependent variable in column (2) is change in long-run gas price inflation expectations. Standard errors in parentheses.

What do the estimates tell us about the effects of gas price inflation on headline inflation perceptions and expectations? First, the estimate $\omega = 0.04$ is remarkably similar to the consumer expenditure share on gasoline. Thus, when gas price inflation rises, consumers' perceptions of headline inflation rise by the same amount as actual headline inflation rises[9]; inflation *perceptions* are not excessively sensitive to gas prices.

For one-year-ahead inflation expectations, the derivative of $\pi^{e}_{it,1}$ with respect to π^{g}_{t} is

1% largest absolute forecast revisions. So that similarly extreme absolute forecast revisions for gas prices are dropped, I use 15 as a cutoff for the absolute change in long-run expected gas inflation and 44 for the absolute change in short-run expected gas inflation, and also drop a small number of observations for which any of the expected inflation responses are above 20% or below -10%, which likely indicates misinterpretation of the question.

[9] I verify that in a regression of inflation on gas and non-gas inflation, the coefficient on gas inflation is 0.05, the expenditure share of gas.

$\omega a_{gg} + (1-\omega)a_{cg}$. With my estimates, this derivative is 0.01: a one percentage point increase in gas price inflation results in an 0.01 percentage point increase in one-year-ahead expected headline inflation. This is in line with the estimates in Table 2. The estimates of the parameters a_{gg}, ω, and a_{cg} allow me to decompose this derivative into the three factors discussed in the introduction that jointly account for the effect of changes in gas prices on headline inflation expectations. Namely, ωa_{gg} is the weight the consumer puts on gas price inflation multiplied by her belief about the persistence of gas price inflation. Since a_{gg} is negative, consumers expect higher-than-average gas price inflation to be followed by lower-than-average gas price inflation in the future. This is consistent with the negative reduced form coefficients on gas price inflation in columns (5) and (6) of Table 2. Since $a_{gg} = -0.16$ and $\omega = 0.04$, this term is small and negative (-0.007). The term $(1-\omega)a_{cg}$ represents the indirect effects of gas price inflation on headline inflation expectations through core inflation expectations. My estimate of this term is 0.018, where the estimate $a_{cg} = 0.02$ represents consumers' beliefs about the pass-through of shocks to current gas price inflation into next-period core inflation. When gas inflation rises, the increase in one-year-ahead expected headline inflation is almost entirely attributable to higher expectations of future core inflation.

At longer horizons, the derivative of $\pi^e_{it,h}$ with respect to π^g_t is[10]:

$$\frac{d\pi^e_{it,h}}{d\pi^g_t} = \omega a_{h,gg} + (1-\omega)a_{h,cg}, \tag{21}$$

[10] To see this, recall that expectations of headline inflation at horizon h are:

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

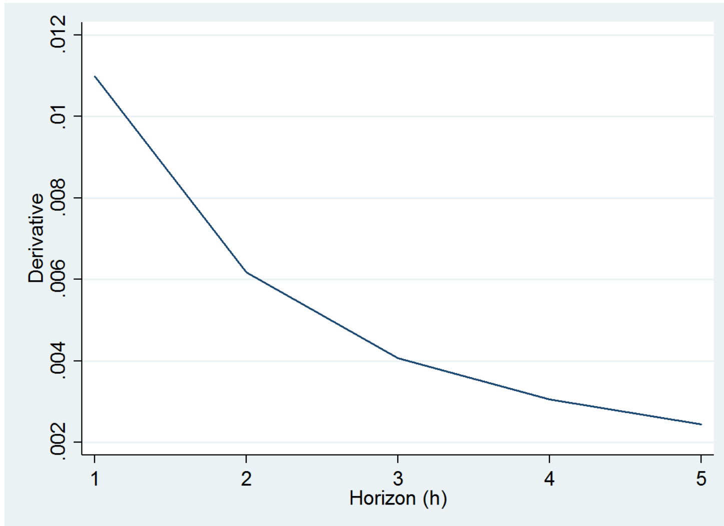
$$= (\omega \hat{a}^h_{gg} + (1-\omega)\hat{a}^h_{cg})(\pi^g_t + e^g_{it}) + (\omega \hat{a}^h_{gc} + (1-\omega)\hat{a}^h_{cc})(\pi^c_t + e^c_{it}) + \begin{bmatrix} 1-\omega \\ \omega \end{bmatrix}' S_h \Gamma_i$$

where I denote the elements of A^h by $A^h = \begin{bmatrix} a_{h,cc} & a_{h,cg} \\ a_{h,gc} & a_{h,gg} \end{bmatrix}$. The interpretation is similar to the one-year horizon. This is easiest to see in the case where a_{gc} is near zero.[11] Then $\frac{d\pi^e_{it,h}}{d\pi^g_t}$ is approximately $\omega a^h_{gg} + (1-\omega)\frac{a_{cg}(a^h_{gg} - a^h_{cc})}{a_{gg} - a_{cc}}$. Again, the first term tells us that effect of gas price inflation on headline inflation expectations depends on the weight ω that the consumer puts on gas price inflation multiplied by her belief about the persistence a_{gg} of gas price inflation. The second term represents indirect effects of gas price inflation on expectations of future core inflation. With my parameter estimates, this term decreases with h, and the effect of gas price inflation on inflation expectations shrinks rapidly with horizon. For the two-year horizon, $\frac{d\pi^e_{it,2}}{d\pi^g_t} = 0.001$. Figure 6 plots the derivative of $\bar{\pi}^e_{it,h}$ with respect to π^g_t for different values of h. The derivative of $\bar{\pi}^e_{it,5} = \frac{1}{5}\sum_{j=1}^5 \pi^e_{it,j}$ with respect to π^g_t is 0.0024; this comes almost entirely from the increase in $\pi^e_{it,1}$ rather than an increase in expected inflation at any longer horizons. Again, this estimate is in line with the reduced form estimate in Table 2 (Column 4). Note that the estimates in Table 2 include actual gas price inflation as a regressor, while these estimates come entirely from expectations data, and do not make use of actual gas price inflation, so it is interesting and reassuring that the implied derivatives of expected inflation with respect to gas price inflation are the same.

How do consumers' beliefs about inflation dynamics, as reflected in the estimates of a_{cc}, a_{cg}, a_{gc}, and a_{gg}, compare to actual inflation dynamics? In Table A.1, I regress year-over-year gas and non-gas inflation on gas and non-gas inflation from one year earlier. A one percentage point increase in gas inflation predicts an 0.01 percentage point increase in core inflation in the following year—smaller, but on the same order of magnitude as a_{cg}. The estimate of $a_{cc} = 0.08$ is not unreasonable, since the coefficient on lagged core inflation in the first column is 0.18, but not statistically different from zero. In the second column,

[11] 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 $A^h = PD^hP^{-1} = \begin{bmatrix} a^h_{cc} & \frac{a_{cg}(a^h_{cc} - a^h_{gg})}{a_{cc} - a_{gg}} \\ 0 & a^h_{gg} \end{bmatrix}$.

Figure 6: Derivative of $\bar{\pi}^e_{it,h}$ with respect to π^g_t by horizon



Notes: Figure shows estimates of the derivative of $\bar{\pi}^e_{it,h}$ with respect to π^g_t for values of h from 1 to 5, where $\bar{\pi}^e_{it,h} = \frac{1}{h}\sum_{j=1}^{5} \pi^e_{it,j}$.

neither non-gas nor gas inflation is a statistically significant predictor of future gas inflation and both coefficients are negative, so it is reasonable that a_{gc} and a_{gg} are negative.

3.2 Robustness Checks

Table A.2 includes several alternative specifications as robustness checks. The first specification includes changes in other expectations reported by the consumer: expectations of unemployment, of short- and long-run business conditions, and interest rates. Only the coefficients on changes in expected long-run business conditions are statistically significant. They are negative, so more favorable long-run business expectations are associated with lower long-run inflation expectations and lower long-run gas inflation expectations. The second specification includes these changes in expectations and also changes in the unemployment and CPI inflation rates. When unemployment increases, long-run inflation expectations increase but long-run gas inflation expectations decrease. The third specification includes time fixed effects to control for any events at time t that might lead respondents to revise both gas price and core inflation expectations. In all three specifications, estimates of ω and implied estimates of A are similar to the baseline. As another robustness check, in Table A.3, 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 (20) using these measures of gas price inflation expectations, and again find similar estimates of ω and A.

3.3 Demographic Variations

Cross-sectional differences in spending patterns may lead to cross-sectional differences in sensitivity to gas prices. Coibion and Gorodnichenko (2015) raise two possibilities: first, that sensitivity increases with the *share* of income an individual spends on gas, and second, that sensitivity increases with the *total amount* an individual spends on gas (because individuals who spend more on gas probably purchase gas more frequently). The latter would be more consistent with hypotheses that the high frequency of gas price purchases may lead consumers to overweight gas prices in their perceptions of inflation. 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 the frequency of gas purchases, high income households should be most sensitive, but if sensitivity increases with budget share, they should be the least sensitive.

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. Table A.4 summarizes $Spend_{it}$ and $Share_{it}$

by income quintile and age group.[12] 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.[13] Coibion and Gorodnichenko modify Equation (1) to include an interaction of $Spend_{it}$ or $Share_{it}$ with the percent change in oil price:

$$\Delta\pi^e_{it,1} = \beta_0 + \beta_1\pi^{oil}_t + \beta_2\pi^{oil}_t * Spend_{it} + \epsilon_{it}, \tag{22}$$

$$\Delta\pi^e_{it,1} = \beta_0 + \beta_1\pi^{oil}_t + \beta_2\pi^{oil}_t * Share_{it} + \epsilon_{it} \tag{23}$$

They find a positive coefficient β_2 on the $\pi^{oil}_t * Spend_{it}$ interaction term when using income quintiles, a positive but not statistically significant coefficient on the $\pi^{oil}_t * Spend_{it}$ interaction term when using age groups, and negative but not statistically significant coefficients on the $\pi^{oil}_t * Share_{it}$ interaction term in both cases. They conclude that inflation expectations are most sensitive to oil prices for consumers who spend most on gas in absolute terms. 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 (20) so the first equation takes one of the following forms:

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

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

Table A.5 reports estimates of equation (24) where spending is assigned based on income quintile in the first column and based on age in the second column. In neither case is the coefficient on the interaction statistically significant. Coefficients on the $\Delta\bar{\pi}^g_{it,5} * Share_{it}$ interactions are also not significant (results omitted to save space). Of course, $Spend_{it}$ is

[12]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.

[13]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.

only a proxy for the frequency with which respondent i purchases gasoline, so noisiness could be biasing the estimate of ω_{spend} toward zero. Nonetheless, these estimates are consistent with the idea that consumers do not overweight gas prices in their inflation perceptions due to frequency bias.

4 Conclusion

Large fluctuations in gasoline and other energy prices present a challenge to monetary policymakers. Core inflation may be a better indicator of underlying inflation trends than headline inflation, possibly justifying its use as the primary target of monetary policy. However, if major shifts in non-core prices like gasoline can cause inflation expectations to become unanchored, then a greater emphasis on headline inflation by monetary policymakers could be merited. Saliency or frequency bias theories suggest that, since gas is purchased so frequently and its price is so visible and volatile, consumers may over-weight gas prices relative to the expenditure share on gas when forming perceptions of inflation. If such biases exist, they may point to a need for central bank communications specifically aimed to address them.

Survey data on inflation *expectations* is indeed correlated with gas prices, but in the absence of data on inflation *perceptions*, it is difficult to discern whether this correlation in fact reflects any bias in the formation of perceptions and expectations. In fact, interpretation of a correlation between the *level* of gas prices and the expected *rate of change* in the price level should not be immediately obvious. This paper shows that expected inflation is also correlated with gas price *inflation*, but argues that this still does not provide evidence of bias. In particular, I note that the response of consumer inflation expectations to gas price fluctuations depends on both how heavily consumers weight changes in gas prices in their perception of inflation and on what consumers believe about the dynamics of gas price and non-gas price inflation.

This paper uses panel microdata from the Michigan Survey of Consumers on gas price expectations and inflation expectations to study the dynamics of gas price and inflation expectations. The multi-horizon data on expectations allows me to circumvent the lack of data on perceptions and estimate that the weight consumers place on gas price inflation in their inflation perception is approximately equal to the expenditure share on gas. Consumers on average view gas price inflation as negatively autocorrelated. They do expect gas price inflation to feed into future core inflation, but this quickly decreases with forecast horizon. The net result is that if gas price inflation increases by one percentage point, then one-year-ahead headline inflation expectations increase by about 0.01 percentage points and five-year-ahead inflation expectations increase by about 0.003 percentage points. Since gas price inflation has ranged from around -50% to around 50% over the past decade, the effect size at the one-year horizon is large enough to result in substantial fluctuations in inflation expectations. But these fluctuations neither indicate excessive sensitivity resulting from biased expectations formation, nor inherently point to low central bank credibility.

Still, it is well documented that consumers' inflation expectations depart substantially from full-information rational expectations. In particular, they are highly heterogeneous, likely indicating the presence of information constraints (Mankiw and Reis, 2002; Sims, 2003; Mackowiak and Wiederholt, 2015; Armantier et al., 2016; Binder, 2017b). Heterogeneity of gas price expectations is also substantial. Even if the average consumer is not excessively sensitive to gas prices, information constraints, biases, and rules of thumb in expectations formation merit further research.

References

Aladangady, Aditya and Claudia R. Sahm (2015) "Do Lower Gasoline Prices Boost Confidence?" *FEDS Notes*.

Alquist, Ron, Lutz Kilian, and Robert J. Vigfusson (2013) *Handbook of Economic Forecasting*, Vol. 2A, Chap. Forecasting the Price of Oil, pp. 427–507: Elsevier.

Anderson, Soren T., Ryan Kellogg, James Sallee, and Richard T. Curtin (2011) "Forecasting Gasoline Prices Using Consumer Surveys," *American Economic Review: Papers & Proceedings*, Vol. 101, pp. 110–114.

Anderson, Soren T., Ryan Kellogg, and James M. Sallee (2013) "What do consumers believe about future gasoline prices?" *Journal of Environmental Economics and Management*, Vol. 66, pp. 383–403.

Aoki, Kosuke (2001) "Optimal Monetary Policy Responses to Relative Price Changes," *Journal of Monetary Economics*, Vol. 48, pp. 55–80.

Armantier, Olivier, Scott Nelson, Giorgio Topa, Wilbert van der Klaauw, and Basit Zafar (2016) "The Price Is Right: Updating Inflation Expectations in a Randomized Price Information Experiment," *Review of Economics and Statistics*, Vol. 98, pp. 503–523.

Barsky, R. and Lutz Kilian (2002) *NBER Macroeconomics Annual 2001*, Chap. Do We Really Know that Oil Caused the Great Stagflation? A Monetary Alternative, pp. 137–183.

Barsky, Robert B. and Lawrence H. Summers (1988) "Gibson's Paradox and the Gold Standard," *ournal of Political Economy*.

Baumeister, Christiane, Lutz Kilian, and Thomas K. Lee (2017) "Inside the Crystal Ball: New Approaches to Predicting the Gasoline Price at the Pump," *Journal of Applied Econometrics*, Vol. 32, pp. 275–295.

Benjamin, Daniel and Levis Kochin (1984) *A Retrospective on the Classical Gold Standard*, Chap. War, Prices, and Interest Rates: A Martial Solution to Gibson's Paradox, Chicago: University of Chicago for NBER.

Bernanke, Ben (2007) "Inflation Expectations and Inflation Forecasting," in *Monetary Economics Workshop of the National Bureau of Economic Research Summer Institute*.

Bessembinder, Hendrik, Paul Seguin Jay Coughenour, and Margaret Smoller (1995) "Mean reversion in equilibrium asset prices: Evidence from the futures term structure," *Journal of Finance*, Vol. 50, pp. 361–375.

Binder, Carola (2017a) "Fed Speak on Main Street: Central Bank Communication and Household Expectations," *Journal of Macroeconomics*, Vol. 52, pp. 238–251.

——— (2017b) "Measuring Uncertainty Based on Rounding: New Method and Application to Inflation Expectations," *Journal of Monetary Economics*, Vol. 90, pp. 1–12.

Blanchard, Olivier J. and Jordi Gali (2010) *International Dimensions of Monetary Policy*, Chap. The Macroeconomic Effects of Oil Price Shocks: Why Are the 2000s So Different from the 1970s: University of Chicago Press.

Blinder, Alan and Ricardo Reis (2005) "Understanding the Greenspan Standard," in *The Greenspan Era: Lessons for the Future,*, Jackson Hole, Wyoming: Federal Reserve Bank of Kansas City, August.

Bodenstein, Martin, Christopher J. Erceg, and Luca Guerrieri (2008) "Optimal monetary policy with distinct core and headline inflation rates," *Journal of Monetary Economics*, Vol. 55, p. 518533.

Bruine de Bruin, Wandi, Wilbert van der Klaauw, and Giorgio Topa (2011) "Expectations of Inflation:The Biasing Effect of Thoughts about Specific Prices," *Federal Reserve Bank of New York Staff Report*.

Bullard, James (2011) "Measuring Inflation: The Core Is Rotten," Speech to Money Marketeers of New York University.

Busse, Meghan R., Christopher Knittel, and Florian Zettelmeyer (2013) "Are consumers myopic? Evidence from new and used car purchases," *American Economic Review*.

Cavallo, Michele (2008) "Oil Prices and Inflation," *Federal Reserve Bank of San Francisco Economic Letter*.

Celasun, Oya, Roxana Mihet, and Lev Ratnovski (2012) "Commodity Prices and Inflation Expectations in the United States," *IMF Working Paper*.

Chen, Mingyu and Yi Wen (2011) "Oil Price Shocks and Inflation Risk," *Federal Reserve Bank of St. Louis Economic Synopses*.

Chen, Shiu-Sheng (2009) "Oil price pass-through into inflation," *Energy Economics*, Vol. 31, pp. 126–133.

Clark, Todd E. and Stephen Terry (2010) "Time Variation in the Inflation Passthrough of Energy Prices," *Journal of Money, Credit and Banking*, Vol. 42, pp. 1419–1433.

Coibion, Olivier and Yuriy Gorodnichenko (2015) "Is The Phillips Curve Alive and Well After All? Inflation Expectations and the Missing Disinflation," *American Economic Journal: Macroeconomics*, Vol. 7, pp. 197–232.

Coulombe, Serge (1998) "A Non-Paradoxical Interpretation of the Gibson Paradox," *Bank if Canada Working Paper*.

Dhawan and Jeske (2007) "Taylor rules with headline inflation: a bad idea," *Federal Reserve Bank of Atlanta Working Paper*.

Evans, Charles and Jonas Fisher (2011) "What are the implications of rising commodity prices for inflation and monetary policy?" *Chicago Fed Letter*.

Fisher, Irving (1930) *The Theory of Interest*, New York: Macmillan.

Fuhrer, Jeffrey (2009) "Inflation Persistence," *Federal Reserve Bank of Boston Working Papers*.

Georganas, Sotiris, Paul J. Healy, and Nan Li (2014) "Frequency bias in consumers' perceptions of inflation: An experimental study," *European Economic Review*, Vol. 67, p. 144158.

Gibson, Rajna and Eduardo S. Schwartz (1990) "Stochastic convenience yield and the pricing of oil contingent claims," *Journal of Finance*, pp. 959–976.

Goodfriend, Marvin and Robert King (1997) "The New Neoclassical Synthesis and the Role of Monetary Policy," in Ben S. Bernanke and Julio Rotemberg eds. *NBER Macroeconomics Annual*, Vol. 12: MIT Press, pp. 231–296.

Gregorio, Jose De, Oscar Landerretche, and Christopher Neilson (2007) "Another Pass-Through Bites the Dust? Oil Prices and Inflation," *Economia*, Vol. 7, pp. 155–196.

Hamilton, James (1983) "Oil and the Macroeconomy since World War II," *Journal of Political Economy*, Vol. 91, pp. 228–248.

——— (2012) "Commentary: Import Prices and Inflation," *International Journal of Central Banking*, Vol. 8, pp. 271–279.

Harris, Ethan S., Bruce C. Kasman, Matthew D. Shapiro, and Kenneth D. West (2009) "Oil and the Macroeconomy: Lessons for Monetary Policy," *U.S. Monetary Policy Forum Report*.

Ip, Greg (2016) "Dont Panic Over Falling Inflation Expectations," *The Wall Street Journal*.

Keynes, John Maynard (1930) *A Treatise on Money*.

Khettry, N. Neil K. and Loretta J. Mester (2006) "Core Inflation as a Predictor of Total Inflation," *Federal Reserve Bank of Philadelphia Research Rap Special Report*.

Kilian, Lutz (2008) "The Economic Effects of Energy Price Shocks," *Journal of Economic Literature*, Vol. 46, pp. 871–909.

Kilian, Lutz and L.T. Lewis (2011) "Does the Fed Respond to Oil Price Shocks?" *Economic Journal*, Vol. 121, pp. 1047–1072.

King, Robert and Alexander Wolman (1998) *Monetary Policy Rules*, Chap. What Should the Monetary Authority Do When Prices Are Sticky?: The University of Chicago Press.

LeBlanc, Michael and Menzie Chinn (2004) "Do High Oil Prices Presage Inflation? The Evidence from G-5 Countries," *Business Economics*, Vol. 39, pp. 38–48.

Mackowiak, Bartosz and Mirko Wiederholt (2015) "Business Cycle Dynamics under Rational Inattention," *The Review of Economic Studies*, Vol. 82, pp. 1502–1532.

Mankiw, Gregory and Ricardo Reis (2002) "Sticky Information Versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve," *Quarterly Journal of Economics*, Vol. 117, pp. 1295–1328.

Mankiw, N. Gregory and Ricardo Reis (2003) "What Measure of Inflation Should a Central Bank Target?" *Journal of the European Economic Association*.

Mishkin, Frederic (2007) "Inflation Dynamics," *International Finance*, Vol. 10, pp. 317–334.

Morewedge, Carey K., Daniel T. Gilbert, and Timothy D. Wilson (2005) "The least likely of times: How remembering the past biases forecasts of the future.," *Psychological Science*, Vol. 16, pp. 626–630.

van den Noord, Paul and Christophe Andre (2007) "Why Has Core Inflation Remained So Muted in the Face of the Oil Shock?" *OECD Economics Department Working Papers*.

Patton, Andrew and Allan Timmermann (2010) "Why do forecasters disagree? Lessons from the term structure of cross-sectional dispersion," *Journal of Monetary Economics*, Vol. 57, pp. 803–820.

Pindyck, Robert (2001) "The Dynamics of Commodity Spot and Futures Markets: A Primer," *Energy Journal*, Vol. 22, pp. 1–29.

Roache, S. K. and D.A. Reichsfeld (2011) "Do Commodity Futures Help Forecast Spot Prices?" *International Monetary Fund Working Paper*.

Sims, Chris (2003) "Implications of Rational Inattention," *Journal of Monetary Economics*, Vol. 50, pp. 665–690.

Summers, Lawrence (1983) *Macroeconomics. Prices, and Quantities: Essays in Memory of Arthur Okun*, Chap. The Nonadjustment of Nominal Interest Rates, Washington: the Brookings Institution.

Trehan, Bharat (2011) "Household Inflation Expectations and the Price of Oil: Its Deja Vu All Over Again," *FRBSF Economic Letter*.

Verbrugge, Randal and Amy Higgins (2015) "Do Energy Prices Drive the Long-Term Inflation Expectations of Households?" *Federal Reserve Bank of Cleveland Economic Trends*.

Wong, Benjamin (2015) "Do Inflation Expectations Propagate the Inflationary Impact of Real Oil Price Shocks?: Evidence from the Michigan Survey," *Journal of Money, Credit and Banking*, Vol. 47, pp. 1673–1689.

Wynne, Mark A. (1999) "Core Inflation: A Review of Some Conceptual Issues," *Federal Reserve Bank of Dallas Research Department Working Paper*.

Yellen, Janet (2009) "Discussion of "Oil and the Macroeconomy: Lessons for Monetary Policy"," *Presentation to the U.S. Monetary Policy Forum conducted by the University of Chicago Booth School of Business and Brandeis International Business School, New York.*

——— (2013) "Communication in Monetary Policy," in *Society of American Business Editors and Writers 50th Anniversary Conference*, Washington, D.C. April.

Appendix A Tables and Figures

Table A.1: Core and gas inflation dynamics

	(1)	(2)
	π_t^c	π_t^g
π_{t-12}^c	0.184	-9.157
	(0.242)	(8.906)
π_{t-12}^g	0.011***	-0.270
	(0.003)	(0.202)
Constant	1.542***	21.690
	(0.487)	(18.435)
Observations	122	122
R^2	0.23	0.11

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Newey West standard errors in parentheses. Monthly data, where inflation rate is the year-over-year percent change in the price index, π_t^g is gas price inflation, and π_t^c is inflation of the CPI less energy (CPILEGSL).

Table A.2: Regression results with control variables or time fixed effects

	(1)		(2)		(3)	
	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$
$\Delta\bar{\pi}^{ge}_{it,5}$	0.046***		0.045***		0.042***	
	(0.006)		(0.006)		(0.006)	
$\Delta\pi^{e}_{it,1}$	0.220***	-0.024***	0.222***	-0.011	0.217***	0.012
	(0.006)	(0.008)	(0.006)	(0.009)	(0.006)	(0.008)
$\Delta\pi^{ge}_{it,1}$	0.000	0.174***	0.000	0.171***	-0.000	0.155***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)
$\Delta U^{e}_{it,1}$	-0.032	0.094*	-0.031	0.094*		
	(0.035)	(0.049)	(0.035)	(0.048)		
$\Delta B^{e}_{it,1}$	-0.024*	-0.008	-0.024*	-0.021		
	(0.013)	(0.019)	(0.013)	(0.019)		
$\Delta B^{e}_{it,5}$	-0.053***	-0.035*	-0.051***	-0.043**		
	(0.015)	(0.021)	(0.015)	(0.021)		
$\Delta R^{e}_{it,1}$	-0.031	-0.085*	-0.031	-0.061		
	(0.031)	(0.044)	(0.031)	(0.043)		
ΔU_t			0.075**	-0.219***		
			(0.036)	(0.051)		
$\Delta\pi_t$			-0.018	-0.275***		
			(0.016)	(0.023)		
Observations	13451	13451	13451	13451	16423	16423
R^2	0.100	0.224	0.100	0.232	0.102	0.264
Time Fixed Effects	No		No		Yes	
Definitions of Additional Expectation Variables from MSC						
U^{e}_{it}	Expect unemployment rate to rise (1), stay same (0), or fall (-1)					
$B^{e}_{it,1}$	Expect economy next year to have bad times (1),...,good times (5)					
$B^{e}_{it,5}$	Expect economy next 5 years to have bad times (1),...,good times (5)					
R^{e}_{it}	Expect interest rates next year to rise (1), stay same (0), or fall (-1)					

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Table contains modifications of regression in Table 6. 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 the unemployment rate U_t and CPI inflation π_t as control variables. Specification (3) includes time fixed effects. Seemingly-unrelated regression standard errors in parentheses.

Table A.3: Regressions with regional gasoline prices

	$\Delta\pi^{e}_{it,5}$	$\Delta\pi^{ge}_{it,5}$
$\Delta\pi^{ge}_{it,5}$	0.041***	
	(0.006)	
$\Delta\pi^{e}_{it,1}$	0.217***	-0.016**
	(0.005)	(0.008)
$\Delta\pi^{ge}_{it,1}$	-0.000	0.174***
	(0.002)	(0.003)
Observations	16423	
R^2	0.094	0.225

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.

Table A.4: Spending on gasoline by age and income groups, 2006-2014

Demographic group	Gas expenditures ($/year)	Gas budget share (%)	Spend ratio	Share ratio
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				
Quintile 1	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
Quintile 5	3771	3.9	3.38	0.76

Notes: Data from BLS Consumer Expenditure Survey. Spend ratio and share ratio are the ratio of the expenditure level or budget share to the expenditure level or budget share of the baseline group (Under 25 or Quintile 1).

Table A.5: Regressions with income quintile and age group relative expenditure levels on gasoline

	(1)		(2)	
	Change long-run headline		Change long-run headline	
	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$	$\Delta\bar{\pi}^{e}_{it,5}$	$\Delta\bar{\pi}^{ge}_{it,5}$
$\Delta\bar{\pi}^{ge}_{it,5}$	0.062***		0.036*	
	(0.016)		(0.021)	
$\Delta\bar{\pi}^{ge}_{it,5}$*Spend	-0.006		0.008	
	(0.006)		(0.014)	
$\Delta\pi^{e}_{it,1}$	0.212***	-0.011	0.213***	-0.011
	(0.006)	(0.008)	(0.006)	(0.008)
$\Delta\pi^{ge}_{it,1}$	-0.001	0.167***	-0.001	0.169***
	(0.002)	(0.003)	(0.002)	(0.003)
Observations	14586	14586	14942	14942
R^2	0.092	0.208	0.093	0.212

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Regression results correspond to system of equations (20), where first equation is replaced by (24). In specification (1), spending ratio on gas is for the respondent's income quintile relative to the bottom quintile. In specification (2), spending ratio on gas is for the respondent's age group relative to the 18-24 age group. Seemingly-unrelated regression standard errors in parentheses.