

Household Inflation and Aggregate Inflation *

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Abstract

This project postulates that an additional cost of increased inflation is an increase in the cross-sectional dispersion of household-level inflation rates. Using scanner data and the Consumer Expenditure Survey, I construct novel measures of household-level inflation and show that households experience inflation at very different rates. An increase in a household's personal inflation rate leads to a persistent increase in their price index, and households respond to this shock by decreasing nominal consumption, which means that real consumption falls more than one-for-one; poor households are the least able to smooth their consumption in response to household inflation shocks. I find that inflation dispersion (the variance of household inflation rates) increases with the level of absolute aggregate inflation. This relationship is robust across time, methodology, and data.

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1 Introduction

A critical decision for macroeconomic policy makers is how much to focus on controlling inflation versus other indicators such as unemployment or the output gap. Correct judgment on the optimal level of inflation “hawkishness” requires an understanding of the costs of inflation. Past research has focused on both the optimal level inflation for central banks to target (see Diercks 2017 for a summary), which ranges from -7.6 to 6 percent, as well as how much weight the central bank should place on stabilizing inflation at that level, usually as a coefficient in a Taylor rule.

This paper postulates an additional cost of increased inflation: an increase in the cross-sectional diffusion of household inflation rates, which I call inflation dispersion. The central idea behind inflation dispersion is that households do not have the same inflation rates because of (1) different preferences for goods (due to age, income, or other idiosyncrasies), or (2) different abilities to adjust to changes in prices (because of preference intensity, ability to travel to stores, accept lower quality products, etc). I document that the standard deviation of household level inflation rates each quarter is around 3-5 percentage points using both a large scanner data-set and the consumer expenditure survey. However, the dispersion of inflation rates is not constant; during periods of greater aggregate price change, inflation dispersion increases.

While a household’s wage or pension and the interest rate on borrowing and savings may be indexed to the aggregate inflation rate, only the price paid for the household’s basket of consumption goods is related to their personal inflation rate. This means that with inflation dispersion, households with high inflation will have a real welfare loss compared to households with low inflation. I show that an inflation shock leads to a persistent increase in a household’s price index and the household responds by weakly reducing their nominal consumption expenditures; this means that real consumption falls more than one-for-one. Even if the household would like to smooth its consumption with respect to household inflation shocks, they appear to be unable to do so. Poorer households seem to be the least able to smooth their consumption, which means that an increase in inflation dispersion disproportionately increases the volatility of consumption of poor households relative to wealthier

households. Although households benefit from deflation shocks, risk averse households should prefer lower inflation dispersion and smoother consumption.

I relate inflation dispersion to aggregate inflation by showing that there is a robust relationship between the level of aggregate inflation and cross-sectional distribution of household level inflation rates. I estimate that a one percent increase in the absolute value of aggregate inflation increases the standard deviation of individual inflation rates by 0.38 percentage points (in my preferred specification). This relationship is robust to differences in price index calculation (Laspeyres, Paasche, Fisher, or Sato-Vartia), data, and time (present in city level CPI data back to 1915). I find some evidence that unexpected inflation is driving this relationship (higher expected inflation may even reduce inflation dispersion).

I develop a multi-sector menu cost model where households have heterogeneous preferences and I solve this model in partial-equilibrium. In this model, the elasticity of demand for a firm's product differs across sectors, which means that the profit function for firms is more curved in some sectors than in others, which endogenously leads to differences in price setting behavior. Households have heterogeneous preferences across sectors. When aggregate inflation increases, firms with high elasticities of substitution for their products are more likely to change their prices. Household's with a greater consumption share of products in these sectors experience a higher inflation rate than others and the distribution of household level inflation rates widens. Simulations of my model lead to a relationship between inflation dispersion and the absolute value of aggregate inflation that fall within my empirical estimates.

My project contributes to several strands of literature. The first is a very large literature on the costs of inflation and the corresponding optimal inflation rate. While I will not endeavor to summarize this entire literature, past literature has shown that increases in inflation is related to increases in inflation volatility (Kim and Lin 2012). Doepke and Schneider (2006) show that unexpected inflation can lead to redistribution from lenders to borrowers. Past research has discussed the so called "shoe leather" cost of inflation where households spend real resources to protect themselves from inflation (Pakko 1998). Menu costs incurred by firms as they most employ more labor to determine optimal prices (Golosov and Lucas Jr 2007, Nakamura and Steinsson 2010) and many more. An increase in inflation

dispersion is unlike many of the other costs of inflation, since it cannot be resolved by indexing to the aggregate inflation rate; i.e. loans, wages, rent, etc. can be indexed to the aggregate inflation rate, but not to a household’s personal price index.

The cost of inflation is a perennial question with a mature literature, but there have been some recent developments. In a New Keynesian model, the largest cost of inflation is an increase in price dispersion (Coibion et al. 2012). Higher inflation rates mean that firm prices are more likely to be far from their desired price, which leads costly misallocation of resources to firms with “artificially” low prices. However, Nakamura et al. (2018) do not find increases in price dispersion during the US great inflation of the 1970s. While Alvarez et al. (2018) do find evidence of price dispersion during the Argentine Hyperinflation, they do not find price dispersion when inflation is at more moderate levels. Given the absence of a relationship between moderate inflation and price dispersion in the data, policy makers may need to worry less about inflation when choosing optimal monetary policy especially since there is increasing concern about once again hitting the zero-lower bound. My project is timely, in that it shows that inflation may lead to increased inflation dispersion and is an additional cost that policy makers should consider. My multi-sector menu-cost model does not produce a relationship between inflation and price dispersion, but is able to reproduce the relationship between the absolute value of aggregate inflation and inflation dispersion that I find in the data.

There is also an emerging literature on demographic group specific price indexes. Argente and Lee (2017) shows that during the great recession, inflation for the lowest income group was around half a percent greater than for the highest income group. Cravino et al. (2018), show that rich households spend a larger fraction of their income on “sticky” goods such as education compared to middle-income households who spend more money on goods like gasoline that change their prices often; this makes the price index of middle-income households more responsive to monetary policy shocks than the price index of richer households. Like my project, Kaplan and Schulhofer-Wohl (2017) also use the Nielsen Homescan data to compute household specific inflation rates; however, they restrict their inflation measure only to products defined at the barcode level that the household buys in between two periods. This results in their inflation measures only being representative of around a quar-

ter of total spending in the Nielsen Homescan. My project makes many improvements on their household inflation measure (including increasing the relevance of the measure to be representative of 60-99 percent of Nielsen spending) and I also use the broader Consumer Expenditure Survey to calculate household level inflation rates. My project is also the first to examine how households react to having higher or lower inflation than aggregate.

This project also expands on recent work by Gelman et al. (2016) on the marginal propensity to consume (MPC) out of changes in gasoline prices. They find that the estimated (MPC) out of savings from lower gasoline prices is approximately one. My work looks at changes in the entire price index of the household rather than just gasoline prices. I do find evidence that households increase their consumption spending following a fall in their price index (which can be thought of as a persistent wealth shock). However, my estimates for increases in spending following a deflation shock are smaller (around 0.8).

The remainder of the paper proceeds as follows. Section 2 explains how I create the individual inflation measures using first the Nielsen Homescan and second the consumer expenditure survey. Section 3 presents a simple household level model showing that a household reacts to increases in its price index by reducing real consumption and then confirms this fact empirically. I also show that changes in a household's personal price index are quite persistent. Section 4 shows that there is a robust relationship between inflation and inflation dispersion. Section 5 develops a menu-cost model that can explain this relationship. Section 6 concludes.

2 Measuring Household-Level Inflation

For this project, I construct novel measures of household-level inflation using two large and complementary datasets: the Nielsen Homescan Consumer Panel Data and the Consumer Expenditure Survey (CEX). The Nielsen Homescan, is a for-profit market research survey that tracks the retail purchases of approximately 178 thousand households from 2004-2017. The Consumer Expenditure Survey, administered by the Bureau of Labor Statistics, surveys households up to five times at three month intervals (only four of these surveys are available for public use) on all of the household's consumer expenditure; the consumption weights in

the Consumer Price Index (CPI) are constructed using results from the CEX.

Each of these data have distinct advantages. The Nielsen Homescan is able to track households for a long period of time (the average household is surveyed for eight years) includes very detailed information on the products the households purchase (at the barcode level), and has a large number of households (40,000 from 2004-2005, and 60,000 from 2006-2017); however, the Nielsen Homescan only includes information on the household's retail purchases (about 30 % of the spending in the CEX (Kaplan and Schulhofer-Wohl 2017)) and excludes purchases of some major categories including housing, transportation, and medical care. In contrast, the CEX explicitly asks households the total sum of all of their consumption spending in the past three-months and includes more detailed information on all of the large categories that are used to construct the CPI. Additionally, the CEX is available for a longer time period than the Nielsen data: this project is using CEX data from 1996-2017, but it is possible to extend the sample back until 1980¹. However, the CEX only includes survey responses for about 10% of the number of households as the Nielsen Homescan (5,416 in 2017Q1) and households are in the survey for at most 4 quarters. By using both the Nielsen Homescan and the CEX, I am able to show that my results are robust to the main weaknesses of these datasets.

2.1 Nielsen Homescan

The Nielsen Homescan Consumer Panel Data tracks the retail purchases of 40,000-60,000 households from 2004-2016 and includes information on household demographics and income levels. The most novel feature of these data is that they track the products that households purchase at the barcode level, which makes these data uniquely situated to measure very detailed household level retail inflation rates , as well as the total retail consumption of these households.

Households in the panel are given financial incentives to record consumption purchases (similar to a credit card rewards program). To facilitate the survey, each household is given a barcode scanner so that they can easily record the individual products that they buy.

¹There may be problems with survey quality in earlier years (see NBER's discussion www.nber.org/data/ces.cbo.html)

Table 1: Distribution of Spending [REDO]

	CPI-U	CEX	Consumption (Nielsen)	Household Inflation
Health and Beauty Aids	2.57	1.43	10.3	10.0
Food	8.60	8.91	63.4	64.3
Dry Grocery			35.4	36.4
Frozen Food			9.6	9.5
Dairy			8.4	8.7
Deli			3.3	3.0
Packaged Meat			3.2	3.2
Produce			3.5	3.5
Non-Food Grocery			11.1	11.2
Alcohol	0.95	1.03	3.5	3.7
General Merchandise			11.5	10.5
Other			0.02	0.06

Note: Raw unweighted shares. CPI-U and CEX shares from Kaplan and Schulhofer-Wohl (2017). The household inflation data is based on the common price and represents 82% of the spending in the full Nielsen Homescan.

Household's are also asked to record where they bought the product. If the product was bought at one of Nielsen's partner stores then the price is automatically recorded as the average price in that store for that product during the week of purchase, if the product is bought somewhere else then the consumer is asked to record the price. Nielsen argues that the homescan panel is representative of 30% of all consumption (Kaplan and Schulhofer-Wohl 2017).

While households are able to record gasoline purchases and other non-grocery products, the actual survey responses are heavily skewed toward grocery purchases. Table 1 shows an overview of the purchases in the Nielsen Homescan compared to the CPI-U and the Consumer Expenditure Survey. While food at home represents less than 9 percent of the basket for the CPI-U and the CEX, it is more than 60 percent in the Nielsen Homescan.

Purchases in the Nielsen Homescan are recorded at the barcode (UPC) level. Each UPC is also associated with a hierarchy of classifications of increasing levels of aggregation: brand, module, group and department. For example, if a household were to purchase a particular type of toothpaste it would be associated with the Health and Beauty Aids department in the toothpaste module and the UPC would denote the specific flavor/ingredients. For my analysis I will use the product module as the definition of an individual product, however,

my main result is qualitatively robust to using more aggregate or dis-aggregate product definitions (see future appendix). Further details of my product classification will be included in the appendix.

Since households may enter or exit the survey in the middle of a quarter, I exclude each household's first and last quarter in the panel. I also exclude households with breaks in recorded transactions for more than a quarter and households with extreme changes in their price index ($> 300\%$) from quarter to quarter.

Using the Nielsen Homescan, I can track individual households recorded retail spending each quarter, the quantities they purchase of each product, and the prices they pay for each product². I use this information to compute Laspeyres, Paasche, Fisher, and Sato-Vartia style household specific chained price indexes. Household level inflation rates are computed as the annual percentage change in the chained price index (between quarter t and $t-4$). I create each of these household level price indexes using both national prices (the weighted average of all prices paid for that product) and regional prices (the average in one of Nielsen's 52 metropolitan areas). Summary statistics for each of these 8 price indexes are shown in table 2.

Laspeyres and Paasche are the familiar undergraduate price indexes formed by weighting each product in a household's basket by its beginning (Laspeyres) or ending (Paasche) expenditure share (they implicitly assume the household has Cobb-Douglas utility over products). By nature, the Laspeyres index understates changes in the cost of living as it does not allow for substitution on the part of households. Similarly, the Paasche index overstates inflation. The fisher index is the geometric average of the two. Lastly, the Sato-Vartia index assumes that individual households have CES utility over the N products in their basket:

$$P_{h,t} = \left(\sum_{k=1}^N \left(\frac{p_{k,t}}{\varphi_{k,h}} \right)^{1-\sigma_h} \right)^{\frac{1}{1-\sigma_h}}. \quad (2.1)$$

²There is definitely measurement error in the Nielsen Homescan. However, as long as the measurement error is orthogonal to inflation rates and monetary policy shocks then it should not bias my results. Einav et al. (2010) show that measurement error does exist, but is similar to the recording error in other widely used economic data.

Since I compute this index at the individual level, each household h , has its own specific elasticity of substitution over products σ_h , which can be an important source of heterogeneity in inflation rates as some households are able to adjust more to price changes than others. I'm able to avoid estimating σ_h for each household since:

$$s_{k,h,t} = \left(\frac{p_{k,t}}{\varphi_{k,h} P_{h,t}} \right)^{1-\sigma_h}$$

which implies

$$\pi_{h,t} = \log \left(\frac{P_{h,t}}{P_{h,t-1}} \right) = \sum_{k=1}^N \omega_{k,h,t} \log \left(\frac{p_{k,t}}{p_{k,t-1}} \right) \quad (2.2)$$

where

$$\omega_{k,h,t} = \left(\frac{\frac{s_{k,h,t} - s_{k,h,t-1}}{\log(s_{k,h,t}) - \log(s_{k,h,t-1})}}{\sum_{\ell=1}^N \frac{s_{\ell,h,t} - s_{\ell,h,t-1}}{\log(s_{\ell,h,t}) - \log(s_{\ell,h,t-1})}} \right).$$

So I can look at changes in the Sato-Vartia price index for each household, as long as I have expenditure share information for each product in period t and $t-1$. Since households stop buying some products from quarter to quarter, this means that my Sato-Vartia price index is not representative of all of the households Nielsen spending (about 60% of a household's purchases are from products that a household buys in quarter t and $t-1$). This is a limitation of the Sato-Vartia index that the Laspeyres and Paasche do not share since for these indexes I only need price information in two quarters and share info for only one quarter (Laspeyres and Paasche indexes are representative of about 98% of Nielsen spending).

I do not consider the popular Feenstra (1994) index nor the more recent Redding and Weinstein (2018) index. Each of these indexes contain a variety adjustment term that is meant to capture changes in the cost of living due to new products entering the market (they are also based on the CES utility and since CES has a preference for variety, new products equals lower cost of living). However, it is not clear how these new products should

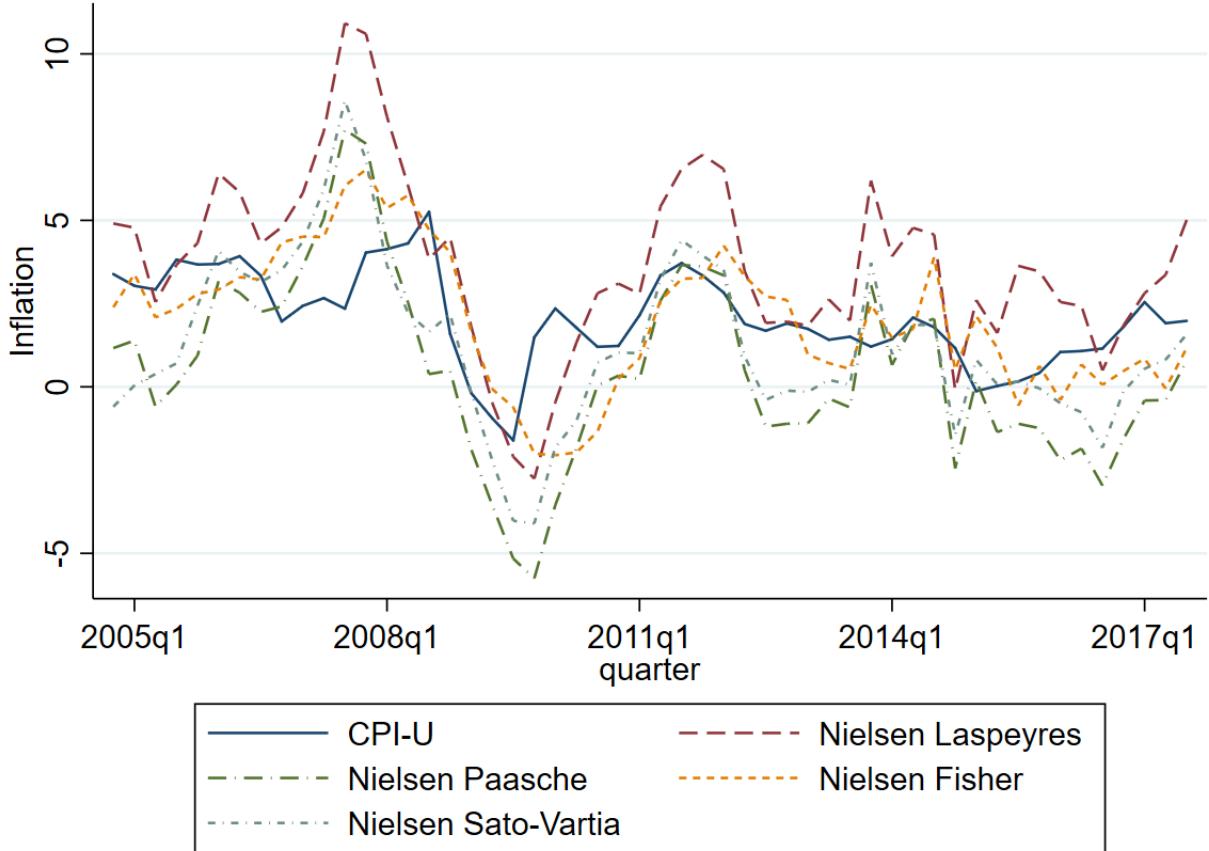
affect individual level cost of living³. When an individual purchases a product that they did not buy in the previous quarter it should not have the same effect on their cost of living as a new product entering the market. Practically, both Feenstra (1994) and Redding and Weinstein (2018) indexes require estimating elasticices of substitution, which would be both computationally heavy and introduce substantial measurement error if estimated at the household level.

The Nielsen Homescan data includes information on the actual price paid for the barcode level product. Argente and Lee (2017) and Kaplan and Schulhofer-Wohl (2017) use changes in the actual price paid at the barcode level for income groups and households respectively to compute changes in the cost of living. I do not follow their example for two reasons: (1) my definition of product is more aggregated (product module instead of barcode) so changes in the price paid by the household could possibly be just the household switching from a less expensive to a more expensive item within a category, (2) at the household level, one reason that a price paid for a product could change is that the household may buy the product at a cheaper location one period (say a bulk grocery store) and then buy that same product at more more expensive location the next (a convenience store); although such household level decisions are interesting, they introduce substantial noise into my inflation measures and are outside of the scope of changes in the cost of living that I want to consider (the combination of a less-aggregated definition of product and using household level prices in Kaplan and Schulhofer-Wohl (2017) leads their inflation rates to only be representative of 25% of Nielsen household spending). See appendix F for a more complete discussion on my use of common (national) versus effective (price paid) prices.

Figure 1 shows the weighted average of the Nielsen individual inflation rates computed using each of the four methods (with national prices) compared to the CPI-U. As expected, in each quarter the Laspeyres inflation measure has the highest inflation rate, while the Paasche measure is the lowest. The Sato-Vartia and the Fisher are in the middle. The CPI-U is less volatile than any of the other indexes likely because it includes a wider variety of products rather than just representing retail inflation as in the Nielsen data, however, it

³One can assume that the new products affect all household's cost of living equally, however, since I'm looking at differences in cost of living changes between households the Feenstra index would simply collapse to the Sato-Vartia.

Figure 1: Nielsen Individual Inflation v. CPI-U



Note: Nielsen Inflation rates are the weighted average of the individual inflation rates for the quarter (democratic index). Prices for each product module are the average national prices.

does roughly follow the same trends as the four Nielsen inflation measures.

2.2 Consumer Expenditure Survey

I also create individual inflation measures using the consumer expenditure survey from 1996-2017. The manner that I construct these measures is straightforward and is similar to what Hobijsn and Lagakos (2005) does at the demographic-group level. Households are in the survey for up to four quarters and are asked about their expenditure on a variety of different product classes (gasoline, rent, electronics, etc.) during the quarter. I aggregate their responses into one of 26 categories for which the BLS provides category specific CPI's and

then match household level expenditure shares with the BLS category level CPI data (see appendix for more details). For each household I construct sequential Laspeyres π^l and Paasche π^p indexes as:

$$\pi_{h,t}^l = 100 \left(\sum_i^h s_{i,t-4} \frac{p_{i,t}}{p_{i,t-4}} - 1 \right), \quad \pi_{h,t}^p = 100 \left(\sum_i^h s_{i,t} \frac{p_{i,t}}{p_{i,t-4}} - 1 \right), \quad (2.3)$$

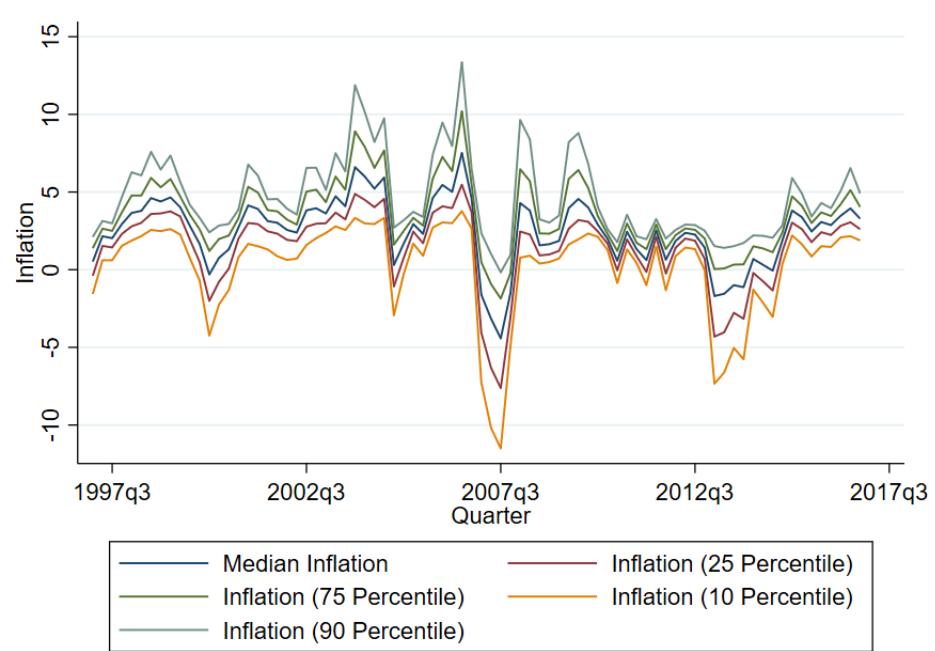
where p_i is the CPI index for category i . Only my Paasche inflation rates line up with consumer expenditure information for the quarter since the Laspeyres individual inflation rates require prices a year after the share data, which is after the household has dropped from the sample.

Figure 2 shows the distribution of individual inflation rates over time. As seen in the figure, the distribution is quite wide, households experience inflation at very different rates. Also, the distribution narrows and widens over time. Periods of high inflation or deflation seem to have wider distributions than periods of tame inflation.

Finally, Table 2 shows the summary statistics of the Nielsen expenditures, Quarterly expenditures in the CEX measured in two ways, and my computed inflation measures.⁴ The CEX spending is considerably higher than the Nielsen spending, which is as expected since the Nielsen homescan only includes retail spending. Interestingly, the standard deviation of individual inflation rates (with national prices) is close to 5 percentage points regardless of the dataset or manner in which inflation is calculated. Inflation rates using regional prices are much more dispersed than those using national prices. I should note that the summary table pools all of the data together in the entire sample. When I first look at the standard deviation of inflation rates by quarter, the average standard deviation is smaller (ranging from 3.4-5.06 percentage points for Nielsen national prices).

⁴In the CEX survey they ask households their total spending in each of many categories during each month of the quarter. The total categorical CEX spending is the quarterly total of this measure and this is also the expenditure I use to create household level inflation rates. Households are also asked about total expenditures in the last three months. Since households are interviewed in either the first, second, or third month of the quarter, this latter question does not line-up with the calendar quarter.

Figure 2: Distribution of Individual Inflation Rates: CEX Laspeyres Index



Note: Individual Inflation from the CEX using a Sequential Laspeyres Price Index for each household.

Table 2: Summary Statistics

Panel A: Individual Data

	Mean	Median	SD	10 %	90 %
Quarterly Expenditure (Nielsen)	1082	925	716	378	1959
Quarterly Expenditure (CEX Last Three Months)	7284	4919	8258	1482	15360
Quarterly Expenditure (CEX total Categorical)	6755	4373	9387	1577	12888
Nielsen National Prices					
Laspeyres Inflation	3.57	2.85	5.80	-1.71	9.04
Paasche Inflation	0.33	0.48	5.11	-4.71	5.46
Fisher Inflation	1.87	1.71	3.95	-2.33	6.23
Sato-Vartia Inflation	1.10	0.97	4.53	-3.44	5.83
Nielsen Regional Prices					
Laspeyres Inflation	6.69	4.73	13.03	-3.99	9.04
Paasche Inflation	1.85	1.15	19.03	-9.06	12.15
Fisher Inflation	3.80	2.98	9.90	-4.58	12.59
Sato-Vartia Inflation	2.54	1.57	37.24	-7.15	11.94
CEX					
Laspeyres Inflation	1.69	2.36	5.27	-2.63	5.62
Paasche Inflation	1.57	2.24	5.65	-3.03	5.94

Panel B: Standard Deviation of Inflation Measures

	Quarterly		
	Average	Min	Max
Nielsen National Prices			
$\sigma(\text{Laspeyres } \pi)$	5.06	3.00	8.23
$\sigma(\text{Paasche } \pi)$	4.41	2.88	7.21
$\sigma(\text{Fisher } \pi)$	3.40	2.76	4.62
$\sigma(\text{Sato-Vartia } \pi)$	3.90	2.56	6.70
CEX			
$\sigma(\text{Laspeyres } \pi)$	3.75	1.43	8.06
$\sigma(\text{Paasche } \pi)$	4.01	1.71	8.47

Note: Statistics weighted by population projection factors from Nielsen and CEX. Inflation is in terms of percent change in the price index between quarter t-4 and t where the price index is computed as described in the text. Expenditure is in Nominal Dollars.

3 How Consumers React to Higher Household Inflation

The previous section showed that there is a wide distribution of individual inflation rates around the aggregate/mean level of inflation. In this section, I present a simple household-level model that shows how a household reacts to inflation rates that are higher than the aggregate. I then use my Nielsen and CEX expenditure data and household inflation rates to show how households react to higher individual inflation.

3.1 Simple Model

This simple model is meant to show how a single household behaves in an environment where their price index (and inflation) differ from the aggregate, but their wage, interest rate, and all other terms are indexed to aggregate inflation. I show that persistent increases to the household's own price index cause the household to reduce consumption, as if they had been hit by a negative wealth shock. For simplicity, I assume that the household buys a single consumption good, which is a stand-in for the household's unique basket.

I assume that households have concave utility $u(\cdot)$ strictly increasing over real consumption good c , for which they must pay household specific price p_h ; c is meant to represent the household's real consumption bundle and p_h its price index. I also assume that they provide labor in-elastically and receive wage w_t . They can also invest in a one-period bond b which the household can sell at real price Q_t . I assume that the households wage and savings are indexed to the aggregate price level (P_t) only.

The household's budget constraint is then:

$$p_{ht}c_t + P_tb_{t+1} = P_tw_t + P_tb_tQ_t \quad (3.1)$$

Dividing through by the aggregate price level, I denote the part of the household price index that is orthogonal to the aggregate price index as \tilde{p}_{ht} and real valued wage and bonds as \tilde{w} and \tilde{b} respectively. The real interest rate corresponding with Q is r_t^* .

The household's problem is:

$$\begin{aligned}
& \max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta u(c_t) \\
\text{s.t. } & \tilde{p}_{ht} c_t + \tilde{b}_{t+1} = \tilde{w}_t + \tilde{b}_t (1 + r_t^*) \\
& \lim_{s \rightarrow \infty} \left(\prod_{k=1}^s (1 + r_{t+k}^*) \right)^{-1} \tilde{b}_{t+s} = 0.
\end{aligned} \tag{3.2}$$

The Euler equation resulting from this simple model is:

$$\frac{u'(c_t)}{\tilde{p}_{ht}} = \mathbb{E}_t \frac{u'(c_{t+1})}{\tilde{p}_{ht+1}} \psi_t \tag{3.3}$$

where $\psi_t = \beta(1 + r_{t+1}^*)$. It follows that when a household expects that their price index will be lower tomorrow than today, they will decrease their consumption today and increase their consumption tomorrow, which reflect the fact that the effective real interest rate for the household is different than the real interest rate of the economy as a whole. Hence, in this model, shocks to a household's inflation rate will lead to shocks to their real consumption. If $u(\cdot)$ is such that the household is risk averse, the household would prefer that p is constant over-time (aka, that their inflation is always equal to aggregate inflation).

As an illustration, consider the simple case where the household has quadratic utility $u(c_t) = c_t - \gamma c_t^2$. Under perfect foresight of the path of their future price index and the assumption that $(1 + r^*)(\beta) = 1$ it can be shown that:

$$c_t = \frac{r}{1+r} \left(\sum_{j=0}^{\infty} \frac{\beta^j}{\tilde{p}_{ht+j}} \mathbb{E}_t (\tilde{w}_{t+j} + \tilde{b}_t) \right). \tag{3.4}$$

Consumption at time t is a fraction $\frac{r}{1+r}$ of expected future income streams, current assets, and the expected buying power of the income and assets. Increases in the future path of the price index lead to decreases in real consumption, as higher price levels mean that the

household can buy less with the same amount of income. See the appendix for more details.

3.2 Household consumption response in the data

I next turn to the data to show (a) how a household level inflation shock affects the household's price index over time, and (b) how households respond to this shock. I find that a shock to a household's price index is quite persistent for all price indexes and permanent for shocks to the Paasche and Sato-Vartia price indexes. Consistent with the simple model presented above, following an inflation shock households reduce their real consumption. I also find weaker evidence that a household reduces its nominal consumption expenditures following an inflation shock, which implies that real consumption falls more than one-for-one following a household level price shock. I should note that since I cannot reliably see changes in income in the Nielsen or CEX data, I cannot determine if the behavioral changes I see are because households are adjusting their savings or their labor inputs in response to an inflation shock.

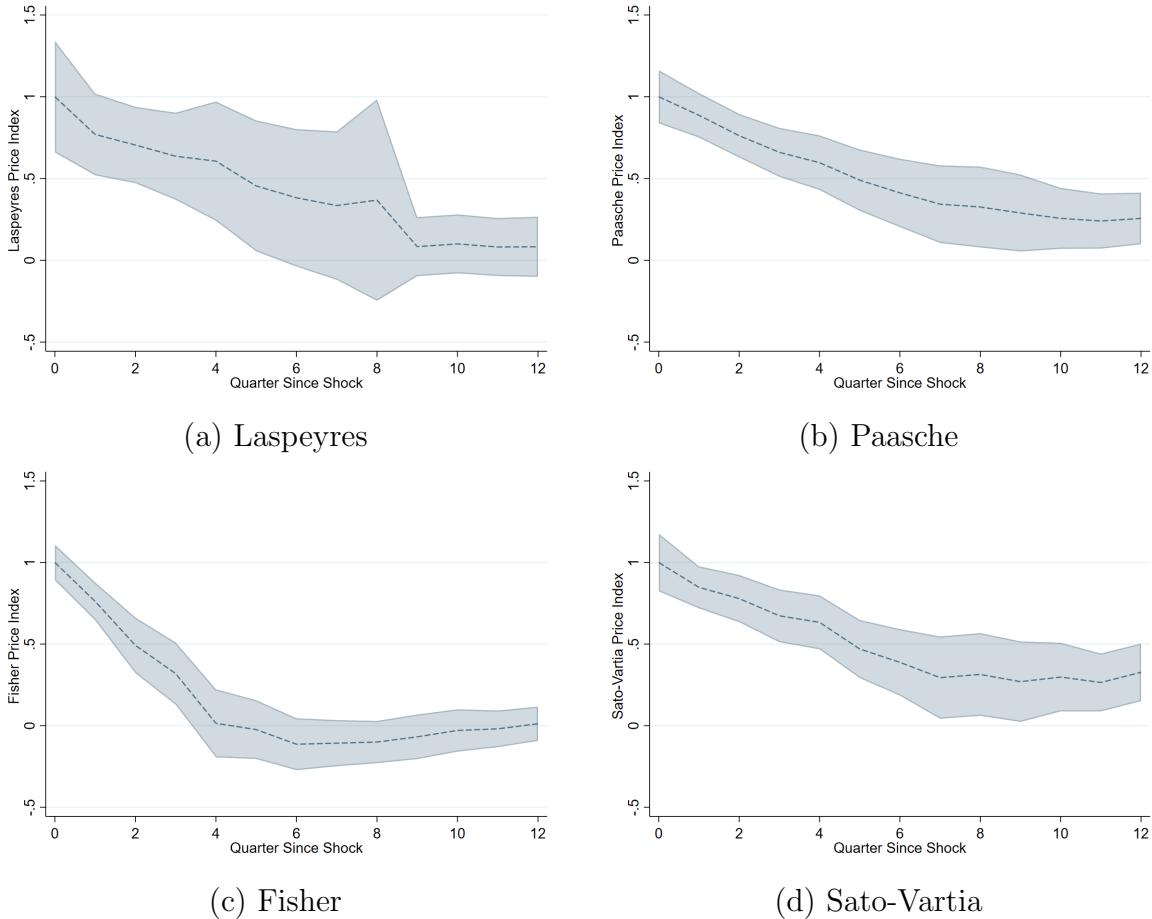
I start by using the chained-price indexes and corresponding inflation rates in the Nielsen data to construct impulse responses of the price index, nominal consumption, and real consumption following a shock to the household's inflation rate. I construct the IRF's following the Jordà (2005) method:

$$y_{h,t+k} = \beta_0 + \beta_1 \pi_{h,t} + \beta_3 y_{h,t-1} + \gamma_h + \alpha_t + \varepsilon_{h,t+k}, \quad k \in \{0, 1, \dots, 12\}. \quad (3.5)$$

Above, $y_{h,t+k}$ is the price index, log of nominal consumption, or log of real consumption for household h at time $t+k$. The household specific Laspeyres, Paasche, Fisher, or Sato-Vartia inflation rate denoted by $\pi_{h,t+k}$ is normalized so that it results in a one unit increase in the price index at time t . Household fixed effects are denoted by γ_h and time fixed effects by α_t .

Figure 3 shows the results of the regressions of the price index on the inflation shock. The time fixed effects are designed to absorb the movement of the aggregate price index, so that the IRF's of the individual price index can be interpreted as the difference between

Figure 3: Path of Household Retail Price-Index Following Household Inflation Shock

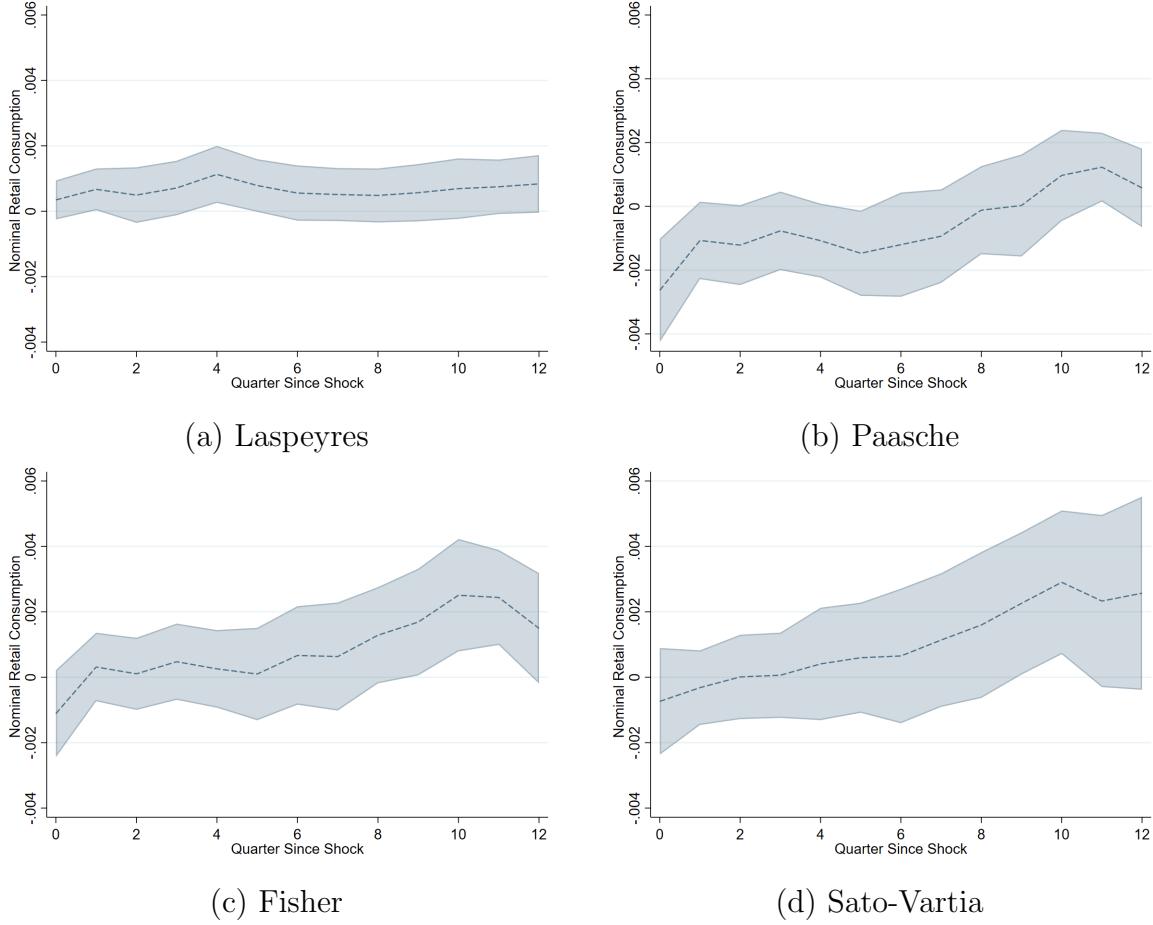


Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Confidence interval (99 percent) is shown as the shaded area.

the individual price index and the aggregate index. I find that following an inflation shock, the individual's price index stays above the aggregate price index for at least 4 quarters and remains at a permanently higher level for the Paasche and Sato-Vartia style price indexes. Note that all of these price indexes allow the household to adjust its basket each quarter and even accounting for these behavioral changes the price index shock is quite persistent (lasting around 2-3 years). One way to interpret these household inflation shocks is as a persistent shock to the households wealth.

I next show how this same inflation shock affects the household's nominal consumption expenditures (Figure 4). If households are attempting to smooth their real consumption then we should expect that they would increase their nominal expenditures following an

Figure 4: Response of Nominal Household Retail Consumption to one-unit Household Inflation Shock

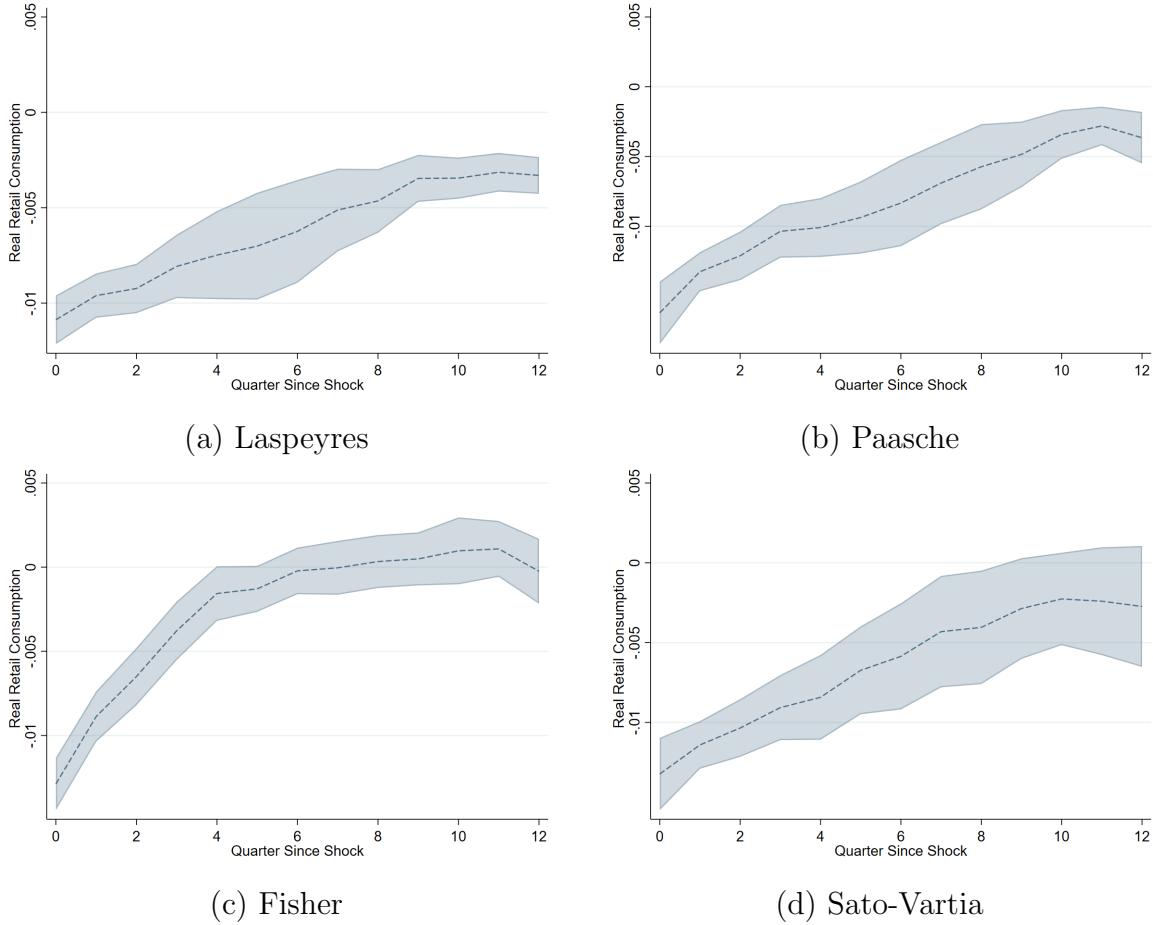


Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Blue shaded area indicates 95 percent confidence interval.

increase in their price index, however, I find some evidence that the opposite is happening. Household's appear to reduce their nominal consumption (for Paasche, Fisher, and Sato-Vartia style inflation shocks) in the period of the inflation shock. Later on, once their price index has reverted closer to the aggregate price index, household's increase their nominal consumption. Similar to the results from the simple model, household's seem to buy more when prices are low and buy less when prices are high.

Finally, I show how a household's real retail consumption expenditures react to an inflation shock. I calculate real consumption expenditures by dividing a households nominal consumption by their chained price index. Figure 5 shows the results of this analysis. Fol-

Figure 5: Response of Real Household Retail Consumption to one-unit Household Inflation Shock



Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Blue shaded area indicates 95 percent confidence interval.

lowing a one unit inflation shock, real consumption falls by more than one percent in each of the definitions of real consumption. The fall in real consumption is quite persistent and only recovers for Fisher style real consumption. It remains at a permanently lower level for the other measures of real consumption. This suggests that household level inflation shocks can have large welfare effects.

The results I have presented above using the Nielsen data only show a household's retail expenditure response to their retail price index. Since I only observe households for at most 4 quarters in the CEX, I cannot construct similar IRF's using all of the household's consumption expenditures. However, to test whether a household responds to an inflation

Table 3: Response of Household Spending to Household Inflation Shock: CEX

	$\ln(P \cdot C)$ (last 3 months)	$\ln(P \cdot C)$ (total categorical)	$\ln(P \cdot C)$ (last 3 months)	$\ln(P \cdot C)$ (total categorical)
$\pi_{h,t}$	-0.00523* (0.00273)	-0.0141 (0.0135)		
$\pi_{h,t-1}$	-0.00125** (0.000577)	-0.00386 (0.00246)		
$\pi_{h,t}^+$			0.000895 (0.00487)	0.0123 (0.0155)
$\pi_{h,t-1}^+$			-0.000567 (0.00120)	0.00393 (0.00256)
$\pi_{h,t}^-$			0.00749*** (0.00256)	0.0269 (0.0164)
$\pi_{h,t-1}^-$			0.00161* (0.000920)	0.00844** (0.00370)
N	347,462	347,354	347,462	347,354

Note: Standard errors, in parentheses, clustered at time level and are robust to auto-correlation. Significance at the one percent, five percent and ten percent levels indicated by ***, **, and *. Individual and time fixed effects and a lag of the dependent variable are also included.

shock by smoothing their real consumption or reducing their consumption as in my simple model I regress the household's CEX nominal consumption expenditures on their Paasche inflation rate, and lags of their expenditure and inflation rate along with household and time fixed effects. In my baseline model, I only include one lag⁵ I also check to see whether there is asymmetry in the household's response to inflation shocks that are either above or below aggregate inflation. I denote $\pi_{h,t}^+ = \max\{\pi_{h,t} - \bar{\pi}_t, 0\}$ and $\pi_{h,t}^- = -\min\{\pi_{h,t} - \bar{\pi}_t, 0\}$ where $\bar{\pi}_t$ is aggregate Paasche inflation for period t.

I show the results from this analysis in Table 3. Columns 1 and 2 show the response of a household's consumption (measured as either the household's total reported expenditure in the last three months or the total of their categorical expenditure) to the household specific inflation rate. As with the Nielsen data, nominal consumption appears to decline following a household inflation shock and I can reject that the household smooths its consumption

⁵I can include at most two lags. I have up to four observations for each household, and the household fixed effect takes up one observation, the expenditure and two lags take up the other three.

(aka that nominal consumption increases by 1 percent following a 1 percent inflation shock) at the 99 percent level for lagged inflation and the 90 percent level for contemporaneous inflation. Columns 3 and 4 show the response of household consumption but this time allowing for asymmetric responses for positive and negative personal inflation shocks. I find that following a negative inflation shock, household's appear to take advantage of the lower price index and increase their consumption, however, I also find that following a positive inflation shock households appear to also increase their consumption. However this second result is not significant and I can reject that households are able to smooth their real consumption following an increase in their price index at the 90 percent level for column 3. For column 4, I cannot reject that households are able to smooth their real consumption.

It is possible that households would like to smooth their real consumption following an increase in their price index, but not all households are able to do so because of credit constraints. Table 9 in the appendix shows the difference in household's consumption responses to an inflation shock by income group. Richer households are far more responsive to inflation shocks than poorer households (to both positive and negative inflation shocks). This could imply that richer households are less credit constrained; less credit constrained households are more able to take advantage of low prices following a negative inflation shock and smooth their consumption following a positive income shock. However, other explanations, such as different preferences to smooth consumption over time can also explain this same pattern.

4 Inflation Dispersion and Inflation

In this section I discuss the relationship between inflation dispersion and aggregate inflation. I show that there is a robust relationship between the level of absolute aggregate inflation and individual inflation dispersion.

I start by showing that the correlation between aggregate price changes and inflation dispersion is robust. Table 4 shows the results of regressing the standard deviation of individual inflation rates on the absolute value of aggregate inflation; the even columns include the expected inflation rate in that period (the difference between the TIPs 5 year bond yield and the 5 year treasury yield). Panel A shows the results using inflation rates calculated

Table 4: Household Inflation Dispersion and Aggregate Inflation

Panel A: Nielsen Homescan

	Laspeyres		Paasche		Fisher		Sato-Vartia	
	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$
$ \bar{\pi} $	0.0577 (0.0539)	0.125** (0.0533)	0.293** (0.118)	0.289** (0.114)	0.0738 (0.0579)	0.0645 (0.0640)	0.263*** (0.0725)	0.302*** (0.0706)
$ \mathbb{E}(\bar{\pi}) $		-0.753 (0.483)		0.117 (0.235)		0.0685 (0.147)		-0.562*** (0.163)
N	52	52	52	52	52	52	52	52

Panel B: CEX

	Laspeyres		Paasche	
	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$
$ \bar{\pi} $	0.381** (0.170)	0.180*** (0.0524)	0.395** (0.159)	0.170* (0.0936)
$ \mathbb{E}(\bar{\pi}) $		-1.307*** (0.198)		-0.997*** (0.232)
N	83	60	87	60

Note: Newey-west HAC standard errors in Parentheses. Significance at the one, five and ten percent levels indicated by ***, **, and * respectively. Aggregate Inflation, $|\bar{\pi}|$ is a democratic index of individual inflation weighted using the population weights in the Nielsen Homescan or CEX. Expected inflation, $|\mathbb{E}(\bar{\pi})|$, is the difference between the yield on a 5-year treasury bond and the corresponding 5-year Inflation Protected bond (TIPs). Nielsen Homescan Data from 2004-2017, CEX from 1996-2017, TIPs Expected Inflation 2003-2017. National prices are used throughout.

using the Nielsen data. I find that the relationship between aggregate inflation (defined as the weighted average of the individual inflation measures, a democratic index) is positive in all cases. It is statistically significant for the Paasche, and Sato-Vartia definitions of inflation and for the Laspeyres definition of inflation once expected inflation is included.

Panel B shows the results using the CEX data, which are positive and statistically significant in every specification; a one percent increase in Laspeyres inflation increases the standard deviation of individual inflation rates by 0.38 percentage points (off of a mean of 3.75). In the CEX data, I find that it is unexpected inflation that is driving this relationship; in fact increases in expected inflation seem to decrease inflation dispersion.

Table 5: Regional Household Inflation Dispersion and Regional Inflation

	Laspeyres $\sigma^r(\pi_h)$	Paasche $\sigma^r(\pi_h)$	Fisher $\sigma^r(\pi_h)$	Sato-Vartia $\sigma^r(\pi_h)$
$ \bar{\pi}_r $	0.544*** (0.0260)	1.575*** (0.171)	0.516*** (0.0620)	4.020*** (0.466)
Region FE	X	X	X	X
Time FE	X	X	X	X
Observations	10,656	10,656	10,656	10,656
R-squared	0.568	0.459	0.453	0.791

Note: Standard errors, in parentheses, two-way clustered at region and time levels and are robust to auto-correlation. Significance at the one percent level indicated by ***. Aggregate Regional Inflation, $|\bar{\pi}_r|$ is a democratic index of individual inflation weighted using the population weights in the Nielsen Homescan. Regional prices are used throughout.

McLeay and Tenreyro (2019), use the fact that regions have their own labor market conditions and inflation rates to identify regional Phillips curves, since the national Phillips curve can be hard to identify due to central bank actions. In a similar way, I check the robustness of the relationship between inflation and inflation dispersion by running similar regressions at the regional level. This lets me confirm that it is not oil price shocks that are affecting inflation and some products thereby also causing inflation dispersion. It also significantly increases my statistical power. For these regressions I regress the standard deviation of the Nielsen Household inflation rates using regional prices on the regional inflation rate; I also include time and region fixed effects. Table 5 shows the results of this analysis and confirms that the relationship between inflation and inflation dispersion also exists at the regional level.

Vavra (2013) and Li (2019) discuss the relationship between price change dispersion and the business cycle. In order to ensure that the pattern I find is related to inflation and inflation dispersion rather than simply a story of the cyclical pattern of inflation dispersion, I repeat the empirical exercise in tables 4, but I include the National unemployment rate as a control. Table 6 shows the results of this robustness check (with the Nielsen Data). Even when controlling for the business cycle, the relationship between inflation dispersion and the absolute value of inflation still holds.

Table 6: Robustness Check with Unemployment Rate

	Laspeyres		Paasche		Fisher		Sato-Vartia	
	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$	$\sigma(\pi_h)$
$ \bar{\pi} $	0.449*** (0.151)	0.366** (0.145)	0.856*** (0.111)	0.853*** (0.113)	0.672*** (0.212)	0.661*** (0.215)	5.937*** (1.160)	4.989*** (1.085)
$ \mathbb{E}(\bar{\pi}) $		1.400 (1.318)		0.825 (0.946)		0.731 (0.498)		0.342 (0.402)
UR	0.0111 (0.230)	0.0965 (0.203)	0.0822 (0.202)	0.144 (0.153)	-0.0601 (0.119)	-0.00684 (0.114)	0.0975* (0.0525)	0.110** (0.0423)
N	52	52	52	52	52	52	52	52

Note: Newey-west HAC standard errors in Parentheses. Significance at the one, five and ten percent levels indicated by ***, **, and * respectively. Aggregate Inflation, $|\bar{\pi}|$ is a democratic index of individual inflation weighted using the population weights in the Nielsen Homescan or CEX. Expected inflation, $|\mathbb{E}(\bar{\pi})|$, is the difference between the yield on a 5-year treasury bond and the corresponding 5-year Inflation Protected bond (TIPs). Nielsen Homescan Data from 2004-2017, CEX from 1996-2017, TIPs Expected Inflation 2003-2017. National prices are used throughout.

Next, I investigate whether the relationship I find between inflation and inflation dispersion is driven primarily by differences in the sectoral composition of household purchases (i.e. some households spend more money on education a sticky sector than others) or a more fundamental element of price setting behavior that also exists within sectors (i.e. difference in price setting patterns of the individual education goods that the individual purchases). To do this, I exploit the fact that the Nielsen Homescan data has information on the actual bar-code of the product the household purchases along with the group (product module in the Nielsen data) to which that product belongs (the Nielsen inflation measure that I use in the rest of the paper is based on purchases in the broader product module category). I construct quarterly individual specific inflation rates for each of the 1,235 product modules in the Nielsen data. I then compare the standard deviation of the inflation rate in each of these product modules compared to the average inflation rate in the category. The results of this analysis is shown in table 7; I find a strong correlation between inflation and inflation dispersion even at the very narrow category level!

In order to ensure that this relationship is not only the product of trends in the late 1990s and 2000s, I repeat a similar analysis using city level CPI data going back until 1915.

Table 7: Module level Household Inflation Dispersion and Module Inflation

	Laspeyres $\sigma^r(\pi_h)$	Paasche $\sigma^r(\pi_h)$	Fisher $\sigma^r(\pi_h)$	Sato-Vartia $\sigma^r(\pi_h)$
$ \bar{\pi}_t $	4.048*** (1.199)	0.799*** (0.0716)	0.526*** (0.0393)	1.099*** (0.0393)
Time FE	X	X	X	X
Product Module FE	X	X	X	X
R-squared	0.732	0.592	0.505	0.838

Note: Standard errors, in parentheses, two-way clustered at module and time levels and are robust to auto-correlation. Significance at the one percent level indicated by ***. Aggregate Regional Inflation, $|\bar{\pi}_r|$ is a democratic index of individual inflation weighted using the population weights in the Nielsen Homescan. Regional prices are used throughout.

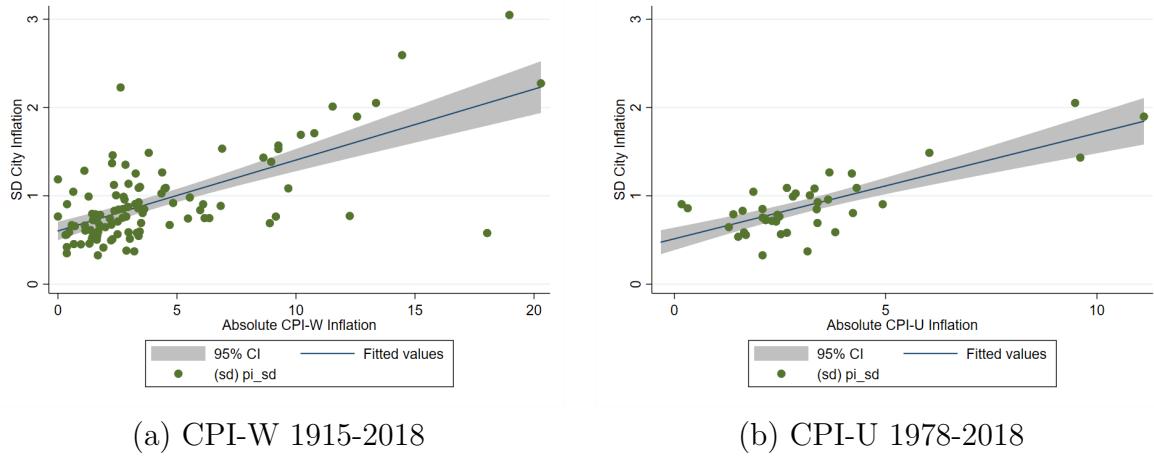
I cannot calculate individual inflation rates that far back, but to the extent that cities have differences in consumption baskets then one may expect to see a similar relationship between city level inflation dispersion and aggregate inflation as that seen for individuals. The results from this analysis are shown in Figure 6. I note that there is a relationship between the variance of city inflation rates and aggregate absolute inflation going back until 1915.

5 Menu-cost model

I need a model that generates a positive relationship between absolute inflation and inflation dispersion, but does not introduce a relationship between inflation and price dispersion (like in the New Keynesian model). In this section I present a partial-equilibrium menu cost model that reproduces the link between aggregate inflation and household inflation dispersion that I find in the data. In addition to heterogeneous household preferences, a key assumption in this model is that the elasticity of substitution for a product differs across sectors⁶. This leads to the firm level profit function being more convex with respect to prices in some sectors than in others, which results in sector level differences in price-sensitivity to the aggregate price level (Barro 1972). The model takes the path of the aggregate price-level P_t

⁶If the elasticity of substitution also differs between higher and lower quality products within a sector then this could explain the results found in appendix F Shampoo prices where prices change differently between higher and lower quality goods, as well as the module level results found in table 7

Figure 6: Inflation and SD of City Inflation Rates



Note: SD is the standard deviation of city-level inflation rates. From city-level CPI data from the BLS. The 95 percent confidence interval is the shaded area.

as given and then models the firm-level price responses and the corresponding distribution of household level inflation rates.

5.1 Households

Households are modeled simply. There are N households with heterogeneous preferences across sectors and common CES preferences within each sector. Households supply one unit of labor inelastically and consume their entire income each period.

Formally, households have Cobb-Douglas utility with heterogeneous preferences across sectors m so that the utility for household h is given by:

$$u_t(h) = \prod_{m=1}^M C_t(m)^{\alpha_{h,m}}, \quad (5.1)$$

where $C_t(m)$ is an aggregated product of purchases from sector m defined implicitly by:

$$C_t(m) = \left(\int_0^1 c_t(z_m)^{\frac{\theta_m - 1}{\theta_m}} \right)^{\frac{\theta_m}{\theta_m - 1}}. \quad (5.2)$$

this implies a sector specific price index that is common for all households and a household specific price index across sectors:

$$P_{h,t} = \prod_{m=1}^M \left(\frac{p_{m,t}}{\alpha_{h,m}} \right)^{\alpha_{h,m}}. \quad (5.3)$$

A household's inflation rate at time t is then:

$$\pi_{h,t} = \sum_{m=1}^M \alpha_{h,m} \log \left(\frac{p_{m,t}}{p_{m,t-1}} \right). \quad (5.4)$$

Cobb-douglas sectorial utility was chosen so that the final inflation rate (5.4) would correspond exactly to the fixed weight Laspeyres and Paasche measures that I examine empirically.

In future work when I move this model from partial to general equilibrium the aggregate price level will be determined by aggregating the demand functions of the various households joint with the firm's decision rule. However, in this draft of the paper I take the aggregate price level as given and make the simplifying assumption that total household demand for firm z 's product aggregates to:

$$c_t(z_m) = C_t \left(\frac{p_t(z_m)}{P_t} \right)^{-\theta_m} \quad (5.5)$$

where P_t is the exogenous aggregate price level and C_t is aggregate consumption, which is fixed in real terms and normalized to one.

5.2 Firms

There are M sectors and in each sector m , there is a continuum of monopolistic firms each producing a differentiated good. Firm z sets its price $p_t(z)$ and then produces consumption good $y(z)$ according to the following production function:

$$y_t(z) = A_t(z)L_t(z) \quad (5.6)$$

where $A_t(z)$ is firm z 's total factor productivity at time t and $L_t(z)$ is the quantity of labor employed.

The per-period firm profit function is:

$$\Pi_t(z) = p_t(z)y_t(z) - W_t L_t(z) - \chi_j W_t I_t(z). \quad (5.7)$$

here W_t is the wage rate, $I_t(z)$ is an indicator equal to one if the firm changes their price in period t and χ_j is the proportion/multiple of the prevailing wage rate that the firm must spend to change their price.

Demand for firm z 's product comes from (5.5). Combining firm demand with the firm's profit function yields a maximization problem with one choice variable: the product price.

Recursively, the firm's problem becomes:

$$V\left(A_t(z), \frac{p_{t-1}(z)}{P_t}\right) = \max_{p_t(z)} \left(\Pi_t(z)^R + E_t \left[D_{t,t+1}^R V\left(A_{t+1}(z), \frac{p_t(z)}{P_{t+1}}\right) \right] \right), \quad (5.8)$$

where $D_{t,t+1}$ is the firm's discount factor and the R superscript denotes real valued.

The firm problem differs for each firm because of different TFP values $A_t(z)$ and starting prices p_{t-1} , as well as a different curvature of the profit function because of varying elasticities of substitution for their products.

5.3 Simulation

I test whether this model is able to explain the relationship between the absolute value of aggregate inflation and inflation dispersion that I find in the data by simulating the model with 10 sectors. I use value function iteration to solve for the value function (and corresponding policy function) for firms in each sector. I then simulate the firm's responses

Table 8: Model Simulation Results

	$\sigma(\pi_h)$	$\sigma(p(z, t))$
$ \bar{\pi} $	0.158*** (0.0003)	0.0001 (0.000015)

to changes in TFP and the aggregate price level for 250,000 periods. In order to focus on changes in aggregate inflation, I assume that the TFP shocks are common across all firms. Finally, I construct price indexes for 1000 households by assigning each household random uniformly distributed preference weights for each sector. I assume that each sector has elasticities of substitution ranging from 2 to 26 spaced evenly. I calibrate the rest of the model following Nakamura and Steinsson (2010).

I use the model results to regress the standard deviation of household level inflation rates on the absolute value of democratic aggregate inflation, which exactly mirrors my empirical exercise. The results of this experiment are shown in table 8. I find that a one percentage point increase in the absolute value of aggregate inflation is related to a 0.158 increase in the standard deviation of household inflation rates, which is around the mid-range of my empirical estimates. I also check whether there is a relationship between inflation and price dispersion in my model, column 2 shows the results; while the relationship between inflation and price dispersion is statistically significant, it is extremely small.

6 Conclusion

This project enlisted two large household-level datasets (the Consumer Expenditure Survey and the Nielsen Consumer Panel) to calculate household level inflation rates. I have found that household level inflation dispersion is costly: (1) shocks to a household's price index are persistent and are permanent in the case of Paasche and Sato-Vartia inflation; (2) households appear to reduce both their nominal and real consumption following shocks to their inflation rate; (3) poorer households are less able to smooth their consumption following shocks to

their inflation rate. I also found that there is a robust relationship between aggregate inflation and inflation dispersion distinct from the business cycle, which can be explained by a partial equilibrium menu-cost model where the elasticity of substitution (and therefore the curvature of the firm's profit function) varies across sectors.

Inflation is costly because not everyone experiences inflation in the same way and increased inflation expands the cross-sectional volatility of household-level inflation. This is a cost that cannot be fixed by indexing paychecks, loans, etc. to the aggregate inflation rate. The increase in volatility can be especially costly for low-asset households that cannot smooth their consumption, so the increase in inflation volatility is matched by an increase in real consumption volatility.

Also, given the wide distribution of household inflation rates it should come at no surprise that expectations of future inflation rates in the Michigan survey and others are so widely dispersed (Mankiw et al. 2003). While some have speculated this may be due to the inattention or sticky information on the part of respondents (Carroll 2003, Mankiw et al. 2003), households may be simply responding based rational beliefs that their inflation rates may not conform to projected aggregate rates.

This research is particularly pertinent to the current debate over whether central banks should increase their inflation targets from around 2 percent to a higher level (the ECB is currently considering this proposal in their strategy review). Several papers have considered the welfare costs of increasing an inflation target in the US from 2 to 4 percent (Ascari et al. 2018, Ascari 2004, Amano et al. 2007) and find that this would lead to a consumption equivalent welfare loss between 0.25% and 4 %. Given the relationship between inflation dispersion and inflation that I find, an unexpected increase in the inflation target should lead to an additional welfare loss due to increased cross-sectional volatility of individual inflation rates.

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Appendix

A Household Model

Consider a household with quadratic utility over consumption good c_t , stochastic income stream $\{w_t\}_{t=0}^\infty$, household specific price level p_t and the ability to invest in a risk free bond b_t at interest rate r . My goal is to see how the household responds to unanticipated and anticipated increases to their own price index.

The household's problem becomes:

$$\max \mathbb{E}_0 \beta u(c_t) \quad (\text{A.1})$$

$$s.t. p_t c_t + b_{t+1} \left(\frac{1}{1+r} \right) = w_t + b_t \quad (\text{A.2})$$

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta_t b_t^2 \right] < \infty \quad (\text{A.3})$$

where $\beta < 1$ is the household's discount factor. I assume that the household has per-period quadratic utility that takes the form:

$$u(c_t) = c_t - \gamma c_t^2. \quad (\text{A.4})$$

I further assume that the household consumes in the region in which marginal utility is positive.

The Household Euler equation is:

$$\frac{1 - 2\gamma c_t}{p_t} = \beta \mathbb{E}_t \frac{1 - 2\gamma c_{t+1}}{p_{t+1}} (1 + r). \quad (\text{A.5})$$

I make a further simplifying assumption that the interest rate $r = 1/\beta - 1$. I consider three types of changes to the household's price index when the household has perfect foresight:

(1) an unanticipated permanent increase in p at time T from p^A to p^B , (2) an anticipated permanent shock in p from p^A to p^B at time T , and (3) an unanticipated temporary shock to p at time T . Finally, using a slightly modified model, I show the household's response to price index shocks when they do not have perfect foresight.

A.1 Permanent Unanticipated Shock

In case (1), the household now assumes that $p_t = p^B \forall t > T$, so the Euler equation (A.5) becomes:

$$\begin{aligned}\frac{1 - 2\gamma c_t}{p^A} &= \mathbb{E}_t \frac{1 - 2\gamma c_{t+1}}{p^A} \text{ if } t \leq T - 1 \\ \frac{1 - 2\gamma c_t}{p^B} &= \mathbb{E}_t \frac{1 - 2\gamma c_{t+1}}{p^B} \text{ if } t > T - 1.\end{aligned}\tag{A.6}$$

In either case, (A.5) becomes $c_t = \mathbb{E}[c_{t+1}]$.

From the transversality condition (A.3), I get that

$$\lim_{t \rightarrow \infty} \beta^{t/2} b_{t+1} = 0\tag{A.7}$$

I combine (A.7) with the budget constraint (A.2) to get that:

$$-\frac{b_t}{p'} = \sum_{j=0}^{\infty} \frac{\beta^j}{p^B} \mathbb{E}_{\approx} (w_{t+j} - c_{t+j}) \quad \forall t > T - 1\tag{A.8}$$

Next I use the martingale property of the euler equation, and the fact that $\beta < 1$ to solve for c_t as a function of future income streams and current bond holdings:

$$\frac{c_t}{1 - \beta} = \sum_{j=0}^{\infty} \frac{\beta^j}{p^B} \mathbb{E}_T (w_{t+j} + b_t) \quad \forall t > T - 1\tag{A.9}$$

$$c_t = \frac{r}{1 + r} \sum_{j=0}^{\infty} \frac{\beta^j}{p^B} \mathbb{E}_T (w_{t+j} + b_t) \quad \forall t > T - 1.\tag{A.10}$$

It is straightforward to show that as the household's price index increases, current consumption decreases. This is because an increase in the household's price index is equivalent to a decrease in the household's lifetime income. A positive price index shock is a negative wealth shock and consumption is a normal good.

I can also show what happens to current real consumption regardless of the path of future price index shocks assuming that the household has perfect foresight. If the price index changes again at time $T + 1$ to p^C then consumption at time $T+1$ should be:

$$c_T = \frac{r}{1+r} \left(\frac{\beta^j}{p^B} \mathbb{E}_T (w_t + b_t) + \sum_{j=1}^{\infty} \frac{\beta^j}{p^C} \mathbb{E}_T (w_{t+j} + b_t) \right). \quad (\text{A.11})$$

Continuing this process, but letting each time $t + j$ have its own price index p_{t+j} , then under perfect foresight the household's consumption at time t becomes:

$$c_t = \frac{r}{1+r} \left(\sum_{j=0}^{\infty} \frac{\beta^j}{p_{t+j}} \mathbb{E}_t (w_{t+j} + b_t) \right). \quad (\text{A.12})$$

Nominal consumption does not change with respect to changes in p as

$$p^B c_t = \frac{r}{1+r} \sum_{j=0}^{\infty} \beta^j (w_{t+j} + b_t) \quad (\text{A.13})$$

does not depend on p^B .

A.2 Permanent Anticipated Shock

Under the second case (2), I show what happens to consumption and nominal consumption in period $T-1$ the period prior to the price index shock, if the household expects the increase in the price index.

Then the Euler equation becomes:

$$\frac{1 - 2\gamma c_{T-1}}{p^A} = \mathbb{E}_{T-1} \left[\frac{1 - 2\gamma c_T}{p^B} \right] \quad (\text{A.14})$$

$$1 - 2\gamma c_{T-1} = \mathbb{E}_{T-1} \left[\frac{p^A}{p^B} \left(1 - 2\gamma \frac{r}{1+r} \sum_{j=0}^{\infty} \frac{\beta^j}{p^B} (w_{T+j} + b_T) \right) \right] \quad (\text{A.15})$$

$$c_{T-1} = \frac{1}{2\gamma} - \frac{p^A}{p^B} \frac{1}{2\gamma} + \frac{p^A}{p^B} \left(\frac{r}{1+r} \sum_{j=0}^{\infty} \mathbb{E}_{T-1} \frac{\beta^j}{p^B} (w_{T+j} + b_T) \right). \quad (\text{A.16})$$

Both nominal and real consumption decrease at time $T-1$ in anticipation of the increased price index if and only if:

$$\frac{1}{2\gamma} < \frac{2}{p^B} \left(\frac{r}{1+r} \sum_{j=0}^{\infty} \mathbb{E}_{T-1} \beta^j (w_{T+j} + b_T) \right). \quad (\text{A.17})$$

A.3 Transitory Shock

This subsection shows how a household would respond to a transitory shock to their price level. I start by showing analytically the household's response to a one period transitory shock (at T from p^A to p^B) that they expect to subside the next period. Next, I use numerical methods (dynare) to show the household's response if shocks to their price index follow an AR(1) process.

First, if there is a one-period shock to the household's price level from p^A to p^B at time T , then the euler equation at time T becomes:

$$\frac{1 - 2\gamma c_T}{p^B} = \mathbb{E}_T \left[\frac{1 - 2\gamma c_{T+1}}{p^A} \right] \quad (\text{A.18})$$

Similar to the previous subsection, consumption at time T is then:

$$c_T = \frac{1}{2\gamma} - \frac{p^B}{p^A} \frac{1}{2\gamma} + \frac{p^B}{p^A} \left(\frac{r}{1+r} \sum_{j=1}^{\infty} \mathbb{E}_T \frac{\beta^j}{p^A} (w_{T+j} + b_T) \right). \quad (\text{A.19})$$

As before, we have different responses of nominal consumption depending on the values of γ and w ; however, if

$$\frac{1}{\gamma} < \frac{p^A}{p^B 2\gamma} + \frac{2}{p^A} \left(\frac{r}{1+r} \sum_{j=1}^{\infty} \mathbb{E}_T \beta^j (w_{T+j} + b_T) \right) \quad (\text{A.20})$$

then nominal consumption increases in period T. If the household is sufficiently risk averse then they respond to the increase in their price level by increasing their nominal consumption to then smooth their real consumption. Finally, real consumption also increases after an increase in price index if and only if:

$$\frac{1}{2\gamma p^A} < \frac{1}{(p^A)^2} \left(\frac{r}{1+r} \sum_{j=1}^{\infty} \mathbb{E}_T \beta^j (w_{T+j} + b_{T+j}) \right) \quad (\text{A.21})$$

A.4 Stochastic Shock Process

In the previous subsections, the household “knew” about the future path of their price index. Consider instead the case where the price index follows a stochastic path:

$$p_t = e^{\pi_t} \quad (\text{A.22})$$

$$\pi_t = \rho \pi_{t-1} + \epsilon_t. \quad (\text{A.23})$$

The household knows the distribution of future price shocks, but not the path itself. In this case, consumption is no longer a martingale, so I use numerical methods to solve the model as I can no longer solve for current consumption analytically.

This household model is similar to some open economy models, since the interest rate in the model is not dependent on the household’s bond holdings. This means that the steady state bond-holdings in the model are dependent on initial bond holdings and the history of price shocks. To solve the model, I follow Schmitt-Grohé and Uribe (2003) by introducing a debt-elastic interest rate in the model. The higher the household’s level of debt, the higher

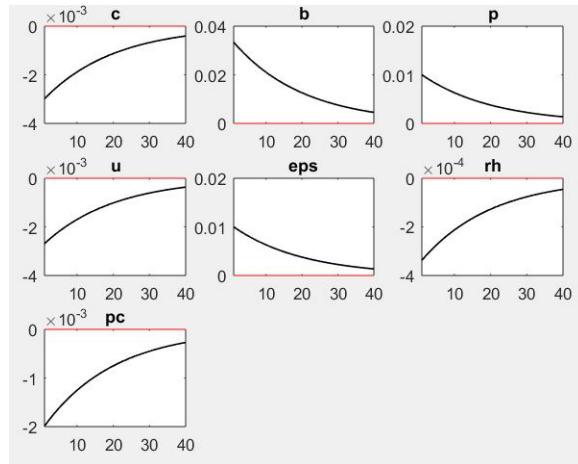
premium the household will have to pay to service their debt. This is mostly a practical addition to solve the model, but does have economic meaning in the sense that extremely indebted households are riskier for lenders and so must pay higher interest.

The household's interest rate is then:

$$r_{h,t} = r^* e^{-b_t}. \quad (\text{A.24})$$

Figure 7 shows the response of the household to a one percent shock to their price index ($\beta = .99$, $\gamma = .5$, $\rho = .95$, $w_t = .1 \forall t$). A persistent shock to the household's price index shock leads to a fall in real and nominal consumption, and an increase in savings.

Figure 7: Response to Price Index Shock

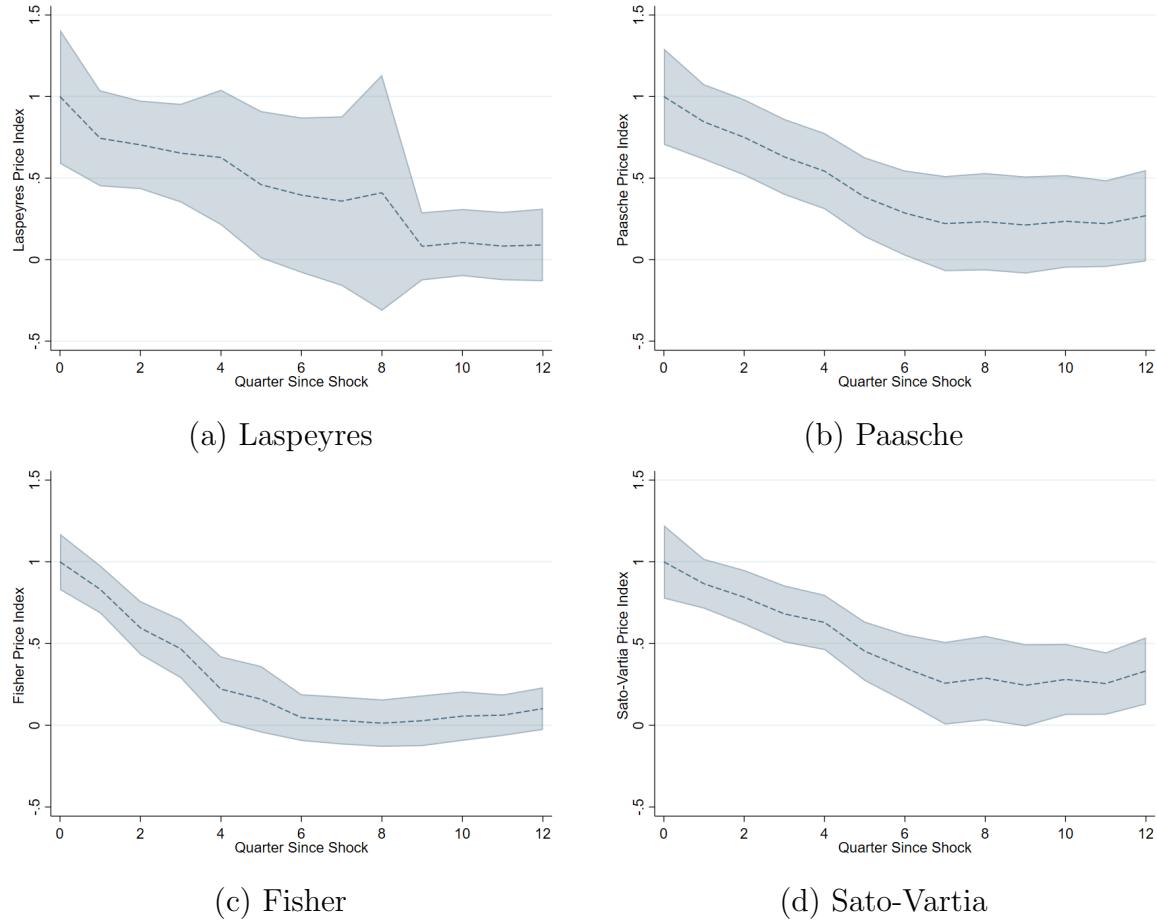


B Asymmetric Responses to Household Inflation Shocks

In this section I perform a similar analysis as the one used to construct figures 3, 4, and 5, but I allow for asymmetric responses to inflation and deflation shocks. I define a positive inflation shock as $\max\{0, \pi_{ht}\}$ and a negative inflation shock (deflation) as $\min\{0, \pi_{ht}\}$.

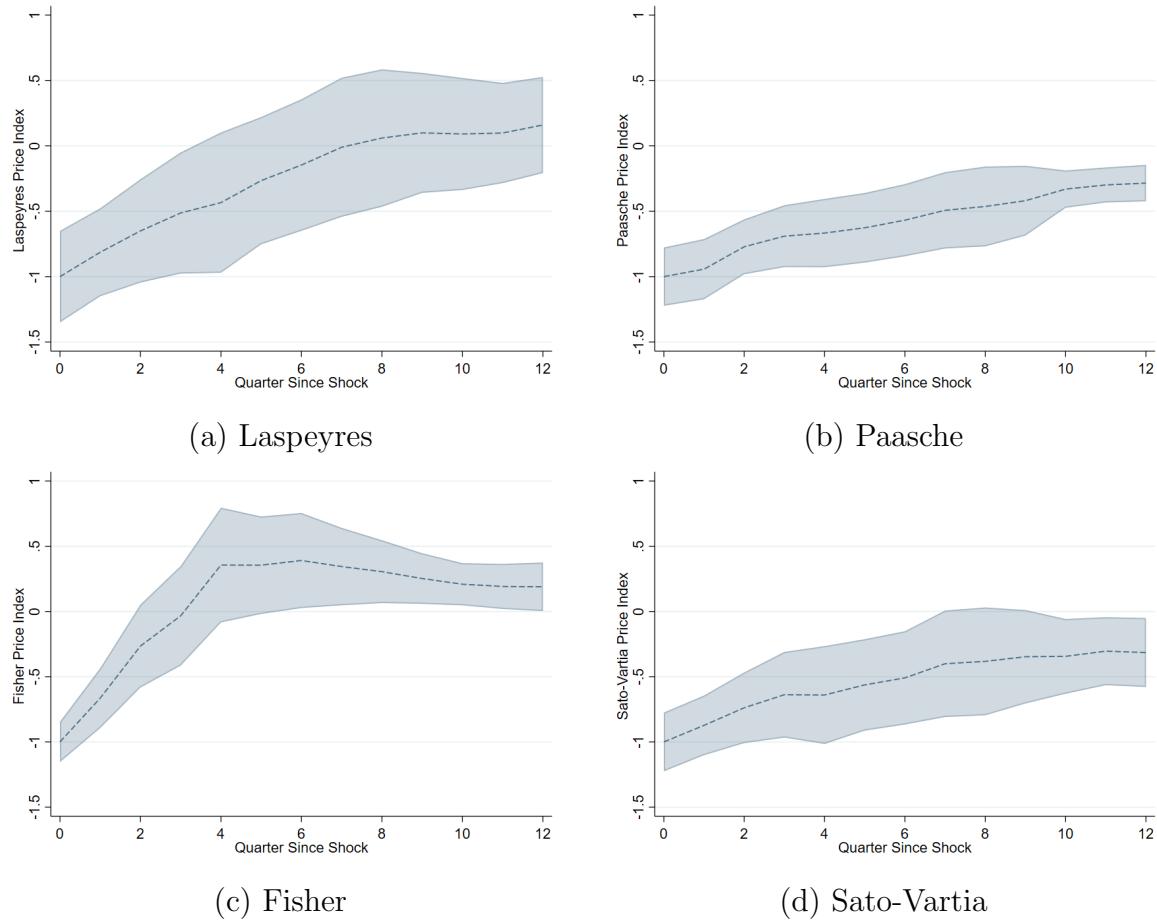
B.1 Price Index

Figure 8: Path of Household Retail Price-Index Following Positive Household Inflation Shock



Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Confidence interval (99 percent) is shown as the shaded area.

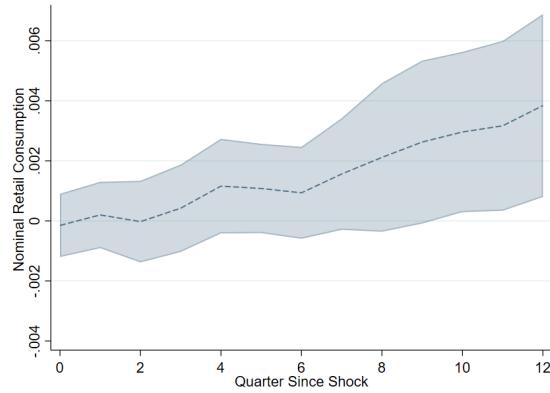
Figure 9: Path of Household Retail Price-Index Following Negative Household Inflation Shock



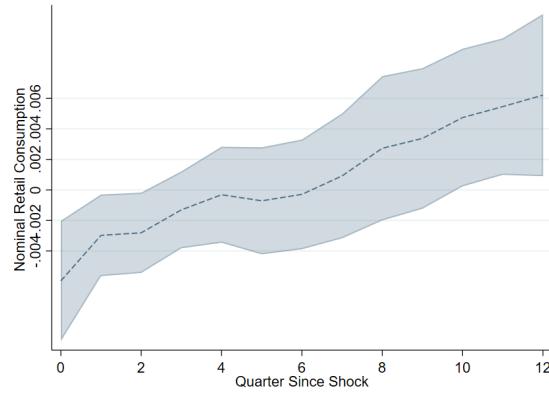
Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Confidence interval (99 percent) is shown as the shaded area.

B.2 Nominal Consumption

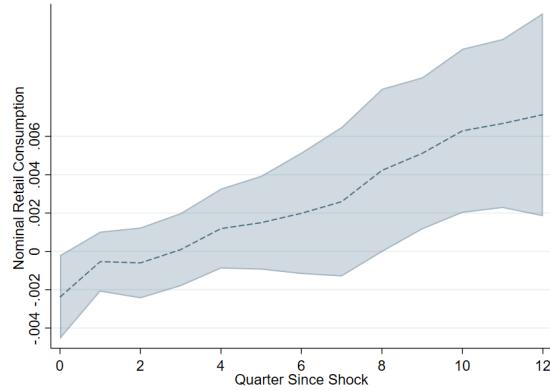
Figure 10: Response of Nominal Household Retail Consumption to a Positive one-unit Household Inflation Shock



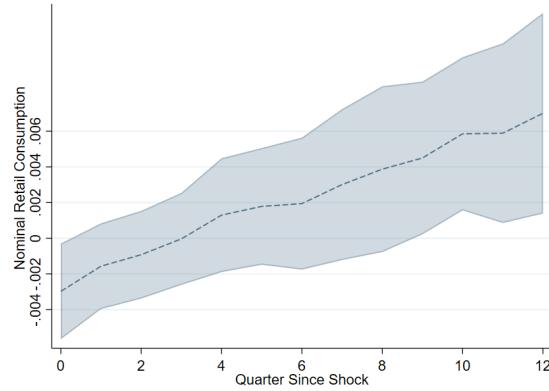
(a) Laspeyres



(b) Paasche



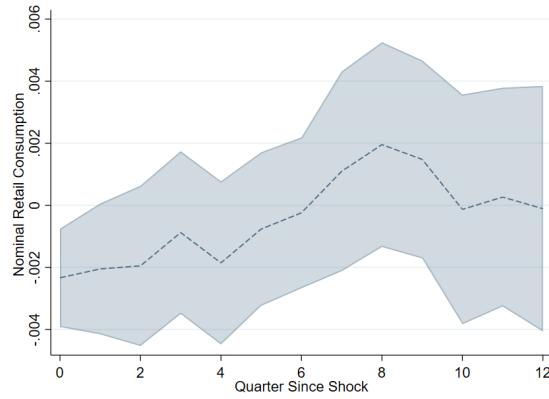
(c) Fisher



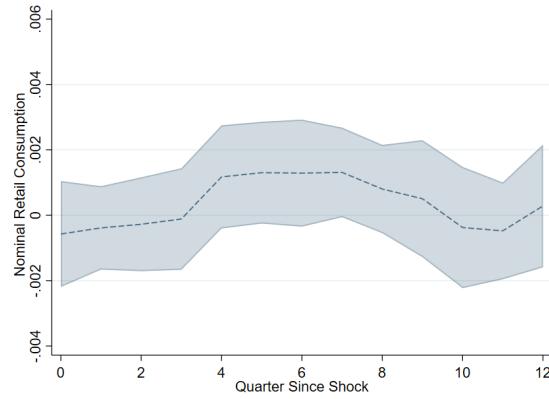
(d) Sato-Vartia

Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Blue shaded area indicates 95 percent confidence interval.

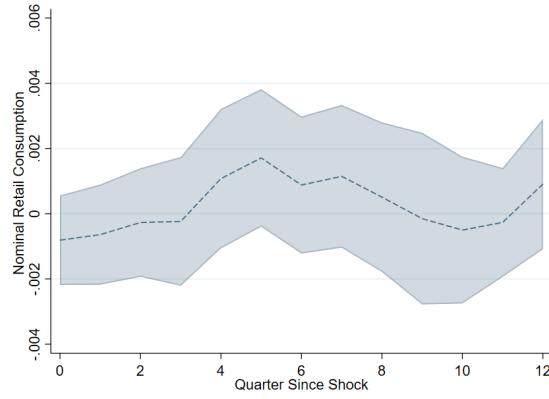
Figure 11: Response of Nominal Household Retail Consumption to a Negative one-unit Household Inflation Shock



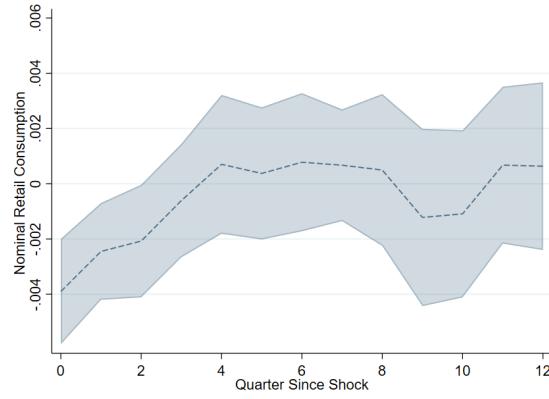
(a) Laspeyres



(b) Paasche



(c) Fisher

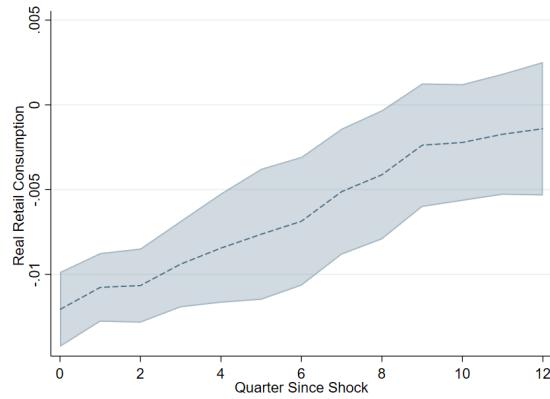


(d) Sato-Vartia

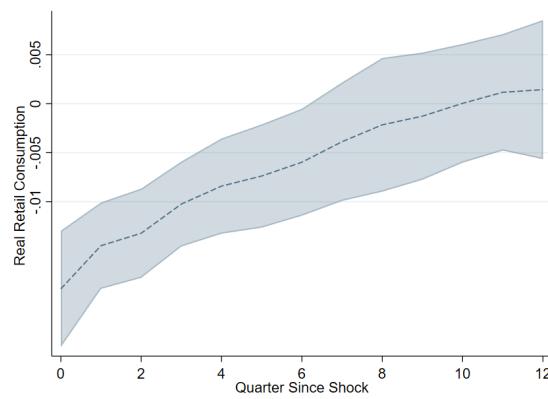
Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Blue shaded area indicates 95 percent confidence interval.

B.3 Real Consumption

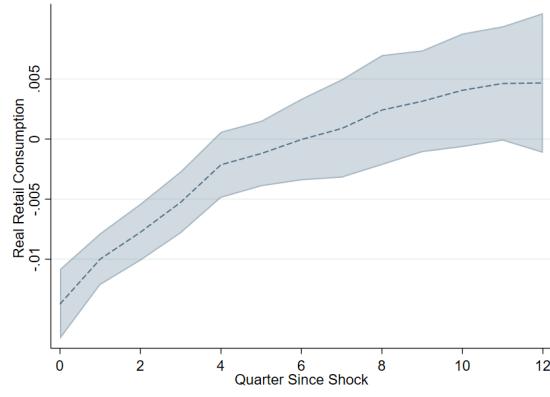
Figure 12: Response of Real Household Retail Consumption to a Positive one-unit Household Inflation Shock



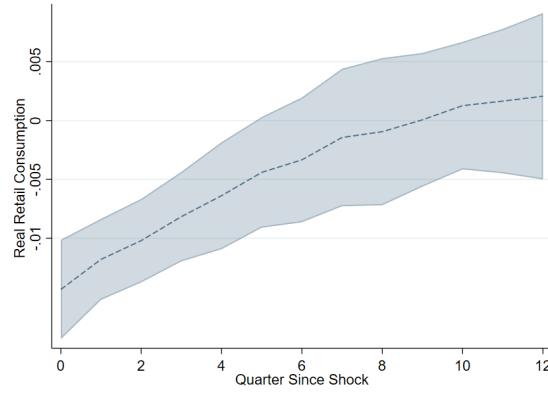
(a) Laspeyres



(b) Paasche



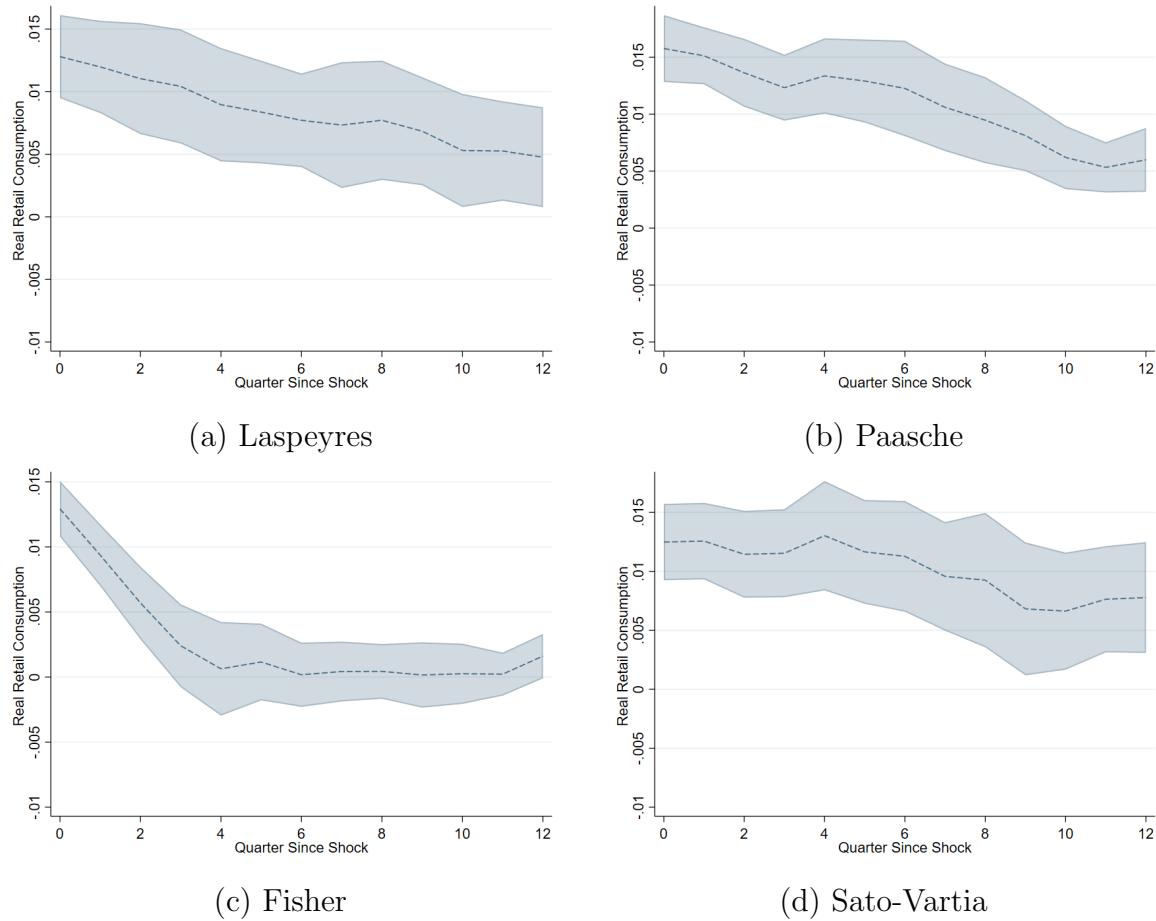
(c) Fisher



(d) Sato-Vartia

Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Blue shaded area indicates 95 percent confidence interval.

Figure 13: Response of Real Household Retail Consumption to a Negative one-unit Household Inflation Shock



Note: Standard errors robust to auto-correlation and are two-way clustered at the quarter and household level. Blue shaded area indicates 95 percent confidence interval.

C Response of Consumption to Inflation Shock by Income Group

D Simple model of household inflation rates

From an earlier version of the paper. Shows how the relationship between inflation and inflation dispersion is not simply mechanical.

Suppose firms (k) produce one consumption good and set prices so that:

Table 9: Response of Spending to Household Inflation Shock by Income Group: CEX

	$\ln(P \cdot C)$ (last 3 months)	$\ln(P \cdot C)$ (total categorical)	$\ln(P \cdot C)$ (last 3 months)	$\ln(P \cdot C)$ (total categorical)
$\pi_{h,t}$	-0.00149 (0.00220)	-0.00622 (0.00929)		
$\pi_{h,t}^+$			-0.00991* (0.00520)	-0.0124 (0.0140)
$\pi_{h,t}^-$			-0.00235 (0.00155)	0.000808 (0.00651)
$\pi_{h,t} \times$ 2nd Quartile	-0.00439*** (0.00108)	-0.00460*** (0.00165)		
$\pi_{h,t} \times$ 3rd Quartile	-0.00660*** (0.00123)	-0.00861*** (0.00229)		
$\pi_{h,t} \times$ 4th Quartile	-0.00645*** (0.00172)	-0.0104** (0.00402)		
$\pi_{h,t}^+ \times$ 2nd Quartile			0.00900*** (0.00312)	0.0143*** (0.00484)
$\pi_{h,t}^+ \times$ 3rd Quartile			0.00774** (0.00316)	0.0116** (0.00474)
$\pi_{h,t}^+ \times$ 4th Quartile			0.0169*** (0.00576)	0.0284** (0.0127)
$\pi_{h,t}^- \times$ 2nd Quartile			0.0111*** (0.00252)	0.0174*** (0.00525)
$\pi_{h,t}^- \times$ 3rd Quartile			0.0205*** (0.00463)	0.0290*** (0.00832)
$\pi_{h,t}^- \times$ 4th Quartile			0.0257*** (0.00633)	0.0473*** (0.0138)
N	382,058	381,927	382,058	381,927

Note: The omitted group is the first income quartile. Standard errors, in parentheses, clustered at the individual and time level and are robust to auto-correlation. Significance at the one percent, five percent and ten percent levels indicated by ***, **, and *. I also include income group and time fixed effects, as well as a lag of the dependent variable.

$$p_{k,t} = \varphi_k \bar{P}_t e^{z_{k,t}}. \quad (\text{D.1})$$

Where φ_k is a constant markup, \bar{P}_t is the aggregate price level at time t and $z_{k,t}$ is a firm and time specific cost-push shock. ($\sum_{k=1}^N \alpha_k z_{k,t} = 0$). Think of the time specific cost-push shock as coming from the firms decision to change prices in a Golosov and Lucas Jr (2007) style model. Suppose further that this idiosyncratic shock evolves in the following way:

$$z_{k,t} = \rho_k z_{k,t-1} + \epsilon_{k,t} \quad (\text{D.2})$$

$$\epsilon_{k,t} \sim (0, \sigma_{k,t}) \quad (\text{D.3})$$

Each period the firm gradually adjusts prices back to its normal markup over the aggregate price level, but is also subject to a new shock ($\epsilon_{k,t}$). Change in prices for firm k can then be given by:

$$\log(p_{k,t}/p_{k,t-1}) = \log\left(\frac{\bar{P}_t}{\bar{P}_{t-1}}\right) + (\rho_k - 1)z_{k,t-1} + \epsilon_{k,t}.$$

For simplicity, assume that households have Cobb-Douglas style utility over the goods provided by N firms (this corresponds exactly to Laspeyres or Paasche inflation).

Then their price index is:

$$P_{h,t} = \prod_{k=1}^N \left(\frac{p_{k,t}}{\alpha_{h,k}} \right)^{\alpha_{h,k}} \quad (\text{D.4})$$

Combining the household's price index and the law of motion of firm prices allows me to

solve for the expected value and variance of the households inflation rate:

$$\mathbb{E}[\pi_{h,t}] = \log\left(\frac{\bar{P}_t}{\bar{P}_{t-1}}\right) + \sum_{k=1}^N \alpha_{h,k}(\rho_k - 1)z_{k,t-1} \quad (\text{D.5})$$

$$Var[\pi_{h,t}] = \sum_{k=1}^N \alpha_{h,k}^2 \sigma_{k,t}^2 \quad (\text{D.6})$$

On average, households should expect their inflation rate to equal aggregate inflation plus the weighted average of the firms prices adjusting back toward their normal level. If I make the simplifying assumption, that the distribution of the cost-push shock is the same for all firms then:

$$Var[\pi_{h,t}] = \sigma_t^2 \sum_{k=1}^N \alpha_{h,k}^2 \quad (\text{D.7})$$

The variance of the household's inflation shock (which corresponds to inflation dispersion) depends on two things: (1) the variance of the firms price shocks (price change dispersion, which is a rate and different than the level price dispersion in New Keynesian models). (2) The household's Herfindahl index (preference intensity) over goods.

I test whether this model can explain the relationship I find between inflation dispersion and inflation by testing whether σ_t^2 varies with aggregate inflation. I extract the firm's cost push shocks ($\epsilon_{t,k}$) from the Nielsen data by running the following series of regressions:

$$\log(p_{k,t}) - \log(p_{k,t-4}) = \beta_0 \bar{\pi}_t + \nu_{k,t} \quad (\text{D.8})$$

where $p_{k,t}$ is average price of a unit in Nielsen product module k in quarter t and $\bar{\pi}_t$ is average annual household inflation rate in quarter t . Note that:

$$\nu_{k,t} = (\rho_k - 1)z_{k,t-4} + \epsilon_{k,t} = (\rho_k - 1)(\rho_k z_{k,t-8} + \epsilon_{k,t-4}) + \epsilon_{k,t} \quad (\text{D.9})$$

So $\epsilon_{k,t}$ should be the residuals from regression of $\nu_{k,t}$ on $\nu_{k,t-4}$. Note that the coefficient on this regression should be negative (it is). Finally, I regress the standard deviation of the firm's cost push shocks on aggregate inflation. My resulting coefficient is 0.006 with a standard error of 0.002. While this result is positive and statistically significant indicating that this model can help explain the relationship between inflation dispersion and aggregate inflation, it is orders of magnitude too small.

One key assumption I made was that $\sigma_{k,t} = \sigma_t \forall k$. I do not expect that firms should all have the same relationship between the “cost-push” shock and aggregate inflation. For example, firms in some sectors may be more able to adjust their prices to inflation than firms in other sectors. Households buy different goods of varying stickiness (Cravino et al. 2018), which could help explain the large relationship between inflation and inflation dispersion that I see; however, this does not explain the relationship between inflation and inflation dispersion within narrow product categories. Kim (2019) shows that as product price (and by extension quality) within categories increases, price changes become more infrequent. Differences in the average product quality of a household's bundle may then also contribute to inflation dispersion.

Despite its failure to explain the inflation dispersion and inflation relationship, the model's prediction that households with higher preference intensity should have more volatile inflation rates is quite accurate.

I measure each household's inflation volatility as deviations from the aggregate inflation rate as $(\pi_{h,t} - \bar{\pi}_t)^2$ and regress this measure on their Herfindahl index. Table 10 shows the results of this regression using sequential Laspeyres inflation rates in the Nielsen data (note that this is an older result and will be updated).

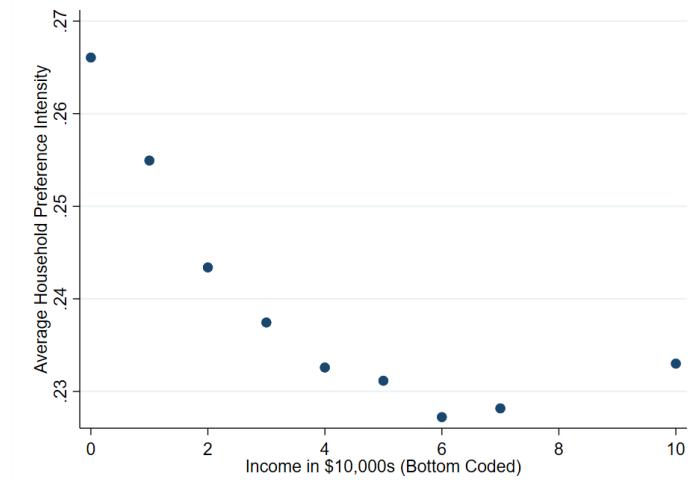
Figure 14 shows that poorer households on average have a higher preference intensity over products, which suggests that poor households may have more volatile inflation rates. However, the actual average difference in preference intensity between income groups is not that large.

Table 10: High Preference Intensity \implies Volatile Inflation

	$(\pi_{h,t} - \bar{\pi}_t)^2$	$(\pi_{h,t} - \bar{\pi}_t)^2$
$\sum_{k=1}^N \alpha_{h,k}^2$	20.71 (4.121)	21.05 (4.207)
$ \bar{\pi}_t $		1.572 (0.412)
Observations	2,404,480	2,404,480

Standard Errors (in parentheses) robust to auto-correlation and are two-way clustered at the household and quarter levels.

Figure 14: Preference Intensity by Income Group



E Inflation Rates and Volatility by Income Group

Table 11: Household Inflation Volatility and Income

Panel A: Nielsen Homescan

Household Income	Laspeyres $(\pi_{h,t} - \bar{\pi}_t)^2$	Paasche $(\pi_{h,t} - \bar{\pi}_t)^2$	Fisher $(\pi_{h,t} - \bar{\pi}_t)^2$	Sato-Vartia $(\pi_{h,t} - \bar{\pi}_t)^2$
\$25k-50k	1.973*** (0.664)	1.452** (0.567)	0.441* (0.254)	0.433 (0.517)
\$50k-100k	1.909*** (0.693)	1.758** (0.684)	0.555* (0.285)	0.741 (0.611)
> \$100k	1.441* (0.858)	1.297* (0.664)	0.377 (0.295)	0.991 (0.720)
Time Fixed Effects	X	X	X	X
N	1,894,135	1,894,135	1,894,135	1,894,135

Panel B: CEX

Household Income	Laspeyres $(\pi_{h,t} - \bar{\pi}_t)^2$	Paasche $(\pi_{h,t} - \bar{\pi}_t)^2$
2nd Quartile	-15.72*** (2.316)	-16.79*** (2.335)
3rd Quartile	-17.13*** (2.299)	-17.81*** (2.300)
4th Quartile	-18.56*** (2.422)	-19.39*** (2.364)
Time Fixed Effects	X	X
N	243,468	243,468

Note: Omitted category is less than \$25,000 household income for the Nielsen Homescan and 1st quartile for the CEX. Standard errors,in parentheses, clustered at the household and quarter levels (Newey-west HAC standard errors were too much for my computer; I will run this on the server later). Significance at the one, five and ten percent levels indicated by ***,**, and * respectively. Aggregate Inflation, $|\bar{p}_i|$ is a democratic index of individual inflation weighted using the population weights in the Nielsen Homescan or CEX. National prices are used throughout.

Table 12: Average Inflation Rates of Income Group Compared to National Rate

Panel A: Nielsen Homescan

Household Income	Laspeyres	Paasche	Fisher	Sato-Vartia
	$\pi_{h,t} - \bar{\pi}_t$	$\pi_{h,t} - \bar{\pi}_t$	$\pi_{h,t} - \bar{\pi}_t$	$\pi_{h,t} - \bar{\pi}_t$
\$25k-50k	0.0375* (0.0194)	-0.0917*** (0.0112)	-0.0292*** (0.00981)	-0.0883*** (0.0116)
\$50k-100k	-0.00714 (0.0227)	-0.164*** (0.0145)	-0.0845*** (0.0126)	-0.157*** (0.0169)
> \$100k	-0.0526* (0.0275)	-0.159*** (0.0154)	-0.103*** (0.0141)	-0.150*** (0.0198)
Time Fixed Effects	X	X	X	X
N	2,325,692	2,325,692	2,325,692	2,325,692

Panel B: CEX

Household Income	Laspeyres	Paasche
	$\pi_{h,t} - \bar{\pi}_t$	$\pi_{h,t} - \bar{\pi}_t$
2nd Quartile	-0.120*** (0.0277)	-0.0780*** (0.0248)
3rd Quartile	-0.205*** (0.0357)	-0.146*** (0.0322)
4th Quartile	-0.314*** (0.0364)	-0.266*** (0.0342)
Time Fixed Effects	X	X
N	243,468	243,468

Note: Omitted category is less than \$25,000 household income for the Nielsen Homescan and 1st quartile for the CEX. Standard errors,in parentheses, clustered at the household and quarter levels (Newey-west HAC standard errors were too much for my computer; I will run this on the server later). Significance at the one, five and ten percent levels indicated by ***, **, and * respectively. Aggregate Inflation, $|\bar{p}_i|$ is a democratic index of individual inflation weighted using the population weights in the Nielsen Homescan or CEX. National prices are used throughout.

F Effective versus Common Prices

In this project I calculated household inflation rates using the household shares for the particular product as weights and the change in the national average price paid for the product as the price change p_t/p_{t-1} ; however, it is not obvious that using the common/average prices for the product is the most accurate way to calculate changes in a household's inflation rate.

Kaplan and Schulhofer-Wohl (2017) use the price the household actually paid for the product instead (effective price). As I discussed in the text, there are several problems with using the effective versus the common price:

- In order to calculate the change in price between two periods the household must buy that same product in both periods, which is only a small fraction of their total basket (around 25 percent in Kaplan and Schulhofer-Wohl (2017)). Since household behavior is likely shaped by changes in prices this would lead to households endogenously sorting to products that have either not changed their price or lowered their price rather than products that have increased their price; which would bias the household's inflation rate downward.
- Changes in the household's effective price paid could be a result of the household switching stores or using coupons in one period and not using them in the next. In terms of the standard cost of living index (COLI), those using effective prices to calculate household inflation rates should take a stance on the consequences of store-switching and the change in effort (coupons or no coupons, shopping during sales during the quarter, etc) on household utility.
- In my main analysis, I use either the Nielsen product module or the CEX expenditure category as my definition of product. Use of effective prices virtually necessitates using the upc code or the brand as the definition of product, else changes in effective price from one period to another could simply be the result of product switching. I will discuss my rational for using a slightly larger category of product in another section of the appendix.

I favor using the common (national) rather than the effective price in my analysis for the reasons above and because the common price is exogenous to the household's behavior. However, In the remainder of this section I justify my decision: (1) I show that my results are robust to repeating my main analysis in table 4, but using effective rather than common prices; (2) I follow Kaplan and Menzio (2015) in creating a relative price index for each household which is based exclusively on the prices that the household pays for their bundle

Table 13: Household Inflation Dispersion and Aggregate Inflation with Effective Prices

	Laspeyres $\sigma(\pi_h)$	Paasche $\sigma(\pi_h)$	Fisher $\sigma(\pi_h)$	Sato-Vartia $\sigma(\pi_h)$
$ \bar{\pi} $	0.587 (0.372)	0.321*** (0.0355)	0.462* (0.231)	0.232*** (0.0511)
N	52	52	52	52

Note: Newey-west HAC standard errors in Parentheses. Significance at the one, five and ten percent levels indicated by ***, **, and * respectively. Aggregate Inflation, $|\bar{\pi}|$ is a democratic index of individual inflation weighted using the population weights in the Nielsen Homescan. Effective prices are used throughout.

relative to national prices. I show that the distribution of changes in these “relative” price indexes is stable over time; (3) I attempt to create another version of household inflation with effective prices by combining the Nielsen Retail Scanner data with the Consumer panel data (I do this only for one product module due to the massive amount of computing power this requires). I construct inflation rates where the product is defined at the upc-store level, which fixes the household’s choice of store over time. I show that this new measure of inflation is highly correlated with my household level inflation rates using common prices, but not to the Kaplan and Schulhofer-Wohl (2017) style inflation rates using effective prices.

F.1 Robustness check using effective prices

Table 13 shows the results of repeating my main analysis from table 4, but using effective prices rather than common prices. My results are similar in magnitude to the results using common prices, although they are not quite as statistically significant. Here, I define a product as the product module as I do in my main text.

F.2 Distribution of Relative Price Indexes over time

When measuring changes in the cost of living, how important is using exactly the price that a household pays for a given product? To help answer this question, I follow Kaplan and Menzio (2015) and create relative price indexes in the following manner:

Table 14: Household relative price distribution AR(1)

	(1) RP_{ht}	(2) RP_{ht}
RP_{ht-1}	0.746*** (0.00920)	0.743*** (0.00963)
Δ Household Size		0.000235 (0.000156)
Δ Marital Status		-0.000493*** (0.000180)
Time FE	X	X
Household Income FE		X
N	2,972,187	2,972,187

Note: Newey-west HAC standard errors in Parentheses clustered at the quarter household level. Significance at the one, five and ten percent levels indicated by ***, **, and * respectively.

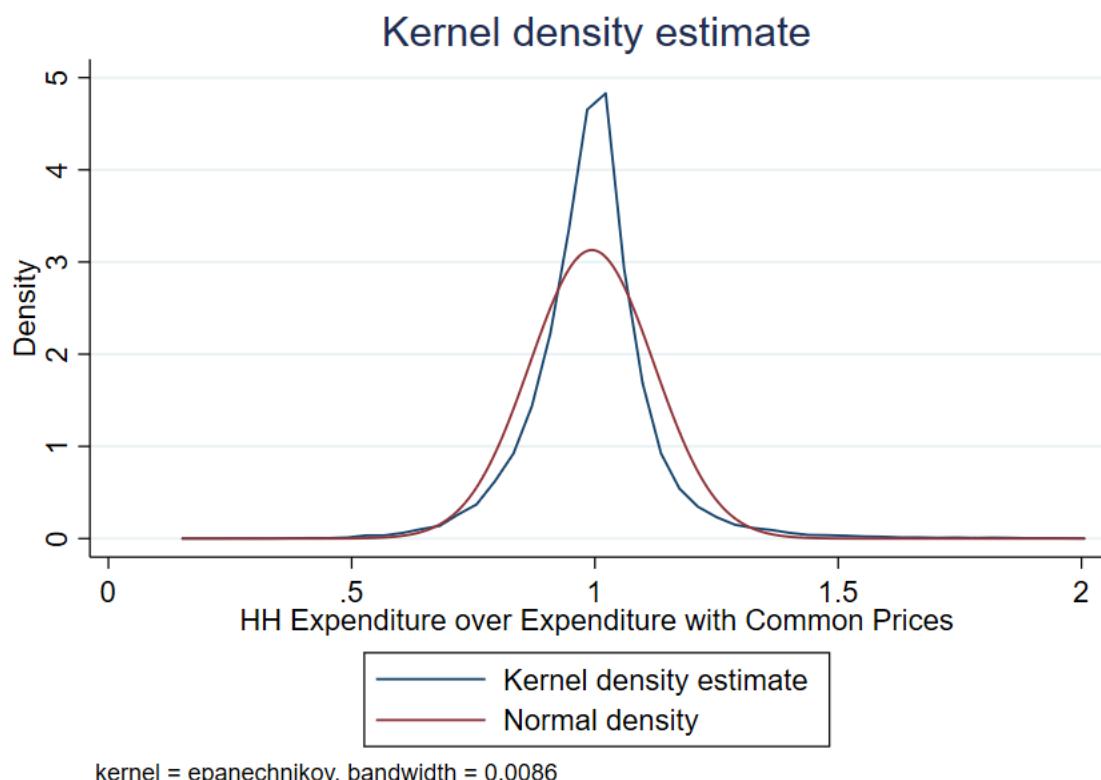
$$RP_{ht} = \frac{\sum_n s_{n,h,t} p_{n,ht}}{\sum_n s_{n,h,t} p_{n,t}}, \quad (\text{F.1})$$

where $s_{n,h,t}$ is the household (h) specific consumption share of good n at time t, $p_{n,ht}$ is the price that the household actually pays for product n, and $p_{n,t}$ is the national average price for the product. RP_{ht} is equal to one when the household on average pays the same prices for products in their bundle as national prices, while $RP_{ht} < 1$ or $RP_{ht} > 1$ implies that the household is buying their bundle at a discount or a premium respectively. The relative price index is a convenient way to separate changes in the cost of living into changes in prices the household pays compared to national prices and differences in consumption shares compared to the national average.

Figure 15 shows the distribution of relative price indexes for all households in 2017Q1 in blue. For comparison, I also included the standard normal pdf in red. The relative price index has less variance and heavier tails than the normal and is slightly skewed to the right.

Does the household's position in the relative price index distribution change over time?

Figure 15: Distribution of Relative Price Indexes: 2017Q1



Note: Nielsen Consumer Expenditure Survey 2017Q1.

That is, do households frequently switch from paying a premium for their bundle to getting their bundle at a discount? Table 14 shows the results of regressing a household's RP_{ht} on their relative price index from the previous quarter. Column 1 presents the baseline results while column 2 adds additional controls for changing marital status, household size and income level. I find that there is a strong correlation between a household's relative price index this period and last period, however this correlation is not one; so households do shift around in the distribution of relative prices (possibly because of store switching, using coupons, etc.).

How important are changes in household RP_{ht} for shifts in the distribution of household inflation rates? Figure 16 shows the distribution of changes in the relative price index (defined as $\frac{RP_{ht} - RP_{ht-1}}{RP_{ht-1}}$) over time. The distribution is relatively constant except for a spike in 2012 (heretofore unidentified data issues with prices in the Nielsen Homescan). Since the distribution is constant, changes in the distribution of relative price indexes cannot explain the relationship we find between inflation and inflation dispersion.

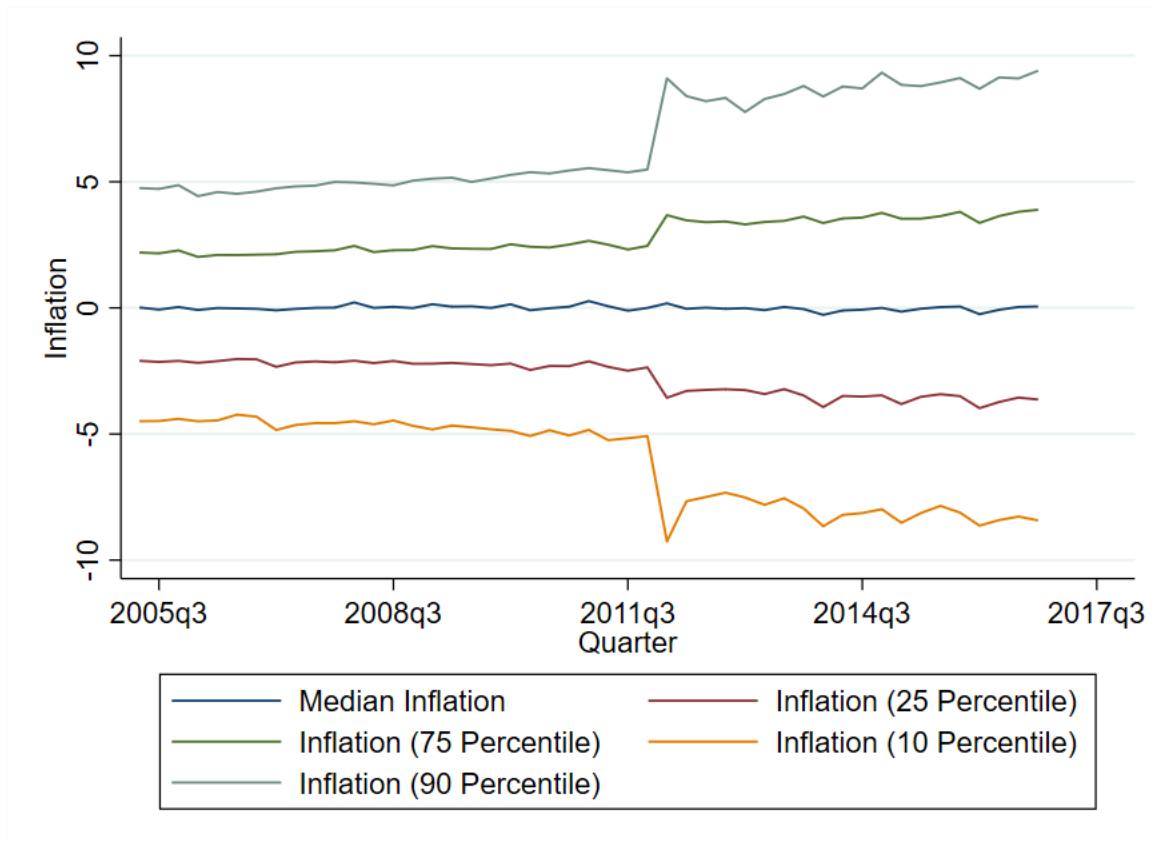
F.3 Household inflation rates using store-specific prices

When a household buys a product the price the household pays for the product n can be decomposed into three different components:

$$p_{n,h,t} = \underbrace{p_{n,t}}_{\text{Common Price}} \times \underbrace{S_{n,h,t}}_{\text{Store Premium}} \times \underbrace{\varphi_{n,h,t}}_{\text{Shopping Effort Premium}} . \quad (\text{F.2})$$

As discussed before, when trying to calculate household inflation rates using changes in $p_{n,h,t}$ the prices $p_{n,h,t}$ are only observed for products the household buys in both periods (common products). Furthermore, the change in $p_{n,h,t}$ could be a result of changes in shopping effort $\varphi_{n,h,t}$ or a change in $S_{n,h,t}$ because of store switching. Rather than taking a stand on household utility from shopping effort or store switching or trying to extrapolate changes in the cost of living for common products on non-common products, I use the Nielsen Retail Scan data to create a more complete measure of household inflation.

Figure 16: Distribution of changes in RP_{ht} over time



Note: Nielsen Consumer Expenditure Survey 2004-2017.

The Nielsen Retail Scan (RMS) data is point of sale data from over 30,000 retail stores that includes the revenue and quantity sold for every product (defined at the upc level) during each week (it is from these data that the Nielsen Consumer Panel extrapolates household level prices for goods purchased at participating stores). The Nielsen Consumer panel has a store code for purchases from stores that are also listed in the RMS data. For select product modules (currently cereal) I combine the Consumer Panel and the RMS data and calculate household level prices as:

$$p_{n,h,t-k}^t = p_{n,t-k} \times S_{n,t-k}^{n,h,t}. \quad (\text{F.3})$$

Here, $S_{n,t-k}^{h,n,t}$ is the store premium for the store that the household bought good n at time t. This allows me to fix shopping effort and store rather than take a stance on the relationship of shopping effort and store switching with household utility. Another benefit is that since stores stop selling products much less often than households stop buying products I no longer need to rely on goods that are common to the household's basket in both periods.

So household inflation is defined as:

$$\pi_{h,t}^S = \sum_n w_{n,h,t} \frac{p_{n,h,t}^t}{p_{n,h,t-4}^t}, \quad (\text{F.4})$$

where the period is a quarter and I look at the change in prices four quarters back to control for seasonality. Finally, $w_{n,h,t}$ is the household weight on product n (in this example I use Laspeyres weights). Not all household purchases are from a store that is in the RMS data. Non RMS-store purchases simply use the common price instead of $p_{n,h,t-k}^t$.

Constructing this household inflation measure is computationally intense. Rather than construct this measure for all product modules I test how similar this measure is to my previously constructed inflation measures: π^c common prices, π_r regional prices, and π_f effective prices (which corresponds to the inflation rates in Kaplan and Schulhofer-Wohl (2017)). Table 15 shows the results of this comparison. There is a high correlation between the common and region price inflation rate measures that I use in the text and the store

Table 15: Household Inflation Rates with Store Specific Prices v. Other Inflation Measures

	π^s	π^s	π^s
π^c	0.713*** (0.0270)		
π^r		0.730*** (0.0134)	
π^f			-0.0131*** (0.00317)
Household FE	X	X	X
Time FE	X	X	X
N	428,879	428,879	428,878
R-squared	0.421	0.753	0.389

Note: Nielsen Consumer Panel and Nielsen Retail Scan data. Only includes cereal products. Products defined at the upc level. Standard errors in parentheses. Significance at the one, five and ten percent levels indicated by ***, **, and * respectively.

price measure. The effective price measure is actually negatively correlated to the store price inflation measure (perhaps because of the selection bias issue that I raised earlier).

G Shampoo Prices

Using Nielsen RMS data on Shampoo sales I look at the relationship between price changes for a product (defined at the barcode) and the price of the product. I find that more expensive prices have stickier prices than middle price products.

Figure 17: Shampoo Prices Over Time

