Non-homothetic Demand Shifts and Inflation Inequality

Jacob Orchard

Federal Reserve Board

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Abstract

How do income-level inflation rates respond to aggregate shocks? In this paper, I document two new facts: (1) during every US recession since 1959, aggregate spending has shifted toward products purchased relatively more by low-income households (necessities); and (2) relative prices of necessities rise during recessions. I show that non-homothetic demand accompanied by a concave production possibility frontier can explain both facts as adverse macroeconomic shocks which lower expenditure cause households to shift expenditure away from luxuries toward necessities, which leads to higher relative prices for necessities. I show empirically, with monetary policy and oil news price shocks, that this mechanism operates for both demand and supply shocks. For the oil price shock, I decompose the effect on relative prices into a direct effect from differences in oil shares in production and an indirect nonhomothetic effect due to the fall in real expenditure; the nonhomothetic effect is responsible for nearly half of the oil price induced change in relative necessity prices. I embed the mechanism into a quantitative model which is able to explain the majority of the variation in necessity prices and shares from 1961 to 2024. The model shows that the fall in expenditure due to a recessionary shock similar to the Great Recession leads to inflation for low-income households to increase by more than 1.5 percentage points relative to inflation for high-income households. The results suggest that low-income households are hit twice by adverse shocks: once by the shock itself and again as their price index increases relative to that of other households.

JEL Classification: E30, D12
KEYWORDS: inflation, non-homotheticity, real income inequality, business cycle, monetary policy

Contact: jake@jakeorchard.com
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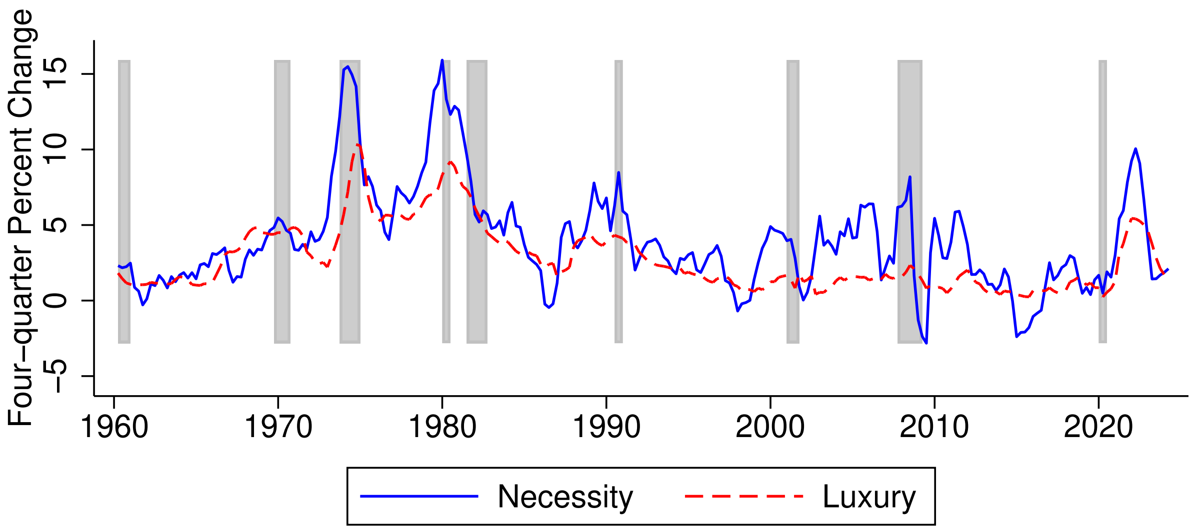
Recent literature has established that over the last several decades, inflation has been higher for low-income than high-income households.[1] In this paper I show that not only does the gap in inflation between low- and high-income households (inflation inequality) vary overtime, it increases following adverse shocks such as recessions and oil shocks. Shocks that lower aggregate expenditure also lead to a shift in demand from luxuries to necessities. In the short-term, this shift in demand raises the relative price of necessities, which impacts low-income households more as necessities occupy a higher proportion of their budgets relative to high-income households.

This paper makes three main contributions. First I show empirically, that the types of products that are a larger share of low-income households budgets than high-income households (defined as necessities in this paper) have counter-cyclical relative demand. This is both true in the aggregate time-series where the aggregate share of necessities has increased in every recession since 1959, but also true in response to plausibly exogenous shocks that lower aggregate expenditure. Second, I show that these same products also have counter-cyclical relative prices that are positively correlated with unemployment and other measures of economic slack in the aggregate time series (conditional on oil prices) and they increase following exogenous shocks that lower aggregate expenditure. Third, I argue that non-homothetic demand and a concave production possibilities frontier can rationalize these facts and I place this framework into an otherwise standard business cycle model and this model is able to explain the majority of the variation in relative necessity prices from 1961-2024. The quantitative model is able to decompose changes in inflation inequality into contributions from the non-homothetic and other channels and finds that the non-homothetic channel has contributed substantially to inflation inequality in many US recessions (including increasing inflation inequality by over 1 percentage points in each of the Great Recession, COVID-19 Recession, and the two Volcker recessions).

In order to study differences in household-level price indices across time, I match products in the BEA's Personal Consumption Expenditures (PCE) with equivalent spending in the Consumer Expenditure Survey (CEX) resulting in 148 product sectors for which I have aggregate expenditure and prices, alongside household level purchasing patterns. I define

[1] See for example Jaravel (2019), Argente and Lee (2021), and Jaravel and Lashkari (2024)

Figure 1: Inflation Rates of Luxuries and Necessities



Source: BLS, BEA, and Author's own calculations.
Notes: Necessities defined as sectors whose average expenditure share from 1980-2023 was higher for low-income than high-income households. Chained fisher price indices. Excludes housing and non-market consumption.

necessities as products where low-income households have a higher budget share than high income households, while and luxuries are products purchased relatively more by high-income households. To control for confounding factors including that energy prices are highly volatile and oil products are a larger portion of low-income households budgets (Känzig 2023), I derive oil production shares for each product sector using data from the BEA's input-output accounts data.

I define necessities based on household level consumption patterns, but how does *aggregate* consumption shifts between luxuries and necessities over the business cycle? I find that the aggregate expenditure share devoted to necessities has increased during every recession in my sample (from 1959 to 2024). I formally test the relationship between aggregate spending on necessities or luxuries and economic slack in a panel regression using all 148 product sectors. I find that a 1 percentage point increase in the unemployment rate is associated with a 1.6-1.7 percent increase in the aggregate share of spending on necessities.[2]

[2]This relationship continues to hold even when controlling for whether products are durables or services. and is not simply mechanically related to higher necessity prices, as a necessity product's relative real expenditure (nominal aggregate expenditure divided by the product-specific price index) is also positively related to unemployment.

Figure 1 shows the inflation rates of necessities (solid in blue) and luxuries (dashed in red) from 1960 to 2024. On average the inflation rate of necessities has been 4.1 percent annually compared to 2.9 percent for luxuries. Higher inflation on average for products purchased relatively more by low-income households is consistent with the findings in prior literature (e.g. Jaravel and Lashkari (2024)). However, there is considerable variation in the difference between necessity and luxury inflation and during recessions the difference has averaged 2.2 percentage points, which is twice as large as during non-recessions.

After conditioning on oil prices, which have a larger cost-share in necessities, I find that the gap between necessity and luxury inflation rate increases during recessions, is positively associated with the unemployment rate, and is negatively associated with the output gap, and changes in real PCE. In a panel regression using the 148 product sectors, I find that a 1 percent increase in the unemployment rate is associated with a 0.1-0.4 percentage point increase in the gap between inflation for necessities and luxuries. This relationship is robust to including controls for whether the product is a durable, a service, and the typical price-change frequency of the product, and the sector's labor share.

Having documented that both necessity relative prices and aggregate shares increase during recessions, I formally introduce a static model that can rationalize these facts. The critical components of this model are non-homothetic preferences at the aggregate level and a concave production possibilities frontier (PPF). The non-homothetic preferences lead to cyclical demand shifts between necessities and luxuries that track the evolution of aggregate consumption expenditure. The concave production possibilities frontier leads to higher relative costs for the expanding sector. These components are sufficient for an aggregate decrease in expenditure to lead to a relative expansion in the necessity sector and higher relative necessity prices. The source of the shock to expenditure does not matter in the model, both aggregate demand shocks and supply shocks that induce the same fall in expenditure will induce the same change in relative prices when holding the relative supply curve constant. However, supply shocks that affect productivity in one sector more than the other can have an additional direct affect on the relative supply curve and can be decomposed into a direct effect on relative prices and a secondary income effect due to non-homothetic preferences and a concave PPF. For supply shocks that have a higher cost-share in necessity production, such as changes to the oil price, both the direct and secondary income effects will both lead to higher necessity prices.

Is aggregate demand non-homothetic? While the cross-sectional data show that low-income and high-income households buy different bundles, this finding does not necessarily imply that aggregate preferences are non-homothetic; i.e. in response to an exogenous shock that changes aggregate consumption, does the aggregate consumption bundle become more like the low-income household's bundle?[3] I test this assumption along with the model's primary conclusion, an increase in necessity prices following a decrease in aggregate expenditure, using monetary policy news shocks from Bauer and Swanson (2022b) as a stand in for a pure demand shock and oil price news shocks from Känzig (2021) as an adverse supply shock. These results show that an exogenous shock that lowers aggregate expenditure also leads to higher relative necessity prices and consumption.

Since the non-homothetic demand shift mechanism operates through changes in expenditure, I first show that both a one-standard deviation monetary policy news shock and a one-standard deviation oil price shock both lead to approximately 0.2 percent declines in real PCE spending that persist for several years after the initial shock. In a panel local projection of the 148 PCE sectors, the same one-standard deviation monetary policy shock leads to a 0.5 percent increase in the aggregate share of low-income intensive products and a 0.25 percent increase in their relative price, which implies that the necessity relative price elasticity to expenditure is around -1.

In panel local projections, I empirically decompose the oil price shock into a total effect on necessity relative shares and prices, and an indirect effect due to the oil-shock induced decline in expenditure. I find that the total effect of the oil price shock leads to approximately a 0.3 percent increase in necessity shares and a 0.2 percent increase in necessity prices in the three years following the shock. Part of the increase in relative prices is due to the much larger share that oil plays in necessity production. I isolate the indirect nonhomothetic effect of these oil price shocks on necessity relative shares and prices by conditioning the

[3]This question is also related to the relationship between income and expenditure elasticities. I define products as necessities/luxuries based on income elasticity and then test the aggregate expenditure elasticity of these products. The relationship between household income and aggregate expenditure elasticities is partially responsible for cyclical price index disparities across income groups.

local projection at each horizon by the change in oil prices until that horizon interacted with the PCE sector's oil share in production. I find that the indirect effect on relative shares is approximately the same as the total effect. For relative necessity prices, I find that nearly half of the total effect of the oil price change is due to the indirect effect.

Next, I present a two-sector quantitative New Keynesian model that integrates non-homothetic preferences and sector-specific oil intensities in production. Household preferences are represented by the Almost Ideal Demand System (AIDS) (Deaton and Muellbauer 1980). The AIDS inherits well-behaved aggregation properties from the Generalized Linear class of demand systems (Muellbauer 1975), which allows me to solve for aggregate necessity shares and relative necessity prices using a representative agent framework. The quantitative model is able to qualitatively match the empirical response to monetary and oil shocks and it is also able to explain a significant fraction of the historical variation in relative necessity prices and shares.

With the model in hand, I examine the contributors to variations in inflation inequality over the last 60 years. I break down the contribution to inflation inequality (cumulative changes in the non-homothetic price index between low- and high-income households) in each of the NBER defined US recessions since 1961 into the non-homothetic expenditure channel, the direct contribution of oil prices, and other (non-modeled) factors. In the Great Recession (2007Q4 to 2009Q2) the expenditure channel increased inflation inequality by 1.8 percentage points, the direct contribution of oil added another 0.7 percentage points, and other factors added another 1.5 percentage points leaving cumulative inflation for low-income households nearly *4 percentage points higher* than high-income households relative to the pre-recession trend. During other recessions, the factors can largely cancel each other out, for example during the COVID-19 induced recession the expenditure channel increased inflation inequality by nearly two percentage points, however, that was more than offset by the large fall in global oil prices and other factors over that period and the inflation rate of low-income households actually fell compared to high-income households.

This paper is most closely related to the literature on inflation inequality.[4] Early re-

[4]Inflation inequality may be a confusing term since price inflation traditionally has been defined as a general increase in the prices of goods and services in an economy or a decrease in the purchasing power of a particular currency. In the emerging literature on changes in the cost-of-living across income groups,

search by Amble and Stewart (1994), Garner et al. (1996), Hobijn and Lagakos (2005), and McGranahan and Paulson (2005) found only limited differences in inflation rates across demographic groups.[5] However, more recent work has leveraged detailed product categories as well as barcode level data to document substantial differences in inflation-rates across households (Kaplan and Schulhofer-Wohl 2017, Jaravel 2019, Cavallo 2020, Gürer and Weichenrieder 2020, Argente and Lee 2021, Lauper and Mangiante 2021) This literature has focused on either trends in inflation rate disparities (Jaravel 2019, Gürer and Weichenrieder 2020) or particular events such as the Great Recession (Argente and Lee 2021), the 1994 Mexican devaluation (Cravino and Levchenko 2017), and the COVID-19 pandemic (Cavallo 2020, Jaravel and O'Connell 2020, Chen et al. 2024). In contrast, this paper shows empirically and theoretically that inflation inequality increases following any shock that affects aggregate consumption expenditure.

Recent work has highlighted the difficulty of translating differences in trends in inflation inequality over a long-time period into differences in welfare as the basket of all households changes and becomes more luxury centric (Oberfield 2023, Jaravel and Lashkari 2024). In contrast, over the course of the busines cycle the baskets of low- and high- income households remain quite differentiated, so relative price increases for products bought more by low-income housholds prior to the recession still disproportionately affect the welfare of these low-income households.

This paper also contributes to the immense amount of research showing that recessionary shocks have heterogeneous effects on households and can exacerbate inequality.[6] Much of the past literature has focused on the cyclical behavior of nominal consumption and income inequality and has overlooked cost of living differences across households, which is the denominator of real inequality. This paper shows that failing to include differential changes in the cost-of-living can dramatically understate the true distributional consequences of recessions and other adverse shocks. As an example, Krueger et al. (2016) find that during

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"inflation inequality" is generally defined as differences in the change of the cost of achieving a particular level of utility across household groups (Jaravel 2021).

[5] An exception in this early-period is work by Crawford and Oldfield (2002) who found that few households in Britain have inflation close to the official Retail Price Index

[6] See Heathcote et al. (2020), Feiveson et al. (2020), Krueger et al. (2016), Meyer and Sullivan (2013) and Hoynes et al. (2012)

the Great Recession, nominal consumption growth fell by 0.3 percent more for households in the lowest wealth quintile compared with those in the highest. A back-of-the-envelope calculation incorporating this paper's inflation inequality estimates suggests that the actual difference in the fall of *real* consumption is an order of magnitude higher.[7]

Finally, this paper contributes to the literature on endogenous demand shifts. For example, Jaimovich et al. (2019) show that households switched from high- to low-quality products during the Great Recession and this shift in demand led to lower labor demand since low-quality products use less labor in production. Over a longer horizon, Boppart (2014) and Comin et al. (2021), show that non-homothetic demand can explain the shift from agriculture to manufacturing and services in advanced economies. Comin et al. (2020) show how long-term shifts can contribute to labor-market polarization. Work by Bils and Klenow (1998) uses product expenditure elasticities to test competing business cycle models. This paper shows that over the short term, shifts in demand can lead to higher prices in the expanding sector, which can have heterogeneous effects on income-level cost of living. Contemporary work by Andreolli et al. (2024) finds a similar relationship between the relative expenditures on luxuries in necessities over the business cycle and in response to monetary policy shocks, but unlike this paper does not show that these results are robust to other major features of the product, such as its oil share, labor share, or durability.

The remainder of the paper proceeds as follows: Section 2 describes how I define necessities and luxuries and presents the twin motivating facts (counter-cyclical necessity prices and aggregate shares), Section 3 formally presents the cyclical demand shift mechanism, Section 4 tests the conclusions of the mechanism empirically via monetary policy and oil price news shocks, Section 5 presents the quantitative model, and Section 6 concludes.

2 Data and Stylized Facts

In order to study the cyclical behavior of low-income versus high-income household inflation rates I focus on the products which are purchased relatively more by low-income households compared to high-income households. I call these low-income intensive products

[7]Krueger et al. (2016) classify households based on wealth levels, where this paper sorts households based on income. This estimate adds the difference in nominal consumption inequality for wealth quintiles with this papers estimate of inflation inequality (from the non-homothetic expenditure channel, the direct oil channel and non-modelled channels) for income quintiles.

necessities and other products luxuries. This differs from the textbook definition of a necessity, which are products whose expenditure elasticity is less than one. At the cross-sectional level, the expenditure and income elasticity of a product are highly related since household income is highly correlated with household expenditure (in fact many studies use household income as an instrument for household expenditure when calculating Engel curves Aguiar and Bils (2015), Bils and Klenow (1998)).

I show that necessities, which I define in the household cross-section, exhibit countercyclical relative demand, which implies that they are also necessities in the aggregate time-series. I also show that conditional on the oil price, necessity relative inflation is countercyclical; relative necessity prices increase in tandem with relative necessity expenditure during recessions.

2.1 Defining Necessities and Luxuries

This project's primary data sources are the Consumer Expenditure Survey (CEX) from the BLS, which I use to distinguish between luxury and necessity goods, and the Personal Consumption Expenditure price and expenditure (PCE) series from the underlying detail of the BEA's National Income and Product Accounts. I combine these data sources with the BEA's Total Requirement and Use tables from the Input and Output accounts to construct sector-level oil production shares and labor shares, and then I also combine these data with sector price change frequency data from Montag and Villar (2022).[8]

I divide households into five different income groups based on the household's distribution in absolute income over the entire CEX sample (1980-2022) and derive the income-group expenditure shares on each of 148 different PCE categories that represent the same type of spending in the NIPA product accounts and the CEX (see the online appendix section B for details).[9] These 148 sectors represent 73 percent of all PCE spending in 2019. I pool the expenditure shares across time to create a single expenditure share for each income group

[8]The price change frequency data from Montag and Villar (2022) is at the entry level item (ELI) level. I match these to PCE categories by first matching ELI's with CEX UCC codes using the BLS concordance, and then matching UCC codes to PCE sectors using the extended BLS CEX-PCE concordance that I discuss in section B of the online appendix.

[9]In the online appendix section B.5 I also show that my motivating facts are also robust to classifying households into income groups based on their distribution in relative income for each individual monthly CEX survey rather than over the same sample.

and product. I define R_j, as the ratio of the share of consumer spending in the lowest income quintile to the share of spending in the highest quintile:

$$R_j = \frac{\sum_t \frac{1}{N_{t,Q1}} \sum_{h \in Q1} s_{jth}}{\sum_t \frac{1}{N_{t,Q5}} \sum_{h \in Q5} s_{jth}}. \tag{2.1}$$

R_j is equal to one if, on average, low- and high-income households spend the same percentage of their expenditure on product j. I define products as necessity goods if low-income households have a higher expenditure share on these goods relative to high-income households ($R_j > 1$), and I define luxury goods as products with $R_j < 1$.

Figure 2: Expenditure Ratio Based on Engel Curve

(a) Necessity **(b) Luxury** **(c) Necessity**

Note: Panel (a) shows a product j with a downward sloping Engel curve (necessity). Panel (b) shows a luxury product. Panel (c) shows a product with a hump shaped Engel curve; in this example, it is a necessity since the average expenditure share for j is higher for the lowest income group, Q_1, than the highest, Q_5.

Figure 2 shows how this approach is is similar to comparing the level of the share based Engel curve at the top and bottom of the income distribution. If the Engel curve is linear, then the "necessity" rank of the good using this method would be the same as the rank derived from the slope of the Engel curve (where a slope of zero would correspond to an expenditure share ratio of one). If the underlying Engel curve is non-linear (as suggested by Atkin, Faber, Fally, and Gonzalez-Navarro (2020)), then this method continues to rank goods by their importance in the consumption basket of low-income versus high-income households regardless of consumption patterns for the middle income-groups.

Table 1 shows that luxuries tend to be more concentrated in services and durable goods, have higher oil requirements and lower labor requirements in production, and adjust prices more frequently. The average oil production share for each good is derived from the BEA's

Total Requirement tables for commodities combined with their PCE bridge file.[10]

Table 1: Descriptive statistics for luxuries and necessities

Descriptive Stats		
	Necessity	**Luxury**
Average Oil Production Share	0.12	0.03
Average Labor Share	0.45	0.59
Monthly Fraction Price Change	0.32	0.13
Percent expenditure durables	7%	19%
Percent expenditure services	48%	67%

Source: Consumer expenditure survey, BEA, Montag and Villar (2022), and author's own calculations. Note: These 148 products exclude the two housing products: rent and owners equivalent rent and PCE non-market sectors. The oil and labor shares are derived from the 2012 BEA total requirements commodity table combined with the commodity PCE bridge. Sectoral price frequency is the average from 1978-2023 excluding sales and is aggregated from the BLS entry level item (ELI) level using 1998 CEX weights. The percent of expenditure in durables or services is based on 2019 PCE data. Average statistics in this paragraph are weighted by the PCE sector's share in aggregate expenditure.

2.2 Necessity Relative Expenditure Shares and Prices are Counter-Cyclical

Fact 1: Relative Spending on Necessities is Counter-Cyclical

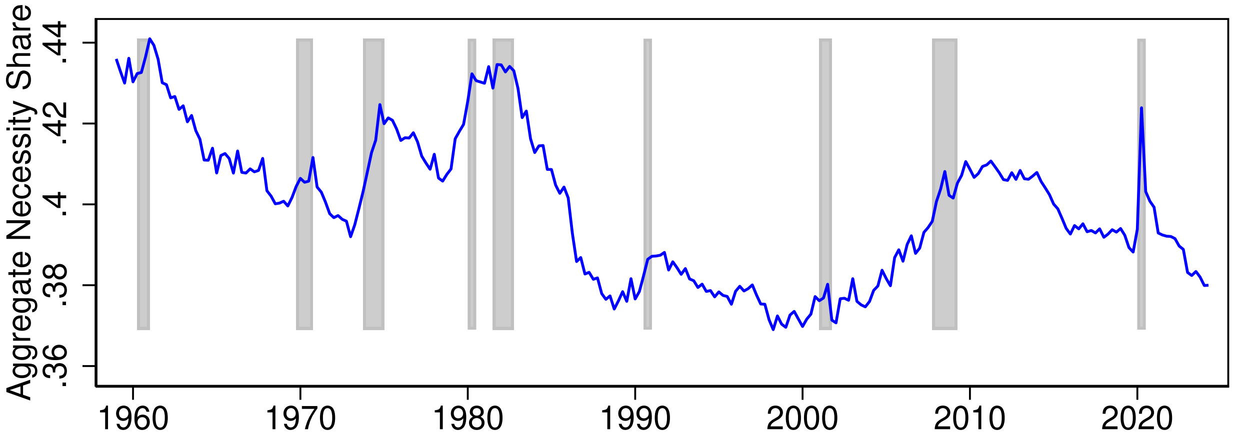
In US recessions since 1959 total PCE has tended to decline. The annualized quarterly total PCE growth rate in NBER recessions has average -0.9 percent, while during non-recessions it has average 3.8 percent. Figure 3 shows that the fall in expenditure during recessions is not equal for all products and that falls in luxury expenditure (leading to relatively higher necessity expenditure) are responsible for the majority of the fall in PCE during recessions. While the aggregate necessity share has fallen from about 43 percent at the start of the sample to 38 percent in 2024, there is considerable cyclical variation and the aggregate necessity share has increased in every single recession since 1959. This figure shows that while necessities in this paper are defined using income at the household level, these same products also tend to be necessities at the aggregate time-series level.

Fact 2: Counter-Cyclical Necessity Prices

Figure 4 shows the difference between the necessity and luxury four-quarter inflation rates

[10] I use the 2012 Total Requirements table, but my results are robust to using the 2007 or 2017 tables.

Figure 3: Aggregate Expenditure Share on Necessities

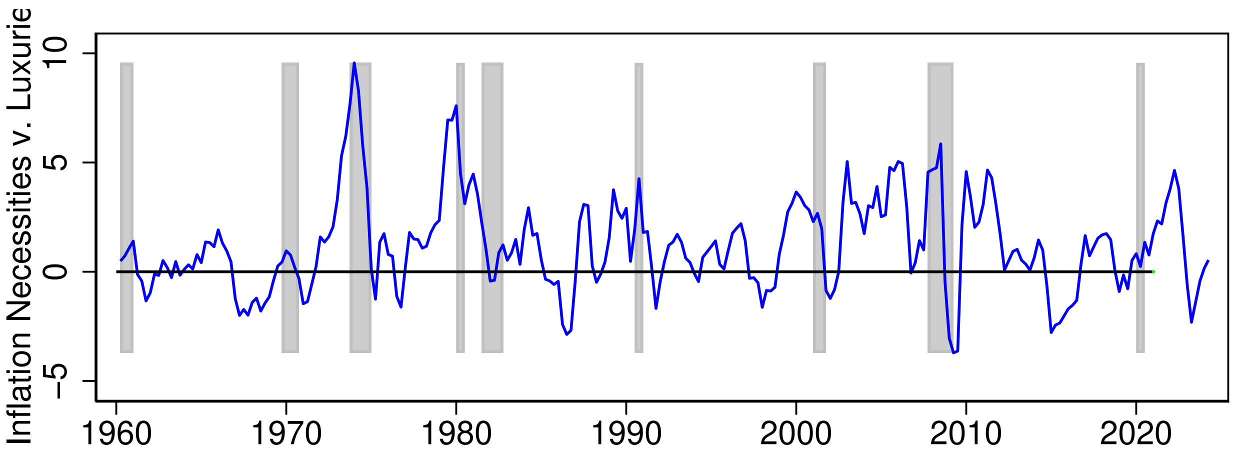


Source: Consumer Expenditure Survey, BEA, and author's own calculations.
Note: The necessity share of aggregate expenditure is the total share of aggregate expenditure using the 148 included PCE categories and excludes non-market and housing products.

originally shown in figure 1. From 1960-2024, necessity inflation has averaged 1.2 percentage points higher than luxury inflation. During NBER recessions the gap is over twice as large at 2.2 percentage points compared to 1 percentage point during non-recessions. As I will show in table 2, part of this gap is due to oil prices since necessities have a larger oil-cost share in production than luxuries and oil shocks have coincided with several US recessions, however, even when conditioning on oil prices the gap between necessity and luxury inflation is 0.7 percentage points higher in recessions than non-recessions.

Table 2, which displays the results of simple time-series regressions of the inflation gap on aggregate variables, shows that after conditioning for oil prices the gap between necessity and luxury inflation widens in periods of economic slack. Column 1, which regresses the inflation gap on a binary variable for the quarter being an NBER recession shows that the inflation gap is 1.2 percentage points higher in NBER recession quarters than other quarters. Column 2, adds the 4-quarter change in the WTI oil-price as a control and shows that the gap is still around 0.7 percentage points higher in NBER recessions; here the results are also more precise. In column 3, I use the unemployment rate instead of the NBER recession as the measure of economic slack and I find that a one percentage point increase in the unemployment rate is associated with a 0.17 percentage point increase in necessity inflation

Figure 4: Inflation difference between Necessities and Luxuries



Source: Consumer Expenditure Survey, BEA, and author's own calculations.
Note: Graph shows the difference in the 4-quarter fisher inflation rates between necessity and luxury sectors. Necessities defined as sectors whose average expenditure share from 1980-2023 was higher for low-income than high-income households ($R_j > 1$). Chained fisher price indices. Excludes housing and non-market consumption.

Table 2: Time Series Data: Necessity Relative Inflation is Countercyclical

	Difference Necessity v. Luxury Inflation				
	(1)	(2)	(3)	(4)	(5)
Right hand side variables:					
NBER Recession	1.09*	0.64**			
	(0.64)	(0.28)			
Unemployment Rate			0.17*		
			(0.093)		
Output Gap				−3.46	
				(9.60)	
Δ Real PCE					−0.13*
					(0.073)
Δ Oil Price		0.050***	0.052***	0.051***	0.051***
		(0.0046)	(0.0044)	(0.0046)	(0.0037)
Observations	259	259	259	259	259

Notes: Newey-West HAC Standard errors in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. The dependent variable is the difference between the Four-quarter Fisher Necessity Inflation rate and the 4-quarter Fisher Luxury Inflation rate. Δ Real PCE is the four-quarter percent change.

relative to luxury inflation. In column 4, I use the output gap and here I find a negative association between an output gap that is one percentage point higher, meaning that the economy is growing faster than potential, and the gap between necessity and luxury inflation (-3.5 percentage points). Finally, in the last column I show that a one percentage point stronger growth in real PCE spending is associated with a 0.13 percentage point smaller gap in necessity versus luxury inflation.

2.3 Panel Evidence

The aggregate evidence presented shows that on average necessity relative expenditure increases in recessions along with their relative prices, however, the aggregate evidence is not able to parse out whether this counter-cyclical behavior is due to products being necessities rather than other features of products that are correlated with both income elasticity and cyclicality. For example, table 1 shows that necessities are less likely to be durables than luxuries, slightly less likely to be services, adjust prices much more frequently, have a much larger oil share in production, and a slightly smaller labor share. Past literature has shown that durable purchases are quite cyclically sensitive (McKay and Wieland 2021, Barsky et al. 2007) and service expenditure tends to be much smoother than good expenditure.[11]

I am able to exploit the panel nature of the 148 product sectors that I study to at-least partially assuage concerns that other aspects of necessity products are solely responsible for the counter-cyclical nature of necessity relative shares and prices by regressing the log-share or inflation rate at the sector level on the interaction between whether the product is a necessity and the unemployment rate along with various controls:

$$x_{j,t} = \beta_0 + \beta_1 U_t \times 1\{R_j > 1\} + \beta_1 U_t \times Z_j + \beta_2 \Delta P_t^O \times S_j^O + \delta_t + \gamma_j + \varepsilon_{j,t}. \tag{2.2}$$

Here, the dependent variable, $x_{j,t}$ is the log-share of products in sector j at time t or the sector level 12-month inflation rate. The dependent variable is regressed on the interaction of the unemployment rate with $1\{R_j > 1\}$ a binary variable equal to one if the product is a necessity (I show qualitatively similar results in the appendix where I instead use the

[11]For some service categories, the BEA estimates service expenditure using a single annual survey and than extrapolates for the rest of the year U.S. Bureau of Economic Analysis (2023), which could mechanically make service consumption smoother than good consumption.

continuous R_j) . I also include time δ_t and sector γ_j fixed effects (which absorb the level effect in the interaction). Z_j is a vector that include binary variables for whether the product is a durable, whether the product is a service, and continuous variables for the average frequency of price change of that sector from Montag and Villar (2022) and that sectors share of labor in total costs.[12] Finally, ΔP^O is the 12-month change in the WTI oil price and S_j^O is the sector level share of oil in total production costs from the BEA input-output tables. Controlling for the price of oil results in much more precise estimates since necessities have a much higher cost-share of oil in final production and the price of oil is much more volatile than the unemployment rate.

Table 3 shows the results from these regressions. In column one and four I show results from a simplified version of the panel regression where in addition to the interaction of interest (between the unemployment rate and necessity) I include an interaction between the change in the oil price and necessity. Here I find that a one percentage point increase in the unemployment rate is associated with a 1.69 percentage point increase in the share of aggregate expenditure spent on the product if it is a necessity (I multiply the coefficient by 100 to ease interpretation) and a 0.17 percentage point increase in the product's relative inflation rate. In columns two and five I instead control for the interaction between the change in the oil price and the product specific oil share in production, which yields very similar results. Finally in columns three and six I also include the $U_t \times Z_j$ interactions which condition on whether the product is a durable, service, the labor share, and the frequency of price change of the sector.[13] In the final columns, results are quite similar for the relationship between the unemployment and the relative expenditure share of necessities; however, results are much larger for inflation, where a one percentage point increase in the unemployment rate is associated with a 0.4 percentage point increase in relative necessity inflation once conditioned on each product's price change frequency, and whether the product is a service or durable.[14] In the appendix section B.5 I show that these results are quantitatively similar

[12]The average frequency of price change is based on BLS micro-level CPI data and is constructed from 1978-2023 and excludes temporary sales.

[13]The sample size is smaller in columns 3 and 6 since as described in sub-section 2.1 there are some PCE categories for which I do not have data on price adjustment frequency.

[14]The sample size is smaller in the final columns as Montag and Villar (2022) do not have price change frequency data for all of the PCE sectors that I consider here.

Table 3: Relative Necessity Shares and Inflation increase with Unemployment

	100× Log-Share			Inflation		
	(1)	(2)	(3)	(4)	(5)	(6)
Right hand side variables:						
UR × Necessity	1.69***	1.71***	1.64***	0.17***	0.15**	0.43***
	(0.17)	(0.18)	(0.48)	(0.06)	(0.06)	(0.09)
Δ Oil Price × Necessity	0.02			0.05***		
	(0.01)			(0.00)		
Δ Oil Price × Oil Share		0.30***	0.33***		0.57***	0.57***
		(0.10)	(0.10)		(0.04)	(0.03)
UR × PC Frequency			3.39***			-0.26
			(1.16)			(0.36)
UR × Labor Share			0.55			0.03
			(0.89)			(0.21)
UR × Service			0.20			0.32***
			(1.47)			(0.11)
UR × Durable			-2.72***			0.42***
			(0.73)			(0.11)
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes	Yes
Observations	113,484	113,484	89,697	111,720	111,720	88,305

Notes: The unit of observation is at the sector-time level. Necessity is defined as a sector with an expenditure share equal to or greater than one (low-income households consume relatively more than high-income households). Inflation is the 12-month percent change in the consumption sector price level. The change in oil price is the 12-month percent change in WTI prices. Standard errors, in parentheses, are clustered at the time level and are robust to auto-correlation. Significance at the 1, 5, and 10 percent levels indicated by ***,**, and *.

when necessities are defined using the continuous measure of necessity R_j or if income groups are based on the household's position in the distribution of real income during the date they were surveyed rather than over the entire 1980-2022 CEX sample.

To summarize, I find a statistically and economically significant correlation between relative necessity inflation and expenditure shares with the unemployment rate. This result is not driven by differences in the oil-share of the sector, it's price change frequency or whether the product is a durable or service. In the next section, I present a mechanism that can explain these two facts.

3 A Static Model of Relative Supply and Demand

In this section, I present a static model with a necessity and a luxury sector represented by perfectly competitive firms with concave production over labor. Households have non-homothetic preferences over those two sectors. This model is presented in partial equilibrium, and I abstract from the household labor market and savings decisions. Instead, the level of household expenditure, X, is exogenous. I show that a decline in the expenditure level, X, leads to higher equilibrium consumption shares and prices for the necessity sector. I also show, under the same assumptions, how a negative supply shock that both lowers expenditure and productivity for one sector can be decomposed into a direct effect on relative prices and an indirect effect on relative prices coming through the expenditure channel.

3.1 Firms

There are two sectors $\{N, L\}$. Each sector is competitive and is represented by a firm with a homogeneous production function over labor:

$$Y_i = F(H_i). \tag{3.1}$$

I assume that $F(\cdot)$ is positive and homogeneous of degree $k \in (0,1)$, implying that the firm has concave production over labor. Firms can hire labor at an exogenous fixed wage rate w. Profit maximization implies that the ratio of the wage and the sector price is equal to the marginal productivity of labor:

$$\frac{w}{p_i} = F_H(H_i). \tag{3.2}$$

Lemma 1 (see mathematical appendix), shows that the marginal rate of transformation (MRT) between the two sectors is increasing (i.e. the production possibilities frontier (PPF) between the two sectors is concave). Since markets are competitive, this is akin to saying that:

$$\frac{p_i}{p_j} = \frac{F_{j,H}(H_j)}{F_{i,H}(H_i)} = \frac{F_{j,H}(F_j^{-1}(Y_j))}{F_{i,H}(F_i^{-1}(Y_i))} \tag{3.3}$$

is sloping upward in $\left(\frac{Y_i}{Y_j}, \frac{p_i}{p_j}\right)$ space over some range Y. Intuitively, in the *short-term* firms, can expand only by changing their labor input. If one sector expands relative to the other, they must expand by increasing their relative share of labor, which increases their relative marginal cost. An example of this type of production function pair would be $F_i(H_i) = A_i H_i^{\alpha}$ where $\alpha \in (0,1)$ and is common across sectors.[15] If both sectors have linear production over

[15]If sectors each have production over labor, but not of the same curvature (i.e. it violates the assumption of production being homogeneous of degree $k \in (0,1)$ for each sector) then the relative supply curve is not necessarily upward sloping across the domain. For example, suppose that both sectors decrease production, but one sector j decreases production more. Sector j will shrink relative to the other sector, but the actual

labor, then the relative marginal cost curve would be flat. An increasing marginal product of labor would lead to a downward-sloping curve.

3.2 Households and Intratemporal Substitution

The representative household is given an exogenous endowment of expenditure, X. They have non-homothetic preferences over consumption in the necessity and luxury sectors $U(c_N, c_L)$ such that for prices p_N, p_L and nominal expenditure X over some interval around X, the ordinary demand of the luxury good $C^L(\cdot)$ increases in relation to that of the necessity good with an increase in X:

$$\frac{\partial}{\partial X}\frac{C^L(X, p_N, p_L)}{C^N(X, p_N, p_L)} > 0. \tag{3.4}$$

Since we have only two goods, this equation implies that when X increases, the share spent on the necessity good s_N decreases.

Figure 5 shows a representation of how the relative marginal cost curves (relative supply) and relative demand could look in $(s_N, \frac{p_N}{p_L})$ space. The relative supply curve slopes upward because of the homogeneous production of degree $k \in (0, 1)$ in each sector. The relative demand curve slopes downward, as with only two goods they must be net substitutes. If there is a decrease in expenditure X, then relative demand for necessities will rise, and the relative demand curve will shift to the right. Equilibrium necessity expenditure share and the relative price will both increase (as pictured, this is a move from point A to point B).

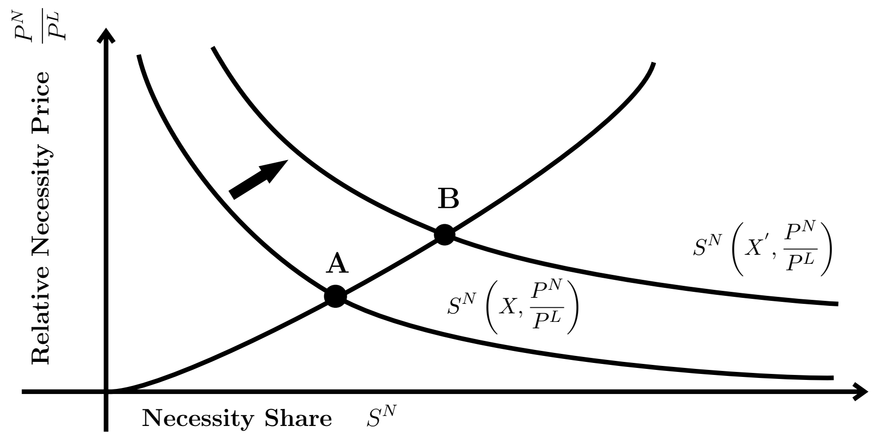
The intuition behind figure 5 is stated formally in the following proposition (the proof is included in the mathematical appendix). [16]

Proposition 1 *In a two-sector competitive economy with a representative household that has preferences satisfying equation* (3.4)*, production function in each sector* $F_i(H_i) : [0, \infty) \rightarrow [0, \infty)$ *both homogeneous of degree* $k \in (0, 1)$ *and standard market clearing conditions, then an decrease/increase in household expenditure will lead to an increase/decrease in the relative price of necessities.*

change in relative marginal costs will depend on the size of the decrease in average production versus the relative decrease in production in sector j.

[16] In the proposition, the representative household is assumed to have non-homothetic consumption preferences. However, this is not always the same assumption as the micro-level households having non-homothetic consumption preferences. I discuss this issue in more detail in the mathematical appendix.

Figure 5: Relative Demand to Expenditure Shock



Note: The relative demand curve, which slopes downward, shows how demand for necessities varies with the relative necessity price for a fixed level of expenditure. The relative supply curve shows the quantity provided of necessities relative to luxuries at different relative necessity prices and in this example it slopes upward. The economy starts at point A. After a shock that *lowers* expenditure from X to X' the relative curve shifts outward and the economy moves to point B.

3.3 Relative Supply Shocks

Proposition 1 shows that when there are non-homothetic preferences and a concave production possibility frontier then changes in expenditure lead to changes in relative prices for necessities. This proposition does not address the source of the shock to expenditure whether it be a shock to aggregate demand or supply, but in principle both aggregate demand and supply shocks that change expenditure will lead to the same proportional affect on relative prices given that they do not shift the relative supply curve. However, a supply shock that affects the productivity of one sector more than the other would have an ambiguous affect on relative prices or shares.

As an example, suppose that there is a shock to labor productivity in both sectors, $A_{t,j}$ so that $F_{j,H}(A_{t,j}H_j) < F_{j,H}(H_j)\ \forall\ H_j$, furthermore suppose that the fall in labor productivity is relatively greater in the necessity sector, so that:

$$\frac{F_{L,H}(A_{L,t}H_L)}{F_{N,H}(A_{N,t}H_N)} > \frac{F_{L,H}(H_L)}{F_{N,H}(H_N)}\ \forall\ (H_N, H_L). \tag{3.5}$$

It follows that for every level of the necessity share S^N, the relative price of necessities will be greater since it has become relatively less productive to produce them. This example is depicted in figure 6 where the economy moves from point A to point B. Since the economy is now less productive in aggregate, expenditure falls, which triggers the mechanism from proposition 1 and the relative demand curve shifts outward. This causes the economy to move to point C. In this example, both the effect on relative prices coming from the shift of the relative supply curve (equation 3.5) and the indirect effect from the shift in the relative demand curve both lead to higher relative necessity prices leaving them unambiguously higher. The change in the necessity share is ambiguous however, as the rise in relative necessity prices coming from equation (3.5) and the fall in expenditure decrease and increase respectively S^N and the overall effect on the necessity share will depend on the price elasticity of demand for necessities, the change in expenditure, and the expenditure elasticity of necessities. If instead the fall in labor productivity is greater in the luxury sector then the necessity share will increase, while the change in relative prices will be ambiguous.

We can decompose the change in relative prices into a direct effect with the new labor productivity (holding expenditure constant) and an indirect effect coming from both the induced change in the relative demand for necessities at the old expenditure level (a move along the relative demand curve) and the change in relative demand for necessities due to the change in expenditure (a shift of the relative demand curve):

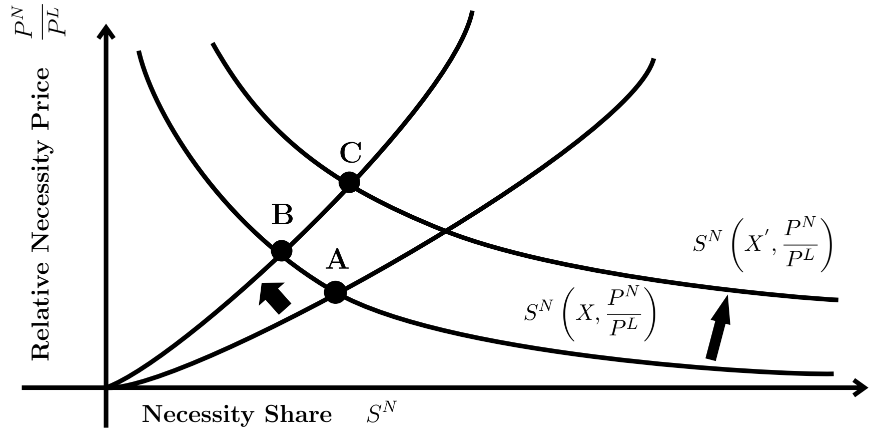
$$\Delta \log\left(\frac{p_{N,t}}{p_{L,t}}\right) = \underbrace{(k-1)\log\left(\frac{A_{L,t}}{A_{N,t}}\right)}_{\text{Direct Effect}} + \underbrace{\Delta \log\left(\frac{F_{L,H}(H_{L,t})}{F_{N,H}(H_{N,t})}\right)}_{\text{Indirect Effect}}. \tag{3.6}$$

The direct effect of the change in labor productivity on relative prices is log-linearly proportional to the relative productivity change in each sector.[17] Equation (3.6) is not reliant on the assumption of an upward sloping relative supply curve, and can also be derived in the same way if both production functions are homogeneous of degree $k \in (-\infty, \infty)$.

The indirect effect can be further decomposed into the move along the relative demand curve MD, which is dependent on the price elasticity of demand and the shift of the relative

[17] If we relax the assumption that both productivity functions are homogeneous of degree k and instead assume that both the necessity and luxury production functions are homogeneous, but of degrees k and g respectively then the direct affect would not only be proportional to the relative changes in productivity, but also depend on the degrees of homogeneity of the two functions $(k-1)\log\left(\frac{1}{A_{N,t}}\right) - (g-1)\log\left(\frac{1}{A_{L,t}}\right)$. I control for one aspect of homogeneity in the online appendix by using the sector's labor share.

Figure 6: Relative supply and Relative Demand to Supply Shock



Note: The economy starts at point A. A negative supply shock affects production of necessities relatively more, which causes the relative supply curve to move up and inward, which would shift the economy to point B absent any change to total expenditure. The negative supply curve also lowers expenditure from X to X', which shifts the relative demand curve outward and the economy ends at point C.

demand curve SD, which is dependent on the elasticity of expenditure to the supply shock and the expenditure elasticity of necessities.

$$\underbrace{\Delta \log\left(\frac{F_{L,H}(H_{L,t})}{F_{N,H}(H_{N,t})}\right)}_{\text{Indirect Effect}} = MD + SD. \tag{3.7}$$

4 Empirical Strategy

The static model in the previous section showed how under certain assumptions lower aggregate expenditure leads to a higher relative share of necessities in aggregate expenditure, as well as an increase in the relative price of necessities. I use exogenous shocks to expenditure to test: (1) how the aggregate necessity share responds to a shock that lowers expenditure, and (2) how relative necessity prices respond to the same shock. These two questions are directly related to the assumption that the representative consumer has non-homothetic preferences and the assumption that the relative supply curve is upward sloping.

To test the model assumptions, I use plausibly exogenous monetary and oil price shocks. Both of these shocks lead to statistically significant declines in real PCE. The monetary shock is the quintessential example of an aggregate demand shock and assumed to shift *only* the relative demand curve and leave the relative supply curve unchanged. This is important as any shock that directly affects the position of the relative supply curve will obscure efforts to test its slope. In contrast, for oil price shocks, I discuss under what assumptions I can control for shifts in the relative supply curve and decompose the oil price shock into a direct effect and an indirect non-homothetic effect on relative prices similar to equation (3.6).

I find that a one-standard deviation contractionary monetary policy shock or oil shock each lead to around a 0.2 percent decline in aggregate real consumption spending 24- to 36- months after the shock. This same monetary shock leads to an increase of around 0.5 percentage points in the share of expenditure on necessities and an increase in necessity prices of approximately 0.2 percent, which implies an elasticity of relative necessity prices to aggregate expenditure of around -1. The oil price shock leads to an approximately 0.2 percentage point increase in the necessity expenditure share and after controlling for the sector's oil share, an indirect effect on relative necessity prices of approximately 0.1 percent, which implies an elasticity of relative necessity prices to aggregate expenditure of -0.5.

4.1 Aggregate Demand Shock: Monetary Contraction

In the textbook New Keynesian model, the interest rate appears only in the household side of the model and operates through the Euler Equation (Galí 2015), which makes monetary policy shocks a natural candidate for testing how necessity relative shares and prices respond to a shock that affects expenditure, but not the relative supply curve. I will address potential violations of this assumption later in subsection 4.1.2.

Since central banks respond to macroeconomic events, making interest rate changes endogenous, there is a large literature using monetary policy news as an external shock on interest rates (Gürkaynak et al. 2004, Gertler and Karadi 2015, Miranda-Agrippino and Ricco 2021, Bauer and Swanson 2022a). As a proxy for a monetary policy shock, I use the estimated monetary policy news shock from Bauer and Swanson (2022b).[18] This news shock is computed as the first principle component of the change in the first four quarterly Euro-Dollar contracts in a 30-minute window around each Federal Open Market Committee (FOMC) meeting and Fed Chair speech from 1988 to 2019. The first principle component is then orthogonalized with respect to macroeconomic news known to traders before the

[18] See also Swanson and Jayawickrema (2023).

FOMC announcement. In the appendix, I show that qualitatively similar results on relative necessity prices are obtained when I instead use the news shocks from Gertler and Karadi (2015) or the news shocks orthogonalized to the Federal Reserve staff forecast developed by Miranda-Agrippino and Ricco (2021).

In order to test the differential response of interest changes on necessity and luxury product shares and prices, I estimate a local projection of the dependent variable (x_j) on the interaction between the monetary policy shock and the product's expenditure ratio (Jordà 2005):

$$x_{j,t+h} = \sum_{k=0}^{12} \left[\boldsymbol{\gamma}^{\boldsymbol{h,k}} i_{t-k} \times R_j + \Gamma_{h,k} W_{j,t-k}\right] + \sum_{l=1}^{12} \left[\sum_{y\in\{s,p\}} \left(\beta^{h,y,l} y_{j,t-l}\right)\right] + \delta_{h,t} + \psi_{h,j} + \alpha_{j,t+h}. \tag{4.1}$$

In the above equation, the dependent variable, $x_{j,t+h}$, is either the log-aggregate share of product j at time $t+h$ or the log-price. The coefficient of interest $\gamma^{h,0}$ (the coefficient of the interaction of the contemporary monetary policy shock i_t and expenditure ratio R_J) is the differential response of sector shares/prices based on expenditure ratio, which corresponds to the Blinder-Oaxaca extension to the local projection framework discussed in Cloyne et al. (2020). In each regression, I include a year of lags of both dependent variable, $\sum_{l=1}^{12} \sum_{y\in\{s,p\}} \left(\beta^{h,y,l} y_{j,t-l}\right)$. I include time fixed effects, $\delta_{h,t}$, which absorb the direct effect of monetary policy on shares/prices, as well as any other macroeconomic events occurring at time t. I also include product fixed effects, $\psi_{h,j}$, which control for the average level of share/prices for product j. I include a year of lags of all monetary policy shock interactions to account for serial correlation of the monetary policy shocks (Ramey 2016). All regressions use standard errors that are clustered at the time level and are robust to serial correlation.[19]

The main identifying assumption is that monetary shocks affect product prices differently only to the extent that they shift demand through non-homothetic preferences. However, demand for durable goods can be more sensitive to interest rate changes than for non-durable goods and services (McKay and Wieland 2021, Barsky et al. 2007), which is why in the baseline model I include interactions between a binary variable equal to one if the

[19] Standard errors are similar when using heteroskedasticity-consistent robust standard errors that are not robust to auto-correlation (Herbst and Johannsen 2021, Montiel Olea and Plagborg-Møller 2021).

PCE sector j is a durable sector and the monetary policy shock for both the contemporary shock and 12 lags. Since the oil price is volatile and since the central bank can respond directly to oil shocks, in my baseline model I include an interaction between the sector $j's$ total cost share in oil S_j^O and the 12-month change in the WTI oil price ΔP_t^O at time $t-k$.[20] These additional controls are denoted by $\Gamma_{h,k} W_{j,t-k}$. The appendix section B.7 shows that point estimates are similar when the durable good and oil price controls are removed. I also show results where $\Gamma_{h,k} W_{j,t-k}$ also includes interactions between the sector level-price change frequency and the contemporary and lags of the monetary policy shock and when interactions between the sector labor share and the monetary policy shock is included.[21]

If aggregate demand responds non-homothetically to monetary policy shocks, then I would expect $\gamma^{h,0}$ to be positive when the dependent variable is the log-share. A positive coefficient means that aggregate expenditure shifts to products bought more by poor households (the expenditure ratio R_j is higher) following a contractionary monetary policy shock compared with other products. Furthermore, an upward sloping relative supply curve implies that $\gamma^{h,0}$ in the price regression should have the same sign as $\gamma^{h,0}$ in the demand regression.

4.1.1 Results: Monetary Policy Shock

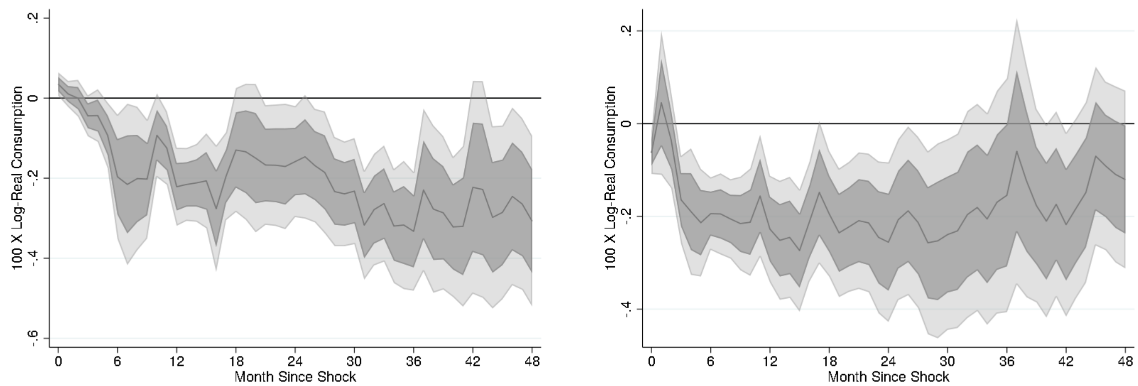
In the model presented in the preceding section, a fall in expenditure causes households to shift their demand to necessities because of non-homothetic preferences. Accordingly, I test directly how the monetary news shocks affect aggregate expenditure using a simple local projection of log-real PCE on a one-standard deviation monetary policy shock (Jordà 2005). I follow Ramey (2016) and include 12 lags of the monetary instrument and 12 lags of the dependent variable. I also include 12 lags of the PCE price level, one-year Treasury yield, 12-month change in WTI oil prices, and the unemployment rate. Figure 7 panel (a) shows that following a one standard deviation monetary policy shock real PCE falls after around 6-months and reaches a trough of around -0.33 percent about 36-months after the monetary policy shock.[22] The appendix section B.6 shows that the 1- and 10 year treasury yields increase in response to the monetary policy shock.

[20] Despite the fact that the Bauer and Swanson (2022b) shocks control for macroeconomic news, Gagliardone and Gertler (2023) find that these shocks can still be predicted by changes in the oil price.

[21] The results with the price change frequency rely on a smaller number of PCE categories for which a match with data from Montag and Villar (2022) exists.

[22] For the readers convenience, the dependent variables have been multiplied by 100 prior to estimation.

Figure 7: Real Expenditure Falls after Monetary Contractions and Oil Shocks



a) Monetary Shock

b) Oil Shock

Note: Panel A: data from 1989-2019, Panel B: data from 1976-2023. Estimated coefficients,from Local Projections represent the response of 100 times log-real PCE expenditure to a one-standard deviation monetary contraction or oil price shock using the Bauer and Swanson (2022b) monetary shocks or Känzig (2021) oil shocks respectively. The unit of observation is the month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively. Standard errors are robust to auto-correlation.

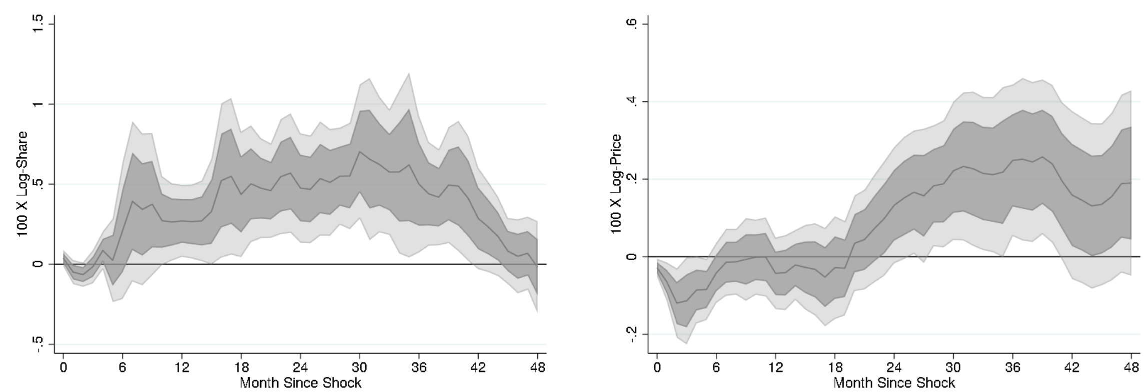
Figure 8 shows the impulse response functions (IRFs) estimated following equation (4.1). Panel (a) shows that aggregate expenditure shifts towards necessity products following a contractionary monetary shock. The IRF peaks at around 0.5 30 months after impact, which means that products with an expenditure ratio 1-point higher than average increase their aggregate share by approximately one half of a percent relative to other products. The IRF on the log-share is positive and statistically significant at the 90 percent level as soon as 12 months after the monetary shock. Panel (b) shows how the relative price of necessity goods increases following the monetary contraction. A product with expenditure ratio 1 point higher than average increases in relative price by around 0.25-percent, which peaks 30-36 months after the monetary policy shock. If we combine the results of the response of expenditure to the monetary policy shock from figure 7 with those in figure 8 it implies that the elasticity of the relative price of a product with an expenditure ratio 1 point higher than average to expenditure is -1.[23] In the appendix, section B.7 I repeat this analysis

[23] In principle, one could estimate this directly by using the monetary policy shocks as an instrument for expenditure and then testing how the relative price responds to a change in expenditure; however, this type of analysis gives the Econometrician a large-choice set of specifications because in addition to the typical choices of which controls to include the Econometrician must choose how many lags of the monetary policy shock should be included as instruments for expenditure; as figure 7 shows expenditure is significantly depressed

using a binary definition of necessity instead of the continuous R_j measure used here and the results are quantitatively similar. Additional robustness tests in the appendix section B.7 show similar results under a variety of robustness checks including alternate types of monetary policy shocks and alternate specifications.

The empirical results provide evidence for the mechanism presented in the static model. Following shocks that lower aggregate expenditure, aggregate spending shifts towards necessities raising their relative prices. It should be noted, that the aggregate necessity share responds faster empirically than the rise in relative necessity prices, which could be consistent with sticky prices. Sticky prices are not a feature of the static model I presented in section 3, but they are incorporated into a version of the quantitative model presented in the online appendix.

Figure 8: $\gamma^{h,0}$: Necessity Response to Monetary Policy Shock



a) Log-Necessity Share

b) Log-Necessity Price

Note: Data from 1989-2019. Estimated coefficients, $\gamma^{h,0}$ from Local Projections in equation (4.1) represent the response of the dependent variable to a one-standard deviation monetary contraction using the Bauer and Swanson (2022b) monetary shocks interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure.

4.1.2 Interest Rate Effects on the Relative Supply Curve

The simple New Keynesian framework ignores potential supply side effects of monetary policy. For example, Barth III and Ramey (2001) argue that monetary policy can impact

for several years following the shock.

the cost of working capital, which includes inventories. A contractionary monetary policy shock can lower aggregate supply through increases in the cost of financing working capital, which could shift the relative supply curve if some sectors rely more on working capital than others and would be particularly problematic if it were necessities that relied more on working capital since that could imply that the increase in the relative necessity price I find in figure 8 is partially due to the shift in the supply curve.[24]

As an alternative to monetary policy shocks, I show in appendix section B.8 that uncertainty shocks also lead to a fall in aggregate expenditure, but importantly lead to lower interest rates. Following an uncertainty shock, relative necessity shares and prices increase and I estimate that the necessity relative price expenditure elasticity is between -0.5 and -1 depending on the type of uncertainty shock considered.[25] These results are very similar to those when using monetary policy shocks and imply that if there is a relative supply effect coming from an increase in interest rates then the relative supply effect is small compared to the effect of the change in expenditure on necessity relative prices.

4.2 Aggregate Supply Shock: Oil Price

Oil prices represent a larger fraction of the total cost of low-income household's budgets than high-income households, so even in the absence of the mechanism I present in this paper increases in the cost of oil will have higher inflationary consequences for low-income households (Känzig 2023). However, as I show in figure 7 an oil price shock also lowers real aggregate expenditure, which could lead to additional income effects on necessity relative demand and prices beyond that implied by the higher cost-share of oil of those products.

The main issue with using oil-shocks to test the assumptions of aggregate non-homothetic demand and an upward sloping relative supply curve is that an oil shock should lead to both a shift in the relative demand curve and a shift in the relative supply curve, which makes identification difficult. However, if we can isolate the direct effect of the oil price shock on relative prices (as shown in equation 3.6) then we could control for the shift in the relative

[24] In contrast, if it is luxuries that rely more on working capital then the results in figure 8 would mean that the change in prices coming from the income effect was larger than the shift in prices from the relative supply effect.

[25] I use the VIX index, the economic policy uncertainty shocks from Baker et al. (2019), and the econometric uncertainty shocks from Jurado et al. (2015).

supply curve.

4.2.1 Total Response to an Oil Shock

I begin by estimating the overall response of necessity relative shares and prices to an oil shock by estimating a panel local projection with all 148 sectors of the log-share or log-price to a Känzig (2021) oil news shock:

$$\begin{aligned} x_{j,t+h} = \sum_{k=0}^{12} \left[\boldsymbol{\sigma^{h,k}} ON_{t-k} \times R_j + \gamma^{h,k} i_{t-k} \times R_j\right] + \\ \sum_{l=1}^{12} \left[\sum_{y \in \{s,p\}} \left(\beta^{h,y,l} y_{j,t-l}\right) + \beta^{h,O,l} \Delta P^O_{t-l} \times S^O_j\right] + \delta_{h,t} + \psi_{h,j} + \alpha_{j,t+h}. \end{aligned} \tag{4.2}$$

The coefficient of interest is $\sigma^{h,0}$ (the coefficient of the interaction of the contemporary oil price news shock ON_t and expenditure ratio R_J). In order to isolate the effect of the oil news shock from monetary policy responses, I also include the contemporary and 12 lags of the monetary policy news interaction $\gamma^{h,k} i_{t-k} \times R_j$. I include time and PCE sector fixed effects and a year of lags of both dependent variables as in the earlier local projections. To isolate the effect of the contemporary shock, I also include a year of lags of previous 12-month changes in oil prices ΔP^O_{t-l} interacted with that sectors cost share of oil S^O_j.

4.2.2 Expenditure Induced Response to an Oil Shock (Indirect)

I condition the response to the oil news shock at time h on the cumulative percent change in oil price from time t to h interacted with the sector oil share in order to separate out the indirect expenditure induced response to the oil news shock:

$$\begin{aligned} x_{j,t+h} = \sum_{k=0}^{12} \left[\boldsymbol{\xi^{h,k}} ON_{t-k} \times R_j + \gamma^{h,k} i_{t-k} \times R_j\right] + \kappa^h \Delta|_{t-1}^{t+h} P^O \times S^O_j + \\ \sum_{l=1}^{12} \left[\sum_{y \in \{s,p\}} \left(\beta^{h,y,l} y_{j,t-l}\right) + \beta^{h,O,l} \Delta P^O_{t-l} \times S^O_j\right] + \delta_{h,t} + \psi_{h,j} + \alpha_{j,t+h}. \end{aligned} \tag{4.3}$$

Where, $\xi^{h,0}$ is the coefficient of interest. $\Delta|_t^{t+h} P^O$ is the cumulative percent change in the WTI oil price from time $t-1$ to $t+h$, and S^O_j is the total cost share of oil in production for sector j.

The total oil cost share in production, S^O_j, from the BEA's input and output tables is an estimate of the increase in production costs for sector j after a one unit increase in the cost of oil. The inclusion of $\kappa^h \Delta|_{t-1}^{t+h} P^O \times S_j^O$ then orthogonalizes the estimates of $\xi^{h,k}$ to increases in costs for industry j coming from the direct cost of the oil increase assuming that (1) the estimates from the BEA are correct over time and (2) the dynamics of the oil price change on production costs are similar across industries.

The BEA's estimates of the oil cost share of commodities in the total requirement tables do change and while I check for robustness using the 2007 and 2017 input output tables (baseline uses the 2012 input output tables) the S_j^O estimates may not reflect the actual cost share of oil for PCE sectors in early periods such as the 1970s, which would violate (1). For assumption (2), the BEA's estimate includes all of the direct input costs of "Oil and Natural Gas Extraction," as well as all network costs of oil from upstream providers, however, Minton and Wheaton (2023) show that downstream firms can be slow to adjust prices in response to input costs of upstream providers, so while S_j^O may correctly reflect differences in the the cost share of oil eventually, in the periods immediately after the oil shock these cost shares may be too high for sectors that are more downstream from oil production; in the appendix, section B.7, I show that results are qualitatively similar when the decomposition accounts for the price stickiness of the sector, which suggests that this issue is less of a concern for my analysis. Finally, given that assumptions (1) and (2) hold and we can decompose the direct and indirect effects of the oil shock as in equation 3.6, the static model in the previous section assumes perfect competition; if markups are higher/lower for necessities then $\xi^{h,0}$ would be biased upward/downward. Contemporary work by Nord (2023) and Sangani (2022) suggest that markups are generally lower for products purchased more by low-income households, which suggests that these results could underestimate the indirect effect of the oil shock on necessity prices.

For the relative price results, $\xi^{h,0}$ is the sum of both the indirect effect due to the move along the relative demand curve MD and the shift of the relative demand curve SD. The shift of the relative demand curve is due to non-homothetic preferences and only SD is comparable to the results in the previous section with monetary policy shocks, where we assumed that the relative supply curve did not shift. However, as I show below, for oil price shocks I estimate that MD is quite small so $\xi^{h,0} \approx SD$. If MD is positive then the results I find for $\xi^{h,0}$ would be an underestimate of the change in the relative prices of necessities due to the expenditure induced non-homothetic demand shift.

4.3 Results: Oil Price Shock

Figure 9 shows the estimation results of the effect of the oil price shock on necessity relative shares and prices. Panel a) and b) show the total response to the oil price shock $\sigma^{h,0}$. The relative share of necessities rises by around 0.3 percent shortly after impact and the relative necessity prices increases by nearly 0.2 percent on impact before increasing to over 0.3 percent a few months after the shock. The total effect on relative necessity prices stabilizes at around 0.15. The indirect effect on relative necessity shares, panel c), is essentially the same as the direct effect, which implies that very little of the shift in necessity demand is due to the change in the price of oil coming from differences in oil production shares between sectors, which could mean that short-run demand for oil intensive goods is quite inelastic and the move along the relative demand curve (MD) due to the oil price shock is small.[26]

The indirect effect on relative necessity prices, panel d), is above 0.1 percent in the months shortly after impact before stabilizing a bit below 0.1 percent. Slightly less than half of the total effect of oil prices on necessity relative prices is due to the indirect expenditure induced effect and the relative necessity price expenditure elasticity is approximately -0.5.

4.4 Discussion

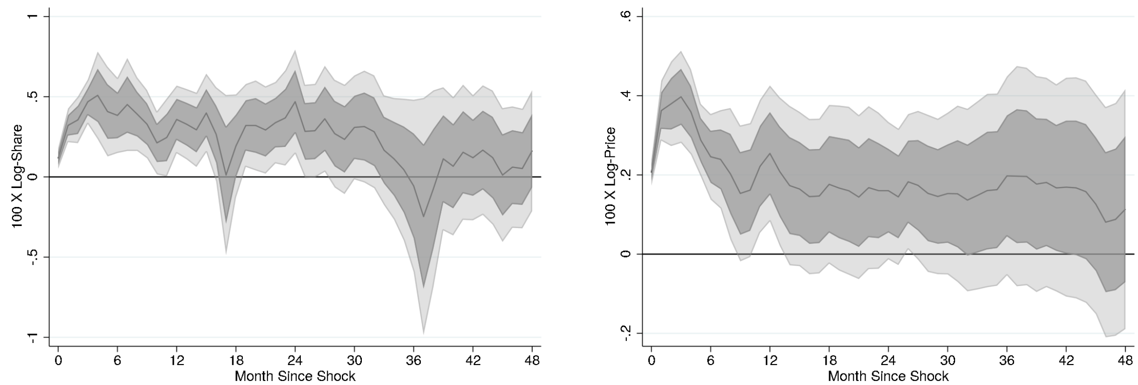
The results in this section suggest that the expenditure elasticity of the necessity expenditure share ranges from -2 to -1, while the expenditure elasticity of necessity prices is between -1 and -0.5. The results are consistent with the assumptions of the static model in the previous section, that is that aggregate demand is non-homothetic and the relative supply curve is upward sloping.

The empirical results cannot disentangle the mechanism from the static model from all other potential mechanisms that can explain the co-movement between aggregate expenditure, necessity expenditure shares, and necessity relative prices. For example, an upward sloping supply curve suggests that firms are raising their prices to meet relatively higher demand as their relative marginal costs have increased. However, firms could also raise their

[26]Estimates for the demand elasticity of gasoline tend to be very low even if they have risen a bit in recent data.(Brons et al. 2008, Goetzke and Vance 2021).

Figure 9: Necessity Response to Oil Shock

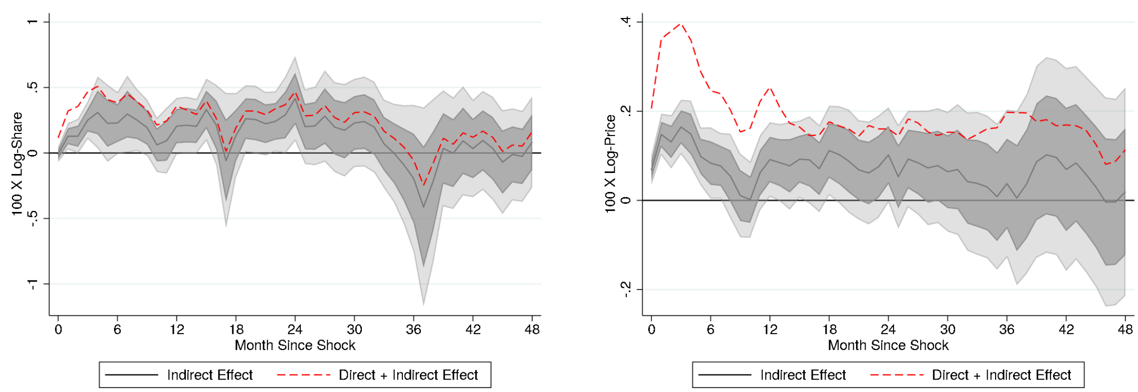
$\sigma^{h,O}$: Total Response to Oil Shock (Direct and Indirect)



a) Log-Necessity Share

b) Log-Necessity Price

$\xi^{h,O}$: Expenditure Induced Response to Oil Shock (Indirect)



c) Log-Necessity Share

d) Log-Necessity Price

Note: Data from 1976-2023. Estimated coefficient from Local Projections represent the response of the dependent variable to a one-standard deviation Känzig (2021) interacted with R_j. Panels c) and d) control for the interaction between the oil price at horizon h and the PCE sector's oil share, as well as for the contemporaneous (time 0) and lags of the monetary policy shock interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure.

relative markups in response to the higher relative demand even if their relative marginal costs have not changed. Absent data on PCE sector costs or dynamic markups, this alternate explanation is observationally equivalent to the static model presented in the previous section although the increase in necessity prices would still be due to nonhomothetic demand. Similarly, even if markups are constant overtime, but the markup for necessities is lower than luxuries than a fall in marginal costs due to lower demand would lead to higher relative necessity prices as they fall less than luxury prices, although the shift in demand due to nonhomotheticity would provide further upward pressure on necessity prices. Recent work by Baqaee et al. (2024) suggest that markups are not constant in response to a monetary shock and a contractionary monetary shock leads to an increase in markups for high-markup firms; as stated earlier, contemptorary literature suggests luxuries are more likely to have high-markups (Nord 2023, Sangani 2022) and if that were true for my sample then the results that I present here suggest that the upward sloping relative supply curve I presented in the static model is better able to explain the increase in necessity relative prices to a contractionary shock than a change in markups.[27]

5 New Keynesian Model with Non-homothetic Consumption Preferences

How important are aggregate shocks for the inflation rates experienced for households across the income distribution? In this section, I take a version of the static model presented in section 3, allow for dynamics and show how relative prices for necessities respond to aggregate oil and demand shocks. I then decompose the non-trend portion of the historical gap in the inflation rates between necessities and luxuries shown in figure 4 into contributions from aggregate supply and demand shocks and find that these aggregate shocks can explain roughly 70 percent percent of the variation in relative necessity inflation from 1961-2024. Finally, I use the model to examine the contributions to inflation inequality coming from the nonhomothetic expenditure channel, the oil share in production channel, and other factors.

5.1 Households

5.1.1 Intratemporal Consumption Choice: The Almost Ideal Demand System

Household preferences follow the Almost Ideal Demand System (AIDS) first introduced by Deaton and Muellbauer (1980). The AIDS has several advantages (1) it is a first order approximation to any demand system and (2) unlike many forms of non-homothetic pref-

[27]Similarly, non-homothetic demand is an alternative explanation to the shift in inputs from high- to low-markup firms that Baqaee et al. (2024) find following a contractionary shock.

erences, they can be aggregated and the representative consumer has the same preferences as the individual households (Muellbauer 1975). AIDS aggregation properties allow me to estimate aggregate parameters using micro-data since the parameters for the representative and micro-level households are the same.[28]

The functional form for the household level indirect utility function is

$$V(X^h, \mathbf{p}) = \left(\frac{X}{a(\mathbf{p})}\right)^{1/b(\mathbf{p})}, \tag{5.1}$$

where $a(\mathbf{p})$ and $b(\mathbf{p})$ are price aggregators over a vector of sector level prices $\mathbf{p}$ defined by:

$$log(a(\mathbf{p})) = a_0 + \sum_k a_k \log(p_k) + \frac{1}{2}\sum_j \sum_k \gamma_{jk} \log(p_j) \log(p_k) \tag{5.2}$$

$$\log(b(\mathbf{p})) = \sum_j \beta_j \log(p_j) \tag{5.3}$$

where γ_{jk} are cross-price semi-elasticities and β_j are expenditure semi-elasticites. Parameters have the following restrictions: $\sum_{j=1}^N a_j = 1, \sum_{j=1}^N \beta_j = \sum_{j=1}^N \gamma_{jk} = 0$ and $\gamma ij = \gamma ji\ \forall i, j$.

Households must pay some cost for subsistence level consumption $\log(a(\mathbf{p}))$, where $a(\mathbf{p})$ is a homothetic translog price aggregator. The second aggregator, $b(\mathbf{p})$ introduces non-homotheticicities into the cost-function. A household's cost to reach a higher level of utility (expenditure) increases with $b(\mathbf{p})$. This leads to a non-homothetic price index for a household with fixed utility u_h:

$$\log P\left(\mathbf{p}^1, \mathbf{p}^0, u_h^0\right) = \log\left(\frac{a(\mathbf{p}^1)}{a(\mathbf{p}^0)}\right) + \log\left(u_h^{b(\mathbf{p}^1)-b(\mathbf{p}^0)}\right) \tag{5.4}$$

The greater the household's utility (expenditure) x^h, the higher is the welfare gain from reductions in $b(\mathbf{p})$. Similarly, households with a low-expenditure level have changes in the cost of living closer to changes in the subsistence price index $a(\mathbf{p})$. So the difference in inflation between a household with expenditure X^l and expenditure X^h from period t to $t+h$ is just:

$$\textit{Inflation Inequality} = \log\left(V(X_t^l, \mathbf{p}_t) - V(X_t^h, \mathbf{p}_t)\right)\left(b(\mathbf{p}_{t+h}) - b(\mathbf{p}_t)\right) \tag{5.5}$$

Roy's identity applied to equation (5.1) yields the following Marshallian demand share

[28] A disadvantage is that the AIDS is not generally regular. There are levels of expenditure and prices for which the AIDS is not a valid utility function. However, this is not an issue for the calibration and expenditure levels that I study.

for products in sector j:

$$s_j = a_j + \sum_k \gamma_{jk} \log(p_k) + \beta_j \log\left(\frac{x^h}{a(\mathbf{p})}\right). \tag{5.6}$$

A household's share of expenditure on a particular product j is dependent on prices and real expenditure level. The demand share increases with real expenditure if $\beta_j > 0$ (luxuries). The households expenditure elasticity for good j is $1 + \frac{\beta_j}{s_j}$, while the cross price elasticity is $\delta_{jk} + \frac{\gamma_{jk} - \beta_j(\alpha_j + \sum_k \gamma_{jk} \log(p_k))}{s_j}$ where δ_{jk} is the Kronecker delta term.

Household intratemporal aggregate demand can be represented completely by a representative household with expenditure $X^r = X^{mean} exp\left(\sum \frac{x^h}{X^{mean}} \ln\left(\frac{x^h}{X^{mean}}\right)\right)$ where the term on the right $\left(\sum \frac{x^h}{X^{mean}} \ln\left(\frac{x^h}{X^{mean}}\right)\right)$ is the Theil index of the expenditure distribution, which increases with expenditure inequality Muellbauer (1975), Deaton and Muellbauer (1980).

5.1.2 Intertemporal Consumption Choice and Labor Supply

Each household chooses consumption expenditures to maximize their sum of discounted indirect utility over time:

$$\mathbb{E}_0 \sum_{t=0} \beta^t \left[F\left(V(X_t^h, \mathbf{p}_t)\right) - g(H_t^h)\right], \tag{5.7}$$

where $g()$ is the disutility of labor and H is hours worked. $F(\cdot)$ is taken to be the isoelastic utility function $F(y) = \frac{y^{1-\eta}-1}{1-\eta}$:

One feature of isoelastic preferences is, the elasticity of intertemporal substitution is generally constant. However, that is not the case in this model. Similar Browning (2005), the elasticity of intertemporal substitution is $EIS = -\frac{\nu_x(X_t, \mathbf{p}_t)}{X_t \nu_{xx}(X_t, \mathbf{p}_t)}$, where $\nu(X_t, \mathbf{p}_t) = F\left(V(X_t^h, \mathbf{p}_t)\right)$. So in this model the elasticity of intertemporal substitution is $-\frac{b(\mathbf{p}_t)}{1-\eta-b(\mathbf{p}_t)}$, which varies with the level of relative prices in the economy (Crossley and Low 2011, Attanasio and Weber 1995). When relative prices for luxuries are higher, this increases the concavity of the indirect utility function making further increases in utility more difficult, which raises the elasticity of intertemporal substitution.

One important thing to note is that while the elasticity of intertemporal substitution is dependent on relative prices, it does not depend on the household's income or expenditure level. The household's disutility of labor also does not depend on household expenditure or income (in this model). So, household intertemporal and labor supply decisions can also be characterized by a representative household.[29]

In practice, I solve for equilibrium prices and aggregate shares using the representative household. I can then back out household level price indices given aggregate prices. This approach has the advantage of being able to study welfare effects with heterogeneous consumption bundles using the large toolbox of solution methods for representative agent models.

The representative household works for wages W_t and can invest in a one-period nominally riskless bond B_t that pays one monetary unit in the next period at price Q_t. The resulting household budget constraint and the no-Ponzi scheme condition are shown below:

$$\begin{gathered} X_t + Z_t Q_t B_t \leq B_{t-1} + W_t H_t + D_t \\ \lim_{T\to\infty} \mathbb{E}_t \left(\Lambda_{t,T} B_t \right) \geq 0. \end{gathered} \tag{5.8}$$

In the above expression, D_t is a dividend from firm profits and $\Lambda_{t,T} = \beta^{T-t}\frac{V_{X,T}}{V_{X,t}}$ where β is the discount factor. Z_t, is an interest rate wedge shock that is distributed $i.i.d$ and acts to dampen or increase a household's per-period expenditure.

The household's optimization problem and budget constraint yield the following Euler Equation:

$$Q = \beta \mathbb{E}\left[\frac{a(\mathbf{p})b(\mathbf{p})}{a(\mathbf{p'})b(\mathbf{p'})} \frac{\left(\frac{X'}{a(\mathbf{p'})}\right)^{\frac{1-\eta}{b(\mathbf{p'})}-1}}{\left(\frac{X}{a(\mathbf{p})}\right)^{\frac{1-\eta}{b(\mathbf{p})}-1}} \frac{1}{Z} \right]. \tag{5.9}$$

I assume that the disutilty of labor takes the familiar form (with ϕ the inverse of the Frisch elasticity of labor supply):

$$g(H_t) = \varphi \frac{H_t^{1+\phi}}{1+\phi}. \tag{5.10}$$

However, households do not decide how much labor to provide. Rather, they allow a labor union to bundle and sell their labor, which introduces sticky wages and nominal rigidity (see Erceg et al. (2000), Auclert et al. (2018), Auclert et al. (2020), Broer et al. (2020), Ramey

[29] While there has been extensive work showing that households intertemporal responses vary based on income level (see Kaplan, Moll, Violante (2018) for an example), heterogeneous intertemporal responses is not the key feature of this paper. Some macroeconomic policies such as the 2020 and 2021 stimulus checks could have first-order effects on relative prices, as only low to moderate-income individuals were given checks. If low-income household expenditure increases sufficiently after such a policy then the Theil Index could rise enough to partially offset aggregate increases in expenditure.

(2020)). The mathematical appendix shows that the Wage-Phillips curve is:

$$
\begin{aligned}
(1+\pi_t^w)\pi_t^w =& \beta \mathbb{E}_t\left[(1+\pi_{t+1}^w)\pi_{t+1}^w\right] \\
&+ \left(\frac{\epsilon_w}{\psi_w}\right)\left(\varphi H_t^{\phi} - \left(\frac{\epsilon_w - 1}{\epsilon_w}\right)\frac{W_t}{a(\mathbf{p}_t)b(\mathbf{p}_t)}\left(\frac{X_t}{a(\mathbf{p}_t)}\right)^{(\frac{1-\eta}{b(\mathbf{p}_t)})-1)}\right)
\end{aligned}
\tag{5.11}
$$

5.2 Firms

There is a necessity and a luxury sector. Differentiated intermediate goods in each each sector are indexed by $i \in [0,1]$ and are constructed by firms using a sector specific technology. Firms have constant returns to scale production functions in steady state, but in the short-run capital k is fixed, which makes their production functions concave over labor h. The production function for a differentiated firm i in sector j is:

$$
y_t(i) = A_{jt} P_t^O(i)^{-\kappa\alpha_{oj}} H_t(i)^{\alpha_{hj}} \bar{K(j)}^{\alpha_{kj}} \ \textit{where} \ \ \alpha_{hj} + \alpha_{kj} = 1 \tag{5.12}
$$

Increases in the oil price P^O act as a negative productivity shock to labor similar to the example in the static model. The size of the negative productivity shock depends on the sector's oil concentration α_o and κ, which is estimated as the passthrough of an oil price shock to consumer prices from equation 4.3 in the previous section.

Firms sell their goods in perfectly competitive markets with flexible prices. In the appendix, section C.2.1 I show and extension with monopolistic competition and sticky prices.

To cut down on the number of characterizing equations, I set the price of the necessity good $P_t(N)$ as the numeraire, so $P_t^L = \frac{P_t(L)}{P_t(N)}$ and the necessity relative price is $\frac{1}{P_t^L}$.

5.3 Oil prices and the Central Bank

The price of oil, P_t^O, is set in the world market and is exogenous to the model. There is a central bank that uses a Taylor rule to set interest rates:

$$
-\log(Q_t) = i_t = \psi^{\pi}(\pi_t^w) + \epsilon_{mt} \tag{5.13}
$$

where ϵ_{mt} is a monetary policy shock.

5.4 Baseline Calibration

The three most important sets of parameters for the model are (1) $\beta_L = -\beta_N$ the degree of non-homotheticity, and (2) the labor share α_h, and (3) the oil shares α_o and passthrough κ. The first is important since it governs the degree to which representative household spending shifts between sectors over the course of the business cycle. For example, a value of $\beta_L = -\beta_N = 0$ would imply that the household has homothetic preferences, and macroeconomic shocks would not affect the relative demand for necessities or luxuries. The labor share, α_h, controls the price response of the expanding sector, and α_o joint with κ govern how much an oil shock effects both relative prices and expenditure.

In the baseline calibration, I choose β_L so that the steady-state necessity share for low- and high-income households in the model matches that for low- and high-income households in the data; that is $\beta_L = \frac{s_{L,low} - s_{L,high}}{\log(X_{low}) - \log(X_{high}}$ where low and high denote the representative low-income household and high-income household respectively.

In the baseline calibration, I let $\alpha_{hN} = \alpha_{hL}$ and choose the labor share to be one minus the midpoint of estimates of the capital share in the literature.[30] However, an astute reader can point out that the labor shares in luxuries and necessities are not the same (see table 1). I make this simplification in the baseline model to make understanding the historical decomposition easier, the model's interpretation of the impact of shocks on expenditure come only through differences in demand shifts rather than production function differences.[31] In the appendix section C.2.2, I show how shocks respond differently when we allow the labor shares between luxuries and necessities to differ. Results are quantitatively similar as in the baseline.

The oil shares for necessities (α_{on}) and luxuries (α_{ol}) are taken straight from the estimates using the BEA input and output accounts. κ is estimated from the panel local projections equation (4.3) in the previous section where after roughly 6-months, κ^h, stabilizes at around 0.6.

The remaining parameters I take either from the literature, or from targeting the steady-state expenditure and necessity share of the representative agent to match representative expenditure and aggregate necessity shares in the data.[32] I target the calibration, so that

[30]There are a variety of estimates of α, the capital share, in the literature. These can range from as low as 0.16, the implied value based on the estimated elasticity of marginal cost to quantity produced from Feenstra and Weinstein (2017), to as high as 0.37 estimated directly in Fernald (2014). For the baseline specification, I set the capital share as the midpoint of these extreme values.

[31]One could also make the argument, that there are many other variable inputs in production besides labor and oil, so one minus the capital share is a better way to calculate the share of these inputs in production rather than strictly the labor share as computed in the use and total requirement tables.

[32]Representative expenditure in the data is average real PCE multiplied by the calculated Theil index in

Table 4: Calibration

Parameter	Desc.	Value	Source
α_h	Labor share	0.74	Midpoint Fernald (2014), Feenstra & Weinstein (2017)
α_{on}	Oil share (necessity)	0.12	BEA I-O, Author calc.
α_{ol}	Oil share (luxury)	0.03	BEA I-O, Author calc.
κ	Oil shock passthrough	0.6	Author calc. (Equation 4.3)
β	Discount rate	0.99	–
$1/\eta$	EIS (steady state)	0.5	–
ϕ	Inverse Frisch elasticity	1	–
ψ_w	Wage adj. penalty	20.7	Targets Phillips slope 0.29, Gali & Gambetti (2019)
ϵ_w	Labor substitutability	6	Colciago (2011)
ψ^π	Taylor Rule parameter on wage inflation	1.5	–
β_L	Non-homotheticity	0.29	Targets high- vs. low-income necessity shares
γ_{LN}	Cross-price semi-elasticity	0.095	Feenstra & Weinstein (2017)
γ_{LL}	Own-price semi-elasticity	-0.19	Feenstra & Weinstein (2017)
α_N	Necessity taste param.	2.2	Targets aggregate necessity share of 0.4

in the steady-state necessity and luxury prices are equal (which means that the Elasticity of intertemporal substitution is equal to $1/\eta$) and expenditure in the model is equal to average real expenditure over the sample multiplied by the pooled Theil Index from the CEX. Table 4 shows the chosen calibration.

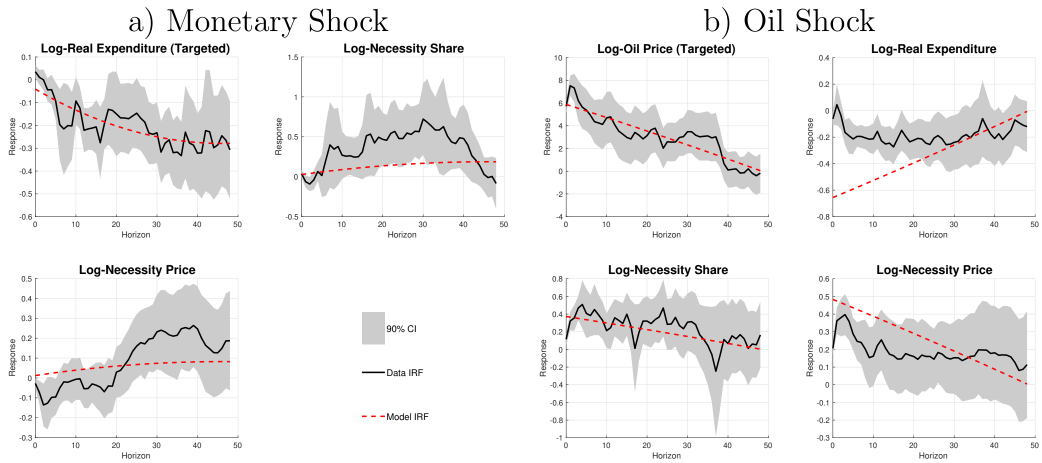
5.5 Model Results

Figure 10 compares the response in the model to a demand shock that affects expenditure and to an oil price shock. In panel a), I show how the model responds to a set of monetary shocks (ϵ_{mt}) so that log-real expenditure in the model matches the smoothed path of the IRF of expenditure to a monetary policy news shock from the last section. The northwest subgraph shows the targeted real expenditure series in the model. The northeast subgraph shows how the non-targeted expenditure share in the model responds to the same set of discount factor shocks. The model's log-necessity share also increases following the demand shock but by around half as much as in the data. The log-necessity price IRF in the model (shown in the southwest subgraph of panel a) is generally within the 90 percent confidence interval of the results from the local projections, but is only around half the value from the empirical results (so in the model the expenditure elasticity of relative necessity prices is around -0.5).

While the model's necessity price and share are less responsive to demand shocks than in the empirical results, I find that the model is more responsive to oil shocks. In panel b)

the CEX.

Figure 10: Model and Data: Response to Aggregate Shocks



Note: In panel a), interest rate/discount shocks in the model are targeted so that expenditure in the model matches smoothed expenditure from the IRFs of log-real expenditure to a monetary news shock in panel a) of figure 7. The remaining variables (log-necessity share and log necessity price) are untargeted. In panel b), the oil shock in the model is chosen so that the log-oil price in the model matches the smoothed response of the log-oil price to a oil news shock in the data (shown in appendix figure A3). Expenditure, log necessity share, and log necessity price are not targeted.

of figure 10, I introduce a series of oil price shocks (P^O) so that the oil price series in the model matches a smothed version in the empirical IRFS. In this case, real-expenditure is not targeted and we can see that the model has a larger response of real consumption to the oil price shock than we see empirically, especially within the first 18 months. Correspondingly, the log-necessity price responds more to an oil price shock in the model than in the data, while the log-necessity share oil price semi-elasticity actually quite closely matches the empirical counterpart.

5.5.1 Contribution of Aggregate Shocks to Inflation Inequality

How well does the model predict necessity prices and shares over time? As a validation exercise, I shock the model with a series of discount factor shocks Z_t, aggregate TFP shocks (common across sectors), monetar shocks, and oil price shocks so that the model's oil price, expenditure, nominal interest rate, hours, and wage, match the WTI, real PCE, and the 1-year Treasury Yield, US aggregate employment hours, and US average hourly earnings respectively for production and non-supervisory workers. I filter the log of each of the data variables using the Hamilton (2018) filter and similar results are found when using a one sided HP filter. Since the monthly PCE price series begins in 1959, my filtered data series for most variables begins in the last quarter of 1961. I use Dynare's method's in Adjemian et al. (2022) to estimate the shocks and their persistence. As I discuss in appendix section C.0.1, the model series for the non-targeted necessity relative price and necessity share are highly correlated (both over 60 percent) with their data counterparts.

Figure 11 shows how the model interprets the sources relative necessity prices inflation from these shocks. The thick black line shows the filtered data. The red bars show the impact of the discount factor shocks, the blue bars the TFP shocks, the purple the monetary shocks, the green bars the direct impact of the oil price shock (simply $\kappa P^O(\alpha_{hn} - \alpha_{hl})$) and the yellow bars are the indirect impact of the oil price shocks coming from other features of the model (mainly non-homothetic demand). The grey bars, which are the difference between the model and data series, can be interpreted as either model misspecification (including the assumption that these shocks do not affect expenditure inequality) or non-modelled shocks including shocks to consumer tastes between necessities and luxuries, other relative productivity, or markup shocks. The decomposition shows that the sources of variations in necessity price inflation are highly varied, with both aggregate demand, supply and oil shocks all playing a large role. As an example, the contractionary monetary policy shocks of the Volcker era had a large impact on necessity relative prices in the early 1980s, while during the Great Recession the discount factor shocks played a large role in boosting relative necessity prices.

Table 5 shows how the path of necessity relative prices contributes to inflation inequality in each of the eight US recessions between 1961 and 2024. The first column shows the role that the expenditure channel (which combines the contributions from TFP, monetary, discount factor, and indirect oil shocks) has on cumulative inflation inequality over the recessionary period.[33] The expenditure channel has been an important part of inflation inequality in each recession, but it has been largest in the 1973 oil shock, the Volcker recessions, the Great Recession, and the COVID-19 recession. In each of these recessions, the expenditure

[33] Inflation inequality in the model is interpreted as the difference between low- and high-income inflation inequality, which is computed using the utility implied by the expenditure of the representative household in each of these income groups. Since the non-filtered price indices are trending upward, cumulative inflation inequality from time t to $t + k$ is the sum of inflation inequality from all periods $t + 1$ to $t + k$.

channel increased inflation inequality by over 1 percentage points relative to trend.

The second column shows the contribution of the direct oil shock, which has also been positive in most recessions. However, in the COVID-19 recession, the fall in oil demand led to a large fall in oil prices, which disproportionately lowered the price of low-income households baskets, which negated the impact of the expenditure channel.

The last column (Data) shows the inflation inequality in the data based on the non-homothetic price index. In the data, I construct $B(P)$ using all 137 of the 148 PCE sectors for which I have price data. I estimate the individual β_j for each sector exactly as done when dividing all products into two sectors, that is $\beta_j = \frac{s_{j,low} - s_{j,high}}{\log(X_{low}) - \log(X_{high}}$ where low and high denote the representative low-income household and high-income household respectively. This means that the model series and the data series could differ due to both the model estimating P^N incorrectly, as well as the fact that the model only has two sectors, while there are 137 in the data. The third column, other factors, is the difference between the data and the model contribution.

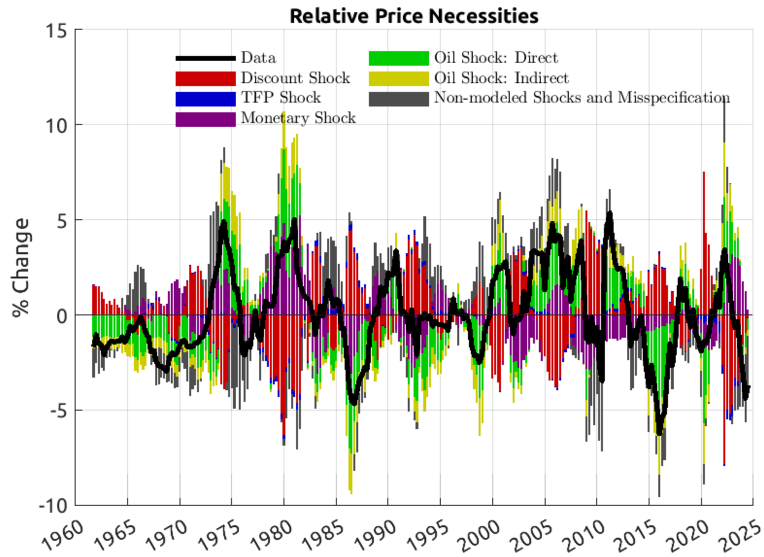
The table shows that inflation inequality can increase due to various factors and when these factors are all positive (such as in the 1973 oil crisis and the Great Recession) the resulting impact on inflation inequality can be quite drastic. In contrast, when the factors go in opposite directions such as in the COVID-19 recession, inflation inequality could be a non-issue or even fall.

6 Conclusion

In this project, I present new evidence on the cyclical behavior of necessity and luxury prices. I find that the the inflation rate and aggregate shares of products bought relatively more by low-income households are counter-cyclical. I show that these facts can be rationalized using a model with non-homothetic preferences and a concave production possibility frontier and test these assumptions using monetary policy and oil shocks. Empirically, I find that the relative necessity price elasticity to expenditure is between -0.5 and -1.

The quantitative model is able to broadly match the empirical results and decompose the contributions to inflation inequality into the non-homothetic expenditure channel, the oil share channel, and other factors. The non-homothetic expenditure channel can have large

Figure 11: Historical Shock Decomposition for Relative Necessity Prices



Note: **Sources of relative necessity price inflation (additional details):** The thick black line shows the filtered data. The bars show the contributions to relative necessity prices of discount rate shocks (red), aggregate TFP shocks (blue), monetary shocks (purple), oil shocks due to differences in oil production shares (green), and the indirect impact of oil shocks due to changes in expenditure (yellow). The grey bars denote the difference between the data and the model estimated relative necessity prices and include both non-modeled shocks (including taste shocks or non-oil relative productivity shocks) along with model misspecification. Shocks are estimated using the Kalman filter method from Adjemian et al. (2022) and targeting model based real expenditure, oil price, and the interest rate to match their data counterparts (see appendix figure A14 for the shock decomposition of these variables and non-targeted necessity shares).

effects on inflation inequality, and since expenditure falls during recessions, this means that inflation inequality generally rises. However, the expenditure channel can be counteracted by other factors especially if if oil prices fall strongly enough, such as in the COVID-19 recession.

It is important to note that this project studies changes in sector-level prices rather than prices within a sector; e.g. furniture is a category made up of many different micro-products each with their own quality and prices. This project also ignores product entry and exit, which could also affect income-level cost-of-living (Feenstra 1994). To the extent that cyclical demand shifts occur within product categories, causing price increases for low-quality products or changes in product variety (at the business cycle frequency) is a topic for future research, although results by Argente and Lee (2021) are suggestive that the within product sector necessity relative prices may behave similarly to the product sector prices I

Table 5: Inflation Inequality during NBER Recessions

Period	Expenditure Channel	Direct Oil	Other Factors	Data: Non-homothetic Inflation
1969Q4-1970Q4	0.69	-1.08	-1.48	-1.87
1973Q4-1975Q1	2.39	2.18	4.34	8.92
1980Q1-1980Q3	1.21	0.90	-0.76	1.35
1981Q3-1982Q4	1.41	-0.05	-1.12	0.23
1990Q3-1991Q1	0.54	0.37	0.21	1.12
2001Q1-2001Q4	-0.15	0.19	1.64	1.67
2007Q4-2009Q2	1.81	0.69	1.47	3.98
2019Q4-2020Q2	1.75	-1.92	-0.87	-1.04

Note: Inflation difference is defined as the percentage point difference in the change of the cost-of-living for Q1 versus Q5 households using the AIDS Non-homothetic price Index cumulative over the recessionary period (inflation inequality). The expenditure channel is the model based estimate of the contributions of aggregate TFP, interest/discount factor, and the indirect component of oil shocks on the cumulative gap in inflation inequality. Direct oil is the model based estimate of the direct contribution of differences in the production shares of oil on inflation inequality. Other factors include relative productivity shocks for luxuries/necessities other than oil and model misspecificaiton (including the use of only 2-sectors in the model compared to 137 in the data). Data is the estimate of inflation inequality derived from using the 137 of 148 PCE sectors that form a balanced panel from 1961-2024.

show here.[34]

This study also has ramifications for the measurement of aggregate changes in the cost of living. For example, in the measurement of the CPI, the BLS uses the CEX to weigh product sectors so they are representative of spending by the average household. However, these weights are updated with a lag (currently of up to two years). Since my study shows that *aggregate* spending shifts to necessities during recessions, that means that the CPI underweights necessities in recessions and overweights them during expansions. This result implies that measurement of inflation via the CPI is potentially biased downward during both recessions (when necessity prices are rising more rapidly) and expansions (when luxury prices are rising more rapidly).

[34]Jaimovich et al. (2019) show that household engage in quality downgrading within sectors during the Great Recession.

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A Mathematical Appendix

A.1 Proof of Proposition 1

Lemma 1 *If $F(H) : [0,\infty) \to [0,\infty)$ is homogeneous of degree $k \in (0,1)$ then* $\frac{\partial \frac{F'(H_j)}{F'(H_i)}}{\partial \frac{F(H_i)}{F(H_j)}} > 0$.

First I show that a function that is homogeneous of degree $k \in (0,1)$ is strictly increasing. Suppose $H_i > H_j$ then:

$$F(H_i) = H_i^k F(1) > H_j^k F(1) = F(H_j)$$

For notational convenience, let $Y_i := F(H_i)$. By Euler's Homogeneous Function Theorem, $F(H_i) = F'(H_i)H_i$, which implies that:

$$\begin{aligned}\frac{F'(H_j)}{F'(H_i)} &= \frac{Y_j}{Y_i}\left(\frac{H_i}{H_j}\right) \\ &= \frac{Y_j}{Y_i}\left(\frac{F^{-1}(Y_i)}{F^{-1}(Y_j)}\right),\end{aligned}$$

where the inverse function must exist since F is strictly increasing. Next, I take the derivative with respect to the output ratio:

$$\frac{\partial}{\partial \frac{F(H_i)}{F(H_j)}} \frac{F'(H_j)}{F'(H_i)} = \frac{Y_j}{Y_i} \frac{\partial}{\partial \frac{F(H_i)}{F(H_j)}} \left(\frac{F^{-1}(Y_i)}{F^{-1}(Y_j)}\right) - \frac{F^{-1}(Y_i)}{F^{-1}(Y_j)} \tag{A.1}$$

Since the inverse of a homogeneous function of degree k, is a homogeneous function of degree $1/k$ it follows that:

$$\frac{\partial}{\partial \frac{Y_i}{Y_j}} \left(\frac{F^{-1}(Y_i)}{F^{-1}(Y_j)}\right) = \frac{\partial}{\partial \frac{Y_i}{Y_j}} \left(\left(\frac{Y_i}{Y_j}\right)^{1/k} \frac{F^{-1}(1)}{F^{-1}(1)}\right) \tag{A.2}$$

$$= \frac{1}{k}\left(\frac{Y_i}{Y_j}\right)^{(1-k)/k}. \tag{A.3}$$

By substituting equation (A.3) into equation (A.1) I find that:

$$\begin{aligned}\frac{\partial}{\partial \frac{F(H_i)}{F(H_j)}} \frac{F'(H_j)}{F'(H_i)} &= \frac{Y_j}{Y_i}\frac{1}{k}\left(\frac{Y_i}{Y_j}\right)^{(1-k)/k} - \left(\frac{Y_i}{Y_j}\right)^{1/k} \\ &= \left(\frac{Y_i}{Y_j}\right)^{1/k}\left(\frac{1}{k} - 1\right),\end{aligned}$$

which is > 0 if and only if $k < 1$. $\blacksquare$

Corrollary 1 *If $F(H) : [0, \infty) \to [0, \infty)$ and $G(H) : [0, \infty) \to [0, \infty)$ are both homogeneous of degree $k \in (0, 1)$ then $\frac{\partial \frac{G'(H_j)}{F'(H_i)}}{\partial \frac{F(H_i)}{G(H_j)}} > 0$.*

This proof follows from the proof above, except replace $\frac{F^{-1}(1)}{F^{-1}(1)}$ in equation (A.2) with $\frac{F^{-1}(1)}{G^{-1}(1)}$, which implies that:

$$= \frac{F^{-1}(1)}{G^{-1}(1)} \left(\frac{Y_i}{Y_j} \right)^{1/k} \left(\frac{1}{k} - 1 \right),$$

$\blacksquare$

Proposition 1 *In a two-sector competitive economy with a representative household that has preferences satisfying equation (3.4), production function in each sector $F_i(H_i) : [0, \infty) \to [0, \infty)$ both homogeneous of degree $k \in (0, 1)$ and standard market clearing conditions, then an decrease/increase in household expenditure will lead to an increase/decrease in the relative price of necessities.*

Due to market clearing, it follows that

$$C^i(X, p_N, p_L) = F_i(H_i) \ \forall i$$

From equation (3.4) we know that

$$\frac{\partial}{\partial X} \frac{C^L(X, p_N, p_L)}{C^N(X, p_N, p_L)} > 0.$$

This implies that:

$$\frac{\partial}{\partial X} \frac{F_L(H_L)}{F_N(H_N)} = \frac{\partial}{\partial X} \frac{Y_L}{Y_N} > 0. \tag{A.4}$$

Relative prices can be expressed as:

$$\frac{p_L}{p_N} = \frac{F_{N,H}(H_N)}{F_{L,H}(H_L)}$$

From lemma and corollary 1, we get that:

$$\frac{\partial}{\partial \frac{Y_L}{Y_N}} \frac{F_{N,H}(H_N)}{F_{L,H}(H_L)} > 0. \tag{A.5}$$

Combining equation (A.4) with equation (A.5) and the chain-rule implies that:

$$\frac{\partial}{\partial X} \frac{p_L}{p_N} > 0$$

So the price of the expanding sector (luxuries in this case) must increase. ■

A.2 A Note on Aggregation

In general, it is not true that if micro-households have non-homothetic preferences then the aggregate household will also have non-homothetic preferences of the same form. Very few types of non-homothetic preferences are Gorman-Polar (Stone-Geary is a notable exception), so these type of preferences cannot simply be added up across households to create an aggregate household with the same preference structure and parameters as the micro households (Muellbauer 1975).

Muellbauer (1975) shows that a necessary and sufficient condition for there to exist an income/expenditure level such that a representative household with that income/expenditure level to have preferences identical to the average of all households is that households must have Generalized Linear preferences. The expenditure/income of a slightly less general version of these preferences, Price Independent Generalized Linear is shown to depend positively on both aggregate income/expenditure and the inequality of the income/expenditure distribution. Intuitively, the reason is that in a more unequal economy, all else being equal, will have a higher portion of aggregate income/expenditure concentrated in a few hands, which means that more luxuries will be consumed. Hence, the representative household should have higher income/expenditure than those implied by the aggregate expenditure in the economy.

If the representative household proceeds to purchase relatively more necessity goods, then these purchases will cause necessity prices to increase. Since poorer households have lower expenditure than richer households, these households will have a larger percentage of their basket devoted to the necessity good. This increase in necessity prices will increase the low-income households price index relative to high-income households.

It has been documented that both recessions (Heathcote et al. 2020) and contractionary monetary policy (Coibion, Gorodnichenko, Kueng, Silvia 2018) increase inequality. Since demand for the necessity good depends on both aggregate expenditure (decreasing) and inequality (decreasing), a shock that simultaneously lowers aggregate expenditure and raises inequality would have ambiguous effects on relative necessity demand. To fix ideas, if representative expenditure x^r is a function F($\cdot$) of aggregate expenditure $\bar{x}$ and expenditure inequality Σ_x then the elasticity of representative expenditure to a macroeconomic shock, $\mathcal{E}_{x^r,shock}$, would be:

$$\mathcal{E}_{x^r,shock} = \mathcal{E}_{x^r,\bar{x}}\mathcal{E}_{\bar{x},shock} + \mathcal{E}_{x^r,\Sigma_x}\mathcal{E}_{\Sigma_x,shock}. \tag{A.6}$$

In equation (A.6), the elasticity of representative expenditure to a shock depends on both the elasticity of aggregate expenditure to the shock and the elasticity of inequality to the shock, where each term is scaled by the elasticity of representative expenditure to either aggregate expenditure or inequality.[35] In the empirical section, I show that following a monetary policy shock the effect coming through aggregate expenditure dominates.

A.3 Derivation of Wage-Phillips Curve

I add sticky wages by following the convention in the literature and creating market power in the labor market via a labor union (see Erceg et. al. 2000, Auclert et. al. 2018, Auclert et. al. 2020, Broer et. al. 2020, Ramey 2020).

Specifically, each worker (i) in the economy provides h_{ikt} hours of labor to each of a continuum of unions indexed by $k \in (0, 1)$. Total labor for person (i) is then:

$$h_{it} = \int_k h_{ikt} dk. \tag{A.7}$$

Each union k aggregates units of work into a union specific task $H_{kt} - \int_i h_{ikt} di$.

There is a competitive labor packer that takes labor from unions and packages it into

[35]In the PIG-Log (AIDS) specification I adopt in the main text, the elasticity of x^r with respect to both aggregate expenditure and inequality (as measured by the Theil index) is one, so equation (A.6) reduces to just $\mathcal{E}_{\bar{x},shock} + \mathcal{E}_{\Sigma_x,shock}$. Coibion et al. (2017) finds that the elasticity of the standard deviation of expenditure increases by .03 four months after a one-standard deviation monetary policy shock, while consumption falls by approximately 0.5 percent. Given that the Theil coefficient for a log-normal distribution is $\sigma^2/2$ it follows that the aggregate expenditure elasticity dominates the inequality elasticity.

one unit of "usable" labor following a CES function. Aggregate labor is then:

$$H_t = \left(\int_k H_{kt}^{\frac{\epsilon_w - 1}{\epsilon_w}} \right)^{\epsilon_w/(\epsilon_w - 1)}, \tag{A.8}$$

where ϵ_w is the elasticity of substitution between different types of labor.

Unions set a common wage w_{kt} for all members and require each member household to supply uniform hours: $h_{ikt} = H_{kt}$.

Following (Auclert et al. 2018,2020) I add an extra disutility term for households, so that households dislike adjusting wages:

$$\frac{\psi_w}{2} \int_k \left(\frac{w_{kt}}{w_{kt-1}} - 1\right)^2 dk, \tag{A.9}$$

where ψ_w scales the degree of wage stickiness.

At time t, union k sets wage w_{kt} to maximize (on behalf of all union workers):

$$\max_{w_k t} \mathbb{E}_t \sum_{\tau > 0} \beta^{t+\tau} \left(\int \left[V(X_{it+\tau}, \mathbf{p}_{t+\tau}) - g(h_{i,t+\tau}) \right] d\psi_{it+\tau} - \frac{\psi_w}{2} \int_k \left(\frac{w_{kt}}{w_{kt-1}} - 1\right)^2 dk \right)$$
$$s.t.\ H_{kt} = \left(\frac{w_{kt}}{W_t} \right)^{-\epsilon_w} H_t \tag{A.10}$$

The union takes as given the distribution ψ_{it} of workers (in this version of the model, all workers are identical) and all prices excluding w_{kt} (note that $W_t = \left(\int_k w_{kt}^{1-\epsilon_w} dk \right)^{1/(1-\epsilon_w)}$.)

The envelope theorem allows me to ignore both the intertemporal reoptimization of saving or spending in response to a marginal change in wages, along with the intratemporal reoptimization of spending across sectors. I treat any change in income as a change in consumption expenditure:

$$\begin{aligned}
\frac{\partial X_{it}}{\partial w_{kt}} &= \frac{\partial}{\partial w_{kt}} \int_0^1 w_{kt} h_{ikt} dk \\
&= \int_0^1 \frac{\partial}{\partial w_{kt}} w_{kt} \left(\frac{w_{kt}}{W_t} \right)^{-\epsilon_w} H_t dk \\
&= (1 - \epsilon_w) \left(\frac{w_{kt}}{W_t} \right)^{-\epsilon_w}.
\end{aligned}$$

I next derive the change in hours worked to a change in wages for household (i) using the labor rule that $H_{kt} = h_{ikt} \forall i$ and the demand constraint:

$$
\begin{aligned}
\frac{\partial h_{it}}{\partial w_{kt}} &= -\epsilon_w \left(\frac{w_{kt}^{-\epsilon_w - 1}}{W_t^{-\epsilon_w}} \right) \\
&= -\epsilon_w \frac{H_{kt}}{w_{kt}}.
\end{aligned}
$$

It follows that the first order condition of the union's maximization problem equation (A.10) becomes:

$$
\begin{aligned}
\int H_{kt} \left[V_X(X_it, \mathbf{p}_t)(1-\epsilon_w) \left(\frac{w_{kt}}{W_t} \right)^{-\epsilon_w} + \frac{\epsilon_w}{w_{kt}} g'(h_{it}) \right] d\psi_{it} - \psi_w \left(\frac{w_{kt}}{w_{kt-1}} - 1 \right) \frac{1}{w_{kt-1}} \\
+ \beta \psi_w \mathbb{E}_t \left[\left(\frac{w_{k,t+1}}{w_{k,t}} - 1 \right) \left(\frac{w_{k_t+1}}{w_{kt}^2} \right) \right] = 0.
\end{aligned}
$$

This simplifies when we note that the maximization problem for all unions is identical, so in equilibrium $w_{kt} = w_t$. Denoting $\pi_t^w \equiv \left(\frac{w_t}{w_{t-1}} - 1 \right)$ and using the functional forms for $V[\cdot]$ and $g(\cdot)$ provided in section 6 yields:

$$
\begin{aligned}
\psi_w \pi_t^w (1 + \pi_t^w) =& \beta \mathbb{E}_t \left(\psi_w \pi_{t+1}^w (1 + \pi_{t+1}^w) \right) + \\
& H_t w_t \int \left[\frac{1}{a(\mathbf{p}_t) b(\mathbf{p}_t)} \left(\frac{X_t}{a(\mathbf{p}_t)} \right)^{((1-\eta)/b(\mathbf{p}_t))-1} (1-\epsilon_w) + \frac{\epsilon_w}{W_t} \varphi H_{it}^{\phi} \right] d\psi_{it}.
\end{aligned}
$$

In the representative agent model that I am considering here, this further simplifies to:

$$
\begin{aligned}
(1+\pi_t^w)\pi_t^w =& \beta \mathbb{E}_t \left[(1+\pi_{t+1}^w)\pi_{t+1}^w \right] \\
&+ \left(\frac{\epsilon_w}{\psi_w} \right) \left(\varphi H_t^{\phi} - \left(\frac{\epsilon_w - 1}{\epsilon_w} \right) \frac{W_t}{a(\mathbf{p}_t) b(\mathbf{p}_t)} \left(\frac{X_t}{a(\mathbf{p}_t)} \right)^{((1-\eta)/b(\mathbf{p}_t))-1} \right)
\end{aligned}
\tag{A.11}
$$

It follows that the union will adjust wages in expectations of future wage inflation or when the marginal disutility of labor is higher than the product of marginal utility of expenditure and the optimal wage.

B Data Appendix

B.1 Defining Household Income Groups

I use both the diary and interview survey from the 1980-2022 CEX waves. I divide households into five different income groups similar to Aguiar and Bils (2015) (the main deviation is that I use a much longer sample of CEX data). Namely, I keep only households that participate in all four CEX interviews and are complete income reporters. I also include only urban households and households whose household head is between 25 and 64. I divide households into five different income groups based on their pre-tax income. In addition to pre-tax income reported in the CEX, I include income from alimony, gifts, gambling winnings, inheritance, and any other payments from persons outside the household; similarly, I subtract from income the alimony, child support, etc. paid by the household. Since I am using survey data from multiple years, I deflate all household income by the PCE price index. Next, I regress this income measure on dummies of the household size, max age of household head, and the number of income earners in the household.

Then, I organize households into five different groups based on their real income percentile across the entire sample (1980-2022). The five groups represent quintiles of the income distribution, so the bottom income group is households under the 20th percentile of income and the top group are households in the top income quintile. Groups 2, 3, and 4 are households in the 20th-40th percentile, 40th-60th percentile, and 60th-80th percentile, respectfully.

B.2 PCE Categories

I match PCE sectors with UCC codes from the CEX using the BLS staff's PCE-CE crosswalk (Bureau of Labor Statistics 2019). This crosswalk was designed for the post-1990 CEX survey waves, so I extend the crosswalk to match UCC codes that only exist in the earlier 1980 waves of the CEX.[36]

I exclude rent and owners-equivalent-rent since most high-income households are homeowners while low-income households generally rent their homes. While the BLS constructs an imputed owners' equivalent rent series, homeowners do not actually pay this price. When rent prices change, homeowners can still consume at their initial endowment point and are shielded from increases in home prices. While studying the effects of owning versus renting on real income and wealth inequality is an interesting area of research, it is not the focus of this article. I also exclude non-market PCE prices and quantities such as charitable donations, gambling, and meals or rent as pay.

This leaves me with 148 distinct categories for which I have aggregate spending and price

[36]This extended crosswalk is available upon request from the author.

data from the NIPA underlying detail tables and income level expenditure information from the diary and interview CEX surveys. The 148 categories represent 73 percent of December 2019 total PCE.

B.3 Expenditure Shares

I create income group expenditure shares as the household survey weighted average of household expenditure shares for all households in the income group (democratic weighting). Note that this procedure is different from how the BLS creates expenditure shares for the CPI, since they also base their shares on the contribution of the household to total spending, which puts more weight on higher spending households. Since this paper is focused on non-homotheticicities in consumption shares, weighting based on expenditure is problematic, as it would give more weight to households at the upper end of an income group (say those nearer to the 20th percentile versus those nearer the 5th percentile). This weighting could also be a problem when some households report more of their expenditure than others (see Aguiar and Bils (2015) for under-reporting in the CEX).

I start by creating average sector-level income group expenditure shares separately in the interview and diary survey. To maintain democratic weighting, when categories in the diary and interview survey represent both the same type and aggregation level of spending (such as for some clothing categories) I use the expenditure share for the interview survey since the interview survey is representative of the household's complete expenditure basket. For categories that overlap but that are at a finer level of aggregation in the diary survey (for example subcategories of food at home) I multiply the expenditure weight of the larger interview category J by the diary subcategory share of spending on sector J:

$$s_{ji} = s_{Ji} \times \frac{x_{ji}}{\sum_{k \in J} x_{ki}} j \in J. \tag{B.1}$$

As an example, for subcategories of food at home, I create the expenditure share by multiplying each subcategories share of food at home spending from the diary survey by the share of food at home in total spending from the interview survey.

Table A1: Top luxury and necessity products

Panel A: Top Luxury Sectors

	Percent Expenditure		
PCE Category	**Low-Income**	**High-Income**	R_j
Water transportation	0.01	0.03	0.26
Domestic services	0.10	0.35	0.28
Wine	0.02	0.06	0.34
Spirits	0.01	0.03	0.33
Passenger fares for foreign travel	0.16	0.45	0.36
Hotels and motels	0.32	0.85	0.37
Musical instruments	0.03	0.09	0.35
Jewelry	0.12	0.34	0.37
Clocks, lamps, lighting fixtures, and other household decorative items	0.10	0.26	0.36
Amusement parks, campgrounds, and related recreational services	0.09	0.23	0.38

Panel B: Top Necessity Sectors

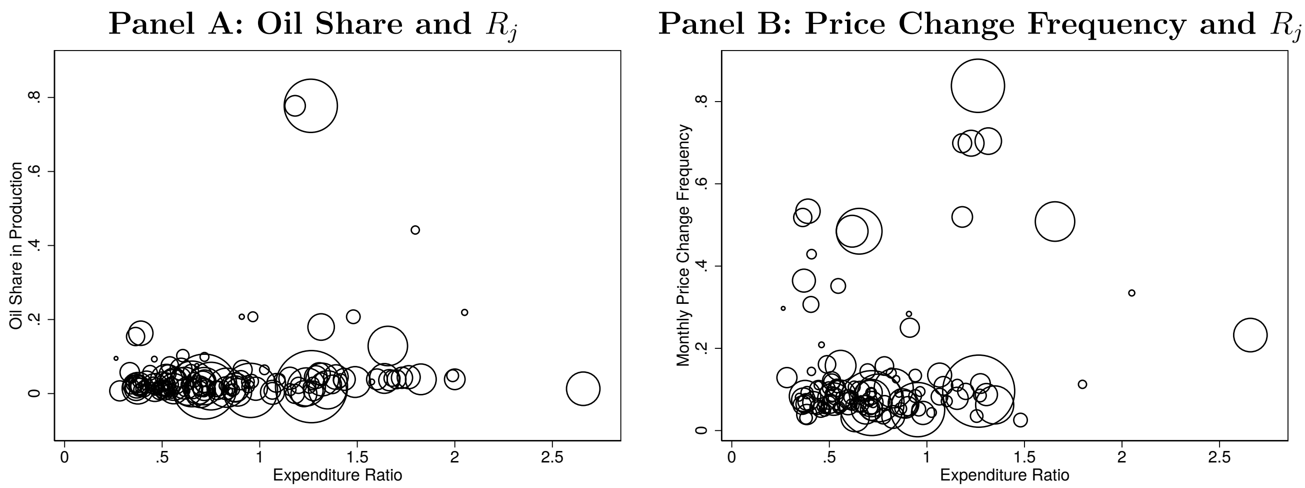
	Percent Expenditure		
PCE Category	**Low-Income**	**High-Income**	R_j
Tobacco	1.07	0.40	2.66
Other fuels	0.05	0.02	2.05
Pork	0.57	0.29	2.00
Eggs	0.19	0.09	1.99
Lubricants and fluids	0.06	0.03	1.80
Beef and veal	0.82	0.45	1.83
Fresh milk	0.76	0.43	1.76
Poultry	0.55	0.32	1.73
Other meats	0.39	0.23	1.70
Electricity	3.36	2.03	1.66

Note: Expenditure ratio (R_j) is defined as the average expenditure share of households in the bottom income group divided by the average expenditure share of households in the top income group.
Source: Consumer expenditure survey and author's own calculations.

B.4 Top Luxuries and Necessities

Table A1 Panel A shows the top 10 luxury goods. The consumption category that has the highest comparative expenditure by those in the top income group is "Water transportation", which has an expenditure ratio, R_j, of 0.26. So, on average, households in the highest income group spend 3.8 times as much of their budget on this category compared to households in the lowest income group. Other top luxury goods include Domestic Services, Wine, and Hotels

Figure A1: Oil Share, Price Frequency, and R_j



Source: Consumer Expenditure Survey, BEA, Montag and Villar (2022) and author's own calculations.

Note: The size of the circles denotes that PCE sector's average share in aggregate expenditure.

and motels. Panel B shows the top 10 necessity goods. These include tobacco products, energy, and food products.

As shown in figure A1 panel A, most product sectors have a rather low oil share in production (the median is 2.4 percent), but there are some large outliers. For example, it perhaps goes without saying that gasoline is the PCE sector with the highest share of oil in total production costs (nearly 80 percent). Some of the other PCE sectors with high oil shares include other energy sectors, which are mostly necessities and public transportation sectors such as air travel, which tend to be luxuries. I take the price change frequency from each sector from Montag and Villar (2022).[37] Like the oil share, the price change frequency is highly concentrated at a low level and the median product has a price change frequency of only 8 percent. However, there are also some large outliers amongst both necessities and luxuries. These outliers also tend to be transportation services and energy products, although motor vehicles and parts subcategories also tend to adjust prices more frequently.[38]

[37] Only 117 of the 148 PCE sectors have matching price frequency data from Montag and Villar (2022) since the price micro-data for some PCE sectors is not available.

[38] All median and average statistics in this paragraph are weighted by the PCE sector's share in aggregate expenditure.

B.5 Panel Regression Results using Alternate Definition of Necessity

Tables A2 and A3 show alternate versions of table 3 in the main text. Table A2 replaces the binary definition of necessity in the interaction terms with R_j, the ratio of the sector's consumption share for low-income households over that of high income households. The interpretation of the coefficient on UR $\times R_j$ is the relative increase in the log share or inflation rate of a product with a one point higher expenditure ratio R_j when there is a one point increase in the unemployment rate. The coefficients for most of these regressions are of a similar magnitude to the coefficients in the main text that uses the binary definition of necessity. This could be due to the fact that the average R_j for luxuries is 0.6, while for necessities it is 1.4 exactly one point higher. Results are of a similar size and statistically significant for all columns except for the inflation columns that do not control for other aspects of the product (columns 4 and 5).

Table A3 uses an alternate definition of income groups. In the baseline version, a household's income group is based on where the household is in the distribution of real income over the entire CEX sample from 1980-2022. Instead, in this alternate definition, a household's income group is based on where they are in the distribution of income in the month they are interviewed. For example, if a household is interviewed in January 2019, their income group is based on their percentile of income only compared to other households interviewed in January 2019. Results using this alternate definition of income group are virtually identical to those shown in the main text.

B.6 Time Series Local Projection Results

Figures A2 shows additional time series results of responses to the Bauer and Swanson (2022b) monetary shock. Panel a) shows that following the monetary policy shock the 1-year treasury yield increases, however, the increase is not statistically significant. In contrast, the 10-year treasury yield, shown in panel b) increases following the shock and reaches a peak of around 7.5 basis points between 18- and 30- months after the monetary policy news surprise. Panel c) shows that the PCE price index declines starting a bit after 6-months after the shock and reaches a trough of around 0.1 percentage points lower 18 months after

Table A2: Continuous Measure of Necessity

	100× Log-Share			Inflation		
	(1)	(2)	(3)	(4)	(5)	(6)
Right hand side variables:						
UR $\times R_j$	1.79***	1.79***	1.89***	0.06	0.06	0.49***
	(0.46)	(0.45)	(0.18)	(0.08)	(0.07)	(0.10)
Δ Oil Price $\times R_j$	0.02			0.03***		
	(0.02)			(0.00)		
Δ Oil Price × Oil Share		0.30***	0.33***		0.57***	0.57***
		(0.10)	(0.10)		(0.04)	(0.03)
UR × PC Frequency			3.99***			-0.10
			(1.02)			(0.35)
UR × Labor Share			0.95			0.13
			(0.91)			(0.18)
UR × Service			0.56			0.41***
			(1.54)			(0.12)
UR × Durable			-2.31***			0.52***
			(0.66)			(0.11)
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes	Yes
Observations	113,484	113,484	89,697	111,720	111,720	88,305

Notes: The unit of observation is at the sector-time level. R_j is the ratio of the expenditure share on the PCE sector for low-income households over high-income households. Inflation is the 12-month percent change in the consumption sector price level. The change in oil price is the 12-month percent change in WTI prices. Standard errors, in parentheses, are clustered at the time level and are robust to auto-correlation. Significance at the 1, 5, and 10 percent levels indicated by ***,**, and *.

the shock. Finally, the oil price initially declines following the shock before rising back to baseline and then falling again.

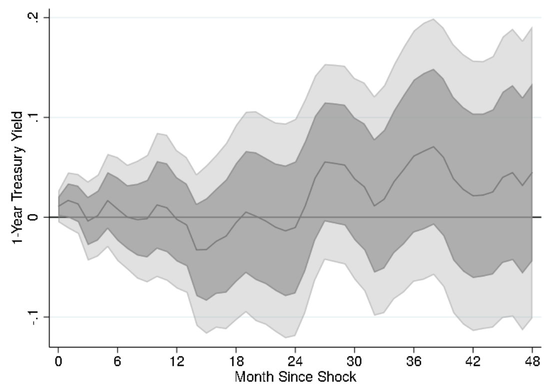
Figure A3 shows additional time series results of the response of interest rates, the PCE price index, and the oil price to a Känzig (2021) oil shock. The oil shock leads to a statistically significant increase in both the 1- and 10-year treasury yields, as shown in panels a) and b). The oil shock also leads to a persistent increase in the overall PCE price index of around 0.2 percentage points. Finally, the oil price increases by around 7 percent 3-months after the shock before receding to between 3 and 4 percent 12 to 36 months after the shock. The oil price mean reverts after 40-months.

Table A3: Income Groups Based on Relative Income at Survey Date

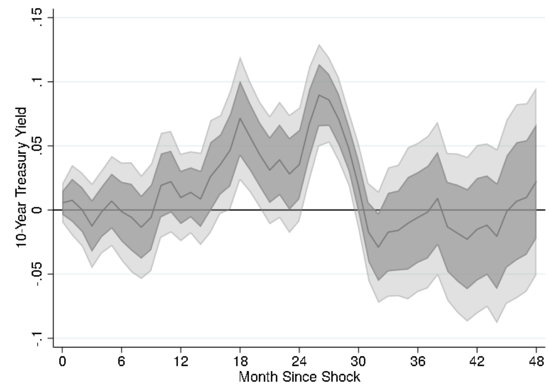
	100× Log-Share			Inflation		
	(1)	(2)	(3)	(4)	(5)	(6)
Right hand side variables:						
UR × Necessity	1.73***	1.75***	1.68***	0.16**	0.13**	0.42***
	(0.17)	(0.17)	(0.33)	(0.07)	(0.06)	(0.08)
Δ Oil Price × Necessity	0.02			0.05***		
	(0.01)			(0.00)		
Δ Oil Price × Oil Share		0.30***	0.33***		0.57***	0.57***
		(0.10)	(0.10)		(0.04)	(0.03)
UR × PC Frequency			3.24***			-0.29
			(1.12)			(0.36)
UR × Labor Share			0.40			-0.02
			(0.87)			(0.20)
UR × Service			0.23			0.33***
			(1.50)			(0.11)
UR × Durable			-2.69***			0.42***
			(0.69)			(0.11)
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Weighted	Yes	Yes	Yes	Yes	Yes	Yes
Observations	113,484	113,484	89,697	111,720	111,720	88,305

Notes: The unit of observation is at the sector-time level. Necessity is defined as a sector with an expenditure share equal to or greater than one (low-income households consume relatively more than high-income households) where the income group is based on the distribution of income at the survey date. Inflation is the 12-month percent change in the consumption sector price level. The change in oil price is the 12-month percent change in WTI prices. Standard errors, in parentheses, are clustered at the time level and are robust to auto-correlation. Significance at the 1, 5, and 10 percent levels indicated by ***,**, and *.

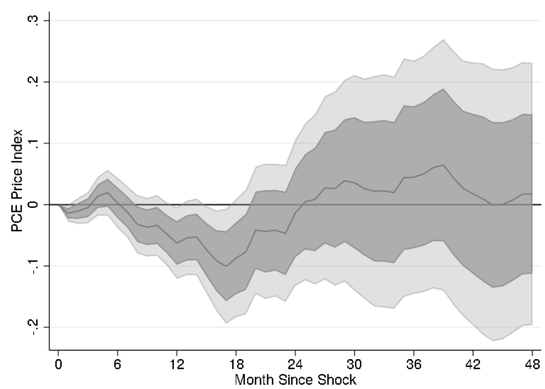
Figure A2: Response to Monetary Policy Shock



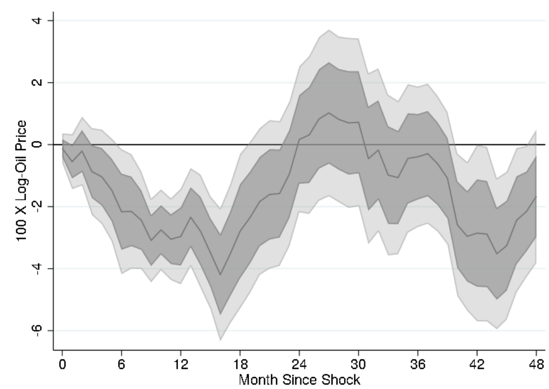
a) 1-Year Treasury Yield



b) 10-Year Treasury Yield



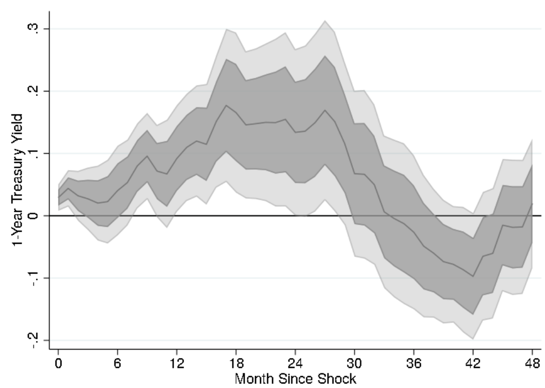
c) PCE Price Index



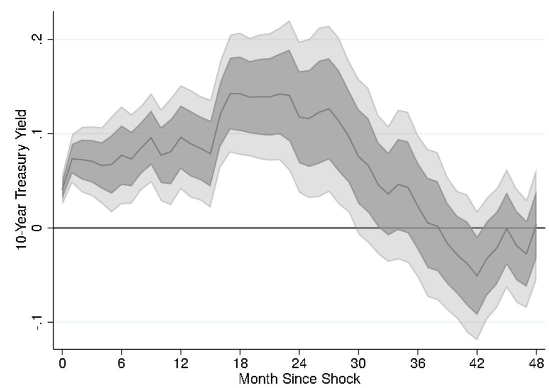
d) Log-Oil Price

Note: Data from 1989-2019. Estimated coefficients, from Local Projections represent the response of the dependent variable to a one-standard deviation Bauer and Swanson (2022b) monetary shock. The unit of observation is the month. The unit of observation is the month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively. Standard errors are robust to auto-correlation.

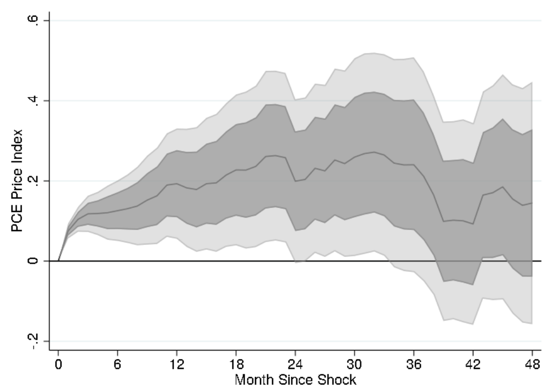
Figure A3: Response to Oil Price Shock



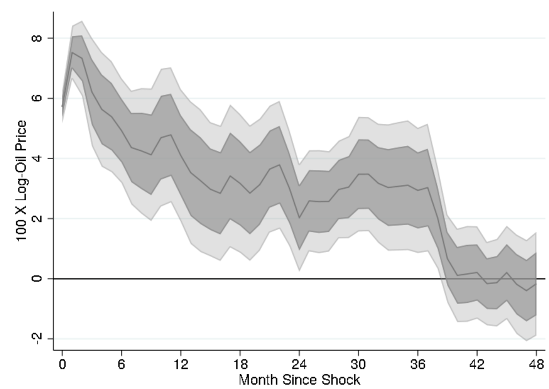
a) 1-Year Treasury Yield



b) 10-Year Treasury Yield



c) PCE Price Index



d) Log-Oil Price

Note: Data from 1976-2023. Estimated coefficients, from Local Projections represent the response of the dependent variable to a one-standard deviation Känzig (2021) oil shocks . The unit of observation is the month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively. Standard errors are robust to auto-correlation.

B.7 IRF Robustness Checks

B.7.1 Monetary Robustness Checks

Here I present several robustness checks that complement my IRF results in the main text. In figure A4, I show results from my baseline monetary model from equation 4.1, but using the monetary high-frequency news shocks from Gertler and Karadi (2015) or Miranda-Agrippino and Ricco (2021). These alternative shocks have been widely cited in the literature. Like the Bauer and Swanson (2022b) shocks, they are based on high frequency movements of Fed-future prices in a small window around FOMC meetings. Unlike the Bauer and Swanson (2022b) shocks, these other shocks do not use information from FED chair speeches, which Swanson and Jayawickrema (2023) argues can be more important for macro variables than regular monetary policy announcements. These other shock series are also a bit shorter than the Bauer and Swanson (2022b) series; the Gertler and Karadi (2015) goes from 1990 to 2012 and the Miranda-Agrippino and Ricco (2021) is from 1991-2009 compared to 1989-2019 for the Bauer and Swanson (2022b) series. The Miranda-Agrippino and Ricco (2021) orthogonalizes the monetary policy surprise by the Federal Reserve Staff's forecast.

As shown in panel a) the results for necessity shares are mixed. The Gertler and Karadi (2015) shocks result in a much smaller effect on relative necessity shares than in my baseline, while Miranda-Agrippino and Ricco (2021) results in a smaller increase in the relative log-share of around 0.3 percentage points, compared to the around 0.5 percentage points in my baseline specification. Panel b) shows that the results on the log-price are more consistent, with the IR for the two alternative monetary policy shocks mostly within the one-standard deviation confidence interval of my baseline model. However, consistent with these alternative shocks having a smaller impact on necessity shares, the results on necessity prices are somewhat smaller as well.

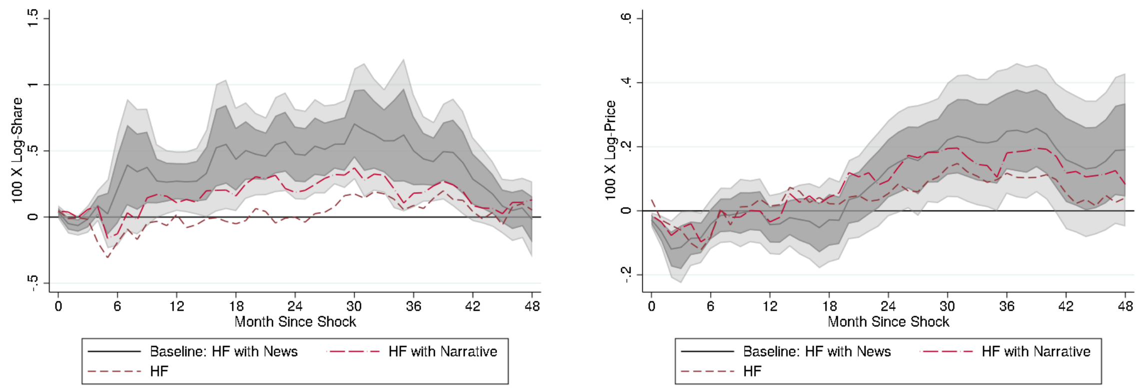
In figure A5 I show results from several different alternative specifications where $\Gamma_{h,k}W_{j,t-k}$ is taken to include the interaction between the PCE sectors total oil cost-share and the current and lagged changes in the oil prices (baseline shown as the black solid line), only the oil price change interaction (shown as the green dashed line), empty (shown as the long dashed yellow line), to include the baseline interactions as well as an interaction between the PCE sector's monthly price change frequency and the monetary policy shock (the long-dash red line), and finally to also include the baseline interactions as well as an interaction between the PCE sector's labor share and the monetary policy shock (solid purple line). The results for the log-share IRF are very similar between the baseline and the alternative specifications. For the response of the necessity log-price to the monetary policy shock, the baseline results are most similar to the specification that removes the durable interaction. The specification that removes both the durable and oil price interactions leads to a lower increase in the necessity price than in the baseline, although the results are mostly within the 90 percent confidence interval. In the specification that includes the price change frequency interaction the log-price responds more than in the baseline for the first 24 months, and less from months 24-48, with the results mostly within the baseline 90 percent confidence interval. Finally, in the specification that includes the labor share, the relative log-necessity price is more than in the baseline for the first 18 months, but then it flattens out at a lower level (around 0.08 compared to 0.25 in the baseline) afterward.

In figure figure A6, I redo the IRFs and robustness tests, but the main coefficient of interest is now the interaction between a binary definition of necessity and the monetary policy shock, rather than the continuous expenditure ratio measure that I use in the main text. The estimated coefficients are quite similar to the results in the main text: a one-standard deviation monetary policy shock leads to a 0.5 percent increase in relative necessity shares and a 0.2 percent increase in relative necessity prices, quite similar to the results in the main text. This implies a necessity relative price elasticity of expeniture of around -1.

Finally, figure figure A9 computes IRFs of real-sectoral expenditure to a monetary policy shock. This set of results show that relative real demand for necessities rise following a monetary policy shock and the results for the log-share that I find in the main text are not simply mechanically driven due-to higher necessity prices.

B.7.2 Oil Price Shock Robustness Checks

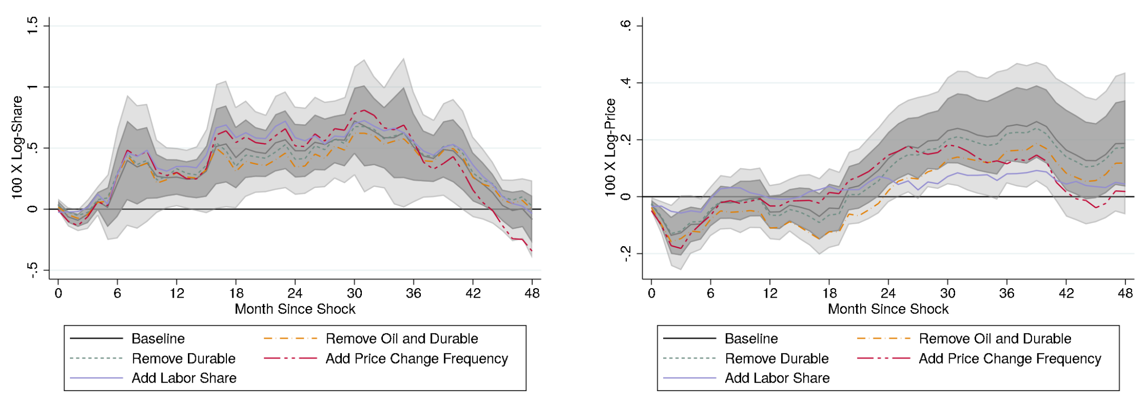
Figure A4: Necessity Response to Alternate Monetary Policy Shock



a) Log-Necessity Share　　　　b) Log-Necessity Price

Note: Estimated coefficients, $\gamma^{h,0}$ from Local Projections in equation (4.1) represent the response of the dependent variable to a one-standard deviation monetary contraction using the Bauer and Swanson (2022b), Gertler and Karadi (2015), or Miranda-Agrippino and Ricco (2021) monetary shocks interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively for the Bauer and Swanson (2022b) shock. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure. Monetary Policy shock normalized to be mean zero and standard deviation of one.

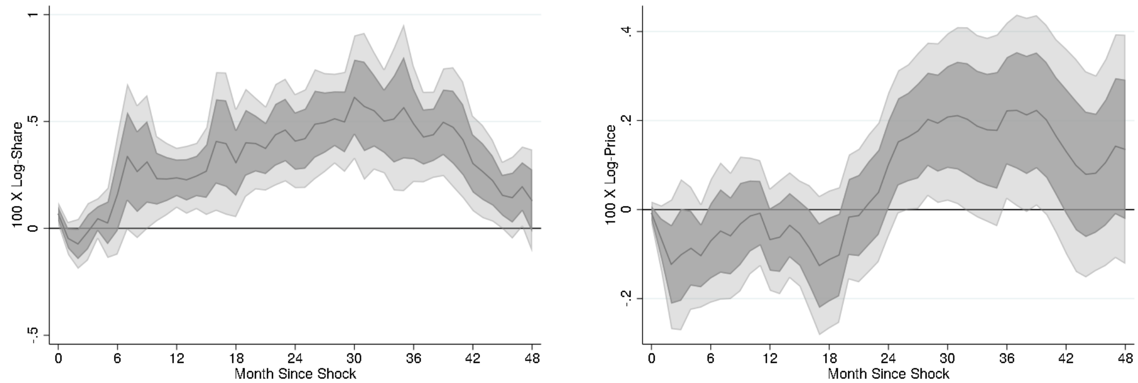
Figure A5: Necessity Response to a Monetary Policy Shock: Alternate Specifications



a) Log-Necessity Share　　　　b) Log-Necessity Price

Note: Data from 1989-2019. Estimated coefficients, γ^{h} from Local Projections in equation (4.1) represent the response of the dependent variable to a one-standard deviation monetary contraction using the Bauer and Swanson (2022b) monetary shocks interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively for the baseline specification. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure. Monetary Policy shock normalized to be mean zero and standard deviation of one.

Figure A6: Binary Definition of Necessity Response to Monetary Policy Shock

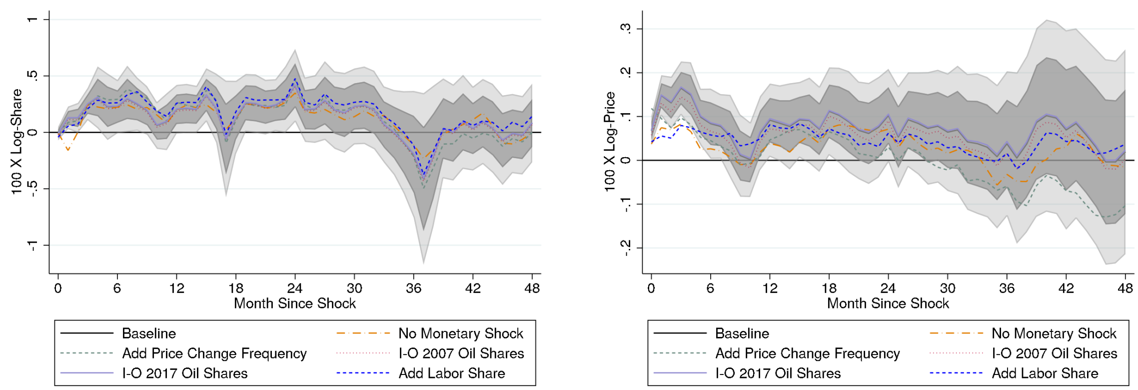


a) Log-Necessity Share

b) Log-Necessity Price

Note: Data from 1989-2019. Estimated coefficients, $\gamma^{h,0}$ from Local Projections in equation (4.1) represent the response of the dependent variable to a one-standard deviation monetary contraction using the Bauer and Swanson (2022b) monetary shocks interacted with $1\{R_j > 1\}$. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure. Monetary Policy shock normalized to be mean zero and standard deviation of one.

Figure A7: Necessity Response to an Indirect Oil Shock: Alternate Specifications

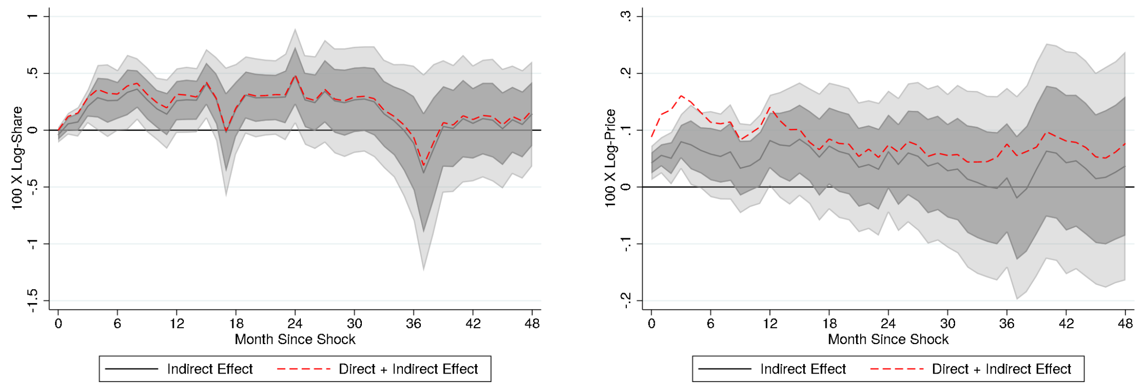


a) Log-Necessity Share

b) Log-Necessity Price

Note: Data from 1989-2019. Estimated coefficients, γ^h from Local Projections in equation (4.1) represent the response of the dependent variable to a one-standard deviation monetary contraction using the Bauer and Swanson (2022b) monetary shocks interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively for the baselien specification. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure. Monetary Policy shock normalized to be mean zero and standard deviation of one.

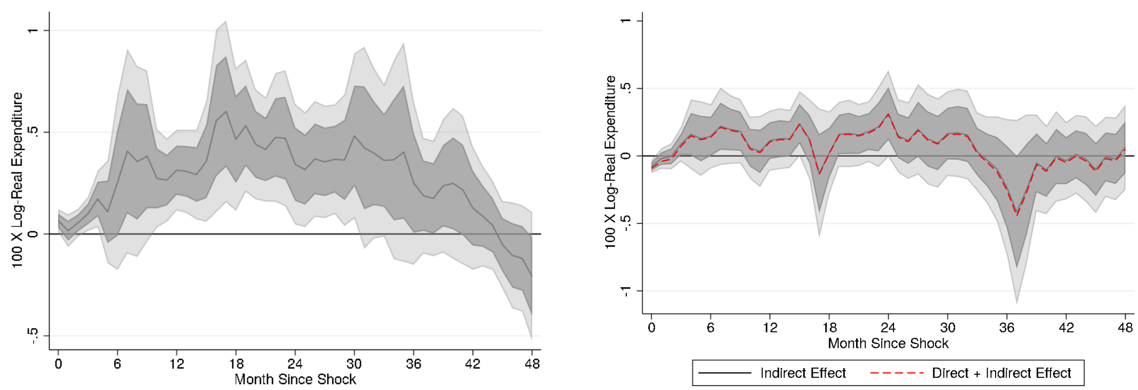
Figure A8: Relative Necessity Price Response to an Indirect Oil Shock: Include Labor Share



a) Log-Necessity Share b) Log-Necessity Price

Note: Data from 1989-2019. Estimated coefficients, γ^h from Local Projections in equation (4.1) represent the response of the dependent variable to a one-standard deviation monetary contraction using the Bauer and Swanson (2022b) monetary shocks interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively for the baselien specification. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure. Monetary Policy shock normalized to be mean zero and standard deviation of one.

Figure A9: Panel Local-Projection: Necessity Real Expenditure Response to Monetary and Oil Shocks



a) Monetary Shock b) Oil Shock

Note: Data from 1989-2019 in panel a) and 1976-2023 in panel b). Estimated coefficients, γ^h from Local Projections in equation (4.1) represent the response of log-expenditure deflated by the sector specific price index to a one-standard deviation Bauer and Swanson (2022b) monetary shock or Känzig (2021) oil shock interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure.

B.8 Uncertainty Shock

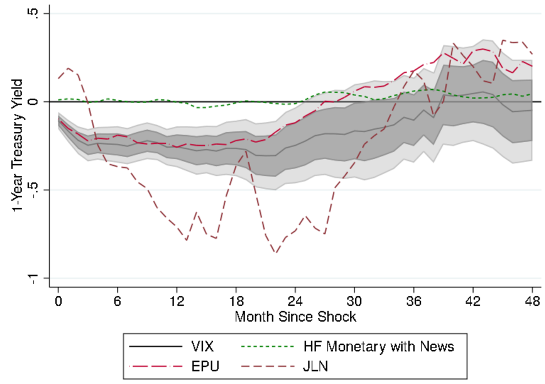
I estimate the response of treasury yields, expenditure, relative necessity prices and shares to several different types of uncertainty shocks. The first is the VIX index, which has been widely used in the literature ordered first in a VAR, which assumes that the VIX can contemporaneously impact other macroeconomic variables, but not the other way around (see Leduc and Liu (2016) and Basu and Bundick (2017); my local projection specification makes the same assumption. I also use the Economic Policy Uncertainty (EPU) index developed by Baker et al. (2016), which uses newspaper articles to measure uncertainty about future US economic policy including congressional outcomes, presidential elections, and Federal Reserve Policy. Finally, I also use the Jurado et al. (2015) (JLN) 1-month ahead econometric uncertainty shocks.

Figure A10 shows the effect that these uncertainty shocks have on treasury yields, and aggregate consumption. Panel a) and b) shows that each of the uncertainty shocks considered lead to large and persistent declines to treasury yields, which is the opposite sign of the effect of monetary policy shocks on yields (the baseline monetary policy shock is shown as the green dashed line). Panel c) shows that each of these shocks also lead to large falls in real PCE. Compared to the monetary policy shock, the uncertainty shocks have a more immediate and larger effect on consumption. The JLN shocks have by far the largest effect on real PCE, and a one-standard deviation JLN shock leads to around a 2 percent decline in real PCE that peaks 18- to 24-months after the shock, while the VIX and EPU shocks lead to a 0.5 and a 0.3 percent decline in real-PCE respectively on average in the first 12-months after the shock.

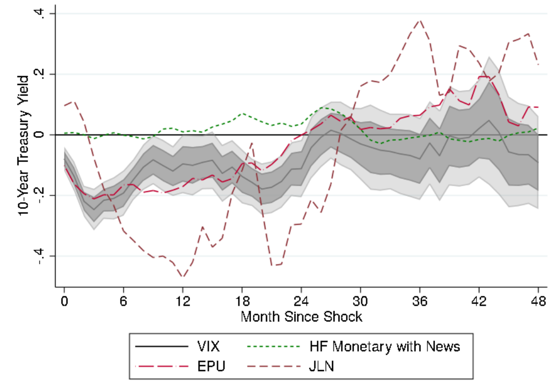
Figure A12 estimates the relative necessity share and price response to uncertainty shocks using the baseline specification in 4.1, but replacing the monetary policy shock with uncertainty shocks. I find large impacts on necessity shares and prices. Panel a) shows that following the shock, the necessity share increases by approximately 0.4 percent after the EPU shock, 0.6 percent after the VIX shock, and 2.4 percent after the JLN shock (averaging horizons 12-36). The baseline monetary policy shock effect on relative necessity prices lies between the EPU and VIX shocks and is dwarfed by the response to the JLN shock.

Panel b) shows the effect on necessity prices. Necessity relative prices begin increasing

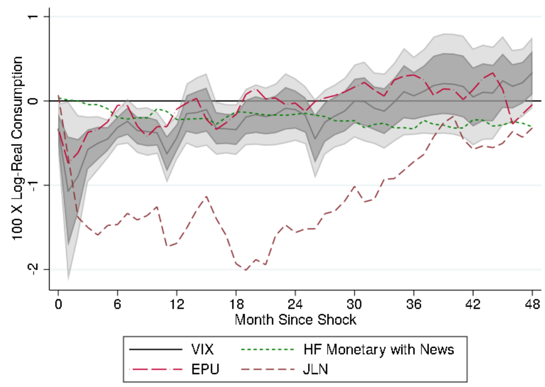
Figure A10: Response to Uncertainty Shock



a) 1-Year Treasury Yield



b) 10-Year Treasury Yield

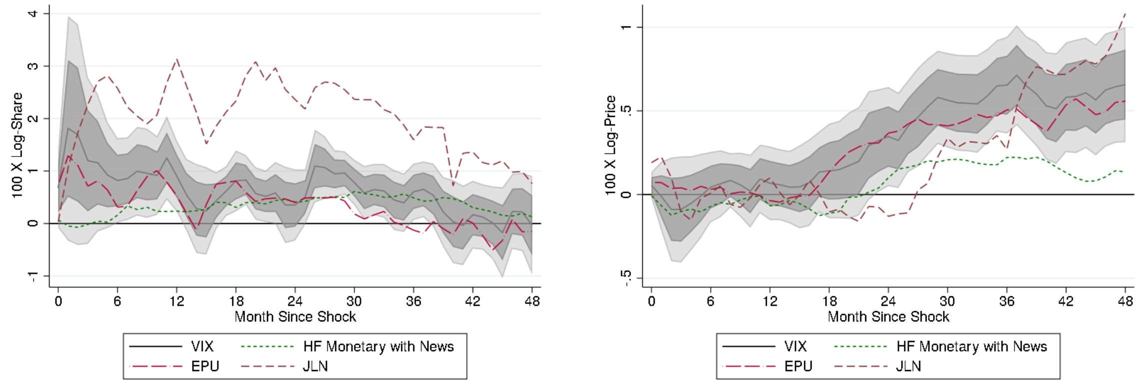


c) Real PCE

Note: Data from: 1989-2019 (Monetary Policy Shock), 1990-2024 (VIX), 1985-2024 (EPU), and 1960-2023 (JL). Estimated coefficients, from Local Projections represent the response of the dependent variable to a one-standard deviation uncertainty or monetary shock. The unit of observation is the month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively for the VIX shock. Standard errors are robust to auto-correlation.

roughly 18-months after the EPU and VIX shocks, which leads the response to the monetary policy shock by about 6 months. The relative necessity price response to the EPU and VIX shocks peak 2 to 3 years after the initial shock at over 0.5 percent (for the VIX) and at over 0.4 percent (for the EPU). The JLN shocks effect on relative necesity prices lags behind the other uncertainty and monetary policy shocks, but ultimately surpasses them peaking at nearly one percent. This implies that the necessity relative price expenditure elasticity is around -1 for the VIX shock, slightly below -1 for the EPU shock and around -0.5 for the JLN shock.

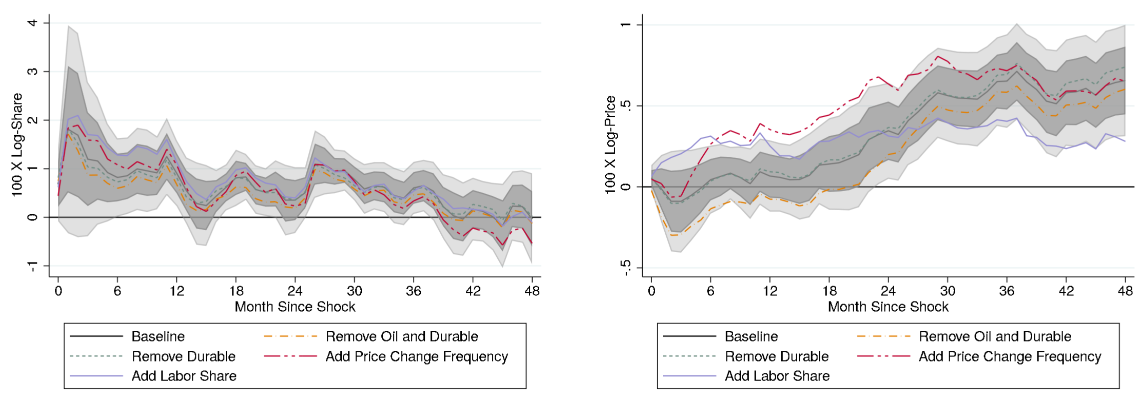
Figure A11: Necessity Response to Uncertainty Shock



a) Log-Necessity Share b) Log-Necessity Price

Note: Data from: 1989-2019 (Monetary Policy Shock), 1990-2024 (VIX), 1985-2024 (EPU), and 1960-2023 (JLN). Estimated coefficients, $\gamma^{h,0}$ from Local Projections in equation (4.1) represent the response of the dependent variable to a one-standard deviation uncertainty or monetary shocks interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively for the VIX shock. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure. Monetary Policy shock normalized to be mean zero and standard deviation of one.

Figure A12: Necessity Response to Uncertainty Shock: Alternate Specifications



a) Log-Necessity Share b) Log-Necessity Price

Note: Data from: 1989-2019 (Monetary Policy Shock), 1990-2024 (VIX), 1985-2024 (EPU), and 1960-2023 (JLN). Estimated coefficients, $\gamma^{h,0}$ from Local Projections in equation (4.1) represent the response of the dependent variable to a one-standard deviation uncertainty or monetary shocks interacted with R_j. The unit of observation is the PCE sector-month. The dark and light shaded areas represent 90 and 68 percent confidence bands respectively for the VIX shock. Standard errors are robust to auto-correlation and are clustered at the monthly level. PCE sectors weighted by their share in pooled aggregate expenditure. Monetary Policy shock normalized to be mean zero and standard deviation of one.

C Additional Results: Quantitative Model

C.0.1 Historical Simulation

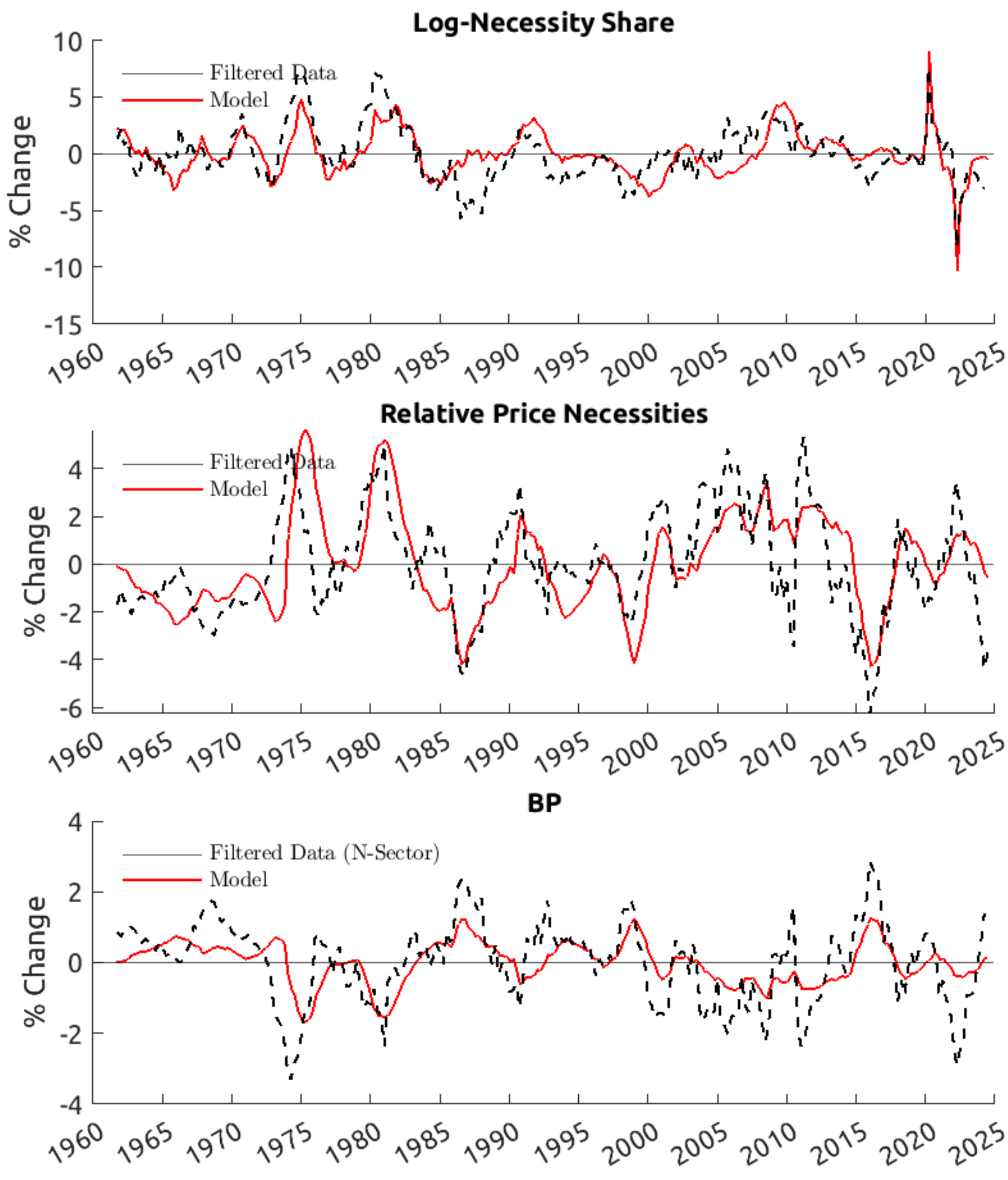
How well does the model predict necessity prices and shares over time? As a validation exercise, I shock the model with a series of discount factor shocks Z_t, aggregate TFP shocks (common across sectors), and oil price shocks so that the model's oil price, expenditure, and nominal interest rate match the WTI, real PCE, and the 1-year Treasury Yield respectively. I filter the log of each of the data variables using the Hamilton (2018) filter and similar results are found when using a one sided HP filter. Since the monthly PCE price series begins in 1959, my filtered data series for most variables begins in the last quarter of 1961.

I then compare the necessity share and price series in the simulated model with their filtered counterparts in the data. Figure A13 shows the results of this simulation. The top panel shows the path of both model and data log-necessity share from 1961Q4 to 2024. There is a strong 0.65 correlation between the data and model series and the R-squared of a regression of the data on the model series is 0.42. We also see prominent increases in the necessity shares in the model and the data during the Volcker monetary tightening in the early 1980s, during the Great Recession, and offsetting increases and decreases around the COVID-19 pandemic.

The second panel compares relative necessity prices in the data with the cyclical component of the composite necessity price in the data. The data and the model series match each other quite closely, however the model underestimates some of the high frequency movements in the data. The data series has a 0.73 correlation with the model and the R-squared is 0.53.

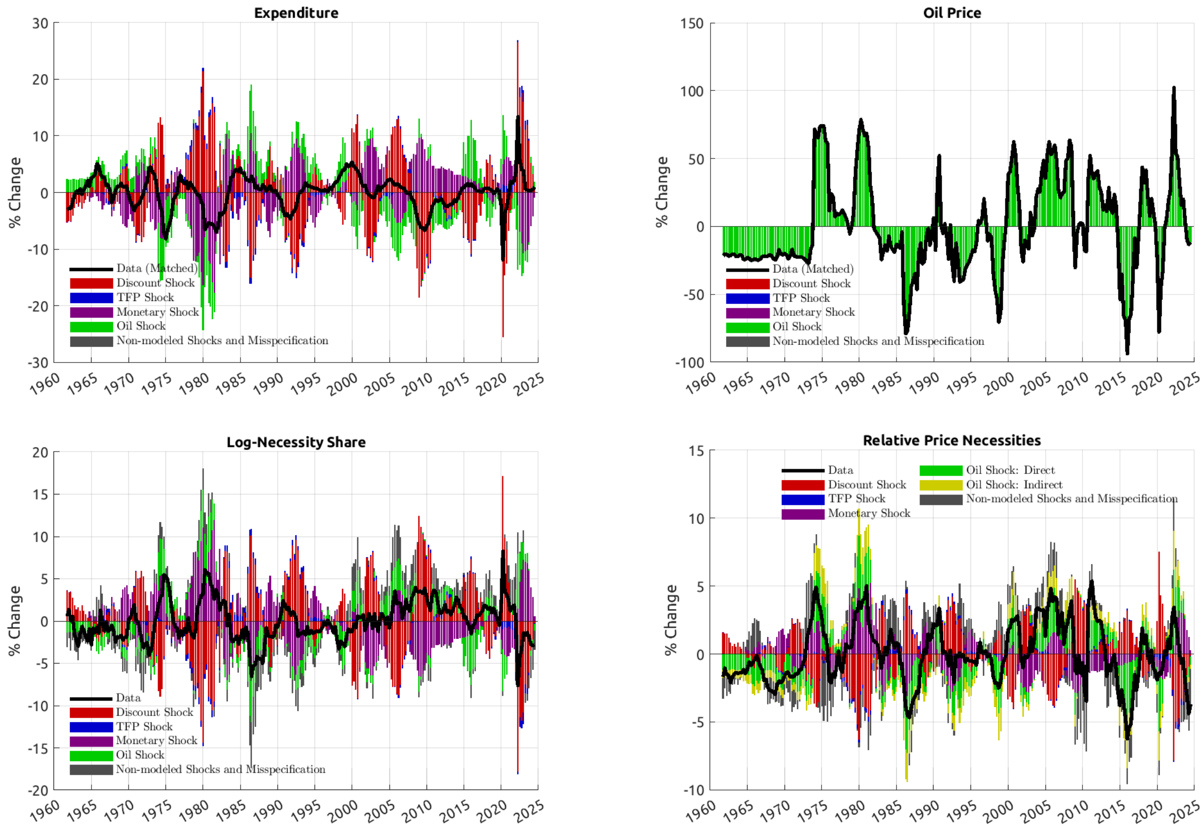
Finally, the bottom panel shows $B(P)$ in the data and in the model. $B(P)$ is the key series that matters for inflation inequality in the model. In the data, I construct $B(P)$ using all 137 of the 148 PCE sectors for which I have price data. I estimate the individual β_j for each sector exactly as done when dividing all products into two sectors, that is $\beta_j = \frac{s_{j,low} - s_{j,high}}{\log(X_{low}) - \log(X_{high}}$ where low and high denote the representative low-income household and high-income household respectively. This means that the model series and the data series could differ due to both the model estimating P^N incorrectly, as well as the fact that the model only has two sectors, while there are 137 in the data.

Figure A13: Model v. Data: Historical Simulation



Note: Author targeted shocks to match real expenditure, the price of oil, and the 1-year treasury yield. Necessity share, relative necessity price, and the non-homothetic price index $b(p)$ are untargeted. Data is filtered following Hamilton (2018).

Figure A14: Historical Shock Decomposition for Other Variables



Note: The thick black line shows the filtered data. The bars show the contributions to relative necessity prices of interest or discount rate shocks (red), aggregate TFP shocks (blue), oil shocks due to differences in oil production shares (green), and the indirect impact of oil shocks due to changes in expenditure (yellow). The grey bars denote the difference between the data and the model estimated relative necessity prices and include both non-modeled shocks (including taste shocks or non-oil relative productivity shocks) along with model misspecification. Shocks are estimated using the Kalman filter method from Adjemian et al. (2022) and targeting model based real expenditure, oil price, and the interest rate to match their data counterparts.

C.1 Historical Decomposition

I use Dynare's built in estimation package to estimate the oil price, TFP, monetary, and discount factor shocks that best fit the targeted variables (Adjemian et al. 2022). In figure A14 I show the results of this analysis for expenditure and the oil price (which are targeted to the data), the log-necessity share, and reproduce the results for the relative necessity price from the main text.

C.2 Model Extensions

C.2.1 Sticky Prices

Suppose that instead of firms selling in a competitive market with flexible prices, instead firms sell their good for price $p_t(i)$ to a sector specific retail firm, which aggregates differentiated goods using a Dixit Stiglitz production function so that output in sector j is $Y_t(j) = \left(\int_0^1 (y_t(i)^{\frac{\epsilon_p - 1}{\epsilon_p}} di)\right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$.

Firms are subject to Calvo pricing frictions, where each period only a fraction $(1 - \theta_j)$ of sector j's firms are able to adjust prices.

To cut down on the number of characterizing equations, I set the price of the necessity good $P_t(N)$ as the numeraire, so $P_t^L = \frac{P_t(L)}{P_t(N)}$ and the necessity relative price is $\frac{1}{P_t^L}$. So the Calvo pricing parameter for relative luxury prices becomes $\theta = \theta_L \times \theta_N$ since the probability of price adjustment is independent in each sector.

Luxury firms solve the following problem for optimal reset price $p_t^*(i)$ where the marginal cost $MC_t(i)$ at any point in time is increasing in firm $i's$ output and is relative to the marginal cost in the necessity sector:[39]

$$p_t^*(i) = \frac{\sum_{k=0}^{\infty} \theta_j^k \beta^k \mathbb{E}_t \left[\Lambda_{t,t+k}^f \cdot \left(\frac{p_t^*(i)}{P_{t+k}^L}\right)^{-\varepsilon} Y_{t+k}^L \cdot MC_{t+k|t}(i)\right]}{\sum_{k=0}^{\infty} \theta^k \beta^k \mathbb{E}_t \left[\Lambda_{t,t+k}^f \cdot \left(\frac{p_t^*(i)}{P_{t+k}^L}\right)^{-\varepsilon} Y_{t+k}^L\right]}. \tag{C.1}$$

In the above equation $\Lambda_{t,t+k}^f$ is the firm's stochastic discount factor, which matches the household's and firms are forward looking.

Luxury prices then evolve according to:

$$\left(\frac{P_t^L}{P_{t-1}^L}\right)^{1-\epsilon_p} = \theta + (1-\theta)\left(\frac{p_t^*(L)}{P_{t-1}^L}\right)^{1-\epsilon_p} \tag{C.2}$$

I set $\theta_L = 0.66$ and $\theta_N = 0.31$, based on the quarterly price change frequency from the luxury and necessity sector respectively derived from Montag and Villar (2022).

The results from this model with sticky prices are shown in the orange line in figure A15. The results are virtually identical as those in the baseline model (partially due to $\theta_L \times \theta_N$ being quite low).

[39] In steady state, the desired markup $\epsilon_p/(1-\epsilon_p)$ cancel out.

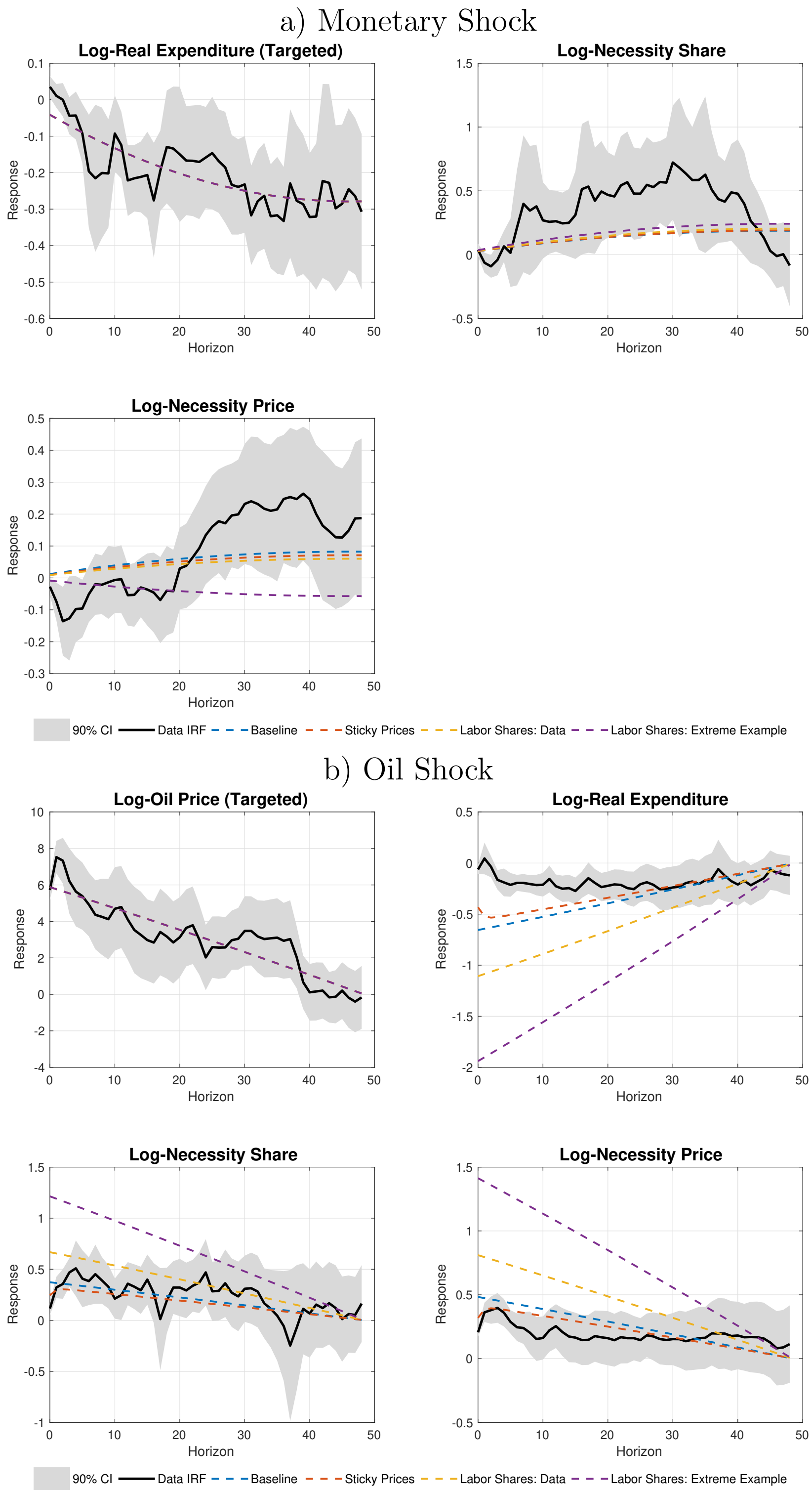
C.2.2 Different Returns to scale for necessities and luxuries

In the baseline model, the labor share was the same in each sector. Since labor is the only factor of production that the firm can choose in the short-run, the labor share is inversely related to the marginal cost elasticity of demand for that sector. The model abstracts from other short-run variable inputs.

We do have data on labor shares by sector, and as a robustness check I calibrate the model so that the relative labor shares of the necessity and luxury sectors match their data counterparts. In the data, the average labor share of necessity sectors is 0.45, while it is 0.59 for necessity sectors. I scale these up so that on average, the labor share in this calibration matches the labor share in the main text $\bar{S}_N \alpha_{hn} + (1 - \bar{S}_N)\alpha_{hl} = \alpha_{h,baseline}$. This results in $\alpha_{hn} = 0.62$ and $\alpha_{hl} = 0.81$. The results in this calibration are shown as the yellow line in figure A15 and are quite similar to those in the baseline model.

For pedagogical purposes, I also consider a case where the labor shares in the necessity and luxury sector are drastically different ($\alpha_{hn} = 0.55$ and $\alpha_{hl} = 0.95$), an extreme calibration that is not supported by the data. Results from these calibrations, shown by the purple line in figure A15, are quite different from the baseline. In this case, a demand shock that lowers expenditure will actually result in lower relative necessity prices since the necessity sector has a much more concave production function than the luxury sector. The oil price shock still leads to an increase in relative necessity prices as the much more extreme fall in expenditure leads to a more drastic shift to necessity consumption.

Figure A15: Alternative Calibrations



Note: In panel a), interest rate/discount shocks in the model are targeted so that expenditure in the model matches smoothed expenditure from the IRFs of log-real expenditure to a monetary news shock in panel a) of figure 7. The remaining variables (log-necessity share and log necessity price) are untargeted. In panel b), the oil shock in the model is chosen so that the log-oil price in the model matches the smoothed response of the log-oil price to a oil news shock in the data (shown in appendix figure A3). Expenditure, log necessity share, and log necessity price are not targeted.