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Jacob Orchard

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Abstract

This paper shows that adverse macroeconomic shocks systematically increase inflation for low-income households relative to high-income households. I document two key facts: (i) during every U.S. recession since 1959, aggregate spending shifts toward products disproportionately purchased by low-income households (necessities); and (ii) relative prices of necessities rise during recessions. These patterns can be explained by a model with non-homothetic demand and a concave production possibility frontier: shocks that reduce expenditure induce households to reallocate spending from luxuries to necessities, raising their relative prices. I empirically show that this mechanism operates for both demand and supply shocks, using monetary policy and oil price news shocks. Incorporating this mechanism into a quantitative model reproduces most 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 inflation to increase by more than 1.5 percentage points for low-income households relative to 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

Contact: jake@jakeorchard.com
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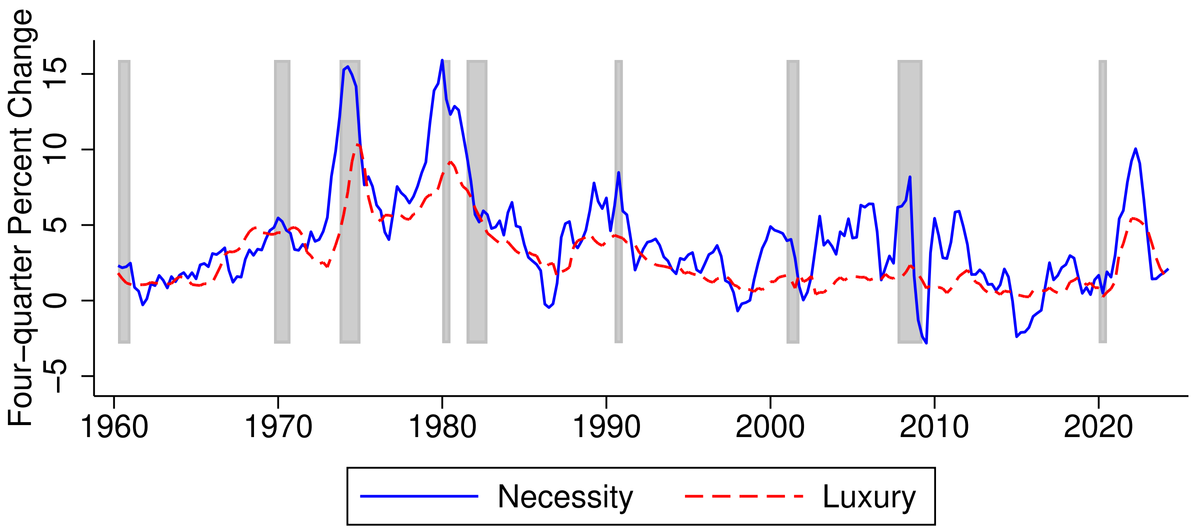
Recent literature has established that over the past several decades, inflation has been higher for low-income households than for high-income households.[1] In this paper, I show that the gap in inflation between low- and high-income households (inflation inequality) varies over time and increases following adverse macroeconomic shocks. Shocks that lower aggregate expenditure also induce households to reallocate spending from luxuries to necessities, raising the relative price of necessities, which disproportionately affects low-income households because these products occupy a larger share of their budgets.

This paper makes three main contributions. First, I show empirically that necessities—product categories with a larger budget share for low-income than high-income households—have countercyclical relative demand. This holds in the aggregate time series, where the share of necessities rises in every recession since 1959, and following plausibly exogenous shocks that reduce aggregate expenditure. Second, I show that these same product categories also have countercyclical relative prices. In the aggregate time series, necessity relative prices are positively correlated with unemployment and other indicators of economic contraction, and they increase in response to shocks that lower aggregate expenditure. Third, I develop a framework with non-homothetic demand and a concave production possibility frontier that rationalizes these facts. Embedding this mechanism in a standard business cycle model shows that it explains most of the variation in relative necessity prices and expenditure shares since 1961 and that non-homotheticity materially amplifies inflation inequality during recessions, including by over 1 percentage point in the Great Recession, the COVID-19 recession, and the 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 resulting in 148 product sectors for which I have aggregate expenditure and price data, alongside household-level purchasing patterns. I define necessities as products where low-income households have a higher budget share than high-income households. Although this definition is based on household-level data, these products also behave as necessities in the aggregate: their expenditure share increases during every recession since 1959.

[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 to 2021 was higher for low-income than for high-income households. Chained Fisher price indices. Excludes housing and non-market consumption.

Figure 1 shows the inflation rates of necessities (solid blue line) and luxuries (dashed red line) from 1960 to 2024. On average, the inflation rate of necessities has been 4.1 percent annually compared to 2.9 percent for luxuries, which is consistent with prior literature (for example, Jaravel and Lashkari (2024)). However, there is considerable variation in the gap between necessity and luxury inflation: during recessions, the gap has averaged 2 percentage points, roughly twice that of non-recession periods.

To examine whether countercyclical relative necessity expenditure shares and prices reflect differences in products' Engel curve slopes rather than other characteristics, I use panel regressions across all 148 product categories. The regressions control for whether a category is a durable, a service, its labor and oil shares in production, and its price-change frequency. I find that a 1 percentage point increase in the unemployment rate is associated with around a 1.7 percent increase in the aggregate share of spending on necessities and a 0.2 to 0.4 percentage point increase in the inflation rate of necessities relative to luxuries.

Having documented that both necessity relative prices and aggregate shares increase during recessions, I introduce a static model that can rationalize these facts. The critical components are non-homothetic preferences at the aggregate level and a concave production possibilities frontier (PPF). Non-homothetic preferences generate cyclical demand shifts between necessities and luxuries that track aggregate consumption. The concave PPF leads to higher relative costs for the expanding sector. An aggregate decline in expenditure therefore expands the necessity sector and raises its relative prices, independent of the source of the expenditure shock. Supply shocks that differentially affect productivity across sectors can also alter the relative supply curve. These shocks can be decomposed into a direct effect on relative prices and a secondary income effect due to non-homothetic preferences and the concave PPF. This framework is consistent with countercyclical necessity expenditure shares and relative prices. It also allows relative supply shocks, such as oil shocks, to be decomposed into non-homothetic and direct effects, an insight I use to test the mechanism empirically.

The static model predicts that shocks that lower expenditure will lead to higher relative spending shares and prices for necessity products. I test these predictions 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. 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 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, consistent with the predictions of the mechanism in the static model.

Since oil is a larger part of the production process for necessities, I use logic from the static model to decompose oil price shocks into a total effect on necessity relative shares and prices, and an indirect effect operating through the oil-shock–induced decline in expenditure. The total effect raises necessity shares by about 0.3 percent and necessity prices by 0.2 percent over three years. For the indirect effect, I isolate the portion of the change in relative necessity shares and prices that is orthogonal to the change that would be implied solely by that sector's oil production intensity. I find that this indirect non-homothetic effect accounts for nearly all of the increase in necessity relative shares and about half of the increase in necessity relative prices. These results suggest that oil price shocks matter for inflation inequality not only through direct production cost increases, but also via the non-homothetic expenditure channel that amplifies their impact.

Having confirmed the static model's predictions in the data, I present a two-sector quantitative New Keynesian model. It 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 both qualitatively match the empirical response to monetary and oil shocks as well as explain a significant fraction of the historical variation in relative necessity prices and shares.

With the model in hand, I decompose the sources of inflation inequality across all NBER-defined U.S. recessions since 1961 into three channels: (i) the non-homothetic expenditure channel, (ii) the direct impact of oil prices, and (iii) residual, non-modeled factors. In some recessions, these channels reinforce each other, while in others they offset. For example, in the Great Recession, the non-homothetic 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 that for high-income households relative to the pre-recession trend. In contrast, during the COVID-19 induced recession the non-homothetic expenditure channel increased inflation inequality by nearly 2 percentage points. However, this effect 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. Taken together, the model highlights the systematic role of the non-homothetic expenditure channel in shaping inflation inequality over the past 60 years.

This paper builds on several literatures in macroeconomics, most directly the work on inflation inequality. Early work found only limited differences in inflation rates across groups (Amble and Stewart 1994, Garner et al. 1996, Hobijn and Lagakos 2005, McGranahan and Paulson 2005), while more recent research leveraging detailed product categories and barcode data has documented substantial disparities (Kaplan and Schulhofer-Wohl 2017, Jaravel 2019, Cavallo 2020, Gürer and Weichenrieder 2020, Argente and Lee 2021, Lauper and Mangiante 2021). A key distinction from recent work is that I take a systematic business cycle perspective. Prior studies have examined inflation inequality in specific episodes, such as the Great Recession or the COVID-19 recession, but this paper is the first to show that the mechanism operates consistently across U.S. recessions. Long-run comparisons of inflation inequality face the challenge that household baskets themselves evolve toward more luxury-intensive consumption (Oberfield 2023, Jaravel and Lashkari 2024). By contrast, during recessions the baskets of low- and high-income households remain highly differentiated, so relative price increases for goods consumed disproportionately by low-income households translate directly into welfare losses for these groups.

In addition, the paper relates to the literature on the distributional consequences of recessions, which has emphasized heterogeneous responses of income and nominal consumption (Heathcote et al. 2020, Feiveson et al. 2020, Krueger et al. 2016, Meyer and Sullivan 2013, Hoynes et al. 2012). I show that excluding cost-of-living differences misses an important part of the picture: recessions disproportionately raise the prices of goods consumed by low-income households, amplifying real inequality beyond what is captured by nominal measures alone.

Finally, the paper connects to work on endogenous demand shifts. Non-homothetic preferences have been used to explain long-run structural change (Boppart 2014, Comin et al. 2021; 2020) and short-run business cycle dynamics (Bils and Klenow 1998, Jaimovich et al. 2019). This paper highlights a complementary short-run channel: cyclical shifts in demand toward necessities raise their relative prices, which in turn drives inflation inequality.[2]

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 presents the static model that is able to rationalize the motivating facts. Section 4 tests the conclusions of the static model empirically via monetary policy and oil price news shocks. Section 5 presents the quantitative model. Section 6

[2]Contemporary work by Andreolli et al. (2024) documents similar cyclical expenditure patterns, but does not link them to differential cost-of-living changes across households, nor do they show that results are robust to other major features of the product, such as its oil share, labor share, or durability.

concludes.

2 Data and Stylized Facts

In order to study the cyclical behavior of inflation across the income distribution, I focus on products that are purchased relatively more by low-income households than by high-income households. I label these goods "necessities" and refer to the remaining goods as "luxuries." This definition departs from the textbook usage, where a necessity is any good with an expenditure elasticity less than one. Because household income is strongly correlated with household expenditure, the two elasticity concepts are closely related, and many studies instrument for expenditure using income when estimating 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. Moreover, conditional on oil prices, necessity relative inflation is countercyclical. Relative necessity prices rise alongside relative necessity expenditure in downturns, implying that low-income households systematically face higher inflation than high-income households 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 combine these data with sector price change frequency data from Montag and Villar (2022).[3]

I divide households into five different income quintiles based on the household's distribution in absolute income over the entire CEX sample (1980 to 2021) and derive the

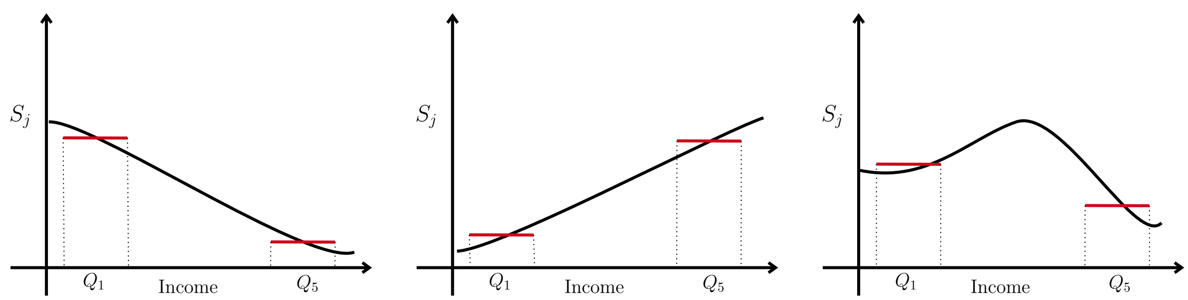
[3] The price change frequency data from Montag and Villar (2022) is at the entry level item (ELI) level. I match these to PCE categories by first matching ELI's with CEX UCC codes using the BLS concordance, and then matching UCC codes to PCE sectors using the extended BLS CEX-PCE concordance that I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

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 online appendix section B for details).[4] 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 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. Products are classified as necessities if $R_j > 1$ and as luxuries if $R_j < 1$.

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 for the highest, Q_5.

Figure 2 shows how this approach 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 Engel curve is nonlinear—as suggested by Atkin, Faber, Fally, and Gonzalez-Navarro (2020)— this method still ranks goods by their importance to low- versus

[4]In online appendix section B.5, I 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.

high-income households, regardless of middle-income consumption.

Table 1 shows that necessities tend to be less 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.[5]

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 to 2023 excluding sales and is aggregated from the BLS entry level item (ELI) level using 1998 CEX weights. Average statistics in this table are weighted by the PCE sector's share of aggregate expenditure. The percent of expenditure in durables or services is based on 2019 PCE data.

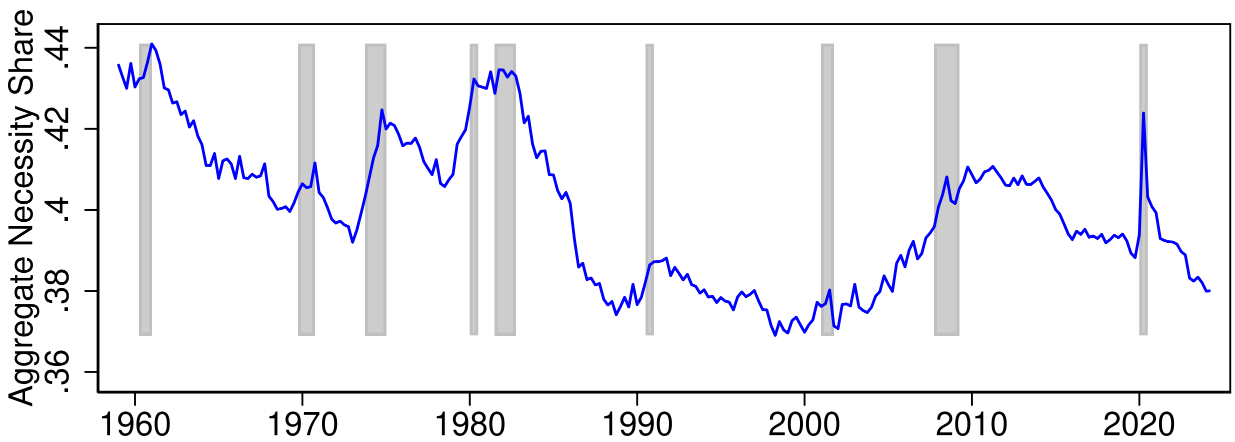
2.2 Necessity Relative Expenditure Shares and Prices Are Countercyclical

Fact 1: Relative Spending on Necessities is Countercyclical

In U.S. recessions since 1959, total PCE has tended to decline. The annualized quarterly total PCE growth rate in NBER recessions has averaged negative 0.9 percent, while during non-recessions it has averaged 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 in 1959 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

[5] 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.

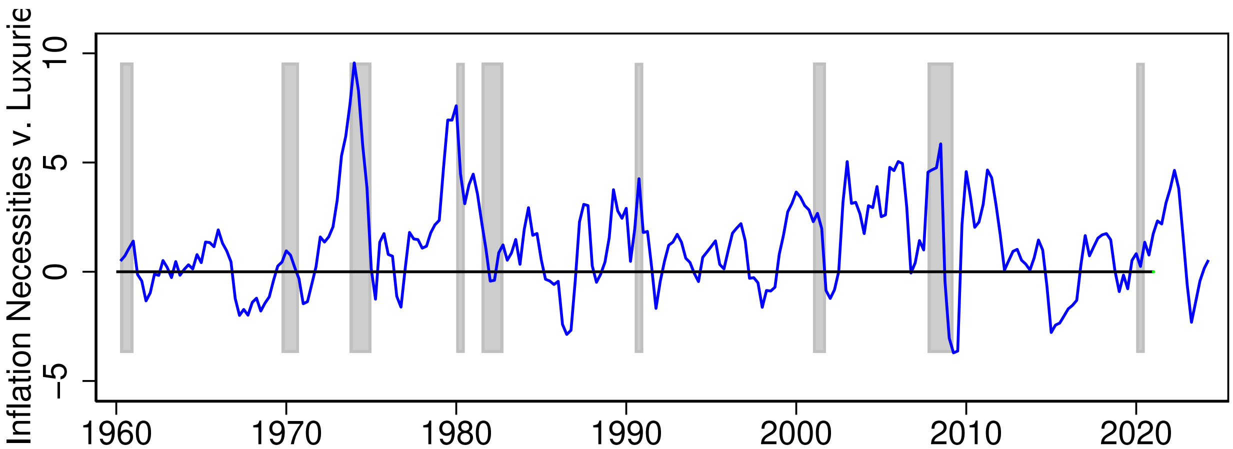
while necessities in this paper are defined using income at the household level, these same products also tend to be necessities at the aggregate time series level.

Fact 2: Countercyclical Necessity Prices

Figure 4 shows the difference between the necessity and luxury four-quarter inflation rates originally shown in Figure 1. From 1960 to 2024, necessity inflation has averaged 1.2 percentage points higher than luxury inflation. During NBER recessions, the gap is around twice as large, at around 2 percentage points compared to around 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 U.S. recessions; however, even when conditioning on oil prices, the gap between necessity and luxury inflation is 0.6 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 slower economic growth. Column 1, which regresses the inflation gap on a binary variable for the quarter being an NBER recession, shows that the inflation gap is 1.1 percentage points higher in NBER recession quarters than other

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 four-quarter Fisher inflation rates between necessity and luxury sectors. Necessities are defined as sectors whose average expenditure share from 1980 to 2021 was higher for low-income than high-income households ($R_j > 1$). 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.

quarters. Column 2 adds the four-quarter change in the WTI oil price as a control and shows that the gap is still around 0.6 percentage points higher in NBER recessions; here, the results are also more precise.[6] In column 3, I use the unemployment rate instead of the NBER recession as the measure of economic slowdown and I find that a 1 percentage point increase in the unemployment rate is associated with a 0.17 percentage point increase in necessity inflation relative to luxury inflation. In column 4, I use the output gap and here I find an output gap that is 1 percentage point higher is associated with the gap between necessity and luxury inflation being 3.5 percentage points smaller. Finally, in the last column, I show that stronger growth in real PCE spending of 1 percentage point is associated with a 0.13 percentage point smaller gap in necessity versus luxury inflation.

2.3 Panel Evidence

The aggregate evidence shows that necessity relative expenditure increases in recessions along with their relative prices. However, it cannot determine whether this countercyclical behavior arises from a product being a necessity or from other correlated product characteristics. For example, Table 1 shows that necessities are less likely to be durables than luxuries, slightly less likely to be services, adjust prices more frequently, have larger oil shares in production, and slightly smaller labor shares. Past literature has shown that durable purchases are cyclically sensitive (McKay and Wieland 2021, Barsky et al. 2007), while service expenditure tends to be smoother.[7]

I exploit the panel structure of the 148 sectors to isolate the effect of being a necessity on cyclical expenditure and prices. I regress the log-share or 12-month inflation rate of sector j at time t on the interaction between the unemployment rate and a necessity indicator, along with various controls:

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

The dependent variable, $x_{j,t}$, is either the log-share or 12-month inflation rate of sector

[6] The West Texas Intermediate (WTI) oil price is retrieved from FRED, Federal Reserve bank of St. Louis, https://fred.stlouisfed.org/series/DCOILWTICO.

[7] Some service categories are measured annually and extrapolated for the rest of the year (U.S. Bureau of Economic Analysis 2023), which mechanically smooths consumption.

j. It is regressed on the interaction of unemployment with a necessity indicator ($R_j > 1$),[8] controlling for time (δ_t) and sector (γ_j) fixed effects. Z_j is a vector that include binary variables for whether the product is a durable, whether the product is a service, as well as continuous variables for the average frequency of price change of that sector from Montag and Villar (2022) and that sector's share of labor in total costs. 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 columns 1 and 4, controlling for the interaction between the change in the oil price and the necessity indicator, I find that a 1 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 and a 0.17 percentage point increase in the product's relative inflation rate. In columns 2 and 5 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.[9] 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 1 percentage point increase in the unemployment rate is associated with a 0.43 percentage point increase in relative necessity inflation. In appendix section B.5, I show that these results are quantitatively similar 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 to 2021 CEX sample.[10]

[8] Appendix results using the continuous R_j are qualitatively similar.

[9] The sample size is smaller in columns 3 and 6, since, as Montag and Villar (2022) do not have price change frequency data for all of the PCE sectors that I consider here.

[10] The relationship between necessity relative spending shares and unemployment is not mechanically driven by the relationship by higher necessity prices, as necessity relative real expenditure (nominal aggregate expenditure divided by the product-specific price index) is also positively related to unemployment.

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 *.

3 A Static Model of Relative Supply and Demand

In this section, I develop a static partial equilibrium model that accounts for the countercyclical behavior of necessity relative prices and expenditure shares documented in the previous section. The economy consists of two sectors—necessities and luxuries—produced by perfectly competitive firms with concave production in labor. Households have non-homothetic preferences over these goods, and total expenditure X is treated as exogenous, abstracting from labor supply and savings decisions.

The model delivers two main insights. First, a decline in expenditure raises both the consumption share of necessities and their relative price. Second, when a negative supply shock lowers overall expenditure and one sector's productivity, the change in relative prices can be decomposed into a direct productivity effect and an indirect effect operating through non-homothetic expenditure. Together, these outcomes provide a theoretical foundation for the observed rise in necessity relative spending and prices during recessions.

3.1 Firms

There are two sectors, N (necessities) and L (luxuries). Each is competitive and has a production function over labor: $Y_i = F(H_i)$. I assume $F(\cdot)$ is positive and homogeneous of degree $k \in (0,1)$, so production is concave. Firms hire labor at a fixed wage w. Profit maximization implies: $\frac{w}{p_i} = F_H(H_i)$, where the wage-price ratio equals marginal labor productivity.

Lemma 1 (see appendix) shows that the marginal rate of transformation (PPF slope) is increasing, so the relative supply curve slopes upward. In other words, relative prices rise if one sector expands more than the other because short-term output can increase only by hiring more labor, which raises marginal costs. Formally:

$$\frac{p_i}{p_j} = \frac{F_{j,H}(H_j)}{F_{i,H}(H_i)} = \frac{F_{j,H}(F_j^{-1}(Y_j))}{F_{i,H}(F_i^{-1}(Y_i))}. \tag{3.1}$$

A simple example of this type of production function is $F_i(H_i) = A_i H_i^{\alpha}$ with $\alpha \in (0,1)$ common across sectors.[11]

3.2 Households and Intratemporal Substitution

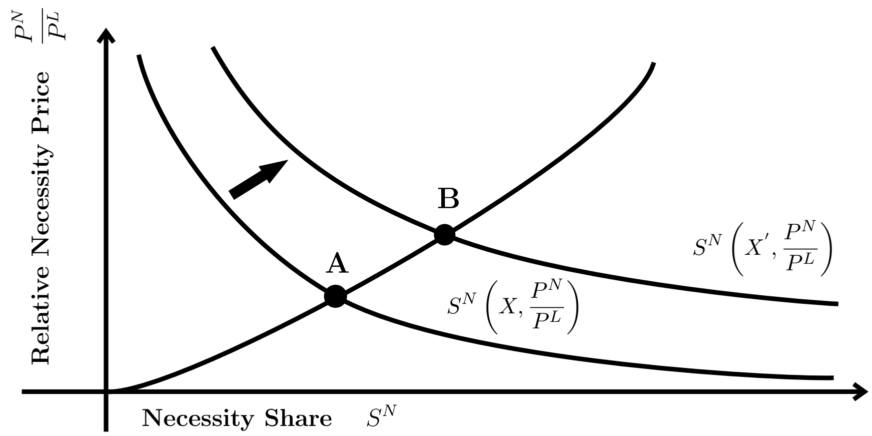
The representative household has an exogenous expenditure X and non-homothetic preferences $U(c_N, c_L)$. Ordinary demand satisfies: $\frac{\partial}{\partial X}\frac{C^L(X,p_N,p_L)}{C^N(X,p_N,p_L)} > 0$. With only two goods, this implies that the necessity share s_N falls when X rises.

Figure 5 illustrates relative supply (upward-sloping) and relative demand (downward-sloping) in $(s_N, p_N/p_L)$ 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. A fall in X raises the relative demand for necessities, shifting the demand curve outward and moving equilibrium from point A to point B, increasing both the necessity share and relative price. [12]

[11] If sectors have different curvature or linear production, the relative supply curve could be flat or downward-sloping; In the appendix, I consider a version of the quantitative model where the labor share differs across sectors

[12] A similar figure appears in Bergstrand (1991), which shows that price levels can be higher in wealthier countries due to a similar mechanism—non-homothetic demand combined with a concave production possi-

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.

The intuition behind Figure 5 is stated formally in the following proposition (the proof is included in appendix section A). [13]

Proposition 1 *In a two-sector competitive economy with a representative household that has preferences satisfying section 3.2, 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 a decrease/increase in household expenditure will lead to an increase/decrease in the relative price of necessities.*

3.3 Relative Supply Shocks

Proposition 1 implies that non-homothetic preferences combined with a concave PPF cause expenditure changes to affect relative necessity prices. The source of the expenditure shock—demand or supply—does not change this logic, as long as the relative supply curve is unchanged. However, a supply shock that hits one sector more than the other can have

bility frontier (in the Bergstrand (1991) case the upward-sloping relative supply curve is due to fixed factor levels and differing factor intensities between tradables (necessities) and non-tradeables (luxuries)).

[13] 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 appendix.

ambiguous effects on relative prices and shares.

Consider a shock to labor productivity, $A_{t,j}$, reducing marginal productivity: $F_{j,H}(A_{t,j}H_j) < F_{j,H}(H_j)$ for all H_j. If the fall is larger in necessities, then:

$$\frac{F_{L,H}(A_{L,t}H_L)}{F_{N,H}(A_{N,t}H_N)} > \frac{F_{L,H}(H_L)}{F_{N,H}(H_N)} \; \forall \; (H_N, H_L), \tag{3.2}$$

meaning the relative cost to produce necessities rises.

For any necessity share S^N, relative prices rise because the necessity sector is now less productive. 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.

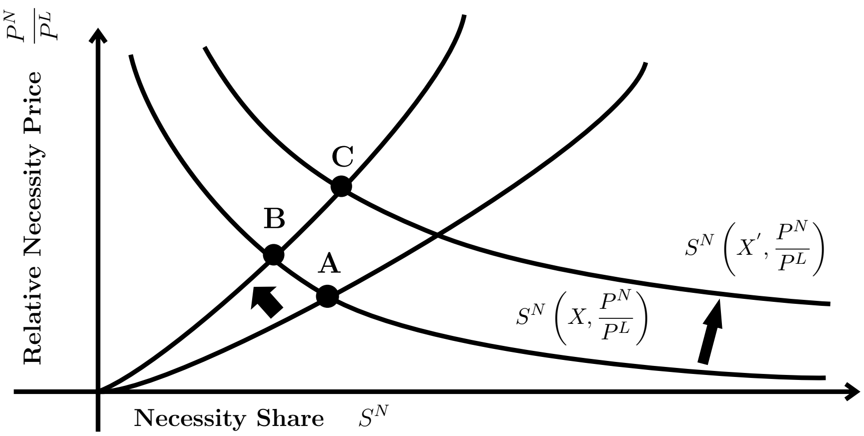
In this example, both the direct effect on relative prices from the shift of the relative supply curve (equation 3.2) and the indirect effect from the outward shift of the relative demand curve increase relative necessity prices, so relative necessity prices are unambiguously higher. The effect on the necessity share, S^N, is ambiguous. The rise in relative prices from the supply shock reduces S^N, while the decline in aggregate expenditure increases S^N. The net change in S^N therefore depends on three factors: the price elasticity of demand for necessities, the magnitude of the expenditure change, and the expenditure elasticity of necessities. If the productivity drop is larger in the luxury sector instead, S^N will rise unambiguously, while the effect on relative prices becomes ambiguous.

We can decompose the change in relative prices into a direct effect with the new labor productivity (holding the change in S^N 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):

$$\Delta \log\left(\frac{p_{N,t}}{p_{L,t}}\right) = \underbrace{(k-1)\log\left(\frac{A_{L,t}}{A_{N,t}}\right)}_{\text{Direct Effect}} + \underbrace{\Delta \log\left(\frac{F_{L,H}(H_{L,t})}{F_{N,H}(H_{N,t})}\right)}_{\text{Indirect Effect}}. \tag{3.3}$$

The direct effect of the change in labor productivity on relative prices is log-linearly

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.

proportional to the relative productivity change in each sector.[14] Equation (3.3) does not require an upward-sloping relative supply curve and holds for any homogeneous degree k.

The indirect effect has two components: a movement along the relative demand curve MD (dependent on the price elasticity of demand) and the shift of the relative demand curve SD (dependent on the elasticity of expenditure to the supply shock and the expenditure elasticity of necessities).

$$\underbrace{\Delta \log\left(\frac{F_{L,H}(H_{L,t})}{F_{N,H}(H_{N,t})}\right)}_{\text{Indirect Effect}} = MD + SD. \tag{3.4}$$

The static model highlights two mechanisms behind the countercyclical behavior of necessity prices and expenditure shares. First, because households have non-homothetic preferences, lower aggregate expenditure raises the relative demand for necessities, increasing both their share in aggregate spending and—given the upward sloping relative supply curve—their relative price. Second, supply shocks that lower productivity operate through two channels:

[14] 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.

a direct effect on relative costs and an indirect effect through reduced expenditure.

4 Empirical Strategy

The static model in the previous section demonstrated that, under certain assumptions, a decline in aggregate expenditure raises the relative share of necessities in total consumption and increases relative necessity prices. To test these predictions empirically, I use exogenous shocks that lower expenditure to answer two questions: (1) How does the aggregate necessity share respond to a decline in expenditure? (2) How do relative necessity prices respond to the same shock? Both questions are directly linked to the two key assumptions of the model: (i) the representative consumer has non-homothetic preferences, and (ii) 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 (3.3).

I find that a one standard deviation contractionary monetary policy shock or oil shock reduces aggregate real consumption by around 0.2 percent after 24 to 36 months. This same monetary shock leads to an increase of around 0.5 a percentage point 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 negative 1. The oil price shock leads to an approximately 0.2 percentage point increase in the necessity expenditure share and after accounting for sectoral oil production shares, an indirect effect on relative necessity prices of approximately 0.1 percent, which implies an elasticity of relative necessity prices to aggregate expenditure of negative 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. While interest rate changes could theoretically influence the supply curve, appendix section B.8 provides evidence from uncertainty shocks indicating that such supply effects are minor; the observed increase in necessity relative prices is primarily driven by changes in aggregate expenditure.

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).[15] This news shock is computed as the first principal 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 principal component is then orthogonalized with respect to macroeconomic news known to traders before the 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):

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

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

Here, $x_{j,t+h}$ is either the log-aggregate share or log-price of product j at time $t+h$. 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). Each regression includes 12 lags of both dependent variables, $\sum_{l=1}^{12} \sum_{y \in s,p} \left(\beta^{h,y,l} y_{j,t-l}\right)$, time fixed effects $\delta_{h,t}$ (absorbing the direct effect of monetary policy and other contemporaneous macro shocks), and product fixed effects $\psi_{h,j}$ (controlling for average share/price levels). I also include 12 lags of all monetary policy shock interactions to account for serial correlation (Ramey 2016). Standard errors are clustered at the time level and robust to serial correlation.[16]

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). To account for this, the baseline model includes interactions between a binary indicator for durable sectors and both the contemporary and 12 lags of the monetary shock.[17] Since oil prices are volatile and can trigger central bank responses, the baseline model also includes interactions between sectoral oil cost shares S_j^O and 12-month changes in WTI oil prices ΔP_t^O at time $t-k$.[18] These controls are denoted by $\Gamma_{h,k} W_{j,t-k}$. Appendix section B.7 shows similar results when durable and oil price controls are removed. Additional robustness tests include interactions with sector price change frequency and labor shares.

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

[16]Results are similar using conventional heteroskedasticity-consistent standard errors.

[17]**?** show that a temporary VAT cut affects durable consumption more than non-durables, consistent with higher interest rate elasticity.

[18]Gagliardone and Gertler (2023) show that these shocks may still correlate with oil price changes despite controlling for macroeconomic news.

coefficient means that aggregate expenditure shifts to products bought more by low-income 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

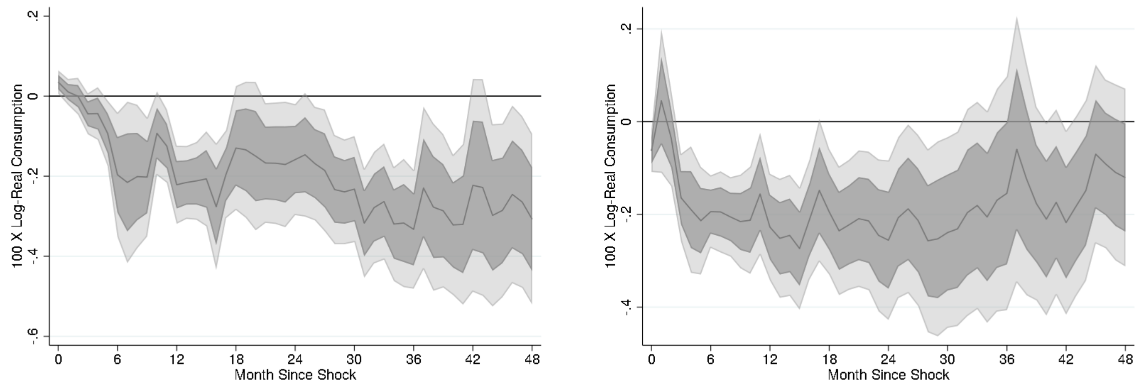
In the model presented in the preceding section, a fall in expenditure causes households to shift their demand to necessities because of non-homothetic preferences. Accordingly, I test directly how the monetary news shocks affect aggregate expenditure using a simple local projection of log-real PCE on 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.[19] 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 negative 0.33 percent about 36-months after the monetary policy shock.[20] Appendix section B.6 shows that the 1- and 10- year Treasury yields increase in response to the monetary policy shock.

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 percent around 30 months after impact, which means that products with an expenditure ratio 1 point higher than average increase their aggregate share by approximately 0.5 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 an expenditure ratio 1 point higher than average increases in relative price by around 0.25-percent, which peaks 30 to 36 months after the monetary policy shock. Together, Figures 7 and 8 imply that, for a product with an expenditure ratio one point above the average, the

[19] The PCE price level, treasury yield, WTI oil price and unemployment rates are all retreived from FRED, Federal Reserve Bank of St. Louis.

[20] For the reader's 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: Data from 1989 to 2019. 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.

elasticity of its relative price with respect to aggregate expenditure is negative 1.[21] This back of the envelope calculation of the relative necessity price expenditure elasticity assumes that the monetary policy shock in figures 7 and 8 are the same, which given that the controls are different (we can use time fixed effects in the panel regression) is not guaranteed. In particular, if the shock proxy used in the aggregate specification differs in timing or strength from the effective shock in the panel regression—due to differing controls—then the two sets of IRFs may not be directly comparable. Nonetheless, both the aggregate and panel regressions use the same time period (1989 to 2019) and scale the monetary policy shock by its standard deviation, which suggests that the approximation is informative, even if not exact.

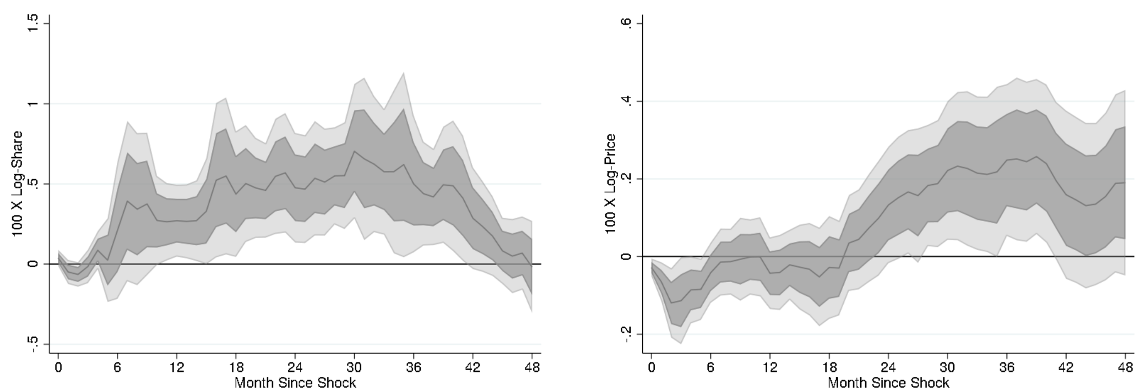
In appendix section B.7 I repeat this analysis using a binary definition of necessity instead of the continuous R_j measure used here and the results are quantitatively similar. Additional

[21] 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 for several years following the shock.

robustness tests in 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 to 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.

4.2 Aggregate Supply Shock: Oil Price

Oil prices represent a larger fraction of the total cost of low-income households' budgets than that of 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 primary challenge in using oil shocks to test the assumptions of aggregate non-homothetic demand and an upward-sloping relative supply curve is that such shocks induce simultaneous shifts in both the relative demand and relative supply curves, complicating identification. However, if the direct effect of the oil price shock on relative prices can be isolated, as formalized in equation 3.3, it becomes possible to control for shifts in the relative 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)

In order to disentangle the non-homothetic expenditure induced response of the oil shock from the direct effect due to differential oil shares, 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:

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

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_j^O is the total cost share of oil in production for sector j.

The total oil cost share in production, S_j^O, 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 do vary over time. I check robustness using the 2007 and 2017 input-output tables, while the baseline uses 2012 tables. Nevertheless, S_j^O may not reflect earlier periods, which could violate assumption (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 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 3.3, 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. Panels 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.[22]

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 negative 0.5.

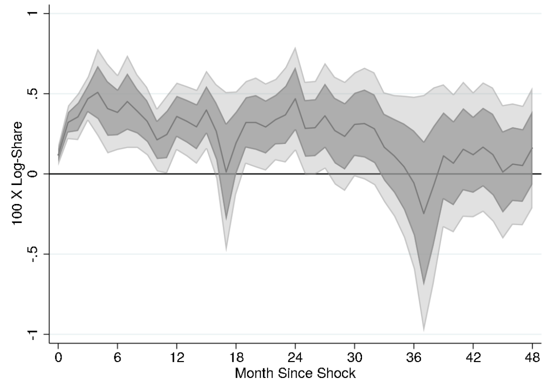
4.4 Discussion

The results in this section suggest that the expenditure elasticity of the necessity expenditure share ranges from negative 2 to negative 1, while the expenditure elasticity of

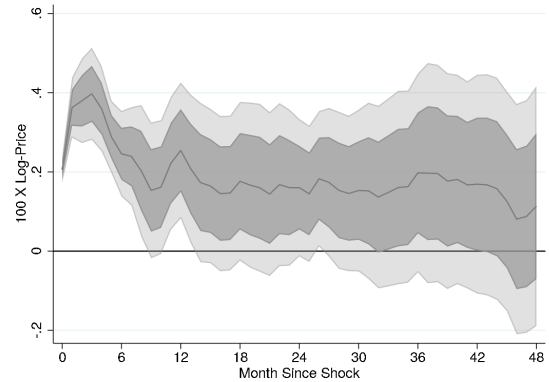
[22]Estimates for the demand elasticity of gasoline tend to be very low even if they have risen a bit in recent data.(Brons et al. 2008, Goetzke and Vance 2021).

Figure 9: Necessity Response to Oil Shock

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

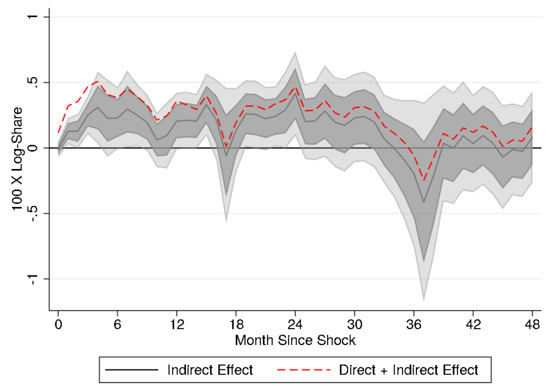


a) Log-Necessity Share



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 1989 to 2019. 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.

necessity prices is between negative 1 and negative 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 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 non-homothetic demand.

Markups could still be an issue for inference even if they are constant over time. If the markup for necessities is lower than that for luxuries then 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 non-homotheticity would provide further upward pressure on necessity prices. Recent work by Baqaee et al. (2024) suggests that markups are not constant in response to a monetary shock and that a contractionary monetary shock leads to an increase in markups for high-markup firms. As stated earlier, contemporary literature suggests luxuries are more likely to have high markups (Nord 2023, Sangani 2022). 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.[23]

5 New Keynesian Model with Non-homothetic Consumption Preferences

How important are aggregate shocks for the inflation rates experienced by 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 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

[23] 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.

percent of the variation in relative necessity inflation from 1961 to 2024. Finally, I use the model to examine the contributions to inflation inequality coming from the non-homothetic 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 preferences, it 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.[24]

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-homotheticities 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:

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

[24]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.

The greater the household's utility (expenditure) x^h, the higher 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 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).

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 that the elasticity of intertemporal substitution is generally constant. However, that is not the case in this model. Similar to 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 is not dependent 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.[25]

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 disutility 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

[25] 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.

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 (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 sector and a luxury sector. Differentiated intermediate goods in 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:

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

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 pass-through 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 appendix section C.2.1, I show an 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, (2) the labor share α_h, and (3) the oil shares α_o and pass-through 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 jointly with κ govern how much an oil shock affects 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.[26] 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.[27] In 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

[26] 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.

[27] 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.

0.6.

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

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.[28] I target the calibration, so that 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

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

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 negative 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) of Figure 10, I introduce a series of oil price shocks (P^O) so that the oil price series in the model matches a smoothed 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. These results imply that in the historical decomposition, the model will assign more weight to oil shocks than to monetary policy shocks compared to the empirical IRFS.

5.5.1 Contribution of Aggregate Shocks to Inflation Inequality

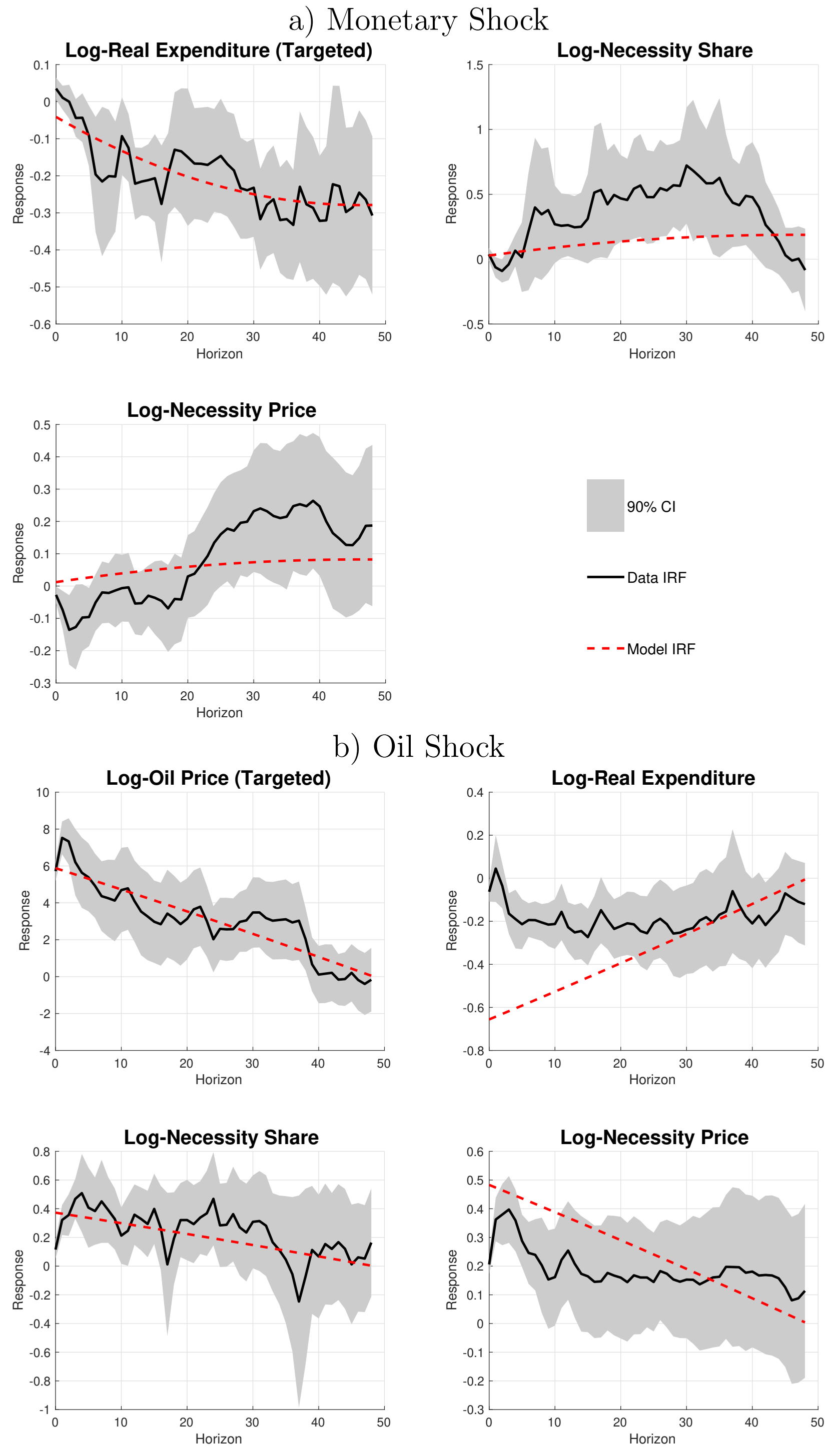
How well does the model predict necessity prices and shares over time? As a validation exercise, I shock the model with a series of discount factor shocks Z_t, aggregate TFP shocks (common across sectors), monetary shocks, and oil price shocks so that the model's oil price, expenditure, nominal interest rate, hours, and wage match the WTI, real PCE, one-year Treasury Yield, US aggregate employment hours, and U.S. average hourly earnings respectively for production and non-supervisory workers.[29] I filter the log of each of the data variables using the Hamilton (2018) filter, and qualitatively similar results are found when using a one sided HP filter.[30] 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 methods 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 of relative necessity prices inflation

[29]For fitting the shocks to the data, I also allow measurment error shocks for wages and hours.

[30]The results with the HP filter are qualitatively similar, but a bit smaller for some recessions. For example, under the HP filter the expenditure channel is only responsible for a 1 percent increase in inflation inequality during the COVID-19 recession.

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.

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 bars 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 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 non-homothetic expenditure channel (which combines the contributions from TFP, monetary, discount factor, and indirect oil shocks) has on cumulative inflation inequality over the recessionary period.[31] The expenditure channel was an important part of inflation inequality in each recession, but it was largest in the 1973 oil shock, the Volcker recessions, the Great Recession, and the COVID-19 recession. In each of these recessions, the expenditure channel increased inflation inequality by over 1 percentage points relative to trend.

The second column shows the contribution of the direct oil shock, which was also 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 household baskets, which negated the impact of the expenditure channel.

The last column (Data) shows the inflation inequality in the data based on the non-

[31] 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 $t + k$.

homothetic price index. In the data, I construct $B(P)$ using all 137 of the 148 PCE sectors for which I have price data over the entire 1961-2024 sample.[32] 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), and 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.

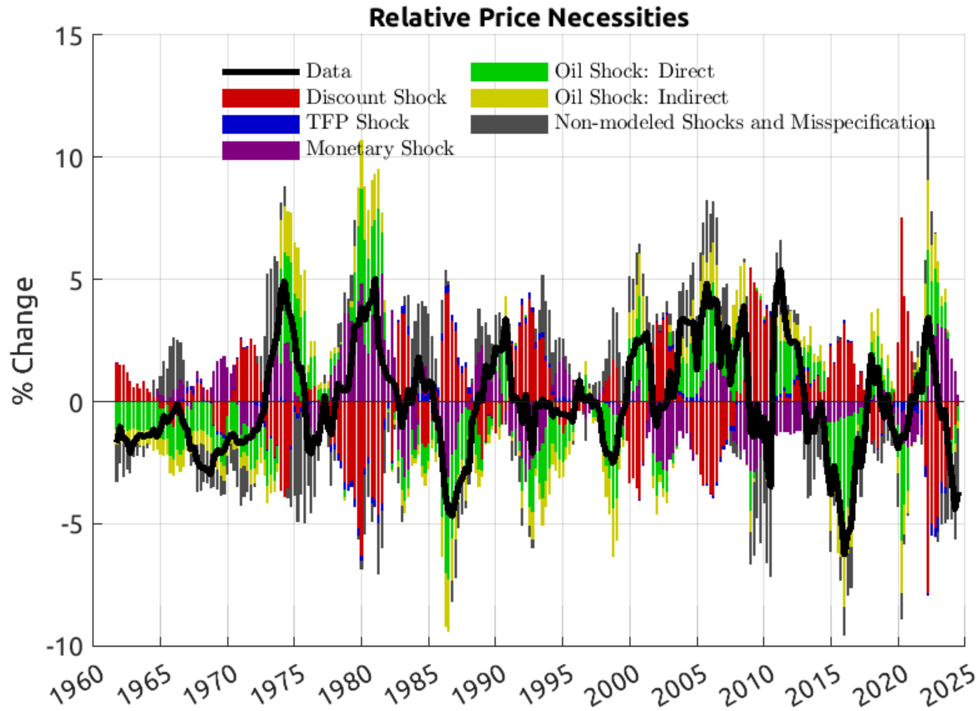
Table 5: Inflation Inequality during NBER Recessions

Period	Non-homothetic 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 low-income versus high-income households using the AIDS Non-homothetic price Index cumulative over the recessionary period (inflation inequality). The non-homothetic 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.

[32] Some categories, such as "Internet Access" have data that starts later.

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 A13 for the shock decomposition of these variables and non-targeted necessity shares).

6 Conclusion

This paper documents that prices and expenditure shares of goods consumed more by low-income households are countercyclical. A model with non-homothetic preferences and a concave production frontier explains these patterns, and evidence from monetary and oil shocks supports this conclusion. The non-homothetic expenditure channel emerges as a key driver of inflation inequality, raising the relative price of necessities in recessions, though its effects can be offset when oil prices fall sharply.[33]

[33]This study also has implications for the measurement of aggregate inflation. Because CPI product weights are updated with a lag, and aggregate spending shifts toward necessities in recessions, the CPI tends to underweight necessities in downturns and overweight them in expansions. This biases inflation

This project studies changes in sector-level prices rather than prices within a sector and abstracts from product entry and exit. The extent that non-homothetic 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 suggests that within-sector necessity prices were also countercyclical 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 $k < 1$. ■

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:

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

■

Proposition 1 *In a two-sector competitive economy with a representative household that has preferences satisfying section 3.2, 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 section 3.2 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.[34] 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

[34]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:

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

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):

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

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:

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

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

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

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:

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

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

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

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 to 2023 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 to 2023). 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.[35]

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.

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

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

B.4 Top Luxuries and Necessities

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.

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 around 4 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. Panel B shows the top 10 necessity goods. These include tobacco products, energy, and food products.

Figure A1 summarizes sectoral heterogeneity in oil intensity, labor shares, and price adjustment frequencies. Panel A shows that most product sectors have a low oil share in production (the median is 2 percent), but there are some large outliers. For example, gasoline has nearly an 80 percent oil share in production. 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. Panel B shows the relationship between each sector's labor share and expenditure ratio. Necessities tend to have a lower labor share in production than luxuries. Panel C shows the relationship between the price change frequency and the expenditure ratio, using data from Montag and Villar (2022).[36] Like the oil share, the price change frequency is concentrated at a low level: the median product has a frequency of only 9 percent. But again there are large outliers, particularly among transportation services and energy products, although motor vehicles and parts subcategories also adjust prices more frequently.[37] Notably, products that change prices more frequently also tend to have a high oil share (correlation 0.49), while there is a negative correlation between a product's price-change frequency and its labor share (correlation negative 0.45), consistent with energy-intensive sectors being more flexible in pricing than labor-intensive ones. Taken together, these patterns suggest that while necessities often feature higher oil shares, lower labor shares, and more frequent price changes than luxuries, there is substantial heterogeneity within both groups, and sectors are quite diverse along these dimensions.

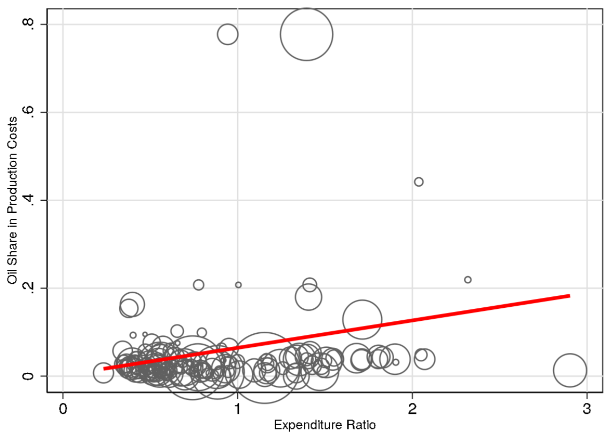
B.5 Panel Regression Results using Alternate Definition of Necessity

[36] 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.

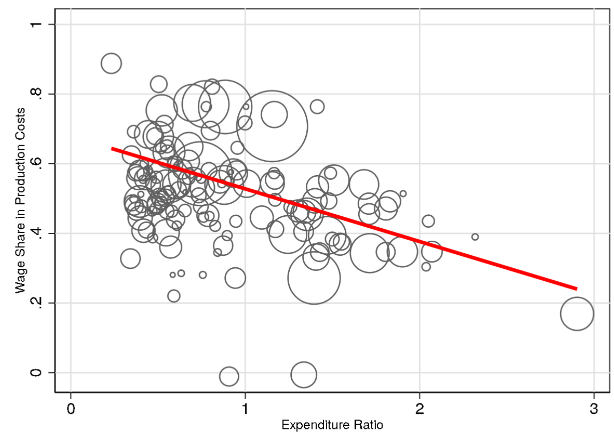
[37] All median and average statistics in this paragraph are weighted by the PCE sector's share in aggregate expenditure.

Figure A1: Oil Share, Price Frequency, and R_j

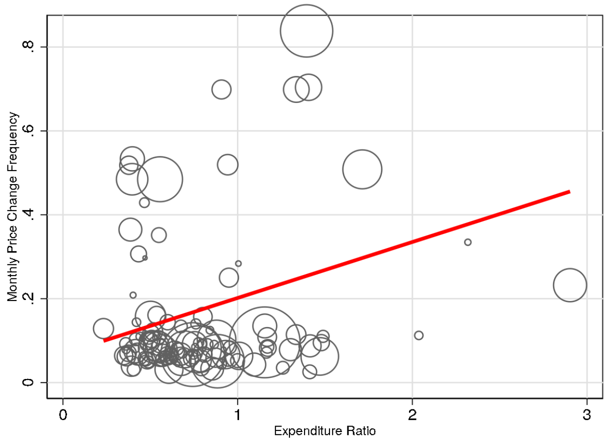
Panel A: Oil Share and R_j



Panel B: Labor Share and R_j



Panel C: Price Change 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.

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 to 2023. 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 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 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

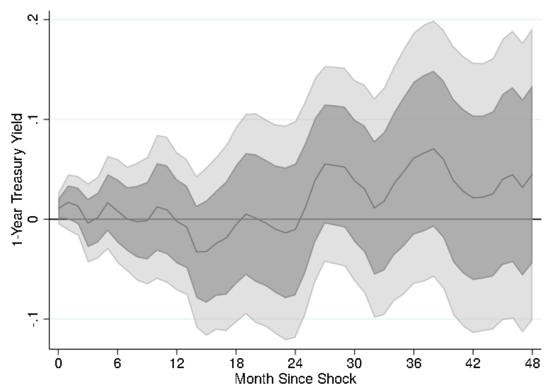
Notes: The unit of observation is at the sector-time level. R_j is the ratio of the expenditure share on the PCE sector for low-income households over high-income households. Inflation is the 12-month percent change in the consumption sector price level. The change in oil price is the 12-month percent 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 *.

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

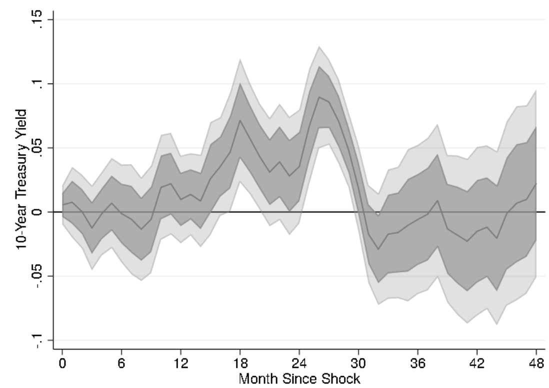
	100× Log-Share			Inflation		
	(1)	(2)	(3)	(4)	(5)	(6)
Right hand side variables:						
UR × Necessity	1.73***	1.75***	1.68***	0.16**	0.13**	0.42***
	(0.17)	(0.17)	(0.33)	(0.07)	(0.06)	(0.08)
Δ Oil Price × Necessity	0.02			0.05***		
	(0.01)			(0.00)		
Δ Oil Price × Oil Share		0.30***	0.33***		0.57***	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 *.

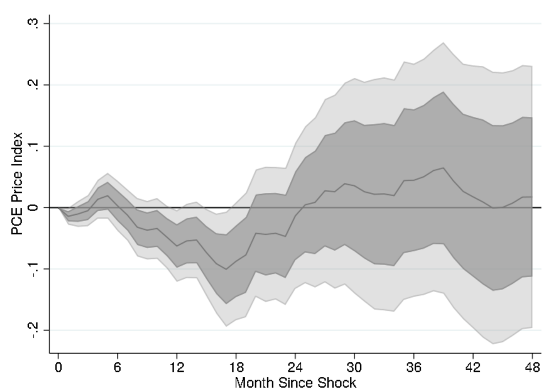
Figure A2: Response to Monetary Policy Shock



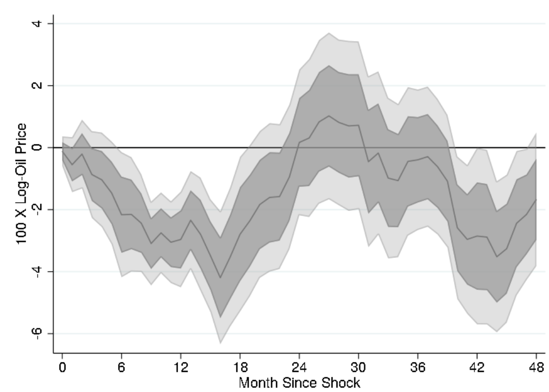
a) 1-Year Treasury Yield



b) 10-Year Treasury Yield



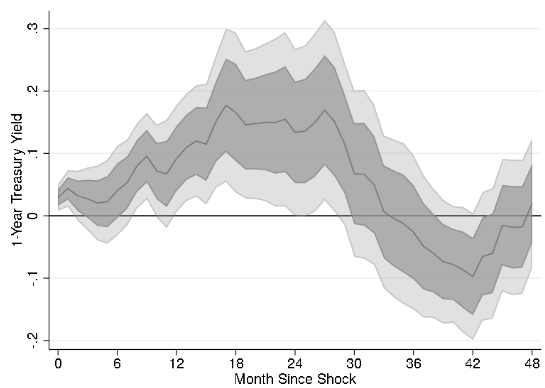
c) PCE Price Index



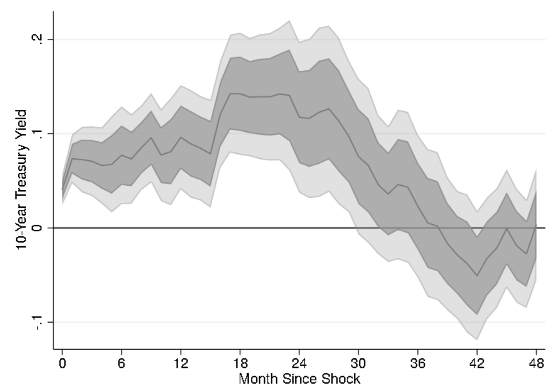
d) Log-Oil Price

Note: Data from 1989 to 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.

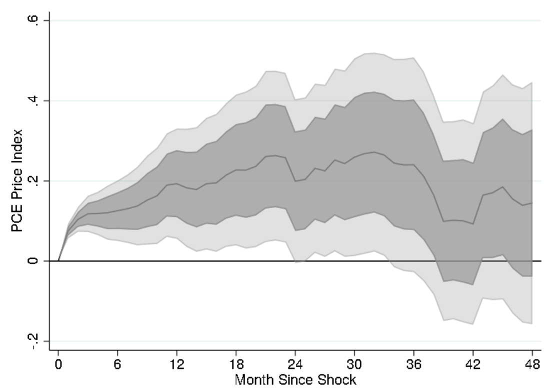
Figure A3: Response to Oil Price Shock



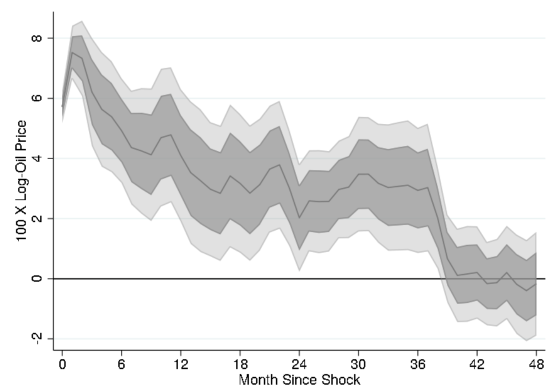
a) 1-Year Treasury Yield



b) 10-Year Treasury Yield



c) PCE Price Index



d) Log-Oil Price

Note: Data from 1989 to 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 to 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.

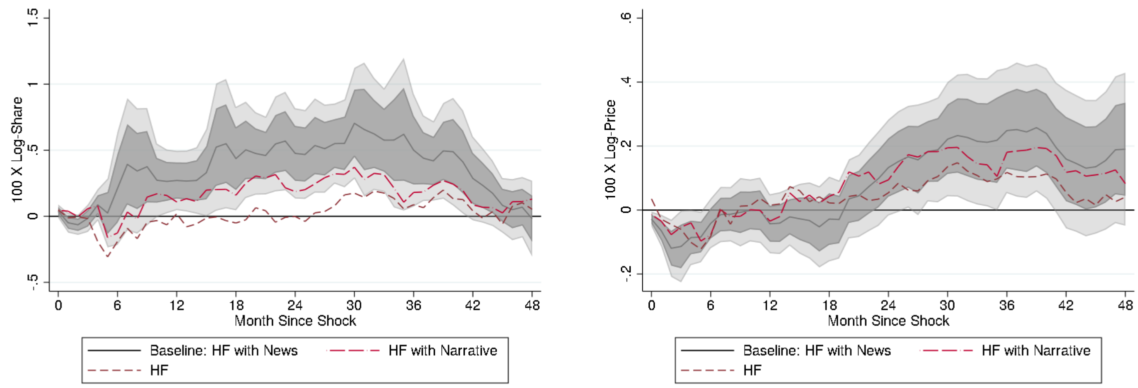
In Figure figure A6, I redo the IRFs and robustness tests, but the main coefficient of interest is now the interaction between a binary definition of necessity and the monetary policy shock, rather than the continuous expenditure ratio measure that I use in the main text. The estimated coefficients are 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 A8 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

Relative necessity prices and shares increase due to the indirect effect of an oil price shock and this result is robust to a range of specifications. Figure A7 shows that results are similar when removing the monetary policy shock interaction as a control, when conditioning both the direct and indirect effects of the oil price shock on the sectors price change frequency,

Figure A4: Necessity Response to Alternate Monetary Policy Shock



a) Log-Necessity Share

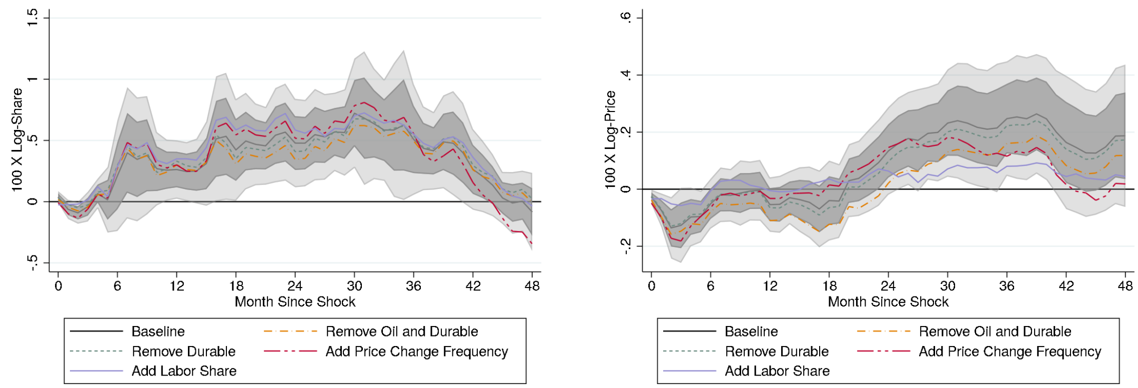
b) Log-Necessity Price

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.

when using the BEA total requirement estimates from different years (2007 or 2017), or adding the labor share. In both panels, the black line shows the results from the baseline regressions in the main text. The yellow dash-dotted line represents an IRF that is identical to the specification in the main text, except that the current and lagged interactions of the Bauer and Swanson (2022b) with R_j are not included; the omission of the monetary policy shock leads to a longer sample from 1976 to 2023 compared to 1989 to 2019 in the main text. The red dotted and purple solid lines, show results using the 2007 and 2017 BEA input and output tables respectively.

The green dashed line shows results when controlling for the sector's price change frequency. As mentioned in the main text, Minton and Wheaton (2023) show that downstream firms can be slow to adjust prices in response to input costs of upstream providers. This suggests that observed responses of necessity prices to the indirect component of oil shocks might reflect differences in price adjustment frequency rather than genuine non-homothetic shifts. In order to properly parse out all direct effects of oil on prices, I modify equation 4.3 in the main text, so that the direct effect of oil on the sector's prices or shares $\Delta|_{t-1}^{t+h} P^O$ is multiplied

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



a) Log-Necessity Share

b) Log-Necessity Price

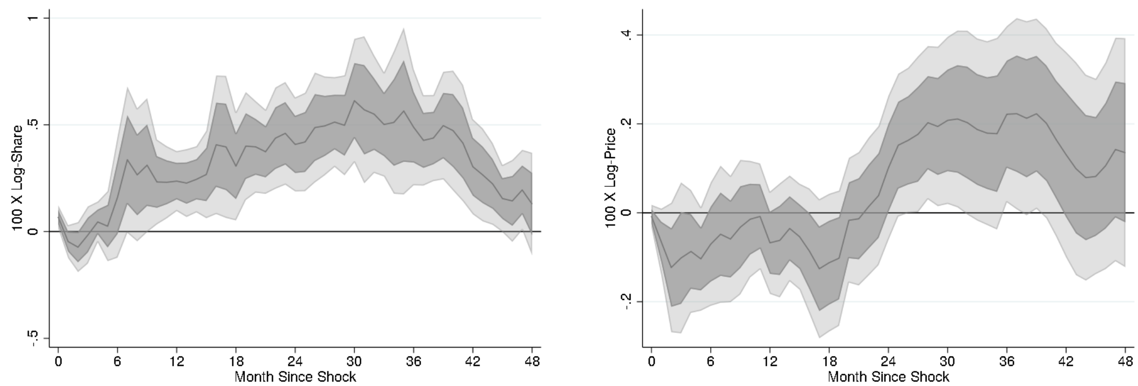
Note: Data from 1989 to 2019. Estimated coefficients, γ^h from Local Projections in equation (4.1) represent the response of the dependent variable to a one standard deviation monetary contraction using the Bauer and Swanson (2022b) monetary shocks interacted with R_j. The unit of observation is the 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.

by the probability that that sector adjusted prices at that horizon h ($P^h = (1-(1-pm_j))$ where pm_j is sector j's monthly price change frequency. In this regression, I also control for the current and lags of the sector's price change frequency interacted with the oil price shock. Equation B.2 shows in bold the changes from the main text.

$$x_{j,t+h} = \sum_{k=0}^{12} \left[\boldsymbol{\xi^{h,k}} ON_{t-k} \times R_j + \gamma^{h,k} i_{t-k} \times R_j + \boldsymbol{\beta^{h,s,l} ON_{t-k} \times pm_j}\right] + \kappa^h \boldsymbol{P^h} \Delta|_{t-1}^{t+h} P^O \times S_j^O + \sum_{l=1}^{12} \left[\sum_{y \in \{s,p\}} \left(\beta^{h,y,l} y_{j,t-l}\right) + \beta^{h,O,l} \Delta P_{t-l}^O \times S_j^O \right] + \delta_{h,t} + \psi_{h,j} + \alpha_{j,t+h}. \tag{B.2}$$

Finally, the blue dashed line shows results when the sector's labor share is included. In the static model, 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

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



a) Log-Necessity Share

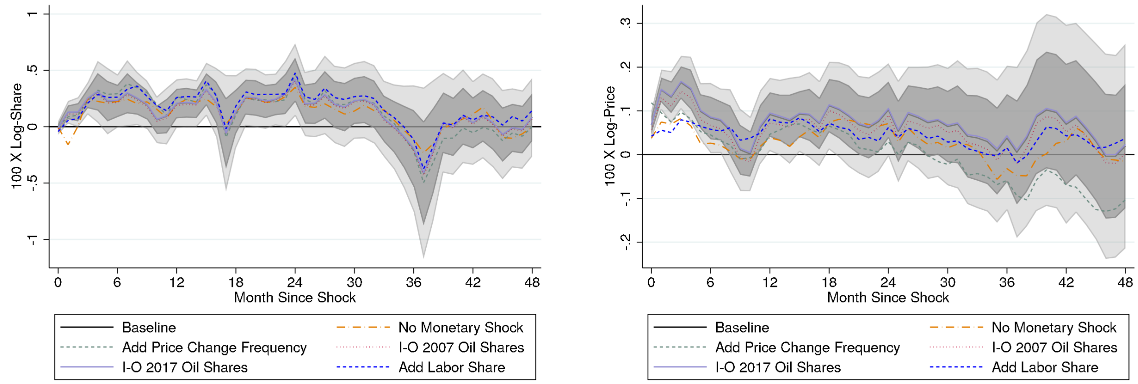
b) Log-Necessity Price

Note: Data from 1989 to 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.

of homogeneity of the two functions $(k-1)\log\left(\frac{1}{A_{N,t}}\right) - (g-1)\log\left(\frac{1}{A_{L,t}}\right)$. While I cannot observe every aspect of a sector's productivity function, the sector's labor share is one aspect that I can estimate via the BEA's input and output accounts. Equation B.3 highlights in bold the modifications relative to the main specification, showing how the direct effect of oil on prices is now adjusted for the sector's labor intensity $\alpha_{h,j}$. To account for other effects of the oil price shock on a sectors prices or shares coming exclusively through differences in labor shares, I also include the contemporary oil price news shock and lags with the sector's labor share. Results are largely similar as to the main text, although the initial response of necessity prices is smaller.

$$x_{j,t+h} = \sum_{k=0}^{12} \left[\boldsymbol{\xi^{h,k}} ON_{t-k} \times R_j + \gamma^{h,k} i_{t-k} \times R_j + \boldsymbol{\beta^{h,H,l} ON_{t-k} \times \alpha_{h,j}}\right] + \kappa^h \boldsymbol{\alpha_{h,j}} \Delta|_{t-1}^{t+h} P^O \times S_j^O + \sum_{l=1}^{12}\left[\sum_{y\in\{s,p\}} \left(\beta^{h,y,l} y_{j,t-l}\right) + \beta^{h,O,l} \Delta P_{t-l}^O \times S_j^O\right] + \delta_{h,t} + \psi_{h,j} + \alpha_{j,t+h}. \tag{B.3}$$

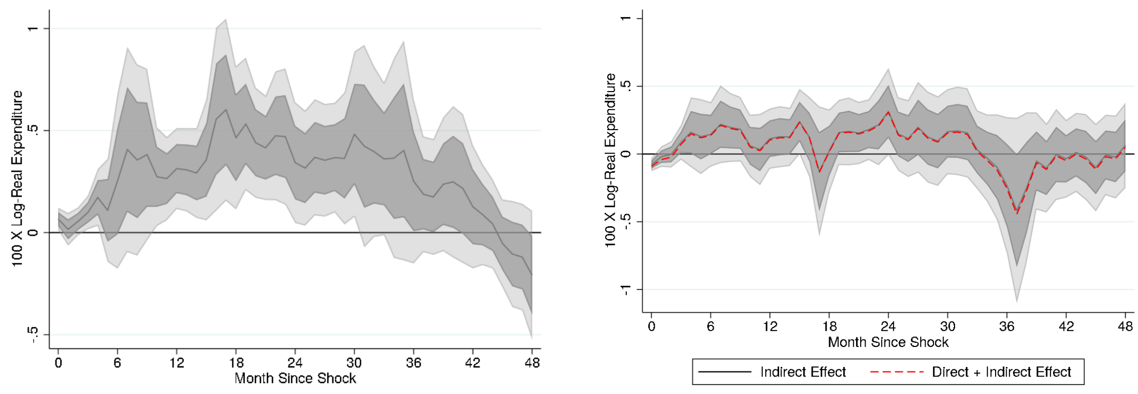
Figure A7: Necessity Response to an Indirect Oil Shock: Alternate Specifications



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

Note: Data from 1989 to 2019 for most specifications and from 1976 to 2023 for the dashed yellow line (no monetary policy shock). Estimated coefficient from Local Projections represent the response of the dependent variable to a one standard deviation Känzig (2021) interacted with R_j controlling for the interaction between the oil price at horizon h and the PCE sector's oil share. 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 A8: Panel Local-Projection: Necessity Real Expenditure Response to Monetary and Oil Shocks



a) Monetary Shock b) Oil Shock

Note: Data from 1989 to 2019. 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

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 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.[38]

As an alternative to monetary policy shocks, I show that uncertainty shocks also lead to a fall in aggregate expenditure, but importantly also 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 negative 0.5 and negative 1 depending on the type of uncertainty shock considered.[39] 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.

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.[40] 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,

[38]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.

[39]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).

[40]The VIX index is a product of the Chicago Board Options Exchange, CBOE Volatility Index: VIX [VIXCLS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/VIXCLS.

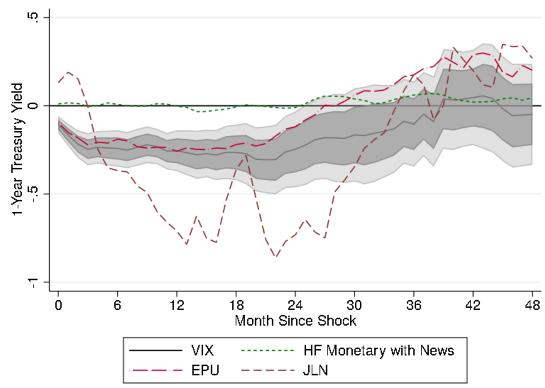
and Federal Reserve Policy. Finally, I also use the Jurado et al. (2015) (JLN) 1-month ahead econometric uncertainty shocks.

Figure A9 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.

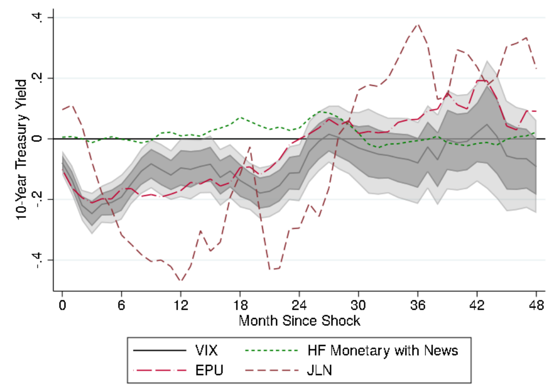
Figure A11 estimates the relative necessity share and price response to uncertainty shocks using the baseline specification in 4.1, but replacing the monetary policy shock with uncertainty shocks. I find large impacts on necessity shares and prices. Panel a) shows that following the shock, the necessity 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 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 negative 1 for the VIX shock, slightly below negative 1 for the EPU shock and around negative 0.5 for the JLN shock.

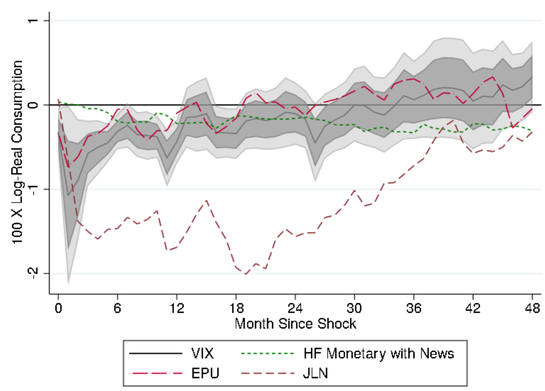
Figure A9: Response to Uncertainty Shock



a) 1-Year Treasury Yield



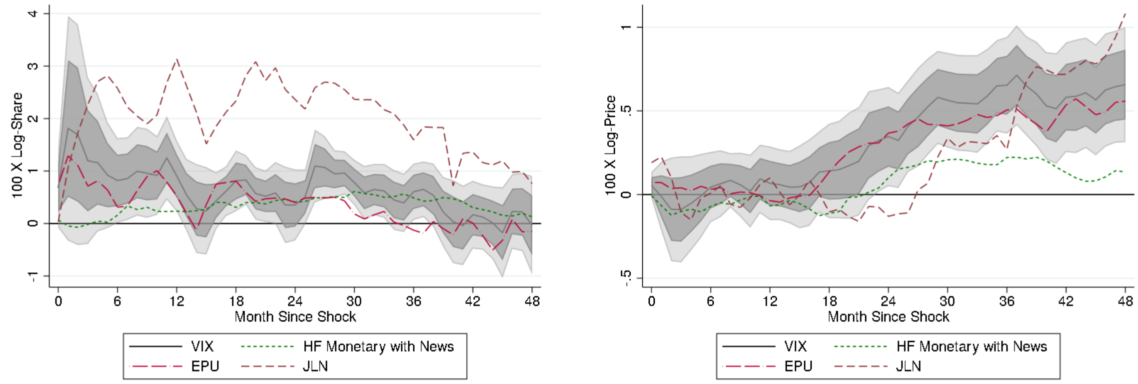
b) 10-Year Treasury Yield



c) Real PCE

Note: Data from: 1989 to 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.

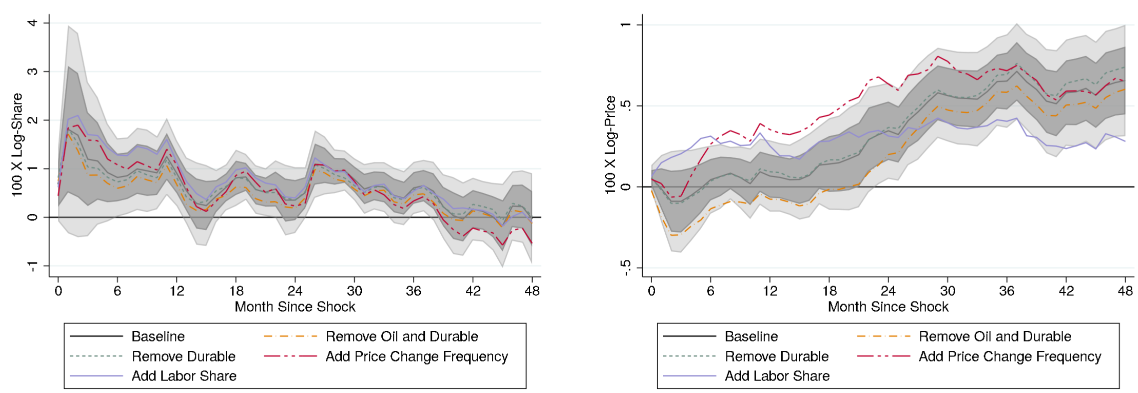
Figure A10: Necessity Response to Uncertainty Shock



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

Note: Data from: 1989 to 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 A11: Necessity Response to Uncertainty Shock: Alternate Specifications



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

Note: Data from: 1989 to 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

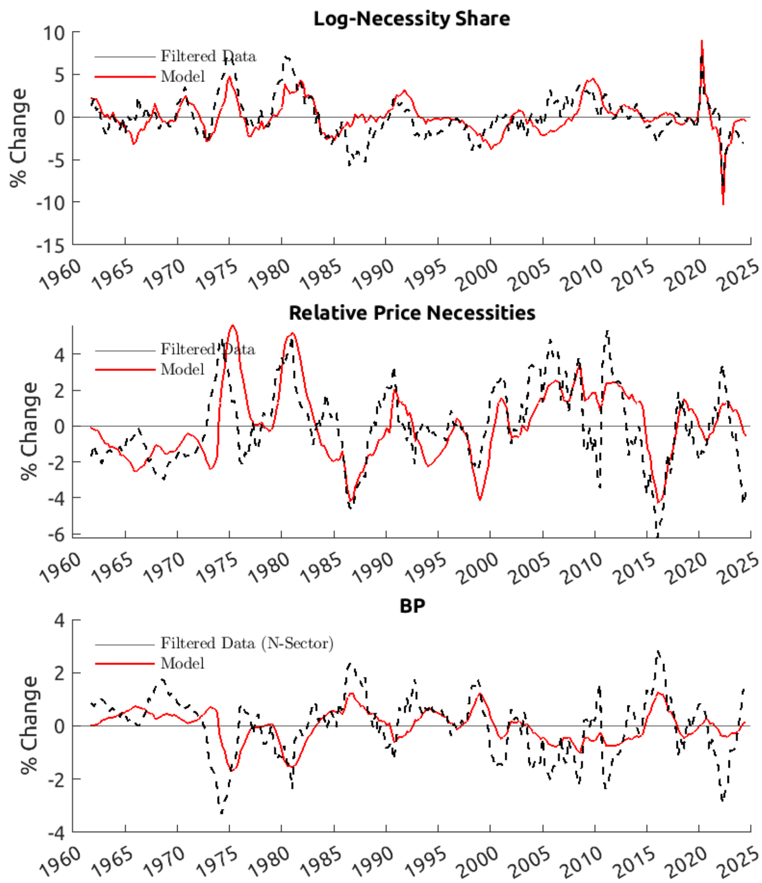
How well does the model predict necessity prices and shares over time? As a validation exercise, I shock the model with a series of discount factor shocks Z_t, monetary shocks, aggregate TFP shocks (common across sectors), and oil price shocks so that the model's oil price, expenditure, and nominal interest 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 A12 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

Figure A12: Model v. Data: Historical Simulation



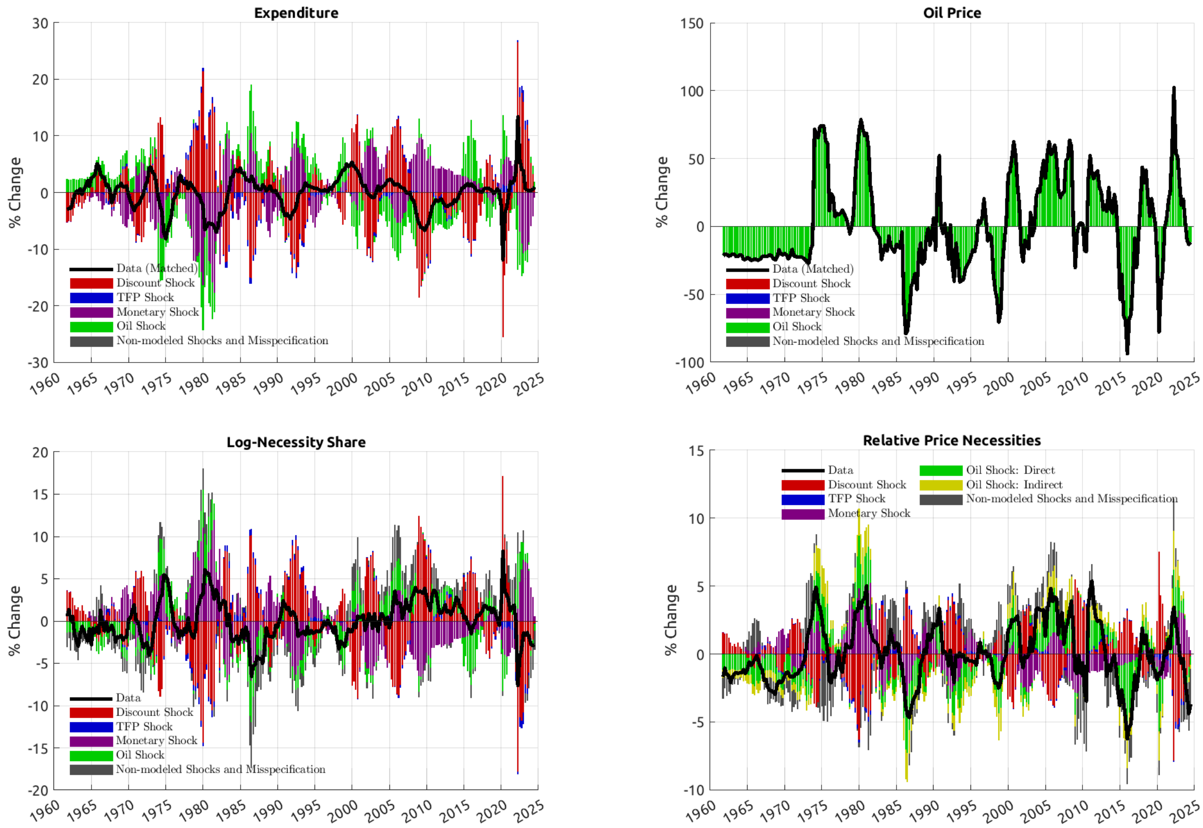
Note: Author targeted shocks to match real expenditure, the price of oil, and the 1-year treasury yield. Necessity share, relative necessity price, and the non-homothetic price index $b(p)$ are untargeted. Data is filtered following Hamilton (2018).

model only has two sectors, while there are 137 in the data.

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 A13 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.

Figure A13: 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.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:[41]

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

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 A14. The results are virtually identical as those in the baseline model (partially due to $\theta_L \times \theta_N$ being quite low).

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

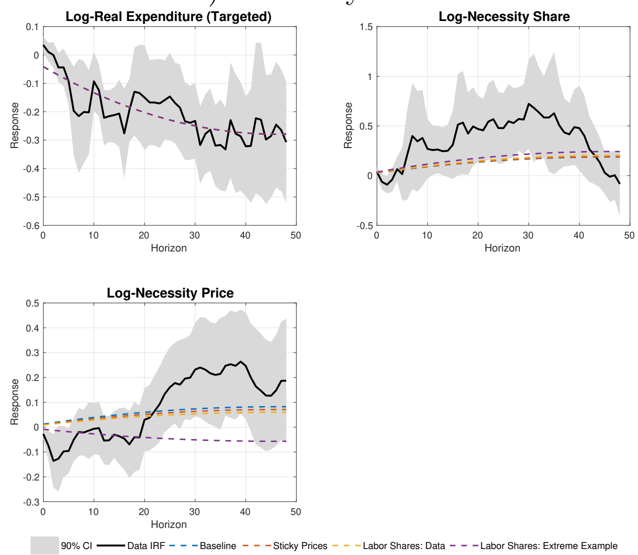
[41] In steady state, the desired markup $\epsilon_p/(1-\epsilon_p)$ cancel out.

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 A14 and are quite similar to those in the baseline model.

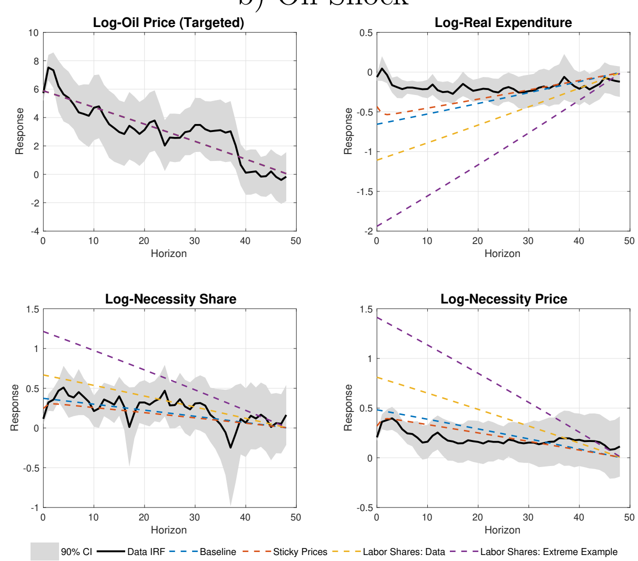
For pedagogical purposes, I also consider a case where the labor shares in the necessity and luxury sector are drastically different ($\alpha_{hn} = 0.55$ and $\alpha_{hl} = 0.95$), an extreme calibration that is not supported by the data. Results from these calibrations, shown by the purple line in Figure A14, 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 A14: Alternative Calibrations

a) Monetary Shock



b) Oil Shock



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.