

Energy Shocks, Consumption Inequality & Fiscal Policy Design

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July 1, 2026

Abstract

Supply-driven energy price shocks generate substantial consumption inequality. Using US household expenditure data and instrumental variable local projections, we show that a one percentage point energy price increase reduces consumption of households in the lowest income decile by 0.5 percent, while consumption of those in the highest decile remains unchanged. This differential response persists for up to one year and reflects both higher energy expenditure shares and tighter liquidity constraints among low-income households. A two-agent New Keynesian model with two production sectors (energy and non-energy) and non-homothetic household preferences replicates these patterns and provides a framework for policy evaluation. At comparable fiscal cost (0.08 percent of GDP over two years), targeted cash transfers fully offset the consumption inequality increase, while energy subsidies reduce it by only half. Cash transfers dominate because they enable constrained households to allocate resources optimally across all consumption categories, whereas subsidies are restricted to energy expenditure. These findings inform the design of fiscal responses to relative price shocks affecting necessity goods.

Keywords: Energy, Consumption Inequality, Fiscal Policy.

JEL Codes: D31, E21, E31, E62, Q43.

*We sincerely thank Martin Bodenstein, Sergio de Ferra, Andrea Ferrero, Lutz Kilian, and Michael McMahon for their feedback. We are also grateful to participants at the Annual CEBRA Workshop for Commodities & Macroeconomics, Federal Reserve Board Brownbag Seminar, OeNB/SUERF Annual Economic Conference, DIW Berlin Workshop for Women in Macroeconomics, Finance and Economic History, ifo Dresden Workshop on Macroeconomics and International Finance, Warwick-Oxford Macro & International Workshop, and Oxford Macro Working Group Seminar for their insightful comments. The views expressed in this manuscript are solely our own and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System, any person associated with the Federal Reserve System, the Bank of England, or its committees. Chankova: rosi.chankova@bankofengland.co.uk | Komatsu: momo.komatsu@frb.gov

1 Introduction

Sharp increases in energy prices pose distinct macroeconomic and distributional challenges. While the aggregate effects of energy shocks on inflation and output have been studied extensively, the recent surge in energy prices highlights the importance of understanding the heterogeneous effects of relative price shocks on households. Accordingly, this paper addresses the question: how do energy price shocks affect consumption patterns across the income distribution, and how effective are different fiscal policy measures at reducing consumption inequality?

The relevance of energy shocks on distributional consequences arises from three stylised facts, already well-established in the literature. First, energy goods make up a disproportionately large share of low-income household expenditure. As a result, asymmetric energy price shocks resemble a regressive consumption tax, unlike a broad-based inflation increase, as lower-income households face a higher effective inflation rate (Chan et al., 2024; Erosa & Ventura, 2002).¹ Second, because energy demand is relatively inelastic (Andreyeva et al., 2010; Labandeira et al., 2017), households are forced to absorb price increases, and low-income households in particular have limited margins of substitution.² Third, liquidity constraints limit the ability of poorer households to smooth consumption through savings or borrowing in response to price spikes (Battistini et al., 2022). Together, these features imply that energy price shocks can produce substantial heterogeneity in consumption responses across the income distribution and cause consumption inequality to rise. Our empirical analysis documents precisely these patterns.

Governments frequently respond to such shocks with short-term fiscal measures designed to sustain the purchasing power of households. These include tax rebates and credits (e.g., the 2008 *Economic Stimulus Act*), temporary suspensions of gasoline taxes (as implemented in Maryland and Georgia in 2022), or direct transfers and subsidies (e.g., the 2020-21 *Economic Impact Payments* - commonly referred to as ‘stimulus checks’, the federal *Low Income Home Energy Assistance Program*, and the *California Alternate Rates for Energy* discount program for low-income households).³ In line with the “three T’s” principle of fiscal design (see Elmendorf and Furman, 2008), these measures were generally *timely* and *temporary*, but not always *targeted*. This paper examines two such targeted interventions—cash trans-

¹This relates to a larger literature which shows households with lower income to experience higher inflation rates than those with higher income (see Hobijn et al., 2009; Jaravel, 2019; Kaplan and Schulhofer-Wohl, 2017; Neyer and Stempel, 2025).

²Low-income households have fewer substitution options, because they are more likely to already consume the least expensive variety within each category of goods and services.

³While the 2008 *Economic Stimulus Act* and 2020 *Economic Impact Payments* were part of broader recovery packages aimed at mitigating wider economic downturns, they were in part also responding to rising energy and living costs following the energy price surges of 2007 and 2021.

fers and energy subsidies—and compares their fiscal costs and effectiveness at reducing consumption inequality.

To address the research question, this paper proceeds in two steps. First, using household-level microdata from the U.S. Consumer Expenditure Survey (CES), we construct decile-specific inflation rates and real consumption series.⁴ We then estimate the causal effects of exogenous energy price shocks on consumption patterns across income groups using an instrumental variables local projection approach à la Jordà et al. (2015). Energy shocks are measured using the OPEC-based supply shock series from Känzig (2021), which captures oil price movements independent of domestic demand. Second, the paper introduces a two-agent New Keynesian model with non-homothetic preferences that captures the heterogeneity between constrained (low-income) and unconstrained (high-income) households. We validate the model with empirical local projections and evaluate alternative fiscal policy measures.

In the empirical analysis, we document two main findings. First, in response to a one percentage point increase in the energy price, consumption of households in the lowest decile of the income distribution decreases by 0.5 percent, whereas consumption of those in the highest decile does not change. The impact of the shock on consumption declines nearly monotonically across income deciles. The results imply a persistent rise in consumption inequality, lasting up to a year after the initial shock. Second, the contraction in energy consumption is deeper and more persistent than that of other, non-energy consumption, though non-energy consumption accounts for most of the aggregate adjustment due to energy's smaller expenditure share.

With the structural model, we confirm the mechanism behind the heterogeneous consumption responses across deciles: lower income households allocate a larger share of their income to energy consumption and have tighter liquidity constraints, reducing their ability to offset temporary shocks. We build a structural model with credit-constrained and unconstrained households. We use non-homothetic household preferences to model energy as a necessity good. This model captures the consumption response dynamics from the empirical analysis closely and provides a valid starting point for counterfactual exercises. We find that at comparable fiscal cost (approximately 0.08 percent of GDP over two years), cash transfers to constrained households fully offset the consumption inequality increase after an energy shock, while energy subsidies reduce the inequality response by half. The high effectiveness of cash transfers arises because they enable constrained households to allocate resources optimally across all consumption categories, whereas subsidies are restricted to energy expenditure, which constitutes only a small share of the total con-

⁴This study focuses on consumption inequality because it is a more welfare relevant measure than income inequality.

sumption basket. This finding has direct implications for the design of fiscal responses to energy shocks, such as the gasoline tax suspensions implemented in multiple U.S. states in 2022 and the widespread energy subsidies deployed across European economies.

Thus, the analysis contributes to the literature in two ways. Empirically, we provide the first quantitative estimates of how supply-driven energy shocks affect consumption inequality across the income distribution, using household microdata and a credible instrumental variable strategy. Theoretically, this paper develops a tractable framework for evaluating the cost-effectiveness of alternative fiscal policy measures in reducing consumption inequality following energy shocks, directly informing policy design in response to relative price shocks.

The remainder of the paper is structured as follows. Section 2 gives an overview of the relevant literature. Section 3 presents the household survey data and descriptive results that motivate the study. Section 4 details the econometric framework and discusses insights from the empirical estimates. Section 5 presents the New Keynesian model, and Section 6 discusses the model dynamics and the results regarding counterfactual policy interventions. Finally, Section 7 concludes with key insights.

2 Literature Review

This paper relates to three strands of literature: (i) the macroeconomic effects of energy price shocks, (ii) the distributional consequences of inflation, and (iii) fiscal policy transmission in heterogeneous agent models.

Although the increase in energy prices over the past few years is striking in scale, sharp fluctuations in these prices are not uncommon given the inherent volatility of these markets (e.g. Parker (2017)). A substantial body of literature examines the macroeconomic impacts of energy price shocks, especially oil prices, and finds mixed results regarding their effects on aggregate consumption and output, with outcomes varying by country and sample period (see Hoang et al. (2019) for a review of previous studies). Kilian (2008) shows that the economic consequences of energy price shocks depend crucially on their underlying source: supply-driven increases in energy prices exert more pronounced adverse effects on output and inflation than demand-driven shocks. While studies suggest that the aggregate impacts of these shocks have lessened over time in advanced economies,⁵ the disproportionate burden on lower-income households is less well understood at the mi-

⁵Blanchard and Galí (2007), Choi et al. (2018), and Hooker (1996) attribute the muted impact of energy shocks to improvements in monetary policy frameworks and greater diversification of energy supplies

cro level. This paper contributes by providing micro-level evidence on how energy price shocks propagate heterogeneously across the income distribution, using household expenditure data to document the consumption inequality dynamics that aggregate studies cannot capture.

The distributional consequences of increases in overall inflation are well-documented: lower-income households are particularly vulnerable to inflationary pressures due to their limited savings and tendency to hold assets in cash or low-interest accounts that do not protect against inflation (see Bettarelli et al. (2023) for a comprehensive review). Galli and Hoeven (2001) and Doepke and Schneider (2006) show that inflation can exacerbate income inequality and Easterly and Fischer (2001) argue that low-income workers are less able to adjust for rising prices given their limited wage bargaining power. Energy price shocks represent a particularly sharp form of distributional shock because (i) energy is a necessity good for which lower-income households allocate a disproportionately large budget share, and (ii) energy prices are highly volatile, creating substantial variation in effective inflation rates across the income distribution. Energy price shocks have been shown to drive significant labour reallocation across sectors (Loungani, 1986). A closely related contribution is Bettarelli et al. (2023), which examines energy inflation in a panel of countries and finds a significant increase in consumption inequality (e.g., the consumption Gini coefficient), particularly in economies with weaker financial systems and monetary policy frameworks. This paper contributes by adopting a ground-up view of inequality, leveraging detailed U.S. microdata to uncover the mechanisms of consumption adjustment following energy shocks, rather than considering inequality in aggregate terms.

Recent advances in the heterogeneous agent literature underscore the importance of accounting for income, wealth, and consumption preference differences in understanding the effects of economic shocks (Auclert, 2019; Bilbiie, 2008, 2017; Broer et al., 2020; Debortoli & Galí, 2017; Dolado et al., 2021; Kaplan et al., 2018; Komatsu, 2025). Two-agent New Keynesian (TANK) models, which distinguish between credit-constrained and unconstrained households, offer a tractable framework for studying distributional effects while maintaining analytical clarity (Debortoli & Galí, 2017). Non-homothetic preferences capture differences in the exposure and response of low- and high-income households to price changes in essential goods, as lower-income households allocate a larger share of their income to necessities (Boppart, 2014). A growing body of work examines fiscal policy responses to mitigate the distributional effects of energy price shocks (Kharroubi & Smets, 2014; Kröger et al., 2023; Meyimdjui & Combes, 2021; Zhang et al., 2014). Jaravel and Olivi (2019) analyse optimal tax policy in the presence of heterogeneous inflation, offering insights relevant to inflationary pressures driven by energy costs. More generally, fiscal measures such as targeted subsidies, cash transfers, and progressive taxation have

been shown to ease the burden on low-income households (Bonifacio et al., 2021). This paper extends the literature by developing a quantitative TANK model with non-homothetic preferences, calibrated to match micro-level consumption responses, and using it to evaluate the fiscal cost and effectiveness of alternative policy interventions—cash transfers versus energy subsidies—a comparison not previously quantified in the structural literature

3 Data and Empirical Background

This section describes the household expenditure data and presents descriptive evidence. Households in the lowest income decile allocate more than double the budget share to energy compared to households in the highest decile. We construct decile-specific inflation rates and show that the gap between low- and high-income inflation rates correlates strongly with energy inflation. These patterns indicate that energy price shocks generate differential inflation exposure across the income distribution, motivating our analysis of consumption responses and inequality dynamics to energy shocks.

3.1 Consumption Expenditure Survey and Other Data

To study heterogeneous consumption behaviour across households, this paper uses micro-data from the “Interview Survey” component of the quarterly U.S. Consumption Expenditure Survey (CES).⁶ The Interview Survey is designed to capture regular and recurring expenditures and follows households for up to four consecutive quarters, allowing for a rich characterization of consumption patterns over time.

The CES is widely used in empirical macroeconomics and public finance (see Aguiar and Bils, 2015; Argente and Lee, 2021; Cravino et al., 2020; Garner et al., 1999; Hobijn and Lagakos, 2005; Hobijn et al., 2009; Jaravel, 2019) and constitutes the primary data source underlying the construction of expenditure weights in the U.S. Consumer Price Index (CPI). Its detailed structure provides information on household income, demographic characteristics, and disaggregated expenditures across more than 1000 consumption categories, including a fine breakdown of food and energy items. This level of granularity is par-

⁶This study focuses on the U.S. due to the public availability of granular household-level data, which enables a more detailed analysis. Extending the framework to Europe is a natural next step for future research, especially given that the 2021/22 inflation surge there was more strongly driven by energy supply shocks than in the U.S.

ticularly well suited to studying the distributional consequences of sector-specific price shocks.

Relative to alternative household surveys, the CES offers two key advantages for the purposes of this paper. First, it provides detailed household-level information on consumption expenditures across a large number of narrowly defined categories, allowing consumption baskets to vary systematically across households. Second, the CES combines a long historical coverage beginning in the mid-1980s with a relatively high frequency, as households are interviewed on a quarterly basis. Together, these features make it possible to exploit the micro-level structure of the CES to trace how supply-driven energy price shocks translate into heterogeneous consumption adjustments across the income distribution, rather than focusing solely on aggregate measures of inequality.

The analysis uses CES Interview Survey data spanning from 1990-Q1 to 2023-Q1, comprising approximately 5,000 to 7,000 household responses per quarter. After applying standard consistency checks (e.g., excluding observations with zero reported expenditures in key categories), the final sample contains roughly 860,000 household-quarter observations, providing both substantial statistical power and a high degree of granularity.

A limitation of the CES is its rotating panel structure, under which households are observed for a maximum of four consecutive quarters and new households enter the sample each period. To address this feature, the analysis constructs a pseudo-panel by grouping households into income percentiles each quarter and tracking cohort-level means over time, following the approach of Deaton (1985), Moffitt (1993), and Verbeek and Nijman (1992).⁷ This approach allows the evolution of consumption responses across the income distribution to be studied even as individual households enter and exit the sample, and as households move across income percentiles over time. By averaging outcomes within income groups, the pseudo-panel mitigates idiosyncratic measurement error in household-level expenditure data. Despite this aggregation, percentile-level expenditure series remain relatively noisy, so that a four-quarter moving average smoothing is applied to the expenditure series.⁸

Additional data used in the analysis include headline, core, food, and energy inflation rates from the Personal Consumption Expenditures (PCE) Price Index, obtained from the Bureau of Economic Analysis. Section 4 further employs the Känzig (2021) shock to isolate

⁷Due to inconsistencies in coding conventions during the early years of the survey, the cohort-based pseudo-panel construction from repeated cross-sections is applied from 1990Q1 onward. The income variable used is defined as “income received from salary or wages before deduction” (coded: `fsalaryx`; U.S. Bureau of Labor Statistics, 2018). Results are robust to alternative measures.

⁸Household survey expenditure data are known to be noisy as they are inherently subject to both sampling and non-sampling errors (e.g., misreporting, recall bias, and interviewer effects), which can introduce substantial volatility into micro consumption series (see Kalton, 1983; Salant and Dillman, 1995)

exogenous, supply-driven variation in energy inflation. The empirical specifications also control for real interest rates, the unemployment gap, and real output growth. Summary statistics for selected variables are reported in Table A.1.

3.2 Descriptive Evidence

Household income plays a decisive role in shaping consumption patterns. Consistent with previous studies (including seminal work by Hagemann (1982) and Michael (1979)), CES data show that households' consumption baskets differ systematically across income. Figure 1 illustrates energy expenditure shares and shows that lower-income households allocate a substantially larger fraction of their budget to energy than higher-income households. Specifically, households in the lowest decile spend more than 12 percent of total expenditure on energy, compared with only about 5 percent among the highest decile. Even when considering potential sampling noise and measurement error around the tails of the distribution, the graph reveals a clear, nearly linear, negative link between income and the energy-expenditure share.⁹ This relationship remains largely stable over time, with only minor fluctuations (see Figure A.1).¹⁰

Because of the heterogeneity in energy expenditure shares, relative price shocks in energy, such as those observed in the 2021/22 inflation episode, yield significant variation in inflation exposure across income groups. To measure the variation, this study calculates distinct inflation rates for income deciles, $i = \{1, 2, \dots, 10\}$, as:

$$\pi_{it} = \sum_{k=1}^K \omega_{kit} \pi_{kt} \quad (1)$$

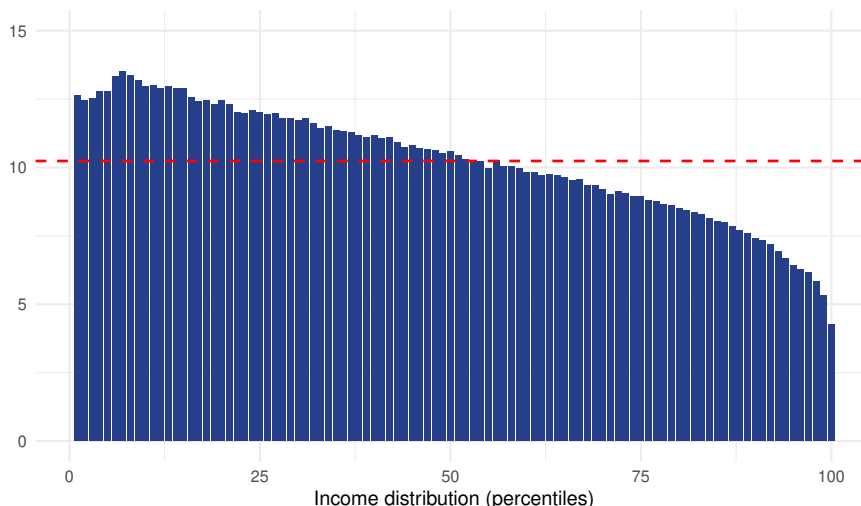
where

$$\omega_{kit} = \frac{E_{kit}}{\sum_{k=1}^K E_{kit}} \geq 0$$

⁹The study also explored whether other household characteristics (including age, gender, region, urbanization, and housing tenure) create such distinct differences in expenditure shares. These factors were found to have relatively minor impacts, highlighting income as the primary dimension driving heterogeneous consumption responses to energy price shocks.

¹⁰Figure A.1 plots the time series of energy expenditure shares by income decile. The series exhibit low within-decile volatility and move closely together over time. Periods of sharp increases in energy prices (e.g., 2007, 2011, and 2021) are associated with temporary increases in energy expenditure shares across all deciles, consistent with energy being a necessity good with relatively inelastic demand.

Figure 1: Energy expenditure shares across the income distribution



Note: Red-dotted line shows the full-sample mean expenditure share across the income distribution (10.23 percent). Bars report average expenditure shares by income percentile. Data sources: CES/ BLS.

is the decile-specific i and time-varying t expenditure weight for good k , π_{kt} denotes the Personal Consumption Expenditures (PCE) inflation for good k , and E_{kit} is the decile's average spending on good k .¹¹ For tractability, $k = \{\text{energy, food, core}\}$.¹²

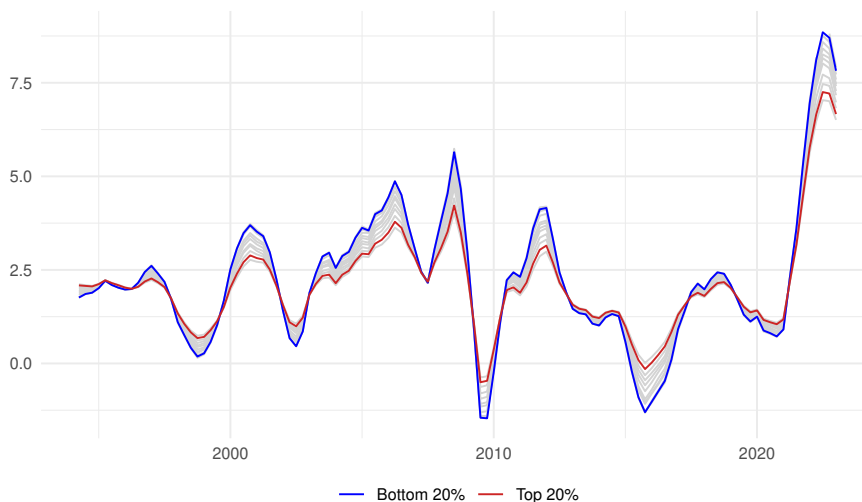
Figure 2 plots the resulting inflation rates for different deciles of the income distribution, where two patterns stand out. First, decile-specific inflation rates comove closely. Second, the extent to which decile-specific inflation rates rise or fall differs across the income distribution, so that, at times, notable gaps emerge between low- and high-income households' inflation rates. Specifically, inflation for poorer households is more volatile, with sharper declines in disinflationary periods and steeper increases during inflationary episodes. During the inflation surge in 2021/22, this has translated into a sizable gap with inflation for the top income quintile peaking at about 7 percent, while being roughly 1.5 percentage points higher for the bottom quintile. Because π_{kt} is assumed common across income groups in this calculation, all cross-decile variation in π_{it} is mechanically driven by differences in expenditure weights ω_{kit} across i . This highlights that heterogeneous ex-

¹¹It is important to note that the decile-specific inflation measure, π_{it} , does not capture within-category substitution. Given data limitations, the construction assumes a common category-level inflation rate π_{kt} across income deciles, whereas in reality inflation is likely to be decile-specific within categories (i.e., π_{ikt}). The inability to account for households' substitution within product categories implies that the true inflation gap across income groups is likely understated. High-income households can substitute toward cheaper varieties when prices rise, whereas low-income households (who are more likely to already consume the lowest-priced options) have more limited scope for such substitution, resulting in higher effective inflation rates.

¹²“Core” denotes goods and services excluding food and energy, following the standard definition in the literature. Accordingly, the expenditure shares satisfy $\sum_{k=1}^K \omega_{kit} = 1 \forall i, t$.

posure (rather than differential price changes) is the key source of dispersion in measured inflation rates.

Figure 2: Inflation rates across low- and high income households



Note: Gray lines show inflation rates across income deciles, while the red and blue lines highlight the top and bottom income quintiles for visualization purposes. Data sources: CES/BLS, BEA.

Let $\bar{i} \equiv 11 - i$ denote the income decile symmetric to i . Then, the *inflation gap* is defined as

$$\pi_{i,t}^{\text{gap}} \equiv \pi_{i,t} - \pi_{\bar{i},t}, \quad i = 1, \dots, 5$$

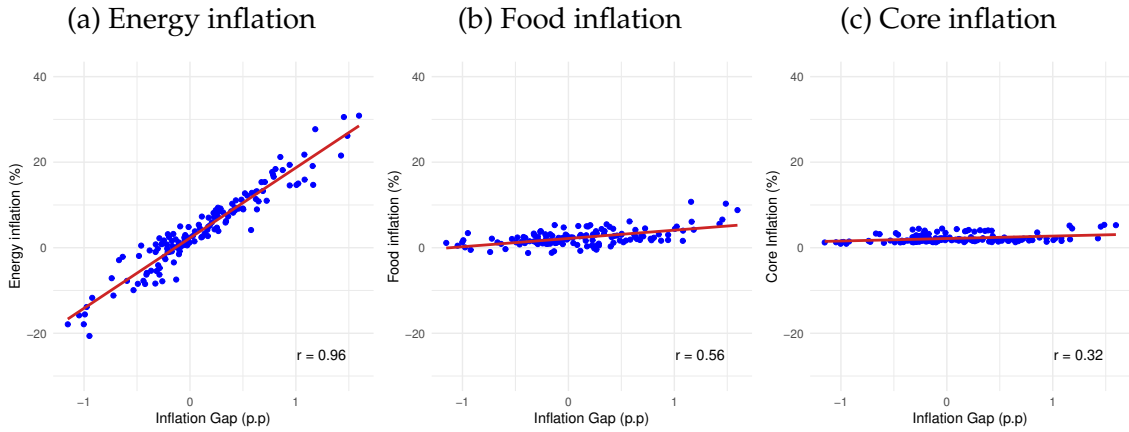
where $\pi_{i,t}^{\text{gap}} > 0$ indicates that the bottom-income decile faces higher inflation than the corresponding top decile.¹³ These fluctuations are key for understanding heterogeneous consumption responses. To explore the sources of the gap, unconditional correlations between inflation components and the inflation gap are shown in Figure 3. Energy inflation exhibits the strongest correlation, followed by food inflation, whereas the correlation with core inflation is relatively weak. Despite accounting for only 10.23 percent of total household expenditure on average (see Figure 1), energy price movements generate a disproportionate share of cross-decile inflation heterogeneity due to their high volatility.¹⁴ This underscores the importance of focusing on energy price shocks when analysing consumption inequality.¹⁵

¹³Figure A.2 illustrates the inflation gap, showing that while the average gap over the full sample is small, it exhibits notable fluctuations.

¹⁴See Table A.1 for summary statistics and standard deviations.

¹⁵The paper also examines the correlation between inflation heterogeneity and consumption inequality (as the ratio of real consumption expenditure between the top and bottom income deciles where nominal expenditures have been deflated with decile-specific inflation rates) which points to an asymmetric relationship (Figure A.3). Specifically, when the inflation gap is positive, the consumption inequality rises sharply. Instead, when the inflation gap is negative, the corresponding reduction in consumption inequality is modest. This asymmetry suggests that inflation heterogeneity may contribute to a structural increase in consumption inequality over time, and offers interesting extensions for future research.

Figure 3: Correlations between the inflation gap and PCE components



Note: Full sample period. Inflation gap refers to top/bottom 20 percent of income earners. Pearson correlation included. Data sources: CES/BLS, BEA.

Taken together, household consumption patterns differ sharply across the income distribution, with lower-income households allocating a larger share of their budget to energy and consequently facing higher and more volatile effective inflation, particularly during episodes such as the 2021/22 surge. These differences, driven primarily by energy price movements, create substantial heterogeneity in inflation exposure. This motivates the subsequent analysis: first, an empirical investigation using decile-level local projections to quantify the dynamic response of consumption and inequality to exogenous energy price shocks, and second, a structural two-agent New Keynesian model to explore fiscal policy alternatives. Together, these approaches allow the paper to connect observed expenditure heterogeneity to causal consumption responses and policy-relevant outcomes.

4 Empirical Analysis

This section documents the causal relationship between supply-driven energy price shocks and consumption patterns across the income distribution. Low-income households experience a sharper decline in both energy and non-energy consumption after an energy shock than high-income households, implying that consumption inequality increases.

4.1 Econometric Framework

To examine how supply-driven energy price shocks influence consumption patterns and inequality, this paper estimates local projections with instrumental variables (LP-IV) using

a two-stage procedure. Originally introduced by Jordà et al. (2015), this approach has become widely used in empirical macroeconomics (see, e.g., Afrouzi et al., 2024; Drossidis et al., 2024; Stock and Watson, 2018). Identification relies on isolating exogenous movements in energy prices that are orthogonal to contemporaneous macroeconomic conditions and household demand. By instrumenting energy inflation with oil supply “news shocks,” the LP-IV framework disentangles the effects of supply-driven energy price changes from broader macroeconomic fluctuations.

First Stage: Instrumenting Energy Inflation

In the first stage, contemporaneous PCE energy inflation is instrumented using exogenous oil supply news shocks constructed from high-frequency movements in oil futures prices around OPEC production announcements, following Känzig (2021). These shocks capture unexpected revisions to global oil supply expectations within a narrow announcement window and have been shown to generate plausibly exogenous variation in energy prices that is orthogonal to domestic demand conditions and macroeconomic developments.¹⁶

Formally, the first-stage regression is given by:

$$\pi_t^E = \delta + \theta Z_t + \sum_{k=1}^K \kappa_k' W_{t-k} + u_t \quad (2)$$

where π_t^E denotes PCE energy inflation, Z_t is the exogenous Känzig (2021) shock, and W_t is a vector of aggregate macroeconomic controls, including the unemployment gap and the real interest rate.

Second Stage: Estimating Decile-Specific Consumption Responses

In the second stage, local projections are estimated to trace the dynamic responses of household consumption across income deciles and expenditure categories to exogenous energy price shocks. For each horizon h and income group d , the second-stage regression takes the form:

$$\widetilde{c}_{t+h}^d = \alpha^d + \beta_h^d \widehat{\pi}_t^E + \sum_{j=1}^J \gamma_{h,j}^d X_{t-j}^d + \sum_{k=1}^K \phi_{h,k}^d W_{t-k} + \epsilon_{t+h}^d \quad (3)$$

where \widetilde{c}_{t+h}^d is the h -period-ahead log-detrended real consumption of households in income decile d . The regressor $\widehat{\pi}_t^E$ denotes the fitted value of energy inflation obtained from the first stage. The vector X_t^d contains decile-specific controls, including lagged consumption \widetilde{c}_t^d , decile-specific inflation π_t^d (defined in Equation (1)), and real income growth y_t^d . Aggregate macroeconomic controls W_t are included as in Equation (2).

¹⁶Recent applications include Afrouzi et al. (2024), Drossidis et al. (2024), Gomes et al. (2025), Sardar and Qureshi (2024), and Zhu et al. (2025).

Decile-specific inflation and income are excluded from the first stage, as they are not expected to directly respond to global oil supply news beyond their impact through domestic energy prices. Equation (3) is estimated both at the aggregate household level and separately by income decile and expenditure category, allowing for heterogeneous dynamic responses to energy price shocks.

In the baseline specification, $J = K = 3$, and impulse responses are estimated for horizons $h = 1, \dots, 8$ quarters over the sample period 1990-Q1 to 2023-Q1. Standard errors are computed using heteroskedasticity- and autocorrelation-consistent estimators with horizon-specific bandwidths to account for serial correlation induced by overlapping observations.¹⁷

4.2 Empirical Results

This section presents the empirical results on how supply-driven energy price shocks affect household consumption. We find two key results: first, low-income households reduce consumption substantially more than high-income households following energy price shocks. Second, while energy consumption differs sharply across income groups, most of the aggregate adjustment occurs through non-energy spending. These results provide the foundation for later structural exercises, where we evaluate counterfactual policy interventions in a model framework.

Figure 4a reports that total consumption aggregated across all households declines by approximately 0.3 percentage points on impact following a shock to PCE energy inflation. The effect is persistent, remaining significant at the 90 percent confidence level for roughly five quarters. It is worth noting that the magnitude of the aggregate response appears larger than some estimates reported in the literature (e.g., Känzig (2021)). This discrepancy reflects a known limitation of the CES, namely its under-representation of the upper tail of the income distribution (Bee et al., 2015; Sabelhaus et al., 2015).

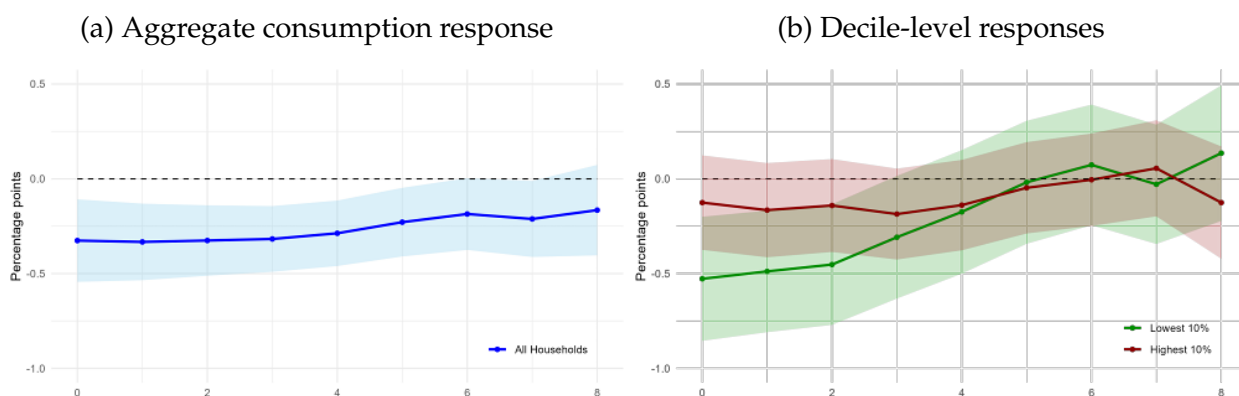
Figure 4b shows that there is substantial heterogeneity in consumption responses across income groups. Households in the bottom decile experience a sharp and persistent contraction of about 0.5 percentage points on impact. By contrast, consumption in the top decile remains close to zero at all horizons and is not statistically distinguishable from no response. In Appendix A we show results of robustness checks with alternative lag

¹⁷The first-stage regression is estimated separately for each horizon h . Across all horizons, the F-statistics on the excluded instrument exceed the Staiger-Stock threshold of 10, indicating that the instrument is sufficiently strong.

structures, additional control variables, and different sample periods. The main findings remain qualitatively unchanged (see Figure A.6).

This pronounced asymmetry indicates that the adjustment to higher energy prices is borne disproportionately by low-income households. Two features are likely to underpin this pattern. First, energy expenditures account for a substantially larger share of total consumption at the bottom of the income distribution, mechanically amplifying the impact of energy price shocks on real purchasing power. Second, lower-income households face tighter liquidity constraints and therefore exhibit limited scope for intertemporal smoothing, translating relative price increases into immediate consumption reductions. In contrast, the muted response among high-income households is consistent with a lower marginal propensity to consume out of transitory income shocks and a smaller exposure to energy costs in their overall expenditure basket. In the next section, we develop a structural model with both features to explain the dynamics after an energy shock.

Figure 4: Total consumption response to shock in energy inflation

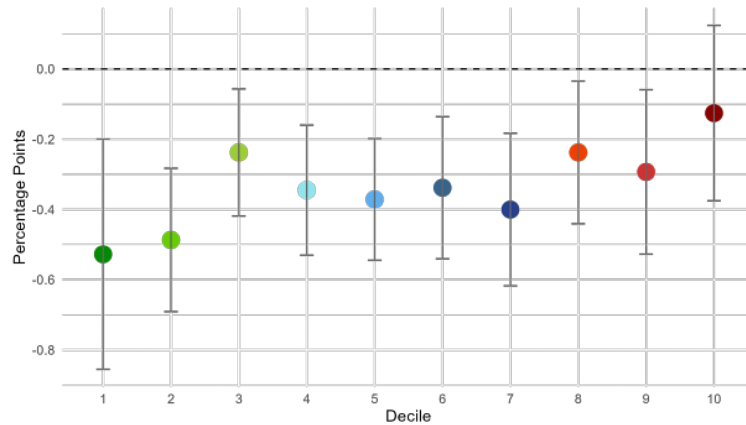


Note: Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, FRED, Känzig (2021).

We further analyse heterogeneity beyond the extremes of the income distribution. Figure 5 summarises the contemporaneous (impact-period) consumption responses to an energy price shock across all income deciles. Figure A.4 in the Appendix reports full dynamic responses. The estimates reveal a clear and approximately monotonic gradient in consumption responses as the contraction is largest among the lowest-income households and steadily attenuates moving up the income distribution. This pattern corroborates that the burden of energy price shocks is not evenly distributed but decreases systematically with household income.

Finally, we decompose the total consumption response into energy and non-energy components in Figure 6 to shed light on the underlying adjustment margins. Non-energy con-

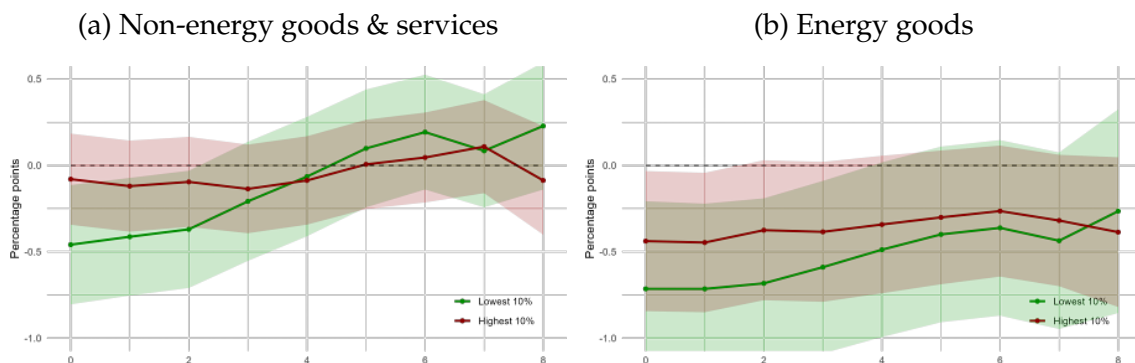
Figure 5: Contemporaneous impact of total consumption



Note: Responses show percentage point deviations from the log-linear trend at $h = 0$. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, FRED, Känzig (2021).

sumption closely tracks the dynamics of total consumption, reflecting its dominant share in household expenditure. Among low-income households, non-energy spending contracts sharply, though less persistently than total consumption, following an energy price shock, whereas the response of high-income households remains small and statistically insignificant. Energy consumption also exhibits pronounced heterogeneity. Low-income households reduce energy expenditures sharply, by roughly 0.75 percentage points on impact, with effects persisting for about one year. High-income households also exhibit a decline, but the response is smaller and short-lived, indicating a greater ability to absorb higher energy prices without substantially adjusting quantities consumed.

Figure 6: Impulse responses across consumption components



Note: Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021), FRED.

Taken together, the results highlight systematic differences in households' responses to supply-driven energy price shocks, implying an increase in consumption inequality. Two factors account for the observed gradient in the consumption responses. First, lower-income households spend a larger share of their budgets on energy and related necessities, so identical price increases reduce their real purchasing power more sharply. Second, liquidity constraints and limited access to smoothing instruments limit low-income households' ability to offset temporary shocks, whereas higher-income households face lower exposure and adjust less. As a result, energy price shocks compress consumption more among households with fewer resources, contributing to short-run increases in consumption inequality. The decomposition across categories shows that most of the aggregate consumption adjustment occurs through non-energy spending, while energy consumption is also an important source of heterogeneity across income groups. These patterns underscore the role of differential exposure and limited smoothing capacity among low-income households, and motivate the structural model in Section 5, which is used to explore the transmission channels and evaluate counterfactual policy interventions.

5 TANK model

The empirical results on the differential impact of shocks to energy inflation on consumption across income groups motivate a model to understand the underlying mechanisms and conduct counterfactual policy analysis. To this end, the paper introduces a two-agent New Keynesian (TANK) model featuring two sectors and non-homothetic preferences.

The model considers a closed economy inhabited by two types of households, two firm sectors, a monetary authority, and a fiscal authority. Households consume goods and supply labour, and are either constrained or unconstrained on the financial market. Both households consume two types of goods, energy goods and other goods, and they have non-homothetic preferences such that energy is a necessity good. The two firm sectors correspond to the two consumption goods. There is monopolistic competition in both sectors. Both sectors use labour as a production input, and the other goods sector also uses energy as a production input. The monetary authority sets interest rates and the fiscal authority is responsible for the distribution of taxed profits from firms and for the issuing of one-period risk-free bonds. Appendix B provides a detailed overview of the model and characterises the steady state (Appendix B.4).

5.1 Households

To account for heterogeneity between income groups, households are denoted by superscripts $k \in \{c, u\}$, representing constrained and unconstrained types.¹⁸ Constrained households, comprising a share $\lambda \in (0, 1)$ of the population, face borrowing constraints and are fully excluded from financial markets. Their consumption choices are therefore more sensitive to income fluctuations and price changes. Unconstrained households, representing a share $1 - \lambda$, have full access to financial markets and can smooth consumption over time, making their consumption decisions less influenced by short-term price movements and income variations. As such, we approximate the behaviour of low-income households in the data by constrained households in the model, and analogously, that of high-income households with unconstrained agents in the model.

5.1.1 Preferences

The preferences are identical for the two types of households: they derive utility from both energy goods, c_{Et}^k , and other goods, c_{Ot}^k . Since the preferences are non-homothetic, the allocation of expenditure between these two goods depends on the total nominal spending of the household:

$$S_t^k = P_{Et}c_{Et}^k + P_{Ot}c_{Ot}^k \quad (4)$$

where P_{Et} and P_{Ot} are the prices of energy and other goods, respectively. The indirect utility function¹⁹ introduced by Boppart (2014) is employed for the preferences:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{\varepsilon_1} \left[\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1} - 1 \right] - \frac{\gamma}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} - 1 \right] \right\} \quad (5)$$

where β is the discount factor and $\gamma > 0$ gives the share of energy consumption in steady state. ε_1 determines the expenditure elasticity of demand while ε_2 governs the elasticity of substitution between energy and other goods, as shown in equations (6) and (7).²⁰

¹⁸Introducing a TANK model with constrained and unconstrained households is a simplification of the continuous income distribution given by the data. Debortoli and Galí (2017) show that the simpler structure of TANK models with constrained and unconstrained households can still replicate the essential dynamics of heterogeneous agent New Keynesian (HANK) models. Given the tractability of TANK over HANK models, the full income distribution is not modelled.

¹⁹An indirect utility function $v(p, S)$ represents the highest level of utility a household can achieve given a specific price vector p for goods and a set expenditure amount S . Typically, there is no corresponding direct utility function that can be used to derive this same indirect utility in all cases.

²⁰When $\varepsilon_1 > 0$, energy demand is less responsive to changes in income (with an elasticity below one), while the demand for other goods is more responsive (with an elasticity above one). This implies that as total nominal expenditure, or income for consumption, falls, demand for energy declines less than proportionally to income, whereas demand for other goods falls more than proportionally.

Using Roy's Identity, the relative demand between the two types of goods is obtained:

$$c_{Ot}^k = \frac{(1 - \gamma \varpi_t^k) P_{Et}}{\gamma \varpi_t^k} \frac{c_{Et}^k}{P_{Ot}} \quad (6)$$

where

$$\varpi_t^k = \left(\frac{P_{Ot}}{S_t^k} \right)^{\varepsilon_1} \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} \quad (7)$$

is the energy expenditure share wedge, which reflects the non-homotheticity of the preferences. The share households spend on energy goods increases when the relative price of energy increases, controlled by ε_2 , but decreases when the relative total expenditure increases (i.e., when the households have more income to spend), controlled by ε_1 . This reflects stylised facts previously discussed. With $\varepsilon_1 = \varepsilon_2 = 0$, the standard Cobb-Douglas case is recovered, with relative demand $c_{Ot}^k = \frac{1-\gamma}{\gamma} \frac{P_{Et}}{P_{Ot}} c_{Et}^k$. In this scenario, both types of goods have an expenditure elasticity equal to one.

5.1.2 Intertemporal Choice

The constrained households have a simple budget constraint, since they do not have access to the financial market:

$$S_t^c = P_{Et} c_{Et}^c + P_{Ot} c_{Ot}^c = W_t n_t^c + P_t \tau_t^c + P_t T_t^c \quad (8)$$

where W_t is nominal wages and n_t^c labour effort. τ_t^c and T_t^c are fiscal transfers explained later. P_t is the aggregate price index given by $P_t = (P_{Et})^\gamma (P_{Ot})^{1-\gamma}$.

Unconstrained households have access to one-period, risk-free bonds B_t with interest rate R_t . Hence, their budget constraint is the following:

$$S_t^u = P_{Et} c_{Et}^u + P_{Ot} c_{Ot}^u = W_t n_t^u + \frac{1-\delta}{1-\lambda} P_t D_t + R_{t-1} B_{t-1} - B_t + P_t \tau_t^u + P_t T_t^u \quad (9)$$

where n_t^u is the labour effort. D_t is the firms' profits and δ their tax rate. So, unconstrained households enjoy the untaxed part of the firms' profits as an extra income, which creates a permanent income difference between constrained and unconstrained households, in line with their interpretation as high- and low-income households. τ_t^u and T_t^u are fiscal transfers.

Taking the first-order conditions, we obtain the Euler equation:

$$\mathbb{E}_t \left(\frac{S_{t+1}^{u,rel}}{S_t^{u,rel}} \right)^{1-\varepsilon_1} = \beta R_t \mathbb{E}_t \left(\frac{1}{\Pi_{O,t+1}} \right)^{1-\varepsilon_1} \quad (10)$$

where $S_t^{rel} = S_t/P_{Ot}$ is the total nominal expenditure relative to the price of other goods and $\Pi_{Ot} = P_{Ot}/P_{O,t-1}$ is gross inflation of other goods. Labour supply is inelastic under these preferences with $n_t^c = \bar{n}^c$ and $n_t^u = \bar{n}^u$, but workers can move between sectors.

5.2 Firms

The economy features two sectors of firms, indexed by $j \in \{E, O\}$, producing energy and other goods, respectively.²¹ A continuum of intermediate firms $i \in [0, 1]$ populate both sectors, competing under monopolistic competition. A final goods producer in each sector bundles the different varieties of goods in that sector produced by the intermediate firms and sells the bundled final good to the households. The two sectors are identical, except for the degree of price rigidity as discussed in Section 5.7.

5.2.1 Final Goods Producers

The final good firm in each sector produces the final consumption good, energy or other, Y_{jt} , using intermediate goods from that sector, $Y_{jt}(i)$, according to:

$$Y_{jt} = \left[\int_0^1 Y_{jt}(i)^{(1-\epsilon)/\epsilon} di \right]^{\epsilon/(1-\epsilon)} \quad (11)$$

where $Y_{jt}(i)$ is the output of the intermediate firm i and ϵ the elasticity of substitution between different varieties of the intermediate good. The firms produce in a competitive market and maximise profits given by $P_{jt}Y_{jt} - \int_0^1 P_{jt}(i)Y_{jt}(i)di$. The first-order condition to the maximization problem gives the demand function of the intermediate good i :

$$Y_{jt}(i) = \left(\frac{P_{jt}(i)}{P_{jt}} \right)^{-\epsilon} Y_{jt} \quad (12)$$

and the price of the final good Y_{jt} :

$$P_{jt} = \left[\int_0^1 P_{jt}(i)^{-(1-\epsilon)} \right]^{1-\epsilon} \quad (13)$$

where $P_{jt}(i)$ is the price of the intermediate good i .

²¹Energy is modelled as domestically produced rather than imported, since the share of net energy imports has represented less than 15 percent of total energy use since 2013 and has been negative since 2019 (World Bank Group Data, 2025).

5.2.2 Intermediate Goods Producers

Energy Producers The intermediate firms i in the energy sector $j = E$ compete under monopolistic competition, using labour N_{Et} as input for production. The total factor productivity, A_{Et} , follows an AR(1) shock process $A_{Et} = \rho_{\alpha_E} A_{E,t-1} + \epsilon_{Et}$ with $\epsilon_{Et} \sim \text{i.i.d. } \mathcal{N}(0, \sigma_E^2)$. The firms face adjustment costs à la Rotemberg (1982).²² The profit maximization problem of the representative firm in sector j is:

$$\max_{P_{Et}(i), N_{Et}(i)} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta \left[\frac{P_{Et}(i)}{P_{Et}} Y_{Et}(i) - \frac{W_t}{P_{Et}} N_{Et}(i) - Y_{Et} FC_{Et} \right] \quad (14)$$

$$\text{s.t. production function} \quad Y_{Et}(i) = A_{Et} N_{Et}(i) \quad (15)$$

$$\text{demand curve} \quad Y_{Et}(i) = \left(\frac{P_{Et}(i)}{P_{Et}} \right)^{-\epsilon} Y_{Et} \quad (16)$$

$$\text{price adjustment costs} \quad FC_{Et}(i) = \frac{\xi_E}{2} \left(\frac{P_{Et}(i)}{P_{E,t-1}(i)} - 1 \right)^2 \quad (17)$$

where $N_{Et}(i) = \lambda n_{Et}^c(i) + (1 - \lambda) n_{Et}^u(i)$ is aggregate labour demand per firm. The first-order condition with respect to $P_{Et}(i)$ yields the standard New Keynesian Philips Curve. Given that all intermediate goods are identical, we have $P_{Et}(i) = P_{Et}$ and $N_{Et}(i) = N_{Et}$. Aggregate firm profits are therefore expressed as $D_{Et} = Y_{Et} (1 - FC_{Et}) - \frac{W_t}{P_{Et}} N_{Et}$.

Other Goods Producers The intermediate goods i in the other goods sector $j = O$ compete and produce analogously to firms in the energy sector, but use energy as a production input. Hence, the production function is a Constant Elasticity of Substitution (CES) aggregator:

$$Y_{Ot}(i) = A_{Ot} \left[(\gamma^f)^{1/\theta^f} \left(E_t^f(i) \right)^{(\theta^f-1)/\theta^f} + (1 - \gamma^f)^{1/\theta^f} \left(N_{Ot}(i) \right)^{(\theta^f-1)/\theta^f} \right]^{\theta^f/(\theta^f-1)} \quad (18)$$

where γ^f is the fraction of energy used in the firms' production and θ^f is the elasticity of substitution between energy and labour. $E_t^f(i)$ is the energy used in the production of other goods. The aggregate profits of the firms producing other goods are:

$$D_{Ot} = Y_{Ot} (1 - FC_{Ot}) - \frac{W_t}{P_{Ot}} N_{Ot} - \frac{P_{Et}}{P_{Ot}} E_t^f \quad (19)$$

²²Note that Calvo (1983) and Rotemberg (1982) pricing setups are equivalent up to first order approximation.

5.3 Monetary Policy

The central bank implements a standard Taylor rule, setting the nominal interest rate R_t in response to deviations of overall inflation and output deviations from steady state, in line with the Federal Reserve's dual mandate:

$$R_t = \frac{1}{\beta} \left(\frac{\Pi_t}{\bar{\Pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^n} \right)^{\phi_y} \exp(\nu_t) \quad (20)$$

where Π_t is aggregate gross inflation, given by:

$$\Pi_t = (\Pi_{Et})^\gamma (\Pi_{Ot})^{1-\gamma} \quad (21)$$

and Y_t is aggregate output, given by:

$$Y_t = Y_{Et} + Y_{Ot} \quad (22)$$

ϕ_π and ϕ_y are the Taylor coefficients of inflation and output. ν_t is a monetary policy shock that follows an AR(1) process.

5.4 Fiscal Policy

The fiscal authority conducts two types of fiscal policy. First, they redistribute taxed firms' profits δD_t as in Debortoli and Galí (2017) by allocating the total taxed profits between constrained and unconstrained households according to:

$$\tau_t^c = (1 - \tau_0) \delta D_t \quad (23)$$

$$\tau_t^u = \left(1 + \frac{\tau_0 \lambda}{1 - \lambda} \right) \delta D_t \quad (24)$$

such that $\lambda \tau_t^c + (1 - \lambda) \tau_t^u = \delta D_t$. The parameter τ_0 determines the fraction of the taxed profits that is redistributed to the constrained households.

We consider two fiscal policy alternatives in our analysis. First, targeted transfers are lump-sum transfers to constrained households. The fiscal authority collects lump-sum taxes from unconstrained households to issue those targeted transfers:

$$(1 - \lambda) T_t^u = -\lambda T_t^c \quad (25)$$

Second, we introduce energy subsidies for constrained households. Subsidies lower the retail price of energy for constrained households only, such that they face $P_{Et}^{retail} < P_{Et}$.

Again, lump-sum taxes from unconstrained households finance the costs:

$$(1 - \lambda)T_t^u = \lambda c_{Et}^c (P_{Et} - P_{Et}^{retail}) \quad (26)$$

In Section 6 we analyse the implications of the different fiscal policy measures.

5.5 Equilibrium and Market Clearing

The equilibrium in this economy is characterised by a sequence of prices $\{W_t, P_{Et}, P_{Ot}\}$ and allocations $\{c_{Et}^c, c_{Et}^u, c_{Ot}^c, c_{Ot}^u, n_t^c, n_t^u\}$ such that the goods market is cleared for both energy and other goods and the labour market is cleared. The full list of equilibrium conditions are in Appendix B.3.

Goods market clearing conditions specify that the output of energy good, Y_{Et} , equals the total consumption demand from constrained and unconstrained households, weighted by their population shares, and from the demand from firms that use energy as an intermediate good. The output of other goods, Y_{Ot} , must meet the aggregate demand from both household types and account for adjustment costs associated with price changes in the production of other goods:

$$Y_{Et} = \lambda c_{Et}^c + (1 - \lambda)c_{Et}^u + E_t^f + Y_{Et} \frac{\xi_E}{2} (\Pi_{Et} - 1)^2 \quad (27)$$

$$Y_{Ot} = \lambda c_{Ot}^c + (1 - \lambda)c_{Ot}^u + Y_{Ot} \frac{\xi_O}{2} (\Pi_{Ot} - 1)^2 \quad (28)$$

Moreover, the labour market clears when total labour demand, N_t , equals the sum of labour demands in the energy sector (N_{Et}) and the other goods sector (N_{Ot}). Additionally, total labour supply is split between constrained and unconstrained households, with the weighted sum equal to total labour.

$$N_t = N_{Et} + N_{Ot} \quad (29)$$

$$N_t = \lambda n_t^c + (1 - \lambda)n_t^u \quad (30)$$

5.6 Inequality

In measuring consumption inequality, the model follows Debortoli and Galí (2017) and introduces ω_t , which represents the relative consumption gap between constrained and unconstrained households:

$$\omega_t = 1 - \frac{c_t^c}{c_t^u} \quad (31)$$

5.7 Calibration and Impulse Response Matching

We calibrate the model with standard values from the literature or with data counterparts, and we perform impulse response matching for a subset of the parameters. We check the robustness of the model results to changing critical parameters in Section 6. Table 1 summarizes the full set of calibrated parameters.

Table 1: Calibration

<i>Parameter</i>	<i>Description</i>	<i>Value</i>
Households		
λ	Fraction of constrained households	0.2
γ	Energy share in consumption basket	0.1
ε_1	Non-homotheticity parameter	0.05
ε_2	Non-homotheticity parameter	0.05
β	Discount factor	0.99
ϵ	Elasticity of substitution within goods	5
Firms		
θ_p^O	Calvo parameter price stickiness, other goods sector	0.8
θ_p^E	Calvo parameter price stickiness, energy sector	0.8
γ^f	Share of energy in production	0.06
θ^f	Elasticity of substitution between energy and labour	0.2
ρ_{a_E}	Technology shock persistence, energy sector	0.78
Monetary policy		
ϕ_π	Taylor-coefficient on inflation	1.5
ϕ_y	Taylor-coefficient on output	0.125
Fiscal policy		
δ	Tax rate on firms' profits	0.266
τ_0	Share of taxed profits for unconstrained households	1

We set the discount factor β to 0.99 following standard literature. The fraction of constrained households λ is set to 0.2, representing the bottom 20 percent of households in the income distribution. The average energy share in the consumption basket γ is set to 0.10, matching the mean expenditure share observed in the CES data, as shown in Figure 1. The tax rate on firm profits is set to $\delta = 0.266$, based on OECD (2020) data.

The share of energy used in production, γ^f , is calibrated to 0.06 such that the production sector uses about 30 percent of total energy production in steady state (U.S. Energy Information Administration, 2025). The elasticity of substitution between energy and labour, θ^f , is set to 0.2 following Bachmann et al. (2024) and Bayer et al. (2023).

The persistence of the energy-sector technology shock, ρ_{a_E} , is set to 0.78 to match the empirical persistence of the energy shock in the data.

The Taylor-coefficients on inflation ϕ_π and output ϕ_y are 1.5 and 0.125 respectively, following standard literature. The share of profits allocated to unconstrained households τ_0 is 1, so that there is consumption inequality between constrained and unconstrained households in steady state.

The remaining parameters are two parameters governing non-homotheticity, ε_1 and ε_2 , and the Calvo (1983) parameters for the other goods sector θ_p^O and the energy sector θ_p^E . We set these parameters to minimise the distance between the model-generated impulse responses and their empirical counterparts following an energy price shock. We target the empirical consumption responses of the bottom 20th percentile and the rest, for energy, other and total consumption over an 8-quarter horizon. The results from this exercise are: $\varepsilon_1 = \varepsilon_2 = 0.05$ and $\theta_p^O = \theta_p^E = 0.8$.²³ Figure 7 shows that the model successfully replicates the key empirical patterns documented in Section 4.2, including the differential consumption responses across income groups and the persistence of inequality effects.

6 Analysis of Impulse Responses

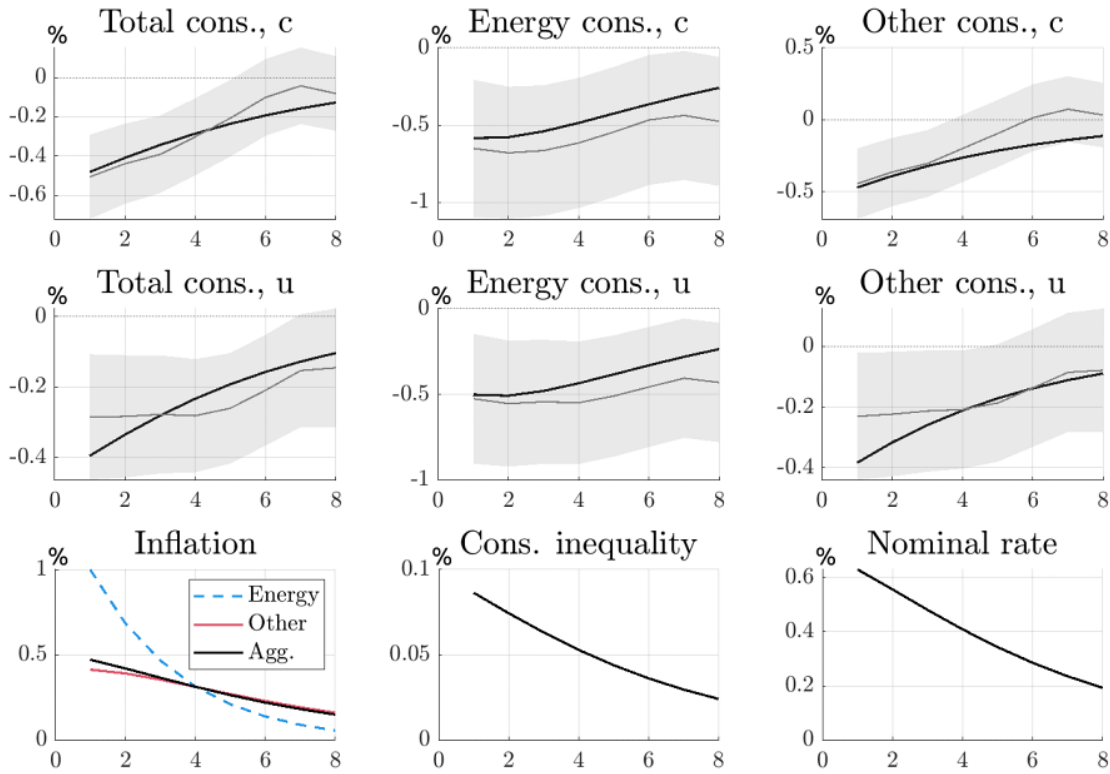
This section analyses the model impulse responses to an energy supply shock. The model replicates the empirical consumption patterns across income groups, which validates the framework for policy counterfactuals. We examine robustness to alternative parameter values. We then evaluate four fiscal policy scenarios: no intervention, targeted cash transfers to constrained households, and two magnitudes of energy subsidies for constrained households.

6.1 Model Dynamics

Figure 7 presents impulse response functions to a negative supply shock in the energy sector, in the absence of fiscal policy measures. The shock is calibrated to generate a one percentage point increase in energy inflation on impact, to compare with the empirical local projections which used a one percentage point deviation from the log-linear trend. Several model parameters are set to minimize the distance between the empirical local projections and the model impulse responses; the model closely replicates the empirical patterns.

²³We do not restrict the two pairs of parameters to be the same.

Figure 7: Impulse responses to a negative energy supply shock



Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The grey lines are empirical local projection results with the shaded areas as the 90 percent confidence intervals based on Newey and West Newey and West (1987) standard errors. The y-axes are percentage point deviations from steady state for the model results and percentage point deviations from the log-linear trend for the empirical results. The x-axes are in quarters. Inflation and the nominal rate are annualized.

The one percentage point rise in energy inflation increases inflation of other goods through pass-through effects. Since energy is one of the production inputs, the price of other goods increases as well, by around 0.4 percentage points. This result is quantitatively in line with the energy pass-through literature. Aggregate inflation, constructed as a weighted average of energy and other inflation, increases by around 0.5 percentage points, which triggers an increase in the nominal interest rate as a price-stabilising effort from the monetary authority.

The increase in inflation rates causes consumption of unconstrained and constrained households to adjust. Despite energy inflation increasing by more than double that of other goods inflation, consumption in other goods declines almost as much as energy consumption. This pattern reflects the role of non-homothetic preferences: as energy is a necessity good with limited scope for substitution, households adjust by cutting back on other goods expenditures too. As a result, the aggregate consumption response is driven mainly by reductions in other goods spending rather than by energy consumption itself.

The consumption responses differ across household types. Constrained households experience a larger decline in total consumption than unconstrained households. This asymmetry reflects two reinforcing mechanisms. First, constrained households devote a larger share of expenditure to energy, so higher energy prices translate into a larger effective loss in real income. Second, limited access to financial markets restricts their ability to smooth consumption intertemporally, forcing a sharper contemporaneous adjustment. Unconstrained households, by contrast, face lower exposure to energy prices and can partially absorb the shock through greater access to financial markets, resulting in a more muted consumption response.

These heterogeneous adjustments generate an increase in consumption inequality following the shock. As constrained households reduce consumption by more than unconstrained households, the dispersion in consumption, which is already present in steady state, widens on impact and remains elevated until the end of the two-year horizon. The inequality response closely tracks the differential consumption dynamics, highlighting that distributional effects of essential goods price shocks arise endogenously from differences in exposure and smoothing capacity.

Overall, the model captures how energy supply shocks generate both aggregate and distributional consequences. While the shock affects all households, its impact is unevenly distributed, with constrained households bearing a disproportionate share of the adjustment. These dynamics provide a disciplined framework for the counterfactual policy experiments considered in the next section, where we investigate alternative fiscal policy measures.

To further validate our model, we perform robustness checks under various settings, in Figures A.9–A.14 in Appendix A. First, we change the setup on the nominal side. In Figure A.9 the central bank looks through energy shocks and only targets inflation of other goods (core inflation targeting) and in Figure A.10 we use a Calvo (1983) parameter of 0.50, a less sticky setting than the baseline, but still in line with literature. Both cases still track the empirical responses quite well, with a notable decline in persistence in the second case. Second, we run the simulations with different degrees of non-homotheticity. In Figure A.11, we turn off the non-homotheticity completely and assume Cobb-Douglas preferences. Energy is not a necessity good any more, so the constrained households suffer less from the energy supply shock. Komatsu (2025) estimates the non-homotheticity parameters in the euro area to be around 0.27, higher than our baseline. In Figure A.12, we apply this setting to our model. Since energy is even more a necessity good, energy consumption decline is dampened whereas the other goods consumption decline is amplified. Last, we check the robustness of our model for different values of the share of constrained

households. In Figure A.13 and A.14, the shares are 0.10 and 0.25 respectively, compared to the baseline of 0.20. The main dynamics do not change with the different shares.

6.2 Fiscal Policy Alternatives

We consider four types of policy alternatives: no explicit fiscal policy in response to the energy supply shock, a targeted cash transfer to constrained households, and two magnitudes of energy subsidies for constrained households. The unconstrained households pay taxes to pay for the transfers and subsidies. We set the transfer amount such that consumption inequality remains at its baseline level after the energy supply shock. For the smaller energy subsidy, we calculate the magnitude that halves the decline in energy consumption of the constrained. The larger energy subsidy sets the energy consumption response of the constrained to zero on impact.

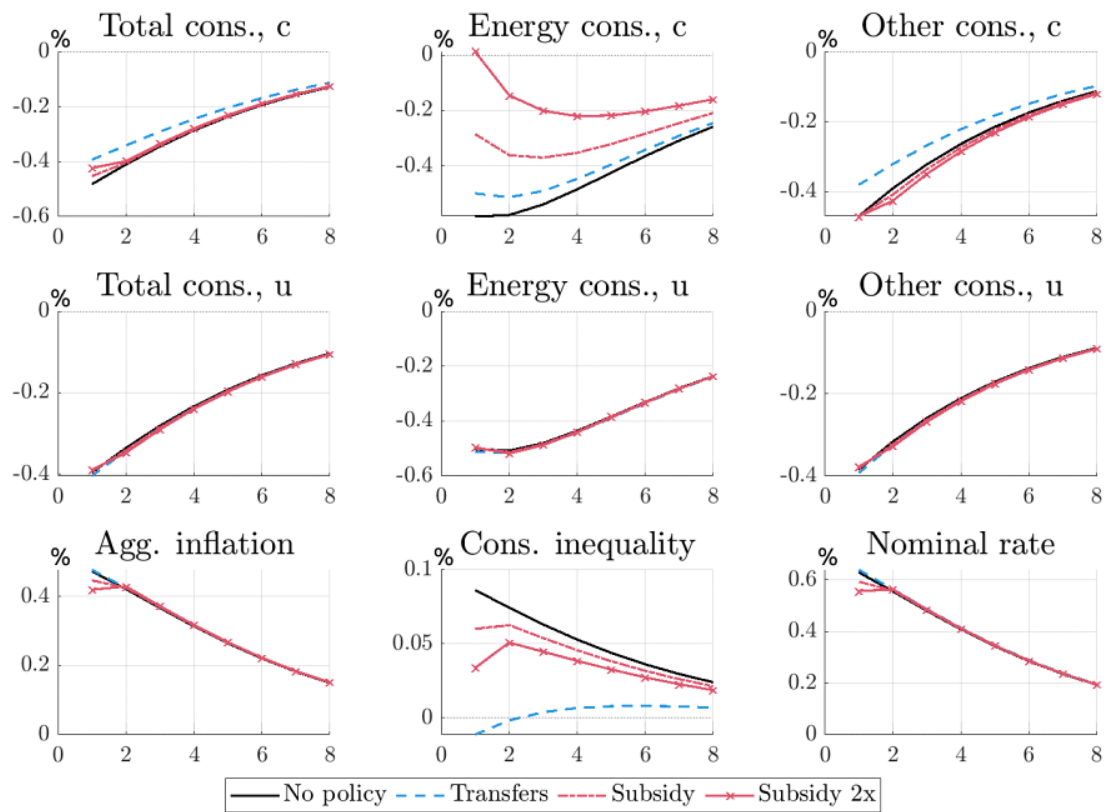
Figure 8 presents the dynamics under each of the four policy alternatives. All alternative scenarios are subject to the same negative energy supply shock as in the baseline scenario in Figure 7. We see that in general, fiscal policy measures targeted to the constrained households barely change the aggregate dynamics of the shock propagation. Because constrained households are 20% of the population, the burden of the fiscal measures is spread out across a larger share of the population, the unconstrained households. Other consumption of unconstrained households, being the biggest share of consumption of the majority group, dictates the fluctuations reflected in the aggregate inflation and the nominal rate.

In the case of the cash transfers, the constrained households see a smaller decline in energy consumption as well as other goods consumption compared to the baseline case of no policy measures. With subsidies specific to energy, energy consumption declines less, but other consumption declines more. Since energy becomes cheaper under the subsidy, and since energy is a necessity good, the constrained households prioritize restoring their energy consumption rather than the consumption of other goods.

In the baseline case without policy measures, consumption inequality increases the most. We design the transfers such that consumption inequality remains broadly unchanged. With energy subsidies, because they do not have a large impact on other goods consumption, the majority of their consumption basket, the dampening of the consumption inequality is much more limited, reducing the inequality increase by approximately half compared to cash transfers.

Figure 9 shows the fiscal cost of each policy alternative, per quarter and cumulative, as a percentage of GDP. The cash transfers and the larger energy subsidy have roughly the

Figure 8: Impulse responses under alternative fiscal policy measures

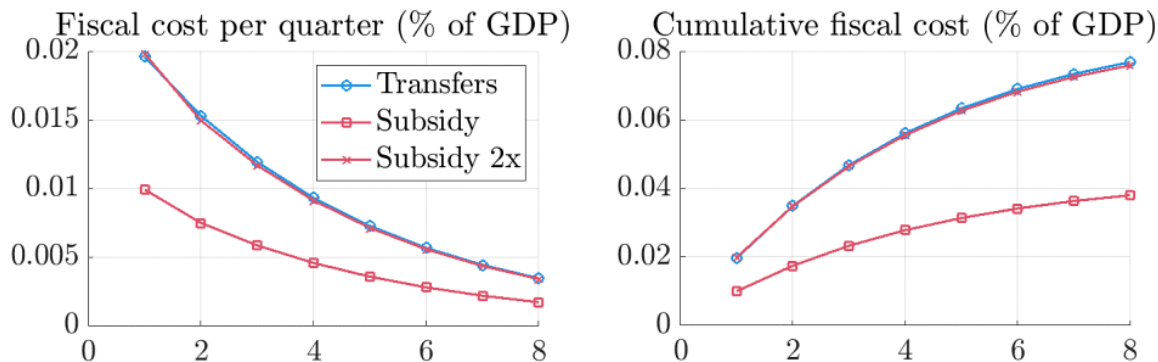


Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The y-axes are percentage point deviations from steady state for the model results. The x-axes are in quarters. Inflation and the nominal rate are annualized.

same fiscal cost: 0.02 percent of GDP on impact, accumulating to 0.08 percent of GDP after two years. Despite similar fiscal costs, the cash transfers are more effective at reducing consumption inequality. Moreover, under a negative energy supply shock, subsidizing energy consumption works against efficient resource allocation. For roughly half of the cost, the government can implement a smaller energy subsidy that reduces the decline in energy consumption of constrained households by half relative to the baseline. However, this measure hardly affects the consumption inequality.

Taken together, transfers to constrained households are an effective fiscal policy measure to reduce the impact of an increase in energy prices on consumption inequality. Since the constrained households are only a fraction of the population, the measure does not affect the aggregate dynamics much compared to the baseline of no responses. Energy subsidies are effective for alleviating the decline in energy consumption of constrained households, but are not as effective in reducing consumption inequality.

Figure 9: Fiscal costs of alternative policy measures



Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The y-axes are percentage point deviations from steady state for the model results. The x-axes are in quarters.

7 Conclusion

This paper quantifies how supply-driven energy price shocks affect household consumption and consumption inequality in the United States, combining evidence from micro-level empirical analysis with a structural model. Using instrumental variable local projections, we show that a one percentage point increase in energy prices reduces consumption of households in the lowest income decile by 0.5 percent, while consumption of those in the highest decile remains essentially unchanged. This differential impact generates a persistent rise in consumption inequality lasting up to one year after the initial shock. The structural model replicates these empirical patterns and provides a disciplined framework for evaluating alternative fiscal policy responses.

The analysis highlights two central mechanisms behind this heterogeneity. Lower-income households are more exposed to energy price fluctuations due to their higher expenditure shares on energy and related necessities, and they face tighter liquidity constraints that limit their ability to smooth consumption. In contrast, higher-income households benefit from more diversified consumption and greater access to financial markets, allowing them to absorb transitory price increases with limited adjustment in consumption. A two-agent New Keynesian model with non-homothetic preferences reproduces these empirical patterns, showing that negative supply shocks disproportionately depress consumption for constrained households and raise consumption inequality.

The counterfactual fiscal policy analysis demonstrates that targeted cash transfers dominate energy subsidies in reducing consumption inequality. At comparable fiscal cost (approximately 0.08 percent of GDP over two years), cash transfers fully eliminate the increase in consumption inequality, while energy subsidies reduce the inequality increase

by only half. This difference arises because cash transfers enable constrained households to allocate resources optimally across all consumption categories, whereas subsidies are restricted to energy expenditure, a relatively small share of total household budgets. These findings carry direct implications for policy design: the gasoline tax suspensions and energy subsidies widely deployed in 2022 across U.S. states and members of the European Union are substantially less cost-effective than targeted transfers at mitigating consumption inequality.

More broadly, these results establish that supply-driven energy shocks generate substantial distributional consequences beyond their aggregate effects, and that policy design matters significantly for addressing consumption inequality. The framework developed here provides guidance for fiscal authorities responding to relative price shocks, particularly when such shocks affect necessity goods that constitute larger expenditure shares for lower-income households.

Several extensions would strengthen the analysis. The structural model assumes a closed economy, abstracting from international energy market linkages. While the United States is a net energy exporter, domestic prices remain tied to global energy markets, suggesting that open economy dynamics could amplify distributional effects. Additionally, the two-agent structure simplifies household heterogeneity into constrained and unconstrained types. A richer framework with multiple income groups could better capture variation across the full distribution and yield more granular policy design recommendations. Finally, exploring interactions between fiscal and monetary policy responses—particularly when central banks face trade-offs between stabilizing inflation and output—represents an important direction for future research.

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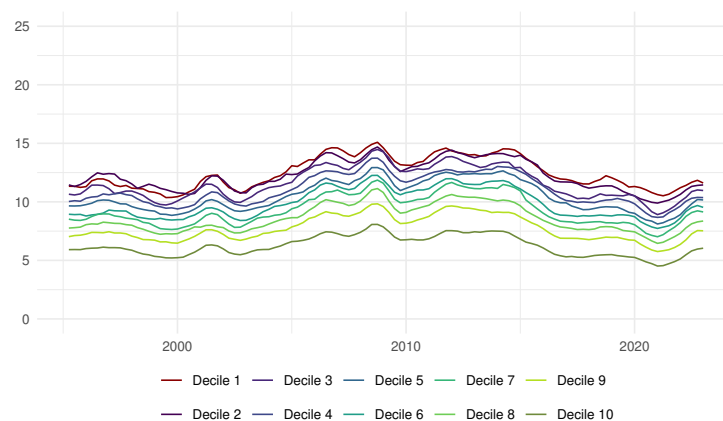
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Appendices

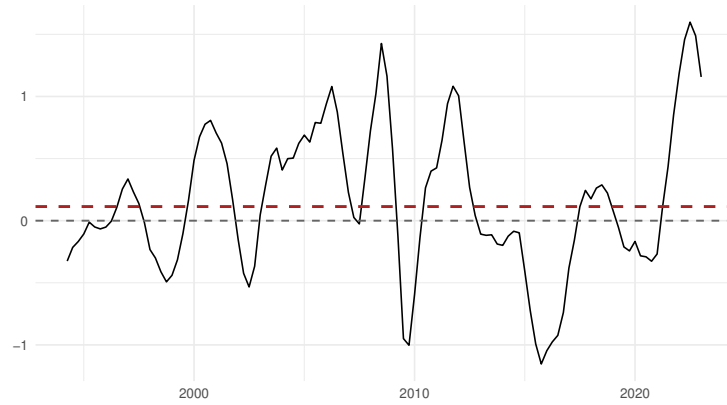
A Supplementary Figures and Data

Figure A.1: Energy expenditure shares across income deciles



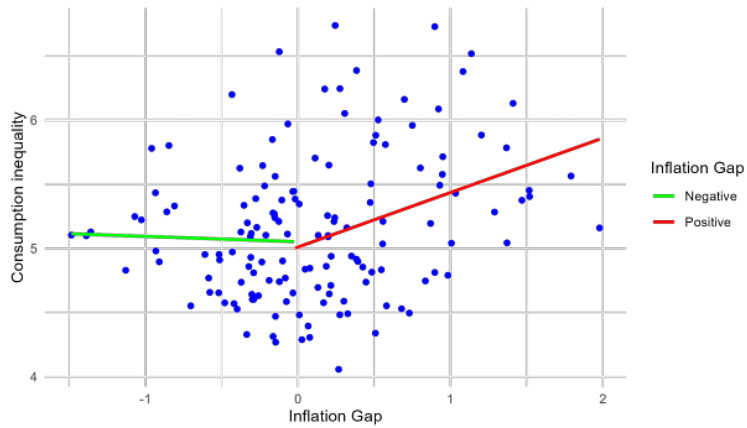
Data sources: CES/BLS.

Figure A.2: Time series of the inflation gap measure



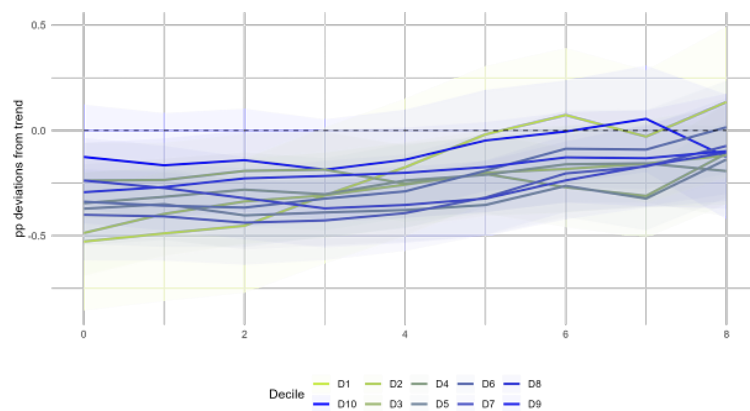
Note: Red-dashed line shows the sample average of the inflation gap. Data sources: CES/BLS, BEA.

Figure A.3: Correlations between the inflation gap and consumption inequality



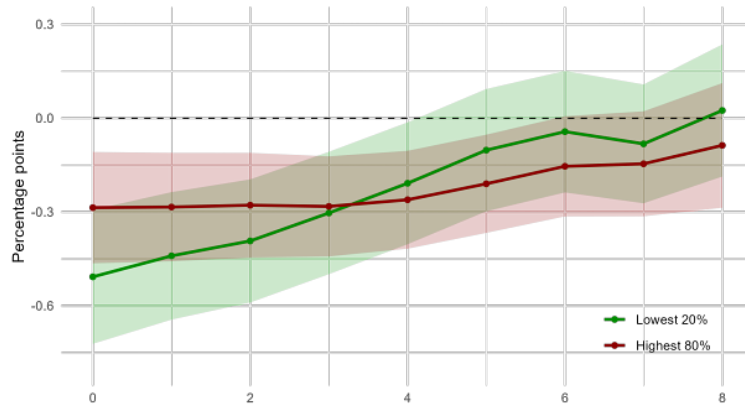
Note: Inflation gap and consumption inequality shown refer to the top/bottom quintile for more robustness away from the tails of the income distribution. Data sources: CES/BLS, BEA, FRED.

Figure A.4: Total consumption response across deciles



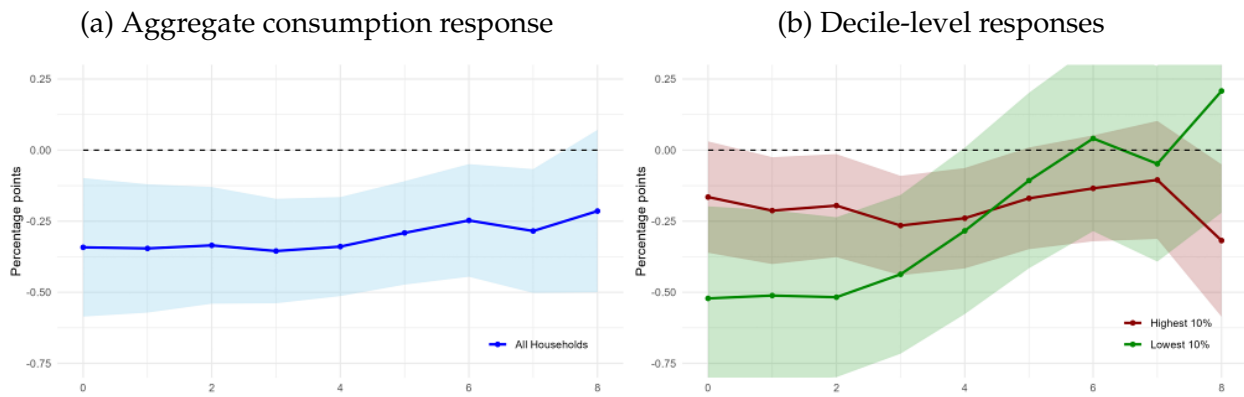
Note: Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021), FRED.

Figure A.5: Total consumption response across 80/20 percent split



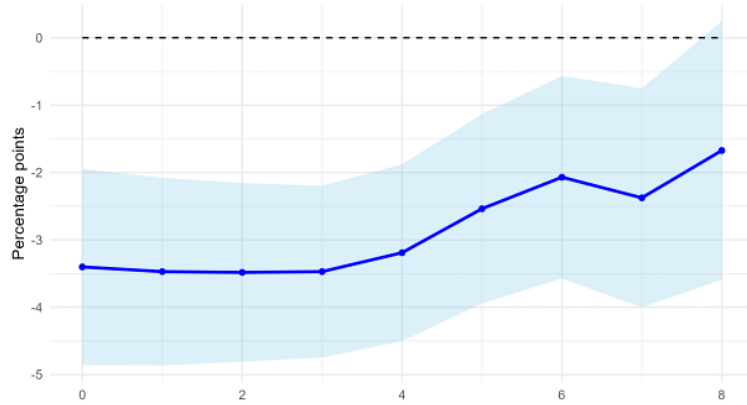
Note: Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021), FRED.

Figure A.6: Robustness of consumption responses



Note: Sample size shortened to 2022-Q1. Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021).

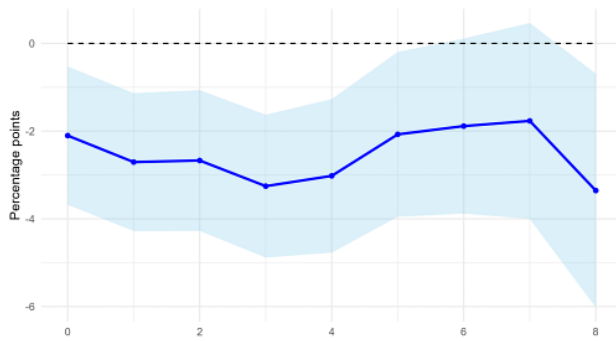
Figure A.7: Total consumption - robustness to food weights



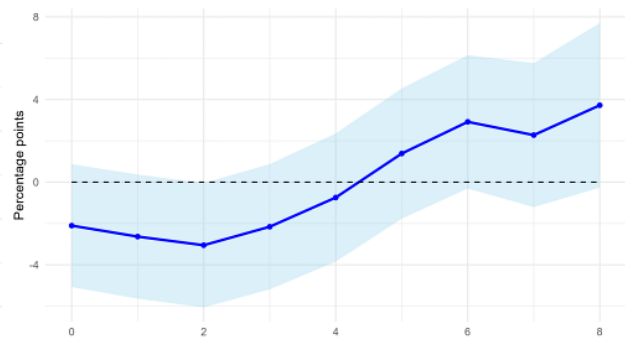
Note: Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021), FRED.

Figure A.8: Total consumption - robustness to food weights

(a) Bottom 10 percent



(b) Top 10 percent



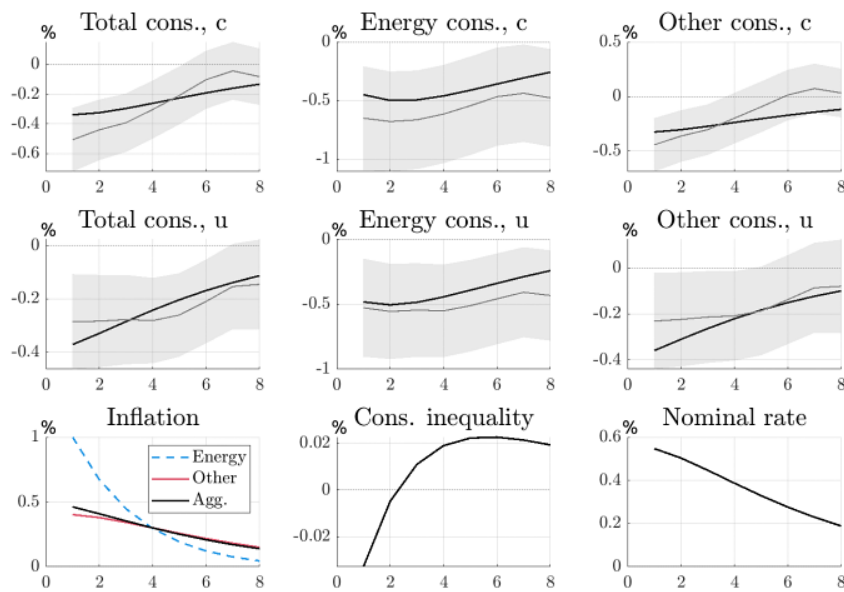
Note: Responses show percentage point deviations from the log-linear trend after a one percentage point shock. Shaded areas denote 90 percent confidence intervals based on Newey and West (1987) standard errors. Data sources: CES/BLS, BEA, Känzig (2021).

Table A.1: Summary statistics

Variable	Mean	Median	Min	Max	SD	IQR
Core inflation (PCE)	2.1	1.8	0.7	5.5	1.0	0.7
Energy inflation (PCE)	4.2	2.6	-26.3	36.8	11.8	12.8
Food inflation (PCE)	2.4	1.8	-1.8	11.9	2.3	2.0
Headline inflation (PCE)	2.2	2.0	-1.2	6.9	1.3	1.2
Income growth: Decile 1	1.7	1.4	-19.4	23.0	8.4	10.2
Income growth: Decile 2	2.2	2.1	-23.2	27.3	9.8	15.8
Income growth: Decile 9	3.4	4.1	-9.3	10.4	3.4	3.4
Income growth: Decile 10	4.2	4.1	-5.8	15.7	4.5	5.2
Inflation: Decile 1	2.4	2.2	-1.5	8.9	1.9	2.1
Inflation: Decile 2	2.4	2.2	-1.4	8.8	1.8	2.1
Inflation: Decile 9	2.3	2.2	-0.6	7.5	1.4	1.4
Inflation: Decile 10	2.3	2.1	-0.4	7.0	1.3	1.3
LD real exp. (core): Decile 1	0.0	0.0	-0.1	0.2	0.1	0.1
LD real exp. (core): Decile 2	0.0	0.0	-0.2	0.2	0.1	0.1
LD real exp. (core): Decile 9	0.0	0.0	-0.1	0.1	0.1	0.1
LD real exp. (core): Decile 10	0.0	0.0	-0.1	0.1	0.1	0.1
LD real exp. (energy): Decile 1	0.0	0.0	-0.1	0.2	0.1	0.2
LD real exp. (energy): Decile 2	0.0	0.0	-0.1	0.2	0.1	0.1
LD real exp. (energy): Decile 9	0.0	0.0	-0.1	0.2	0.1	0.1
LD real exp. (energy): Decile 10	0.0	0.0	-0.1	0.2	0.1	0.1
LD real exp. (food): Decile 1	0.0	0.0	-0.1	0.1	0.1	0.1
LD real exp. (food): Decile 2	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (food): Decile 9	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (food): Decile 10	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (total): Decile 1	0.0	0.0	-0.1	0.1	0.1	0.1
LD real exp. (total): Decile 2	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (total): Decile 9	0.0	0.0	-0.1	0.1	0.0	0.1
LD real exp. (total): Decile 10	0.0	0.0	-0.1	0.1	0.0	0.1
Känzig shock	0.0	0.0	-1.4	1.1	0.3	0.4
Real GDP growth	2.5	2.6	-7.4	12.4	2.1	1.8
Real interest rate	2.7	2.2	0.1	8.2	2.4	4.9
Unemployment rate	5.8	5.5	3.5	13.0	1.7	2.3

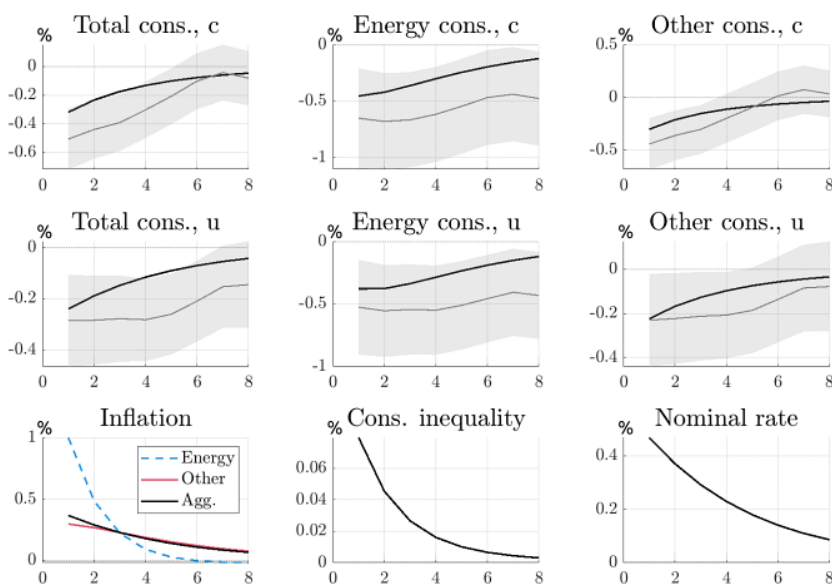
LD: Log detrended, PCE: Personal Consumption Expenditure Price Index, SD: Standard Deviation, IQR: Interquartile Range.

Figure A.9: Impulse responses to a negative energy supply shock under core inflation targeting



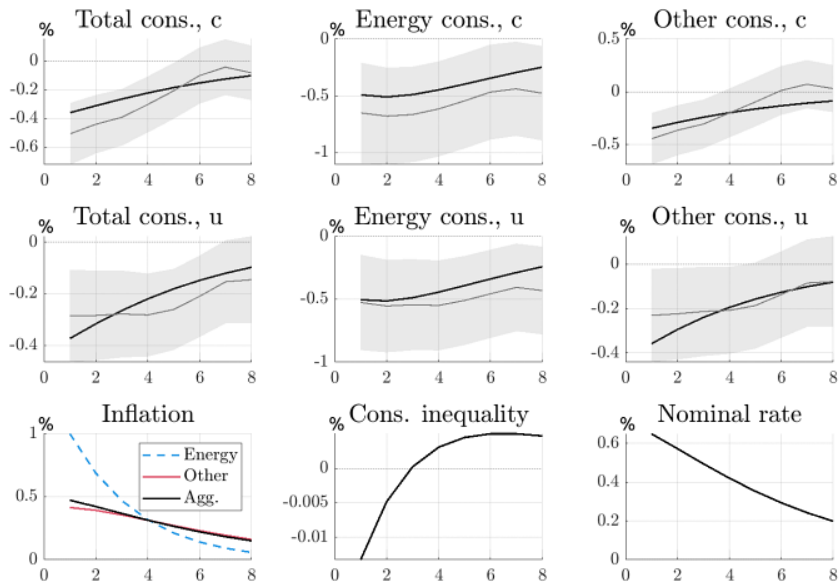
Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The grey lines are empirical local projection results with the shaded areas as the 90 percent confidence intervals based on Newey and West Newey and West (1987) standard errors. The y-axes are percentage point deviations from steady state for the model results and percentage point deviations from the log-linear trend for the empirical results. The x-axes are in quarters. Inflation and the nominal rate are annualized.

Figure A.10: Impulse responses to a negative energy supply shock with lower Calvo (1983) parameter for energy $\theta_p^E = 0.5$



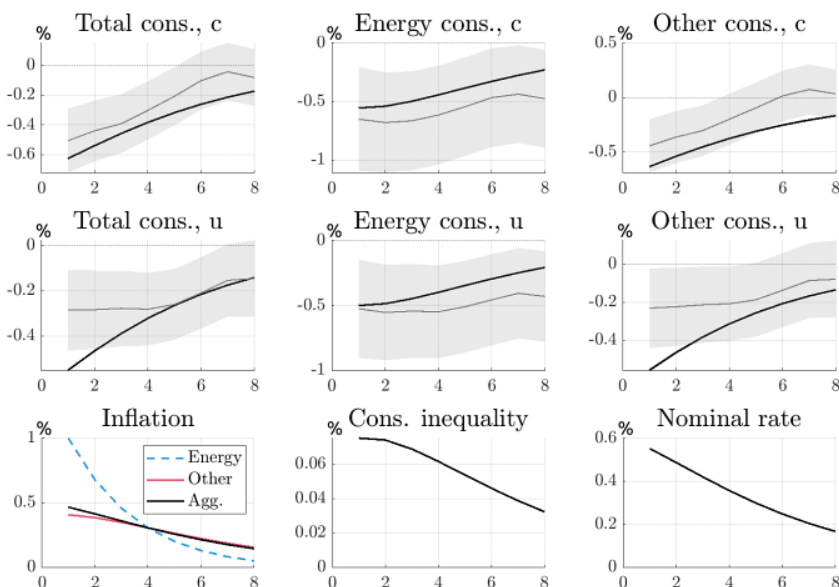
Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The grey lines are empirical local projection results with the shaded areas as the 90 percent confidence intervals based on Newey and West Newey and West (1987) standard errors. The y-axes are percentage point deviations from steady state for the model results and percentage point deviations from the log-linear trend for the empirical results. The x-axes are in quarters. Inflation and the nominal rate are annualized.

Figure A.11: Impulse responses to a negative energy supply shock under homothetic preferences ($\varepsilon_1 = \varepsilon_2 = 0$)



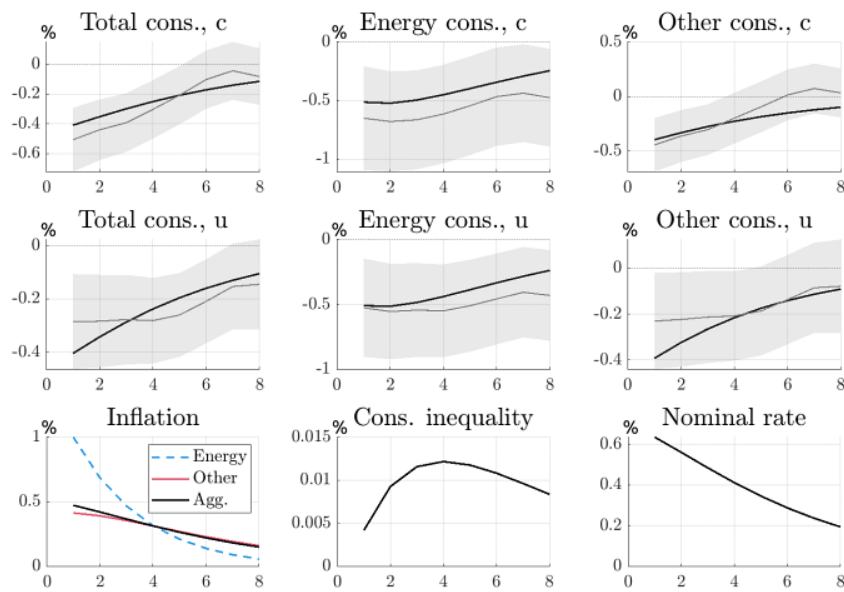
Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The grey lines are empirical local projection results with the shaded areas as the 90 percent confidence intervals based on Newey and West Newey and West (1987) standard errors. The y-axes are percentage point deviations from steady state for the model results and percentage point deviations from the log-linear trend for the empirical results. The x-axes are in quarters. Inflation and the nominal rate are annualized.

Figure A.12: Impulse responses to a negative energy supply shock under stronger non-homothetic preferences ($\varepsilon_1 = \varepsilon_2 = 0.27$)



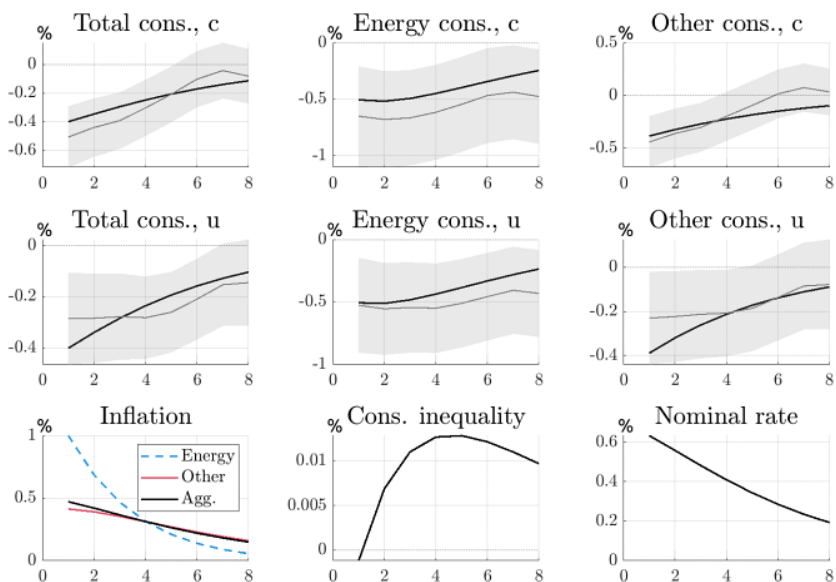
Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The grey lines are empirical local projection results with the shaded areas as the 90 percent confidence intervals based on Newey and West Newey and West (1987) standard errors. The y-axes are percentage point deviations from steady state for the model results and percentage point deviations from the log-linear trend for the empirical results. The x-axes are in quarters. Inflation and the nominal rate are annualized.

Figure A.13: Impulse responses to a negative energy supply shock with lower share of constrained households ($\lambda = 0.10$)



Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The grey lines are empirical local projection results with the shaded areas as the 90 percent confidence intervals based on Newey and West Newey and West (1987) standard errors. The y-axes are percentage point deviations from steady state for the model results and percentage point deviations from the log-linear trend for the empirical results. The x-axes are in quarters. Inflation and the nominal rate are annualized.

Figure A.14: Impulse responses to a negative energy supply shock with higher share of constrained households ($\lambda = 0.25$)



Note: The results are in response to a negative energy supply shock that generates a one percentage point increase in energy inflation. The grey lines are empirical local projection results with the shaded areas as the 90 percent confidence intervals based on Newey and West Newey and West (1987) standard errors. The y-axes are percentage point deviations from steady state for the model results and percentage point deviations from the log-linear trend for the empirical results. The x-axes are in quarters. Inflation and the nominal rate are annualized.

B Model Details

B.1 Households

Indirect utility function with non-homothetic preferences following Boppart (2014):

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{\varepsilon_1} \left[\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1} - 1 \right] - \frac{\gamma}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} - 1 \right] \right\} \quad (\text{B.1})$$

where $0 \leq \varepsilon_1 \leq \varepsilon_2 < 1$ and $\gamma > 0$. Superscript $k \in \{c, u\}$ for constrained and unconstrained households. Constrained households constitute a share $\lambda \in (0, 1)$ of the population, whereas unconstrained households constitute a share $1 - \lambda$. Households supply labor inelastically. The per-period utility takes the form $v = \frac{1}{\varepsilon_1} \left[\left(\frac{S_t}{P_{Ot}} \right)^{\varepsilon_1} - 1 \right] - \frac{\gamma}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} - 1 \right]$.

Intratemporal choice Marshallian demand functions obtained with Roy's identity:

$$c_{Et}^k = - \frac{\partial v / \partial P_{Et}}{\partial v / \partial S_t^k} = \frac{\gamma \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2 - 1}}{\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1 - 1}} \quad (\text{B.2})$$

$$c_{Ot}^k = - \frac{\partial v / \partial P_{Ot}}{\partial v / \partial S_t^k} = \frac{\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1} - \gamma \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2}}{\left(\frac{S_t^k}{P_{Ot}} \right)^{\varepsilon_1 - 1}} \quad (\text{B.3})$$

Rearrange to express c_{Ot}^k in terms of c_{Et}^k to get relative demand²⁴:

$$c_{Ot}^k = \frac{[1 - \gamma \varpi_t^k] P_{Et}}{\gamma \varpi_t^k P_{Ot}} c_{Et}^k \quad (\text{B.4})$$

where

$$\varpi_t^k = \left(\frac{P_{Ot}}{S_t^k} \right)^{\varepsilon_1} \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2} \quad (\text{B.5})$$

is the energy expenditure share wedge. If $\varepsilon_1 = \varepsilon_2 = 0$ (Cobb-Douglas case), then $c_{Ot}^k = \frac{1-\gamma}{\gamma} \frac{P_{Et}}{P_{Ot}} c_{Et}^k$. Expenditure is defined as $S_t^k = P_{Et} c_{Et}^k + P_{Ot} c_{Ot}^k$. Hence, define:

$$S_t^{k,rel} \equiv \frac{S_t^k}{P_{Ot}} = \frac{P_{Et}}{P_{Ot}} c_{Et}^k + c_{Ot}^k \quad (\text{B.6})$$

Intertemporal choice and labor supply Nominal budget constraint of constrained households:

$$S_t^c = P_{Et} c_{Et}^c + P_{Ot} c_{Ot}^c = W_t n_t^c + P_t \tau_t^c + P_t T_t^c \quad (\text{B.7})$$

Constrained households supply labor n_t^c and consume their per-period income according to their preferences.

²⁴See the Appendix in Komatsu (2025) to see an alternative way to rearrange relative demand.

Nominal budget constraint of unconstrained households:

$$S_t^u = P_{Et}c_{Et}^u + P_{Ot}c_{Ot}^u = W_t n_t^u + \frac{1-\delta}{1-\lambda} P_t D_t + R_{t-1} B_{t-1} - B_t + P_t \tau_t^u + P_t T_t^u \quad (\text{B.8})$$

Unconstrained households supply labor n_t^u and have access to the financial market. They smooth consumption according to the Euler equation:

$$\mathbb{E}_t \left(\frac{S_{t+1}^{u,rel}}{S_t^{u,rel}} \right)^{1-\varepsilon_1} = \beta R_t \mathbb{E}_t \left(\frac{1}{\Pi_{O,t+1}} \right)^{1-\varepsilon_1} \quad (\text{B.9})$$

B.2 Firms

Intermediate energy and other goods firms, $j \in \{E, O\}$ face monopolistic competition with firms within the same sector. They face adjustment costs à la Rotemberg. For both types of firms, the first order condition with respect to $P_{jt}(i)$ is:²⁵

$$(1-\epsilon) \left(\frac{P_{jt}(i)}{P_{jt}} \right)^{-\epsilon} \frac{1}{P_{jt}} Y_{jt} - \xi_j \left(\frac{P_{jt}(i)}{P_{j,t-1}(i)} - 1 \right) \frac{1}{P_{j,t-1}(i)} Y_{jt} \\ + \mu_{jt} \epsilon P_{jt}(i)^{-\epsilon-1} \left(\frac{1}{P_{jt}} \right)^{-\epsilon} Y_{jt} + \mathbb{E}_t \left[\Lambda_{t+1} \xi_j \left(\frac{P_{j,t+1}(i)}{P_{jt}(i)} - 1 \right) Y_{j,t+1} \left(\frac{P_{j,t+1}(i)}{P_{jt}(i)^2} \right) \right] = 0 \quad (\text{B.10})$$

which leads to the New Keynesian Philips Curve (NKPC) after imposing the symmetry conditions $P_{jt}(i) = P_{jt}$ and $Y_{jt}(i) = Y_{jt}$. For the energy firms, the first order condition with respect to N_{Et} is:

$$\frac{W_t}{P_{Et}} = \mu_{Et}(i) A_{Et} \quad (\text{B.11})$$

For the other goods firms, the first order conditions with respect to N_{Ot} and E_t^f are:

$$\frac{W_t}{P_{Ot}} = (1-\gamma^f)^{1/\theta^f} \mu_{Ot}(i) \left(\frac{Y_{Ot}(i)}{N_{Ot}(i)} \right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \quad (\text{B.12})$$

$$\frac{P_{Et}}{P_{Ot}} = (\gamma^f)^{1/\theta^f} \mu_{Ot} \left(\frac{Y_{Ot}(i)}{E_t^f(i)} \right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \quad (\text{B.13})$$

²⁵The Lagrange multiplier on the production function μ_{jt} is the marginal cost.

B.3 Summary of Model Equations

Households

$$c_{Ot}^c = \frac{[1 - \gamma\varpi_t^c] P_{Et}}{\gamma\varpi_t^c P_{Ot}} c_{Et}^c \quad (\text{B.14})$$

$$c_{Ot}^u = \frac{[1 - \gamma\varpi_t^u] P_{Et}}{\gamma\varpi_t^u P_{Ot}} c_{Et}^u \quad (\text{B.15})$$

$$\varpi_t^c = \left(S_t^{c,rel}\right)^{-\varepsilon_1} \left(\frac{P_{Et}}{P_{Ot}}\right)^{\varepsilon_2} \quad (\text{B.16})$$

$$\varpi_t^u = \left(S_t^{u,rel}\right)^{-\varepsilon_1} \left(\frac{P_{Et}}{P_{Ot}}\right)^{\varepsilon_2} \quad (\text{B.17})$$

$$S_t^{c,rel} = \frac{P_{Et}}{P_{Ot}} c_{Et}^c + c_{Ot}^c \quad (\text{B.18})$$

$$S_t^{u,rel} = \frac{P_{Et}}{P_{Ot}} c_{Et}^u + c_{Ot}^u \quad (\text{B.19})$$

$$S_t^{c,rel} = \frac{W_t}{P_t} \frac{P_t}{P_{Ot}} n_t^c + \frac{P_t}{P_{Ot}} \tau_t^c + \frac{P_t}{P_{Ot}} T_t^c \quad (\text{B.20})$$

$$\mathbb{E}_t \left(\frac{S_{t+1}^{u,rel}}{S_t^{u,rel}} \right)^{1-\varepsilon_1} = \beta R_t \mathbb{E}_t \left(\frac{1}{\Pi_{O,t+1}} \right)^{1-\varepsilon_1} \quad (\text{B.21})$$

$$\omega_t = \frac{c_t^u}{c_t^c} \quad (\text{B.22})$$

Firms

$$Y_{Et} = A_{Et}N_{Et} \quad (\text{B.23})$$

$$Y_{Ot}(i) = A_{Ot} \left[(\gamma^f)^{1/\theta^f} \left(E_t^f(i) \right)^{(\theta^f-1)/\theta^f} + (1-\gamma^f)^{1/\theta^f} \left(N_{Ot}(i) \right)^{(\theta^f-1)/\theta^f} \right]^{\theta^f/(\theta^f-1)} \quad (\text{B.24})$$

$$(\Pi_{Et} - 1) \Pi_{Et} = \frac{\epsilon}{\xi} (\mu_{Et} - \bar{\mu}) + \beta \mathbb{E}_t \left[(\Pi_{E,t+1} - 1) \Pi_{E,t+1} \frac{Y_{E,t+1}}{Y_{Et}} \right] \quad (\text{B.25})$$

$$(\Pi_{Ot} - 1) \Pi_{Ot} = \frac{\epsilon}{\xi} (\mu_{Ot} - \bar{\mu}) + \beta \mathbb{E}_t \left[(\Pi_{O,t+1} - 1) \Pi_{O,t+1} \frac{Y_{O,t+1}}{Y_{Ot}} \right] \quad (\text{B.26})$$

$$D_{Et} = Y_{Et} \left[1 - \frac{\xi_E}{2} \left(\frac{P_{Et}}{P_{E,t-1}} - 1 \right)^2 \right] - \frac{W_t}{P_{Et}} N_{Et} \quad (\text{B.27})$$

$$D_{Ot} = Y_{Ot} \left[1 - \frac{\xi_O}{2} \left(\frac{P_{Ot}}{P_{O,t-1}} - 1 \right)^2 \right] - \frac{W_t}{P_{Ot}} N_{Ot} - \frac{P_{Et}}{P_{Ot}} E_t^f \quad (\text{B.28})$$

$$D_t = D_{Et} + D_{Ot} \quad (\text{B.29})$$

$$\frac{W_t}{P_t} \frac{P_t}{P_{Et}} = \mu_{Et} A_{Et} \quad (\text{B.30})$$

$$\frac{W_t}{P_t} \frac{P_t}{P_{Ot}} = (1-\gamma^f)^{1/\theta^f} \mu_{Ot} \left(\frac{Y_{Ot}}{N_{Ot}} \right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \quad (\text{B.31})$$

$$\frac{P_{Et}}{P_{Ot}} = (\gamma^f)^{1/\theta^f} \mu_{Ot} \left(\frac{Y_{Ot}}{E_t^f} \right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \quad (\text{B.32})$$

Monetary and fiscal policy

$$R_t = \frac{1}{\beta} \left(\frac{\Pi_t}{\bar{\Pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_t^n} \right)^{\phi_y} \exp(\nu_t) \quad (\text{B.33})$$

$$\Pi_t = (\Pi_{Et})^\gamma (\Pi_{Ot})^{1-\gamma} \quad (\text{B.34})$$

$$\tau_t^c = (1 - \tau_0) \delta D_t \quad (\text{B.35})$$

$$(1 - \lambda) T_t^u = -\lambda T_t^c \quad (\text{B.36})$$

Aggregation and market clearing

$$n_t^c = \bar{n}^c \quad (\text{B.37})$$

$$n_t^u = \bar{n}^u \quad (\text{B.38})$$

$$N_{Et} + N_{Ot} = \lambda n_t^c + (1 - \lambda)n_t^u \quad (\text{B.39})$$

$$c_t^c = c_{Et}^c + c_{Ot}^c \quad (\text{B.40})$$

$$c_t^u = c_{Et}^u + c_{Ot}^u \quad (\text{B.41})$$

$$C_t = \lambda c_t^c + (1 - \lambda)c_t^u \quad (\text{B.42})$$

$$Y_{Et} = \lambda c_{Et}^c + (1 - \lambda)c_{Et}^u \quad (\text{B.43})$$

$$Y_{Ot} = \lambda c_{Ot}^c + (1 - \lambda)c_{Ot}^u + Y_{Ot} \frac{\xi}{2} (\Pi_{Ot} - 1)^2 \quad (\text{B.44})$$

$$Y_t = Y_{Et} + Y_{Ot} \quad (\text{B.45})$$

B.4 Steady State

Prices. Assume that prices of both goods are unity in steady state:

$$\bar{P}_E = \bar{P}_O = 1 \quad (\text{B.46})$$

Hence, we get that the relative price of energy and other goods, $P_t^{rel,EO} \equiv \frac{P_{Et}}{P_{Ot}}$, in steady state is also equal to unity:

$$\bar{P}^{rel,EO} = 1 \quad (\text{B.47})$$

Demand side. The Marshallian demands in steady state are:

$$\bar{c}_E^c = \gamma \frac{\bar{S}^c}{\bar{P}_E} \left(\frac{\bar{P}_O}{\bar{S}^c} \right)^{\varepsilon_1} (\bar{P}^{rel,EO})^{\varepsilon_2} = \gamma (\bar{S}^c)^{1-\varepsilon_1} = \gamma (\bar{S}^{c,rel})^{1-\varepsilon_1} \quad (\text{B.48})$$

$$\bar{c}_E^u = \gamma \frac{\bar{S}^u}{\bar{P}_E} \left(\frac{\bar{P}_O}{\bar{S}^u} \right)^{\varepsilon_1} (\bar{P}^{rel,EO})^{\varepsilon_2} = \gamma (\bar{S}^u)^{1-\varepsilon_1} = \gamma (\bar{S}^{u,rel})^{1-\varepsilon_1} \quad (\text{B.49})$$

$$\bar{c}_O^c = \frac{\bar{S}^c}{\bar{P}_O} \left[1 - \gamma \left(\frac{\bar{P}_O}{\bar{S}^c} \right)^{\varepsilon_1} (\bar{P}^{rel,EO})^{\varepsilon_2} \right] = \bar{S}^c - \gamma (\bar{S}^c)^{1-\varepsilon_1} = \bar{S}^{c,rel} - \gamma (\bar{S}^{c,rel})^{1-\varepsilon_1} \quad (\text{B.50})$$

$$\bar{c}_O^u = \frac{\bar{S}^u}{\bar{P}_O} \left[1 - \gamma \left(\frac{\bar{P}_O}{\bar{S}^u} \right)^{\varepsilon_1} (\bar{P}^{rel,EO})^{\varepsilon_2} \right] = \bar{S}^u - \gamma (\bar{S}^u)^{1-\varepsilon_1} = \bar{S}^{u,rel} - \gamma (\bar{S}^{u,rel})^{1-\varepsilon_1} \quad (\text{B.51})$$

Then the energy expenditure share wedge $\varpi_t^k = \left(\frac{P_{Ot}}{S_t^k} \right)^{\varepsilon_1} \left(\frac{P_{Et}}{P_{Ot}} \right)^{\varepsilon_2}$ in steady state is:

$$\bar{\varpi}^c = (\bar{S}^{c,rel})^{-\varepsilon_1} \quad (\text{B.52})$$

$$\bar{\varpi}^u = (\bar{S}^{u,rel})^{-\varepsilon_1} \quad (\text{B.53})$$

Market clearing. Goods market clearing gives:

$$\bar{Y}_E = \lambda \bar{c}_E^c + (1 - \lambda) \bar{c}_E^u + \bar{E}_f \quad (\text{B.54})$$

$$\bar{Y}_O = \lambda \bar{c}_O^c + (1 - \lambda) \bar{c}_O^u \quad (\text{B.55})$$

Labor market clearing gives:

$$\bar{N}_E + \bar{N}_O = \lambda \bar{n}^c + (1 - \lambda) \bar{n}^u \quad (\text{B.56})$$

$$\bar{N} = \bar{N}_E + \bar{N}_O \quad (\text{B.57})$$

Supply side. Technology is unity in steady state in both sectors:

$$\bar{A}_E = \bar{A}_O = 1 \quad (\text{B.58})$$

Taking the first-order condition of the the intermediate firm (B.10) and (B.11) in steady state, we obtain:

$$\bar{\mu} = \frac{\epsilon - 1}{\epsilon} \quad (\text{B.59})$$

$$\bar{W}_E^{real} = \bar{W}_O^{real} = \bar{\mu} \quad (\text{B.60})$$

Aggregating the firms' profits gives:

$$\bar{D} = \bar{D}_E + \bar{D}_O \quad (\text{B.61})$$

$$= \bar{Y}_E - \frac{\bar{W}_E}{\bar{P}_E} \bar{N}_E + \bar{Y}_O - \frac{\bar{W}_O}{\bar{P}_O} \bar{N}_O - \frac{\bar{P}_E}{\bar{P}_O} \bar{E}^f \quad (\text{B.62})$$

$$= \bar{Y}_E - \bar{\mu} \bar{Y}_E + \bar{Y}_O - \bar{\mu} \bar{Y}_O - \bar{E}_f \quad (\text{B.63})$$

$$= (\bar{Y}_E + \bar{Y}_O) (1 - \bar{\mu}) - \bar{E}_f \quad (\text{B.64})$$

The demand for energy from firms producing other goods gives:

$$\bar{E}^f = \gamma^f \bar{\mu} \bar{Y}_{Ot} \left(\frac{\bar{P}_O}{\bar{P}_E} \right)^{\theta^f} \quad (\text{B.65})$$

$$= \gamma^f \bar{\mu} \bar{Y}_{Ot} \quad (\text{B.66})$$

Use the supply-side steady-state values in the households' nominal budget constraint to get their relative expenditure in steady state:

$$\bar{S}^{c,rel} = \bar{W}^{real} \bar{n}^c \quad (\text{B.67})$$

$$= \bar{\mu} \bar{n}^c + \bar{\tau}^c + \bar{T}^c \quad (\text{B.68})$$

$$\bar{S}^{u,rel} = \bar{W}^{real} \bar{n}^u + \frac{1}{1 - \lambda} \bar{D} \quad (\text{B.69})$$

$$= \bar{\mu} \bar{n}^u + \frac{1}{1 - \lambda} \bar{D} \quad (\text{B.70})$$

$$= \bar{\mu} \bar{n}^u + \frac{1}{1 - \lambda} \bar{D} + \bar{\tau}^u + \bar{T}^u \quad (\text{B.71})$$