# COMMUTING, HOME UTILITIES, AND PRODUCTION: THE DISTRIBUTIONAL EFFECTS OF ENERGY PRICE SHOCKS<sup>\*</sup>

# Mehedi Hasan Oni<sup>†</sup>

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#### ABSTRACT

Energy price shocks are large and persistent relative to other price shocks. How do these shocks affect households across income groups? To quantify the welfare effects of energy price shocks, I develop a heterogeneous-agent incomplete market model featuring non-homothetic consumption preferences, commuting costs, and energy as a factor of production for non-energy goods, taking the energy price as exogenous. A calibrated version of the model successfully reproduces many salient features of United States data, including the cross-sectional distributions of employment, income, wealth, and expenditure shares on energy consumption for both commuting and residential utilities. Quantitatively, I find that a positive energy price shock similar to the one in 2021 results in disproportionate welfare losses across income groups, with the bottom quintile losing almost twice as much as the top quintile in terms of consumption on impact. While the shock's direct impact on consumption dominates for low-income households, high-income households are mainly affected through changes in wage and rental rate. I also show that while work from home opportunity exacerbates consumption inequality, targeted transfer helps to mitigate it.

*Keywords*: Energy Price Shock; Inequality; Commuting Cost; Work from Home.

*JEL Codes*: D63, E21, E30, Q43.

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<sup>†</sup>Department of Economics, University of Arkansas, Fayetteville, Arkansas, United States. E-mail: mhoni.acad@gmail.com.

# 1. INTRODUCTION

Typically, energy prices experience sharp and sustained fluctuations compared to the prices of other goods and services (see Figure 1 Panel A). These fluctuations are common across economies worldwide, including major energy-producing countries like the United States and major energy-importing countries like Germany (see Figure 1 Panel B), stemming from factors such as wars (e.g., political unrest in the Middle East or the recent Russian invasion of Ukraine), energy plant accidents, initiatives aimed at controlling energy use for environmental concerns, or global energy demand. Fluctuations in energy prices have greater significance for an economy than other price changes due to two main reasons: (i) energy is used by both firms and households, and (ii) the demand for energy is inelastic. A primary concern for policymakers has been the potential negative impact of high energy prices on consumer demand, typically addressed through various transfer programs. To effectively design these policies, it is crucial to understand the potential distributional consequences of both energy price shocks and the policies initiated in response. Despite an extensive literature studying the macroeconomic impacts of energy price shocks, there is less work on the distributional effects. Moreover, a careful evaluation of energy-related policies requires a comprehensive framework incorporating different uses of energy.

In this paper, I quantitatively study the distributional effects of energy price shocks in a unified framework incorporating energy use in residential utilities (such as heating, cooling, and cooking), commuting to work, and production.<sup>1</sup> In doing so, I make four key contributions. First, using the Consumer Expenditure Survey (CEX), I document a robust negative relationship between household income and expenditure shares on energy for both residential utilities and commuting. The CEX also indicates that while an energy price hike reduces energy consumption for residential utilities, its effect on commuting energy consumption can be muted or even reversed. Second, I develop a heterogeneous-agent

<sup>1.</sup> Energy price refers to the price index that accounts for all types of final-use energy, which households and firms use directly, such as electricity, gasoline, and piped gas. Since the prices of these energy goods are highly correlated (see Figure G.1 in the Online Appendix), this index effectively captures overall fluctuations.



#### FIGURE 1

Comparison in Fluctuations of Energy vs. Non-Energy Price Index for the U.S. and Energy Price Index for the U.S. vs. Germany

*Note.* Panel (A) plots the detrended Consumer Price Index (CPI) for energy and non-energy in the U.S. (BEA CPI-U: SA0E & SA0LE). Panel (B) plots the CPI for energy in the U.S. and the Harmonized Index of Consumer Prices (HICP) for energy in Germany (Eurostat: EL\_CPHI\_M: CP-HIE).

incomplete market model building on Bewley-Huggett-Aiyagari, incorporating an exogenous energy price, non-homothetic consumption preferences, commuting costs, extensive and intensive margin labor supply choices, and a non-energy production sector that uses energy as a factor of production.<sup>2</sup> Third, in calibrating the model, I provide new estimates for the household demand system that includes energy in the consumption basket. Quantitatively, I find that a positive (negative) energy price shock results in disproportionate welfare losses (gains) across income groups, with the lowest quintile losing (gaining) two to four times more than the highest quintile in terms of consumption. I examine how workfrom-home (WFH) and targeted transfers influence the impact of a positive shock. I show that WFH primarily benefits high-income households due to their disproportionate access,

<sup>2.</sup> The exogenous energy price assumption is common in quantitative macroeconomic studies of energy price shocks. This assumption is supported by the fact that fluctuations in energy prices are typically common worldwide (see Figure 1 Panel B). Endogenizing the energy price might yield similar results; however, it would reduce the tractability of the model, as it would require introducing a supply or demand shock to generate the price shock and then decomposing their effects. Additionally, the resources involved in the energy sector are small relative to the overall economy, with households owning these resources distributed across the income distribution. As a result, such changes are unlikely to significantly affect the results unless the focus is on a highly disaggregated level (e.g., at the percentile level).

exacerbating consumption inequality, while targeted transfers financed by a progressive tax mitigate the shock's impacts on consumption inequality.

In the model, households derive utility from a combination of energy and non-energy consumption and incur disutility from labor supply. They decide whether to work and, if so, the number of hours. Employed households consume additional energy depending on their earnings, leading to commuting costs. Households earn labor and/or asset income, pay taxes, and receive transfers. They use disposable income to finance consumption and can borrow or save to insure against income fluctuations.

On the production side, perfectly competitive firms produce non-energy goods using labor, capital, and energy. To capture the low short-run elasticity of substitution between energy and non-energy factors, firms combine these in fixed proportions. Given that energy prices typically fluctuate due to events exogenous to the U.S. economy, energy is assumed to be imported at an exogenous price.<sup>3</sup>

An energy price shock directly impacts the composition of household energy and nonenergy consumption. Due to the inelastic demand for energy and the dependency of labor supply on commuting costs, such a shock directly impacts household budget constraints. For example, an increase in the energy price reduces household real income, compelling them to increase their labor supply. However, higher labor supply increases commuting costs, leaving households with limited resources for residential energy and non-energy consumption. Hence, a trade-off between earnings and commuting costs influences labor supply decisions. In addition, an energy price shock can indirectly impact household decisions by influencing their earnings and asset return through changes in firms' demand for different factors and their respective prices.

I calibrate the model to U.S. data. Specifically, I use the CEX to estimate the demand system derived from my model and obtain the elasticity of substitution between residential energy and non-energy consumption, along with the parameters governing the expenditure elasticities of demand. Notably, the expenditure elasticity of demand for energy is

<sup>3.</sup> This is a common assumption in quantitative macroeconomic models with energy (see, e.g., Kim and Loungani, 1992; Alpanda and Peralta-Alva, 2010; Fried, Novan, and Peterman, 2018).

roughly half that of non-energy, which is robust to reduced-form estimates I obtain in a validation exercise. I also use the CEX to calibrate parameters related to households' energy use in commuting. Commuting costs increase with household income, which is consistent with the empirical evidence (see, e.g., Ready, Roussanov, and Zurowska, 2019; Kimbrough, 2019). The calibrated model successfully reproduces many salient features of the U.S. data, including the cross-sectional distributions of employment rate, earnings, wealth, and expenditure shares on both residential and commuting energy.

I use the calibrated model to analyze the distributional effects of energy price shocks. A positive energy price shock increases household consumption expenditures, reducing real income and leading to a rise in labor supply. This labor supply response varies across income and wealth distributions due to differences in the marginal utility of consumption. Specifically, low-income households, with no savings to hedge against the shock, rely on increasing their labor supply to smooth consumption. However, this increase in labor supply leads to additional welfare losses, as higher commuting costs limit the ability to consume non-energy and residential energy goods and longer hours worked increase disutility. The quantitative analysis shows that an energy price shock unevenly affects households across income groups, with low-income households being impacted the most. A shock similar to the one in 2021 (equivalent to a 20% increase in the relative price of energy) results in welfare losses for the bottom income quintile almost twice as large as those for the top on impact (-1.25% vs. -0.75% in terms of consumption). Fixing wage and rental rates doubles the consumption/welfare gap between the top and bottom quintiles. This is due to two main reasons. First, the higher energy expenditure share and lack of savings make the shock's direct effect on consumption stronger for low-income households. Second, higher asset holdings and a stronger substitution effect in labor supply decisions amplify the indirect effect through wage and rental rates for high-income households.

To clarify the roles of different model features, I compare the responses to a positive energy price shock in models with alternative assumptions to those in the baseline model. First, a model with homothetic consumption preferences downplays the shock's impact on consumption inequality, as it understates the energy share for low-income households while overstating it for high-income households. Second, without explicit commuting costs, households can allocate resources flexibly, reducing consumption loss from the shock. This flexibility disproportionately benefits low-income households, as they are most affected by the inelastic nature of commuting energy in the baseline model. Third, without energy as a factor of production, energy price shocks do not directly affect the production sector. As a result, factor prices—wage and rental rates—are only moderately affected, weakening the indirect effects of the shock and mitigating income and consumption losses, which disproportionately benefit high-income households.

Lastly, leveraging the baseline calibrated model, I conduct two policy experiments. First, motivated by the growing WFH opportunities, I examine how they influence the impact of a positive energy price shock. WFH significantly reduces commuting costs, enabling households to reallocate resources to other consumption or savings. However, WFH is more common in high-skilled occupations, primarily benefiting high-skilled households (see, e.g., Bick, Blandin, and Mertens, 2023). I show that WFH disproportionately reduces consumption losses for these households, exacerbating consumption inequality. Second, motivated by the U.S. federal energy assistance program—Low Income Home Energy Assistance Program (LIHEAP)—I examine how targeted transfers influence the impact of a positive energy price shock. I find that a lump-sum transfer to low-income households, financed by a progressive earnings tax, can mitigate consumption inequality.

**Outline.** The remainder of the paper is organized as follows. Section 2 reviews the related literature. Section 3 presents empirical evidence that motivates the key features of the quantitative model. Section 4 outlines the model and defines the equilibrium. Section 5 describes the calibration strategy. Section 6 assesses the model's ability to reproduce empirical statistics of interest. Section 7 presents the quantitative analysis. Section 8 concludes.

# 2. RELATED LITERATURE

This paper relates to the macroeconomic literature studying the effects of energy price shocks in quantitative models. Kim and Loungani (1992), Dhawan and Jeske (2008), and Dhawan, Jeske, and Silos (2010) study the effects of energy price shocks on economic aggregates in representative agent models. The recent surge in energy prices has led to several studies examining the effects of energy price shocks in heterogeneous-agent macroeconomic models (e.g., Kuhn, Kehrig, and Ziebarth, 2021; Pieroni, 2023; Auclert, Monnery, Rognlie, and Straub, 2023; Chan, Diz, and Kanngiesser, 2024). My paper distinguishes itself by developing a heterogeneous-agent model incorporating a flexible household demand system, commuting costs, labor supply decisions at the extensive margin, and a production function that, consistent with the data, uses energy and non-energy inputs (capital and labor) in fixed proportions to produce non-energy goods.<sup>4</sup> These features not only provide more precise estimates of shocks' impact, but also make the model suitable for analyzing a wider range of policies than existing models in the literature.

Macroeconomic models featuring household energy and non-energy consumption often set the elasticity of substitution between them based on the price elasticity of demand for energy (see, e.g., Pieroni, 2023). This is because, while an extensive literature estimates the price and income elasticities of energy demand, estimates of the elasticity of substitution between energy and non-energy consumption remain scarce.<sup>5</sup> My paper addresses this gap by estimating a demand system based on non-homothetic Constant Elasticity of Substitution (CES) preferences, providing new estimates of the elasticity of substitution between residential energy and non-energy goods in household consumption baskets.

Finally, the recent surge in energy prices has led to numerous studies exploring their implications for various economic policies. Chan, Diz, and Kanngiesser (2024) analyze the

<sup>4.</sup> To incorporate non-homotheticity in household consumption, most of the papers in the literature use Stone-Geary preferences. While Stone-Geary preferences result in Engel curves that level off quickly as income grows, the demand system of my paper preserves non-homotheticity for all income levels.

<sup>5.</sup> See Labandeira, Labeaga, and López-Otero (2017) for a review of price elasticities of demand for energy and Havranek and Kokes (2015) for income elasticities of demand.

implications of energy price shocks for optimal monetary policy. Several studies have also examined the role of fiscal policies in mitigating the adverse effects of energy price shocks (Bayer, Kriwoluzky, Müller, and Seyrich (2023), Kharroubi and Smets (2024), among others). Auclert, Monnery, Rognlie, and Straub (2023) analyze the role of both monetary and fiscal policies within an open-economy Heterogeneous Agents New Keynesian (HANK) model. Langot, Malmberg, Tripier, and Hairault (2023) examine the tariff shield policy implemented in France in 2022. Similar to a number of these studies, I examine the influence of targeted transfers on shocks' impact. Leveraging the novel features of my model, I also explore how WFH influences the distributional impacts of shocks.

#### **3.** EMPIRICAL EVIDENCE

# 3.1. Energy Consumption of Households and Firms

**Data.** I use data from the U.S. Energy Information Administration (EIA), which provides information on the consumption and expenditures of final-use energy, categorized into four broad sectors: residential, commercial, industrial, and transportation.<sup>6</sup> For my analysis, I reclassify these sectors into household and firm energy use. Household energy consumption includes residential utilities and transportation energy for personal vehicles, while firm energy consumption includes the remaining transportation energy, along with energy use in the industrial and commercial sectors.

I extract household energy consumption as fuel for personal vehicles in three steps. First, I calculate household expenditures on motor fuel by subtracting residential energy expenditures from household total energy expenditures reported in the National Income and Product Accounts (NIPA).<sup>7</sup> Second, I determine the price of transportation energy using consumption and expenditure data from the EIA. Finally, I obtain energy use for personal vehicles by dividing household motor fuel expenditures by the calculated price.

<sup>6.</sup> Final-use energy refers to energy commodities that households and firms directly consume, such as electricity, gasoline, and piped gas.

<sup>7.</sup> Table 2.3.5. Personal Consumption Expenditures by Major Type of Product.



PATTERNS OF ENERGY CONSUMPTION

*Note.* The figure plots historical patterns of energy consumption in the U.S., represented as a share of total final-use energy, measured in British Thermal Units (BTU).

**Fact.** Figure 2 plots the patterns of energy consumption across sectors in the U.S. from 1970 to 2020. Over this period, the shares of energy consumption in all sectors have remained fairly constant, except for a slight decrease in the industrial sector and a slight increase in the commercial sector. The industrial sector accounts for approximately one-third of total energy consumption, followed by the transportation, residential, and commercial sectors. In the transportation sector, about half of the energy is directly consumed by households as fuel for personal vehicles, while the rest is used to provide transportation services.

Overall, Figure 2 indicates that approximately two-thirds of the total energy is used as an input to produce non-energy goods and services. Consequently, considering energy as an input in non-energy goods and services production is non-trivial for my study.

#### 3.2. Response of Energy Demand in Production to Its Price Fluctuations

Figure 3 summarizes the energy demand in the U.S. production sector since 1970. It plots firms' energy expenditure share ( $E_F$  exp. share), energy intensity of output ( $E_F/Y$ ), and the average real price of final-use energy ( $\tilde{p}_E$ ) from 1970 to 2020.

The figure shows that the expenditure share varies with short-run price fluctuations, while the energy intensity of output does not, suggesting limited substitutability between



ENERGY INTENSITY OF OUTPUT

*Note.* The figure shows the firms' energy expenditure share ( $E_F exp. share$ ), the (final-use) energy intensity of output ( $E_F/Y$ ), and the average real energy price ( $\tilde{p}_E$ ) in the U.S. from 1970 to 2020. These plotted objects are related through the identity  $E_F exp. share = \tilde{p}_E \cdot (E_F/Y)$ . The markers represent data points normalized to 1970 values, and the lines show 5-year moving averages.

energy and non-energy inputs in the short run.<sup>8</sup> However, energy intensity declines over the long run, likely due to technological changes or sectoral reallocation (Sue Wing, 2008).<sup>9</sup>

# 3.3. Heterogeneity in Energy Expenditure Shares Across Households

**Data.** I analyze variations in household energy expenditures across income groups using quarterly household-level data from the CEX, a nationally representative survey conducted by the Bureau of Labor Statistics (BLS). The CEX provides detailed data on income, expenditures, and demographic characteristics of U.S. households. Its comprehensive coverage of household consumption expenditures makes it particularly well-suited for my analysis.

I use data spanning from 1999 to 2013, restricting the sample to households with heads aged 25 to 64, participated in at least four interviews, and are complete income reporters.<sup>10</sup>

10. I choose 2013 as the final year of my CEX sample due to the termination of the variable representing

<sup>8.</sup> Hassler, Krusell, and Olovsson (2021) estimate the short-run elasticity of substitution between energy and non-energy inputs using maximum likelihood and find it close to zero.

<sup>9.</sup> Decomposition analyses suggest that improvements in intra-sectoral efficiency, rather than sectoral reallocation, have been the principal driver of falling energy intensity over the years (see, e.g., Metcalf, 2008; Sue Wing, 2008). Several studies in energy crisis and climate policy literature reveal a significant shift in energy prices and energy efficiency improvements coinciding with the energy crisis of the early 1970s (e.g., Baumeister and Kilian, 2016; Fried, 2018; Hassler et al., 2021). Prior to the crisis, energy prices were either constant or decreasing and decomposition analyses suggest that sectoral reallocation was the primary factor driving the reduction in energy intensity for that period (Sue Wing, 2008).

The dataset is constructed following the methodology of Aguiar and Bils (2015), which closely aligns with Krueger and Perri (2006) and Heathcote, Perri, and Violante (2010). The CEX includes household expenditures on hundreds of different items. I categorize these items in household consumption baskets into three broad groups: (i) *commuting energy*, which includes energy commodities consumed as fuel for personal vehicles for commuting to work; (ii) *residential energy*, which includes energy commodities used for purposes other than commuting to work; and (iii) *non-energy*.

The CEX does not report direct information on energy expenditures for commuting to work. However, it provides household expenditures on gasoline and motor oil, including specific spending on these items for long drives and vacations. To extract energy expenditures for commuting to work, I first subtract household energy expenditures for long drives and vacations from their total gasoline and motor oil expenditures. Next, I regress the log of the resulting variable on log after-tax income, log household total expenditure, quadratic time trends, and a binary dummy variable indicating households with zero earners. The coefficient of the dummy variable represents the percentage difference in gasoline expenditures between employed and non-employed households. Using this coefficient, I obtain employed households' energy expenditure for commuting to work. The remaining gasoline expenditures are merged with the residential energy expenditures.<sup>11</sup>

**Fact.** Figure 4 plots household expenditure shares on residential and commuting energy by income deciles. The plotted moments are time-averaged over the sample period (1999-2013). The figure shows a clear negative relationship between household expenditure shares on energy and income levels. Specifically, the expenditure share on residential energy is 4.5 percentage points higher for the lowest income decile than the highest. For

complete income information. On the other hand, I choose 1999 as the starting year to maintain consistency with my quantitative analysis. To estimate parameters related to household consumption preferences, I use a 'Hausman' relative-price instrument, which is constructed by combining the CEX expenditure data with disaggregated regional quarterly price series from the BLS's Urban CPI (CPI-U), which started in 1999. However, it is worth noting that extending the sample period in both directions yields very similar results.

<sup>11.</sup> Given the rise in energy-efficient and electric cars in recent years, commuting energy expenditures are likely lower than those obtained using the above procedure, particularly for high-income groups. Consequently, my measure of commuting energy expenditure share can be considered as an upper bound.



FIGURE 4

DISTRIBUTIONS OF HOUSEHOLD EXPENDITURE SHARE ON RESIDENTIAL AND COMMUTING ENERGY

*Note.* The figure shows the distributions of household expenditure shares for residential (Panel A) and commuting (Panel B) energy using the CEX data. Commuting energy shares are conditional on employment. However, income groups remain unconditional for consistency.

commuting energy, the difference between the lowest and highest income deciles is approximately 0.80 percentage points. This negative relationship between expenditure shares on energy (both residential and commuting) and income remains consistent across various subgroups, including age, family size, education level, and region, confirming that the relation is not a compositional effect but a direct and robust association.<sup>12</sup>

Overall, Figure 4 indicates that the composition of household energy and non-energy consumption varies across income groups. In other words, household preferences over energy and non-energy consumption goods are non-homothetic.

# 3.4. Energy Price Surge and Consumption Response across Income Groups

To examine how a surge in energy prices affects household consumption across income groups, I analyze data from the CEX interview survey following the 2021 energy price surge.<sup>13</sup> The survey includes households in a maximum of four interviews over four consecutive quarters. I restrict the sample to households with heads aged 25 to 64 who par-

<sup>12.</sup> See Section G of the Online Appendix for details.

<sup>13.</sup> The U.S. CPI indicates that during 2021:Q1-2022:Q2 the relative price of energy increases by nearly 20%.

ticipated in four interviews between 2021:Q1 and 2022:Q2, resulting in a final sample of 1,241 households.<sup>14</sup> To increase the sample size, I include interviews from these six quarters instead of any four consecutive ones. I classify households into three income groups. To address potential sampling error, I limit the number of groups to three and use the CEX income rank (i.e., income percentiles) for classification.

In Table 1, I present descriptive statistics for households' first (Panel A) and fourth (Panel B) interviews. Columns 2 through 4 present statistics for three income groups, while the last column presents statistics for the full sample. The values in the table represent real consumption expenditures, which serve as a proxy for real consumption. I deflate households' nominal consumption expenditures using twenty-two category-specific regional CPIs, with 2020:Q4 as the base period.<sup>15</sup>

Comparing household consumption between the first and fourth quarters, I find that overall expenditure decreases across all income groups, with the middle-income group experiencing the largest reduction (-13.59%), followed by the bottom (-11.66%) and the top (-9.50%). Specifically, energy consumption decreases by 6.22% for the bottom group and 1.93% for the middle group, while the top group's energy consumption remains nearly unchanged. Within the energy category, gasoline consumption increases by 5.51% for the middle and 2.25% for the top group but decreases by 5.66% for the bottom group. Conversely, non-gasoline energy consumption declines across all groups: 6.61% for the bottom, 8.18% for the middle, and 1.54% for the top.

Following my energy classification, commuting energy consumption increases by 4.58% for the middle group and 2.69% for the top group, while it decreases by 3.29% for the bottom group. On the other hand, residential energy consumption declines for all groups, with the bottom group experiencing the largest reduction (-6.94%) and the top group experiencing the smallest reduction (-0.5%). Finally, non-energy consumption substantially declines for all groups, with a 14.62% reduction for the middle group, followed by 12.22%

<sup>14.</sup> The interview survey reports expenditures for the three months before the interview. Consequently, households interviewed in 2021:Q1 report their expenditures within 2020:Q4-2021:Q1, and those interviewed in 2022:Q2 report expenditures within 2022:Q1-2022:Q2.

<sup>15.</sup> See Section B.2 of the Online Appendix for details.

	Income Groups (Percentiles)				
	$\leq$ 33	34-67	> 67		
Panel A: First Quarter					
Quarterly Expenditure	\$8188.54	\$10917.89	\$17715.40		
	[\$7269.71 \$9107.37]	[\$10185.21 \$11650.57]	[\$16466.13 \$18964.67]		
Energy	\$766.39	\$883.90	\$1149.78		
	[\$690.73 \$842.04]	[\$833.88 \$933.92]	[\$1099.29 \$1200.28]		
Gasoline	\$313.16	\$403.64	\$532.52		
	[\$261.99 \$364.33]	[\$370.59 \$436.69]	[\$496.83 \$568.21]		
Non-Gasoline	\$453.23	\$480.26	\$617.26		
	[\$406.49 \$499.96]	[\$447.55 \$512.97]	[\$585.35 \$649.17]		
Commuting	\$150.57	\$195.81	\$250.35		
	[\$126.36 \$174.78]	[\$179.66 \$211.97]	[\$233.05 \$267.65]		
Residential	\$615.82	\$688.09	\$899.43		
	[\$556.96 \$674.68]	[\$649.00 \$727.17]	[\$860.52 \$938.34]		
Non-Energy	\$7422.15	\$10033.99	\$16565.62		
	[\$6541.48 \$8302.82]	[\$9314.93 \$10753.05]	[\$15338.06 \$17793.18]		
Panel B: Fourth Quarter					
Quarterly Expenditure	\$7233.69	\$9434.09	\$16031.61		
	[\$6404.71 \$8062.66]	[\$8925.21 \$9942.96]	[\$14727.52 \$17335.71]		
Energy	\$718.69	\$866.84	\$1152.33		
	[\$645.27 \$792.12]	[\$819.13 \$914.54]	[\$1102.41 \$1202.25]		
Gasoline	\$295.43	\$425.90	\$544.54		
	[\$242.14 \$348.72]	[\$392.97 \$458.83]	[\$513.78 \$575.30]		
Non-Gasoline	\$423.26	\$440.94	\$607.78		
	[\$379.20 \$467.33]	[\$412.97 \$468.90]	[\$575.90 \$639.67]		
Commuting	\$145.61	\$204.77	\$257.09		
	[\$119.14_\$172.07]	[\$188.73 \$220.81]	[\$242.29 \$271.88]		
Residential	\$573.09	\$662.07	\$895.24		
	[\$518.65 \$627.52]	[\$626.03 \$698.10]	[\$855.84 \$934.64]		
Non-Energy	\$6515.00	\$8567.25	\$14879.29		
	[\$5719.95 \$7310.04]	[\$8071.20 \$9063.31]	[\$13595.72 \$16162.85]		

TABLE 1Descriptive Statistics of Household Expenditures in Their First and Fourth Quarters<br/>Between 2020:Q4 and 2022:Q1

*Note.* The table presents summary statistics of household quarterly consumption expenditures from the CEX interview survey. The sample is restricted to households with heads aged 25 to 64 who participated in four consecutive interviews between 2021:Q1 and 2022:Q2 and is divided into three income groups. Panel A reports summary statistics from the first interview, while Panel B reports statistics from the fourth and final interview. Dollar amounts are deflated using category-specific regional CPIs, with 2020:Q4 as the base period. The 95% confidence intervals are reported in square brackets.

for the bottom group and 10.18% for the top group.

Overall, the evidence in this subsection indicates that commuting and residential energy consumption may respond differently to an energy price shock, with the impacts varying

across households in different income groups.

The empirical evidence presented in this section motivates the key features of the quantitative model developed in the following section.

#### 4. QUANTITATIVE MODEL

Time is discrete, indexed by  $t = 1, 2, 3, \dots$ , and continues forever. The economy is populated by a continuum of infinitely-lived households with unit measure. Households differ in their labor efficiency  $z_t \in \mathcal{Z}$ . Each household is endowed with one unit of time per period, yielding  $z_t$  units of efficient labor services, where  $z_t$  is independent and identically distributed across households and follows a Markov process. There is no direct insurance against idiosyncratic labor productivity risks. However, households can self-insure by saving or borrowing in a non-state-contingent asset subject to a borrowing constraint.

In the economy, energy serves multiple roles, such as household consumption and production input.<sup>16</sup> It is entirely imported at an exogenous price  $\tilde{p}_{Et}$  as in Kim and Loungani (1992); Alpanda and Peralta-Alva (2010), among others.

#### 4.1. Technology

Firms in a perfectly competitive sector operate using capital, labor, and energy as inputs. To capture the low short-run elasticity of substitution between energy and non-energy inputs, as observed in the literature (see, e.g., Hassler, Krusell, and Olovsson, 2021; Casey, 2023), I consider a constant returns to scale (CRS) Leontief production technology:

$$Y_t = \min\left[K_t^{\alpha} L_t^{1-\alpha}, \kappa A_{Et} E_{Ft}\right],\tag{1}$$

s.t. 
$$\kappa A_{Et} E_{Ft} \leq K_t^{\alpha} L_t^{1-\alpha}$$
, (2)

where  $K_t$  is the capital input,  $L_t$  is the labor input measured in efficiency units,  $E_{Ft}$  is the energy input,  $\alpha \in (0, 1)$  is the output elasticity of capital, and  $\kappa A_{Et}$  represents the energy effi-

<sup>16.</sup> Since all energy prices are highly correlated, I consider a single energy price to enhance tractability and reduce computational burden.

ciency of the production technology.<sup>17</sup>  $A_{Et}$  captures energy-efficient technological progress, and  $\kappa > 0$  is the base level of efficiency in the absence of technological progress.<sup>18</sup> The evolution of the aggregate capital stock is given by:

$$K_{t+1} = (1 - \delta)K_t + I_t,$$
(3)

where  $I_t$  is gross investment and  $\delta$  is the capital depreciation rate.

The Cobb-Douglas composite of capital and labor in equation (1) measures the maximum level of output, and the production process requires energy to operate. The notion of maximum output is captured by constraint in equation (2). In each period, a fraction of the output is devoted to meeting household non-energy consumption, while the remaining fraction is exported to balance trade for the economy's energy imports.

#### 4.2. Preferences

Households derive utility from a basket of consumption goods,  $\mathbf{x}$ , and incur disutility from labor supply, h. The period utility function is separable over consumption and labor supply:  $u(\mathbf{x}, h) = u_x(\mathbf{x}) - u_h(h)$ , where  $u_x$  is strictly increasing, concave, and twice continuously differentiable in its arguments, representing the utility from energy ( $E_R$ ) and nonenergy (C) consumption goods. Energy in the utility function only refers to residential use of energy (i.e., energy use other than commuting to work). Households also consume energy to commute to work, which provides no direct utility. The other part of the utility function  $u_h$  is strictly increasing, convex, and twice continuously differentiable in its argument, capturing the disutility from work. Let  $\beta \in (0, 1)$  be the time discount factor, then the household lifetime utility is given by:

$$\mathcal{U}_0 = \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t \left( u_{xt}(\boldsymbol{x}_t) - u_{ht}(h_t) \right) \right], \tag{4}$$

<sup>17.</sup> Using a capital-labor composite is a more attractive nesting option than alternatives. Specifically, a structure where either capital or labor forms a composite with energy would imply significant changes in the capital or labor income shares in response to energy shocks. However, such changes are not observed in the data (see, e.g., Hassler, Krusell, and Olovsson, 2021).

<sup>18.</sup> Energy-efficient technological progress can address the long-run decline in energy intensity in production, as shown in Figure 3.

where  $\mathbb{E}_0$  denotes the expectation conditional on the information available at time t = 0.

#### 4.3. Budget Constraint

Each period, households' pre-government income comes from two sources: (i) earnings,  $z_tw_th_t$ , where  $w_t$  represents the wage per efficiency unit of labor hour; and (ii) asset income,  $r_ta_t$ , for  $a_t > 0$ , where  $r_t$  denotes the rate of return of the non-state-contingent asset  $a_t \in \mathcal{A} \equiv [\underline{a}, \infty)$ . Households pay taxes on their pre-government income and receive transfers. With disposable income (i.e., income minus taxes plus transfers), households decide on consumption and whether to save or borrow, subject to a borrowing constraint that must not exceed  $\underline{a}$ , where  $\underline{a} \leq 0$ . Hence, the household budget constraint is given by:

$$p_{Et} \Big( E_{Rt} + E_{Tt} (z_t w_t h_t) \cdot \mathbb{1}_{\{h_t > 0\}} \Big) + C_t + a_{t+1} =$$

$$z_t w_t h_t - \mathcal{T} (z_t w_t h_t) + (1 + (1 - \tau^a) r_t) a_t + T(a_t) \cdot \mathbb{1}_{\{h_t = 0\}},$$

$$a_{t+1} \ge \underline{a}, \text{ with } \underline{a} \le 0,$$
(6)

where the price of the non-energy consumption is normalized to 1, and  $p_{Et}$  denotes the relative price of energy.  $E_{Tt} (z_t w_t h_t)$  represents the household energy use for commuting. The indicator function,  $\mathbb{1}_{\{h_t>0\}}$ , is equal to one if  $h_t > 0$  and zero otherwise, implying that commuting costs are applicable only to households with non-zero working hours.  $\mathcal{T} (z_t w_t h_t)$ is the net tax on earnings, calculated using a parametric class of tax and transfer functions  $\mathcal{T}(\cdot)$ .  $(1 - \tau^a)r_t$  is the after-tax rate of return, where  $\tau^a$  is a flat-rate tax on asset income. The last term  $T(a_t)$  represents the means-tested transfers, and the indicator function,  $\mathbb{1}_{\{h_t=0\}}$ , equals one if the household is non-employed ( $h_t = 0$ ) and zero if employed ( $h_t > 0$ ). This transfer is determined as follows:

$$T(a_t) = \max\left\{0, \bar{e} - (1 + (1 - \tau^a)r_t) a_t \cdot \mathbb{1}_{\{a_t > 0\}}\right\},\tag{7}$$

where  $\bar{e}$  denotes the maximum level of lump-sum transfer that a non-employed household can receive. The indicator function,  $\mathbb{1}_{\{a_t>0\}}$ , equals zero if  $a_t \leq 0$  and one if  $a_t > 0$ . Specifically, Equation (7) suggests that non-employed households receive  $\bar{e}$  net of what they could afford by selling off their wealth.

#### 4.4. Government

The government collects taxes on asset returns and earnings and disburses transfers back to households. To ensure a minimum level of consumption expenditure for non-employed households, it operates a means-tested transfer program. Without this transfer program, households with zero wealth would be compelled to work to finance their consumption, irrespective of their productivity level.

The government budget is balanced each period, with spending (i.e., government consumption expenditure,  $G_t$ , and transfers) equaling tax revenues.

#### 4.5. Household Problem

I formulate the household problem in recursive form and use primes to denote next-period variables. The value function of a household with asset possession *a* and productivity level *z* at time *t* is  $V_t(a, z) = \max \{V_t^E(a, z), V_t^U(a, z)\}$ , where  $V_t^E(a, z)$  and  $V_t^U(a, z)$  are the value functions conditional on working and not working, respectively. The household decides to work if  $V_t^E(a, z) > V_t^U(a, z)$  and decides not to work if otherwise.

If the household decides to work, its value function is given by:

$$\begin{aligned} V_t^E(a,z) &= \max_{\{\pmb{x}_t,h_t,a'\}} \Big\{ u_{xt}(\pmb{x}_t) - u_{ht}(h_t) + \beta \mathbb{E}_t \left[ V(a',z') | z \right] \Big\}, \\ \text{s.t.} \quad P_t \pmb{x}_t + p_{Et} E_{Tt}(zw_t h_t) + a' &= zw_t h_t - \mathcal{T} \left( zw_t h_t \right) + (1 + (1 - \tau^a) r_t) a; \\ a' &\geq \underline{a}, \ \pmb{x}_t \geq 0, \ h_t \in [0,1], \end{aligned}$$

where  $P_t$  is the price index of the household consumption basket  $x_t$ .

In contrast, if the household decides not to work, its value function is given by:

$$V_t^{U}(a, z) = \max_{\{\bm{x}_t, a'\}} \left\{ u_{xt}(\bm{x}_t) + \beta \mathbb{E}_t \left[ V(a', z') | z \right] \right\},$$
  
s.t.  $P_t \bm{x}_t + a' = (1 + (1 - \tau^a) r_t) a + T(a);$   
 $a' \ge \underline{a}, \ \bm{x}_t \ge 0.$ 

#### 4.6. Firm Problem

Each period, a representative firm rents capital at rate  $R_t \equiv r_t + \delta$ , hires labor at wage  $w_t$ , and purchases energy at price  $p_{Et}$  to carry out production and maximize profits:

$$\max_{\{L_t, E_{F_t}, K_t\}} \Pi_t \equiv Y_t - R_t K_t - w_t L_t - p_{Et} E_{F_t},$$
(8)

subject to the production technology in equation (1). The output price is normalized to one. The price of the energy input is exogenous, while the rental rate of capital and wage equal their respective marginal products:

$$R_t = \alpha \left( 1 - \frac{p_{Et}}{\kappa A_{Et}} \right) \left( \frac{K_t}{L_t} \right)^{\alpha - 1};$$
(9)

$$w_t = (1 - \alpha) \left( 1 - \frac{p_{Et}}{\kappa A_{Et}} \right) \left( \frac{K_t}{L_t} \right)^{\alpha}.$$
 (10)

Equations (9) and (10) show that the rental rate and the wage are functions of the energy price and energy efficiency in production, implying that a change in the energy price or energy efficiency can directly impact both non-energy factor prices.

#### 4.7. Equilibrium

I consider the economy to be initially in a steady state without aggregate uncertainty and unexpectedly encounter an exogenous shock to the energy price. Following the shock, households have perfect foresight over the future sequence of the energy price.

The state space is denoted as  $S \equiv A \times Z$  and households are indexed by  $s \equiv (a, z) \in S$ . Let  $\Sigma_S$  be the sigma algebra on S and  $(S, \Sigma_S)$  represents the corresponding measurable space. The measure of households on  $(S, \Sigma_S)$  in period t is denoted as  $\Gamma_t$  and the stationary distribution is denoted as  $\Gamma^*$ .

Given  $\Gamma^*$  and the sequence of energy price, a *competitive equilibrium* is a sequence of household decision rules for commuting energy consumption, residential energy consumption, non-energy consumption, hours worked, and savings  $\{E_{Tt}(s), E_{Rt}(s), C_t(s), h_t(s), a_{t+1}(s)\}$ ; value functions  $\{V_t(s)\}$ ; firm allocations  $\{K_t, L_t, E_{Ft}\}$ ; non-energy factor prices  $\{r_t, w_t\}$ ; government expenditures  $\{G_t, T_t(s)\}$ ; and measures of households  $\{\Gamma_t\}$  such that,

for all *t*, the following conditions are satisfied:

- (i) Household decision rules solve Bellman equations.
- (ii) Firms maximize profits.
- (iii) The government budget is balanced:

$$G_t + \int_{\mathcal{S}} T_t(s) \, d\Gamma_t = \tau^a r_t \int_{\mathcal{S}} a_t \, d\Gamma_t + \int_{\mathcal{S}} \mathcal{T}\big(z_t w_t h_t(s)\big) \, d\Gamma_t. \tag{11}$$

(iv) The capital market clears:

$$\int_{\mathcal{S}} a_t \, d\Gamma_t = K_t. \tag{12}$$

(v) The labor market clears:

$$\int_{\mathcal{S}} z_t h_t(s) \, d\Gamma_t = L_t. \tag{13}$$

Note that  $L_t$  is the aggregate efficiency-weighted labor hours. Aggregate labor hours can be expressed as:

$$\int_{\mathcal{S}} h_t(s) \, d\Gamma_t = H_t. \tag{14}$$

(vi) The goods market clears:

$$Y_t = \int_{\mathcal{S}} C_t(s) \, d\Gamma_t + p_{Et} \int_{\mathcal{S}} \left( E_{Rt}(s) + E_{Tt}(s) \right) \, d\Gamma_t + p_{Et} E_{Ft} + G_t + I_t, \tag{15}$$

where  $I_t$  follows equation (3).

#### 4.8. Mechanisms

In the model, an energy price shock impacts household consumption and labor supply decisions both directly and indirectly.

First, a change in energy price directly impacts household consumption by affecting their real income, leading to adjustments in the composition of energy and non-energy consumption. Due to non-homothetic consumption preferences, these changes vary across households with different income levels.

Second, a change in energy price changes household commuting costs, affecting the resources available for other consumption and savings. The resulting change in household consumption affects their marginal utility, consequently influencing their labor sup-

ply decisions. However, since household commuting costs depend on their earnings, ceteris paribus, any change in labor supply decisions will, in turn, affect their commuting costs. Thus, a trade-off between additional commuting costs and earnings influences both the direction and magnitude of labor supply adjustments.

Third, since energy is a factor input for non-energy production, a change in energy price directly impacts energy use in production due to changes in costs. Consequently, firms adjust their factor composition, which affects respective marginal productivities, leading to changes in wages and the rental rate of capital. These adjustments, in turn, influence house-hold consumption and labor supply decisions by impacting their income. In addition, an energy price shock indirectly impacts firms' decisions due to changes in demand for non-energy goods in the economy. This change in demand occurs for two reasons. First, since all energy is imported and trade is balanced by exporting endogenously produced non-energy goods, a change in energy price impacts the demand for these goods. Second, as described earlier, an energy price shock influences household demand for non-energy consumption. Therefore, the aggregate demand for non-energy goods changes, affecting firms' demand for factors by impacting the scale of production.

#### 5. PARAMETERIZATION

I now describe the calibration strategy of the model. I specify functional forms and determine the model parameters. The model period is set to one quarter. A subset of parameters is adopted directly from the literature. Among others, a subset of preference parameters is obtained by estimating the household demand system derived from the model. The remaining parameters are jointly calibrated by matching an equal number of model moments (computed in the initial steady-state equilibrium) to their empirical counterparts.<sup>19</sup> Although every parameter influences every moment, I can point to some strong economic relationships between particular moments and parameters.

<sup>19.</sup> For readers' convenience, I summarize the calibration strategy and present the parameter values in Table F.1 and Table F.2 in the Online Appendix.

#### 5.1. Technology

Following the literature, I set the output elasticity of capital  $\alpha$  to 0.36. Given my main focus on the short-run impacts of an energy price shock, in the baseline analysis, I abstract from technological progress and normalize  $A_{Et}$  to 1. The base energy efficiency of production technology  $\kappa$  is set to 20.0, ensuring that in the initial steady state, firms' expenditure on energy as a share of output matches its empirical counterpart (4.1%). The depreciation rate of capital  $\delta$  is set to 1.53% per quarter, equivalent to a yearly depreciation rate of 6%.

#### 5.2. Idiosyncratic Labor Productivity

I calibrate the stochastic process for idiosyncratic labor productivity in two steps. First, I assume that productivity follows a first-order autoregressive process (AR(1)) in logarithms:

$$\log z_t = \rho_z \log z_{t-1} + \sigma_z \varepsilon_{zt},\tag{16}$$

where  $\varepsilon_{zt} \in \mathbb{R}$  is a standard normal shock,  $\rho_z \in (0, 1)$  denotes the persistence of the shock, and  $\sigma_z \ge 0$  represents its volatility. Following Floden and Lindé (2001), I assign the persistence  $\rho_z$  to 0.975 and the standard deviation  $\sigma_z$  to 0.165. I then approximate the AR(1) process with a sixteen-state Markov chain using the Rouwenhorst method.<sup>20</sup>

Second, based on Castañeda, Díaz-Giménez, and Ríos-Rull (2003), I incorporate an extreme productivity state,  $z_{max}$ , which can only be reached from the upper half of the normal productivity states with equal probability. I introduce two additional parameters,  $\pi_{up}$  and  $\pi_{stay}$ , representing the probabilities of transitioning from z to  $z_{max}$  and of remaining at  $z_{max}$ , respectively. I calibrate these parameters to match the following moments: (i) the wealth share of the top wealth decile (66.44%); (ii) the earnings share of the top earnings decile (35.04%); and (iii) the earnings share of the top 1% of the earnings distribution (11.62%).<sup>21</sup> This procedure yields  $z_{max} = 20.85$ ,  $\pi_{up} = 7.03 \times 10^{-4}$ , and  $\pi_{stay} = 0.98$ .

<sup>20.</sup> See Rouwenhorst (1995) and Kopecky and Suen (2010) for details.

<sup>21.</sup> All three data moments are computed using the biennial waves of the Panel Study of Income Dynamics (PSID) from 1999 to 2013, focusing on households with heads aged 25 to 64.

#### 5.3. Preferences

I set the time discount factor  $\beta = 0.981$  to match the annual after-tax rate of return on assets of 4.1% (McGrattan and Prescott, 2003; Gomme, Ravikumar, and Rupert, 2011).

I specify the household period utility function as:

$$u\left(\boldsymbol{x},h\right) = u_{x}(\boldsymbol{x}) - u_{h}(h),\tag{17}$$

with

$$u_{x}(\boldsymbol{x}) = \begin{cases} \frac{\boldsymbol{x}^{1-\gamma}-1}{1-\gamma} & \text{if } \gamma \neq 1;\\ \log \boldsymbol{x} & \text{if } \gamma = 1, \end{cases}$$
(18)

and

$$u_{h}(h) = \varphi_{1} \frac{h^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}} + \varphi_{2} \cdot \mathbb{1}_{\{h>0\}},$$
(19)

where  $\gamma \ge 0$  governs the relative risk aversion,  $\nu \ge 0$  represents the Frisch elasticity of labor supply,  $\varphi_1 \ge 0$  determines the disutility from intensive margin labor supply, and  $\varphi_2 \ge 0$  is a fixed utility cost from working positive hours. The indicator function,  $\mathbb{1}_{\{h>0\}}$ , is equal to zero if h = 0 and equal to one when h > 0.

I set the coefficient of relative risk aversion  $\gamma$  to 2 and the Frisch elasticity of labor supply  $\nu$  to 0.5.<sup>22</sup> The disutility from intensive margin labor supply  $\varphi_1$  is set to 38.84, ensuring that in the initial steady state employed households allocate on average one-third of their time to work. The fixed utility cost from working  $\varphi_2$  is set to 0.52, such that the model reproduces the aggregate employment rate of 79.63% in the initial steady state.

The consumption basket x consists of residential energy ( $E_R$ ) and non-energy goods (*C*), aggregated using a non-homothetic CES aggregator based on Comin, Lashkari, and Mestieri (2021). Thus, x is implicitly defined as:

$$1 = \left[\Omega_{E_R}^{\frac{1}{\sigma}} \left(\frac{E_R}{\boldsymbol{x}^{\epsilon_{E_R}}}\right)^{\frac{\sigma-1}{\sigma}} + \Omega_C^{\frac{1}{\sigma}} \left(\frac{C}{\boldsymbol{x}^{\epsilon_C}}\right)^{\frac{\sigma-1}{\sigma}}\right],\tag{20}$$

where  $\sigma \geq 0$  denotes the elasticity of substitution between residential energy and non-

<sup>22.</sup> See Keane (2011) for the microeconomic evidence on the Frisch elasticity.

energy consumption,  $\Omega_{E_R} \ge 0$  and  $\Omega_C \ge 0$  are good-specific constant weight parameters, and  $\epsilon_{E_R} \in \mathbb{R} \setminus \{0\}$  and  $\epsilon_C \in \mathbb{R} \setminus \{0\}$  govern the expenditure elasticities of demand for the respective goods. Equation (20) embeds the property of non-homothetic consumption preferences, which rationalizes the systematic variation in demand for energy and non-energy goods across income levels.<sup>23</sup> The usual CES aggregators assumed under homothetic preferences are a particular case of equation (20) with  $\epsilon_C = \epsilon_{E_R} = 1$ .

Based on the above specification of preferences, the optimal demands for residential energy and non-energy goods are as follows:

$$E_R = \Omega_{E_R} \left(\frac{p_E}{Exp}\right)^{-\sigma} \boldsymbol{x}^{\epsilon_{E_R}(1-\sigma)};$$
(21)

$$C = \Omega_C \left(\frac{p_C}{Exp}\right)^{-\sigma} \boldsymbol{x}^{\epsilon_C(1-\sigma)},$$
(22)

where *Exp* denotes the household consumption basket expenditure. I estimate this demand system using quarterly U.S. household consumption expenditure data from the CEX and disaggregated regional quarterly price series from the BLS to obtain the elasticity of substitution and the non-homotheticity parameters. Since the estimation procedure closely follows Comin, Lashkari, and Mestieri (2021), a brief description is provided in the main text, with further details available in Section C of the Online Appendix.

To obtain the estimating equation, I begin by expressing the ratio of household expenditure shares on residential energy ( $\omega_{E_R}$ ) and non-energy ( $\omega_C$ ) goods:

$$\ln\left(\frac{\omega_{E_R}}{\omega_C}\right) = (1-\sigma)\ln\left(\frac{p_E}{p_C}\right) + (1-\sigma)(\epsilon_{ER}-1)\ln\left(\frac{Exp}{p_C}\right) + (\epsilon_{E_R}-1)\ln\omega_C + \underbrace{\ln\left(\Omega_{E_R}\right)}_{\text{constant} \equiv \zeta},$$
(23)

where without loss of generality, I normalize  $\epsilon_C = \Omega_C = 1$ . The variables on both sides of equation (23) are observable. I estimate an empirical counterpart of equation (23) using the

<sup>23.</sup> See Matsuyama (2019) and Comin, Lashkari, and Mestieri (2021) for details.

Parameter	(1)	(2)	(3)
σ	0.251*** (0.015)	0.303*** (0.014)	0.248*** (0.021)
$\epsilon_{E_R}$	0.328*** (0.017)	0.301*** (0.017)	0.346*** (0.020)
Region FE	$\mathcal{X}$	$\checkmark$	$\checkmark$
Year $\times$ Quarter FE	$\mathcal{X}$	$\mathcal{X}$	$\checkmark$

TABLE 2Demand Estimation

*Note.* All regressions include household controls: age (25-37, 38-50, 51-64), household size ( $\leq 2$ , 3-4, 5+), and the number of earners (1, 2+). Standard errors clustered at the household level are shown in parentheses. The number of observations is 130,132 in all regressions. \*\*\* indicates significance at the 1% level.

Generalized Method of Moments (GMM) and report the estimation results in Table 2.<sup>24</sup>

To address potential measurement error and endogeneity issues, I instrument the observed measures of household expenditures and relative prices. First, I instrument quarterly household expenditures with annual after-tax household income and income quintile, following Aguiar and Bils (2015) and Comin, Lashkari, and Mestieri (2021). This instrument captures permanent household income and thus correlates with household expenditures while remaining unaffected by transitory measurement error in total spending. Second, I instrument the relative price of household consumption with Hausman-style relative price, as in Comin, Lashkari, and Mestieri (2021). The price of each consumption category in the relative-price instrument is constructed in two steps. In the first step, for each sub-component of a consumption category, I compute the average price across regions, excluding the own region. Next, the price of each consumption category for a region is constructed using the region-specific expenditure shares of each sub-component as

24. The empirical counterpart of equation (23) used in the estimation process is as follows:

$$\ln\left(\frac{\omega_{iERt}}{\omega_{iCt}}\right) = (1-\sigma)\ln\left(\frac{p_{iEt}}{p_{iCt}}\right) + (1-\sigma)(\epsilon_{ER}-1)\ln\left(\frac{Exp_{it}}{p_{iCt}}\right) + (\epsilon_{ER}-1)\ln\omega_{iCt} + \zeta_{iER} + \varepsilon_{iERt}$$

where  $p_{iERt}$  and  $p_{iCt}$  are, respectively, the prices of energy and non-energy goods faced by household *i* at time *t*. Each of these prices is constructed by taking the household expenditure-weighted average log prices of all sub-components within the respective consumption category. Since expenditure weights are household-specific, this allows me to (imperfectly) account for the fact that each category's effective price may differ across households.  $\zeta_{iER} \equiv \ln(\Omega_{iER})$  accounts for relative taste parameter and  $\varepsilon_{iERt}$  represents the error term. In Section C of the Online Appendix, I also show that the expenditure elasticities computed using the structurally estimated parameter values are consistent with their respective reduced-form estimates.

weights. This price instrument captures the common trend in U.S. household consumption prices and addresses endogeneity concerns arising from regional shocks.

The remaining preference parameter  $\Omega_{E_R}$  is calibrated to ensure that in the initial steady state the average share of consumption basket expenditure on residential energy matches its empirical counterpart of 7.94%. This procedure yields a value of 0.08 for  $\Omega_{E_R}$ .

# 5.4. Tax and Transfer System

The tax and transfer system is parameterized to mimic key features of the U.S. tax and transfer system. I specify government consumption G as a fraction g of aggregate output and set g to 20%, reflecting the average share of government purchases (consumption plus investment) in the U.S. gross domestic product (GDP) over the past five decades.

Following the literature, I set the capital income tax rate  $\tau^a$  to 36% (see, e.g., Trabandt and Uhlig, 2011). I use a parametric class of tax functions to capture the progressivity of U.S. earnings taxation, according to which taxes on earnings are defined as follows:

$$\mathcal{T}(y) = y - \lambda y^{1 - \tau'},\tag{24}$$

where *y* denotes pre-tax earnings,  $\lambda$  captures the level of earnings taxation and allows the tax function to shift without affecting the degree of progressivity, and  $\tau^l \in [-1, 1]$  indexes the degree of tax progressivity. Specifically,  $\tau^l \in [-1, 0)$  implies a regressive tax system,  $\tau^l = 0$  implies a flat tax system with a rate of  $1 - \lambda$ ,  $\tau^l \in (0, 1)$  implies a progressive tax system, and  $\tau^l = 1$  implies a fully redistributive tax system where post-tax earnings equals  $\lambda$ .<sup>25</sup> Following Heathcote, Storesletten, and Violante (2020),  $\tau^l$  is set to 0.09, an estimate obtained by excluding transfers from disposable income. Given the other fiscal parameters,

25. A tax schedule is commonly classified as progressive (regressive) if the ratio of marginal to average tax rates is greater (smaller) than 1 for every level of income. According to my setup, I have

$$\frac{1-\mathcal{T}'(y)}{1-\frac{\mathcal{T}(y)}{y}}=1-\tau^l,$$

which implies that for  $0 < \tau^l < 1$ , marginal tax rates always exceed average tax rates. Consequently, with  $\tau^l$  in that interval, the tax system is progressive, and conversely, when  $\tau^l < 0$ , it is regressive. Additionally,  $\tau^l = 0$  implies that marginal and average tax rates are equal, corresponding to the flat tax system.

 $\lambda$  is calibrated to balance the government budget, yielding a value of 0.79.

The tax function  $\mathcal{T}(\cdot)$  has a long tradition in public finance, first proposed by Feldstein (1969) and more recently used by Bénabou (2000, 2002), and Heathcote, Storesletten, and Violante (2017), henceforth also known as the HSV tax function. It fits the U.S. data well, except for the bottom decile of the income distribution (Heathcote, Storesletten, and Violante, 2020). The observed discrepancy can be attributed to two reasons. First, the tax function implies that marginal taxes are monotone in income. However, marginal tax rates can be high at the bottom of the income distribution due to the phasing out of meanstested programs. Second, this tax schedule lacks a floor for disposable income, meaning households with zero pre-tax income also have zero after-tax income. Nevertheless, in the U.S., programs such as the Supplemental Nutrition Assistance Program (SNAP), Temporary Assistance for Needy Families (TANF), and Unemployment Insurance (UI) guarantee a floor. The means-tested transfer program in the model also ensures a minimum level of support for non-employed households. I set the maximum possible lump-sum transfer to a non-employed household  $\bar{e}$  to 0.24, ensuring that in the initial steady state, the average transfers-to-earnings ratio of the lowest wealth quintile is 14.72%.

#### 5.5. Energy Usage in Commuting

I specify energy use for commuting as  $E_T(zwh) = \iota_0 [\log(1 + zwh)]^{\iota_1}$ , where  $\iota_0 > 0$  is the scaling parameter and  $\iota_1 > 0$  is the sensitivity of energy consumption for commuting to household earnings.  $E_T(\cdot)$  increases with household earnings, implying that high-earning households typically require more energy to commute to work, often because they tend to live farther from their workplaces. This concept aligns with the evidence on commuting time found in the American Time Use Survey (ATUS) (see Kimbrough, 2019).<sup>26</sup>

I set  $\iota_0$  to 0.02, ensuring that, in the initial steady state, employed households' average

<sup>26.</sup> This direct relationship between earnings and commuting costs aligns with the intuition of the classic urban spatial structure model outlined in Mills (1967) and Muth (1969). In my model, the consumer unit is a household, meaning that an increase in household hours worked corresponds to an increase in the number of earners, which leads to higher commuting activity and expenses. This interpretation is supported by the evidence from the CEX, as shown in Figure G.4 in the Online Appendix, where household commuting expenses rise with the number of earners.

Moment	Data	Model
Firms' expenditure on energy as a share of GDP	4.10%	4.10%
Wealth share of top wealth decile	66.44%	64.88%
Earnings share of top earnings decile	35.04%	35.12%
Earnings share of top 1% of the earnings distribution	11.62%	14.32%
After-tax rate of return	4.10%	4.11%
Average share of consumption basket expenditure on $E_R$	7.94%	7.93%
Employed households' average share of hours worked	33.33%	33.34%
Employment rate	79.63%	80.64%
Government purchases as a share of GDP	20.0%	20.0%
Average transfers-to-earnings ratio of lowest wealth quintile	14.72%	15.97%
Employed households' average expenditure share on $E_T$	2.00%	2.00%
Bottom-to-top income quintile workers' expenditure share on $E_T$	1.37	1.37
Share of households with negative wealth	12.58%	10.49%

TABLE 3Targeted Moments: Baseline

*Note.* The table presents targeted moments in the baseline model calibration along with their empirical counterparts. All model moments are computed in the initial steady state. Abbreviations: GDP, gross domestic product;  $E_R$ , residential energy;  $E_T$ , commuting energy.

expenditure share on commuting energy matches its empirical counterpart (2.0%). The sensitivity parameter  $\iota_1$  is set to 0.58 so that the ratio of bottom-to-top income quintile employed households' expenditure share on commuting energy in the initial steady state matches its corresponding data moment (1.37).

# 5.6. Borrowing Limit

The exogenous borrowing limit  $\underline{a}$  is set to ensure that the share of households with negative assets in the initial steady state matches its empirical counterpart (12.58%). This procedure yields  $\underline{a}$  equal to -0.07, which is equivalent to -6.0% of per-capita pre-tax income.

# 6. MODEL FIT

In this section, I assess how well my model replicates the U.S. economy in relevant dimensions. All model statistics presented here are computed in the initial steady state. Table 3 compares the targeted data moments and their corresponding values in the model. Follow-



CROSS-SECTIONAL DISTRIBUTIONS – DATA VS. MODEL

*Note.* The figure shows cross-sectional moments from the model and the data. Panel A shows the distribution of employment rates by income quintiles. Panel B shows earnings shares by earnings quintiles. Panel C shows wealth shares by wealth quintiles. Panel D shows expenditure shares on residential energy by income quintiles. Panel E shows expenditure shares on commuting energy by income quintiles. The empirical moments of employment and earnings distributions are computed using the biennial waves of the PSID from 2001 to 2015, while the moments of the wealth distribution are computed using the PSID waves from 1999 to 2013. This is because the PSID waves record labor market variables from the previous year. The expenditure shares for residential and commuting energy are calculated using the quarterly waves of the CEX from 1999 to 2013 on households that participated in at least four interviews and are complete income reporters. In all cases, the sample is restricted to households with heads aged 25 to 64.

ing that, I present the model's performance in replicating the cross-sectional distributions of employment, wealth, earnings, and expenditure share on energy—dimensions not comprehensively targeted in the calibration.

Panel A of Figure 5 compares the employment rates by income quintiles in the model and the data, while Panel B compares the household earnings and Panel C compares the wealth distributions. In the U.S., earnings and wealth distributions are highly concentrated and skewed to the right (see, e.g., Castañeda, Díaz-Giménez, and Ríos-Rull, 2003; DiazGimenez, Glover, and Ríos-Rull, 2011; Kuhn and Ríos-Rull, 2016). The figure shows that the model successfully captures this right-skewed nature of the distributions, aligning closely with the earnings and wealth shares for each quintile from the data.

The two key features of my model are the non-homothetic consumption preferences and the explicit inclusion of commuting costs. These features are incorporated aiming to capture the cross-sectional distribution of expenditure shares on residential and commuting energy. Panel D of Figure 5 compares the expenditure shares on residential energy by income quintiles in the model and the data, while Panel E compares those on commuting energy. The figure shows that the model effectively reproduces observed expenditure shares across income quintiles for both types of energy consumption.

Overall, the calibrated version of the model replicates many salient features of the U.S. data, providing a cross-sectionally rich and empirically informed framework. I now use this calibrated model as a laboratory for my quantitative analysis.

#### 7. QUANTITATIVE ANALYSIS

In this section, I conduct a set of quantitative experiments to analyze the effects of energy price shocks. First, using the baseline calibrated model, I analyze the effects of a positive energy price shock. Next, I examine how the responses to the shock vary in different versions of my model. These exercises help to understand the roles of different features of the model. Finally, I evaluate the impacts of WFH opportunities and targeted transfers on the responses to a positive energy price shock.

# 7.1. Energy Price Shock

I assume that a shock to the energy price is AR(1).<sup>27</sup> Therefore,  $p_{Et}$  is determined by

$$\log p_{Et} = \rho_E \log p_{E,t-1} + \sigma_E \varepsilon_{Et}, \tag{25}$$

<sup>27.</sup> It is important to mention that using an augmented Dickey-Fuller test at a 5% level of significance, I cannot reject the null hypothesis of a unit root in the energy price process. However, deriving impulse responses to a non-stationary shock is challenging. Therefore, the literature often treats shocks to energy price as stationary (e.g., Kim and Loungani, 1992; Kuhn, Kehrig, and Ziebarth, 2021; Auclert, Monnery, Rognlie, and Straub, 2023). Addressing this limitation could be a valuable direction for future research.



FIGURE 6 IMPULSE RESPONSE OF ENERGY PRICE TO A ONE STANDARD DEVIATION SHOCK TO ITSELF

where  $\rho_{Et} \in (0, 1)$  is the persistence,  $\sigma_E > 0$  denotes the volatility, and  $\varepsilon_{Et} \in \mathbb{R}$  is the innovation of  $p_{Et}$ . The economy starts in a steady state and unexpectedly experiences a shock to energy price that causes  $p_{Et}$  to change by one standard deviation. Following the shock, the path of  $p_{Et}$  is determined as shown in Figure 6.

I set the persistence of the shock  $\rho_{p_E}$  to 0.96, which is equivalent to a shock with a halflife of approximately four years (i.e., the time required for the shock's effect to halve in magnitude), and its volatility  $\sigma_{p_E}$  to 0.05.<sup>28</sup>

# 7.2. Effects of a Positive Energy Price Shock

I now use the baseline calibrated model to examine the effects of a positive energy price shock similar to the one in 2021 (equivalent to a 20% increase in  $p_E$ ). As shown in Figure 7, the energy price hike increases production costs, leading firms to reduce energy use.<sup>29</sup> Since energy and non-energy factors are complementary, the reduction in energy decreases the marginal productivity of non-energy factors, lowering wage and rental rates.

The high energy price increases household consumption expenditures, reducing real

<sup>28.</sup> See Table G.2 in the Online Appendix for details.

<sup>29.</sup> In the Online Appendix, using a Structural Vector Autoregression (SVAR) model, I show that a positive oil supply news shock of Känzig (2021) significantly reduces firm energy consumption (see Panel C of Figure E.1). Section E of the Online Appendix also provides a discussion on why the oil supply news shock is used as an example of an energy price shock.



Responses of Macroeconomic Aggregates to a Twenty Percent Positive Energy Price Shock in the Baseline Model

income and compelling households to adjust their labor supply and savings decisions.<sup>30</sup> Panel B of Figure 8 shows that labor supply responses vary across households, driven by differences in income and substitution effects. Due to higher marginal utility, low-income households are more inclined to increase their labor supply (the income effect dominates). Additionally, these households lack savings to insure against the real income loss induced by the higher energy price, prompting them to rely on increasing their labor supply to smooth consumption. However, this increase in labor supply results in additional welfare losses, as higher commuting costs limit their ability to consume residential energy and non-energy goods, and longer hours worked increase disutility. On the other hand, for high-income households, the substitution effect dominates the income effect, making leisure preferable to work, leading to a reduction in energy use for commuting.<sup>31</sup>

<sup>30.</sup> The decline in capital over a long period results from investment falling short of depreciation. The high energy price reduces household income and increases expenditures, which in turn reduces investment.

<sup>31.</sup> Following a positive energy price shock, high-income households reduce their labor supply due to



Distributional Responses to a Twenty Percent Positive Energy Price Shock in the Baseline  $${\rm Model}$$ 

Note. Abbreviation: CEV, consumption equivalent variation.

Panel C of Figure 8 shows that the size of the consumption basket decreases for households in the lowest income quintile by almost twice as much as for those in the top quintile. This involves reductions in both residential energy and non-energy consumption. Panel D shows that residential energy consumption decreases by approximately the same percentage across income groups. However, Panel E indicates that the adjustment in non-energy consumption varies across income groups. Panel F shows that the shock results in welfare losses for the bottom income quintile almost twice as large as those for the top quintile on

declining wage and rising commuting costs. Figure G.9 of the Online Appendix shows that, in a fullemployment model, fixing household commuting energy at the pre-shock steady-state level leads to an increase in labor supply, even for the top income quintile, in response to the shock. This result helps explain the discrepancy between the baseline model outcome and empirical findings in Table 1 regarding commuting energy consumption. The discrepancy may arise because, in the data, low-income households may switch to alternative commuting modes, such as public transportation, which reduces their energy use for commuting, whereas my model lacks such alternatives. Additionally, while energy use for commuting typically remains unchanged in the data, in the baseline model it depends on earnings. Therefore, the decline in earnings following the shock leads to a reduction in commuting energy consumption.



Consumption Responses to a Twenty Percent Positive Energy Price Shock in a Model Fixing Wage and Rental Rates at the Pre-Shock Steady-State Level

impact (-1.25% vs. -0.75% in terms of consumption).<sup>32</sup>

Figure 9 shows that fixing wage and rental rates at the pre-shock steady-state level doubles the consumption gap between the top and bottom income quintiles. This result stems from two main factors. First, for low-income households, the shock's direct impact on consumption dominates due to their higher energy expenditure share and lack of savings. Additionally, the decline in wage in the baseline model amplifies the income effect, prompting these households to increase their labor supply, which helps mitigate their income and consumption losses. Second, for high-income households, the direct effect is weaker because of their lower energy expenditure share and higher asset holdings. However, these higher asset holdings and the stronger substitution effect in labor supply decisions make the indirect effect through changes in wage and rental rates more pronounced.

#### 7.3. Comparison with Models Under Alternative Assumptions

To examine the roles of different model features, I compare the responses to a one-standarddeviation positive energy price shock in models with alternative assumptions to those in the baseline model. Each alternative model is calibrated separately, with details provided

<sup>32.</sup> Figure G.8 of the Online Appendix shows that the responses to a negative energy price shock are the opposite of those to a positive shock. However, its impacts on macroeconomic aggregates—such as capital, labor, the real rate of return, wages, and output—are less pronounced. This aligns with empirical findings in the literature (e.g., Kilian, 2008).



CONSUMPTION RESPONSES TO A ONE STANDARD DEVIATION POSITIVE ENERGY PRICE SHOCK IN A MODEL WITH HOMOTHETIC CONSUMPTION PREFERENCES

# in Section F.2 of the Online Appendix.

**Homothetic Consumption Preferences.** Although the Engel curve of energy consumption suggests non-homothetic consumption preferences, this is often simplified in the literature by assuming homotheticity (e.g., Auclert, Bardóczy, Rognlie, and Straub, 2021). To examine the importance of non-homothetic consumption preferences, I compare the consumption responses in the baseline model with those from a model with homothetic consumption preferences (henceforth, the homothetic model).

As shown in Figure 10, an energy price shock affects the consumption of the bottom income quintile less in the homothetic model than in the baseline model. The homothetic model understates the residential energy share of low-income households, lowering their burden from the high energy price and thus reducing their consumption drop. Although this model overstates the residential energy share of high-income households, their consumption response is similar to that in the baseline model. This is because the additional energy constitutes only a small share of high-income households' total expenditures. Consequently, an energy price shock moderately impacts consumption inequality in the homothetic model compared to the baseline model.

**No (Explicit) Commuting Costs.** A unique feature of my model is the explicit inclusion of commuting costs. This feature makes the model suitable for evaluating a wider range of policies than models that exclude it. Conventional models in the literature typically



CONSUMPTION AND LABOR SUPPLY RESPONSES TO A ONE STANDARD DEVIATION POSITIVE ENERGY PRICE SHOCK IN A MODEL WITHOUT EXPLICIT COMMUTING COSTS

combine households' energy use for commuting with their other energy consumption in the consumption basket. As a result, in response to an energy price shock, households adjust their composition of energy and non-energy consumption without differentiating between residential and commuting energy.

Figure 11 shows that without explicit commuting costs, a positive energy price shock moderately reduces household consumption on impact compared to the baseline model. Specifically, low-income households experience a disproportionately smaller consumption loss. This is because, in the baseline model, the demand for commuting energy is more inelastic, making it harder to adjust.<sup>33</sup> Consequently, a high energy price increases commuting expenses and reduces the resources available for the consumption basket, amplifying consumption losses. The resulting drop in consumption raises marginal utility, prompting households to increase labor supply. However, since low-income households typically have low labor market productivity, additional labor supply is insufficient to compensate for the losses from explicit commuting costs.

**Excluding Energy as a Factor of Production.** While my paper primarily focuses on the effects of energy price shocks on households in different income groups, the baseline model incorporates energy as a factor of production in addition to its use for commuting and

<sup>33.</sup> This is also supported by the empirical evidence in Section 3.4. Furthermore, using the U.S. data, empirical literature shows that the demand for commuting energy, such as gasoline, is more inelastic than electricity, the primary non-gasoline energy category (see, e.g., Alberini, Gans, and Velez-Lopez, 2011).



Responses to a One Standard Deviation Positive Energy Price Shock in a Model with Non-Energy Factors of Production

residential utilities. Given that a large share of energy in the U.S. is used in the production sector, including it as a factor of production is crucial for capturing the indirect effects of shocks. However, I now examine how the responses to a positive energy price shock differ when the production sector relies solely on non-energy factors.

Since energy is treated as an imported good with an exogenous price, an energy price shock influences the demand for the endogenous production sector's output in two ways. First, each unit of imported energy requires additional output to balance the economy's resource constraint. Second, households' energy and non-energy consumption may decline due to real income losses from the higher energy price. When production relies solely on non-energy factors, energy price shocks do not directly affect the production sector. Consequently, as shown in Figure 12, factor prices—wage and rental rates—are only modestly affected, weakening the indirect impact of the shock. While this weaker indirect impact mitigates income and consumption losses for all households, it disproportionately benefits



CONSUMPTION AND LABOR SUPPLY RESPONSES TO WORK FROM HOME OPPORTUNITY FOLLOWING A POSITIVE ENERGY PRICE SHOCK

high-income households due to their higher asset holdings and labor productivity.

# 7.4. Policy Analysis

**Work from Home Opportunity.** Given the growing trend of WFH opportunities, especially since the COVID-19 pandemic, it is crucial to understand its impact on the effects of energy price shocks. WFH significantly reduces commuting costs, allowing households to real-locate these resources to their consumption or investment. However, WFH opportunities are disproportionately available in high-skilled intensive jobs, such as education, financial, and information services, thus predominantly favoring high-skilled workers (see, e.g., Bick, Blandin, and Mertens, 2023; Barrero, Bloom, and Davis, 2023). This unequal access to WFH opportunities influences the distributional effects of energy price shocks.

To explore the implications of WFH, I assume that following a positive energy price shock, partial WFH becomes permanently feasible for households in the top quintile of the earnings distribution in the initial steady state. This reduces their commuting energy consumption to half of what it would be without the WFH opportunity for the same level of earnings. As a result, their commuting costs decrease, freeing up resources for nonenergy and residential energy consumption. Figure 13 shows that the WFH opportunity mitigates the loss in the consumption basket for households in the top earnings quintile. However, the consumption loss for the bottom earnings quintile remains similar to the no-WFH scenario, increasing consumption inequality.



CONSUMPTION AND LABOR SUPPLY RESPONSES TO A TARGETED TRANSFER PROGRAM FOLLOWING A POSITIVE ENERGY PRICE SHOCK

**Targeted Transfer Program.** In the U.S., a federal transfer program known as the Low Income Home Energy Assistance Program (LIHEAP) provides financial assistance to low-income households for their energy expenses, primarily for residential utilities such as heating and cooling. Some states have also adapted the program to include coverage for gas and electric bills.<sup>34</sup> Motivated by this program, I examine how a lump-sum transfer to low-income households influences the outcomes of a positive energy price shock.

To implement the targeted transfer program following a positive energy price shock, I provide a lump-sum transfer equivalent to 3% of per-capita pre-tax income to households in the lowest income quintile in the initial steady state.<sup>35</sup> The transfer is designed to be temporary, with the amount reduced as the energy price declines to maintain the persistence of the shock. The government finances the transfer through tax revenues, maintaining a balanced budget each period by adjusting  $\lambda$  in the HSV tax function.

As shown in Figure 14, the transfer reduces the consumption loss of the targeted group. However, the top income quintile experiences greater consumption loss due to their heavier tax burden. Consequently, consumption inequality increases less in the transfer scenario than in the no-transfer scenario in response to a positive energy price shock.

<sup>34.</sup> For example, in Texas, the Department of Housing and Community Affairs has adapted LIHEAP to cover both gas and electric bills, renaming it the Comprehensive Energy Assistance Program (CEAP). To qualify for CEAP, households must have an income at or below 150% of the Federal Poverty Guidelines. Additionally, households participating in programs such as SNAP, TANF, Supplemental Security Income (SSI), or certain Means Tested Veterans Programs automatically meet the eligibility requirements.

<sup>35.</sup> I choose the amount based on the current U.S. energy assistance program, which provides up to \$2,000 annually in Texas, corresponding to approximately 3% of the annual per-capita pre-tax income.

# 8. CONCLUDING REMARKS

This paper studies the distributional effects of energy price shocks in a quantitative framework incorporating energy use in residential utilities, commuting, and production. In doing so, it develops a heterogeneous-agent incomplete market model with several novel features, including non-homothetic consumption preferences, commuting costs, and a production sector that uses energy and non-energy factors in fixed proportions to produce non-energy goods. A calibrated version of the model reproduces many salient features of the data, including the cross-sectional distributions of residential and commuting energy expenditure shares. An energy price shock in my model disproportionately affects households across income groups. Low-income households are the most affected, for whom the shock's direct effect on consumption dominates, whereas high-income households are primarily affected through changes in wage and rental rates.

The paper also explores how WFH opportunities and targeted transfers influence the impact of a positive energy price shock. It shows that WFH mainly benefits high-income households due to their disproportionate access, exacerbating consumption inequality. On the other hand, a lump-sum transfer to low-income households, financed by higher earnings tax, mitigates the shock's impact on consumption inequality.

The analysis in this paper can be extended in several dimensions in future research. First, considering multiple non-energy sectors based on their energy intensity could be a meaningful extension. Energy price shocks may disproportionately affect sectors heavily reliant on energy, impacting all associated entities, while sectors with low-energy dependency may experience more muted effects. Second, distinguishing between energyefficient and energy-intensive durables could provide insights into how such shocks influence the adoption of energy-efficient durables across income and wealth groups. Finally, modeling alternative commuting options could be important for studying the impact of energy price shocks in countries where alternatives to driving are widely used.

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