

Fiscal policy and energy price shocks

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HIGHLIGHTS

- During a major energy price shock, key policy goals are in conflict.
- No single policy dampens a recession, saves energy, and prevents energy poverty.
- Tax vs. debt financing significantly impacts welfare.
- Welfare evaluation is crucial; GDP effects don't reflect energy savings or energy poverty.

ARTICLE INFO

JEL Classification:

E62
E64
H31
H32
Q43
Q52

Keywords:

Energy price shock
DSGE
Fiscal policy
Welfare

ABSTRACT

In this analysis, we examine the heterogeneous welfare effects of various crisis relief programs, financed either through distortionary taxes or public debt. To provide a quantitative evaluation of the 2022 energy crisis, we compare the performance of targeted and untargeted transfers and energy price subsidies while considering different financing schemes within a Dynamic Stochastic General Equilibrium (DSGE) model calibrated to the German economy. Our results show that no single measure can resolve the underlying trade-offs. In terms of welfare, low-income and high-income households prefer different policies and financing schemes. Low-income households prefer debt-financed instruments, as these help them smooth consumption in response to the energy price shock. In contrast, high-income households strongly prefer tax-financed interventions. Our analysis highlights the importance of labor market effects and explicitly assessing welfare.

1. Introduction

In 2022, Europe faced the most severe energy crisis since the 1973 oil price shock (Ruhnau et al., 2023). As Europe relies heavily on fossil fuel imports, fossil fuel price shocks adversely affect the economy through multiple channels. They act as a cost push shock in production, affecting economic activity. At the same time, fossil energy price shocks affect consumers through changes in prices and wages, while additionally lowering real incomes due to a deterioration in the terms of trade.

Consequently, the policy response to such shocks is complex (Bartocci et al., 2024). Across Europe, governments responded with expansionary fiscal policy through a variety of price and income support measures (see Fig. 1). A share of crisis relief was explicitly targeted at vulnerable households. As energy is a basic consumption good, fossil energy price shocks lower real incomes and impose a disproportionate burden on low-income households (see, e.g., Schulte and Heindl, 2017). Consequently, the fiscal policy debate has emphasized the need to provide targeted income support to the most vulnerable households (Kharroubi and Smets,

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<https://doi.org/10.1016/j.enpol.2026.115149>

Received 18 December 2024; Received in revised form 21 January 2026; Accepted 2 February 2026

Available online 16 February 2026

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2024).¹ However, despite the large fiscal volume of relief packages,² we still have a limited understanding of how the financing scheme of crisis policies directly affects the ability to protect high- and low-income households.

This paper addresses this gap and aims to provide a quantitative welfare analysis of crisis relief measures during the recent energy crisis in Europe. More specifically, we analyze how different policy measures perform with regard to the three most prominent goals in the policy debate: preventing an increase in energy poverty,³ stabilizing GDP, and maximizing energy savings. Our contribution is to evaluate targeted and untargeted price- and income support measures, while explicitly considering their financing scheme. To do so, we integrate these various perspectives into a Dynamic Stochastic General Equilibrium (DSGE) model calibrated to the German economy. Our tractable setup allows for analyzing specific drivers of welfare-relevant variables for low-income and high-income households. We consider different fossil energy dependencies among households and between households and firms. We jointly analyze the macroeconomic and welfare impacts of various crisis relief programs financed either through distortionary taxes or through the issuance of government bonds. To provide a quantitative evaluation of policy measures in response to the current energy crisis, we estimate the recent energy price shock, as well as the parameters that govern the energy consumption patterns of households from German data.

The remainder of the paper is structured as follows. The next subsection provides an overview of the relevant literature, followed by a description of our model in Section 2. Section 3 discusses the calibration, including the estimation of the preference parameters and the energy price shock. Section 4 reports the results of the evaluation of compensation policies, and Section 5 concludes.

1.1. Related literature

This paper relates to the literature on specific impact channels or goals of policy measures that were adopted during the energy crisis (Ruhnau et al., 2023; Hutter and Weber, 2023; Kola-Bezka and Leki, 2024). While a part of the literature focuses on the aggregate, long-term effects of an embargo on economic growth and on carbon emissions (e.g., Liu et al., 2023; Chepeliev et al., 2022), our aim is to contribute to the large macroeconomic literature that focuses specifically on the impact of fossil energy price shocks. This literature finds that oil price shocks can be a significant driver of national and global recessions (Hamilton, 1983; Barsky and Kilian, 2004; Kilian, 2008, 2009; Baumeister and Hamilton, 2019; Känzig, 2021). As we aim to improve our understanding regarding the ability of fiscal policy to shield high- and low-income households from the adverse impacts of fossil energy price shocks, we relate closely to the literature studying the impact of the energy crisis using macroeconomic models (e.g., Turco et al., 2023; Liadze et al., 2022).

¹ Not only do these households have a higher propensity to consume energy and thus face a greater decline in real incomes from the energy price shock, but additionally they have low saving buffers and are often credit-constrained. Consequently, they tend to reduce their non-energy consumption more strongly. Targeted income support can thus alleviate the negative distributional consequences, support aggregate demand, while limiting fiscal costs.

² While there is a large heterogeneity across countries, EU27 countries taken together have allocated more than 5 percent of 2022 EU27 GDP for crisis relief measures. Information on cumulative allocated funds is taken from Sgaravatti et al. (2023) and compared to 2022 current prices GDP taken from the ECB's data portal.

³ As Drescher and Janzen (2021) note, there is no commonly agreed definition of energy poverty in Germany. Indicators suggested by the EU Energy Poverty Observatory are generally based on the relation between energy-related expenditures and household income. The critical feature of energy poverty we aim to capture through the modeling of an energy consumption subsistence level and the resulting non-homothetic preferences is that some households have minimal options to substitute away from energy consumption and are forced to reduce consumption of other essential goods (Drescher and Janzen, 2021).

We specifically target the literature that uses DSGE models. This literature builds on important contributions by Kim and Loungani (1992); Harrison et al. (2011); Kilian and Vigfusson (2017).

Several contributions study aspects of the energy crisis within DSGE models and are thus related to our work (e.g., Auclert et al., 2023; Bartocci et al., 2024; Bayer et al., 2023; Kharroubi and Smets, 2024; Gornemann et al., 2024). This literature mainly has the following common features. First, the price increase is modeled as some sort of (stochastic) shock. Second, the aim is to study the role of monetary and/or fiscal policy. Third, the setups include some form of heterogeneity among households to consider the regressive nature of the price shock. Closest to our paper are recent contributions by Pieroni (2023) and Bayer et al. (2023), who use a heterogeneous agent New Keynesian model to analyze the consequences of an energy supply shock. Pieroni (2023) shows that targeted transfers can mitigate the adverse effects on low-income households in Germany and Italy. Bayer et al. (2023) studies the effectiveness of fiscal policy in the context of a monetary union.

Methodologically, we complement this literature in two ways. First, we contribute by estimating the model energy price shock using 2022 data and the non-homothetic preferences for energy consumption using household data from the Einkommens- und Verbraucherstichprobe (EVS), a German income and expenditure survey. Second, our setting allows for isolating specific drivers of household welfare across the income distribution. We include a fixed share of low-income, credit-constrained households as in Galí et al. (2007) that spend a greater share of their expenditures on energy.⁴ Our focus is to improve our understanding of how the type, target, and financing scheme of fiscal policy interventions affect the welfare of households.

From a policy perspective, our contribution is to add the public finance dimension to the fiscal policy debate. We analyze a variety of fiscal policy measures, including price subsidies, that EU governments enacted during the recent crisis. In detail, we consider various policy packages that differ in their policy instruments, targets, and financing schemes. While we partly share this focus with Kharroubi and Smets (2024), our study focuses on the quantitative assessment of the welfare impact on low- and high-income households while considering aggregate dynamics and the impact of the financing scheme.

Due to our focus on fiscal policy, we abstract from the potential impacts of the energy price shock on inflation and the role of monetary policy in alleviating the adverse effects of fossil energy price hikes. Consequently, we abstract from price rigidities. Chan et al. (2024); Gornemann et al. (2024); Bartocci et al. (2024); Corsello and Riggi (2023) provide a comprehensive analysis of the role of monetary policy in the recent energy crisis in similar model setups.

Furthermore, because we simplify our analysis by assuming balanced trade, neither the energy price shock nor any of the relief measures affects the country's current account. Clearly, an increase in the energy price — the price of the only import good — deteriorates the country's terms-of-trade in this setting. A more detailed modeling of the international dynamics of the energy price shock and policy responses can be found in Bayer et al. (2023).

2. Model

We extend a standard real business cycle (RBC) model in various dimensions to study the implications of energy price increases for economic welfare and assess the potential scope of fiscal policies. We follow the literature and include energy as an input factor in production (see, e.g., Bretschger and Schaefer, 2017; Punzi, 2019; Pieroni, 2023). Additionally, we explicitly model household energy consumption through a constant elasticity of substitution (CES) demand structure.

⁴ Hinterlang et al. (2023) use a similar setup with a fixed share of constrained households to analyze the fiscal response of the German COVID-19 fiscal stimulus package. Eydam and Diluiso (2022) also use an extension in the context of climate policy and study the double dividend hypothesis.

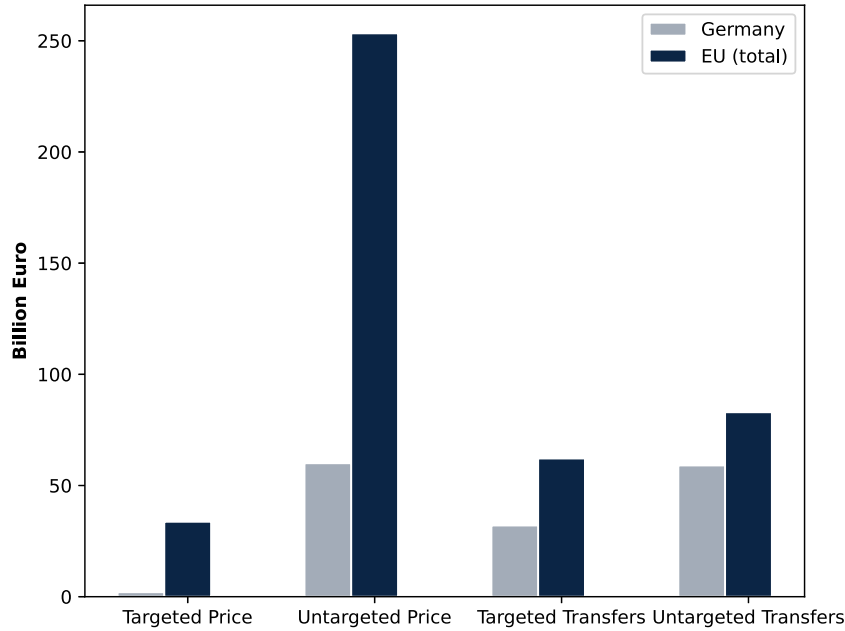


Fig. 1. Allocated and earmarked funding to shield households (Sep 2021 - Jan 2023) according to the type of compensation measure, Germany and EU (total). Source: Sgaravatti et al. (2023).

Furthermore, we take into account the specific nature of energy consumption and incorporate a subsistence level through Stone-Geary preferences (Geary, 1950; Stone, 1954). Following Galí et al. (2007), we differentiate between low-income, credit-constrained households and high-income, unconstrained households. This distinction highlights differences in households' ability to smooth consumption in response to rising energy prices.

2.1. Households

A continuum of households $I \in [0, 1]$ exists. We assume that a fraction λ of households cannot access financial markets. We refer to these low-income, credit-constrained households as non-Ricardian households. The share of financially unconstrained households, referred to as Ricardian households, is given by $(1 - \lambda)$. Both types of households seek to maximize their lifetime utility over consumption c_t , work time h_t , and energy consumption $c_{e,t}$. The objective function is the same across households and is given by:

$$W \left((c_t, c_{e,t}, h_t)_{t=1,2,\dots} \right) = \sum_{t=0}^{\infty} \beta^t u(c_t, c_{e,t}, h_t) \quad (1)$$

Where β is a time discount factor and the period utility is given by:

$$u(c_t, c_{e,t}, h_t) = \frac{([\eta c_t^{-\rho_H} + (1 - \eta)(c_{e,t} - \bar{c}_e)^{-\rho_H}]^{-1/\rho_H})^{(1-\rho)}}{1 - \rho} - \phi \frac{h_t^{1+\xi}}{1 + \xi}, \quad (2)$$

where \bar{c}_e denotes the subsistence level of energy consumption, ρ_H denotes the elasticity of substitution between goods consumption and energy consumption, and η is a weighting parameter. Furthermore, ρ is the inverse of the intertemporal elasticity of substitution, ϕ captures the disutility from working, and ξ denotes the inverse Frisch elasticity. The assumption of Stone-Geary preferences over energy consumption implies that households have decreasing expenditure shares in energy consumption. However, the optimal allocation across goods is static. Consequently, households can optimize intertemporally total consumption expenditures $x_t = c_t + p_{h,t} c_{e,t}$. Note that the price of consumption goods is a numeraire, and $p_{h,t}$ denotes the price households pay for energy consumption. Furthermore, we assume that investment is subject

to convex adjustment costs governed by the parameter κ . In this framework, Ricardian households maximize discounted lifetime utility subject to the following constraints:

$$x_{R,t} + \frac{(k_{t+1} + b_{t+1})}{(1 - \lambda)} = \left(w_t \bar{h}_{R,t} + z_t \frac{k_t}{(1 - \lambda)} \right) (1 - \tau_t) + \left((1 - \delta)k_{t-1} + R_t \frac{b_t}{(1 - \lambda)} \right) + T_{R,t} \quad (3)$$

$$k_{t+1} = \left[1 - \frac{\kappa}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right] i_t + (1 - \delta)k_t \quad (4)$$

where i_t denotes investment into physical capital k_t and b_t denotes the holdings of government bonds. Households earn wages w_t and receive pre-tax returns on capital z_t . Effective hours $\bar{h}_{R,t}$ are obtained by multiplying hours worked $h_{R,t}$ with a productivity parameter $\theta_{R,t}$. Together with its non-Ricardian counterpart $\theta_{NR,t}$, this determines the difference in labor income between the two types of households. Labor income $w_t \bar{h}_{R,t}$ and capital income $z_t k_t$ are subject to income taxation τ_t . A no-arbitrage condition imposes that $R_t = (1 - \tau_t)z_t$ is the interest borne by government bonds. $T_{R,t}$ denotes government transfers to the Ricardian household. The solution to the intertemporal optimization problem yields the following first-order conditions for consumption, labor supply, capital, and investment:

$$\mu_t = M_t q_t (x_{R,t} q_t - p_{c,t} \bar{c}_e (1 - q_t))^{-\rho} \quad (5)$$

$$\phi_R h_{R,t}^\xi = (1 - \tau_t) w_t \theta_{R,t} \mu_t \quad (6)$$

$$p_{k,t} = \beta \frac{\mu_{t+1}}{\mu_t} ((1 - \tau_{t+1}) z_{t+1} + (1 - \delta) p_{k,t+1}) \quad (7)$$

$$1 = p_{k,t} \left(1 - \frac{\kappa}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 - \kappa \left(\frac{i_t}{i_{t-1}} - 1 \right) \frac{i_t}{i_{t-1}} \right) + \beta \frac{\mu_{t+1}}{\mu_t} p_{k,t+1} \kappa \left(\frac{i_{t+1}}{i_t} - 1 \right)^2, \quad (8)$$

where μ_t denotes the marginal utility of consumption. For reasons of tractability we define the auxiliary variables $M_t \equiv (1/\rho_H)/$

$(\eta + (1 - \eta)^{1+\rho_H} \eta^{\rho_H/1+\rho_H} p_{h,t}^{\rho_H/1+\rho_H})$ and $q_t \equiv 1/((1 - p_{h,t})(\eta p_{h,t}/(1 - \eta)^{1+\rho_H} p_{h,t}))$. Furthermore, $p_{k,t}$ denotes the price of capital relative to consumption. Non-Ricardian households face the same objective function as Ricardian households but have no access to financial markets and thus must rely on their labor supply to smooth consumption. The budget constraint of non-Ricardian households reads:

$$x_{NR,t} = (1 - \tau_t)w_t \tilde{h}_{NR,t} + T_{NR,t} \quad (9)$$

where effective hours are given by $\tilde{h}_{NR,t} \equiv \theta_{NR} h_{NR,t}$. The first-order condition for labor supply of non-Ricardian households is given by:

$$\phi_{NR} h_{NR,t}^{\xi} = (1 - \tau_t)w_t M_t q_t (x_{NR,t} q_t - p_e \bar{c}_e (1 - q_t))^{-\rho}. \quad (10)$$

2.2. Aggregation

Aggregate consumption x_t , aggregate goods consumption c_t , aggregate energy consumption $c_{e,t}$ and effective labor supply of households h_t are weighted averages of the household specific consumption variables:

$$x_t = \lambda x_{NR,t} + (1 - \lambda)x_{R,t} \quad (11)$$

$$c_t = \lambda c_{NR,t} + (1 - \lambda)c_{R,t} \quad (12)$$

$$c_{e,t} = \lambda c_{e,NR,t} + (1 - \lambda)c_{e,R,t} \quad (13)$$

$$h_t = \lambda \theta_{NR} h_{NR,t} + (1 - \lambda)\theta_R h_{R,t}. \quad (14)$$

2.3. Firms

Firms combine effective labor h_t , physical capital k_t , and fossil energy e_t to produce final consumption goods. Production takes place according to the following production function:

$$y_t = h_t^{1-\alpha-\gamma} \left(\frac{\alpha}{\alpha+\gamma} k_t^{-\rho_f} + \frac{\gamma}{\alpha+\gamma} e_t^{-\rho_f} \right)^{-\frac{\alpha+\gamma}{\rho_f}}, \quad (15)$$

where α denotes the production elasticity of physical capital, γ denotes the production elasticity of energy, and ρ_f denotes the elasticity of substitution between physical capital and energy. Markets are competitive and production factors are paid according to their marginal product. The profit maximization of firms yields the following wage and the factor price of capital:

$$w_t = (1 - \alpha - \gamma)y_t/h_t \quad (16)$$

$$z_t = \alpha k_t^{(-1-\rho_f)} h_t^{(1-\alpha-\gamma)} \left(\frac{\alpha}{\alpha+\gamma} k_t^{-\rho_f} + \frac{\gamma}{\alpha+\gamma} e_t^{-\rho_f} \right)^{-\frac{\alpha+\gamma}{\rho_f}-1}. \quad (17)$$

Firms buy fossil energy at the price $p_{f,t}$. The energy demand of firms is then given by:

$$p_{f,t} = \gamma e_t^{(-1-\rho_f)} h_t^{(1-\alpha-\gamma)} \left(\frac{\alpha}{\alpha+\gamma} k_t^{-\rho_f} + \frac{\gamma}{\alpha+\gamma} e_t^{-\rho_f} \right)^{-\frac{\alpha+\gamma}{\rho_f}-1}. \quad (18)$$

We assume that fossil energy is bought on international markets at the exogenous price p_t . However, fossil energy prices are volatile due to price shocks. The persistence and standard deviation of these shocks are estimated from the data. Specifically, we model the price of fossil energy as follows:

$$p_t = (1 - \rho_p)\bar{p} + \rho_p p_{t-1} + \epsilon_{p,t}, \quad (19)$$

where \bar{p} denotes the steady state price level, ρ_p denotes the autocorrelation of the energy price and ϵ denotes stochastic innovations. The final price of fossil energy paid by households and firms differs, as we include *iceberg costs* \bar{i} that increase the energy price paid by households and capture the price differential between household and firm prices in

Table 1
Model fit.

| | $\frac{c}{GDP}$ | $\frac{i}{GDP}$ | $\frac{p_h c_{e,R}}{y_R}$ | $\frac{p_h c_{e,NR}}{y_{NR}}$ | $\frac{p_e \epsilon}{y - p_e \epsilon}$ | $\frac{c_e}{c_e + \epsilon}$ |
|-------|-----------------|-----------------|---------------------------|-------------------------------|---|------------------------------|
| Model | 60.4 | 19.3 | 10.1 | 12.8 | 6.4 | 32.0 |
| Data | 55.00 | 22.00 | 11.00 | 14.00 | 5.00 | 28.00 |

Germany.⁵ Moreover, the prices can differ due to targeted price subsidies sub_t^i paid by the government:

$$p_{h,t} = p_t - sub_t^h + \bar{i} \cdot \bar{p} \quad (20)$$

$$p_{f,t} = p_t - sub_t^f. \quad (21)$$

The total energy consumption of the economy is given by $m_t = c_{e,t} + e_t$.

2.4. Government

In the model, the government issues risk-free bonds and levies income taxes to finance its expenditures. The government budget constraint is given by:

$$b_{t+1} = \bar{g} + g_t - \tau_t(w_t h_t + z_t k_t) + R_t b_t, \quad (22)$$

where \bar{g} denotes the exogenous level of steady-state government expenditures and g_t denotes the time-variant government expenditures that are either used for transfers or to finance energy price subsidies.

To ensure stationarity of the government budget, we employ the following fiscal rule:

$$\tau_t = \bar{\tau} + \Phi(b_t - \bar{b}), \quad (23)$$

where \bar{b} denotes the steady state debt target, and Φ regulates how strongly taxes adjust in response to deviations of debt from the target.

In the following, we assume that the size of financial support g_t is dynamic and proportional to the increase in energy prices associated with the average energy consumption of households \bar{x} , i.e., $g_t = \omega(p_t - \bar{p})\bar{x}$. The parameter ω determines how much of the direct burden of fluctuating energy prices is covered by the compensation measures. We rely on the average ex-ante energy consumption for two reasons. First, since this is a fiscal policy rule, the government cannot anticipate the dynamic behavioral adjustment of households. Furthermore, the adjustment of energy consumption depends on the specific fiscal policy instrument. In the competitive equilibrium of the model, the budget constraints of Ricardian households (3), the budget constraint of non-Ricardian households (9), and the government budget (22) must hold.

3. Calibration

A quantitative exercise requires calibrating the model. The calibration procedure and the data sources are explained in detail in [Appendix A](#). Its aim is two-fold. First, we want to match key characteristics of the German economy and replicate consumption patterns from household data. To do so, we proceed in two steps. We start by taking some established parameter values from the literature in order to reduce the dimensionality of the calibration exercise. These choices as well as the sources are shown in [Table 2](#). Next, we choose the two household preference parameters η and σ_H as well as the production function parameter γ to minimize the distance between the steady state values and their empirical counterparts for the following four variables: the value of the energy input used by industry, the share of household

⁵ This price differential captures taxes and fees that make up more than half of the electricity price paid by private consumers in Germany. Since the largest part of it is fees and therefore independent of the price, we model the iceberg cost as unit costs.

Table 2
Model Parameters.

| Parameter | Value | Description | Target/Source |
|------------------------|--------------------------|--|---|
| β | 0.9975 | Discount factor | Annual real rate of 1%, standard in DSGE literature (e.g., Caldara et al., 2024; Holtemöller and Sardone, 2024) |
| η | 0.9775 | CES share - Utility | Joint calibration procedure |
| θ_{ce} | 0.0581 | Subsistence level energy consumption | Based on Schulte and Heindl (2017) |
| ρ | 1.5226 | Inverse intertemp. EOS | Drygalla et al. (2020) |
| α | 0.31 | Output elasticity capital | German Federal Statistical Office (2024c) |
| δ | 0.025 | Depreciation rate | Annual depreciation of 10%, standard in DSGE literature (e.g., Caldara et al., 2024; Holtemöller and Sardone, 2024) |
| λ | 0.27 | Share of non-Ricardian households | German Federal Statistical Office (2022) |
| σ_f | 0.34 | Elasticity of substitution (Firms) | Haertel et al. (2022) |
| ρ_f | $\frac{1}{\sigma_f} - 1$ | | |
| σ_h | 0.8109 | Elasticity of substitution (Households) | Joint calibration procedure |
| ρ_h | $\frac{1}{\sigma_h} - 1$ | | |
| γ | $7 \cdot 10^{-6}$ | CES share - Production | Joint calibration procedure |
| ξ | 1.6732 | Inverse Frisch elasticity | Drygalla et al. (2020) |
| $\phi_{L,NR}$ | 87.9 | Labor disutility non-Ricardian | $h = 1/3$, Drygalla et al. (2020) |
| $\phi_{L,R}$ | 56.7 | Labor disutility Ricardian | $h = 1/3$, Drygalla et al. (2020) |
| θ_R/θ_{NR} | 1.48 | Productivity ratio Ricardian vs. non-Ricardian | German Federal Statistical Office (2022) |
| κ | 3.9065 | Investment Adj. Costs | Drygalla et al. (2020) |
| p_{ss} | 1.0 | Steady state energy import price | Normalization |
| \bar{i} | 1.14 | Iceberg-costs of household energy | German Federal Statistical Office (2023); Arbeitsgemeinschaft Energiebilanzen e.V. (2023) |
| ρ_p | 0.88 | Auto correlation price shock | Arbeitsgemeinschaft Energiebilanzen e.V. (2023) and World Bank (2024) |
| σ_p | 0.17 | Standard deviation price shock | Arbeitsgemeinschaft Energiebilanzen e.V. (2023) and World Bank (2024) |
| Φ | 0.05 | Fiscal reaction parameter | Berti et al. (2016) |

energy consumption in total energy consumption and the energy expenditure shares of Ricardian as well as non-Ricardian households. Table 1 describes how the model matches these variables as well as the macroeconomic ratios of consumption as a fraction of GDP and investment as a fraction of GDP, which were not used for the calibration and were taken from the German Federal Statistical Office (German Federal Statistical Office, 2024e).⁶

The second objective is to reproduce the essential characteristics of the increase in energy prices and the compensation measures implemented in Germany. For this purpose, we construct an energy price index for the German economy, drawing on multiple data sources. Consistent with common practice in the literature, we estimate the shock process using ordinary least squares (OLS). In line with the 2022 context, we find that the energy price index rose by approximately 130 percentage points in that year. Furthermore, we calibrate the fiscal burden of the compensation measures (in percent of GDP) to match the fiscal spending of Germany since the beginning of the energy crisis.

Table 2 summarizes the calibration.⁷

4. Quantitative analysis

In this section, we aim to quantitatively study the interaction between the exogenous shock, the government's response, and the differential impact on welfare of poor and rich households. The focus lies on how different compensation measures can mitigate the adverse effects of an unexpected energy price shock. We focus on an energy price shock of the magnitude observed in Germany in 2022. The increase in 2022 followed a period of low fossil energy prices due to the COVID-19 pandemic and the associated drop in production and energy demand.⁸ Prior to the recent price increase, fluctuations in energy prices had been

⁶ Assuming balanced trade, GDP is given by gross output minus the value of energy used as input to production, $GDP_t = y_t - p_t \times e_t$, in our model.

⁷ For further details on the data sources and estimation procedures, see Appendix A.

⁸ Fig. 8 depicts the energy price dynamics for the German economy.

mainly driven by oil prices. Gas prices in Germany were very stable at a low level. Coal prices fluctuated, but less than oil prices (Blanz et al., 2025). In contrast to the frequently observed fluctuations in energy prices, the recently observed increase in energy prices in Germany was extraordinarily large. Plausibly, neither households nor firms anticipated such a marked increase in energy prices. Hence, we treat this shock as an unexpected event in the following computations. Specifically, we assume that the economy is initially in steady state, and in period $t = 1$, economic agents are confronted with an increase in energy prices that builds up over one year and peaks at 130 percent. Subsequently, energy prices start to decline gradually. To underscore the significance of the energy price shock, we compare its effects on both aggregate and individual variables with those of a total factor productivity (TFP) shock—a standard macroeconomic shock—calibrated to produce the same output loss as the energy price shock. This comparison reveals the pronounced differences between the two shocks and motivates the targeted choice of policy instruments. Details of the comparison are provided in Appendix B.

In our analysis, the government can address the adverse effects of energy price shocks through various instruments. We aim to consider all types of compensation measures that Germany and other European countries introduced to address the energy price hike they faced (see Fig. 1).⁹ On the demand side, we examine both direct transfers and price subsidies for households. Furthermore, due to distributional concerns and the risk of increasing energy poverty, the government may need to focus on low-income households. These households typically spend a larger share of their income on energy, making them more vulnerable to rising costs.¹⁰ Therefore, we distinguish between equal per capita transfers and transfers that target only non-Ricardian households.

⁹ Note that the categories used by Sgaravatti et al. (2023) do not perfectly coincide with our policy measures. For example, their "Transfer" categories include government transfers to firms. In Germany, these included inter alia grants for energy-intensive companies and costs associated with creating and dissolving gas reserves.

Table 3
Overview of fiscal measures, their financing, and recipients.

| Code | Measure | Financing | Recipients |
|------|----------------------|-----------|--------------------------|
| TT-T | Targeted transfers | Taxes | Non-Ricardian households |
| TT-D | Targeted transfers | Debt | Non-Ricardian households |
| ET-T | Equal transfers | Taxes | All households |
| ET-D | Equal transfers | Debt | All households |
| SH-T | Household subsidies | Taxes | All households |
| SH-D | Household subsidies | Debt | All households |
| SF-T | Firm subsidies | Taxes | Firms |
| SF-D | Firm subsidies | Debt | Firms |
| SU-T | Untargeted subsidies | Taxes | All households and firms |
| SU-D | Untargeted subsidies | Debt | All households and firms |

Moreover, we compare both transfer schemes with subsidies that lower the energy price for consumers (see Eq. (20)). On the supply side, we consider price subsidies for firms instead of income support measures (see Eq. (21)). Due to the ownership structure in our model, common in the DSGE literature, it is difficult to distinguish transfers to firms from transfers to households. Lastly, we also consider untargeted energy price subsidies, where energy prices for households and firms are reduced by the same amount. Table 3 gives an overview of the scenarios considered.

Given the observed scale of crisis relief measures,¹¹ we explicitly consider how policy instruments are financed. The government can finance expansionary fiscal policy through an increase in distortionary taxes or public debt. This holds for all compensation measures regardless of their type or target. However, a consistent assessment of policy interventions requires an equal fiscal burden. In our main specification, we consider compensation packages that match the overall size of German relief measures and keep the fiscal burden per period constant across scenarios.

Our evaluation of crisis relief measures consists of three parts. First and second, we analyze the dynamics of aggregate and household-level variables. Third, we assess the general welfare implications associated with different policies. Our benchmark is the scenario in which no compensation policy is enacted.

4.1. Macroeconomic dynamics

We begin by examining how aggregate variables respond to the energy price shock, as this offers valuable insights into the dual policy objectives of avoiding a recession and promoting energy savings. Therefore, we focus on the effects of crisis relief measures, which differ in their type, target group, and financing scheme. The discounted cumulative change in GDP and cumulative total energy use as well as the fiscal multiplier¹² of the policy measures over a 10-year horizon in percent deviations from the no-policy scenario are reported in Table 4. The same results for a 5-year and a 200-year horizon are displayed in

¹⁰ As preferences are non-homothetic, the same increase in energy prices affects households differently (Muellbauer, 1974). Non-Ricardian households are more strongly affected by higher energy prices because they spend a larger share of their expenditures on energy. Additionally, they have limited possibilities to smooth their consumption due to their lack of savings. Therefore, the welfare loss under the no-policy benchmark is larger for non-Ricardian households than for Ricardian households. Note that we use the term *welfare* to refer to the utility of the two groups of Ricardian and non-Ricardian households. It does not refer to the social welfare of society as a whole, which requires the specification of an aggregation process for the single utilities.

¹¹ According to Sgaravatti et al. (2023), the total volume of German relief measures is 249.37 billion Euros. Based on a GDP figure of 3,876.8 billion Euros in 2022 (current prices) as reported by the German Federal Statistical Office, the relief measures amount to 6.45% of the German GDP in 2022.

¹² The fiscal multiplier is computed as the discounted cumulative change in GDP divided by the discounted cumulative change in government spending (Uhlig, 2010).

Table 4

Welfare effects of different policy scenarios (see Table 3 for the scenario keys) in consumption equivalent variations over a 10-year horizon. The welfare effects are reported relative to the no-policy scenario. Aggregate welfare constitutes the population-weighted sum of welfare of Ricardian and non-Ricardian households. Changes in output are reported as discounted cumulative output differences relative to the no-policy scenario in percentage points.

| Scenario | Ricardian | Non-Ricardian | Aggregate | GDP | Multiplier | Energy |
|----------|-----------|---------------|-----------|-------|------------|--------|
| TT-T | -0.21 | -0.23 | -0.22 | -7.08 | -1.47 | -0.23 |
| TT-D | -0.22 | 0.15 | -0.12 | -3.27 | -0.68 | -0.16 |
| ET-T | -0.07 | -0.47 | -0.18 | -6.44 | -1.34 | -0.17 |
| ET-D | -0.07 | -0.09 | -0.08 | -2.71 | -0.56 | -0.10 |
| SF-T | 0.02 | -0.38 | -0.09 | -3.52 | -0.73 | 0.48 |
| SF-D | 0.01 | -0.03 | -0.00 | -0.06 | -0.01 | 0.55 |
| SH-T | -0.04 | -0.48 | -0.16 | -5.74 | -1.19 | -0.22 |
| SH-D | -0.05 | -0.10 | -0.07 | -1.95 | -0.40 | -0.15 |
| SU-T | -0.00 | -0.42 | -0.11 | -4.25 | -0.88 | 0.24 |
| SU-D | -0.01 | -0.05 | -0.02 | -0.68 | -0.14 | 0.31 |

Tables 5 and 6 in Appendix F. Fig. 2 summarizes the dynamic responses under transfer scenarios, while Fig. 3 presents the corresponding results for subsidy scenarios. Results for untargeted price subsidies are reported in Appendix E. All impulse responses are displayed for a period of ten years, that is, until the energy price returns to its pre-shock level.

Fig. 2 shows that the energy price shock leads to a decline in GDP, firms' energy demand, investment, and private consumption, alongside an increase in hours worked. Qualitatively, the macroeconomic dynamics under the various transfer schemes closely resemble those observed in the no-policy scenario (gray line). However, tax-financed transfers amplify the downturn, producing a sharper decline in GDP and investment (blue dashed lines). The simulation results indicate that a 135% increase in energy prices causes GDP to fall by about 5.5% at its trough, which occurs after roughly five quarters. Across all transfer schemes, firms reduce energy use by 30% in the fourth quarter before gradually increasing utilization as energy prices ease. Associated with the decline in GDP, we observe a drop in investment of around 18% after 5 quarters, along with a peak decline in private consumption of approximately 5% in quarter 4. Furthermore, we see a modest increase in hours worked of around 2%. Note that the increase in hours worked is roughly 0.5 percentage points smaller under the tax-financed transfer schemes.

While most aggregate dynamics in response to the energy price shock align with expectations, the positive reaction of hours worked appears surprising. As we will demonstrate later, labor market adjustments play a crucial role in the economy's response to rising energy prices. The observed increase in hours worked can be explained by the parametrization of the production function (15), more precisely by the assumed unit elasticity of substitution between labor, energy, and capital, but limited substitutability between capital and energy, governed by the inverse elasticity of substitution ρ_f . With ρ_f calibrated at 1.94, capital and energy act as complements in production, restricting the extent to which firms can substitute away from energy when its price rises. Moreover, the presence of investment adjustment costs in the model further constrains short-term changes in the capital stock. As a consequence, wages decline relatively strongly, causing the income effect to dominate the substitution effect and leading to a modest increase in hours worked. The sensitivity analysis in Appendix C.1 demonstrates that a higher elasticity of substitution between capital and energy leads to a decline in hours worked following the energy price shock. However, we also find that variations in ρ_f have only minor implications for the welfare results reported in the main text.

Next, we compare the aggregate dynamics across the different subsidy schemes, as illustrated in Fig. 3. In general, the qualitative patterns resemble those observed for transfer schemes. Tax-financed subsidy measures amplify the decline in GDP. In general, although firm subsidies help stabilize output, they also stabilize energy imports under

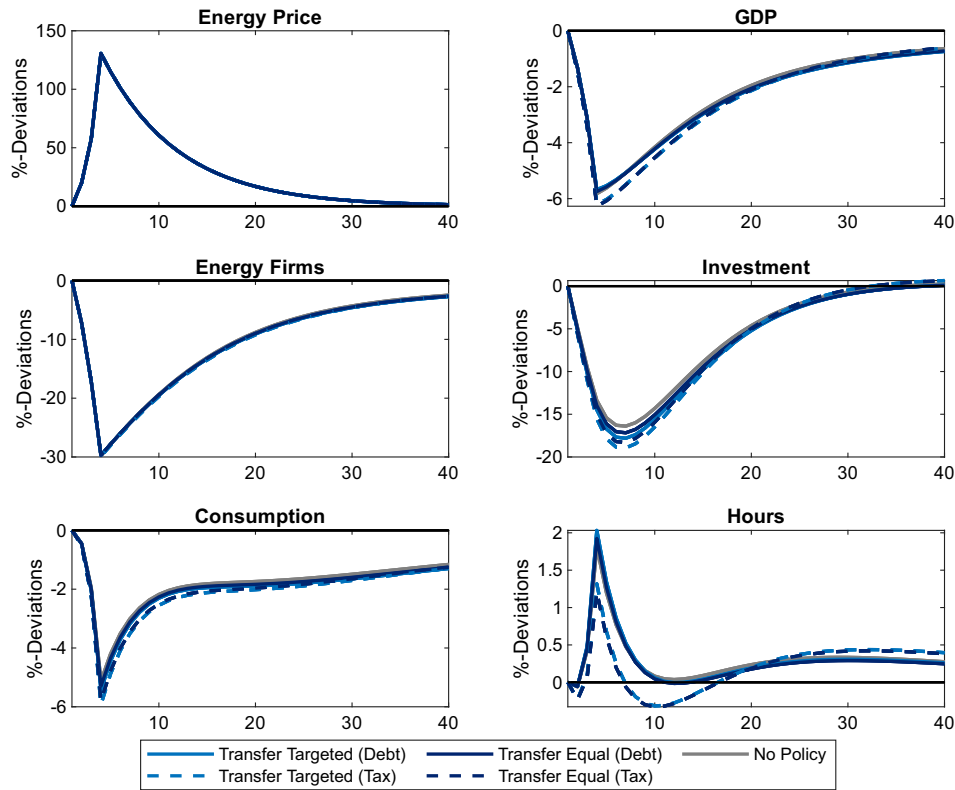


Fig. 2. Unexpected increase in energy prices, transfers, macroeconomic variables. Quarterly time steps.

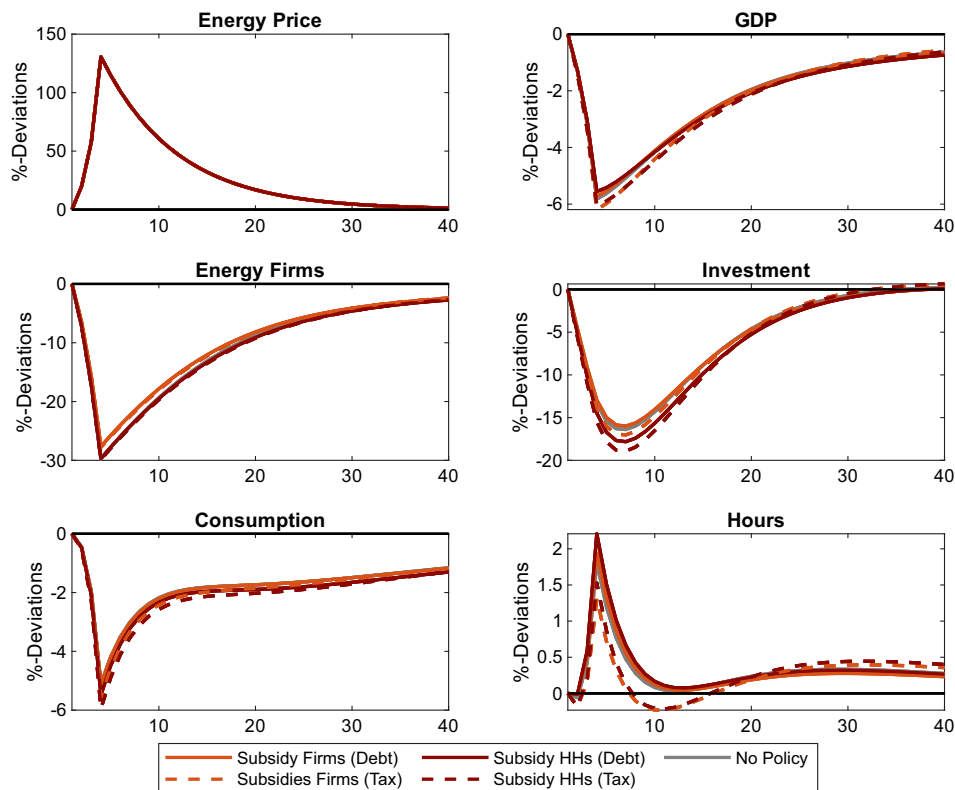


Fig. 3. Unexpected increase in energy prices, energy price subsidies, macroeconomic variables. Quarterly time steps.

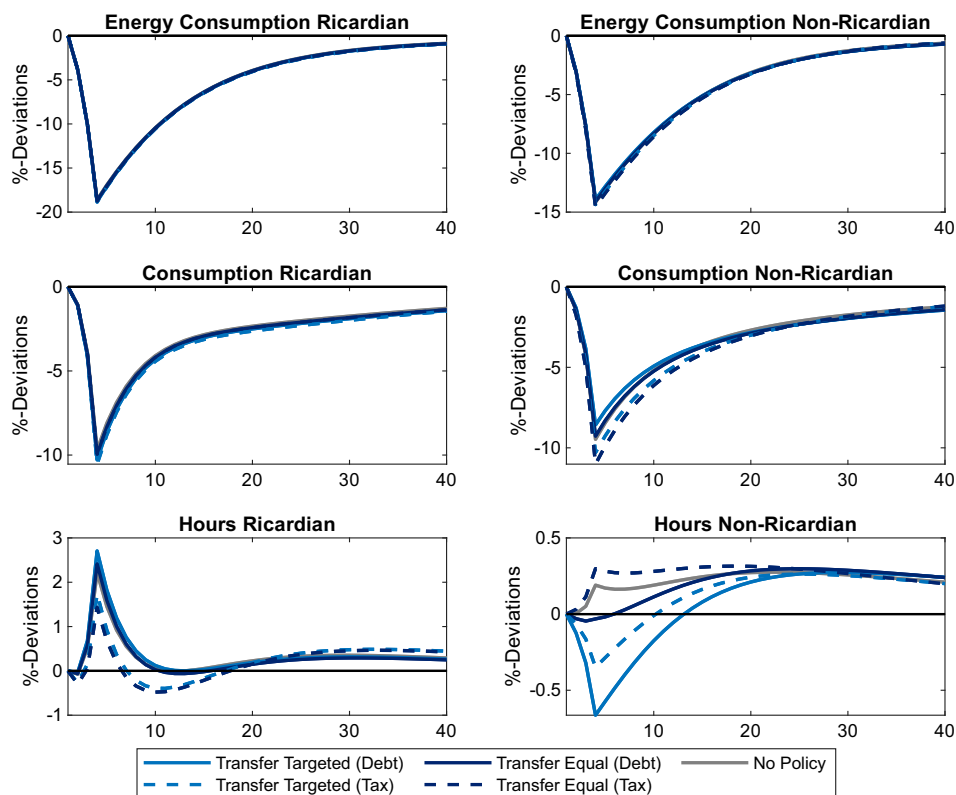


Fig. 4. Unexpected increase in energy prices, transfers, distributional variables, quarterly time steps.

deteriorated terms of trade, which depress GDP. In our baseline calibration, these opposing effects largely offset one another. Investment contracts most under tax-financed household subsidies and least under debt-financed firm subsidies. Because of this, the latter have a positive effect on GDP over a 5-year horizon. Finally, it is noteworthy that the reduction in firms’ energy demand is roughly 2 percentage points smaller under firm energy price subsidies compared to household energy price subsidies.

The cumulative results for the 10-year horizon in Table 4 offer several insights. In line with the graphical impression, the discounted cumulative output loss in response to the energy price shock is largest under the transfer scenarios. The largest overall loss in GDP is observed in a scenario with targeted transfers to non-Ricardian households financed by taxes. In contrast, the smallest cumulative loss in GDP is observed in the scenarios with debt-financed subsidies. While these measures have a positive effect on GDP in the short run, it becomes negative in the long run (see Tables 5 and 6 in Appendix F). There, tax-financed firm subsidies perform best and have a positive cumulative effect on GDP. This aligns with the results of Turco et al. (2023), who found that energy tariff reductions are the most effective policy measure for stabilizing output.

This pattern is also confirmed when considering the fiscal multipliers associated with the different policies. The least negative fiscal multiplier is observed for firm energy price subsidies and debt-financed mixed subsidies. For the 10-year horizon, debt-financed measures have a larger fiscal multiplier than tax-financed measures. This can partly be explained by the additional distortions associated with tax increases that manifest themselves directly. Indeed, when considering a longer time horizon, the fiscal multiplier is larger for tax than for debt-financed firm subsidies (see Table 6 in Appendix F).

Across all time horizons, the cumulative results on total energy consumption confirm the visual impression: Any subsidy that lowers the energy price for firms leads to lower energy savings. This is important

because of two reasons. First, lower energy savings conflict with the goal of reducing energy consumption, which has become a priority due to constrained energy supply during the crisis. Second, they may affect European energy prices in a way that is not captured by our model, resulting in detrimental beggar-thy-neighbor dynamics.¹³

Overall, the analysis of macroeconomic dynamics provides valuable insights into the two policy objectives of achieving aggregate energy savings and preventing a recession. Despite the substantial fiscal volume of the measures analyzed, no policy can prevent the recession. Debt-financed energy price subsidies for firms prove to be the most effective tool for alleviating the recession in the short run, as they mitigate the negative impacts of the energy price shock on both output and investment. However, their long term effect on GDP is negative and they distort firms’ energy savings incentives, thus jeopardizing the goal of maximizing energy savings.

4.2. Household-level dynamics

The next step of our analysis is to dissect the effect of the energy price shock on household-level dynamics. This is conducive to understanding how policy measures affect households and which policy measures are best suited to achieve the goals of maximizing energy savings and mitigating energy poverty. As before, we start by comparing the effects of the transfer policy schemes, followed by an examination of the subsidy schemes. Fig. 4 illustrates the responses for the transfer scenarios; Fig. 5 shows the responses for the subsidy scenarios.¹⁴

¹³ Appendix D provides some calculations on these effects. A more detailed analysis of the impacts of an energy price shock in a monetary union is provided in Bayer et al. (2023). The authors find that energy price subsidies most efficiently limit the recessionary impact of the shock but come with negative spillover effects for the rest of the union.

¹⁴ The results for the untargeted price subsidies can be found in the Appendix E.

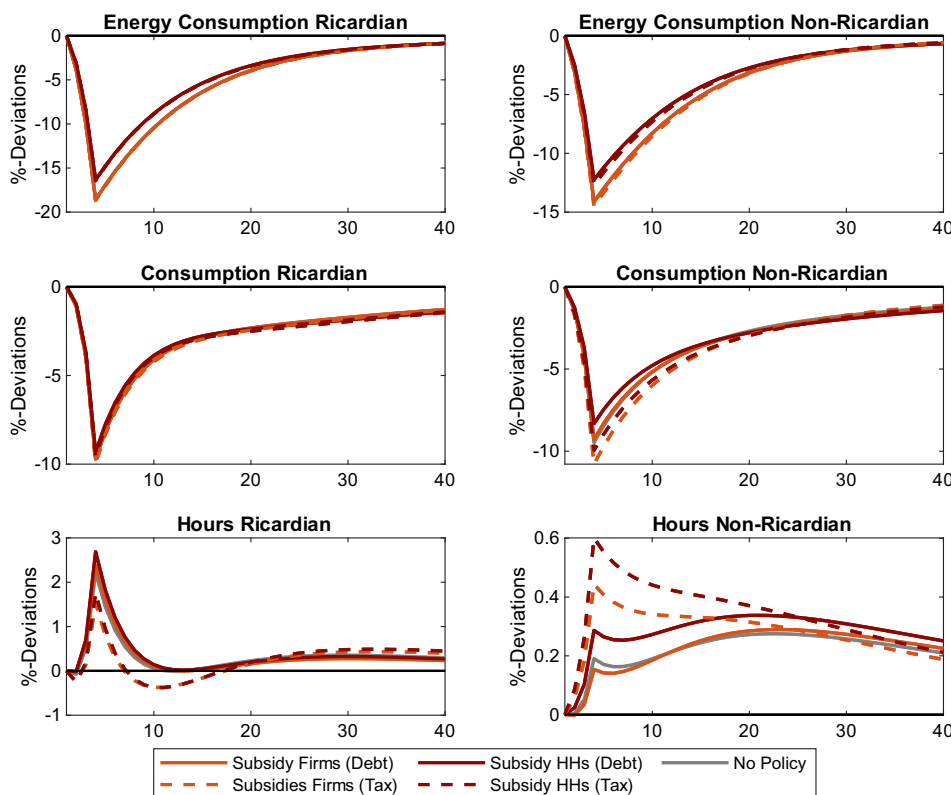


Fig. 5. Unexpected increase in energy prices, energy price subsidies, distributional variables. Quarterly time steps.

As illustrated in Fig. 4, the sharp absolute and relative increase in energy prices leads to a pronounced decline in household energy consumption. At the same time, households also cut back on non-energy consumption due to the income effect of higher energy costs. The adjustment in consumption portfolios is heterogeneous across household types. Owing to non-homothetic preferences, Ricardian households reduce their energy consumption by about 18%, whereas non-Ricardian households—being closer to their subsistence level of energy consumption—reduce it by only about 14%. Ricardian households reduce non-energy consumption by about 10% after four quarters, largely independent of the transfer scheme due to their ability to smooth consumption intertemporally. By contrast, non-Ricardian households’ adjustment is policy-dependent: under tax-financed measures, they cut non-energy consumption by roughly 10%, whereas under debt-financed transfers, the reduction is limited to around 7%. This reflects their direct exposure to policy design, with debt-financed schemes cushioning consumption losses and tax-financed schemes offsetting transfer gains through higher taxes.

Finally, the response of hours worked varies with the transfer scheme. Ricardian households increase labor supply by about 2.5% under debt-financed measures and by roughly 2% under tax-financed measures, the difference reflecting the distortionary effect of higher income taxation. For non-Ricardian households, the reaction is qualitatively different and quantitatively smaller. Under debt-financed targeted transfers, hours worked decline by around 0.7% at peak after four quarters and remain below baseline for the first ten quarters. We observe similar dynamics for tax-financed targeted transfers, with a peak decline of roughly 0.2% after four quarters. By contrast, for equal transfers and in the no-policy case, labor supply increases modestly with a peak increase of roughly 0.3% after four quarters for tax-financed equal transfers. The reduction in labor supply under targeted transfers indicates a temporary overcompensation, consistent with the relatively large transfers that limit the decline in non-energy consumption to about 7%.

Fig. 5 illustrates the responses of household energy consumption, non-energy consumption, and hours worked by household type under different subsidy schemes. Qualitatively, the patterns are similar to those in the no-policy scenario. However, the declines in energy consumption for both household types are about 1.5 percentage points smaller when household energy prices are subsidized. As before, non-energy consumption of Ricardian households remains largely unaffected by the policy, whereas non-Ricardian households reduce non-energy consumption by roughly 2 percentage points less under debt-financed household subsidies compared to tax-financed firm subsidies. This difference reflects the mitigated impact of the energy price increase, which helps stabilize disposable income for non-Ricardian households. Regarding labor market dynamics, both household types increase hours worked in response to the shock, irrespective of the policy scheme. Ricardian households raise labor supply by about 2.7% under debt-financed measures and by roughly 1.7% under tax-financed measures, reflecting the distortionary effect of higher income taxation. Non-Ricardian households’ hours increase by approximately 0.6% under tax-financed household subsidies, whereas under debt-financed firm subsidies the peak increase is only around 0.2%.

In summary, the analysis of household-level dynamics provides several key insights regarding the effects of transfer schemes compared to energy price subsidies. First, while transfer schemes leave household energy consumption largely unchanged, household energy price subsidies dampen the decline in energy consumption by roughly 2 percentage points. This suggests that price subsidies can help alleviate energy poverty, particularly for non-Ricardian households, but may undermine the goal of maximizing energy savings. Second, non-energy consumption of Ricardian households is largely unaffected by the policy type, whereas non-Ricardian households benefit from debt-financed measures, highlighting that the choice of financing has important short-run implications for household utility. Third, labor market responses constitute a relevant margin of adjustment and depend on the

financing scheme. Tax-financed measures tend to dampen the labor supply response of Ricardian households, while debt-financed measures are associated with a smaller labor supply response from non-Ricardian households.

In light of the relatively small differences in aggregate dynamics and the systematic differences at the household level, one can gain insights into how policy measures perform in terms of energy savings and consumption stabilization. However, given the observed differences in output, investment, and labor market dynamics, a welfare comparison is warranted to accurately capture the overall effects of the policies.

4.3. Welfare analysis

As discussed, the dynamics under different policy measures reveal variations in both aggregate outcomes and household-level variables. Therefore, to evaluate the effectiveness of these policies, it is essential to assess their welfare effects across scenarios. To this end, we compute the welfare effects of the different policy instruments in light of an energy price shock relative to the deterministic steady state of the model. Formally, to compute the welfare effects we solve for the compensating variation $\Delta^{(j)}$ of scenario j for household $i = R, NR$ ¹⁵:

$$\sum_{t=0}^T \beta^t u((1 - \Delta_i^{(j)})x_{i,ss}, h_{i,ss}) = \sum_{t=0}^T \beta^t u^{\text{Policy}}(x_{i,t}^{(j)}, h_{i,t}^{(j)}), \quad (24)$$

where $x_{i,t} \equiv c_{i,t} + p_{h,t} c_{e,i,t}$ encompasses both consumption types. We then compute the difference between $\Delta_i^{(\text{Policy})}$ and $\Delta_i^{(\text{No-Policy})}$, $i = R, NR$, as the measure of welfare.

The results for a time-period of 10 years are displayed in Table 4. These are consistent with the impulse responses we displayed and discussed in Sections 4.1 and 4.2. We complement this analysis by comparing welfare effects of the different policy scenarios over a time-period of 5 years and 200 years, displayed in Tables 5 and 6 in Appendix F. The 5-year horizon corresponds to the length of a legislative cycle, a time horizon that we deem to be particularly relevant for present-biased governments.¹⁶ The 200-year horizon represents an infinite time horizon,¹⁷ the usual normative benchmark. Unsurprisingly, the longer the time horizon, the smaller the welfare differences between the policy measures.¹⁸

The results of the welfare analysis clearly indicate that non-Ricardian and Ricardian households prefer different compensation measures, as well as financing schemes. Regardless of the policy instrument, from a welfare perspective, non-Ricardian households prefer debt financing over tax financing. As they cannot smooth consumption, financing relief measures through an increase in public debt leads to a smoother consumption profile. However, the specific compensation measure matters for the magnitude of the welfare effects.

Non-Ricardian households benefit most from targeted transfers, for which their welfare gains amount to around 0.15 percentage points. This translates into a present value of gains of roughly 340 Euros in total (see Table 7 in Appendix F).¹⁹

The finding that targeted transfers effectively compensate the non-Ricardian households aligns with the results of Kröger et al. (2023). According to their analysis, low-income households would receive 1380

¹⁵ In this case, $\Delta^{(j)} \cdot x_{i,ss}$ is the payment *per period* in steady state that makes the household $i = R, NR$ indifferent between this steady state setup and being exposed to the energy price shock combined with the combination of government policy and financing scheme for T periods in the scenario j . In other words, welfare effects are expressed as receiving a payment of $\Delta_i^{(j)} \cdot x_{i,ss}$ *per period* for being exposed to the particular scenario.

¹⁶ Yared (2019) summarizes how several political factors imply that a government's behavior can be represented by an agent with present-biased and dynamically inconsistent preferences.

¹⁷ In our model, after 200 years, all variables return to their steady state and results remain effectively unchanged. In particular, all debt taken-on to finance relief measures is redeemed.

Euros per year. The difference in our findings can partly be explained by the fact that Kröger et al. (2023) estimate the isolated impact of transfer payments. In contrast, our analysis focuses on welfare and incorporates broader macroeconomic effects, particularly labor market impacts. The results resonate with Pieroni (2023), too, who argues that targeted transfers are well-suited to addressing the unequal burden of energy price shocks. However, the associated costs to Ricardian households are substantial. Therefore, a government would only favor this policy measure if sufficient consideration were given to non-Ricardian households.²⁰

Surprisingly, non-Ricardian households prefer firm subsidies over equal transfers or household energy price subsidies. This finding is directly related to the stabilization of production associated with subsidies for energy prices for firms, which sustain labor income. Investment adjustment costs play a crucial role in explaining the positive effect on non-Ricardian households. Following an energy price increase, profit-maximizing firms reduce their energy consumption but cannot immediately scale down their capital input to the same extent due to these adjustment costs. As energy price subsidies temper the price increase, the need for reductions in factor inputs is similarly moderated. This leads to higher capacity utilization of labor and capital, stabilizing factor incomes – particularly real wages. For non-Ricardian households, who smooth consumption solely through their labor supply, higher wages reduce the cost of consumption smoothing. Notably, in the short run, non-Ricardian households work less under debt-financed firm subsidies than in the no-policy scenario (see Fig. 5), allowing them to better stabilize both labor supply and consumption. In line with Pieroni (2023), labor market adjustments in response to an energy price shock serve as a key transmission channel in our model.

The picture is different for Ricardian households. Because they can perfectly smooth consumption, they do not benefit from debt financing. In contrast, they prefer compensation measures that are tax-financed. The reason is the adjustment in the labor supply of non-Ricardian households. When compensation measures are tax-financed, non-Ricardian households respond by increasing their labor supply relatively more. This benefits Ricardian households because it stabilizes capital income.

From a welfare perspective, Ricardian households clearly prefer tax-financed firm subsidies over alternative measures. Again, this is a matter of stabilizing overall production, from which Ricardian households benefit doubly through their wage and capital income. Ricardian households face the largest welfare losses when transfers are exclusively for non-Ricardian households. In this case, they pay for the measures but do not receive any benefits, and the present value of their losses amounts to around 765 Euros (see Table 7 in Appendix F).

Differences in individual welfare effects are directly reflected in differences in aggregate welfare effects, computed as the population-weighted sum of welfare of Ricardian and non-Ricardian households.²¹ In our setup, debt-financed firm subsidies emerge as the most favorable option, even though their welfare impact is neutral. Their relatively

¹⁸ In line with the argumentation of Lucas (1987), the potential long-run welfare gains from stabilization measures are relatively moderate. Furthermore, the differences regarding the financing schemes vanish, too.

¹⁹ We compute the euro-valued welfare gains over the whole period since, when calibrating the model, we match the cumulative fiscal cost of the analyzed policy measures. In detail, we compute the discounted sum of consumption equivalent variations $\sum_{t=0}^T \beta^t \cdot (\Delta_i^{(j)} - \Delta_i^{(\text{No Policy})}) \cdot x_{i,ss}$ of household type i and scenario j over $T = 40$ periods. To convert it to Euro, we multiply it with the factor $\frac{3 \times \bar{x}_{emp}}{\lambda \times N_{R,ss} + (1 - \lambda) \times N_{NR,ss}}$, where \bar{x}_{emp} is the monthly average consumption expenditure of German households in 2018 taken from the EVS.

²⁰ This could be the case if the welfare effects are evaluated with a utilitarian social welfare function. In this case, the relatively higher marginal utility of non-Ricardian households would add weight to their welfare gains.

²¹ Note that aggregate welfare does not correspond to welfare as computed with a classical Utilitarian welfare function. Rather, our aggregate welfare measures indicate – when positive – a Kaldor-Hicks improvement.

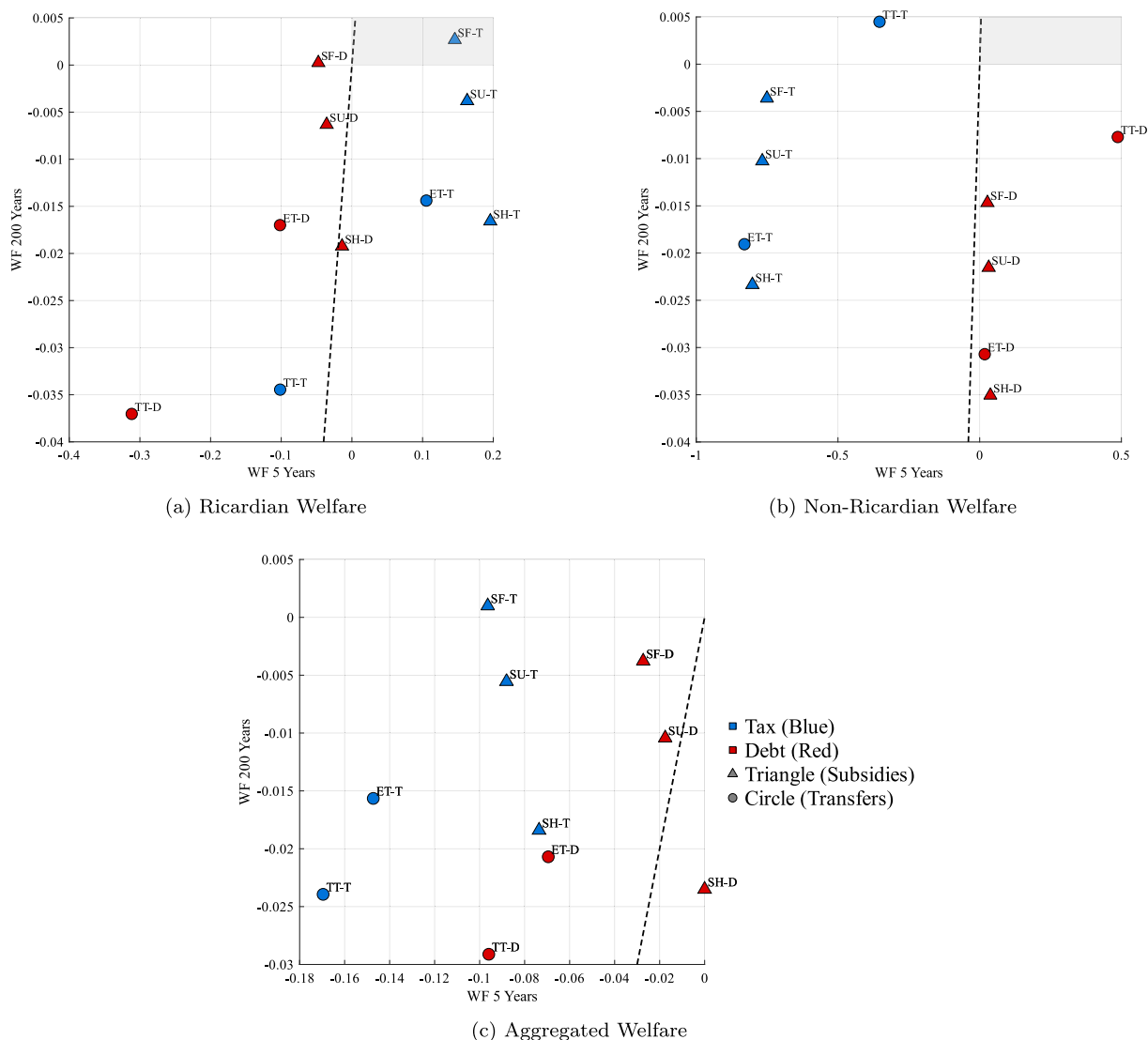


Fig. 6. Comparison of welfare outcomes of different policy measures (see Table 3 for the scenario keys) across Ricardian households, Non-Ricardian households, and an aggregated measure. The dashed line depicts the 45° line through the origin. The grey shaded area indicates the positive quadrant.

strong performance in terms of aggregate welfare stems from two effects discussed above. On the one hand, Ricardian households place value on output-stabilizing policies. On the other hand, non-Ricardian households benefit from measures that facilitate labor market adjustment — particularly when such policies are financed through public debt.

The finding that energy price subsidies for firms can improve welfare contrasts with the results of Bayer et al. (2023), who conclude that such subsidies are welfare-inferior to direct transfers to households. A potential explanation for this discrepancy lies in differences in the modeling approaches and calibration choices. Notably, the energy share in production is higher in the present study, as it reflects a broad mix of fossil energy sources used in production. In contrast, Bayer et al. (2023) calibrate the energy share in production to 0.005, which is intended to represent the use of natural gas specifically. As a result, energy price subsidies for firms have a more pronounced impact on output in the present analysis. Additionally, this study does not account for the potential effects of subsidies on fossil fuel spot market prices, as discussed in Appendix D.

An important result of our analysis is that focusing on the effects of a policy measure on GDP is not always indicative of the welfare effects. This is particularly true for non-Ricardian households and, therefore,

relevant in situations where the main goal is to prevent energy poverty. For example, debt-financed transfers targeted to the non-Ricardian households perform best with respect to the welfare of the latter while having a negative effect on GDP. This highlights the need for macroeconomic policies to explicitly focus on welfare effects rather than exclusively targeting GDP.

Next, we extend our welfare analysis by comparing short- and long-run welfare effects of the different policy measures. This comparison sheds light on which policies might be sensible in the long run and politically feasible, due to their welfare effects in the short run.

Fig. 6 provides a graphical comparison between the short and long term effects. Any policy measure located in the gray area in the top-right corner has a positive welfare effect both in the short and the long run. Policy measures to the left of the dashed line have a higher welfare effect in the long run compared to the short run. The opposite is true for policy measures on the right-hand side of the dashed line.

Fig. 6(a) shows the results for the Ricardian households. In the short run, almost all tax-financed measures have a positive welfare impact on Ricardian households. As already mentioned, this can be traced back to the labor market effects on non-Ricardian households, who increase hours worked in reaction to tax increases relatively more. This

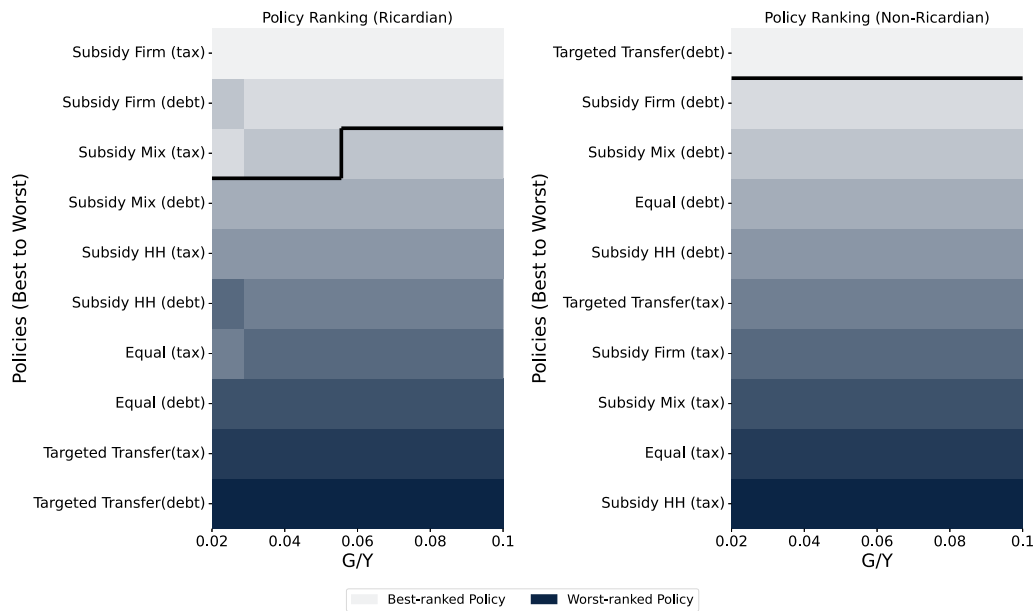


Fig. 7. Welfare ranking of policy packages for different fiscal volumes for low and high-income households. We vary cumulative fiscal spending between 2 and 10% of steady-state output. Welfare is calculated in consumption equivalent variations over a 10-year horizon. The black lines separate positive from negative welfare impacts. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

benefits Ricardian households by stabilizing capital income. All measures that involve firm subsidies (including the untargeted subsidies) perform quite well in both short and long run. The only measure that is positive in both cases is the tax-financed provision of firm subsidies. In other words, while several policy measures might gain the political support of Ricardian households because of their positive welfare effects in the short run, only the tax-financed provision of firm subsidies seems sensible in the long run, as well. However, it is important to bear in mind that all measures including firm subsidies perform poorly when it comes to energy savings, increasing energy consumption in comparison to the no-policy scenario. They are at odds with the goal of maximizing energy savings. When tax-financed, they perform poorly when it comes to preventing energy poverty, too.

Fig. 6(b) shows the results for the non-Ricardian households. No policy measure has positive welfare effects in both short and long run. In other words, among the policy measures considered, none finds political support from non-Ricardian households and is sensible in the long run. In the short run — and in contrast to Ricardian households — all debt-financed measures have a positive welfare effect. Among them, debt-financed targeted transfers have the biggest effect. They are particularly effective in targeting low-income households in the short run. In the long run, only tax-financed targeted transfers have a positive welfare effect. However, the effect is very small, particularly compared to its relatively large negative effect in the short run. If the government's goal is to prevent energy poverty, a combination of tax- and debt-financing might reconcile political feasibility with positive effects in the long run. Further analysis is needed to verify this hypothesis.

The aggregate results are displayed in Fig. 6(c). As for the non-Ricardian households, no single policy measure has a positive welfare effect in both short and long run. In fact, only few policy measures have a positive effect along any dimension. Debt-financed subsidies perform least badly. The comparison of the welfare effects in the short and long run show, that it is difficult to reconcile the long run perspective with what might be feasible in the short run. For instance, when it comes to the goal of preventing energy poverty, policies that have positive short run effects on low-income households are detrimental in the long run, and vice versa. Exploring combinations between tax- and debt-financing might be a valuable extension of this work.

4.4. Sensitivity analysis

To verify the robustness of our results, we perform several sensitivity analyses. In Appendix C, we compare the welfare results for different values of the investment adjustment cost κ , the intertemporal elasticity of substitution from the utility function η as well as the substitution elasticity between capital and energy from the production function σ_f . For κ and η , the sensitivity analysis reveals only small quantitative changes. Most importantly, the preference ordering by Ricardian and non-Ricardian households remains unchanged and we observe only a few sign switches for some subsidy measures for the Ricardian households.

The elasticity of substitution between energy and capital σ_f is a key parameter in our model. For a given shock, the elasticity governs the response of firms. A higher elasticity corresponds to more flexibility and a quicker return to the initial steady state. In terms of welfare, this elasticity affects both the labor demand of firms and the distortion created by the financing of relief measures. The sensitivity analysis with regard to σ_f reveals that the financing scheme loses importance for non-Ricardian households, the higher the elasticity σ_f . Preferences with regard to the policy instrument are stable. A similar pattern arises for Ricardian households. Interestingly, for higher levels of σ_f , Ricardian households prefer debt-financing, too. This is most likely due to the weaker effect of taxes on non-Ricardian households, who do not increase their labor supply anymore in reaction to the shock, for higher elasticities. Regardless of the choice of σ_f , Ricardian households prefer energy price subsidies for firms over all other policy measures while non-Ricardian households experience the greatest gains from debt-financed targeted transfers.

The welfare effects additionally depend on the size of the compensation package since both the support for households and the distortion through financing depend on its magnitude. Therefore, we analyze how individual and aggregate welfare change for different sizes of the compensation package.²² Fig. 7 provides a welfare ranking of policies for

²² In our baseline scenario, we split up the (announced) cumulative fiscal volume of the German intervention (6.45% of 2022 GDP) over the entire time horizon and allocate funds in proportion to the deviation of the energy price from steady state.

different fiscal volumes for both household types. In this sensitivity analysis, we vary compensation packages from 2% to 10% of GDP and observe significant differences between non-Ricardian and Ricardian households. For non-Ricardian households, the compensation size does not affect the welfare ranking; the financing scheme is the key driver. Debt financing, regardless of the intervention type, helps non-Ricardian households smooth consumption. For instance, debt-financed firm subsidies outperform tax-financed targeted transfers, regardless of package size. However, only debt-financed targeted transfers result in an absolute welfare gain. In this case, the welfare gain increases with the size of the compensation package.

For high-income households, the policy ranking is less straightforward. While tax-financed firm subsidies are always best and targeted transfers are always worst, the ranking varies for certain policies. Specifically, when compensation packages are smaller, Ricardian households prefer tax-financed untargeted subsidies over debt-financed firm subsidies. However, as compensation packages increase, they consistently favor debt-financed firm subsidies. This shift occurs because, for smaller packages, the labor market effects caused by a tax-financed scheme outweigh the benefits of broadly stabilizing factor incomes through firm subsidies. But as the compensation size grows, the negative labor market effects of untargeted subsidies diminish, and the stabilizing impact of firm subsidies becomes more dominant. Overall, for Ricardian households, energy price subsidies for firms lead to welfare gains in absolute terms regardless of the financing scheme. However, only the welfare gain of debt-financed firm subsidies increases with the size of the compensation package. The welfare impact of tax-financed untargeted subsidies is positive for smaller packages and becomes negative for larger compensation packages.

The takeaway messages from the analysis of the compensation package size are the following. Households rank policies regardless of the size of the compensation package. Non-Ricardian households rank first according to the financing scheme and then to the type of intervention. All debt-financed measures perform better than tax-financed measures. Within a specific financing scheme, non-Ricardian households then have a stable ranking of policies depending on their type. In contrast, Ricardian households rank policies first according to their type and then to the financing scheme. For example, subsidies are always better than transfers, and equal transfers are always better than targeted transfers. For a specific policy, Ricardian households prefer tax to debt-financing. An exception to this rule is small compensation packages, where the financing scheme gains importance and the Ricardian's preference for tax-financing partially mixes up the otherwise clear cut ranking between policy measures.

5. Conclusion

The surge in fossil energy prices in 2022 posed a severe challenge for European governments, straining both households and industry. Given the magnitude and external nature of the shock, policymakers introduced a range of crisis measures to stabilize economic activity, promote energy saving, and alleviate rising energy poverty. In this paper, we present a comprehensive assessment of alternative policy instruments and their financing schemes, using a DSGE model calibrated to the German economy. Specifically, we compare energy price subsidies with direct transfers, distinguishing between targeted and untargeted approaches. This framework allows us to evaluate both the macroeconomic implications and the distributional consequences of the policy responses adopted in Germany during the energy crisis.

The analysis of macroeconomic dynamics in response to the energy price shock shows that no policy measure can prevent a recession. However, debt-financed firm energy price subsidies appear to be best suited to mitigate the decline in GDP. This stabilization reduces firms' energy savings by about 3% relative to other policies. Furthermore, we see that consumption by low-income households benefits most from debt-financed targeted transfers and household energy price subsidies.

In terms of welfare, low-income and high-income households prefer different policies and financing schemes. On the one hand, low-income households prefer debt-financed instruments, as these help them smooth consumption in response to the energy price shock. Overall, they favor targeted transfers but also benefit from the wage-stabilizing effect of firm subsidies. On the other hand, high-income households strongly prefer tax-financed instruments. Since they are better able to cope with rising energy prices, they benefit from the labor market effects associated with tax-financed measures. These findings emphasize the importance of considering labor market dynamics as a key driver of welfare impacts.

Our findings imply that the evaluation of compensation policies depends on the target of the policymaker. If the goal is to prevent an increase in energy poverty, debt-financed targeted transfers or energy price subsidies for consumers are suitable policies. However, the same policy may not be suitable for protecting firms and stabilizing GDP. When evaluating supply-side instruments, long-term concerns related to permanent deindustrialization due to rising fossil energy prices play a role, particularly in the German debate. There may be conflicts between targets in the short and long run. If large declines in output increase the likelihood of a permanent reallocation of production, debt-financed energy subsidies for firms appear to be a useful tool to avoid this. At the same time, these subsidies undermine the goal of maximizing energy savings, which is particularly important in this context given the limited natural gas supply. However, our framework is designed to analyze deviations around the long-term trend and, thus, is not suitable for assessing potential structural breaks like the decision to relocate production by domestic firms.

Lastly, our analysis shows that focusing solely on the effects of a policy measure on GDP does not necessarily reflect its welfare impacts. This is especially true for low-income households, making an explicit welfare assessment particularly relevant when the main goal is to prevent energy poverty. In such cases, policies must focus explicitly on welfare rather than output. In general, no single compensation package can resolve the trade-offs that decision-makers face during the crisis. Confronted with an energy price shock of such magnitude, societies must decide which conflicting goals to prioritize. Our contribution sheds light on the underlying trade-offs and the paths that can be taken. However, our analysis clearly indicates that the welfare impact of crisis relief measures depends both on the type and financing scheme, as well as on the fiscal volume of the intervention. Therefore, a clear policy implication is that the design of crisis intervention needs to be context- and country-specific.

The present findings—and the policy implications derived from them—are contingent on the underlying modeling assumptions. As noted, due to the focus of our analysis, we abstract from important factors affecting the aggregate impact of the recent energy crisis. Our analysis of price subsidies abstracts from potential spillover effects of German policies on broader European energy markets. A more comprehensive approach would require a multi-country DSGE framework, which could capture both cross-border impacts on energy prices and the repercussions of the energy price shock on international trade in other commodities. Developing such a framework represents a promising avenue for future research.

CRedit authorship contribution statement

Alkis Blanz: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Ulrich Eydam:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Maik Heinemann:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Matthias Kalkuhl:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition,

Formal analysis, Conceptualization. **Nikolaj Moretti**: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used GPT-4o and GPT-5 in order to generate some of the figures displayed in this article. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Funding

This work was supported by the German Federal Ministry of Research, Technology and Space (BMFTR) as part of the ARIADNE project (grant references: 03SFK5J0 and 03SFK5P0-2).

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Alkis Blanz reports that financial support was provided by German Federal Ministry of Education and Research (BMBF). Ulrich Eydam reports that financial support was provided by German Federal Ministry of Education and Research (BMBF). Maik Heinemann reports that financial support was provided by German Federal Ministry of Education and Research (BMBF). Matthias Kalkuhl reports that financial support was provided by German Federal Ministry of Education and Research (BMBF). Nikolaj Moretti reports that financial support was provided by German Federal Ministry of Education and Research (BMBF). If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We are very grateful to Ottmar Edenhofer and Francesca Diluiso, as well as the participants of the 28th Annual Conference of the European Association of Environmental and Resource Economists, the 2023 ZEW Public Finance Conference, the Potsdam Research Seminar in Economics, and the seminar series of the PIK Potsdam Future Lab on Public Economics and Climate Finance, for their useful discussions and comments.

Appendix A. Calibration

A.1. Energy price shock

In order to specify the properties of the energy price shock, we construct an energy price index for the German economy based on data from [Arbeitsgemeinschaft Energiebilanzen e.V. \(2023\)](#) and the [World Bank \(2024\)](#). The exchange rates between US dollars and euros are taken from [Board of Governors of the Federal Reserve System \(2024\)](#). For the consumption price index and Gross Domestic Product, we rely on data from the Bundesbank ([Deutsche Bundesbank, 2023](#)) and the Federal Statistical Office of Germany ([German Federal Statistical Office, 2024d](#)), respectively. In the construction of the index, we use quarterly import commodity prices on oil, natural gas, and hard coal, weighted by their annual energy consumption shares.²³ To isolate the cyclical component in energy price movements, we apply the HP-Filter to the logarithms of the quarterly price data. As is common in the literature, we estimate the shock process using ordinary least squares (OLS). The estimation results yield $\rho_p = 0.88$ and $\sigma_p = 0.17$, and both coefficients

²³ The energy consumption shares are calculated relative to their energy-equivalent amounts, i.e., in petajoules per year.

are significantly different from zero at the 1 percent level. [Fig. 8](#) depicts the cyclical deviations of the energy price index for the sample period. Between 2006 and 2022, volatility in energy prices has increased. The increase in volatility appears to be especially pronounced since the start of the pandemic in 2020. Starting from the lowest observation during the COVID-19 pandemic, the recent price increase is the largest fossil energy price hike in the entire sample. As can be inferred from the blue line, energy prices in 2022 increased by about 130 percent compared to the average energy price during the sample period. In particular, the sample includes changes in energy imports and energy use during 2022. Thus, substitution across fossil resource types (natural gas, oil, hard coal) and the change in import shares in reaction to the energy price increase are taken into account in the estimation of the shock. Therefore, the modeled energy price shock reflects the increase in energy prices net of the fuel substitution effects that took place on the production side and constitutes a lower bound for the observed price dynamics.

A.2. Non-energy parameters of the model

A range of parameters is adopted from the relevant macroeconomic literature focusing on Germany. Additionally, we calibrate the model to match key variables, such as hours worked and the aggregate consumption-to-output ratio. When it comes to the parameters that govern the labor supply of households, we take the inverse Frisch elasticity parameter ξ from [Drygalla et al. \(2020\)](#) and calibrate the labor disutility parameters ϕ_R and ϕ_{NR} for Ricardian and non-Ricardian households to match the value of hours worked of $h_{R,t} = h_{NR,t} = 1/3$. Using the average income of the top 73% (Ricardian) versus the bottom 27% (non-Ricardian) of the income distribution in the EVS ([German Federal Statistical Office, 2022](#)), we set the earnings of the Ricardians to be 48% higher than the earnings of the non-Ricardians in steady state ($\theta_R/\theta_{NR} = 1.48$). Productivity parameters are then normalized to $\theta_R = 1.096$ and $\theta_{NR} = 0.7405$ to obtain a steady-state value of aggregated effective hours $h_{SS} = 0.33$.

The intertemporal elasticity of substitution ρ and the investment adjustment cost κ are taken from [Drygalla et al. \(2020\)](#). Both the discount factor β and the depreciation rate of physical capital δ are set to values common in the DSGE literature (see e.g., [Caldara et al., 2024](#); [Holtemöller and Sardone, 2024](#)). The discount factor β is set to 0.9975, which results in an annual real interest rate of 1 percent while δ is set to a yearly rate of 10%. The share of non-Ricardian households $\lambda = 0.27$ is again calculated from the EVS data ([German Federal Statistical Office, 2022](#)). In detail, we calculate λ from the data as the share of households who do not receive income from any capital-related source. The value of λ is in line with previous estimates for the case of Germany ([Grabka and Halbmeier, 2019](#)) and somewhat below the range estimated by [Forni et al. \(2009\)](#) for the Euro area.

Lastly, in our policy comparison, we set the fiscal rule parameter $\Phi = 0.05$ in debt financing scenarios (see [Eq. \(23\)](#)). This value ensures that policy measures are financed through increases in government debt.²⁴ On the contrary, in tax financing scenarios, we set $\Phi = 999$ to ensure that spending is fully financed through increases in taxes.

A.3. Energy related parameters of the model

Energy plays a crucial role in our analysis. Hence, the calibration of energy-related parameters is essential. In our model, energy is used both as an input to the production process and consumed directly by households, thereby entering their utility function. Since these two parts of the model are closely related we choose the following calibration strategy: First, reduce the degrees of freedom by

²⁴ There is extensive literature on estimating the coefficients of fiscal reaction functions. An overview of this literature can be found in [D'Erasmus et al. \(2016\)](#). As explained there, the estimated coefficients vary depending on the sample and estimation method. Based on the overview from [Berti et al. \(2016\)](#), for an advanced economy such as Germany, the value of 0.05 appears appropriate.

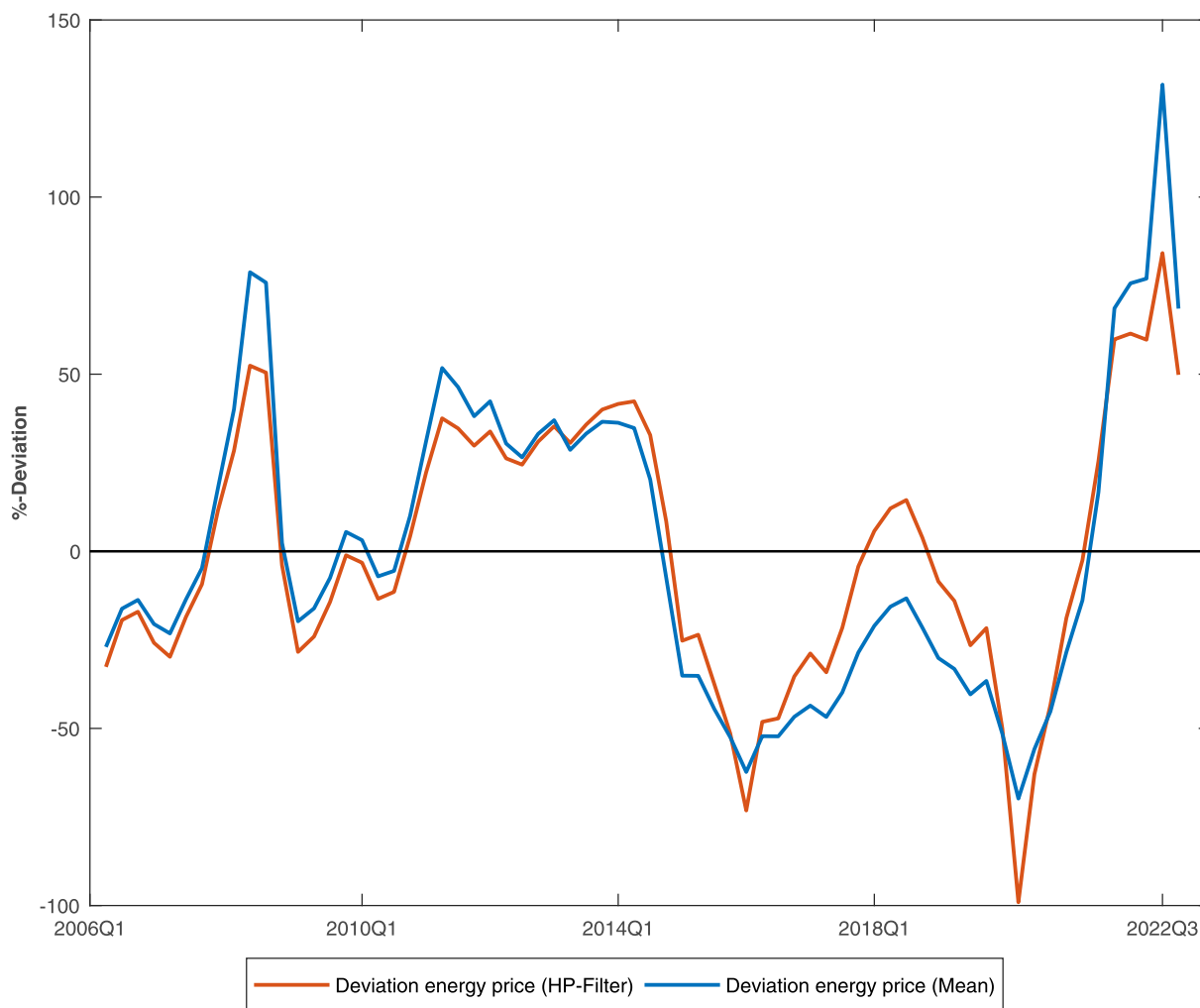


Fig. 8. Energy price dynamics for Germany 2006Q1-2022Q4 based on quarterly data. The red line shows the cyclical deviations of the energy price index from the trend extracted using the HP-Filter. The blue line shows deviations of the energy price from the average energy price. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

estimating some parameters from data and setting some parameters to reliable values from the literature. Second, we jointly set parameters from both the production- and the utility function to minimize the distance between key model variables in steady state and their empirical counterparts.

We start by setting the output elasticity of capital to 0.31 to match the average capital share in Germany between 1991–2021 (German Federal Statistical Office, 2024c). This choice of α is very close to the value chosen by Drygalla et al. (2020). We further estimate the iceberg cost of energy for households \bar{i} to be equal to 1.14. For this, we rely on gas and electricity price data from 2008–2022 published by the German Federal Statistical Office (German Federal Statistical Office, 2023). We weigh the markup paid by households by the respective share of energy use (Arbeitsgemeinschaft Energiebilanzen e.V., 2023).

The parameters taken from the literature are the elasticity of substitution between energy and capital σ_f in our nested CES production function. We follow the macroeconomic model of the Deutsche Bundesbank (Haertel et al., 2022) and set $\sigma_f = 0.34$. Next, we define the subsistence consumption level as a function of (time-invariant) steady state average overall consumption expenditures $\bar{c}_e := \theta_{ce} \cdot \bar{x}_{ss}$ and set $\theta_{ce} = 5.8\%$. We obtain this value for θ_{ce} relying on Schulte and Heindl (2017). In more detail, we add up their empirical estimates for subsistence expenditure values for heating and electricity, which they estimate based on the EVS and divide it by average monthly consumption expenditure from

the EVS.²⁵ We follow Schulte and Heindl (2017) and convert the consumption expenditure data to 2014 CPI Euro using World Bank CPI data (World Bank, 2025).

After this procedure, we are left with three undetermined energy-related parameters: First, the share parameter of energy in the CES production function γ . Second, the share parameter of non-energy consumption in the households' utility function η . Third, the elasticity of substitution between energy and non-energy consumption in the households' utility function σ_H .

We determine these parameters jointly as the solution to a numerical optimization problem²⁶ as the values that minimize the weighted percentage deviation between the steady-state model variables and empirical counterparts of the following four variables: First and second, the energy expenditure shares of Ricardian and non-Ricardian households $\frac{p_{h,ss} c_{e,j,ss}}{x_{j,ss}}$, $j = NR, R$. To obtain their empirical counterparts, we compute the energy expenditure shares of the lower 27 percentiles of the income distribution (non-Ricardian households, 14%) and of the upper 63 percentiles (Ricardian households, 11%), respectively, based on EVS data from 2018 (German Federal Statistical Office, 2022).

²⁵ Due to data availability, we only use EVS data from 1998, 2003, and 2008.

²⁶ We use the *L-BFGS-B* algorithm implemented in the Python solver *minimize* from the *Numpy* library.

The third target variable is the value of energy input to production in percent of GDP $\frac{p_{e,ss} e_{ss}}{y_{ss} - p_{e,ss} e_{ss}}$. We set the empirical target value to 5% of GDP. To determine the value of energy input to production, we extend the energy dataset from the estimation of the fossil energy price shock to include energy from non-fossil sources. For the price of the non-fossil energy sources, we use data on industrial energy prices from the Federal Statistical Office of Germany from 2006 to the end of 2021 (German Federal Statistical Office, 2024a). The respective shares of the energy sources and the total energy use, excluding private households, are taken from *Arbeitsgemeinschaft Energiebilanzen e.V.* (2023). Moreover, we use GDP data for Germany from Eurostat (2024).

The fourth target variable is the share of energy consumption by households in total domestic energy consumption $\frac{c_{e,ss}}{c_{e,ss} + e_{ss}}$. Its empirical target value is set to 28% based on data about the primary energy consumption of households and firms (average over the period 2000-2020) from the German Federal Statistical Office (German Federal Statistical Office, 2024b).

The weights used for the four targets in the minimization problem were (0.38, 0.38, 0.18, 0.06) and are chosen manually to produce a good overall fit.

As a result of this calibration procedure, we set the share parameter of energy in the CES production function $\gamma = 7 \cdot 10^{-6}$, the share parameter of non-energy consumption in the households' utility function $\eta = 0.9775$. Third, the elasticity of substitution between energy and non-energy consumption in the households' utility function $\sigma_H = 0.8109$.

Finally, we normalized the energy import price to 1 to improve the model's numerical performance. We can do this since energy has no physical unit in our model but is instead measured in relation to the non-energy consumption good. What matters is the share of energy expenditures of households and firms in relation to total expenditures and GDP, respectively. We ensure that these model ratios are plausible through our calibration procedure.

Appendix B. Comparison of energy price shocks and TFP shocks

In this appendix, we compare the no-policy benchmark response to an energy price shock with the dynamics caused by a TFP shock calibrated to create the same output loss (Fig. 9). This provides a reference point that is familiar to many readers. Furthermore, it is informative to illustrate the specific characteristics and dynamics of an energy price shock.

A comparison of the macroeconomic effects of an energy price shock and a productivity shock (Fig. 9) yields a central insight: abstracting from the nature of the underlying disturbance leads to a substantial underestimation of its adverse consequences for aggregate variables. While output is, by construction, identical across the two scenarios, the dynamics of all other variables diverge significantly. Firms' energy demand, for instance, remains virtually unchanged under a productivity shock, but contracts markedly in response to an energy price shock. Physical capital and non-energy consumption display qualitatively similar trajectories in both cases, yet their declines are quantitatively smaller following a productivity shock. A comparable pattern emerges for aggregate hours worked.

These differences can be traced to the complementarity of energy, capital, and labor in production, and to the fact that, despite identical output paths, GDP-defined as output net of energy imports—responds very differently across the two shocks. In the energy price shock, the contraction in energy use induces a substantially larger decline in the net interest rate than in the productivity shock, where the interest rate falls in proportion to output. The sharper interest rate response reduces the relative attractiveness of asset holdings, prompting greater dissaving among Ricardian households. Wages are likewise influenced by input complementarity, though the effect is attenuated by the calibration of the nested CES production function, leading to a less pronounced decline in wages compared to the fall in interest rates. The simultaneous reduction in disposable income and increase in energy costs amplifies

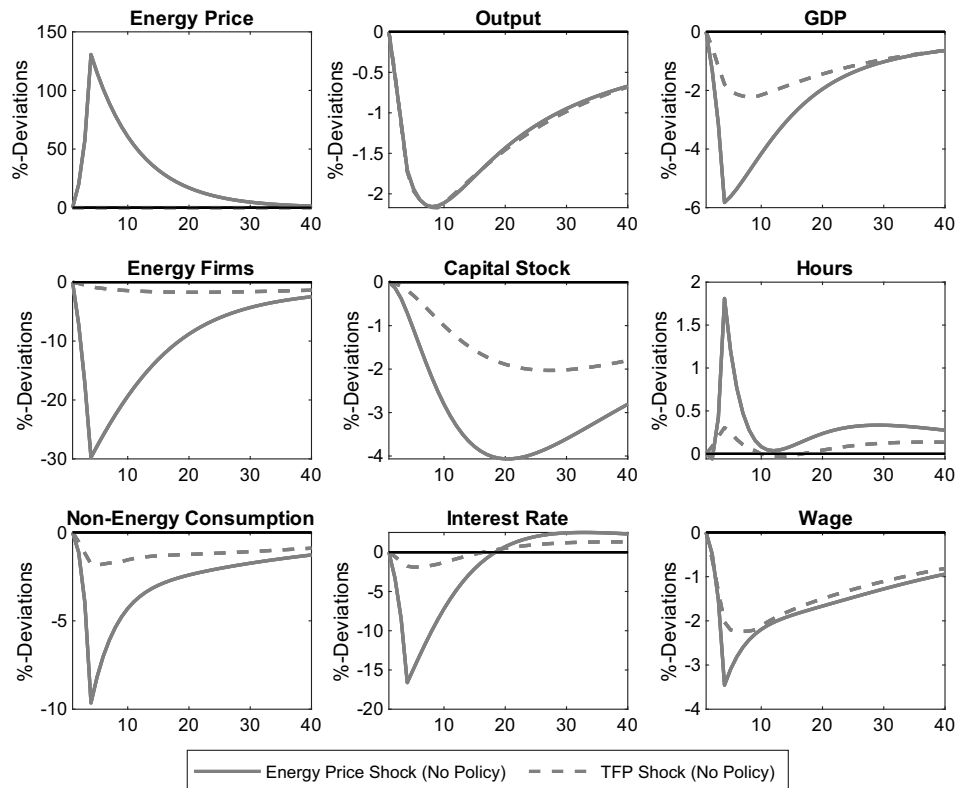


Fig. 9. Comparison: Energy Price Shock vs. TFP Shock - Macroeconomic Aggregates. Quarterly time steps.

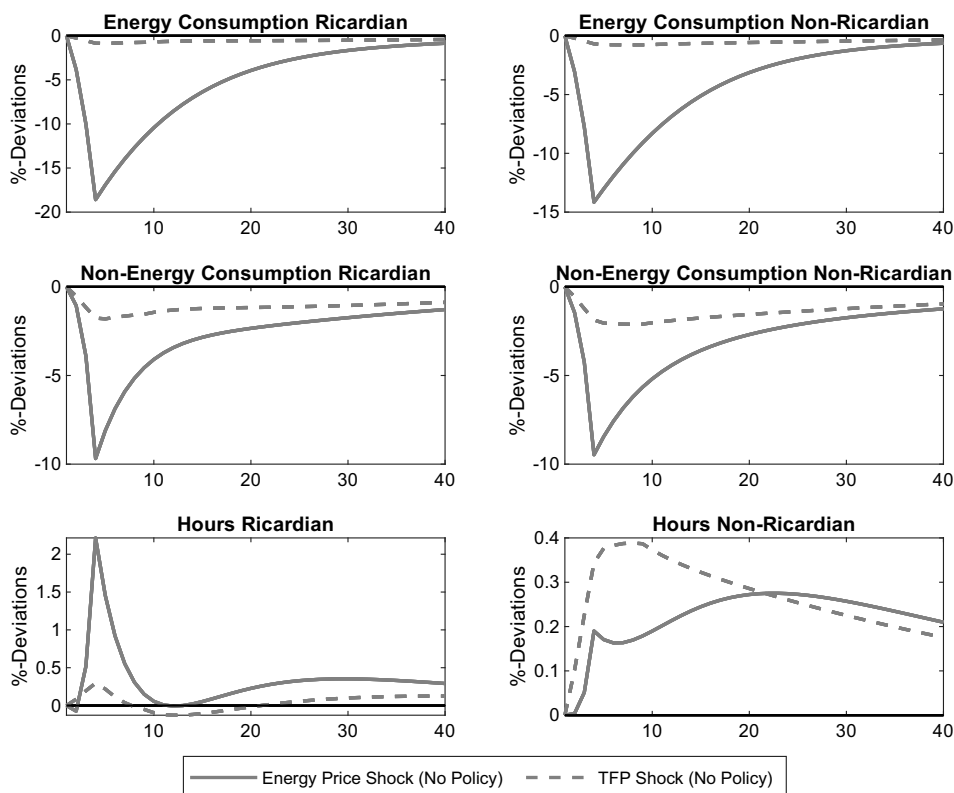


Fig. 10. Comparison: Energy Price Shock vs. TFP Shock - Distributional Variables. Quarterly time steps.

the contraction in non-energy consumption. This mechanism accounts for the steeper decline in GDP observed under the energy price shock, which is primarily driven by the higher value of energy imports.

The heterogeneous dynamics of macroeconomic aggregates under the two shocks are mirrored in household-level responses. Fig. 10 contrasts the no-policy benchmark of the energy price shock with a TFP shock.

The comparison highlights sizable differences in the three variables central to household utility: energy consumption, non-energy consumption, and hours worked. Incorporating an explicit energy price shock reveals substantial household-level consequences. Because energy is a basic necessity with a minimum subsistence requirement, households are highly exposed to rising energy costs. This vulnerability is especially acute for non-Ricardian households, who devote a larger share of income to energy expenditures. As shown in Fig. 10, both energy and non-energy consumption exhibit far stronger responses under the energy price shock than under a TFP shock, with notable heterogeneity across household types. Accordingly, a TFP shock systematically understates the adverse distributional consequences of an energy price shock. Similar considerations apply to the labor supply response of Ricardian households. Since these three variables jointly determine household utility, welfare analysis becomes particularly salient in the context of energy price shocks.²⁷

²⁷ The sharp adjustment in hours worked among non-Ricardian households may raise concerns about discontinuity in the response. This kink arises in part from the modeling strategy, which calibrates the energy price shock to capture the steep initial rise in energy costs. Given their greater sensitivity, non-Ricardian households' labor supply closely tracks this initial price spike, thereby smoothing consumption dynamics. As energy prices gradually stabilize, their labor supply response correspondingly becomes less pronounced.

Appendix C. Sensitivity analysis

C.1. Sensitivity analysis of labor market dynamics

The aggregated labor market dynamics in response to an energy price shock—as illustrated in Fig. 2—as well as the household-level responses shown in Fig. 4 indicate an increase in hours worked. Given the decline in wages, this outcome may at first seem counterintuitive. The subsequent analysis, however, explains these dynamics by showing that the increase in labor supply is primarily driven by firms' ability to substitute capital and energy when energy prices rise. Moreover, the sensitivity analysis demonstrates that variations in the elasticity of substitution between capital and energy, σ_f , exert only a limited influence on the welfare comparison across policy instruments.

To illustrate how a higher elasticity of substitution, σ_f , shapes labor market dynamics in response to an energy price shock, we consider the impulse responses of hours worked in the no-policy scenario for $\sigma_f = 0.55$ (see Fig. 11). The results show that aggregate hours, as well as hours worked by both Ricardian and non-Ricardian households, decline following the shock. This stands in contrast to the baseline results reported in the main text. The difference arises due to the higher elasticity of substitution, which increases the substitutability between energy and capital. With a greater ability to substitute away from energy, firms adjust their input mix more efficiently and reduce energy and capital use less aggressively, resulting in a smaller decline in wages compared to the baseline. Consequently, for larger values of σ_f , the weaker wage response dampens the income effect, while the substitution effect dominates, prompting households to reduce hours worked. In contrast, when σ_f is smaller and wages fall more sharply, the income effect dominates, and households increase labor supply slightly in response to the stronger wage contraction.

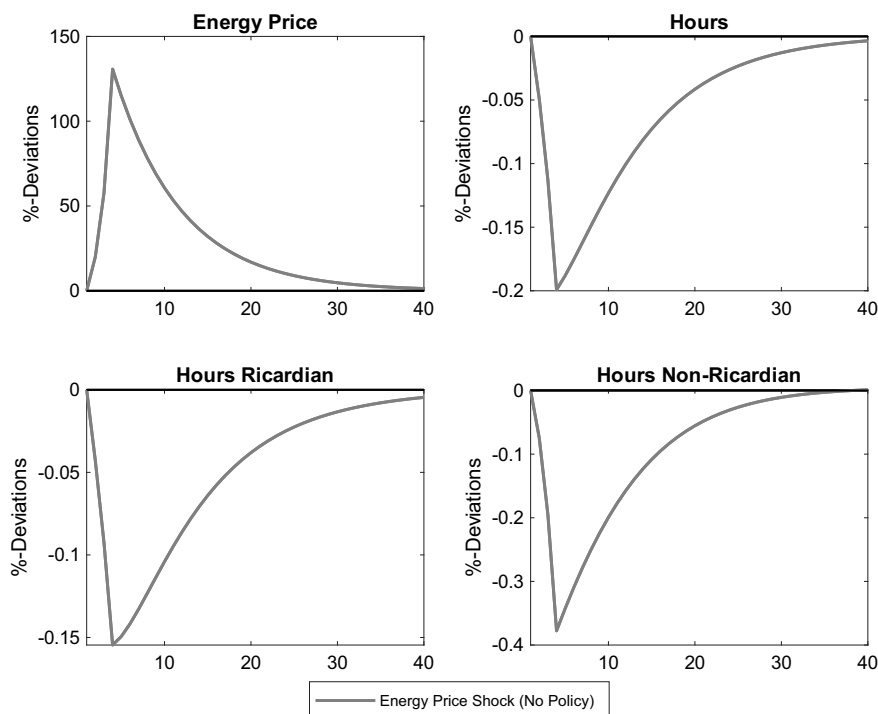


Fig. 11. Impulse responses to an energy price increase for $\sigma_f = 0.55$.

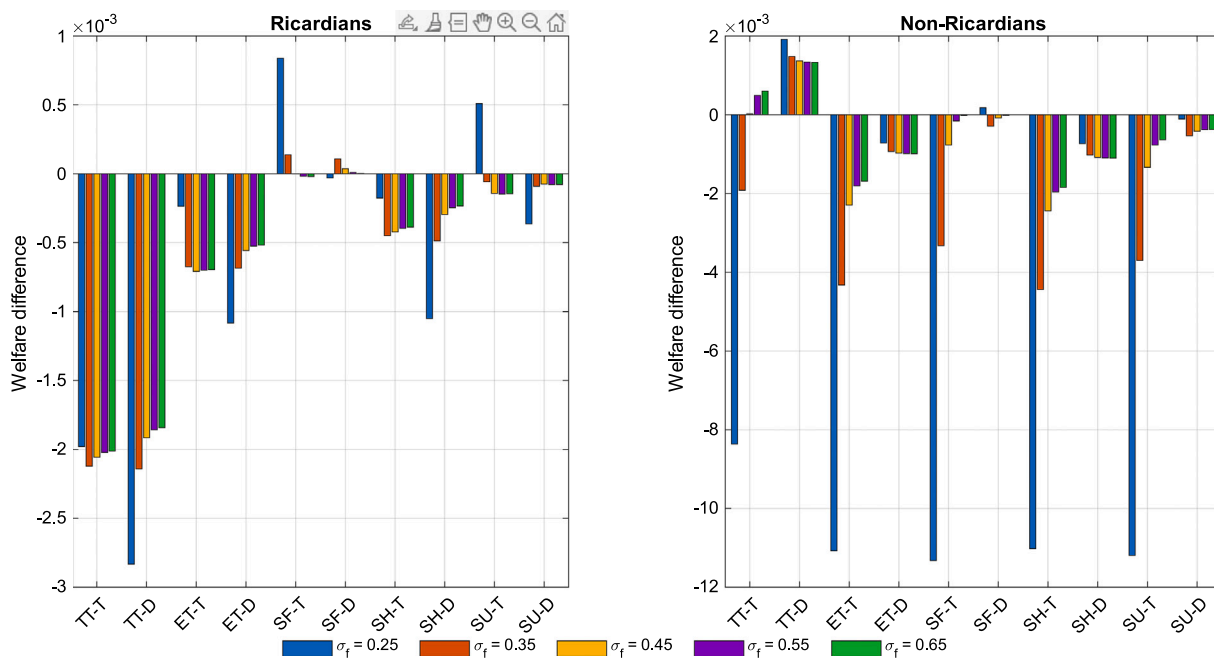


Fig. 12. Welfare effects across policy instruments for different values of σ_f .

C.2. Sensitivity analysis elasticity of substitution between capital and energy

The qualitative differences in labor market dynamics across values of σ_f naturally raise the question of how variations in σ_f affect welfare outcomes. Hence, based on the calibration for Germany, as reported in Table 2, we conduct a parameter sensitivity analysis and vary the relevant parameters. Fig. 12 reports the welfare effects of policy measures for both household types at $\sigma_f = 0.25, 0.35, 0.45, 0.55$, and 0.65 .

This parameter range covers alternative empirical estimates, including an estimate for the elasticity of substitution for Germany from Kemfert (1998) of 0.65.²⁸

²⁸ Kemfert and Welsch (2000) find an even higher elasticity of 0.87. However, these higher elasticity estimates reflect long-run substitution possibilities between capital and energy. For example, Kemfert (1998) derives estimates based

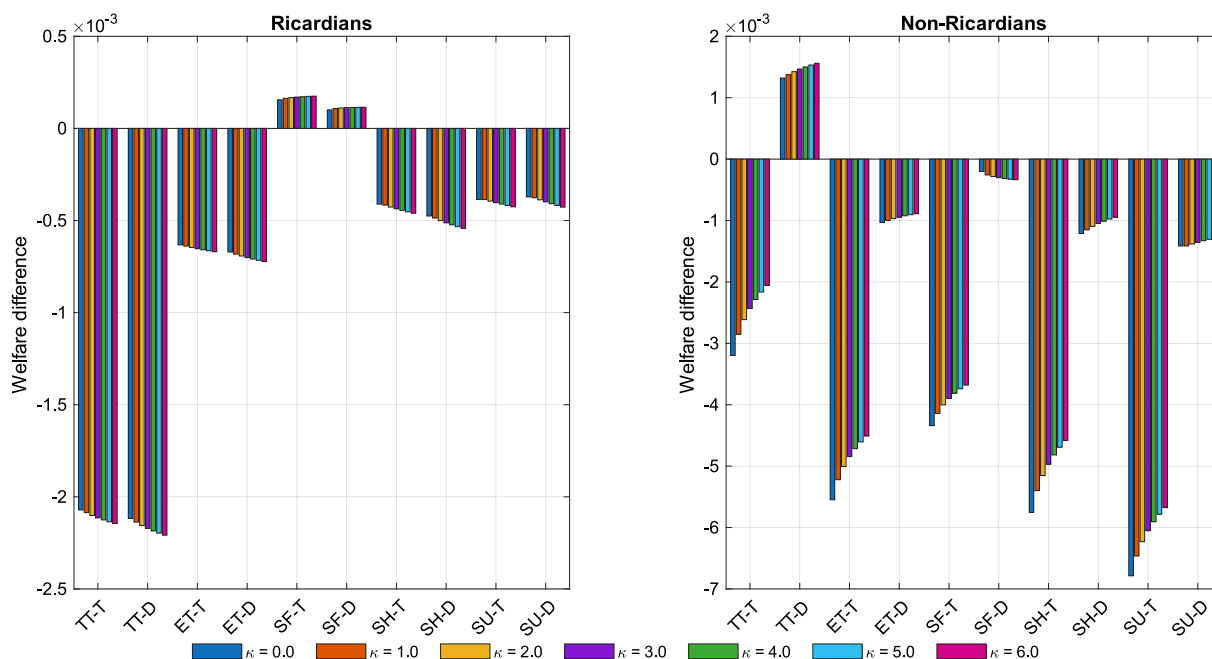


Fig. 13. Welfare effects across policy instruments for different values of κ .

Compared to the baseline welfare results, the sensitivity analysis reveals some quantitative variation—most notably for the case $\sigma_f = 0.25$, where the welfare effects differ from the other elasticity values. For $\sigma_f = 0.25$, we observe small welfare gains for Ricardian households under tax-financed, untargeted transfers. Aside from this exception, the overall welfare ordering of policies remains largely unchanged. Moreover, we find that the financing side becomes more important at smaller values of σ_f . Interestingly, for elasticities $\sigma_f \geq 0.45$, the welfare ordering of the policy instruments remains constant, but there is a reversal in the preferred financing option: Ricardian households then prefer debt financing over tax financing as well. For non-Ricardian households, the results for the lower elasticity $\sigma_f = 0.25$ show a clear dominance of the financing instrument: all debt-financed policies are preferred to their tax-financed counterparts. The ranking within debt-financed instruments is unchanged, while the ordering within tax-financed instruments exhibits only minor adjustments. For elasticities $\sigma_f \geq 0.45$, the importance of the financing side diminishes. The welfare ranking observed within each financing category at $\sigma_f = 0.35$ now emerges irrespective of the financing scheme. Nevertheless, for any given policy instrument, debt financing continues to be preferred over tax financing.

Remarkably, for both household types, the preferred policy remains unaffected by the choice of σ_f : Ricardian households experience the greatest gains from firm energy price subsidies, while non-Ricardian households benefit most from debt-financed targeted transfers.

C.3. Sensitivity analysis investment adjustment costs

Fig. 13 presents a bar plot of the welfare effects over a 10-year horizon across a range of values for κ , the intensity of investment

on more than 30 years of data, and Kemfert and Welsch (2000) uses a sample spanning nearly 20 years. In contrast, our application pertains to short-run responses. It is therefore sensible to rely on the lower, short-run elasticities reported by Haertel et al. (2022), which we use in our baseline specification.

adjustment costs. In this context, the choice of κ is crucial because investment adjustment costs represent a second margin that limits the economy’s ability to adjust factor inputs in response to shocks, complementing the elasticity of substitution, which constitutes the first margin. To evaluate the impact of these costs on the simulation results, the figure shows welfare differences relative to the no-policy scenario without investment adjustment costs ($\kappa = 0$) and across a relevant range of κ values, up to $\kappa = 6$. As shown in the figure, the choice of κ has only minor quantitative effects on the results. Overall, welfare changes for Ricardian households tend to increase with higher adjustment costs, which is intuitive since greater costs limit their ability to smooth consumption. In contrast, welfare for non-Ricardian households rises with κ , likely reflecting gains from slower wage adjustments when investment adjustment costs are higher.

C.4. Sensitivity analysis intertemporal elasticity of substitution

Fig. 14 presents a sensitivity analysis over different values for the inverse of the intertemporal elasticity of substitution ρ . This parameter is directly relevant to household welfare and affects intertemporal substitution. To assess how ρ affects the welfare results reported in the main text, we compute welfare for values ranging from $\rho = 1.5$ to $\rho = 4.5$, the respective welfare differences vis-a-vis the no-policy scenario are captured by the length of the bars. Evidently, the choice of ρ primarily has quantitative effects on the welfare of non-Ricardian households. Specifically, under targeted debt-financed transfers, both welfare gains and losses decrease as ρ increases. For Ricardian households, the pattern is less straightforward. Welfare gains from tax-financed firm subsidies initially increase with ρ , but for values $\rho > 3$, they decline slightly. For tax-financed household subsidies, Ricardian households experience a welfare loss for $\rho > 4$, with a small gain at even higher values. Similarly, untargeted subsidies yield positive welfare effects for Ricardian households when $\rho > 1.5$. Nevertheless, across all values of ρ , tax-financed firm subsidies consistently remain the most beneficial instrument for Ricardian households.

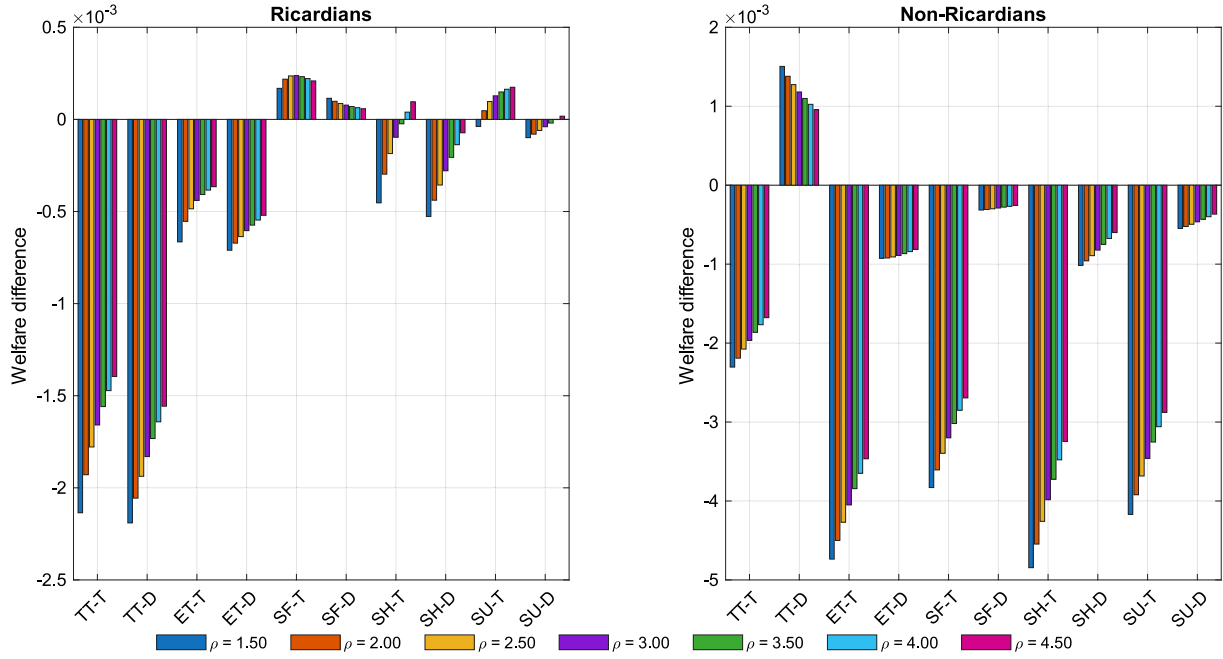


Fig. 14. Welfare effects across policy instruments for different values of ρ .

Appendix D. Accounting for country-spillovers of price-distorting policies

Consider the share of energy ψ that is imported but where supply is restricted due to capacity constraints for a group of countries that share a common energy market. With a binding capacity shock (i.e., due to the banning of Russian gas imports while the remaining gas import infrastructure is at its capacity limit), aggregate demand for gas in these countries is limited $\sum_i E_i \leq E^*$. Hence, any unilateral domestic increase in gas demand has to be offset by reductions of gas demand in other countries in the common market.

Assuming a common gas price p and uniform price elasticities of demand demand of country j is

$$E^i = (p + \tau^i)^\epsilon \bar{E}^i \quad (D.1)$$

with $\bar{E}^i \equiv E_0^i p_0^\epsilon$ calibrated such that energy demand matches baseline demand E_0^i at baseline price p_0 . Considering the case of a unilateral domestic price intervention at country j while assuming that other countries do not intervene, aggregate demand is

$$E = \sum_j E_j = (1 - \lambda^j) p^\epsilon \bar{E} + \lambda^j (p + \tau^j)^\epsilon \bar{E} \quad (D.2)$$

$$= p^\epsilon \bar{E} \left((1 - \lambda_j) + \lambda_j \left(\frac{p + \tau_j}{p} \right)^\epsilon \right) \quad (D.3)$$

with λ^j the share of j 's energy demand on total demand in the baseline and $\bar{E} \equiv \sum_i \bar{E}^i$. In the case of a binding capacity constraint, a change in the domestic tax τ_j will leave aggregate energy demand unaffected, $dE/d\tau_j = 0$. Hence, considering that the price level of the common market is affected by the domestic price policy, $p = p(\tau_j)$ taking the derivative of (D.3) with respect to τ_j and with $dE/d\tau_j = 0$ gives after rearranging

$$\frac{dp}{d\tau_j} = -\lambda^j \bar{E} (p + \tau)^\epsilon \frac{p}{E} \quad (D.4)$$

When the baseline domestic price distortion is zero $\tau^j = 0$, we have from (D.3) $E = p^\epsilon \bar{E}$ and (D.4) becomes for $\tau^j = 0$:

$$\frac{dp}{d\tau_j} = -\lambda^j \quad (D.5)$$

Hence, a marginal increase of a unit tax (subsidy) on the domestic energy price from a non-distortive baseline ($\tau^j = 0$) implies a reduction (increase) of the energy price in the capacity-constrained common market by λ^j . The net price effect of a domestic tax after the price adjustment in the common market will, therefore, be $\tau^j (1 - \lambda^j)$.

During the energy crisis, Germany was part of a 'high-price island' of the countries as infrastructure bottlenecks prevented price convergence to international liquefied natural gas prices.²⁹ Germany's gas consumption share in this group of countries is 35%,³⁰ implying $\lambda^{DEU} = 0.35$. As natural gas constituted 39% of the fossil energy imported (measured in energy content), $\psi = 0.39$. Hence, the effect of German natural gas subsidies on the aggregate energy price index is $\lambda^{DEU} \times \psi \approx 0.14$.

Note that in case of a subsidy, $\tau^j < 0$, the additional energy price increase by λ^j falls on a scarcity rent of the owner of the import capacity, which is at its limit. In the case of Germany, limited import capacities such as liquefied natural gas terminals were largely outside the country, implying that the price increase by λ^j can be understood as a loss to the German economy.

²⁹ Examples of these countries include among others Denmark, Austria, Hungary, Bulgaria, Italy, and Poland.

³⁰ Based on pre-crisis 2019-levels of inland consumption of natural gas (terajoule) from Eurostat (2024).

Appendix E. Figures

Figs. 15 and 16 show the IRF for untargeted energy price subsidies.

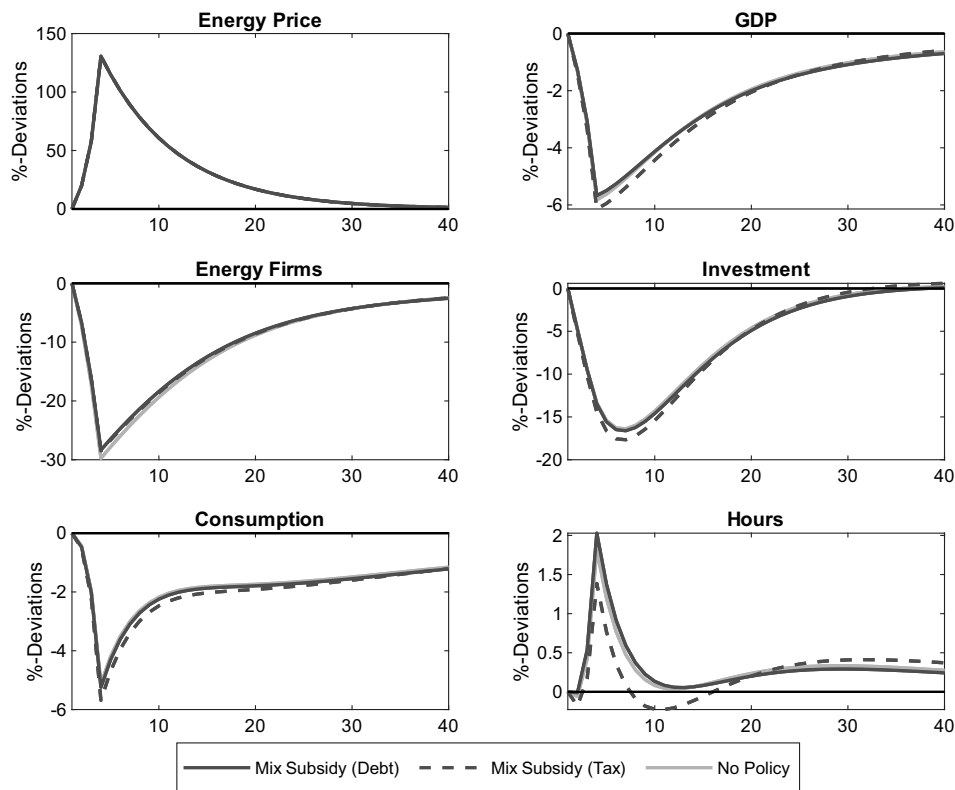


Fig. 15. Unexpected increase in energy prices, untargeted energy price subsidies, macroeconomic variables. Quarterly time steps.

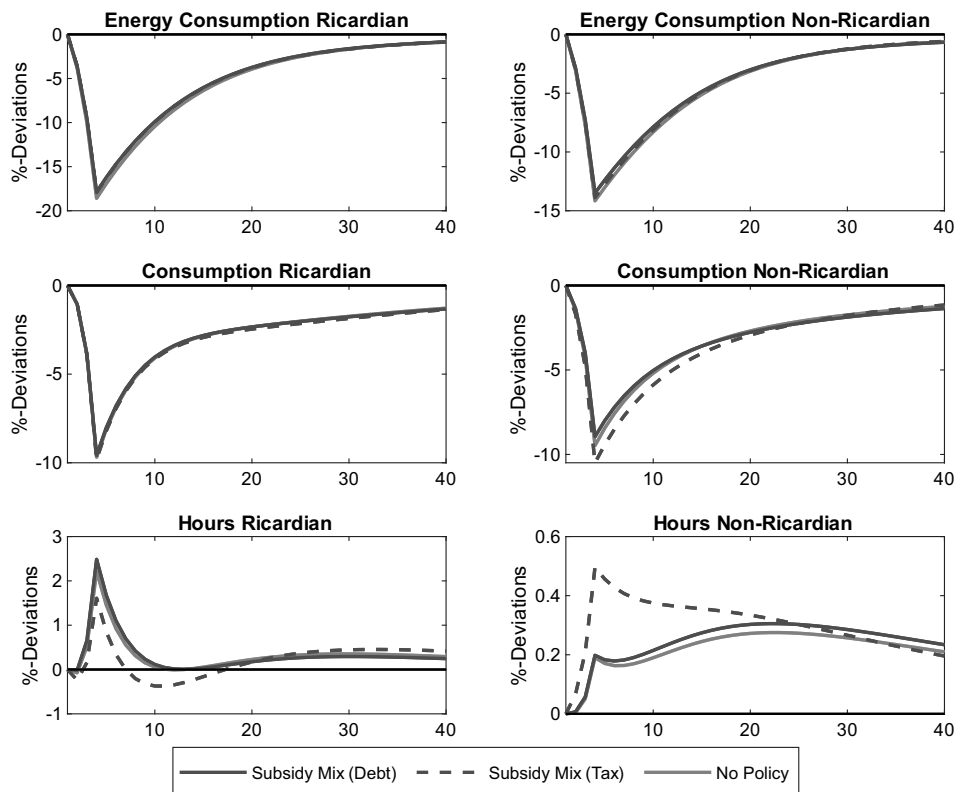


Fig. 16. Unexpected increase in energy prices, untargeted energy price subsidies, distributional variables. Quarterly time steps.

Appendix F. Welfare effects at different time-horizons

Table 5

Welfare effects of different policy scenarios (see Table 3 for the scenario keys) in consumption equivalent variations over a 5-year horizon. The welfare effects are reported relative to the no-policy scenario. Changes in output are reported as discounted cumulative output differences relative to the no-policy scenario in percentage points.

| Scenario | Ricardian | Non-Ricardian | Aggregate | GDP | Multiplier | Energy |
|----------|-----------|---------------|-----------|-------|------------|--------|
| TT-T | -0.10 | -0.35 | -0.17 | -5.92 | -1.36 | -0.25 |
| TT-D | -0.31 | 0.49 | -0.10 | -1.03 | -0.24 | -0.11 |
| ET-T | 0.11 | -0.83 | -0.15 | -5.75 | -1.32 | -0.20 |
| ET-D | -0.10 | 0.02 | -0.07 | -0.91 | -0.21 | -0.07 |
| SF-T | 0.15 | -0.75 | -0.10 | -3.88 | -0.91 | 0.87 |
| SF-D | -0.05 | 0.03 | -0.03 | 0.58 | 0.14 | 0.99 |
| SH-T | 0.20 | -0.80 | -0.07 | -4.66 | -1.08 | -0.23 |
| SH-D | -0.01 | 0.04 | -0.00 | 0.16 | 0.04 | -0.10 |
| SU-T | 0.16 | -0.77 | -0.09 | -4.12 | -0.96 | 0.49 |
| SU-D | -0.04 | 0.03 | -0.02 | 0.46 | 0.11 | 0.62 |

Table 6

Welfare effects of different policy scenarios (see Table 3 for the scenario keys) in consumption equivalent variations over a 200-year horizon. The welfare effects are reported relative to the no-policy scenario. Changes in output are reported as discounted cumulative output differences relative to the no-policy scenario in percentage points.

| Scenario | Ricardian | Non-Ricardian | Aggregate | GDP | Multiplier | Energy |
|----------|-----------|---------------|-----------|-------|------------|--------|
| TT-T | -0.03 | 0.00 | -0.02 | -2.47 | -0.51 | -0.00 |
| TT-D | -0.04 | -0.01 | -0.03 | -6.88 | -1.42 | -0.02 |
| ET-T | -0.01 | -0.02 | -0.02 | -1.41 | -0.29 | 0.00 |
| ET-D | -0.02 | -0.03 | -0.02 | -5.80 | -1.19 | -0.01 |
| SF-T | 0.00 | -0.00 | 0.00 | 2.36 | 0.49 | 0.03 |
| SF-D | 0.00 | -0.01 | -0.00 | -1.74 | -0.36 | 0.02 |
| SH-T | -0.02 | -0.02 | -0.02 | -1.18 | -0.24 | -0.00 |
| SH-D | -0.02 | -0.04 | -0.02 | -5.56 | -1.14 | -0.02 |
| SU-T | -0.00 | -0.01 | -0.01 | 1.17 | 0.24 | 0.02 |
| SU-D | -0.01 | -0.02 | -0.01 | -3.02 | -0.62 | 0.01 |

Table 7

Welfare effects of different policy scenarios (see Table 3 for the scenario keys) in Euros over a 10-year horizon, present discounted value. Computed based on 2018 average consumption expenditures from the EVS.

| Scenario | Ricardian (Euro) | Non-Ricardian (Euro) |
|----------|------------------|----------------------|
| TT-T | -165.01 | 13.92 |
| TT-D | -177.32 | -23.86 |
| ET-T | -68.89 | -59.06 |
| ET-D | -81.33 | -95.11 |
| SF-T | 12.87 | -11.23 |
| SF-D | 1.17 | -45.45 |
| SH-T | -79.38 | -72.37 |
| SH-D | -92.09 | -108.62 |
| SU-T | -18.23 | -31.81 |
| SU-D | -30.25 | -66.71 |

Data availability

Data will be made available on request.

References

Arbeitsgemeinschaft Energiebilanzen e.V., 2023. Auswertungstabellen zur energiebilanz deutschland 1990-2022. https://ag-energiebilanzen.de/wp-content/uploads/2023/10/awt_2022_deutsch.pdf.

Auclert, A., Monnerly, H., Rognlie, M., Straub, L., 2023. Managing an energy shock: fiscal and monetary policy. https://scholar.harvard.edu/sites/scholar.harvard.edu/files/straub/files/energy_shock.pdf (Accessed 13 July 2023).

Barsky, R.B., Kilian, L., 2004. Oil and the macroeconomy since the 1970s. *J. Econ. Perspect.* 18, 115–134. <https://doi.org/10.1257/0895330042632708>

Bartocci, A., Cantelmo, A., Cova, P., Notarpietro, A., Pisani, M., 2024. Monetary and fiscal policy responses to fossil fuel price shocks. *Energy Econ.* 136, <https://doi.org/10.1016/j.eneco.2024.107737>

Baumeister, C., Hamilton, J.D., 2019. Structural interpretation of vector autoregressions with incomplete identification: revisiting the role of oil supply and demand shocks. *Am. Econ. Rev.* 109, 1873–1910. <https://doi.org/10.1257/aer.20151569>

Bayer, C., Kriwoluzky, A., Müller, G.J., Seyrich, F., 2023. Hicks in HANK: Fiscal Responses to an Energy Shock. Discussion Papers 2056. DIW Berlin, <https://doi.org/10.2139/ssrn.4619906>. <https://ssrn.com/abstract=4619906>.

Berti, K., Colesnic, E., Despoints, C., Pamies, S., Sail, E., 2016. Fiscal Reaction Functions for European Union Countries. European Economy – Discussion Papers 28. Directorate General Economic and Financial Affairs, European Commission.

Blanz, A., Eydam, U., Heinemann, M., Kalkuhl, M., 2025. Market-based climate policy with fluctuating fossil energy prices. *Econ. Model.* 144, 106982. <https://doi.org/10.1016/j.econmod.2024.106982>. <https://www.sciencedirect.com/science/article/pii/S0264999324003390>.

Board of Governors of the Federal Reserve System, 2024. U.S. Dollars to EURO spot exchange rate. Federal reserve bank of ST. Louis. Federal Reserve Bank of St. Louis <https://fred.stlouisfed.org/series/EXUSEU> (Accessed 22 January 2024). retrieved from FRED.

Bretschger, L., Schaefer, A., 2017. Dirty history versus clean expectations: can energy policies provide momentum for growth? *Eur. Econ. Rev.* 99, 170–190. <https://doi.org/10.1016/j.eurocorev.2017.01.001>

Caldara, D., Ferrante, F., Iacoviello, M., Prestipino, A., Queralto, A., 2024. The international spillovers of synchronous monetary tightening. *J. Monet. Econ.* 141, 127–152. <https://doi.org/10.1016/j.jmoneco.2023.10.017>

Chan, J., Diz, S., Kanngiesser, D., 2024. Energy prices and household heterogeneity: monetary policy in a gas-tank. *J. Monet. Econ.* 147, 103620. <https://doi.org/10.1016/j.jmoneco.2024.103620>. <https://www.sciencedirect.com/science/article/pii/S0304393224000734>. Monetary Policy Challenges for European Macroeconomies.

Chepeliev, M., Hertel, T., van der Mensbrugghe, D., 2022. Cutting russia's fossil fuel exports: short-term economic pain for long-term environmental gain. *The World Econ.* 45, 3314–3343. <https://doi.org/10.1111/twec.13301>. <https://onlinelibrary.wiley.com/doi/10.1111/twec.13301>.

Corsetti, F., Riggi, M., 2023. The Heterogeneous Effects of Energy Shocks on Inflation. Technical Report 1429. Banca D'Italia (Bank of Italy), https://www.bancaditalia.it/pubblicazioni/temi-discussione/2023/2023-1429/en_tema_1429.pdf.

D'Erasmo, P.N., Mendoza, E.G., Zhang, J., 2016. Chapter 32 - what is a sustainable public debt? In: Taylor, J.B., Uhlig, H. (Eds.), *Handbook of Macroeconomics*. Volume 2 of *Handbook of Macroeconomics*, Elsevier pp. 2493–2597. <https://doi.org/10.1016/bs.hesmac.2016.03.013>. <https://www.sciencedirect.com/science/article/pii/S1574004816000148>.

Deutsche Bundesbank, 2023. Producer and harmonised index of consumer prices. <https://www.bundesbank.de/en/statistics/overview-of-the-statistical-series/-/producer-and-harmonised-index-of-consumer-prices-808734>.

Drescher, K., Janzen, B., 2021. Determinants, persistence, and dynamics of energy poverty: an empirical assessment using German household survey data. *Energy Econ.* 102, <https://doi.org/10.1016/j.eneco.2021.105433>

Drygalla, A., Holttemöller, O., Kiesel, K., 2020. The effects of fiscal policy in an estimated DSGE model—the case of the German stimulus packages during the great recession. *Macroecon. Dyn.* 24, 1315–1345.

Eurostat, 2024. Real gross domestic product for Germany. <https://fred.stlouisfed.org/series/CLVMNACSCAB1GQDE>. code number: CLVMNACSCAB1GQDE.

Eurostat, D., 2024. Supply, transformation, and consumption of gas. Eurostat, https://doi.org/10.2908/nrg_cb_gas. https://ec.europa.eu/eurostat/databrowser/view/nrg_cb_gas/default/table?lang=en (accessed 22 January 2024).

Eydam, U., Diluio, F., 2022. How to redistribute the revenues from climate policy? Discussion papers 45. Cent. Econ. Policy Anal., <https://doi.org/10.25932/publishup-54896>

Forni, L., Monteforte, L., Sessa, L., 2009. The general equilibrium effects of fiscal policy: estimates for the EURO area. *J. Public Econ.* 93, 559–585. <https://doi.org/10.1016/j.jpubeco.2008.09.010>. <https://www.sciencedirect.com/science/article/pii/S0047272708001382>.

Gali, J., López-Salido, J.D., Vallés, J., 2007. Understanding the effects of government spending on consumption. *J. Eur. Econ. Assoc.* 5, 227–270. <https://doi.org/10.1162/JEEA.2007.5.1.227>

Geary, R.C., 1950. A note on a constant-utility index of the cost of living. *Rev. Econ. Stud.* 18, 65–66. <https://doi.org/10.2307/2296107>

German Federal Statistical Office, 2022. Einkommens- und verbrauchstrichprobe 2018. https://www.statistischebibliothek.de/mir/receive/DEHeft_mods_00137871.

German Federal Statistical Office, 2023. Data on energy price trends. https://www.destatis.de/EN/Themes/Economy/Prices/Publications/Downloads-Energy-Price-Trends/energy-price-trends-pdf-5619002.pdf?_blob=publicationFile. published on January 31, 2023. Code number: 5619002221124.

German Federal Statistical Office, 2024a. Strompreise für nicht-haushalte: deutschland. <https://www-genesis.destatis.de/genesis/online?operation=table&code=61243-0006&bypass=true&levelindex=0&levelid=1705920540398#abreadcrumb> (Accessed 22 January 2024). table no. 61243-0006.

German Federal Statistical Office, 2024b. Umweltökonomische gesamtrechnung. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/UGR/energiefluesse-emissionen/Publikationen/Downloads/umweltnutzung-und-wirtschaft-energie-pdf-5850014.pdf?_blob=publicationFile (Accessed 9 September 2024). table No. 1.1 (Aggregate und Kennziffern).

- German Federal Statistical Office, 2024c. Vgr des bundes. <https://www-genesis.destatis.de/datenbank/online/statistic/81000/details> (accessed 9 November 2024).
- German Federal Statistical Office, 2024d. Vgr des bundes - bruttonationaleinkommen, volkseinkommen. <https://www-genesis.destatis.de/genesis/online?sequenz=statistikTabellen&selectionname=81000#abreadcrumb> (Accessed 22 January 2024). table no. 81000-0004.
- German Federal Statistical Office, 2024e. Vgr des bundes - verwendung des bruttolandsprodukts (nominal/preisbereinigt). <https://www-genesis.destatis.de/genesis/online?sequenz=statistikTabellen&selectionname=81000#abreadcrumb> (Accessed 9 November 2024). table no. 81000-0019.
- Gornemann, N., Hildebrand, S., Kuester, K., 2024. Limited (energy) supply, monetary policy, and sunspots. *Eur. Econ. Rev.* 168, 104823. <https://doi.org/10.1016/j.eurocorev.2024.104823>. <https://www.sciencedirect.com/science/article/pii/S0014292124001521>.
- Grabka, M.M., Halbmeier, C., 2019. Vermögensungleichheit in Deutschland Bleibt Trotz Deutlich Steigender Nettovermögen Anhaltend Hoch. DIW Wochenbericht 40. Deutsches Institut für Wirtschaftsforschung (DIW), Berlin. https://doi.org/10.18723/diw_wb:2019-40-1
- Haertel, T., Hamburg, B., Kusin, V., 2022. The Macroeconometric Model of the Bundesbank Revisited. Technical Report. Deutsche Bundesbank. <https://www.bundesbank.de/resource/blob/888376/f46d04ea2747074cba9ebc8b44e639/ml/2022-01-technical-paper-data.pdf>.
- Hamilton, J.D., 1983. Oil and the macroeconomy since world war II. *J. Polit. Econ.* 91, 228–248. <https://doi.org/10.1086/261140>
- Harrison, R., Thomas, R., de Weymarn, I., 2011. The Impact of Permanent Energy Price Shocks on the UK Economy. Working Paper 433. Bank of England. <https://doi.org/10.2139/ssrn.1898066>
- Hinterlang, N., Moyer, S., Röhe, O., Stähler, N., 2023. Gauging the effects of the German Covid-19 fiscal stimulus package. *Eur. Econ. Rev.* 154. <https://doi.org/10.1016/j.eurocorev.2023.104407>
- Holtemöller, O., Sardone, A., 2024. Optimal Monetary Policy in a Two-Sector Environmental DSGE Model. IWH Discussion Papers, No. 18/2024. Halle Institute for Economic Research (IWH). <https://www.econstor.eu/bitstream/10419/301153/1/1897940394.pdf>.
- Hutter, C., Weber, E., 2023. Russia Ukraine war: a note on short-run production and labour market effects of the energy crisis. *Energy Policy* 183, 113802. <https://doi.org/10.1016/j.enpol.2023.113802>. <https://www.sciencedirect.com/science/article/pii/S0301421523003877>.
- Känzig, D.R., 2021. The macroeconomic effects of oil supply news: evidence from OPEC announcements. *Am. Econ. Rev.* 111, 1092–1125. <https://doi.org/10.1257/aer.20190964>
- Kemfert, C., 1998. Estimated substitution elasticities of a nested CES production function approach for Germany. *Energy Econ.* 20, 249–264. [https://doi.org/10.1016/S0140-9883\(97\)00014-5](https://doi.org/10.1016/S0140-9883(97)00014-5)
- Kemfert, C., Welsch, H., 2000. Energy-capital-labor substitution and the economic effects of CO₂ abatement: evidence for Germany. *J. Policy Model.* 22, 641–660. <https://ideas.repec.org/a/eee/jpolmo/v22y2000i6p641-660.html>.
- Kharroubi, E., Smets, F., 2024. Energy shocks as Keynesian supply shocks: implications for fiscal policy. *Eur. Econ. Rev.* <https://doi.org/10.1016/j.eurocorev.2024.104875>
- Kilian, L., 2008. The economic effects of energy price shocks. *J. Econ. Lit.* 46, 871–909. <https://doi.org/10.1257/jel.46.4.871>. <https://www.aeaweb.org/articles?id=10.1257/jel.46.4.871>.
- Kilian, L., 2009. Not all oil price shocks are alike: disentangling demand and supply shocks in the crude oil market. *Am. Econ. Rev.* 99, 1053–1069. <https://doi.org/10.1257/aer.99.3.1053>
- Kilian, L., Vigfusson, R.J., 2017. The role of oil price shocks in causing U.S. Recessions. *J. Money Credit Bank.* 49, 1747–1776. <https://doi.org/10.1111/jmcb.12430>
- Kim, I.M., Loungani, P., 1992. The role of energy in real business cycle models. *J. Monet. Econ.* 29 (2), 173–189. [https://doi.org/10.1016/0304-3932\(92\)90011-P9](https://doi.org/10.1016/0304-3932(92)90011-P9)
- Kola-Bezka, M., Leki, K., 2024. Household energy behaviour in the times of crisis: lessons for policy initiatives from peripheral, fossil-dependent regions of the European Union. *Energy Policy* 188, 114113. <https://doi.org/10.1016/j.enpol.2024.114113>. <https://www.sciencedirect.com/science/article/pii/S0301421524001332>.
- Kröger, M., Longmuir, M., Neuhoff, K., Schütze, F., 2023. The price of natural gas dependency: price shocks, inequality, and public policy. *Energy Policy* 175, 113472. <https://doi.org/10.1016/j.enpol.2023.113472>
- Liadze, I., Macchiarelli, C., Mortimer-Lee, P., Juanino, P.S., 2022. The Economic Costs of the Russia-Ukraine Conflict. Policy Paper 32. National Institute of Economic and Social Research.
- Liu, L.J., Jiang, H.D., Liang, Q.M., Creutzig, F., Liao, H., Yao, Y.F., Qian, X.Y., Ren, Z.Y., Qing, J., Cai, Q.R., Edenhofer, O., Wei, Y.M., 2023. Carbon emissions and economic impacts of an EU embargo on Russian fossil fuels. *Nat. Clim. Change* 13, 290–296. <https://doi.org/10.1038/s41558-023-01606-7>. <https://www.nature.com/articles/s41558-023-01606-7>.
- Lucas, R.J., 1987. *Models of Business Cycles*. Blackwell, Oxford.
- Muellbauer, J., 1974. Prices and inequality: the united kingdom experience. *Econ. J.* 84, 32–55. <https://doi.org/10.2307/2230482>
- Pieroni, V., 2023. Energy shortages and aggregate demand: output loss and unequal burden from bank. *Eur. Econ. Rev.* 154, <https://doi.org/10.1016/j.eurocorev.2023.104428>
- Punzi, M.T., 2019. The impact of energy price uncertainty on macroeconomic variables. *Energy Policy* 129, 1306–1319. <https://doi.org/10.1016/j.enpol.2019.03.015>
- Ruhnau, O., Stiewe, C., Muessel, J., Hirth, L., 2023. Natural gas savings in Germany during the 2022 energy crisis. *Nat. Energy* 1–8. <https://doi.org/10.1038/s41560-023-01260-5>
- Schulte, I., Heindl, P., 2017. Price and income elasticities of residential energy demand in Germany. *Energy Policy* 102, 512–528. <https://doi.org/10.1016/j.enpol.2016.12.055>
- Sgaravatti, D.G., Tagliapietra, S., Trasi, C., Zachmann, G., 2023. National policies to shield consumers from rising energy prices. Bruegel, <https://www.bruegel.org/dataset/national-policies-shield-consumers-rising-energy-prices>.
- Stone, R., 1954. Linear expenditure systems and demand analysis: an application to the pattern of British demand. *Econ. J.* 64, 511–527. <https://doi.org/10.2307/2227743>
- Turco, E., Bazzana, D., Rizzati, M., Ciola, E., Vergalli, S., 2023. Energy price shocks and stabilization policies in the matrix model. *Energy Policy* 177, <https://doi.org/10.1016/j.enpol.2023.113567>
- Uhlig, H., 2010. Some fiscal calculus. *Am. Econ. Rev. Pap. & Proc.* 100 (2), 30–34. <https://doi.org/10.1257/aer.100.2.30>
- World Bank, 2024. Commodity markets. <https://www.worldbank.org/en/research/commodity-markets> (accessed 22 January 2024).
- World Bank, 2025. Consumer price index - Germany. <https://data.worldbank.org/indicator/FP.CPI.TOTL?locations=DE> (accessed 22 November 2025).
- Yared, P., 2019. Rising government debt: causes and solutions for a decades-old trend. *J. Econ. Perspect.* 33, 115–140. <https://doi.org/10.1257/jep.33.2.115>