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The fiscal and intergenerational burdens of brakes and subsidies for energy prices

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Abstract

We study the effects of different financing rules for untargeted energy price brakes and subsidies on intergenerational welfare in a large-scale overlapping generations model. The results indicate that, in comparison with a laissez-faire solution without any government interventions, debt-financed implementations of such measures are very detrimental for young and future generations. However, the taxation of windfall profits can significantly contribute to reduce the economic burdens of these generations; whereas, the positive effects on older generations are much less pronounced.

Keyword Fiscal policy, Price brakes, Price subsidies, Energy crisis, Welfare

JEL Classification E62 · E30 · H20 · H30

1 Introduction

After the Russian invasion of Ukraine on February 24, 2022, energy prices for gas and electricity skyrocketed so that, in particular, many European countries had to put emergency plans in place. For example, the lines in Fig. 1 show that the harmonized indices of consumer prices for energy increased by roughly 50% in France, Germany, and Spain; while, Italy even faced increases of about 100% in 2022.[1] As

[1] Source: https://ec.europa.eu/eurostat/databrowser/view/PRC_HICP_MIDX__custom_5411278/default/table (accessed 18 March 2023).

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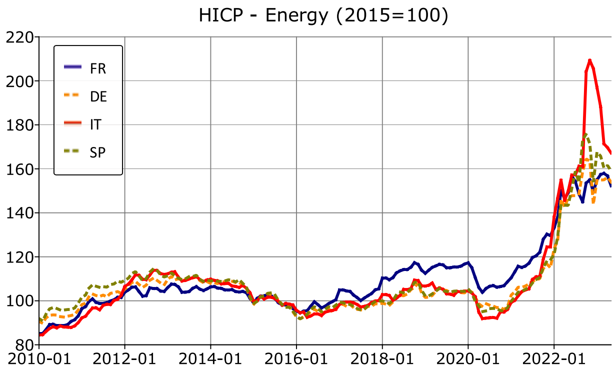

Fig. 1 Harmonized indices of consumer prices: Energy, Source: Eurostat

a consequence, many European governments implemented measures to protect businesses and households from rising energy costs. This paper studies the intergenerational welfare effects of fiscal measures shielding households and firms from rising energy price costs and their corresponding financing rules in a large-scale overlapping generations model.

With regard to European countries, Arregui et al. (2022) and Sgaravatti et al. (2022) provide an overview about the adopted fiscal measures that can be distinguished by two dimensions, the distortion of relative energy prices and the targeted relief of vulnerable groups. On the one hand, according to Arregui et al. (2022), almost all countries implemented at least one untargeted price-distorting measure like reduced energy taxes, fees, charges, or carbon taxes. On the other hand, many countries also enacted non-distortionary measures such as lump-sum income tax credits, lump-sum transfers, or energy vouchers, which were often also untargeted. In particular, the German government introduced so-called energy price brakes for gas and electricity. This instrument transfers the (positive) difference between the current market price and a guaranteed price times a quota, which depends on the specific energy consumption of the previous year, from the government via energy suppliers to households and firms. Therefore, such measures usually provide more pronounced incentives to reduce the consumption of energy in comparison with price-distorting measures like price subsidies. Interestingly, these untargeted interventions amounted to about 70% of total fiscal outlays although they only accounted for slightly more than 50% of all relief measures. Figure 2 displays the associated earmarked and allocated funding (in % of GDP) of different countries. The bars show that, in particular the largest countries in the European Union, Germany, France, Italy, Spain, and Poland were willing to spend relatively high amounts of their GDP to mitigate the negative effects of the energy crisis.

Both price brakes and price subsidies for energy result in a direct relief of consumers. However, regardless of which measure is implemented to protect households

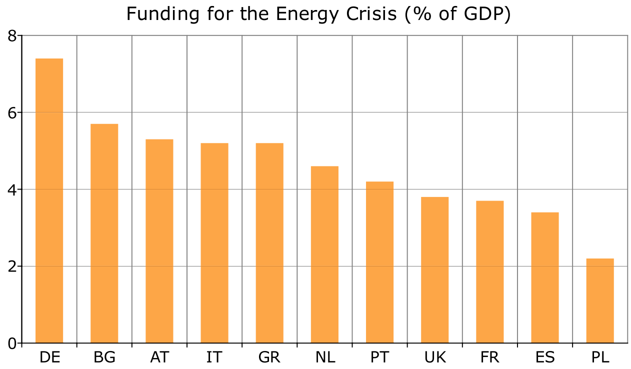

Fig. 2 Governments earmarked and allocated funding to shield households and firms from the energy crisis (% of GDP, Sep 2021 - Jan 2023), Source: Sgaravatti et al. (2022)

and firms from rising energy cost, the energy price shock does not disappear since the financial burdens are only redistributed from consumers to current or future taxpayers. The corresponding fiscal rules that control the responses of taxes and government debt play a decisive role in this regard. If, for example, relief packages are mainly financed by increases in government debt, then the economic burdens are transferred to present young and future generations. In contrast, pure tax-financed increases shift the financial burdens into the present and, thus, on current living generations. From a welfare perspective and with respect to the political decision making process, these two different and possibly opposing effects must therefore be taken into account simultaneously.

In this paper, we study the effects of financing rules for untargeted energy price subsidies and energy price brakes on the intergenerational welfare in a large-scale overlapping generations model. For merely illustrative purposes, we calibrate the model for the German economy and get the following results in comparison with a laissez-faire solution without any government interventions: Both price subsidies and energy price brakes are very detrimental for young and future generations if they are mainly financed by increases in government debt and/or labor income taxes; while, they strongly benefit retirees and people close to retirement. In particular, debt financing leads to very pronounced welfare losses among the youngest and future generations, if the additional government revenue opportunities from taxing windfall profits are not utilized. Overall, the taxation of windfall profits is especially relevant for the economic relief of young and future generations; whereas, it plays a minor role for older generations. In contrast, financing rules that mainly tax asset incomes make young and future generations better off. However, they only slightly mitigate the negative effects of energy price shocks among the oldest individuals and slightly decrease the welfare of older workers and young retirees. Furthermore, our results indicate that the welfare differentials between energy price brakes and energy price subsidies are relatively small since the welfare gains and losses are both qualitatively and quantitatively very similar across all age groups.

The most closely related papers to ours are De Miguel and Manzano (2006), Dhawan and Jeske (2008), Heer and Scharrer (2018), Bachmann et al. (2022), Lan et al. (2022), Ciola et al. (2023), and Turco et al. (2023). De Miguel and Manzano (2006) examine the optimal taxation of oil and show that an extension of their dynamic stochastic general equilibrium (DSGE) model with oil consumption of households implies different optimal tax rates for both firms and households. In this case, their zero taxation result still holds for oil used in the firm sector but governments should levy taxes on household consumption of oil and adjust them as response to economic shocks. Among many others,[2] Dhawan and Jeske (2008) study the contributions of energy price shocks to output fluctuations in a DSGE model with exogenously given energy prices. They find that energy price shocks are associated with more pronounced effects on durables than on fixed capital, which mitigate the impacts on future production. Therefore, TFP shocks primarily account for the majority of output fluctuations in their model. Moreover, Heer and Scharrer (2018) investigate the redistributive effects of government spending shocks financed by either debt or taxes. They find that higher government spending increases both income and wealth inequality; while, debt financing may be particularly harmful to retirees with high accumulated private savings. However, they follow the macroeconomic literature and assume that government spending shocks do not affect the private utility of individuals or overall productivity since they are modeled as pure waste.[3] In contrast, this paper studies deliberate government policies that shield households and firms from rising energy prices. Bachmann et al. (2022) and Lan et al. (2022) examine the effects of a potential cut-off from Russian energy imports on the German economy and predict losses of around 0.2%–2.2% and 1.5% of GDP, respectively. Both studies highlight the importance of policy measures that provide and increase incentives to save and substitute fossil energies. Furthermore, Ciola et al. (2023) use a multi-agent model to investigate the economic and distributional effects of energy shocks both at the aggregate and sectoral level in the US. They find that energy shocks, for example exogenous increases of energy prices, have similar effects at the aggregate level; whereas, the distribution of gains and losses across sectors and agents especially depends on the type of shock. Turco et al. (2023) use a similar multi-agent model for the Euro Area to examine the effects of macro-stabilization policies, i.e., energy price reductions, tax cuts, household and firm subsidies, and taxes on windfall profits. They find that government-funded energy price reductions supplemented with taxes on windfall profits of energy firms are the most effective policy to mitigate GDP losses.

The remainder of this paper is organized as follows. In Sects. 2 and 3, we outline and calibrate our model, respectively, before Sect. 4 presents the steady state. Section 5 shows our results with respect to the effects of financing rules for untargeted energy price subsidies and energy price brakes on intergenerational welfare. The following sensitivity analysis is provided in Sect. 6. In Sect. 7, we summarize and discuss the main findings of this paper.

[2] See, for example, Kim and Loungani (1992), Rotemberg and Woodford (1996), or Huynh (2016).

[3] See, for example, Galí et al. (2007) or Uhlig (2010).

2 The model

In this section, we present a general equilibrium life-cycle model with overlapping generations of households, a representative firm, and a government sector. The households optimize their expected lifetime utility and the representative firm maximizes its profits; while, the government collects tax revenues for government consumption and runs a pay-as-you-go (PAYG) social security system that transfers resources across generations from workers to retirees. Moreover, we assume that each household comprises one individual, so the terms "household" and "individual" are interchangeable in this model.

2.1 Households

Each period, a new cohort of households of constant size at model age $s = 1$, which corresponds to a real life age of 26 years, enters the economy. These households work during the first T_w years, live up to a maximum possible lifespan of T years, and additionally face the survival probabilities ϕ_s from age s to age $s+1$ with $\phi_0 \equiv 1$. Hence, the mass of households ψ_{s+1} at age $s+1$ evolves according to $\psi_{s+1} = \phi_s \psi_s$. As it is standard in the literature, we normalize the total mass of households to one.

In period t, a household maximizes the following discounted expected lifetime utility U_t at age $s = 1$ with respect to normal consumption $c_t^{n,s}$, energy consumption $c_t^{e,s}$, labor supply n_t^s (with $n_t^s \equiv 0$ for $s > T_w$), and savings in the form of financial assets a_{t+1}^{s+1}:

$$U_t = E_t \sum_{s=1}^{T} \beta^{s-1} \left(\prod_{j=1}^{s} \phi_{j-1} \right) \left[u\left(c_{t+s-1}^{n,s}, c_{t+s-1}^{e,s} n_{t+s-1}^{s} \right) + \left(1 - \phi_s\right) b\left(a_{t+s}^{s+1} \right) \right]. \quad (1)$$

Following Trabandt and Uhlig (2011), the specification of the first instantaneous utility function $u(c^n, c^e, n)$ is given by

$$u\left(c_t^{n,s}, c_t^{e,s}, n_t^s\right) = \frac{1}{1-\eta} \left[\left(c_t^s\right)^{1-\eta} \left(1 - \frac{\gamma_0^s (1-\eta)}{1 + 1/\gamma_1} \left(n_t^s\right)^{1+1/\gamma_1} \right) - 1 \right] \quad (2)$$

with the CES aggregator function

$$c_t^s = \left[\nu \left(c_t^{n,s}\right)^{\frac{\sigma-1}{\sigma}} + (1-\nu)\left(c_t^{e,s}\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}. \quad (3)$$

These preferences feature a constant intertemporal elasticity of substitution $1/\eta$ and a constant Frisch elasticity of labor supply γ_1. The age-specific parameter γ_0^s controls the labor supply at age s in the steady state. Moreover, σ denotes the elasticity of substitution between normal consumption goods $c_t^{n,s}$ and energy consumption $c_t^{e,s}$, whereas ν represents a standard utility weight. Furthermore, similar to De Nardi and

Yang (2014) and Kaplan et al. (2020), the second instantaneous utility function $b(a)$ introduces a warm-glow bequest motive at ages $s > T_w$:

$$b(a) = \frac{1_{s>T_w}\theta}{1-\eta}\left(a^{1-\eta} - 1\right), \tag{4}$$

where θ controls the strength of the bequest motive. The corresponding budget constraints at age s in period t are given by

$$\begin{aligned}\left(1+\tau_t^c\right)\left(c_t^{n,s} + p_t^h c_t^{e,s}\right) + a_{t+1}^{s+1} = & \left(1 - \tau_t^w - \tau_t^p\right) w_t e^s n_t^s + tr_t^s + \\ & \left(1 + r_t\left(1 - \tau_t^k\right)\right) a_t^s, \\ & \text{for ages} s \in \left\{1, ..., T_w\right\},\end{aligned} \tag{5}$$

$$\begin{aligned}\left(1+\tau_t^c\right)\left(c_t^{n,s} + p_t^h c_t^{e,s}\right) + a_{t+1}^{s+1} = & \left(1 + r_t\left(1 - \tau_t^k\right)\right) a_t^s + pens_t^s + tr_t^s, \\ & \text{for ages} s \in \left\{T_w + 1, ..., T\right\}.\end{aligned} \tag{6}$$

The variable τ_t^c denotes the statutory value-added tax rate levied both on normal consumption goods $c_t^{n,s}$ and energy $c_t^{e,s}$ that is imported at the (household) price p_t^h. For simplicity, as in Heathcote (2005), we assume that public debt pays the economy-wide pre-tax real return r_t so that government bonds b_t^s and capital k_t^s are perfect substitutes. Therefore, the stock of financial assets of a household at age s in period t is represented by

$$a_t^s = b_t^s + k_t^s, \tag{7}$$

where we assume that households enter the economy without any holdings of financial assets so that $b_t^s \equiv 0$ and $k_t^s \equiv 0$ at age $s = 1$. Hence, only older generations receive asset incomes that are taxed at the asset income tax rate τ_t^k. The net labor income of workers depends on the real wage w_t, the age-specific productivity e^s, the income tax rate τ_t^w, and the contribution rate τ_t^p for the PAYG system. Lump-sum transfers and pension payments from the government to households are denoted by tr_t^s and $pens_t^s$, respectively. Furthermore, to limit the computational cost of our global solution method, we follow a very similar approach as in Heer et al. (2020) and assume that households do not internalize future pension benefits in their labor supply decisions. Therefore, pension benefits only depend on the average past labor earnings of each cohort and the replacement ratio ζ_t:

$$pens_t^s = \begin{cases} \dfrac{\zeta_t}{T_w} \displaystyle\sum_{i=0}^{T_w-1} w_{t-i-1} e^{T_w-i} \bar{n}_{t-i-1}^{T_w-i}, & \text{for } s = T_w + 1, \\ pens_{t-s+T_w+1}^{T_w+1}, & \text{for } s > T_w + 1. \end{cases} \tag{8}$$

2.2 Firms

Following Dhawan and Jeske (2008), a representative firm produces an energy-capital bundle X_t as intermediate good. The corresponding CES production function in its calibrated share form[4] is given by

$$X_t = X\left[\mu\left(\frac{K_t}{K}\right)^{\frac{\chi-1}{\chi}} + (1-\mu)\left(\frac{E_t}{E}\right)^{\frac{\chi-1}{\chi}}\right]^{\frac{\chi}{\chi-1}}. \tag{9}$$

The parameter χ represents the elasticity of substitution between the input factors capital K_t and energy imports E_t, while μ affects the capital income share. Then, this firm uses a Cobb-Douglas production technology to produce the final output Y_t by combining the intermediate good X_t and labor N_t,

$$Y_t = X_t^{\alpha} N_t^{1-\alpha}, \tag{10}$$

where $1-\alpha$ controls the income share of labor.[5] Its resulting profits Π_t consist of the sum of revenues and (potential) transfers Tr_t^f from the government less labor, capital, and energy cost,

$$\Pi_t = Y_t + Tr_t^f - w_t N_t - \left(r_t + \delta\right) K_t - p_t^f E_t. \tag{11}$$

The parameters δ and $p_t^{f,e}$ denote the depreciation rate of capital and the price of energy input E_t, respectively.

2.3 Energy Prices

As in Kim and Loungani (1992) and Dhawan and Jeske (2008), we assume that all energy inputs need to be imported. The corresponding world price of energy is given by

$$\frac{p_t - p}{p} = z_t + \varphi \frac{Q_t^e - Q^e}{Q^e} \tag{12}$$

with

$$Q_t^e = C_t^e + E_t, \tag{13}$$

$$C_t^e = \sum_{s=1}^{T} \psi_s c_t^e. \tag{14}$$

[4] See Cantore and Levine (2012) and Temple (2012).

[5] Alternatively, we could also specify a CES production function with a (KN)E nesting structure as estimated by van der Werf (2008). In Appendix A.1, we show that our results remain qualitatively unaffected if we use this specification instead.

The variable Q_t^e denotes the total aggregate demand for energy, which depends on the aggregate demands C_t^e and E_t from the household and the firm sector, respectively. Without loss of generality, we set $p \equiv 1$ and assume that the shock z_t follows an AR(1) process,

$$z_t = \rho z_{t-1} + \epsilon_t \tag{15}$$

with $|\rho| < 1$ and the disturbance ϵ_t. However, in contrast to Dhawan and Jeske (2008), we additionally introduced the term $\varphi \frac{Q_t^e - Q^e}{Q^e}$ on the right side of Eq. (12) to take into account that a lower aggregate demand for energy Q_t^e has the potential to dampen the upward pressure on the world price p_t after a positive price shock z_t if $\varphi > 0$. Furthermore, in accordance with German data, we assume that firms receive a discount π on their energy demand. Hence, the final energy prices for households and firms are given by

$$p_t^h = p_t, \tag{16}$$

$$p_t^f = (1 - \pi) p_t. \tag{17}$$

2.4 Social Security

The budget constraint of the PAYG system is given by

$$\sum_{s=1}^{T} \psi_s pens_t^s = N_t w_t \tau_t^p + G_t^p. \tag{18}$$

The variable G_t^p represents potential transfers from the government to the social security authority to keep both the contribution rate and the replacement ratio constant over time. Hence, $\tau_t^p = \tau^p$ and $\xi_t = \xi$, where variables without a time index denote the corresponding steady state values.

2.5 Government

As in Heer et al. (2017), we assume that the government collects all accidental bequests Beq_t. Moreover, for ease of interpretation, we distinguish between two different types of government spending, namely normal government spending G_t^g and government expenditure G_t^e for energy subsidies.[6] These expenditure are financed by different tax revenues and government debt B_{t+1} so that the government budget is always balanced:

[6] Note that we follow Galí et al. (2007), Uhlig (2010), and Heer and Scharrer (2018) since we model G_t^g as pure waste or, put differently, as residual in our model. Nevertheless, we could alternatively assume that that government spending enters the utility function in an additive separable way and always yields the constant utility level $v(G)$ for $|G_t - G| \leq \epsilon$ with $\epsilon > 0$ around the steady state of our model.

$$G_t^g + G_t^e + G_t^p + (1 + r_t)B_t = N_t w_t \tau_t^w + \tau_t^c (C_t^n + p_t^h C_t^e) + \tau_t^k r_t (K_t + B_t) + Beq_t + B_{t+1} \tag{19}$$

with

$$Beq_t = \sum_{s=1}^{T} (1 - \varphi_{s-1}) \psi_{s-1} \left[1 + r_t(1 - \tau_t^k)\right] a_t^s. \tag{20}$$

The variables C_t^n and C_t^e represent the aggregate consumption of normal goods and energy, respectively. In this paper, we specify the fiscal implementation of energy price brakes, energy price subsidies, and the associated fiscal rules as follows:

2.5.1 Energy Price Brakes (EPB)

On the one hand, our approximation of the German energy price brake implies that the individual lump-sum transfers $tr_t^{h,s}$ to households at age s are given by

$$tr_t^{h,s} = (p_t^h - p^h)\omega_e c^{e,s}. \tag{21}$$

The term ω_e denotes a quota that refers to the steady state consumption of energy $c^{e,s}$.[7] On the other hand, the lump-sum transfers Tr_t^f to firms are given by

$$Tr_t^f = \left(p_t^f - p^f\right)\omega_e E \tag{22}$$

and depend on the same quota ω_e, which, however, relates to the energy demand E of firms in the steady state. We assume that these transfers are redistributed to households according to the weighted wealth holdings a^s in the steady state,

$$tr_t^{f,s} = \frac{a^s}{\sum_{s=1}^{T} \psi_s a^s} Tr_t^f. \tag{23}$$

Hence, the total transfer to a household at age s is represented by

$$tr_t^s = tr_t^{h,s} + tr_t^{f,s}, \tag{24}$$

so total government expenditure for the energy price brake are given by

$$\begin{aligned} G_t^e &= \sum_{s=1}^{T} \psi_s tr_t^s - R_t^{wp}, \\ &= \omega_e \left[(p_t^h - p^h) C^e + \left(p_t^f - p^f\right) E \right] - R_t^{wp}. \end{aligned} \tag{25}$$

[7] In reality, the German government decided that the caps for gas and electricity relate to the corresponding demands in the previous year. See https://www.bundesregierung.de/breg-en/news/energy-price-brakes-2156430 (accessed 7 June 2023). However, this approach would lead to an even higher number of state variables and thus considerably complicate the numerical global solutions of our model.

The variable R_t^{wp} denotes potential exogenous government revenues from taxes on windfall profits and caps on excess revenues in the energy sector. For simplicity, we assume that these revenues are proportional to the weighted absolute change of energy prices $p_t - p$ with respect to the shock z_t in period 1 (when the price shock ϵ_t hits the economy), the tax rate τ_t^{wp}, and the steady state output Y:

$$R_t^{wp} = \frac{p_t - p}{z_1} \tau_t^{wp} Y. \tag{26}$$

Thus, the government is able to collect additional exogenous tax revenues by setting $\tau_t^{wp} > 0$ in our model. However, this assumption also implies that these revenues are not redistributed back to households if τ_t^{wp} is equal to zero. Note that these implications are not too restrictive and in good accordance with empirical data. For example, for the United States, Weber (2022) points out that the top 1% and the next 9% of the wealth distribution received 53.7% ($48.8 billion) and 35% ($31.6 billion) of total domestic fossil fuel profits in the second quarter of 2022, respectively. Moreover, the Deutsche Bundesbank (2023) provides empirical evidence that only 15% (8%) of German households held stocks (business assets) in 2021, while the share of total net worth of the top 10% was equal to 56%. Thus, windfall profits are very unevenly distributed and, therefore, very likely out of reach for the majority of a population.

2.5.2 Energy Price Subsidies (EPS)

If instead the government decides to introduce price subsidies for energy, Eqs. (16) and (17) change to

$$p_t^h = p + \left(1 - \omega_e\right)\left(p_t - p\right), \tag{27}$$

$$p_t^f = (1 - \pi)\left[p + \left(1 - \omega_e\right)\left(p_t - p\right)\right]. \tag{28}$$

For convenience and ease of comparison, we use the same parameter ω_e that, however, controls the extent of price dampening in this scenario. The associated government expenditure amount to

$$G_t^e = \omega_e\left(p_t - p\right)\left[C_t^e + (1 - \pi)E_t\right] - R_t^{wp}. \tag{29}$$

2.5.3 Fiscal Rules

We use a similar approach as in Galí et al. (2007) and specify the following financing rules for G_t^e:

$$\left(B_{t+1} - B\right) = \omega_b\left(G_t^e + \left(1 + r_t\right)\left(B_t - B\right)\right), \tag{30}$$

$$\left(\tau_t^w - \tau^w\right)N_t w_t = \omega_w\left(G_t^e + \left(1 + r_t\right)\left(B_t - B\right)\right), \tag{31}$$

$$\left(\tau_t^c - \tau^c\right)\left(C_t^n + p_t^{he}C_t^e\right) = \omega_c\left(G_t^e + \left(1 + r_t\right)\left(B_t - B\right)\right), \tag{32}$$

$$\left(\tau_t^k - \tau^k\right)r_t\left(K_t + B_t\right) = \omega_k\left(G_t^e + \left(1 + r_t\right)\left(B_t - B\right)\right), \tag{33}$$

where the parameters ω_i for $i \in \{w, b, c, k\}$ are positive constants. Furthermore, we assume $\omega_w + \omega_b + \omega_c + \omega_k = 1$ so that an increase in government expenditure for energy G_t^e must always be financed with additional tax revenues and/or an increase in government debt. This assumption therefore excludes the possibility that an increase in G_t^e can be offset by lower government expenditure for G_t^g or G_t^p.[8] If, for example, a government sets $\omega_b = 0.95$ and $\omega_w = 0.05$ with $\omega_c = \omega_k = 0$, then 95% of the increase in G_t^e in period 1 is financed with new government debt $\left(B_{t+1} - B\right)$, while the remaining 5% are funded with additional tax revenues $\left(\tau_t^w - \tau^w\right)N_t w_t$ from labor incomes.

3 Calibration

We calibrate the model on an annual basis for the German economy with respect to the year 2017 and compute the dynamics of the model around the steady state with the extended path method originally proposed by Fair and Taylor (1983).[9] If not explicitly otherwise stated, for the reader's convenience, we use the real life age in years in contrast to the model age index $s \in \{1, ..., 65\}$ in the discussions and figures hereinafter.

Households enter the economy at age 26, live at most 65 years, and work for $T_w = 38$ years such that they enter retirement at 64. This age equals the average age of people entering retirement in 2017 according to Deutsche Rentenversicherung Bund (2022). The survival probabilities ϕ_s also refer to the year 2017 and are taken from the German federal statistical office, see GFSO (2023). The age-specific parameters γ_0^s are set so that the model replicates the smoothed pattern of average age-specific labor supply of individuals in the German Socio-Economic Panel (2022) between 2016 and 2018. In addition, we use the same data source to calculate the median of real hourly earnings of individuals for every age in the sample 2016-2018

[8] In our model, however, it is possible that G_t^g decreases while G_t^p increases if aggregate pension entitlements increase since both the contribution rate τ^p and the replacement ratio ξ are constant by assumption, see Eqs. (8) and (18). Note that, for example in 2017, federal government grants made up 24% of total revenues of the German statutory pension system according to Deutsche Rentenversicherung Bund (2022). Therefore, this assumption is also plausible from an empirical point of view.

[9] Note that the extended path method is a global solution method and, therefore, provides significant improvements in accuracy in comparison with local projection methods if our model economy is hit by very large energy price shocks. In particular, we use the solution methods presented in Chapters 3, 9, and 10 in Heer and Maußner (2009) and modified codes of the provided CoRRAM package (see https://www.uni-augsburg.de/de/fakultaet/wiwi/prof/vwl/maussner/dgebook/). The program codes are available upon request.

as an approximation for the productivity profiles e^s. For simplification, the productivity e^s at age 26 is normalized to one. The parameter θ is equal to 3.0 so that the net worth profile is in good accordance with the scaled real median net worth of individuals with non-negative wealth from the SOEP sample 2017.[10] Moreover, we set the discount factor β equal to 0.994. Then, the real rate of return on capital, $r_t - \delta$, equals a value of 4% which describes the long term average according to Busl and Seymen (2013). With respect to the Frisch labor supply elasticity, we use the central estimate $\gamma_1 = 0.40$ recommended by Whalen and Reichling (2017). They review the economic literature on Frisch elasticities and conclude that the most relevant values for fiscal policy analysis range from 0.27 to 0.53. Furthermore, we choose the standard value $\eta = 2$, which implies an intertemporal elasticity of substitution of 0.5.

Schmitz and Madlener (2020) study the determinants of heating and hot water expenditures with SOEP data covering the years 1996-2014. They find that the corresponding energy price elasticity is equal to 0.361 and mention that roughly 83% of household energy demand were attributable to space heating and hot water preparation in Germany in 2015.[11] Moreover, Frondel and Kussel (2019) use data from the German Residential Energy Consumption Survey and estimate a price elasticity of electricity demand of about 0.52. For these reasons, we use a weighted average for the elasticity of substitution between normal consumption and energy consumption by setting $\sigma = 0.83 \cdot 0.361 + (1 - 0.83) \cdot 0.52 \approx 0.39$. Furthermore, we choose $\nu = 0.9992$ so that the share of consumption expenditure for energy equals 5.84%, in line with data provided by the GFSO (2018).

With respect to the government sector and the PAYG scheme, the stationary tax rates are given by $\tau^c = 0.15$, $\tau^k = 0.23$, and $\tau^g = 0.21$ such that $\tau^g + \tau^p = 0.41$, as in Trabandt and Uhlig (2011). In addition, and without loss of generality, we set the level of government debt B equal to 0.16. In accordance with Mbaye et al. (2018) for 2017, this value implies a total stock of debt liabilities issued by the central government that is equal to 41% of GDP. The replacement ratio ζ of pensions relative to average pre-retirement earnings equals 40%, see Kluth and Gasche (2015). The resulting stationary contribution rate amounts to $\tau^p = 19.8\%$. This value is slightly higher than its empirical counterpart of 18.70% for the year 2017.

Regarding the production side of our model economy, we use a relatively conservative value for the calibration of the labor income share $1 - \alpha$ and set $\alpha = 0.30$. See, for example, Heiberger and Ruf (2019) and Flor (2014) using the values 0.27 and 0.34, respectively. We take the depreciation rate $\delta = 0.094$ from Bachmann and Bayer (2014), who determine this parameter with German national accounting data for the non-financial private business sector. Moreover, Bachmann et al. (2022) summarize the empirical literature about price elasticities of energy demand and conclude that the own-price short-run (up to one year) elasticities lie mainly in the range from 0.15 to 0.25. In particular, Labandeira et al. (2017) provide empirical evidence that the average short-run elasticities of the industrial and commercial sector amount to 0.168 and 0.224, respectively. For these reasons, we set $\chi = 0.221$, in line with their central estimate for short-run energy price elasticities. Moreover, we

[10] The SOEP collects data on individual net worth only every five years.

[11] See the Introduction, Table 6, and Eq. (4) in Schmitz and Madlener (2020).

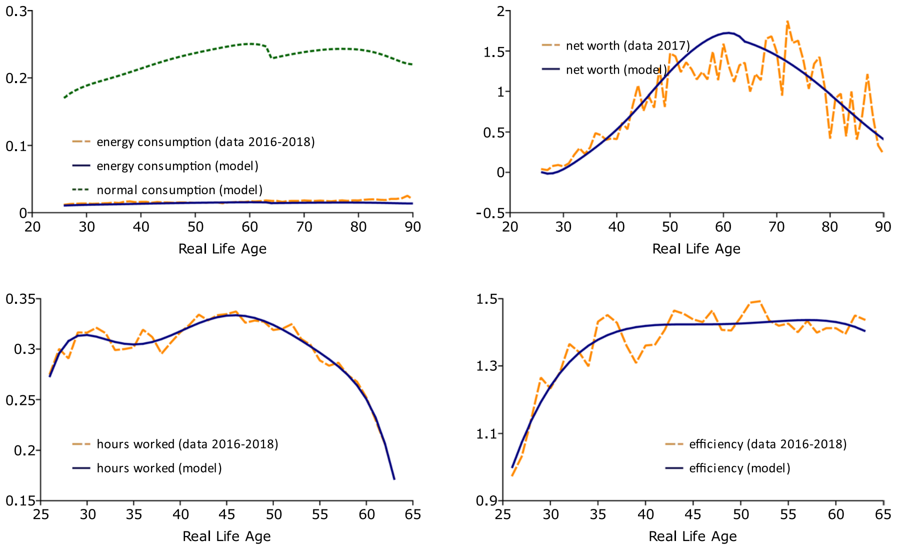

Fig. 3 Steady state—life-cycle profiles

pin down the parameter $\nu = 0.8972$ to match the ratio $E/C^e = 1.74$ with respect to data provided by the BMWK (2021) for 2017. The discount rate on energy demand of firms is set to $\pi = 0.40$. This value represents the semi-annual average discount between 2019:2 and 2021:2, where we use household and firm data on gas and electricity prices published by the GFSO (2023).

4 Steady state

Figure 3 presents the model's steady state life-cycle profiles. The upper left panel shows that conventional consumption increases until an age of 63 years and roughly follows a hump-shaped pattern which is qualitatively consistent with empirical evidence provided by Kluge (2011). Moreover, the energy consumption profile is also in good accordance with the corresponding empirical evidence from the SOEP samples 2016 to 2018. The upper right panel displays the net worth of households over the life cycle, which roughly matches the pattern of its empirical counterpart. The labor supply, as displayed in the lower left panel, replicates the smoothed empirical profile due to the age-specific calibration of the parameter γ_0^s. It increases until an age of 45 and falls monotonously thereafter. The lower right panel displays the household's age-specific efficiency profile. It increases rapidly between the ages of 26 and 35 years and then remains relatively constant until an age of 63 years.

Table 1 Financing Rules - Overview

Cases	Fixed parameters					
	ω_e	ω_b	ω_w	ω_c	ω_k	τ^{wp}
1) Laissez-faire	0	0	0	0	0	0
2) Debt Financing	0.4	0.9	1/30	1/30	1/30	$\{0, 0.25, 0.5\}$
3) Labor Income Tax	0.4	0	1	0	0	$\{0, 0.25, 0.5\}$
4) Consumption Tax	0.4	0	0	1	0	$\{0, 0.25, 0.5\}$
5) Asset Income Tax	0.4	0	0	0	1	$\{0, 0.25, 0.5\}$

5 Results

In our numerical simulations, we set $\varphi = 0$ and $\epsilon_1 = 0.5$ so that both individuals and firms face a price increase of 50% for energy in period 1, which is broadly in line with the data presented in Fig. 1. In contrast, the calibration of the parameter ρ is much more difficult due to the current high level of uncertainty about the persistence of the energy price shock. Therefore, this section presents our results for a rather optimistic scenario with $\rho = 0.25$; whereas, Appendix A.2 shows that a higher persistence parameter does not qualitatively affect our results in a robustness check with $\rho = 0.75$.

According to the European Economic Forecast, see European Commission (2023a), the estimated net expenditure for energy support measures amounted to about 1.2% of GDP in the EU in 2022. Therefore, we choose $\omega_e = 0.4$ to replicate this expenditure share in the first period of the energy price shock with respect to the energy price brake scenario. For comparison, we use the same value in the analyses on price subsidies. The German consumption of primary energy only amounted to 2.1% (15%) of total world (EU) consumption in 2021 according to the British Petroleum Company (2022). For that reason, we are conservative and assume $\varphi = 0$ since the price mitigating effects of a lower domestic demand on the world price of energy are likely to be small. However, EU-wide measures could be associated with more pronounced effects, so we provide results for $\varphi = 1$ in our sensitivity analysis.

Regarding the total government revenues from taxes on windfall profits and excess revenue caps, the European Commission (2022) estimated that the member states are able to collect about 142 billion Euro or, put differently, 0.90% of EU GDP in 2022. In contrast, the estimates of Nicolay et al. (2023) were lower by 25 billion Euro and amounted to 0.70% of EU GDP. However, with respect to potential revenues from revenue caps, the European Commission (2023b) admitted that these revenues were unevenly distributed in the EU and that the underlying assumptions of these estimates became unlikely after the publication of these reports. Moreover, according to this report, Germany's initial total estimate was much lower and amounted to only 23.4 billion Euro with respect to a possible extension until 30 April 2024. However, the implemented measures were only valid from 1 December 2022 to 30 June 2023 in Germany and, thus, after the peaks of energy prices in 2022. In addition, tax avoidance measures, for example cross-border profit shifting of multinational firms, could further reduce the expected revenues. For these

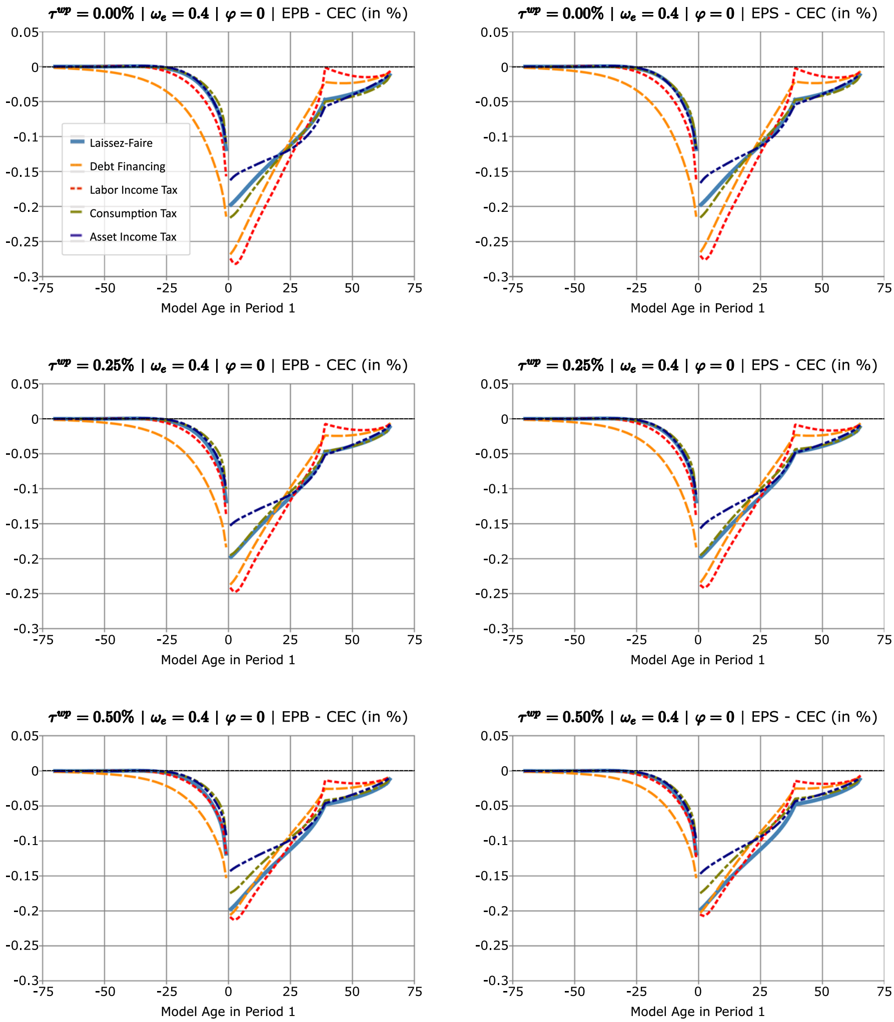

Fig. 4 Consumption equivalent changes (CECs) - benchmark calibration (EPB = energy price brake, EPS = energy price subsidy)

reasons, we expect revenues to be significantly lower than the initial estimates of the European Commission and present our main results for $\tau^{wp} \in \{0, 0.25, 0.5\}$. To examine the impacts of energy price brakes and energy price subsidies on welfare and economic growth with respect to different forms of financing, we consider five cases: (1) a laissez-faire scenario without any fiscal measures, and the cases with implemented energy price subsidies or energy price brakes that are either financed by (2) debt, (3) labor income taxes, (4) consumption taxes, or (5) asset income taxes.

Table 1 summarizes the parameter values of ω_e, ω_b, ω_w, ω_c, ω_k, and τ^{wp} for each case.[12]

Figure 4 displays the consumption equivalent changes (CECs) of both present and future age groups after an energy price shock in period 1. This welfare measure describes the percentage variation of steady state consumption c^s that is equivalent to a given absolute change in lifetime utility.[13] The x-axis denotes the model age in period 1. For example, the positive model age $s = 1$ (10) denotes individuals at a real life age (RLA) of 26 (36) years in period 1, whereas the negative model age $s = -1$ (-2) represents individuals, that will enter the economy in period 2 (3) at real life age 26. The panels in the left column show the welfare results for implemented energy price brakes; whereas, the panels in the right column display the corresponding results for energy price subsidies. Note that, per definition, the laissez-faire solutions, which are displayed by solid light blue lines, are identical across all cases.

The upper left panel of Fig. 4 shows the EPB results for $\tau^{wp} = 0$. Irrespective of the financing form, the youngest individuals, who are alive in period 1, face the most pronounced declines of lifetime utilities. These cohorts are exposed to the negative effects of the energy price shock for the longest period of time and have to deal with the strongest increase in energy prices in period 1. Comparing the CECs across all age groups and all financing forms with respect to the laissez-faire solution shows that, in particular, labor income taxes and debt financing strongly redistribute the economic burdens between old and young/future generations, as depicted by the red and orange lines, respectively.[14] Young generations are worse off in these two cases, whereas older generations, in particular young retirees, benefit from the introduction of the energy price brake since it dampens their welfare losses. For example, the CEC of individuals at model age $s = 1$ (RLA 26) is equal to −0.20 and −0.27% in the laissez-faire and in the debt financing scenario, respectively. In contrast, the corresponding CECs of old individuals at age $s = 40$ (RLA 65) amount to −0.05 and −0.02%, while the values at age $s = 55$ (RLA 80) equal −0.03 and −0.02%. Also note that the welfare improvements of the elderly are especially detrimental for future generations if the introduced energy price brakes are financed with debt. This results

[12] In Case 2, we set $\omega_b = 0.90$ to approximate the form of debt financing since this value still ensures local stability around the steady state in all of our simulations. Moreover, a parameter $\omega_b < 1$ implies that we have to introduce additional adjustments of other tax rates to keep the government budget balanced. For calibrations with high parameter values for ω_b, our results remain, however, essentially unchanged with respect to different allocations of the remaining spending share $(1 - \omega_b)$ to different tax rates. Therefore, we set $\omega_w = \omega_c = \omega_k = (1 - \omega_b)/3$ only for illustrative purposes.

[13] We could also use the absolute deviations of lifetime utilities as welfare measure. However, it is always possible to add a constant to instantaneous utility functions, so relative deviations of lifetime utilities cannot be meaningfully interpreted. Therefore, the CEC is often used in models with overlapping generations since it allows to draw more meaningful comparisons across generations. Nevertheless, both welfare measures are equivalent to each other.

[14] Note that the age-specific inflation for the consumption bundle c_t^s, see equation (3), depends both on the price for energy consumption $c_t^{e,s}$ and the price for normal consumption goods $c_t^{n,s}$. Hence, our model features increases in inflation that are solely driven by increases in energy prices since normal goods (and capital) serve as numeraire in our model. The missing inflationary pressure from the normal goods market is, however, implicitly offset by adjustments of relative prices in our simulations, as, for example, declines in real wages reduce the purchasing power of households.

from the crowding out of productive capital and, primarily, the additional higher interest burdens of future generations. Moreover, the green line shows that the financing case with adjustments of consumption taxes is relatively comparable with the laissez-faire solution, both quantitatively and qualitatively. Therefore, such a policy makes little sense from an economic point of view. In contrast, see the blue lines, asset income taxes most efficiently improve the welfare of young individuals who are alive in period 1; whereas, the positive effects on the oldest individuals are much less pronounced. However, this financing form slightly exacerbates the situation of the wealthiest individuals at ages 21 (RLA 46) to 52 (RLA 77). Nevertheless, this result shows that these age groups are better able to cope with the economic burdens that result from adjustments of asset income taxes, in comparison with the very pronounced additional welfare losses of younger generations under debt financing.

The left panels in the second and third row of Fig. 4 depict the contribution of higher government revenues from windfall profits and excess revenue caps for $\tau^{wp} = 0.25$ and $\tau^{wp} = 0.5$, respectively. On the one hand, young and future generations in particular benefit from these higher tax revenues, with the largest improvements in Cases 2 and 3 with debt financing and labor income taxes. If, for example, a government implements a debt-financed energy price brake and increases τ^{wp} from 0.0 to 0.50, then the CEC of individuals at age 1 (RLA 26) increases from −0.27 to −0.20%. On the other hand, the effects on the life time utilities of older individuals are much less pronounced. Thus, these results suggest that the collection of these potential tax revenues by governments is especially relevant for young and future generations if the emergency measures are financed by increases in government debt. Also note, however, that these tax revenues are not always necessarily associated with a Pareto improvement across all generations. For example, with respect to an energy price brake financed by taxes on labor incomes, the CECs of young retirees even moderately decline with higher additional tax revenues due to less pronounced general equilibrium effects of labor supply on the real interest rate. The right columns of Fig. 4 show the results with respect to price subsidies. In comparison with the cases with an energy price brake in the corresponding left panels, the welfare effects of energy price subsidies are both qualitatively and quantitatively almost identical.

6 Sensitivity analysis

Interestingly, the previous presented results also hold for the (rather extreme) case with $\varphi = 1$ that is displayed in Fig. 5. Compared with Fig. 4, this figure shows the same qualitative results. However, the welfare losses are much less pronounced because of the additional effect of a lower domestic demand that dampens the price of energy and the associated fiscal burdens of fiscal interventions with respect to Cases 2 to 5. Interestingly, even if we take this price mitigating effect into account, then the welfare differences between an implemented energy price brake and an energy price subsidy still remain almost negligible. Nevertheless, this finding should be interpreted with caution since energy price brakes were much more efficient at reducing energy demand in our simulations, which is why we recommend this measure despite the very small welfare differentials observed in this study.

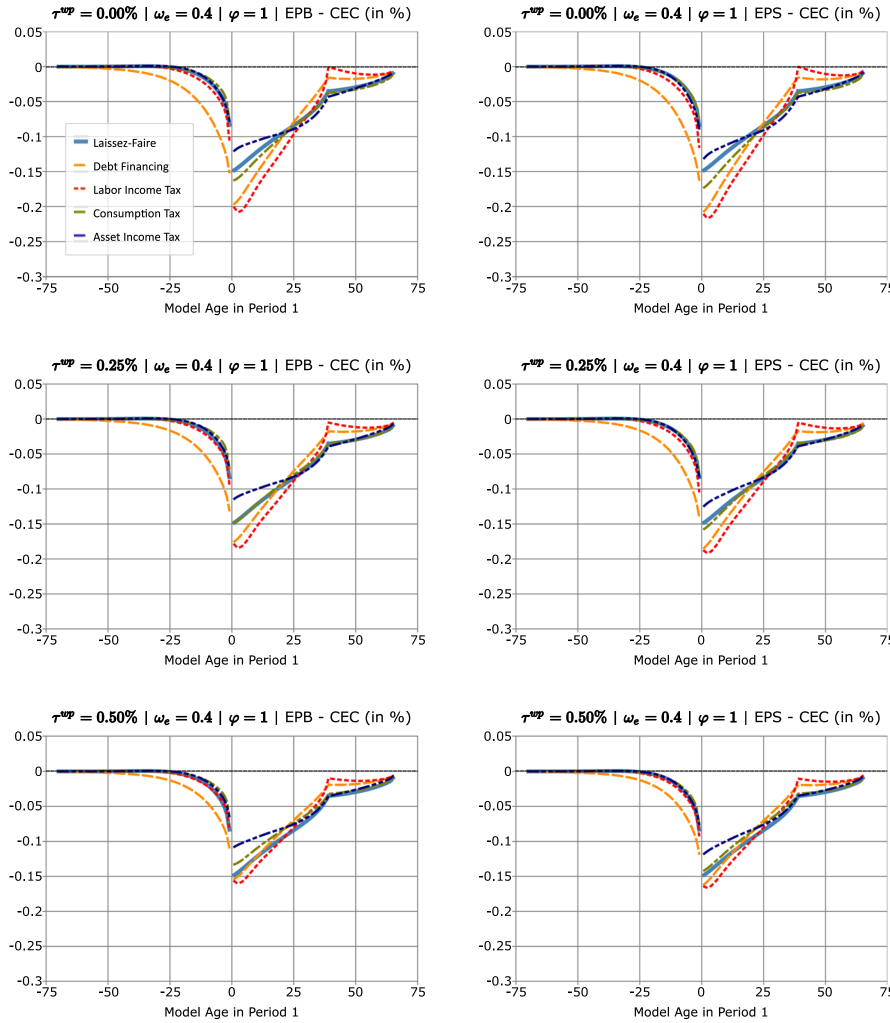

Fig. 5 Consumption equivalent changes (CECs) - benchmark calibration with $\varphi = 1$ (EPB = energy price brake, EPS = energy price subsidy)

As previously mentioned, the European Commission (2022) initially estimated additional revenues of about 142 billion Euro, 117 billion Euro from revenues caps and 25 billion Euro from solidarity contributions. Given these figures, François et al. (2022) propose to tax the increase in market capitalization of companies that strongly benefited from higher energy prices. According to their results, this tax instrument is less prone to tax avoidance strategies and generates additional tax revenues of around 0.25% of EU GDP from windfall profits, in sum 65 billion Euro versus 25 billion Euro from solidarity contributions. In this context, it is therefore interesting to review the welfare results in a sensitivity analysis by assuming that governments implement such

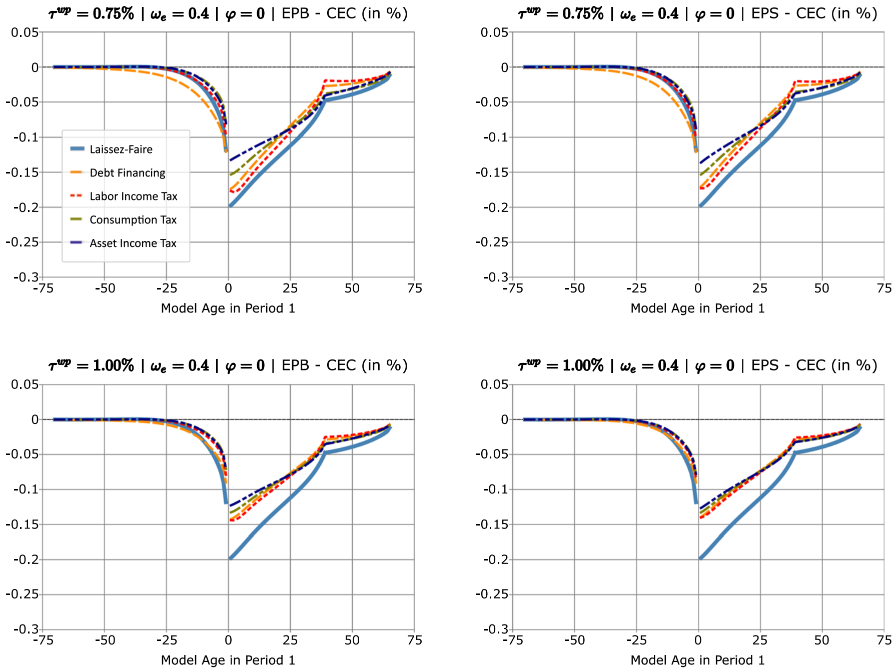

Fig. 6 Consumption equivalent changes (CECs) - benchmark calibration with higher tax revenues from windfall profits (EPB = energy price brake, EPS = energy price subsidy)

recommendations and thereby generate tax revenues of 0.75 or 1% of GDP. With respect to $\tau^{wp} \in \{0.75, 1\}$, Fig. 6 shows that, for all financing forms except debt financing, additional tax revenues of about 0.75% of GDP or more allow to introduce Pareto improving energy price brakes or energy price subsidies that make all current and future generations better off. However, this result should be interpreted with caution. On the one hand, the empirical validity of our exogeneity assumption about tax revenues from windfall profits, see equation (26), is likely to decline with increasing τ^{wp}. On the other hand, such very pronounced tax measures can be distortionary and increase the uncertainty of investors. However, these results indicate that such tax proposals might play a key role with regard to the implementations of Pareto improvements. Put differently, if the additional revenue opportunities of windfall profit taxation are ignored, then the distribution of welfare effects, depending on the form of financing, is often more like a zero-sum game between generations, as depicted in the first rows of Figs. 4 and 5.

7 Conclusion

The unprecedented increases of energy prices after the Russian invasion of Ukraine prompted many European governments to implement fiscal support measures that mitigate the associated economic burdens on households and firms. In this context, this paper studies how different financing rules for untargeted energy price brakes and energy price subsidies, which shield households and firms from rising energy prices, affect the intergenerational welfare. For our analysis, we use a large-scale overlapping generations model that is calibrated, for merely illustrative purposes, for the German economy. Overall, we expect our results to be valid for a wide range of industrialized countries.

Irrespective of the financing form, the age-specific differences in welfare between energy price brakes and energy price subsidies are both qualitatively and quantitatively almost negligible. Thus, from a welfare perspective, it is relatively irrelevant which of these two measures is actually implemented in practice. Nevertheless, energy price brakes are more effective at reducing the aggregate demand for energy, so they should be considered as first choice. Moreover, in comparison with a laissez-faire solution, the results indicate that debt-financed implementations of energy price brakes or energy price subsidies primarily make older generations better off. In contrast, if governments choose this financing form but forgo potential tax revenues from windfall profits, then the welfare of young and future generations strongly declines. These generations are economically overburdened by the additional fiscal cost of higher government spending. The corresponding sensitivity analysis shows that the taxation of windfall profits plays a very important role in this regard, as it is particularly effective at lowering the economic burdens of younger generations and, thus, improving their welfare under debt financing. Furthermore, also in comparison with a laissez-faire solution, financing rules that primarily tax asset incomes are beneficial for young and future generations. If potential tax revenues from windfall profits are, however, also largely ignored, then they only marginally increase the welfare of the oldest individuals and even slightly decrease the welfare of older workers and young retirees.

Note that the results of this study should be interpreted with caution. For example, on the one hand, our assumption about exogenous additional tax revenues from windfall profits is empirically plausible for small shares of GDP. However, the empirical validity almost certainly declines as both tax rates and the associated revenues strongly increase. On the other hand, our model does not take tax avoidance strategies, like international profit shifting, or distortions of investments into account. For these reasons, it is possible that our welfare results are biased upwards due to excessively high tax revenues that result from high tax rates on windfall profits.

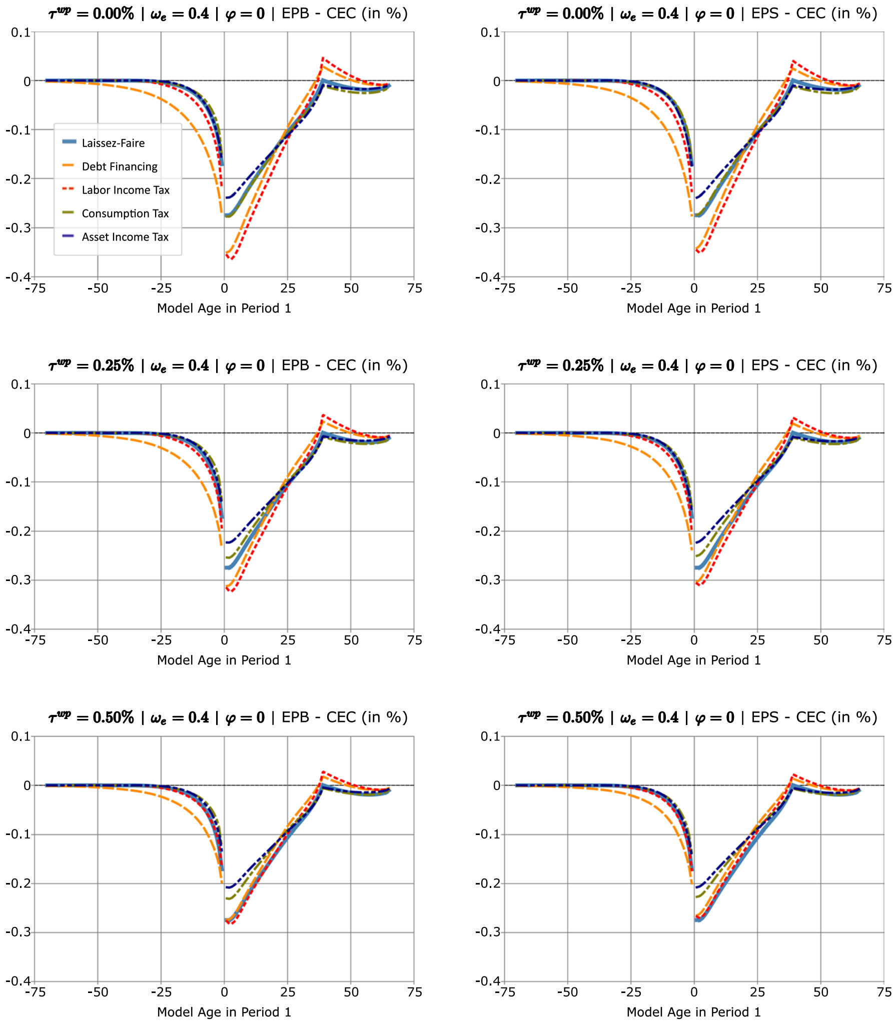

Fig. 7 Consumption equivalent changes (CECs) - benchmark calibration with a (KN)E nesting structure for the CES Production Function (EPB = energy price brake, EPS = energy price subsidy)

A Appendix

A.1 Robustness Check - CES production function

In this section, we conduct a robustness check of our results with respect to a (KN)E nesting structure for the CES production function as proposed by van der Werf (2008). The production function is given by

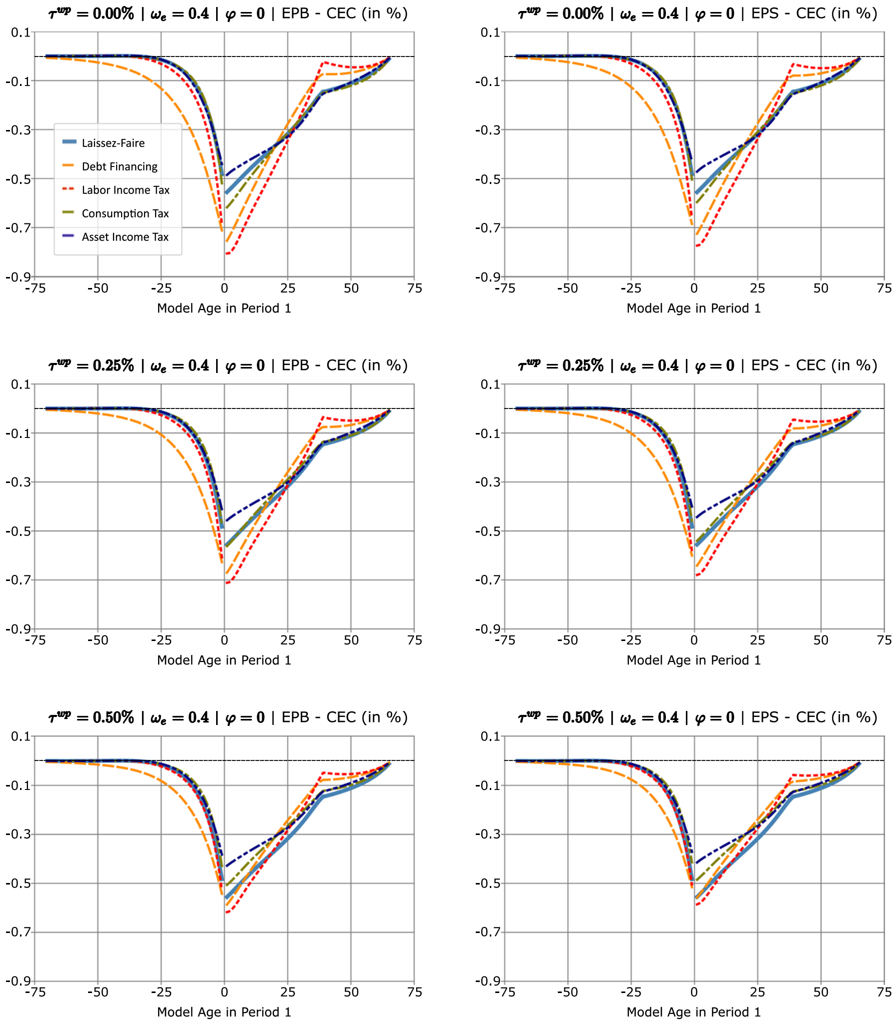

Fig. 8 Consumption equivalent changes (CECs) - benchmark calibration with $\rho = 0.75$ (EPB = energy price brake, EPS = energy price subsidy)

$$Y_t = Y\left[\mu\left(\frac{E_t}{E}\right)^{\frac{\chi_1-1}{\chi_1}} + (1-\mu)\left(\frac{Q_t}{Q}\right)^{\frac{\chi_1-1}{\chi_1}}\right]^{\frac{\chi_1}{\chi_1-1}} \tag{34}$$

with

$$Q_t = Q\left[\alpha\left(\frac{K_t}{K}\right)^{\frac{\chi_2-1}{\chi_2}} + (1-\alpha)\left(\frac{N_t}{N}\right)^{\frac{\chi_2-1}{\chi_2}}\right]^{\frac{\chi_2}{\chi_2-1}}. \tag{35}$$

According to the estimates for West-Germany, see Table 3 in van der Werf (2008), we choose $\chi_1 = 0.3311$ and $\chi_2 = 0.4271$. Moreover, we follow the same calibration strategy as in our benchmark model and set $\alpha = 0.277$ and $\mu = 0.031$. Then, the labor income share and E/C^e also equal 70 percent and 1.74, respectively. Figure 7 displays the corresponding consumption equivalent changes (CECs) of both present and future age groups after an energy price shock in period 1. In comparison with Fig. 4, our results remain qualitatively unaffected. However, the welfare losses are somewhat more pronounced among younger and future generations. In contrast, the welfare losses of older generations are much less pronounced and young retirees can even achieve small welfare gains. These cohorts benefit from stronger increases of real interest rates after an energy price shock, in particular in Cases 2 and 3 with debt financing and labor income taxes, respectively.

A.2 Robustness check - shock persistence

This section presents a robustness check that studies the effects of a more persistent price shock on our welfare results by setting $\rho = 0.75$. Figure 8 shows that a higher persistence does not qualitatively affect our results. However, as expected for such a scenario, price shocks are much more detrimental for current and future cohorts.

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Declarations

Conflict of interest No funding was received for conducting this study. The authors have no relevant financial or non-financial interests to disclose.

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