Energy Economics 130 (2024) 107284

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

How should governments respond to energy price crises? A horse-race between fiscal policies

Geoffroy Duparc-Portier *, Gioele Figus

Department of Economics, University of Strathclyde, 199 Cathedral Street, Glasgow, G4 0QU, United Kingdom

ARTICLE INFO

JEL classification:
C68
D58
Q43
Q48

Keywords:
Energy crisis
Fiscal policy
Income distribution
Computable general equilibrium
Welfare
Windfall tax

ABSTRACT

This paper compares the welfare and distributional implications of fiscal policies aimed at reducing a sudden and significant increase in the price of energy. A dynamic computable general equilibrium model with households disaggregated by income groups is used to compare the effectiveness of five energy price-reducing fiscal policies. The policies are assessed under two financing options, pure government debt and a mix of debt and windfall taxation on energy companies. Results from simulations demonstrate that targeted demand-side policies are more effective at reducing overall energy-driven inflation and increasing welfare. Supply-side policies and mixed demand and supply policies achieve a smaller reduction in the consumer price index but are more expansionary. Financing the policies partly through windfall taxation does not impact the ranking of policies but it delivers better distributional outcomes and higher welfare. The results motivate the use of windfall taxation if governments face high interest rates on debt financing and/ or if households care sufficiently about the provision of public goods. The optimal policy is likely a mix of supply-side measures such as production tax reductions or general price subsidies and either targeted energy price subsidies or targeted income subsidies financed where possible through windfall taxation.

1. Introduction

Beginning in 2021 the world has experienced a dramatic and sudden increase in energy prices. This 'energy crisis' (IEA, 2023) has been attributed to a variety of factors, including the rapid economic rebound following the Covid-19 pandemic and Russia's invasion of Ukraine in February 2022. Crucially, the energy crises has significantly impacted the cost-of-living. This is evidenced by the fact that global inflation increased from 3.1% in 2021 to 7.3% in 2022 whilst world output growth decreased from 6.2% to 3.4% (IMF, 2023). However, the consequences of this shock have not been felt evenly. On a geographical level, for instance, some countries such as Germany and Italy, have been more exposed due to their dependence on gas imports from Russia. Distributionally speaking, lower-income households have been disproportionately affected as they typically consume a larger proportion of their income on energy goods compared with higher-income households (Guan et al., 2023).

To contain the impact of this increase in the price of energy, governments across Europe have been implementing a litany of fiscal policies designed to address aggregate and distributional consequences of the shock (Sgaravatti et al., 2023). These included price subsidies, either to firms and households, to households only or targeted to low-income households, income subsidies, and tax reductions on energy. The policies have been mostly financed by public debt with some exceptions where the funding has come from taxing energy companies' extra profits,[1] the so called 'windfall tax'. Whilst a broad empirical and theoretical literature exists, that quantifies the aggregate and distributional effects of energy shocks and the effects of price subsidies, income subsidies, and tax reductions, there is limited ability to compare the welfare and distributional implications of such policies.

The aim of this paper is to analyse and compare the implications of fiscal policies implemented by European governments to contain the increase in energy prices on output, prices, income distribution and welfare. To achieve a like-for-like comparison of the different policies we develop a dynamic Computable General Equilibrium (CGE) of Germany and the Rest of the EU using the 2020 FIGARO Input-Output database (Remond-Tiedrez and Rueda-Cantuche, 2019). The focus on Germany is purely illustrative of a country with a strong dependence on imported gas. The model considers the production activities of energy

* Correspondence to: Sir William Duncan Building, Strathclyde Business School, 199 Cathedral Street, Glasgow, G4 0QU, United Kingdom.
E-mail address: g.duparc-portier@strath.ac.uk (G. Duparc-Portier).

[1] There is evidence that the hike in energy prices has led to a surge in profits for energy companies. For instance two of the largest oil and gas companies in the world, Shell and BP, saw record profits in 2022 (BP, 2023; Shell, 2023). Jolly and Elgot (2022) suggest that the profits of the 7 largest oil firms in the world exceeded £150bn in 2022.

https://doi.org/10.1016/j.eneco.2023.107284
Received 19 July 2023; Received in revised form 24 November 2023; Accepted 29 December 2023
Available online 5 January 2024

and non-energy industries where energy industries set energy prices in a monopolistic environment. Two household income groups are considered to investigate the distributional implications of the policies. Using the model, we simulate the introduction of five fiscal policies (general/ untargeted/ targeted price subsidies, income subsidies, and production tax reductions) representing the main policies introduced by European governments following an exogenous energy price shock. The simulations are performed by either assuming that the policies are entirely government debt financed or funded through a combination of debt and windfall taxes on energy profits. This allows us to compare the welfare implications of the two financing mechanisms.

Using the CGE model, some stylised conclusions can be drawn. First, targeted income and price subsidies best counteract short-run regressive impacts on consumption and provide the best long-run welfare outcomes following the energy shock. Second, households targeted and untargeted income and price subsidies achieve a greater reduction in inflation. Third, production tax reduction are the most effective policy to counteract downward pressure on aggregate output in the short run. Fourth and last, introducing a windfall tax is welfare-enhancing for all policies as long as households care sufficiently about the provision of public goods.

2. Background and literature

An extensive economics literature starting with (Hamilton, 1983) has documented the contractionary and inflationary effects of energy price shocks (see for example Kilian, 2008; Ven and Fouquet, 2017, for a review and a historical analysis). The literature highlights how these shocks may hit energy importing countries more severely (Jiménez-Rodríguez and Sánchez, 2005; Jiménez-Rodríguez, 2008; Alexeev and Chih, 2021; Peersman and Robays, 2012), and that impacts may be heterogeneous at an industrial level (Jiménez-Rodríguez, 2008; Ahmed et al., 2023; Ferriani and Gazzani, 2023).

Researchers typically find that low-income households are more adversely affected by energy shocks (Michael, 1979; Hagemann, 1982; Pizer and Sexton, 2019; Williams et al., 2015; Metcalf et al., 2008; Guan et al., 2023; Celasun et al., 2022; Turner et al., 2022) for two main reasons. First, low-income households spend larger proportions of their income on energy and goods highly dependent on intermediate energy use. Second, low-income households own proportionally fewer assets than high-income households. Thus they are less likely to benefit from increased returns from energy companies' assets.

An emerging literature is concerned with the distributional impacts of the recent energy crisis (Celasun et al., 2022; Guan et al., 2023; Perdana et al., 2022; Turner et al., 2022). Specifically, Celasun et al. (2022) suggest that in 2022, European households' cost-of-living increased by 7%. Guan et al. (2023) use an international input–output framework and estimate total household energy costs to increase by 62.6–112.9% across the world. These effects are found to be distributed unevenly both within and across countries supporting evidence from (Celasun et al., 2022). Perdana et al. (2022) evaluate the consequences of the trade sanctions on Russia using a CGE methodology, mainly from an environmental perspective, but also find reductions in GDP and Welfare in the EU. Finally, Turner et al. (2022) evaluate the implications of the cost-of-living crisis using a CGE model of the UK. They focus on the distributional impacts of £400 energy payments given by the UK Government to all households and find that the policy still leaves households on the lowest income £350 worse off than before the energy crisis.

Although all the papers above provide an assessment of the impact of the 2022 energy shock, none attempt to compare energy policies using a unified framework. Guan et al. (2023) and Perdana et al. (2022) provide insights on the aggregate and distributional impacts of the energy shock but do not present any fiscal policy measures. On the other hand Turner et al. (2022) analyse a specific policy introduced in the UK but do not compare alternative policies and do not consider windfall taxation. Celasun et al. (2022) provide the most detailed discussion on policy options however the discussion is not based on a single framework and is more qualitative than quantitative.

Thus with our work, we contribute to the above literature by systematically assessing the welfare and distributional impacts of the main fiscal policies implemented across Europe to counteract the impact of increased energy prices as reported in Sgaravatti et al. (2023). The analysis in this paper provides a strong basis for the assessment of the strengths and weaknesses of each of the policies in addressing both welfare and distributional policy objectives under a unified framework. Although the paper is inspired by the current measures implemented across Europe, it is designed as a theoretical contribution. Thus, the focus will be on comparing the policies rather than precisely quantifying the effects of the energy crisis. Equally, the focus on Germany is purely illustrative of an energy import-intensive country. Germany makes the ideal case study as 90% of total crude oil, refined petroleum products and natural gas used in Germany was imported prior to the beginning of the Ukraine conflict (Eurostat, 2023f). Whilst the results from this paper are specific to the German case, the methods developed are directly applicable to any other country. In addition, the results are relevant for countries with similar dependencies on imported energy or with similar economic structures and consumption patterns.

3. Model

We compare the welfare and distributional implications of the fiscal policies by developing and using a multi-region dynamic[2] Computable General Equilibrium (CGE) model of Germany and the rest of the EU. The model is used as a controlled environment to compare the fiscal policies (Freire-González and Ho, 2022). The key building blocks of the model are discussed below.[3]

3.1. Production

The model considers the production activities of 22 aggregated industries including energy industries (*ene*) and non-energy industries sectors (*nene*). Importantly, energy industries are assumed to have an oligopoly structure with a small set of identical representative firms competing for the market implying that they have a degree of market power and therefore earn non-zero profits. Non-energy industries operate in perfectly competitive markets, therefore, earn zero profits.

All industries are assumed to maximise profits from the production of output by using a combination of labour, capital and intermediate inputs. Capital and labour are country specific whereas intermediates can be either domestically produced or imported following the classical Armington (1969) assumption of imperfect substitution. The demand for intermediates $VR_{r,i,j,t}$ in every time period t by sector j from region r sector i is defined as:

$$VR_{r,i,j,t} = \left(\Psi_{i,j}^{V\,\rho_i^V} \cdot \alpha_{r,i,j}^{ARM} \cdot \frac{pv_{i,t}}{pd_{r,i,t}} \right)^{\frac{1}{1-\rho_i^V}} \cdot V_{i,j,t}. \tag{1}$$

In (1) $\Psi_{i,j}^{V}$ and $\alpha_{r,i,j}^{ARM}$ are CES productivity and share parameters respectively, $V_{i,j,t}$ is total intermediate use, $pv_{i,t}$ is the Armington composite price of good i and $pd_{r,i,t}$ is the domestic price of intermediates.

3.2. Household consumption behaviour and budget constraint

There are two representative aggregated household income groups.[4] Low-income households consist of the 75% of households in Germany

[2] The model includes 50 periods which can be interpreted as years as these are based on annual IO accounts.

[3] The equations of the model are described in detail in Appendix A.

[4] The two-group assumption is made for narrative purposes. We expect the general conclusions to hold broadly for further household disaggregations as expenditure patterns are consistent with lower-income households consuming proportionately more energy and energy-intensive goods as demonstrated in Appendix B.

with net incomes below €5000/ month. High-income households consist of the remaining 25% of German households with net incomes exceeding or equal to €5000/ month.[5] These groups are defined following the convention used in the "Continuous household budget surveys" available on the Federal Statistical Office website, Germany's main statistics collection agency (FSO, 2023b).

Each representative household maximises the discounted value of time-separable utility functions following Devarajan and Go (1998) so that:

$$U_h = \sum_{t=0}^{\infty} \beta_h^t \cdot u_h(C_{h,t}^H). \tag{2}$$

In (2), $U_h : \mathbb{R}^\infty \to \mathbb{R}$ is the intertemporal utility function, $u_h : \mathbb{R}_+ \to \mathbb{R}$ is the time-separable household utility function, $C_{h,t}^H \in \mathbb{R}_+$ is households' aggregate consumption $h \in (low, high)$ is set for the two household groups low-income (low) and high-income (high) and $\beta_h \in (0,1)$ is a Samuelson (1937) discount factor. The time path of intertemporal consumption and savings is obtained by maximising Eq. (2) subject to the households' budget constraint (3).

$$II_{h,t}^H = uck_t \cdot KS_{h,t}^H + w_t \cdot LS_{h,t}^H + \theta_h^\Pi \cdot \sum_{ene} \Pi_{ene,t} + TR_{h,t}. \tag{3}$$

Each household receives a capital income ($KS_{h,t}^H$) at rate (uck_t), wage (w_t) income from labour ($LS_{h,t}^H$) and transfers from the government ($TR_{h,t}$).[6] Crucially, only high-income households receive profits in the form of dividends from energy firms. That is: $\theta_{high}^\Pi = 1$ and $\theta_{low}^\Pi = 0$. Household gross income is taxed by the government at a constant rate.

In each time period, households consume goods and services from the 22 industries. This is represented using a Stone–Geary utility function (Stone, 1954; Geary, 1950) which captures the idea of sustenance consumption of certain necessity goods including energy.[7] Similarly to industries, households can either consume domestically produced good or imported goods (Armington, 1969) as follows:

$$CD_{h,r,i,t}^H = \left(\Psi_{h,i}^{C\ \rho_i^V} \cdot \alpha_{h,r,i}^C \cdot \frac{pc_{h,i,t}^T}{pd_{r,i,t}} \right)^{\frac{1}{1-\rho_i^V}} \cdot CT_{h,i,t}^H. \tag{4}$$

In Eq. (4), $\Psi_{h,i}^C$ and $\alpha_{h,r,i}$ are CES productivity and share parameters respectively.[8] ρ_i^V is a substitution parameter linked to the Armington elasticity of substitution. $CD_{h,r,i,t}^H$ and $CT_{h,i,t}^H$ are household h's consumption of good i from region r and the Armington consumption good for household h sector i. $pc_{h,i,t}^T$ is the Armington price of commodity i for household h and $pd_{r,i,t}$ is sector i's sellers price in region r.

3.3. Government

The government receives income from households' income taxes (T_t) and taxes on production ($T_{i,t}^F$).

$$G_t^Y = T_t + \sum_i T_{i,t}^F. \tag{5}$$

This income (G_t^Y) is either spent or saved. The government runs a balanced budget in each period, consumes fixed shares of each sector's output (Leontief) and views domestic and foreign goods as imperfect substitutes (Armington, 1969). The government's saving rate is fixed for simplicity.

[5] The data used excludes households earning over €18,000, self-employed households and homeless households.

[6] For simplicity, we assume that wages change proportionately in both groups however, the initial labour endowment implies distinct wages across the groups.

[7] See equation A.14 in Appendix A for the functional form.

[8] The region subscript is dropped for simplicity on the right-hand-side.

Table 1
Sectoral aggregation and ISIC codes (UN, 2008).

Label	Code
Agriculture, forestry and fishing	A
Mining and quarrying	B
Manufacture of coke and refined petroleum	C.19
Manufacturing (excluding C.19)	C
Electricity, gas, steam and air conditioning supply	D
Water supply; sewerage, waste management and remediation activities	E
Construction	F
Wholesale and retail trade; repair of motor vehicles and motorcycles	G
Transportation and storage	H
Accommodation and food service activities	I
Information and communication	J
Financial and insurance activities	K
Real estate activities	L
Professional, scientific and technical activities	M
Administrative and support service activities	N
Public administration and defence; compulsory social security	O
Education	P
Human health and social work activities	Q
Arts, entertainment and recreation	R
Other service activities	S
Activities of households as employers; undifferentiated goods- and services...	T
Activities of extraterritorial organizations and bodies	U

3.4. The labour market

Employment supply is fixed with a pool of unemployed workers. In the short-run the nominal wage is assumed to be fixed. Following this, a wage curve determines an inverse relationship between the real take home wage and the unemployment rate (Blanchflower and Oswald, 1995).

4. Data

4.1. Social accounting matrices

The structural parameters for the model are based on the industry-by-industry Figaro 2020 input–output tables (Eurostat, 2023b). These are aggregated to 22 sectors as displayed in Table 1. The Figaro data is supplemented by household saving rates and tax-to-GDP ratios for all EU countries to form the baseline Social Accounting Matrices (SAM). For the household savings rate, the 2020 "Gross household saving rate" for "Households; non-profit institutions" series is used (Eurostat, 2023d). Finally, household tax rates are calculated using the "Total receipts from taxes and social contributions" data (Eurostat, 2023e).

4.2. Households income disaggregation

In order to parameterise the consumption block of the model, the Figaro dataset is disaggregated into the two households groups ('low' and 'high') by calculating shares of average gross income, net income, aggregate consumption, sectoral consumption, employment income, savings and taxes. These shares are used to separate the broad categories (e.g. gross income) into household-specific categories (e.g. gross income for low-income households). Average gross income, net income, aggregate consumption, employment income, savings,[9] and taxes are estimated using the 2021 "Continuous household budget survey" (FSO, 2023c). To estimate the low-income group shares, average values in each income group are weighted by the extrapolated household weights provided in the "Continuous household budget surveys" (FSO, 2023b). As capital income is assumed to be proportional to savings in the model,

[9] Savings are defined as net income minus private consumption expenditure.

Table 2
Household disaggregation based on FSO (2023c) and authors' shares calculations; low = low-income households, high = high-income households.

Type	Group	Low	High
Income	Gross	48.0%	52.0%
	Capital	33.7%	66.3%
	Labour	41.4%	58.6%
	Profit	0.0%	100.0%
	Transfers	70.5%	29.5%
Expenditure	Consumption	57.0%	43.0%
	Savings	34.2%	65.8%
	Taxes	41.0%	59.0%
Other	Population weight	74.3%	25.7%

Table 3
Production parameters; σ_i^V = Armington (1969) elasticity, σ_i^K = Elasticity of substitution between capital and labour, $K_{r,i,0}$ = Initial capital demand by sector i. Households parameters; EIS = Elasticity of intertemporal substitution, $\gamma_{h,r,i}^{SG}$ = Stone–Geary sustenance parameter, $CT_{h,r,i,0}^{H}$ = Sector i Armington good for household h.

Parameter	Sector	Value	Source
σ_i^V	Agriculture	2.7	Zofio et al. (2020)
	Energy	2.9	
	Manufacturing	1.7	
	Other sectors	2.2	
σ_i^K	All	0.3	Gechert et al. (2022)
Profit share	Energy	$0.3 \cdot K_{r,i,0}$	Assumption
	Non-energy	0	
EIS: $\epsilon_{h,r}$	–	0.1	Yogo (2004)
Sustenance: $\gamma_{h,r,i}^{SG}$	Energy	$0.9 \cdot CT_{low,r,i,0}^{H}$	Assumption
		$0.8 \cdot CT_{high,r,i,0}^{H}$	
	Non-energy	$0.8 \cdot CT_{low,r,i,0}^{H}$	
		$0.8 \cdot CT_{high,r,i,0}^{H}$	

the capital share equals the savings share. Assuming the profit rates and profits shares in energy firms, government transfers to households then act as a balancing element in the SAM. The key data used to define household shares is displayed in Table 2.

For sectoral consumption, the 2021 "Continuous household budget survey" is used (FSO, 2023a). The survey contains information on consumption on eleven broad categories. These categories are not all perfectly matched to the ISIC categories in the Figaro data. Therefore, a matching procedure is used to provide information on expected consumption by household and sector. When sectoral consumptions cannot be matched, shares are estimated by removing matched category quantities from aggregate private consumption expenditure. The resulting shares then ensure that private consumption per household group is the sum of sectoral consumption for each group. The matched shares are presented in Appendix C.

4.3. Exogenous parameters

Four sets of behavioural parameters are imposed exogenously. These are the Armington elasticity of substitution between domestic and foreign goods (σ_i^V) (Armington, 1969), the elasticity of substitution between capital and labour (σ_i^K), the households' elasticity of intertemporal substitution (EIS) and the Stone–Geary sustenance parameters ($\gamma_{h,r,i}^{SG}$) (Stone, 1954; Geary, 1950). An additional assumption is made to calibrate the initial markup on energy price for the oligopolistic model.

The parameter values are reported in Table 3. The assumed values for the Stone–Geary sustenance parameters are set to reflect the fact that energy consumption is a necessity good especially for the low-income group. Sensitivity analysis is conducted on all assumed parameters.

5. Fiscal policy simulation scenarios

To capture the impact of the initial energy price shock we introduce an illustrative 200% increase in the price of imported energy in both Germany and the rest of the European Union (REU). We call this the no fiscal policies scenario (NFP). We then simulate five fiscal policies iteratively based on (Sgaravatti et al., 2023) and summarised in Table 4.

In all the fiscal policy scenarios the government attempts to mitigate the increase in the energy price for one year using a subsidy τ_t for a total cost of 0.2% of GDP. The policies differ depending on whether they act through the industry energy price, household energy price or households' income, and on whether the direct recipients of the subsidy are industries, all households, low-income households only or both households and industries. The five policy scenarios are simulated under two financing mechanisms as explained in Section 5.2. The technical implementation of the five policies is discussed in the sections below.

5.1. Modelling the policy scenarios

The production tax reduction (TR) policy is introduced according to the following expression:

$$\tau_{i,t}^{P} = \tau_{i,t=0}^{P} \cdot (1 - \tau_t \cdot \theta_i^{ENE}). \tag{6}$$

In (6), $\tau_{i,t}^{P} < 1$ is the production tax rate in sector i at time t,[10] $\tau_{i,t=0}^{P} < 1$ is the production tax rate in the baseline. $\theta_i^{ENE} \equiv \frac{\sum_{ene} V_{ene,i,t=0}}{X_{i,t=0}}$ is an index of the energy intermediate good cost $V_{ene,i,t=0}$ to total revenue $X_{i,t=0}$ for each sector introduced to ensure that the government targets tax rate reductions more towards energy-intensive sectors. In this scenario, τ_t is the endogenous tax rate reduction chosen based on the government's objective.

In the second fiscal policy scenario, the government introduces an untargeted energy price subsidy (UPS) to all households. This is modelled as a reduction to the price paid by households for energy.

$$CD_{h,r,i,t}^{H} = \left(\Psi_{h,i}^{C\,\rho_i^V} \cdot \alpha_{h,r,i}^{C} \cdot \frac{pc_{h,i,t}^{T}}{pd_{r,i,t} \cdot (1 - \tau_t \cdot \theta_{h,i}^{H})} \right)^{\frac{1}{1-\rho_i^V}} \cdot CT_{h,i,t}^{H}. \tag{7}$$

To simulate this, Eq. (7) amends (4) to include a dummy $\theta_{h,i}^{H} \in [0,1]$ which defines whether a household is eligible for a subsidy and whether the sector is an energy sector. In the UPS scenario, all household groups receive the price subsidy hence, $\theta_{h,ene}^{H} = 1$. In this scenario, τ_t is the percentage reduction in the household energy price chosen based on the government's objective.

In the targeted price subsidy (TPS) scenario we use the same expression used for the UPS (Eq. (7)) but set $\theta_{high,ene}^{H} = 0$ and $\theta_{low,ene}^{H} = 1$ so that the subsidy is only given to the low-income household group. In both TPS and UPS, the calculation of the CPI is adjusted to include the subsidised energy price.

The general energy price subsidy (GPS) is targeted to both firms and all households. For households we use again (7) with $\theta_{h,ene}^{H} = 1$. An analogous equation for firm consumption is then introduced by amending (1) as follows:

$$VR_{r,i,j,t} = \left(\Psi_{i,j}^{V\,\rho_i^V} \cdot \alpha_{r,i,j}^{ARM} \cdot \frac{pv_{i,t}}{pd_{r,i,t} \cdot (1 - \tau_t \cdot \theta_i^{GPS})} \right)^{\frac{1}{1-\rho_i^V}} \cdot V_{i,j,t}. \tag{8}$$

[10] In cases where the government subsidises sectors, the sign of θ_i^{ENE} is reversed such that the policy increases the subsidy.

Table 4
Summary of policy simulation scenarios.

Policy	Acronym	Channel	Recipient
Tax reduction	TR	Industry energy price	Industries
Untargeted price subsidy	UPS	Household energy price	All households
Targeted price subsidy	TPS	Household energy price	Lower income households
General price subsidy	GPS	Industry and household energy price	All households and industries
Targeted income subsidy	TIS	Households' income	Lower income households

In (8), θ_i^{GPS} is a dummy defining whether sector i is an energy sector and $\theta_{ene}^{GPS} = 1$ and $\theta_{nene}^{GPS} = 0$. In the GPS, τ_t is the percentage reduction in the price of energy households and firms pay.

$$pv_{i,t} = \frac{\sum_{r,j} pd_{r,i,t} \cdot VR_{r,i,j,t} \cdot (1 - \tau_t \cdot \theta_i^{GPS})}{\sum_j V_{i,j,t}}. \quad (9)$$

As $pv_{i,t}$ is influenced by the price subsidy, the intermediate good price index is modified to Eq. (9).

Additionally, we assume that τ_t is equal for both household and firm subsidies. This ensures that the per unit energy price subsidy is identical regardless of the energy consumer.

Finally, the targeted income subsidy (TIS) is introduced by supplementing the 'low' household group's budget with an additional subsidy as follows:

$$II_{h,t}^H = uck_t \cdot KS_{h,t}^H + w_t \cdot LS_{h,t}^H + \theta_h^\Pi \cdot \sum_i \Pi_{i,t} + TR_{h,t} + \theta_h^\Delta \cdot \Delta_t. \quad (10)$$

Eq. (10) is an extension of Eq. (3) where θ_h^Δ is a dummy capturing whether a household receives the income subsidy. $\theta_{low}^\Delta = 1$ and $\theta_{high}^\Delta = 0$. $\Delta_t \in \mathbb{R}_+$ is the lump sum transfer sent to low-income households in the period following the shock. As low-income households have high marginal utilities of consumption following unexpected payments (Agarwal et al., 2007; Parker et al., 2013), we assume that the marginal propensity to consume from the TIS is 1.[11]

5.2. Financing the fiscal policies

To gather funds for the fiscal policies, we assume that the government has two options. First, it can borrow at an interest rate ir. This is the risk-free interest rate assumed in the baseline. It is equal to the user cost of capital minus the depreciation rate. Alternatively, the government can use a combination of debt financing and a one-time windfall tax on excess profits of the energy companies following the shock to finance the expenditure side fiscal policies. Given that we are interested in the welfare implications of the policies under the two funding mechanisms we repeat the simulation of the five fiscal policies under the two financing options.

5.2.1. Debt financing

For the debt-financed revenue side fiscal policy, the government can borrow at ir during the first year following the shock and then repay this in the following 25 years by running a balanced budget and reducing spending.

$$G_t^Y = T_t + \sum_i T_{i,t}^F - ir \cdot D_t^G - B_t$$
$$D_t^G = D_{t-1}^G - B_t$$
$$B_t = \frac{D_{t=1}^G}{dur}. \quad (11)$$

Eq. (11) extends (5) to capture interest payments and debt repayments. $D_t^G \in \mathbb{R}_+$ is the amount of additional debt accumulated by the government in period t. $B_t \in \mathbb{R}_+$ is the yearly debt payment. $dur \in \mathbb{N}_+$ is the number of periods the government will be repaying the debt and it is set to 25 years.

[11] We discuss the implications of this assumption in Section 7.

5.2.2. Windfall tax financing

The government can choose to accompany the debt financing with a windfall tax on the excess profits of energy firms. In this case the windfall tax revenue, $T_{t=1}^w \in \mathbb{R}_+$, is added to the government's budget Eq. (11):

$$G_t^Y = T_t + \sum_i T_{i,t}^F - ir \cdot D_t^G - B_t + T_{t=1}^w. \quad (12)$$

In Eq. (12), $T_{t=1}^w \in \mathbb{R}_+$ is the total amount of windfall tax revenue collected in period 1.

$$T_{t=1}^w = \sum_{ene}(RT_{ene,t=1} - RT_{ene,t=0}) \cdot \tau_{t=1}^{WT}. \quad (13)$$

Windfall tax revenue is defined in Eq. (13) where $\tau_{t=1}^{WT} \in [0,1]$ is the windfall tax rate set by the government on energy firms. The windfall tax rate is set to 90% which is equal to the rate set in Germany for electricity.[12] Recall that this revenue is collected from high-income households only.[13]

5.3. Welfare

To compare the welfare implications of the five fiscal policies we define intertemporal welfare as the discounted sum of intratemporal welfare. This is done using a welfarist approach (Sen, 1970; Boadway and Keen, 1999) whereby welfare is defined as the sum of households' utility from the consumption of both private and public goods.

$$U_{T,t} = (1 - \gamma_g) \cdot \sum_h \gamma_h \cdot u_h(C_{h,t}^H) + \gamma_g \cdot v(G_t). \quad (14)$$

In Eq. (14), $\gamma_h \in (0,1]$ is a population weight for household group h defined such that $\sum_h \gamma_h = 1$. $v(G_t)$ is the utility of public consumption for both households. γ_g is the weight placed on public good utility relative to private good utility. It is set equal to 0.42 in the baseline following Schram and van Winden (1989).

6. Results

6.1. No fiscal policy scenario

Results from simulations are reported in Table 5 for the German case.[14] Following the 200% increase in the imported energy price, firms and households decrease their purchases of foreign energy and increase their demand for domestic and REU energy. This leads to crowding out of domestic and European energy supply so that the energy price increases by 23%.

Average household energy consumption decreases by close to 3%. This is the result of a 2.9% increase in domestic demand and a 5.4% and 35.1% reduction in REU and rest of the world (ROW) demand respectively. Industries increase their demand for domestic energy relative to ROW and REU energy as well. Overall, however, production costs

[12] This choice is made for narrative purposes and has no impact on the stylised results of the paper.

[13] We assume that energy companies are owned by domestic high-income households only.

[14] Results for the rest of EU as an aggregate are comparatively similar to the German case, thus omitted for sake of brevity.

Table 5
Short-run % deviations from baseline of key variables.

Variable	% change
Consumer price index	2.7
Energy price index	23.0
Non-energy price index	0.5
Output	−1.1
Energy output	−2.5
Non-energy output	−1.0

Table 6
Short-run % deviations from trend of household variables.

Category	Low-income	High-income
Consumer price index	2.76	2.55
Real household income	−1.39	−1.15
Consumption	−1.63	−0.72
Energy consumption	−2.64	−4.57
Non-energy consumption	−1.54	−0.47
Real household savings	−0.89	−1.53

increase and the demand for intermediate inputs, including energy, falls.

Domestic energy firms face more pressure to satisfy domestic demand both from households and from other firms. Sectors that are highly reliant on energy imports from ROW such as manufacturing of refined petroleum sharply increase their price by 59.1% whilst reducing output by 11.5%. On the other hand, mining and quarrying, which has a more domestic supply chain, increases both output and prices by 68.8% and 58.4% respectively.

With higher domestic production costs, firms in most non-energy sectors decrease their demand for capital and labour. Hence, on aggregate output falls by 1.1%. Simultaneously, the consumer price index increases by 3.2% overall, mainly driven by energy price inflation. This has significant implications for households' income and purchasing power.

The adverse aggregate consequences are not distributed evenly across household income groups as it has also been found by Celasun et al. (2022), Guan et al. (2023), Perdana et al. (2022) and Turner et al. (2022) amongst others. This is for two reasons. Firstly, low-income households spend a higher proportion of their income on energy and are closer to their sustenance levels of energy consumption so that energy consumption falls only by 2.64% depleting their disposable income for non-energy consumption. In contrast, high-income households are much further away from their sustenance levels and are able to reduce energy consumption by 4.57%. This asymmetric response across household types means that low-income households have less disposable income for non-energy consumption than high-income households (see Table 6).

Secondly, high-income households reap the benefits of a 14.8% increase in energy firm profits. Payments of energy firm dividends to high-income households partly mitigate the reduction in gross income of high-income households which falls by 1.15% compared with the average household income reduction of 1.27%. Low-income households do not own shares in the energy companies and thus receive no benefits from the increasing profits. Hence, their income falls by 1.39%.

Overall, in the absence of a fiscal policy intervention, gross output falls whilst prices rise, a result consistent with other recent papers (Celasun et al., 2022; Guan et al., 2023; Perdana et al., 2022; Turner et al., 2022) and empirical observations (Eurostat, 2023a,c).

6.2. Debt financed policies

Following the energy shock, as discussed in Section 5, the government may choose to implement one of the following five fiscal policies: energy tax reduction (TR), untargeted and targeted price subsidies (UPS, TPS), general price subsidies (GPS) and targeted income subsidies (TIS).

Results from the simulated policies are summarised in Fig. 1 for the debt-financed case.

We begin by discussing the impact of the five policies on aggregate output and CPI. As can be seen from panel a, Fig. 1, the TR generates the greatest output recovery. In fact, in this scenario output recovers by 17.7% of the distance between the pre-shock equilibrium and the no fiscal policy scenario. The next closest aggregate output recovery is by 4.0% for the GPS. Both policies reduce the marginal cost of production by lowering energy costs proportionately to the pre-shock intermediate energy use. This stimulates demand and leads to a recovery in output. The recovery is greater in the TR since this policy targets industries only whereas the GPS targets both industries and households. Interestingly, the output recovery of energy industries is greater for the GPS as can be seen in panel b, Fig. 1. This is driven by the fact that both industries and households benefit from reduced energy prices both directly and indirectly in terms of energy embodied in production.

The policies targeted directly at households (UPS, TPS and TIS) slightly exacerbate the contraction in output compared to the no fiscal policy (NFP) scenario. This is explained by domestic households crowding out domestic energy and non-energy markets. Specifically, as households pay lower prices for energy compared to firms, more energy and non-energy goods are consumed as final demand rather than purchased as intermediate inputs. This puts upward pressure on energy prices and exacerbates the negative impact of the initial energy price shock.

All policies reduce the CPI, compared with no fiscal policy. UPS, TPS and TIS reduce the CPI by approximately 1.5 pp. Recall that these policies reduce directly the price of energy paid by households. The GPS reduce the CPI by over 0.6 pp by simultaneously targeting the households and industry energy price. The least disinflationary policy is the TR which achieves a reduction in inflation slightly under 0.1 pp but does not target households directly.

The aggregate output and CPI results would suggest that acting through the households' energy price is more effective at reducing the CPI whereas targeting the industry energy price achieves a greater recovery, with GPS achieving a good combination of both. If governments were not concerned about distributional impacts they may prefer GPS as it achieves a balanced outcome. However, a closer inspection of distributional impacts reveals a partly different story.

Panel c, Fig. 1 presents real income by household group for each of the policies. The only policy that fully reverses the regressive effects of the initial energy shock is the TIS. This is since, unlike the price subsidies, this policy acts through income rather than the price of energy. As a result, although its effects on consumption are comparable to the TPS, its implications for real household income are very different. All policies except the TIS do little to address real income inequality. This is because none are designed to work through household incomes. Thus, the initial regressive effects on real household incomes of the energy price shock are mitigated but not reversed by the TR, UPS, TPS and GPS.

Panel d, Fig. 1 summarises the short-run aggregate consumption by household group under each of the policies. The TR has relatively weak effects and only increases consumption by around 0.35 pp for both household groups. The GPS also has a relatively weak effect on consumption, and although it does not reverse the initial regressive outcome of the energy price shock it achieves a more progressive outcome than the TR. The UPS leads to much stronger consumption recoveries in both groups as consumption increases by around 0.5 and 1.5 pp respectively in the high-income and low-income consumption groups under both forms of financing. Despite the fact that the UPS is not targeted at low-income households, it entirely reverses the short-run regressive effect of the initial energy shock.

As is expected, the low-income household targeted policies have much greater redistributive effects on consumption than the untargeted

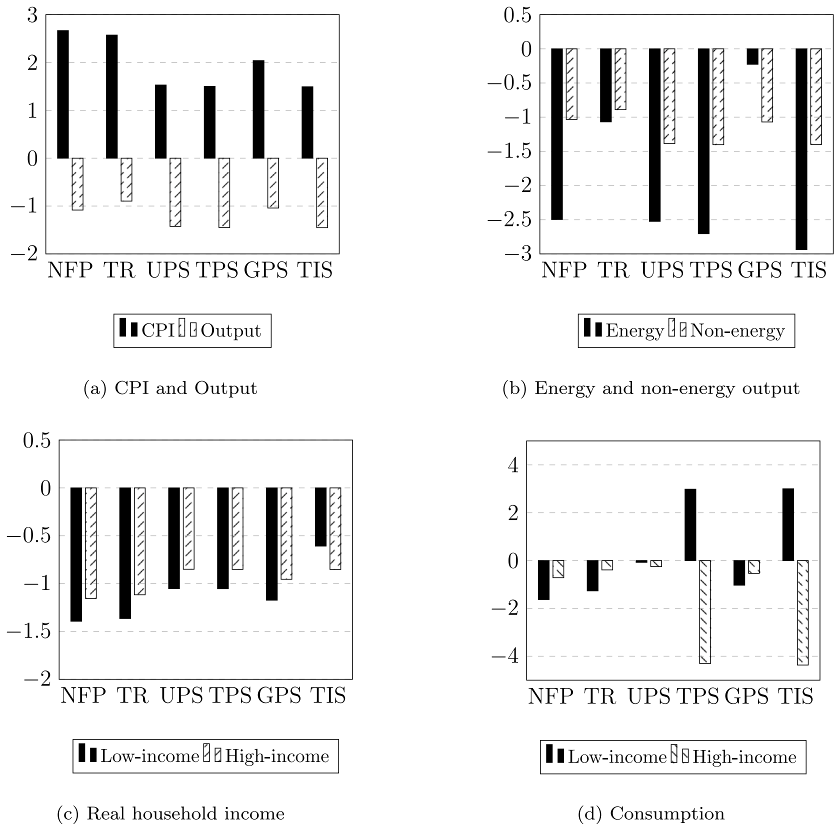

Fig. 1. Short-run % deviations from a no-shock baseline for debt-financed policies; NFP = no fiscal policy, TR = firm tax reduction, UPS = untargeted price subsidy, TPS = targeted price subsidy, GPS = general price subsidy, TIS = targeted income subsidy.

policies. Indeed both the TPS and TIS fully reverse the regressive effects of the energy shock driving low-income households' consumption up by close to 3 pp relative to a no shock baseline whilst reducing high-income households' consumption by over 4 pp relative to a no shock baseline. This result demonstrates the effectiveness of these targeted policies at redistributing the losses from the energy shock. It also shows that this may lead to excessive redistribution towards the lower income households.

6.3. Windfall tax financed policies

In the windfall tax scenarios, between 18% and 21% of the funding for the five policies is financed by windfall taxes.[15] Fig. 2 presents the results from the scenarios.

The aggregate results of the purely debt-financed and partially windfall tax financed policies are very similar. In facts, the ranking of the policies in terms of impacts on output, CPI and redistribution are unchanged. The impact of the policies on output recovery and CPI is marginally smaller when the policies are financed by both windfall taxes and debt. Differences in household outcomes are more noticeable. Real household income of high-income households decreases by between 0.08 and 0.09 pp compared with purely debt-financed policies whereas that of low-income households decreases by less than 0.01 pp. Consumption of high-income households also falls proportionally more than that of low-income households. This is consistent with the fact that the windfall tax directly redistributes income from high-income households to low-income households.

Crucially, windfall taxation has relevant consequences for long-run impacts given that it is both an intertemporal and intratemporal redistributive policy whereas pure debt financing is an intertemporal redistributive policy exclusively. We discuss this more in detail in the following section.

6.4. Welfare

To allow for a comparison of the policies that takes into account both the short-run benefits of the policies and the intertemporal costs through debt repayments and the effects of the policies we calculate welfare for all the policies according to expression (14). This is presented in Fig. 3.[16]

From the figure, it is clear that the TIS and TPS are the best policies given the welfare definition. This is expected as these policies drive larger consumption redistributions. Since the marginal utility of consumption of low-income households is higher than that of high-income households, the redistributive policies lead to large increases in welfare. The UPS improves welfare by around 65% compared to the no fiscal policy scenario and the TIS under debt financing. This welfare improvement is relatively strong given that the UPS has no direct redistributive effects. In comparison, the GPS and TR lead to a 23% increase and a −0.5% decrease in welfare under debt financing. This result suggests that these policies are relatively ineffective at supporting households during energy shocks.

Importantly, whilst the ranking of the policies is identical, welfare is improved for all policies if windfall taxes are employed as long as the relative weight on the public good $\gamma_G \geq 0.14$, as presented in Table 7. The reasons for this are two-fold. First, windfall taxation leads

[15] Profits are endogenous and depend on energy sales but they are taxed at a fixed rate. For this reason the actual amount of tax funded policies varies depending on the policy.

[16] Welfare is normalised such that no fiscal policy is equal to 0 and the best policy equals 1.

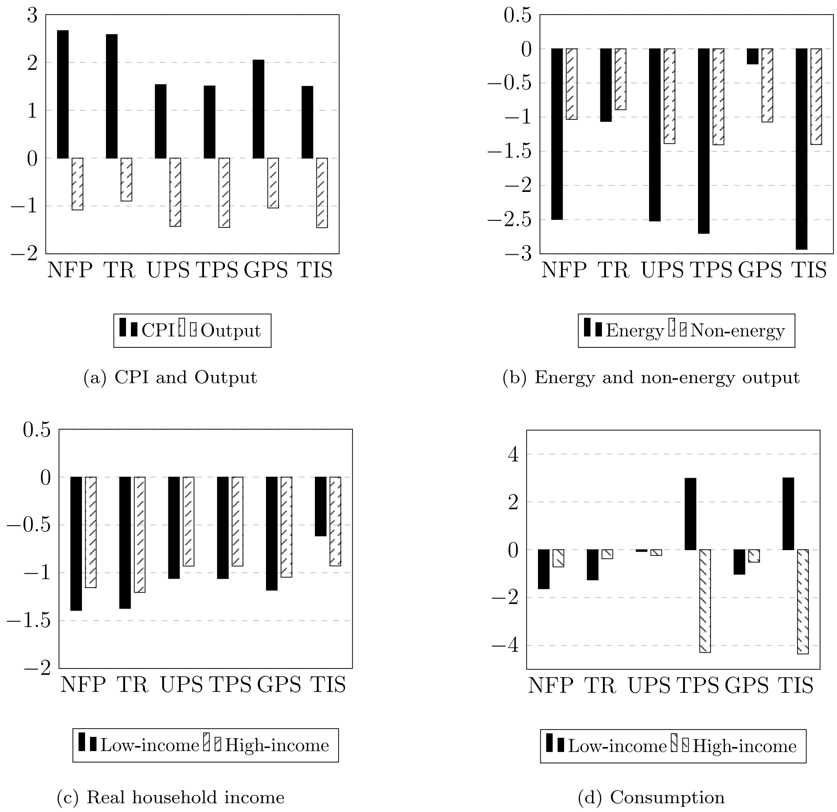

Fig. 2. Short-run % deviations from no-shock baseline of debt and windfall tax financed policies; NFP = no fiscal policy, TR = firm tax reduction, UPS = untargeted price subsidy, TPS = targeted price subsidy, GPS = general price subsidy, TIS = targeted income subsidy.

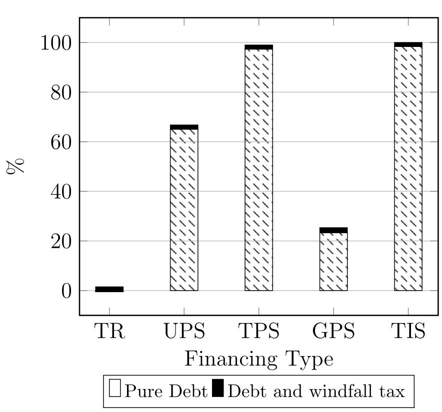

Fig. 3. Welfare under policies and financing when $\gamma_g = 0.42$; TR = firm tax reduction, UPS = untargeted price subsidy, TPS = targeted price subsidy, GPS = general price subsidy, TIS = targeted income subsidy.

Table 7
Critical value of the government weight parameter in Welfare function.

Policy	Debt preferred	Indifferent	Windfall tax preferred
Tax reduction (TR)	$\gamma_g < 0.13$	$\gamma_g = 0.13$	$\gamma_g > 0.13$
Untargeted price subsidy (UPS)	$\gamma_g < 0.14$	$\gamma_g = 0.14$	$\gamma_g > 0.14$
Targeted price subsidy (TPS)	$\gamma_g < 0.14$	$\gamma_g = 0.14$	$\gamma_g > 0.14$
General price subsidy (GPS)	$\gamma_g < 0.13$	$\gamma_g = 0.13$	$\gamma_g > 0.13$
Targeted income subsidy (TIS)	$\gamma_g < 0.14$	$\gamma_g = 0.14$	$\gamma_g > 0.14$

Table 8
Rank of the policies for each target compared to no policy scenario.

Policy	Output	CPI	Distribution	Welfare
Tax reduction (TR)	1	5	5	5
Untargeted price subsidy (UPS)	3	3	3	3
Targeted price subsidy (TPS)	4	2	2	2
General price subsidy (GPS)	2	4	4	4
Targeted income subsidy (TIS)	5	1	1	1

to a direct redistribution of resources under all policies. As a result, regressive effects are counteracted under windfall taxation. Second, the financing collected through windfall taxation has no intertemporal cost to the government. Thus the government will need to repay a smaller debt and can afford a higher public good provision in the following periods. This implies that, as long as households value the provision of public goods sufficiently and even when the interest rate on debt is low, windfall taxation is preferable to debt financing.

7. Summary and sensitivity analysis

We summarise the key results of our simulation in Table 8 and the rank of the policies to show their effectiveness at increasing gross output, reducing the CPI, improving consumption distribution and increasing welfare compared to a situation where no fiscal policies are implemented.

The second column in Table 8 shows that supply-side policies that affect the industry energy price directly (tax reductions and general price subsidies) are more effective at mitigating output losses. Energy firms in Germany are relatively upstream[17] and the reduction in cost of energy used in production driven by the supply side policies is passed more to the other industries than to consumers. On the other hand, the

[17] We have calculated the upstreamness index according to Antràs et al. (2012). Out of 22 aggregated industries Coke and refined petroleum, Electricity, gas stream and air conditioning supply have the 12th, 17th and 22nd highest upstreamness respectively.

third column in Table 8 shows that demand-side policies (untargeted price subsidy, targeted price subsidy and targeted income subsidy) are more effective at lowering the CPI. We also note that the CPI ranking is the reverse of the output ranking for all policies. Thus, although all policies reduce the CPI compared to a situation where no policies are implemented, the increase in output acts in the opposite direction. Hence, in the central case, demand-side policies reduce CPI more than supply-side policies.

The fourth and fifth columns in Table 8 show that the policies targeted at low-income households counteract adverse consumption distribution effects most effectively and improve long-run welfare outcomes more than all other policies. Although TISs are ranked first for distributional and welfare outcomes, the effectiveness of these policies is dependent on a high marginal propensity to consume out of the unexpected subsidy. Finally, the rankings are unaffected by whether the policies are purely financed by government debt or by a combination of government debt and windfall taxation.

We test the sensitivity of our results to the assumed values for the Stone–Geary sustenance parameter and the profit share for energy industries reported in Table 3. For the Stone–Geary parameter, we explore the limiting case where the sustenance parameter is set to 0 for all households[18] and the case where the intra-temporal utility function is a Leontief.[19] When the sustenance parameter is set to 0 for all households the utility function reduces to a Cobb–Douglas which implies an elasticity of substitution of 1. In this case, the demand-side policies become more expansionary than the supply-side policies and therefore less effective at lowering the CPI. With a high elasticity of substitution and no constraint to maintain a sustenance level of energy consumption, households substitute energy with non-energy goods and this drives a strong recovery for non-energy industries. It is important to note that such high elasticity is unlikely to be realistic in the short run, especially for low-income households. Despite this, the ranking of the policies in terms of distributional outcome and welfare is unaffected by the change in this parameter. Setting the utility function to Leontief implies an elasticity of substitution of 0. In this case, none of the rankings change.

To test the sensitivity of our results to the initial value of profit shares we test the consistency of the results under higher and lower profit shares. As can be seen from the results presented in the appendix,[20] this has no impact on the rankings. However, we note that the welfare impacts of windfall taxation are positively related to the size of the initial profit share.

Finally, in our modelling of debt policies, we assumed that governments borrow at a riskless rate. Under higher sovereign default risks, we may expect interest rates on government debt to increase. Thus, we expect that the windfall tax will become relatively more attractive the higher the initial sovereign default risk is.

8. Conclusion

In this paper, we assess the short-run aggregate and distributional implications as well as the long-run welfare effects of a set of fiscal policies used to respond to energy price shocks. A 2-region dynamic CGE model is used to capture the impact of these policies using Germany as an illustrative example. A shock to the price of imported energy is introduced and the government is assumed to have a fixed budget available for all policies aimed at counteracting this initial shock. This budget could be financed through debt or a combination of debt and windfall taxation.

Using this model, we find that targeted policies such as targeted income subsidies (TIS) and targeted price subsidies (TPS) best address inflation, distributional and long-run welfare outcomes. Indeed, TIS and TPS entirely reversed the regressive effects of the initial energy shock and increased long-run welfare much more than the general price subsidy (GPS), untargeted price subsidy (UPS) and tax reduction (TR). Although the TIS and TPS counteract the regressive effects of the energy shock effectively, these have crowding out effects on output due to the additional pressure that households demand puts on domestic energy industries. Supply-side policies such as GPS and TR are less effective at reducing the consumer price index and achieve a lower welfare. However, these policies are more effective in reversing output losses.

Importantly, the ranking of policies does not change when windfall tax financing is introduced. However, with windfall taxation welfare is improved as long as households care sufficiently about public good provision or interest rates on debt are not risk-free and this is achieved with a relatively small cost on aggregate output. This result holds even when government debt is riskless and when consumers value public good provision very little. The fact that the aggregate output impacts and inflationary impacts are only slightly lower under windfall taxation implies that the redistribution has expansionary effects itself as lower-income households have a higher marginal propensity to consume than high-income households.

From a policy perspective, if governments are concerned about output recovery, supply-side policies such as TR and GPS should be preferred. A combination of such policies should provide the government's desired output inflation trade-off. However, if the priority is income equality and welfare, demand-side policies should be preferred. Targeted policies are especially effective as with relatively low debt and or windfall tax financing, these can entirely reverse the regressive effects of energy shocks.[21] These should however be carefully chosen so as not to crowd out the consumption of non-targeted groups.

If possible, governments could also use windfall tax financing to supplement their budgets as this is welfare-enhancing for all policies considered as long as households value public good provision a bit. Even in the absence of public good utility, windfall taxation may be preferred if governments pay more than a riskless rate on debt and/or if energy firm profits are owned by foreign households.

Results presented in this paper provide a starting point for governments of countries with similar dependence on imported energy. However, economic structure may play an important role in defining what policies are ultimately better for any specific country. The methods derived in this model are directly applicable to other countries provided that similar data is available. Future research should consider the replication of this analysis using a different set of countries to consider the extent to which economic structure drives the impact of the fiscal policies. Further research may also consider comparing the environmental implications of the policies.

CRediT authorship contribution statement

Geoffroy Duparc-Portier: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Writing – original draft, Writing – review & editing. **Gioele Figus:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

Declaration of competing interest

All authors declare that they have no conflict of interest.

[18] Implying a Cobb–Douglas intra-temporal utility function.

[19] See full results in figures D.5 and D.6.

[20] See figures D.8 and D.9 for results under lower and higher profit rates.

[21] Targeted policies may be difficult to implement especially in a short time period due to lack of information.

Acknowledgements

The authors are grateful for the useful comments by Dr Grant Allan, Dr Kevin Connolly and Dr Alex Dickson, University of Strathclyde, and the useful questions and comments of participants of the 26th Annual Conference in Global Economic Analysis (June 2023), the Royal Economic Society PhD Conference (June 2023) the 29th International Input-Output Association Conference (June 2023) and the EcoMod2023 International Conference on Economic Modeling and Data Science (July 2023). The authors are grateful for the comments of two anonymous referees.

Funding

Geoffroy Duparc-Portier acknowledges funding from the UK Economics and Social Research Council (ESRC), [project number 2277374], Scottish Graduate School in Social Science, [grant number ES/P000681/1]. Gioele Figus and Geoffroy Duparc-Portier acknowledge funding from the ESRC, Centre for Inclusive Trade Policy, [grant number ES/W002434/1].

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.eneco.2023.107284.

References

Agarwal, S., Liu, C., Souleles, N.S., 2007. The reaction of consumer spending and debt to tax rebates—Evidence from consumer credit data. J. Polit. Econ. 115 (6), 986–1019.

Ahmed, S., Hasan, M.M., Kamal, M.R., 2023. Russia–Ukraine crisis: The effects on the European stock market. European Financial Management 29 (4), 1078–1118.

Alexeev, M., Chih, Y.-Y., 2021. Energy price shocks and economic growth in the US: A state-level analysis. Energy Econ. 98, 105242, URL: https://www.sciencedirect.com/science/article/pii/S014098832100147X.

Antràs, P., Chor, D., Fally, T., Hillberry, R., 2012. Measuring the upstreamness of production and trade flows. Am. Econ. Rev. 102 (3), 412–416, URL: https://www.jstor.org/stable/23245567.

Armington, P.S., 1969. A theory of demand for products distinguished by place of production. Staff Pap. (Int. Monet. Fund) 16 (1), 159–178.

Blanchflower, D.G., Oswald, A.J., 1995. An introduction to the wage curve. J. Econ. Perspect. 9 (3), 153–167.

Boadway, R., Keen, M., 1999. Redistribution. Working Paper 983, Economics Department, Queen's University.

BP, 2023. Fourth quarter and full year 2022 results. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/investors/bp-fourth-quarter-2022-results.pdf.

Celasun, O., Mineshima, A., Arregui, N., Mylonas, V., Ari, A., Teodoru, I., Black, S., Zhunussova, K., Iakova, D., Parry, I., et al., 2022. Surging energy prices in europe in the aftermath of the war: How to support the vulnerable and speed up the transition away from fossil fuels. IMF Work. Pap. 2022 (152), 1–40.

Devarajan, S., Go, D.S., 1998. The simplest dynamic general-equilibrium model of an open economy. J. Policy Model. 20 (6), 677–714.

Eurostat, 2023a. Electricity prices for non-household consumers - bi-annual data (from 2007 onwards). https://ec.europa.eu/eurostat/databrowser/view/NRG_PC_205_custom_5192982/default/table?lang=en.

Eurostat, 2023b. Esa supply, use and input-output tables - data -figaro tables. https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/database.

Eurostat, 2023c. Gas prices for non-household consumers - bi-annual data (from 2007 onwards). https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_203/default/table?lang=en.

Eurostat, 2023d. Key indicators - annual data. https://ec.europa.eu/eurostat/databrowser/view/nasa_10_ki/.

Eurostat, 2023e. Main national accounts tax aggregates. https://ec.europa.eu/eurostat/databrowser/view/GOV_10A_TAXAG/.

Eurostat, 2023f. Simplified energy balances. https://ec.europa.eu/eurostat/databrowser/view/NRG_BAL_S__custom_6292808/default/table?lang=en.

Ferriani, F., Gazzani, A., 2023. The impact of the war in Ukraine on energy prices: Consequences for firms' financial performance. Int. Econom. 174, 221–230, URL: https://www.sciencedirect.com/science/article/pii/S2110701723000343.

Freire-González, J., Ho, M.S., 2022. Policy strategies to tackle rebound effects: A comparative analysis. Ecol. Econom. 193, 107332, URL: https://www.sciencedirect.com/science/article/pii/S0921800921003918.

FSO, 2023a. Consumption expenditure. https://www.destatis.de/EN/Themes/Society-Environment/Income-Consumption-Living-Conditions/Consumption-Expenditure/Tables/liste-net-household-income.html#55124.

FSO, 2023b. Continuous household budget surveys (lwr). https://www.destatis.de/EN/Themes/Society-Environment/Income-Consumption-Living-Conditions/Income-Receipts-Expenditure/Methods/continuous-household-budget-surveys.html.

FSO, 2023c. Income, receipts and expenditure of households: Net household income. https://www.destatis.de/EN/Themes/Society-Environment/Income-Consumption-Living-Conditions/Income-Receipts-Expenditure/Tables/liste-Income-receipts-expenditure-selected-budgetary-signs-net.html.

Geary, R.C., 1950. A note on "a constant-utility index of the cost of living". Rev. Econom. Stud. 18 (1), 65–66.

Gechert, S., Havranek, T., Irsova, Z., Kolcunova, D., 2022. Measuring capital-labor substitution: The importance of method choices and publication bias. Rev. Econ. Dyn. 45, 55–82.

Guan, Y., Yan, J., Shan, Y., Zhou, Y., Hang, Y., Li, R., Yu, L., Liu, B., Nie, Q., Feng, K., Klaus, H., 2023. Burden of the global energy price crisis on households. Nat. Energy 8, 1–13.

Hagemann, R.P., 1982. The variability of inflation rates across household types. J. Money Credit Bank. 14 (4), 494–510.

Hamilton, J.D., 1983. Oil and the macroeconomy since world war II. J. Polit. Econ. 91 (2), 228–248.

IEA, 2023. Global energy crisis. URL: https://www.iea.org/topics/global-energy-crisis.

IMF, 2023. World economic outlook inflation peaking amid low growth. https://www.imf.org/en/Publications/WEO/Issues/2023/01/31/world-economic-outlook-update-january-2023.

Jiménez-Rodríguez, R., 2008. The impact of oil price shocks: Evidence from the industries of six OECD countries. Energy Econ. 30 (6), 3095–3108.

Jiménez-Rodríguez, R., Sánchez, M., 2005. Oil price shocks and real GDP growth: empirical evidence for some OECD countries. Appl. Econ. 37 (2), 201–228, Publisher: Routledge.

Jolly, J., Elgot, J., 2022. Profits at world's seven biggest oil firms soar to almost £150bn this year. Guardian.

Kilian, L., 2008. The economic effects of energy price shocks. J. Econ. Lit. 46 (4), 871–909, URL: https://www.jstor.org/stable/27647084.

Metcalf, G.E., Paltsev, S., Reilly, J., Jacoby, H., Holak, J.F., 2008. Analysis of U.S. Greenhouse Gas Tax Proposals. NBER Working Papers 13980, National Bureau of Economic Research, Inc.

Michael, R.T., 1979. Variation across households in the rate of inflation. J. Money Credit Bank. 11 (1), 32–46.

Parker, J.A., Souleles, N.S., Johnson, D.S., McClelland, R., 2013. Consumer spending and the economic stimulus payments of 2008. Amer. Econ. Rev. 103 (6), 2530–2553.

Peersman, G., Robays, I.V., 2012. Cross-country differences in the effects of oil shocks. Energy Econ. 34 (5), 1532–1547, URL: https://www.sciencedirect.com/science/article/pii/S0140988311002842.

Perdana, S., Vielle, M., Schenckery, M., 2022. European economic impacts of cutting energy imports from Russia: A computable general equilibrium analysis. Energy Strategy Rev. 44, 101006.

Pizer, W.A., Sexton, S., 2019. The distributional impacts of energy taxes. Rev. Environ. Econom. Policy 13 (1), 104–123, arXiv:https://doi.org/10.1093/reep/rey021.

Remond-Tiedrez, I., Rueda-Cantuche, J.M., 2019. European Union inter-country supply, use and input-output tables — Full international and global accounts for research in input-output analysis (FIGARO).

Samuelson, P., 1937. A note on measurement of utility. Rev. Econom. Stud. 4 (2), 155–161.

Schram, A., van Winden, F., 1989. Revealed preferences for public goods: Applying a model of voter behavior. Public Choice 60 (3), 259–282.

Sen, A., 1970. Collective Choice and Social Welfare. Holden Day, San Francisco, Backup Publisher: Holden Day.

Sgaravatti, G., Tagliapietra, S., Trasi, C., Zachmann, G., 2023. National fiscal policy responses to the energy crisis.

Shell, 2023. Fourth quarter 2022 results – february 2, 2023. https://www.shell.com/investors/results-and-reporting/quarterly-results/2022/q4-2022.html.

Stone, R., 1954. Linear expenditure systems and demand analysis: An application to the pattern of British demand. Econ. J. 64 (255), 511–527.

Turner, K., Katris, A., Stewart, J., Corbett, H., 2022. The impacts of the october 2022 gas and electricity price increase on the UK economy and the cost of living for different household income groups. Policy Brief Univ. Strathclyde Cent. Energy Policy 1–4.

UN, 2008. Standard International Trade Classification Revision 4 - UNSD. https://unstats.un.org/unsd/publication/SeriesM/SeriesM_34rev4E.pdf.

Ven, D.J.v.d., Fouquet, R., 2017. Historical energy price shocks and their changing effects on the economy. Energy Econ. 62, 204–216.

Williams, R., Gordon, H., Burtraw, D., Carbone, J., Morgenstern, R.D., 2015. The initial incidence of a carbon tax across income groups. Natl. Tax J. 68 (1), 195–214.

Yogo, M., 2004. Estimating the elasticity of intertemporal substitution when instruments are weak. Rev. Econ. Stat. 86 (3), 797–810.

Zofio, J.L., Diaz-Lanchas, J., Persyn, D., Barbero, J., 2020. Estimating Foreign and National Trade Elasticities in the EU Internal Market Using Generalised Transport Costs. RC Working Papers on Territorial Modelling and Analysis 2020-05, Joint Research Centre (Seville site).