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On curbing the rise in energy prices: An examination of different mitigation approaches

Natascha Hinterlang
(Deutsche Bundesbank)

Marius Jäger
(Deutsche Bundesbank and
Albert-Ludwigs-Universität Freiburg)

Nikolai Stähler
(Deutsche Bundesbank)

Johannes Strobel
(Deutsche Bundesbank)

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

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Non-technical summary

Research Question

Relying on essential production factors that must be imported carries the risk of sudden (possibly politically induced) price increases and/or shortages. Should governments support production through transfers or cost subsidies? Following the energy crisis caused by the Russian war of aggression, exactly these discussions about the design of a "gas price brake" arose in Germany.

Contribution

We use a dynamic multi-sector general equilibrium model with firm entry and exit to assess the macroeconomic consequences of these two possible policy measures. The model is calibrated to Germany and entails a detailed production network with 53 sectors, including clean and brown energy sectors.

Results

We find that the choice between price subsidies and transfers depends on whether the economy is facing a (pure) price increase (where the policy-induced additional demand for the essential input can be met) or a true shortage, where no or little additional demand can be met (at high cost). In the former case, subsidizing production costs is more efficient. This is because the subsidy directly counteracts the adverse effects of the gas price increase. However, it also generates more additional demand. Therefore, this measure becomes extremely costly in the latter case as prices may skyrocket. Transfers to firms are, then, the more cost-effective policy, as the incentive to save on the essential input is prevailed. Ultimately, the ranking of the policies depends on the impact of additional demand on the gas price. This holds for both, welfare and macroeconomic results.

Nichttechnische Zusammenfassung

Forschungsfrage

Müssen essentielle Produktionsfaktoren importiert werden, ist eine Volkswirtschaft dem Risiko von plötzlichen (möglicherweise politisch motivierten) Preisanstiegen oder Knappheiten ausgesetzt. Sollte eine Regierung den Produktionssektor in diesem Fall durch Transfers oder Preissubventionen unterstützen? Nach der durch den russischen Angriffskrieg ausgelösten Energiekriese stellte sich genau diese Frage in der Diskussion zur Ausgestaltung der „Gaspreisbremse“ in Deutschland.

Beitrag

Wir verwenden ein dynamisches, multisektorales allgemeines Gleichgewichtsmodell mit endogenen Firmenein- und -autritten, um die makroökonomischen Folgen dieser beiden Politikmaßnahmen abzuschätzen. Das Modell ist für Deutschland kalibriert und beinhaltet ein detailliertes Produktionsnetzwerk mit 53 Sektoren, darunter einen sauberen und einen braunen Energiesektor.

Ergebnisse

Wir zeigen, dass die Wahl der Politikmaßnahme davon abhängen sollte, ob ein Preisanstieg vorliegt (und zusätzliche, politikinduzierte Nachfrage vergleichsweise günstig befriedigt werden kann) oder eine echte Knappheit (und zusätzliche Nachfrage nicht befriedigt werden kann). Im ersten Fall ist eine Preissubvention effizienter, weil sie direkt die adversen Effekte des Preisanstiegs bekämpft. Allerdings generiert sie auch eine vergleichsweise starke zusätzliche Nachfrage. Das kann bei echten Knappheiten zu einer starken Verteuerung führen, da der Importpreis dann stark ansteigt. Daher sind Transfers im Fall von Mangellagen das kosteneffizientere Mittel, um die Produktionsseite zu unterstützen. Letztlich hängt die Rangfolge der Maßnahmen von deren Effekt auf den Gaspreis ab. Dies gilt sowohl für die Wohlfahrts- als auch für die gesamtwirtschaftlichen Ergebnisse.

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On Curbing the Rise in Energy Prices: An Examination of Different Mitigation Approaches*

Natascha Hinterlang
Deutsche Bundesbank

Marius Jäger
Deutsche Bundesbank & Albert-Ludwigs-Universität Freiburg

Nikolai Stähler
Deutsche Bundesbank

Johannes Strobel
Deutsche Bundesbank

Abstract

The dependency on imported essential production inputs poses a threat of abrupt price hikes and shortages, potentially triggered by political events. The energy crisis resulting from the Russian war of aggression is an example. This paper investigates whether governments should bolster production via transfers or cost subsidies in the event of a crisis, utilizing a dynamic multi-sector economic model that is calibrated to Germany and incorporates endogenous firm entry and exit. Our findings suggest that subsidizing production costs is more beneficial for economic activity and welfare, provided the energy demand due to the subsidy does not significantly influence the price of the essential production input. If it does, this approach could become exceedingly expensive. In such scenarios, it is economically more efficient to provide lump-sum transfers to firms. The effectiveness of these policies ultimately hinges on their impact on the price of the imported input.

Keywords: Dynamic General Equilibrium Model, Input-Output Matrix, Energy crisis, Gas Price Brake

JEL classification: E32, E50, E62, H32, Q58

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[*] Contact address: Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt, Germany. E-mail: natascha.hinterlang@bundesbank.de, marius.jaeger@bundesbank.de, nikolai.staehler@bundesbank.de, johannes.strobel@bundesbank.de. The paper represents the authors' personal opinions and does not necessarily reflect the views of the Deutsche Bundesbank or the Eurosystem. Any errors are ours. We would like to thank Jana Kremer, Philipp Pfeiffer, Oke Röhe, Karsten Wendorff, members of the Bundesbank's DSGE group as well as participants of the 30th Public Economics Meeting, of the 5th Baltic Economics Meeting, the 29th International Conference CEF and of the 17th Dynare Conference for their helpful comments.

1 Introduction

The efficient operation of numerous economies is fundamentally reliant on the accessibility of imported resources like fossil fuels or rare earths. Procuring these inputs from foreign nations at short notice can pose a significant hurdle if their transport necessitates specialized infrastructure or if their availability is limited to a handful of countries. The Russian war of aggression serves as a prime example of how abrupt escalations in prices and scarcities of crucial resources can profoundly impact the macroeconomy. The assault triggered turmoil in energy markets, prompting governments to extend significant aid to households and businesses. This was particularly evident in Western Europe, especially in Germany, which was heavily dependent on Russian gas supplies, sparking an intense debate over the most effective form of assistance.[1]

This study adds to the ongoing discourse by examining two frequently debated forms support measures for firms – energy price subsidies and lump-sum transfers.[2,3] Our conclusions are also relevant to the importation of other essential production factors, such as rare earths, which are necessary for certain types of clean energy.

Our main finding is that the choice between implementing subsidies based on marginal costs or lump-sum transfers is contingent upon the economic conditions, specifically whether the economy is undergoing a sudden surge in the price of a crucial input at which any quantity demanded is supplied) or experiencing an actual shortage (where the supply is entirely price inelastic). In the scenario of a price surge, subsidizing the marginal costs is more efficient. However, in the event of a supply shortage, this policy becomes very expensive as it merely increases the price of the resource. In such circumstances, lump-sum transfers are a more economically viable policy measure. In sum, the assessment of the policy ultimately hinges on whether the economy is dealing with a price hike or a supply shortage. Ultimately, the ranking of the policy measures is determined by the price sensitivity of the potential policy-induced increase in demand.

Our modeling framework is the dynamic closed-economy production network model introduced in Hinterlang, Martin, Röhe, Stähler, and Strobel (2022). The model consists of production sectors that differ in their factor intensity, utilization of intermediate inputs, and contribution to final demand. Energy can be either clean or brown.[4] The model also

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[1] These assistance measures have been commonly referred to as the *energy price brake* or *gas price brake*. For a comprehensive overview, refer to Anil, Arregui, Black, Celasun, Iakova, Mineshima, Mylonas, Parry, Teodoru, and Zhunussova (2022), Sgaravatti, Tagliapietra, Trasi, and Zachmann (2023) and OECD (2023). For additional information about the German *gas price brake*, refer to `https://www.bundesregierung.de/breg-en/news/energy-price-brakes-2156430` and Amaglobeli, Guilhoto, Jahan, Khalid, Lam, Legoff, Meyer, Sheng, Smietanka, Waddell, and Weitz (2024).

[2] Advocates for the energy price subsidy, such as Dullien and Weber (2022) and Krebs (2022), argue that it leads to a decrease in marginal costs. Conversely, Bachmann, Baqaee, Bayer, Kuhn, Löschel, Moll, Peichl, Pittel, and Schularick (2022) and Bachmann, Baqaee, Bayer, Kuhn, Löschel, McWilliams, Moll, Peichl, Pittel, Schularick, and Zachmann (2022) contend that this approach fails to incentivize energy conservation, suggesting that the optimal strategy is to provide firms with lump-sum transfers while allowing the price increase to fully manifest. For additional information, refer to `https://www.bundesregierung.de/breg-en/news/energy-price-brakes-2156430` and Amaglobeli et al. (2024).

[3] While our baseline scenario incorporates policy measures to support households, in order to capture the observed decline in gas supply and demand, our primary emphasis is on firm support.

[4] For a comprehensive technical documentation of the base model and its derivation, see Hinterlang, Martin, Röhe, Stähler, and Strobel (2023).

incorporates natural gas, which has to be imported. Natural gas is used both directly as a production input and indirectly as an intermediate input into energy production. We enhance the model of Hinterlang et al. (2022) by incorporating endogenous entry and exit of firms, thereby providing an effective channel for lump-sum transfers to firms via profits and markups. Additionally, we introduce hand-to-mouth consumers who may be disproportionately impacted by price hikes as they cannot smooth consumption through borrowing. For demonstration purposes, the model is calibrated to Germany with 53 sectors using the most recent version of the World Input-Output Database (WIOD).[5] The sector specification aligns closely with the standard NACE Rev. 2 classification (Eurostat, 2008). We employ the extended path methodology to solve the model non-linearly.

Our analysis proceeds in multiple steps. First, we examine a situation without policy intervention. In this no-policy baseline scenario, we use the model to simulate the effects of an exogenously specified price increase for imported natural gas. Second, we implement the policy measures separately, assuming that there is no rationing. At the exogenously specified price, any quantity demanded is supplied. Third, we analyze the effects of the two policies in the case of a gas shortage. We take the decline in gas from the no-policy baseline scenario as exogenously given and then introduce the policy measures. In this simulation, the import price of gas varies endogenously, while the quantity supplied is fixed.[6]

Our baseline scenario posits a gas price increase so that gas consumption decreases by 25%. The reason for this is that the observed decrease in gas consumption of 23% in the data includes policy measures that were actually implemented.[7] The gas price increase also leads to a 10% reduction in fossil energy production where gas is an important production input. The negative effects of the price increase are amplified by production linkages. This means that even a sector like transportation, which requires very little gas in its production process, experiences a significant increase in input costs due to the rise in energy prices. Only the clean energy-producing sector expands its production. The impact of the gas price shock on key macroeconomic aggregates is consistently negative. On the production side, the higher price of the key input, gas, reduces investment, labor demand, output, wages, and consumption. Through production linkages, the gas price increase affects other sectors and households, and they adjust their demand downward. Quantitatively, the effects are substantial, with output and wages falling by almost 1.5%.

However, if the additional demand for gas created by the subsidy can be met through increased gas imports, then the majority of the negative effects can be alleviated through energy price subsidies according to our simulations. This is because the subsidy directly addresses the price shock. In this scenario, output decreases by approximately 0.6%, meaning that the policy significantly mitigates the decline in output. The quantitative effects on other variables are of a similar magnitude.

The quantitative impact of direct transfers to firms is considerably less pronounced because they primarily influence the decision of households to invest in new firms. Specifically, direct transfers result in an increase in profits per firm, the extent of which is

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[5] For further details, refer to Timmer, Dietzenbacher, Los, Stehrer, and De Vries (2015).

[6] For the sake of simplicity, we allow feedback on the world market price of gas in the second set of simulations despite the assumption of a closed-economy model.

[7] See also Moll, Schularick, and Zachmann (2023) as well as the description in Section 4 for more details.

contingent on the long-term gas usage. Upon becoming aware of the profit surge resulting from the transfers, households predominantly invest in new firms that derive greater benefits from the transfers and would have otherwise been more adversely affected by the hike in gas prices. Furthermore, a reduced number of firms are compelled to exit the market due to their net present value falling below a certain industry-specific scrap value. Consequently, there is an increase in the total number of operational firms, a decrease in their markup, and a subsequent rise in production. However, this policy lacks specificity as it does not directly address the core issue of escalating gas prices relative to the price subsidy. On one side, the mitigating effect of transfers is considerably less. Conversely, the excess gas demand generated by transfers is also significantly smaller.

In the event of input rationing, the policy hierarchy is inverted. This is due to the subsidy lowering the effective gas price post-subsidy, thereby escalating the demand for gas. However, given the fixed supply of gas, this surge in demand inflates the pre-subsidy gas price. The increased expenses incurred from the subsidies for the higher gas price are shouldered by the households optimizing their consumption.[8] In comparison to the baseline without any policy, the gas price subsidy continues to lower energy prices. However, this effect is tiny in the brown energy sector compared to the scenario where quantities were permitted to adjust. In the latter case, the price subsidy significantly boosts gas demand. This subsequently stimulates production and consumption in the economy, yielding substantial positive effects. However, when gas is rationed, this channel is not accessible. Conversely, the subsidy might exacerbate the shock if it drives the pre-subsidy gas price to a level that imposes an excessive (tax) load on households optimizing their consumption. Ultimately, the optimal policy is contingent on what is predetermined - the price trajectory of gas or its quantity. In other words, the price sensitivity of demand changes induced by policy determines the appropriate policy course.

Our research is in line with investigations that scrutinize the repercussions of energy price shocks in the aftermath of the Russian military aggression, such as those conducted by Bachmann et al. (2022), Auclert, Monnery, Rognlie, and Straub (2023), Bayer, Kriwoluzky, Müller, and Seyrich (2023), Gornemann, Hildebrand, and Kuester (2022), Langot and Gazzani (2023), and Alessandri and Gazzani (2023). The initial study by Bachmann et al. (2022) employs a static model with an extensive input-output network, revealing relatively mild effects of energy price shocks. This study is critically appraised by Geerolf (2022). The subsequent study by Auclert et al. (2023) uncovers more significant effects using a heterogeneous agent New Keynesian (HANK) model. Both Bayer et al. (2023) and Langot and Gazzani (2023) also utilize HANK models to evaluate the macroeconomic and redistributive effects of diverse policy measures on the consumer side. Alessandri and Gazzani (2023) conducts an empirical analysis of the effects of a gas price shock on output and inflation. Gornemann et al. (2022) employs an open-economy New Keynesian model to demonstrate that energy shortages can heighten the risk of self-fulfilling fluctuations

In terms of methodology, our research aligns with the study conducted by Baqaee (2018), which employs dynamic multi-sector models with input-output linkages and en-

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[8] In the model we introduce subsequently, the rise in the pre-subsidy gas price primarily impacts the domestic economy, although in reality, this effect may be distributed across regions. Nevertheless, the key mechanisms pertinent to our inquiry remain intact. This also applies to our principal finding: The choice between subsidies or lump-sum transfers as the superior policy option hinges critically on the price elasticity.

dogenous firm entry and exit. This research explains how the number of firms in various industries can influence each other in an economy characterized by imperfect competition and external economies of scale. The exit of firms from an industry can affect the profitability of firms in other industries, leading to alterations in the number of active firms. Other researches utilizing multi-sector models, albeit without endogenous firm entry and exit, such as those by Hinterlang et al. (2022), Ernst, Hinterlang, Mahle, and Stähler (2023), and Bouakez, Rachedi, and Santoro (2023), assess different climate-related policy measures or the magnitude of the government expenditure multiplier.

The rest of the paper is organized as follows. The model is introduced in Section 2, its calibration in Section 3. The simulation design is described in further detail in Section 4. Results are presented and discussed in Section 5. Section 6 concludes.

2 The model

Time t is discrete and runs forever. The model economy comprises $\mathcal{S} = \{1, 2, .., S^{NE}, .., S\}$ production sectors. Up to S^{NE} produce non-energy goods. The remaining $S - S^{NE}$ sectors produce energy goods. Non-energy goods producing sectors are ordered first and correspond to the set of sectors $\mathcal{S}^{NE} = \{1, 2, .., S^{NE}\}$. $\mathcal{S}^{E} = \{S^{NE} + 1, .., S\}$ is the set of energy sectors. We assume sector S to be the brown energy sector that needs a large amount of imported fossil inputs relative to all other sectors (see details below). There are perfectly competitive labor and capital agencies, consumption, investment, and intermediate goods retailers, two types of households (optimizers and rule-of-thumb households, RoTs henceforth), as well as a fiscal authority. Both types of households receive income from providing labor. Optimizers additionally rent out physical capital to sectoral goods producers and create/close down sectoral goods producing firms. Labor and capital are imperfectly mobile across sectors. Sectoral output is transformed into bundles of consumption, investment, and intermediate goods. A fiscal authority runs a balanced budget by levying or paying out lump-sum transfers to optimizers. In what follows, we will describe the economy in more formal detail.

2.1 Households

Following Gali, Lopez-Salido, and Valles (2007), we assume that the economy is populated by a share $\mu \in [0, 1)$ of liquidity-constrained RoT consumers, who do not participate in asset markets and consume their entire income each period, and a remaining share $(1 - \mu)$ of capital and firm owners (optimizers). They are labeled by the subscript $i \in \{o, r\}$ for optimizing and RoT households, respectively. Following Jaimovich and Rebelo (2009), the utility function of each household in group i at time t is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(C_{i,t} - \kappa_{i,N} N_{i,t}^{\zeta} \cdot X_{i,t} \right)^{1-\sigma} - 1}{1 - \sigma} \right], \tag{1}$$

where $X_{i,t} = X_{i,t-1}^{1-\gamma^{ghh}} \cdot C_{i,t}^{\gamma^{ghh}}$, which makes preferences non-time-separable in consumption C_t^i and labor N_t^i of a type-i household.[9] The parameter $\sigma \geq 0$ denotes the inverse of the elasticity of intertemporal substitution and $\kappa_{i,N}$ measures the relative weight of the disutility of labor. $\mathbb{E}_0$ is the expectations operator $\mathbb{E}_t$ at time $t = 0$. The choices of the optimizers are subject to the budget constraint

$$(1+\tau_t^c)C_t^o + P_t^I I_t^o + \sum_{s\in\mathcal{S}} v_{s,t} N_{s,t}^{f,e,o} = (1-\tau_t^w) w_t N_t^o + r_t^k K_{t-1}^o + TR_t^o + \sum_{s\in\mathcal{S}} N_{s,t}^{f,o} \Pi_{s,t}, \quad (2)$$

while the RoT's budget constraint is

$$(1+\tau_t^c)C_t^r = (1-\tau_t^w) w_t N_t^r + TR_t^r. \quad (3)$$

Defining P_t^C as the CPI of consumption goods and $\tilde{P}_t^I$ as the nominal price of a basket of investment goods, I_t^i, we get $P_t^I = \tilde{P}_t^I / P_t^C$ as the real price of the latter resulting from an investment goods basket that can be different to the consumption goods basket. w_t is the real wage rate, r_t^k the return on physical capital holdings K_t^i, and $v_{s,t}$ the real value of the firm in sector s. $N_{s,t}^{f,e,o}$ is the number of new firms created in s by optimizing households. Firm profits are $\Pi_{s,t}$. The average tax rate on the consumption good is τ_t^c and the average labor tax rate τ_t^w. TR_t^i are lump-sum transfers from (or payments to) the government (if negative). In each sector, the number of active firms held by optimizing households is $N_{s,t}^{f,o}$. Aggregation across households implies $x_t = \mu \cdot x_t^r + (1-\mu) \cdot x_t^o$ for $x \in \{C, N, TR\}$ and $x_t = (1-\mu) \cdot x_t^o$ for $x \in \{I, K, N^{f,e}, N^f\}$ (see Stähler and Thomas, 2012).

Capital accumulation is represented by the following law of motion

$$K_t = (1-\delta) K_{t-1} + I_t, \quad (4)$$

with δ denoting the rate of depreciation of physical capital. As in Jaimovich and Floetotto (2008), the evolution of the number of firms in sector s similarly follows

$$N_{s,t}^f = (1-\delta_{s,t}^N) N_{s,t-1}^f + N_{s,t}^{f,e} \quad \forall s \in \mathcal{S}, \quad (5)$$

where $\delta_{s,t}^N$ is the endogenously determined exit rate of firms. The household maximization problem yields the standard intra- and intertemporal first order conditions. For firm entry and exit, see Section 2.5.

2.2 Labor and capital agencies

Labor is imperfectly mobile across sectors. Following Bouakez et al. (2023), a perfectly competitive, representative labor agency hires the total amount of labor, N_t, at the CPI-deflated real wage w_t and sells it to intermediate goods producers operating in S different

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[9] These preferences nest as special cases the two classes of utility functions most widely used in the business cycle literature: If $\gamma^{ghh} = 1$ one gets preferences of the class discussed in King, Plosser, and Rebelo (1988). If $\gamma^{ghh} = 0$ the preferences resemble those proposed by Greenwood, Hercowitz, and Huffman (1988).

sectors, such that

$$N_t = \left[\sum_{s=1}^{S} \omega_{N,s}^{1-\nu_N} N_{s,t}^{\nu_N} \right]^{\frac{1}{\nu_N}},$$

where $\omega_{N,s}$ is the weight attached to labor provided to sector $s \in \mathcal{S}$, and ν_N determines the elasticity of substitution of labor across sectors, capturing the degree of labor mobility. The labor agency's optimization problem can be written as $\max_{N_{s,t}} w_{s,t} N_{s,t} - w_t \cdot N_t$, which leads to the following first-order condition characterizing the sector-specific demand for labor types

$$N_{s,t} = \omega_{N,s} \left(\frac{w_{s,t}}{w_t} \right)^{-\left(\frac{1}{1-\nu_N}\right)} N_t \quad \forall s \in \mathcal{S}. \tag{6}$$

After plugging this expression into the CES aggregator of labor goods, we obtain the aggregate wage index

$$w_t = \left[\sum_{s=1}^{S} \omega_{N,s} w_{s,t}^{-\frac{\nu_N}{(1-\nu_N)}} \right]^{-\frac{(1-\nu_N)}{\nu_N}}. \tag{7}$$

An analogous proceeding for the capital agency yields

$$K_{s,t} = \omega_{K,s} \left(\frac{r_{s,t+1}^K}{r_{t+1}^K} \right)^{-\left(\frac{1}{1-\nu_K}\right)} K_t \quad \forall s \in \mathcal{S}, \tag{8}$$

and

$$r_t^K = \left[\sum_{s=1}^{S} \omega_{K,s} (r_{s,t}^K)^{-\frac{\nu_K}{(1-\nu_K)}} \right]^{-\frac{(1-\nu_K)}{\nu_K}}. \tag{9}$$

2.3 Consumption and investment-goods retailers

Households demand bundles of consumption and investment goods C_t and I_t, which are traded at prices P_t^C and $\tilde{P}_t^I$, respectively. Following Hinterlang et al. (2022), the consumption goods bundle, in turn, is divided into energy and non-energy goods bundles C_t^E and C_t^{NE}. They are traded at prices $P_t^{C^E}$ and $P_t^{C^{NE}}$. The production technology of a perfectly competitive, representative retailer that bundles energy and non-energy consumption bundles is given by

$$C_t = \left[\psi_C^{1-\sigma_C} (C_t^{NE})^{\sigma_C} + (1-\psi_C)^{1-\sigma_C} (C_t^E)^{\sigma_C} \right]^{\frac{1}{\sigma_C}}.$$

The parameters ψ_C and σ_C determine the consumption utility value and control the elasticity of substitution between energy and non-energy consumption bundles. The optimization problem in CPI-deflated real terms can be written as

$$\max_{C_t^E, C_t^{NE}} P_t^C C_t - P_t^{C^{NE}} C_t^{NE} - P_t^{C^E} C_t^E.$$

Taking into account the bundling technology, the first-order conditions are

$$C_t^{NE} = \psi_C \left(\frac{P_t^{C^{NE}}}{P_t^C}\right)^{-\frac{1}{(1-\sigma_C)}} C_t \quad \text{and} \quad C_t^E = (1-\psi_C)\left(\frac{P_t^{C^E}}{P_t^C}\right)^{-\frac{1}{(1-\sigma_C)}} C_t. \tag{10}$$

Plugging these expressions into the constant elasticity of substitution aggregator shows that P_t^C is equal to the weighted sectoral consumption good prices. The production technologies of the perfectly competitive, representative retailers that bundle energy and non-energy consumption goods are

$$C_t^i = \left[\sum_{s\in\mathcal{S}^i} \psi_{C^i,s}^{1-\sigma_{C^i}} (C_{s,t})^{\sigma_{C^i}}\right]^{\frac{1}{\sigma_{C^i}}}, \quad i \in \{NE, E\}. \tag{11}$$

The elasticity of substitution $\sigma_{C^i}, i \in \{NE, E\}$ differs for non-energy and energy goods producing sectors. The parameter governing the consumption utility value $\psi_{C^i,s}$ also differs by sector. Profit maximization implies the following first-order condition

$$C_{s,t} = \psi_{C^i,s}\left(\frac{P_{s,t}}{P_t^{C^i}}\right)^{-\frac{1}{(1-\sigma_{C^i})}} C_t^i, \quad \forall s \in \mathcal{S}^i \textit{ and } i \in \{NE, E\}, \tag{12}$$

where $P_{s,t}$ is the CPI-deflated producer price of sectoral good $s \in \mathcal{S}$. For investment goods, we assume an analogous bundling technology in line with Bouakez et al. (2023), i.e.

$$I_t = \left[\sum_{s=1}^{S} \psi_{I,s}^{1-\sigma_I} I_{s,t}^{\sigma_I}\right]^{\frac{1}{\sigma_I}}, \tag{13}$$

where the investment goods bundler maximizes $\max_{I_{s,t}} P_t^I I_t - \sum_{s=1}^{S} P_{s,t} I_{s,t}$. The derivation is equivalent. The price index (relative to CPI) is thus given by

$$P_t^I = \left[\sum_{s=1}^{S} \psi_{I,s} (P_{s,t})^{-\frac{\sigma_I}{(1-\sigma_I)}}\right]^{-\frac{(1-\sigma_I)}{\sigma_I}}. \tag{14}$$

2.4 Production

Following Jaimovich and Floetotto (2008), in each sector $s \in \mathcal{S}$, the final sectoral good is produced with a constant-return-to-scale production function. It aggregates a continuum of measure one of sub-sectoral goods

$$Y_{s,t} = \left[\int_0^1 \tilde{Y}_{s,t}(j)^{\omega_s^f}\right]^{1/\omega_s^f}, \quad \omega_s^f \in \{0, 1\},$$

where $\tilde{Y}_{s,t}(j)$ denotes output of sub-sector j in sector s. The elasticity of substitution between different sub-sectoral goods is constant and equals $1/(1-\omega_s^f)$. Final sectoral goods producers are competitive.

In each of the j sub-sectors of sector s, there are $N_{s,t}^f$ firms producing differentiated goods that are aggregated into a sub-sectoral good by a CES function. The number of firms can vary across periods. Hence, sub-sectoral output of good j in sector s is given by

$$\tilde{Y}_{s,t}(j) = {N^f_{s,t}}^{1-1/\tau^f_s} \cdot \left[\sum_{i=0}^{N^f_{s,t}} y_{s,t}(j,i)^{\tau^f_s} \right]^{1/\tau^f_s}, \quad \tau^f_s \in \{0,1\},$$

where $y_{s,t}(j,i)$ is the output of firm i in sub-sector j of sector s, and τ^f_s is the elasticity of substitution, with $\omega^f_s < \tau^f_s$. Within each sub-sector, firms are monopolistically competitive such that each firm $i \in [0,1]$ produces a differentiated sectoral variety $y_{s,t}(j,i)$ by transforming labor, $N_{s,t}(j,i)$, capital, $K_{s,t-1}(j,i)$, and a bundle of intermediate inputs, $H_{s,t}(j,i)$. Assuming sector-specific fix costs of production, FC_s, and making use of symmetry, the production function is given by

$$y_{s,t} = \varepsilon_{s,t} \cdot \left(K^{1-\alpha_{N,s}}_{s,t-1} \cdot N^{\alpha_{N,s}}_{s,t} \right)^{\alpha_{H,s}} \cdot \left(H^{1-\alpha_{O,s}}_{s,t} \cdot O^{\alpha_{O,s}}_{s,t} \right)^{1-\alpha_{H,s}} - FC_s. \tag{15}$$

In addition to labor, capital and intermediate goods, all sectors also need intermediate fossil inputs $O_{s,t}$ which can be purchased from abroad.[10] $\varepsilon_{s,t}$ is sector-specific total factor productivity and the α's determine factor intensities. Taking factor prices as given, the first-order conditions for sector $s \in \{1, ..., S\}$ for labor, capital and intermediate inputs are

$$\begin{aligned}
w_{s,t} &= \alpha_{H,s} \cdot \alpha_{N,s} \cdot mc_{s,t} \cdot \frac{y_{s,t}}{N_{s,t}}, & (16)\\
r^k_{s,t} &= \alpha_{H,s} \cdot (1-\alpha_{N,s}) \cdot mc_{s,t} \cdot \frac{y_{s,t}}{K_{s,t-1}}, & (17)\\
P^H_{s,t} &= (1-\alpha_{H,s}) \cdot (1-\alpha_{O,s}) \cdot mc_{s,t} \cdot \frac{y_{s,t}}{H_{s,t}}, & (18)\\
P^{O,\text{eff}}_{s,t} &= (1-\alpha_{H,s}) \cdot \alpha_{O,s} \cdot mc_{s,t} \cdot \frac{y_{s,t}}{O_{s,t}}, & (19)
\end{aligned}$$

where $P^H_{s,t}$ the CPI-deflated real price of intermediate inputs purchased by sector s and $P^{O,\text{eff}}_{s,t}$ is the sectoral effective CPI-deflated real import price of intermediate fossil inputs. Without policy intervention, it equals the (exogenously given) import price P^O_t. We describe how cost subsidization affects the effective price below. $mc_{s,t}$ are real marginal production costs in each sector. Assuming sector-specific, time-varying mark-ups $\mu_{s,t}$ (which are determined in Section 2.5) and flexible prices, it turns out that sectoral CPI-deflated producer prices are given by

$$P_{s,t} = \mu_{s,t} \cdot mc_{s,t}. \tag{20}$$

What remains to be determined is factor demand for sector j-intermediates by sector $s \in \mathcal{S}$. Similar to the consumption goods structure, we assume that there exists an

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[10] One could argue that fossil inputs are needed in the production of brown energy only. We discuss such a scenario in Section 5.3 and show that results are qualitatively analogous. This analogously holds for assuming fossil inputs implemented as CES. The Cobb-Douglas specification, however, is meant to highlight the essentiality.

intermediate goods bundle $H_{s,t}$ that is made up of a non-energy goods bundle $NE_{s,t}$ which, in turn, consists of sectoral inputs $NE_{s,j,t}$ with $j \in \mathcal{S}^{NE}$, as well as an energy goods bundle $E_{s,t}$ that uses inputs $E_{s,j,t}$ with $j \in \mathcal{S}^{E}$. Formally,

$$H_{s,t} = \left[\alpha_{NE,s}^{1-\sigma_H}(NE_{s,t})^{\sigma_H} + (1-\alpha_{NE,s})^{1-\sigma_H}(E_{s,t})^{\sigma_H}\right]^{\frac{1}{\sigma_H}}, \quad \forall s \in \mathcal{S}.$$

The parameter $\alpha_{NE,s}$ weights non-energy and energy input bundles and σ_H determines the elasticity of substitution between those intermediate goods bundles. These parameters may differ across sectors. The optimization problem in CPI-deflated real terms, after accounting for possible taxes and subsidies, can be written as

$$\max_{E_{s,t},NE_{s,t}} P_{s,t}^{H}H_{s,t} - P_{s,t}^{NE}NE_{s,t} - P_{s,t}^{E}E_{s,t}, \quad \forall s \in \mathcal{S}.$$

Taking into account the bundling technology, the first-order conditions $\forall s \in \mathcal{S}$ are

$$NE_{s,t} = \alpha_{NE,s}\left(\frac{P_{s,t}^{NE}}{P_{s,t}^{H}}\right)^{-\frac{1}{(1-\sigma_H)}} H_{s,t} \quad \text{and} \quad E_{s,t} = (1-\alpha_{NE,s})\left(\frac{P_{s,t}^{E}}{P_{s,t}^{H}}\right)^{-\frac{1}{(1-\sigma_H)}} H_{s,t}. \tag{21}$$

The CES aggregator that bundles goods from non-energy and energy producing sectors, respectively, is

$$i_{s,t} = \left[\sum_{j\in\mathcal{S}^i} \psi_{i,s,j}^{1-\sigma_i} i_{s,j,t}^{\sigma_i}\right]^{\frac{1}{\sigma_i}}, \quad i \in \{NE, E\} \text{ and } \forall s \in \mathcal{S}.$$

Hence, for $i \in \{NE, E\}$, the CES aggregator $i_{s,t}$ aggregates the intermediate goods from sectors $j \in \mathcal{S}^i$, after weighting them by the parameter $\psi_{i,s,j}$ and taking into account the elasticity of substitution between those intermediate goods, which is determined by σ_i. Optimization results in the first order condition

$$i_{s,j,t} = \psi_{i,s,j}\left(\frac{P_{j,t}}{P_{s,t}^{i}}\right)^{-\frac{1}{(1-\sigma_i)}} i_{s,t}, \quad i \in \{NE, E\} \text{ and } \forall s \in \mathcal{S}. \tag{22}$$

2.5 Firm value, profits as well as entry and exit

As in Jaimovich and Floetotto (2008), entry decisions are made by a large group of potential entrepreneurs. To found a new firm, an entrepreneur pays an entry cost $\Psi_{s,t}$ in terms of output units. The entrepreneur subsequently sells the firm to the household for the present discounted value of future profits, which (using the household's stochastic discount factor $\beta \cdot \lambda_{t+1}^{o}/\lambda_t^{o}$) is given by

$$v_{s,t} = \Pi_{s,t} + \beta \cdot \mathbb{E}_t\left\{\frac{\lambda_{t+1}^{o}}{\lambda_t^{o}}(1-\delta_{s,t+1}^{N})v_{s,t+1}\right\}. \tag{23}$$

In equilibrium, it must thus hold that $v_{s,t} = \Psi_{s,t} = \Psi_s \cdot w_{s,t}$. Note that we assume that entry costs are denominated in real wage costs as in Ghironi and Melitz (2005) and Bilbiie, Ghironi, and Melitz (2012, 2019).

Profits of a single firm are given by $\Pi_{s,t} = P_{s,t} \cdot y_{s,t} - w_{s,t}N_{s,t} - r^k_{s,t}K_{s,t-1} - P^H_{s,t}H_{s,t} - P^{O,\text{eff}}_{s,t}O_{s,t} + TR^f_{s,t}$, where $TR^f_{s,t}$ are transfers from the government, which we specify below. Using the relevant equations of Section 2.4, this yields (see the technical appendix of Jaimovich and Floetotto, 2008, too)

$$\Pi_{s,t} = \frac{\mu_{t,s} - 1}{\mu_{t,s}} \frac{Y_{s,t}}{N^f_{s,t}} - \frac{\phi_s}{\mu_{s,t}} + TR^f_{s,t}, \tag{24}$$

where the markup evolves according to

$$\mu_{s,t} = \frac{(1-\omega^f_s)N^f_{s,t} - (\tau^f_s - \omega^f_s)}{\tau^f_s(1-\omega^f_s)N^f_{s,t} - (\tau^f_s - \omega^f_s)} > 1. \tag{25}$$

It is monotonically decreasing in the number of firms in the sector.

As in Cavallari (2015), we assume that an intermediate goods producing firm observes its random exit value $\tilde{v}_s$ at the beginning of each period. If this scrap value is higher than expected next-period firm value $v_{s,t+1}$, the firm will leave the market (see also Röhe and Stähler, 2020, for a more detailed discussion). Hence, the exit rate in period t is given by

$$\delta^N_{s,t} = Pr\left(\tilde{v}_s > v_{s,t+1}\right) = 1 - F\left(v_{s,t+1}\right), \text{ with } F\left(v_{s,t+1}\right) = \begin{cases} 1 - \left(\frac{v_{s,t+1}}{\tilde{v}_s}\right)^{-\kappa^{ex}} & v_{s,t+1} \geq \tilde{v}_s \\ 0 & v_{s,t+1} \leq \tilde{v}_s \end{cases} \tag{26}$$

where $F(\cdot)$ is the cumulative distribution function of $v_{s,t+1}$, and κ^{ex} and $\tilde{v}_s$ represent the respective shape and scale parameters of the distribution function.

2.6 Policy

The fiscal authority finances transfers to households, $TR^{HH}_t = (1-\mu)TR^o_t + \mu TR^r_t$, and firms, $\sum_{s=1}^S TR^f_{s,t}$, as well as production cost subsidies, $\sum_{s=1}^S Sub^f_{s,t}$, by labor income and consumption taxation:

$$TR^{HH}_t + \sum_{s=1}^{S} TR^f_{s,t} + \sum_{s=1}^{S} Sub^f_{s,t} = \tau^w_t \cdot w_t \cdot N_t + \tau^c_t \cdot C_t. \tag{27}$$

Negative transfers can considered to be lump-sum taxes. Following the gas price shock, German policymakers decided that producers in sector s should receive a transfer conditional on their pre-shock gas consumption. The transfer is set as if producers pay only the steady-state gas price for a share ι^{trans} of their pre-shock consumption, i.e.

$$TR^f_{s,t} = (P^O_t - \bar{P}^O) \cdot \iota^{trans} \cdot \bar{O}_s, \tag{28}$$

where the bar indicates steady-state values. It was also viably discussed to directly subsidize production costs by reducing the effective gas price to

$$P^{O,\text{eff}}_{s,t} = \frac{\bar{P}^O \cdot \iota^{sub} \cdot \bar{O}_s + P^O_t \cdot (O_{s,t} - \bar{O}_s \cdot \iota^{sub})}{O_{s,t}}, \tag{29}$$

which implies that producers would pay the (lower) steady-state gas price for a fraction ι^{sub} of their pre-shock consumption and the full gas price for any additional amount (i.e. the more they consume, the higher the price). The resulting subsidy amounts to

$$Sub^{f}_{s,t} = \left(P^{O}_{t} - P^{O,\text{eff}}_{s,t}\right) O_{s,t}. \tag{30}$$

In our baseline simulation with no policy intervention, it holds that $\iota^{trans} = \iota^{sub} = 0$. Note that $P^{O,\text{eff}}_{s,t} = P^{O}_{t}$ if $\iota^{sub} = 0$ and/or $P^{O}_{t} = \bar{P}^{O}$. For the transfer (subsidy) simulation, we set $\iota^{trans} = 0.7$ ($\iota^{sub} = 0.7$) according to German legislation.[11]

We assume that the government runs a balanced budget by setting TR^{o}_{t} accordingly. This allows us to interpret changes in TR^{o}_{t} as quasi deficit-like financing costs.[12] When assuming other financing instruments, which could easily be done along the lines of Mitchell, Sault, and Wallis (2000), for example, we would blur our results. Then, the effects of the gas price subsidy/transfer would be mixed with those of distortionary financing costs. To get a clearer picture of the pure effect of the gas price brake, we opt for a balanced budget rule by adjusting lump-sum taxes (in all simulations).

2.7 Market clearing and aggregation

Market-clearing in each sector implies that

$$P_{s,t} \cdot y_{s,t} = P_{s,t} \cdot C^{i}_{s,t} + P_{s,t} \cdot I^{i}_{s,t} + P_{s,t} \cdot \sum_{\tilde{s}=1}^{S} i_{\tilde{s},s,t} + v_{s,t} \cdot N^{f,e}_{s,t} + \phi_{s} \cdot N^{f}_{s,t} + P^{O,\text{eff}}_{s,t} \cdot O_{s,t},$$

with $i \in \{NE, E\}$. Sectoral production must cover consumption, investment and intermediate goods demand, entry costs and fixed costs of production as well as the purchases of gas from abroad. Defining value added as what is left from production for consumption and investment, CPI-deflated aggregate value added can be expressed as

$$Y^{va}_{t} = C_{t} + P^{I}_{t} \cdot I_{t}, \tag{31}$$

where $C_{t} = \sum_{s=1}^{S} C^{i}_{s,t}$ and $I_{t} = \sum_{s=1}^{S} I^{i}_{s,t}$. Because the consumption and investment goods basket differ, we have to take into account the relative price of investment P^{I}_{t}. Note that, while sectoral firm value and entry costs appear in the household budget constraint, the costs for importing gas do not (and they do not belong to value added). They, hence, "disappear" from the system, which we consider to be import costs that have to be paid to someone outside the home economy (similar to time-varying fix costs). This specification treats natural gas as imported from abroad in the closed economy. We believe that, for our purpose, this is a valid shortcut.

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[11] The German government also subsidized consumer energy costs. To save space, we refrain from showing detailed simulations results. Unsurprisingly, however, especially RoT households benefit from this measure as it alleviates the income share that must be spend on energy. In Section 5.3, we also discuss the implications of subsidizing energy prices, $P^{E}_{s,53,t}$ instead of gas prices directly.

[12] As a result of Ricardian equivalence, deficit financing and the use of "true" lump-sum taxes (levied only on optimizers in our setup) is equivalent.

3 Calibration

The model calibration consists of three parts. The first comprises the specification of general parameters related to the aggregate economy, mainly taken from the literature. The second set of parameters captures heterogeneity on the production side by allowing for sector-specific factor intensities, input-output linkages, price rigidities, contributions to final demand as well. Parameters capturing endogenous firm entry and exits are presented in the third part of this section. We calibrate the model to Germany. To save space, we relegate the calibration tables to Appendix A.

General parameters The model is calibrated to the quarterly frequency. We set the discount factor to $\beta = 0.992$, which implies an annual interest rate of 3.3%. The intertemporal elasticity of substitution is fixed at a standard value of $\sigma_c = 2$. Along the lines of Coenen, Straub, and Trabandt (2013), the Frisch elasticity of labor supply is calibrated to 0.5 (i.e. $\Psi = 2$). The relative weight of the disutility of labor is set to $\kappa_N = 6.3307$ in order to match a targeted aggregate labor supply of $\bar{N} = 0.33$. We assume an annual depreciation rate of 10%, which is a standard choice in the literature (see, for example, Cooley and Prescott, 1995). The fiscal parameters rely on estimates of a standard DSGE model for Germany (Gadatsch, Hauzenberger, and Stähler, 2016). Table A.1 summarizes our baseline calibration of general parameters.

Substitution elasticities for goods produced in the different sectors are set as follows. For the consumption basket, we follow Atalay (2017) and Baqaee and Farhi (2019) and choose 0.9. The elasticity of substitution for the investment goods basket is assumed to be a bit lower and is set to 0.75. For intermediate inputs, we follow Bouakez et al. (2023) and Atalay (2017) by choosing a value of 0.1. Baqaee and Farhi (2019) allow for a higher substitution elasticity (of 0.4). Using this or even higher values does not change our results qualitatively and only mildly quantitatively (the adjustment of relative prices is just a bit lower). For the substitution elasticities of labor and capital, we follow Bouakez et al. (2023) and use a value of 2. Antoszewski (2019) provides a critical discussion.

Sector-specific production parameters On the production side of the economy, we distinguish between $S = 53$ sectors, relying on the standard NACE Rev. 2 classification.[13] We allow for several heterogeneities across sectors. The weights of sectoral labor and capital, $\omega_{N,s}$ and $\omega_{K,s}$, are set to match the employment and capital shares, N_s/N and K_s/K, observed in the data. The production technology of intermediate goods producers differs across sectors as we allow for heterogenous factor intensities for labor, capital and intermediate inputs. Moreover, all sectors contribute differently to final demand. For each sector s, these parameters are derived using the most recent release of the World Input-Output Database (WIOD), taking 2014 values (see Timmer et al. (2015)). It includes data on socioeconomic accounts as well as input-output tables for 56 sectors and 43 countries. Sectoral information on number of persons engaged, nominal capital stock, intermediate inputs, labour compensation and gross output from the socioeconomic accounts help us to pin down $\psi_{N,s}$, $\psi_{K,s}$, $\alpha_{N,s}$ and $\alpha_{H,s}$. The provided input-output tables can be used

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[13] Note that we exclude the sections activities of households as employers; undifferentiated goods- and services-producing activities of households for own use (T) and activities of extraterritorial organizations and bodies (U).

to match inter-sectoral trade shares $\psi_{NE,s,j}$, shares of non-energy intermediates $\alpha_{NE,s}$, as well as the shares in the consumption and investment goods bundles, ψ_C, $\psi_{C^{NE},s}$ and $\psi_{I,s}$, respectively.

Regarding the energy sectors, we make the following further assumptions given that there is no distinction between energy types in WIOD. First, α_N, α_H and ψ_{NE} of the brown energy sector (sector 53) are approximated by the respective production parameters of sectors B (mining and quarrying) and C19 (manufacturing of oil and refined petroleum), while the clean sector (52) mirrors the values of sector D (electricity, gas, steam and air conditioning supply). Second, the energy input shares in production, $\psi_{E,s,j}$, the gas shares $\alpha_{O,s}$, as well as the shares of clean and brown energy in the consumption bundle ($\psi_{C^E,s}$) are calibrated using sectoral gross energy use data from the environmental accounts provided by the European commission (see Corsatea, Lindner, Arto, Roman, Rueda-Cantuche, Afonso, Amores, Neuwahl, et al., 2019).[14] For the clean energy sector, we set the brown energy input share to 2%. The aggregate energy shares in the model amount to 7%, 70% and 23% for gas, brown and clean energy, respectively, which match the German data reasonably well.[15] Third, labor and capital weights of the energy sectors are approximated by their respective shares in the production of primary energy as given in the IEA (2021) World Energy Balances.

To facilitate calculations, we normalize relative prices to one in the initial steady state. Sector-specific parameter choices concerning production are summarized in Table A.3. Table A.4 presents the inter-sectoral linkages regarding intermediate inputs.

Endogenous firm entry and exit Our model setting allows for endogenous firm entry and exit rates as well as markups. We use sectoral data published by the German statistical office to pin down steady state exit rates $\bar{\delta}_s^N$.[16] Further, following Jaimovich and Floetotto (2008), we assume homogenous steady state markup rates of $\bar{\mu}_s = \bar{\mu} = 1.3$.

4 Simulation Design

First, we construct a baseline scenario without policy intervention, where the gas price rises exogenously and the gas quantity adjusts endogenously to clear the market.[17]

We specifically posit that an unexpected surge in gas prices occurs over a sequence of five periods, mirroring the timeframe from the first quarter of 2022 to the second quarter of 2023. To derive the baseline price path, we align it with the observed reduction in gas given the policies implemented in Germany. Then, we simulate this price path in the baseline model without policy intervention.[18]

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[14] We classify the energy commodities renewables, nuclear, waste as well as bio fuels as clean. According to the data, some sectors do not use fossil production inputs at all. However, for computational reasons, we need to assume that $\alpha_{O,s} > 0$ and $\psi_{E,s,53} > 0$. Hence, we set them slightly above zero for these sectors.

[15] The respective shares are computed as amount of gas, green or brown energy relative to the sum of the three.

[16] See `https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Unternehmen/Unternehmensdemografie`

[17] This approach to modeling energy price shock follows works such as Kim and Loungani (1992), Dhawan, Jeske, and Silos (2010) or Gavin, Keen, and Kydland (2015).

[18] It is important to note that the policies implemented consist of transfers to households and firms.

Assuming that agents only become aware of a shock upon its occurrence, they anticipate that the gas price will revert to the steady state following the AR(1) process $P_t^O - \bar{P}^O = 0.65 \cdot \left(P_{t-1}^O - \bar{P}^O\right) + \epsilon_t^{PO}$. The shock sequence is designed such that after three positive innovations to the gas price, two additional small negative shocks materialize as prices surprised downward in these periods in the data.

In order to ensure that agents do not learn about the whole sequence of shocks at the beginning of the simulation period, we use the method of extended path. The extended path simulation is also described in more detail in Gadatsch, Stähler, and Weigert (2016). It has the advantage that we take into account all non-linearities of the model. The downside of solving such a large model non-linearly with the extended path method, however, is its significant computational cost.

With the baseline scenario simulations in hand, we investigate the effects of direct transfers to firms as well as subsidizing firms' energy prices. To implement the former measure, we set $\iota^{trans} = 0.7$ and $\iota^{sub} = 0$. To implement the latter, we set $\iota^{trans} = 0$ and $\iota^{sub} = 0.7$. As intended by the actual policy measures observed, all interventions fade over time, i.e. when prices revert to their initial level.

We analyze the policy interventions in the context of two distinct settings. The initial setting uses the gas price trajectory from the baseline scenario, operating under the assumption that the gas supply is flexible, meaning it can meet any level of demand. This scenario is visually represented in the left-hand panel of Figure 1. The findings from these simulations are presented in Section 5.2.1.

In the second setting, we assume that the gas price is flexible but the quantity is constant. Specifically, the price P_t^O adjusts endogenously, while the gas supply is predetermined and follows the AR(1) process $O_t - \bar{O} = 0.762 \cdot \left(O_{t-1} - \bar{O}\right) + \epsilon_t^O$. Under this condition, the distribution of the available gas is dictated by sectoral gas demand, with the aggregate demand required to satisfy $O_t = \sum_{s=1}^{S} O_{s,t}$. The shocks are selected to ensure that the evolution of gas supply and gas prices in the baseline scenarios are comparable across both model simulations.[19] Introducing the same policies as before, the gas supply remains at the predetermined level, necessitating adjustments in gas prices to maintain this. This scenario is visually represented in the right-hand panel of Figure 1. The outcomes of these simulations are summarized in Section 5.2.2.

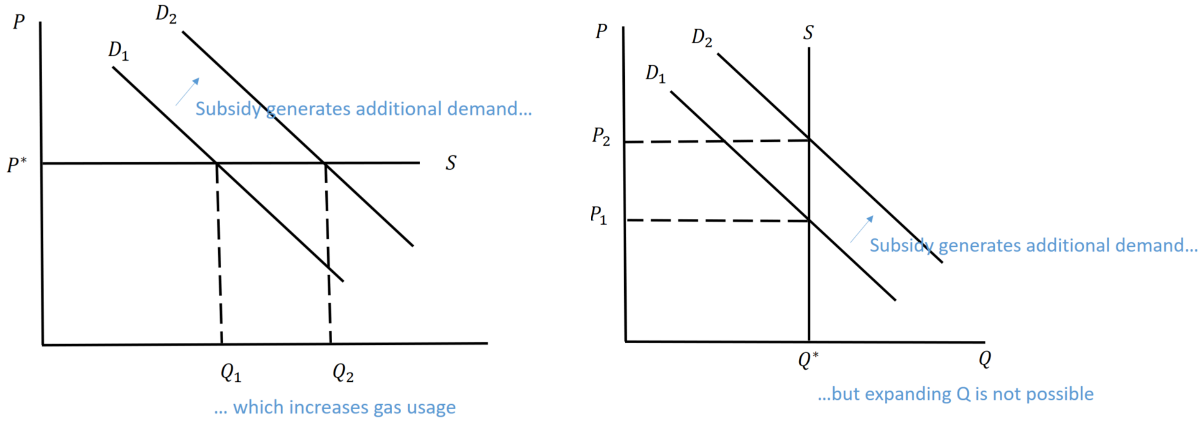
5 Results

We first show the baseline results of simulating the gas price increase without any policy intervention in Section 5.1. Then, in the following Section 5.2.1, we show how the policy measures changes these results given the same gas price path as in the baseline. The effects of the same policy measures in case of a fixed gas supply but variable prices are discussed in Section 5.2.2. Robustness is discussed in Section 5.3.

However, our approach only approximates the true counterfactual gas price path and quantity in the absence of policy intervention, as both variables are unobservable.

[19] In essence, the AR(1) coefficient ensures that, when the system begins to revert to its steady state (undisturbed by shocks), the paths of price and gas supply mirror those in the scenario where the price is set and gas supply is unrestricted.

Figure 1: Stylized representation of the scenarios underlying the policy simulations.


(a) No rationing

(b) Rationing

5.1 Results without policy intervention

Figures 2 and 3 show the results of the baseline simulation, i.e. the simulated effects of the gas price increase on the energy sector as well as on macroeconomic variables without policy intervention. As can be seen in Figure 2, the jump in gas price results in a drop in gas consumption of about 25%. Brown energy production falls by about 10%, and the exit rate rises while both firm entry and the number of firms fall. Surviving firms increase their mark-up, so that profits per firm fall only moderately. In contrast, the clean energy sector expands output, markups, and profits. Households, anticipating a declining firm exit rate, reduce their investment in new brown energy producing firms. Overall, the number of clean energy firms declines slightly, but profits per firm increase by over 30%.

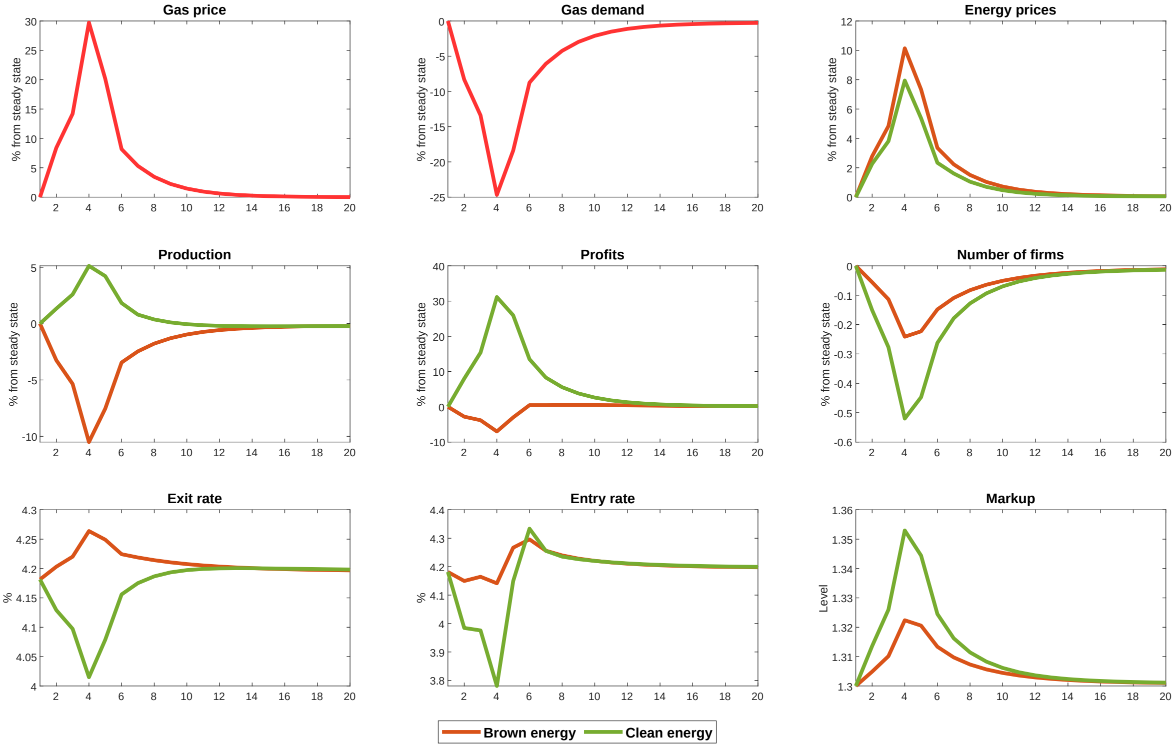
Unsurprisingly, the impact on key macroeconomic variables is consistently negative. The higher price of the key input, gas, reduces investment, labor demand, output, wages, and consumption. Quantitatively, the effects are substantial, with output falling by about 1.4%. RoT consumers are particularly hard hit. Due to the lack of smoothing possibilities, their consumption falls by about 1.6% (relative to optimizing households, whose consumption drops by 1%). As a result, they supply more labor than optimizers despite the drop in wages of about 1.2%. This is also reflected in the welfare of the households, shown in Appendix B. While welfare decreases for both types of households, the negative effects are larger for RoTs compared to optimizers.

5.2 Results with policy intervention

5.2.1 Fixed gas price path, variable gas supply

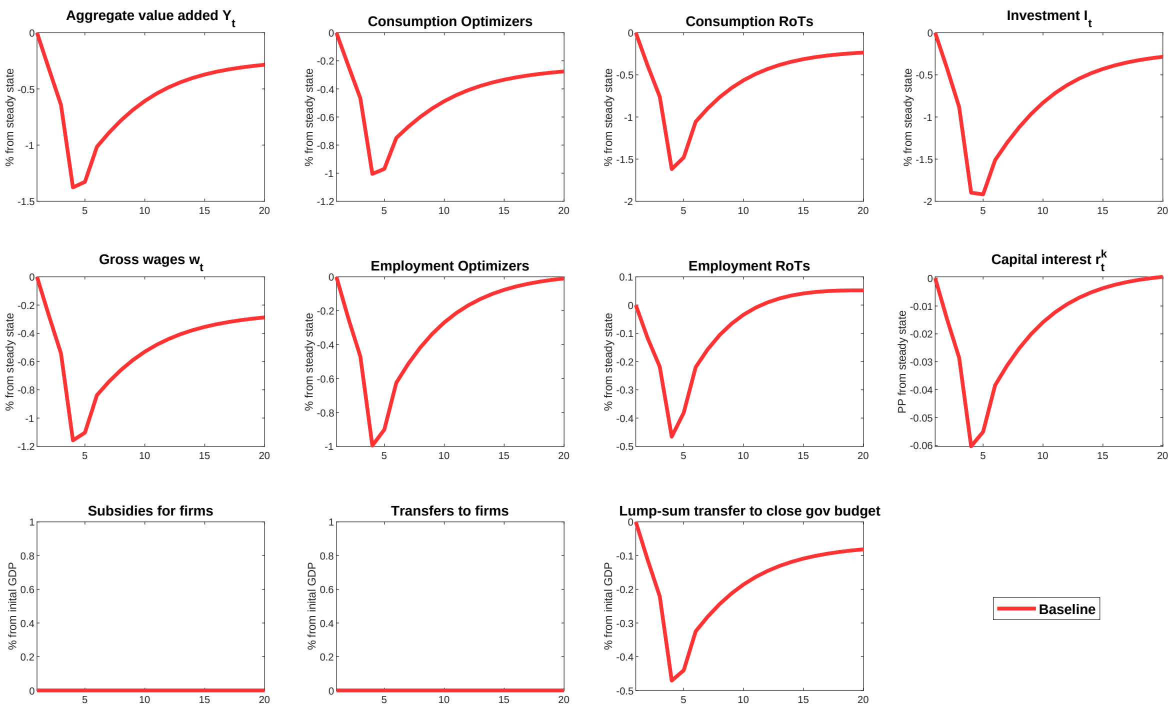
The effects of the policy measures on the energy producing sectors and the macroeconomic variables are shown in Figures 4 and 5, respectively. Throughout, the effects displayed are measured in percentage point deviation from the baseline scenario. The dashed and the dotted lines show the scenario in which producers' energy prices are subsidized and in which direct transfers to firms are made, respectively. In Figure 4, the left and middle panels in the top row show the effects on the exogenous gas price and on gas demand. In

Figure 2: Implications of gas price rise for energy sectors.



Notes: Figure shows exogenous gas price increase and (endogenous) gas demand in percentage deviation from initial steady state (red line). Moreover, figure plots (projected) implications resulting from gas price rise for the energy sectors. The green line shows baseline results for the clean energy sector. Results for the brown energy sector are depicted in brown.

Figure 3: Implications of gas price rise for macroeconomic variables and government budget.



Notes: Figure plots (projected) implications resulting from gas price rise for key macroeconomic variables in percentage deviation (percentage point deviations for policy rate) from initial steady state.

the remaining graphs, the green and brown lines show the effects on the clean and brown energy sectors, respectively.

The middle panel in the top row shows that subsidizing the energy price has a much larger effect on gas consumption than direct transfers to firms. This is because the subsidy makes both clean and brown energy prices dramatically lower, as shown in the right panel of the top row. The brown energy sector, not surprisingly, benefits more than the clean sector and expands relative to the baseline, while the latter sector produces less. Profits per firm and exit rates also move in opposite directions in the two sectors. However, the total number of firms increases in both sectors, and the markup decreases in both energy-producing sectors. In the brown energy sector, the effects are qualitatively identical in the case of direct transfers to firms, but much smaller. In the clean energy sector, they are also much smaller, but qualitatively different. Direct transfers slightly increase profits and output. However, since the changes are very small, the other variables are hardly affected.

The quantitative differences of the policy measures can be understood by considering the transmission mechanisms. The gas price subsidy directly counteracts the adverse effects of the exogenous price. As a consequence, the post subsidy price, $P_{s,t}^{O,\text{eff}}$, that firms have to pay when using gas in the production process falls dramatically. Since any quantity can be supplied at the given price, the additional gas demand resulting from implementing the policy can be covered – with substantial positive effects for the macroeconomy. In addition, the effect is further magnified through production linkages. The brown energy sector, for instance, uses a lot of gas in its production process. Decreasing the input costs of the brown energy sector reduces energy costs not just for firms but also for households.

Transfers, in turn, work primarily through an altered investment incentive for households. The transfers increase profits per firm, with the magnitude of the profit increase depending on the long-run usage of gas. Upon learning about the increase in profits, households increase investments in those new firms in which profits increase more strongly (and who have been more adversely affected from the gas price rise otherwise). Moreover, fewer of these firms have to leave the market because their net present value is worth less than the scrap value. As a consequence, the number of active firms increases, their markup falls and the production rises as well. Compared to the price subsidy, this policy is much less specific in that it does not directly target the underlying problem of the crisis.

The quantitatively large impact of the subsidy is also reflected in the evolution of macroeconomic variables, with output deviating by about 0.9 percentage points from the baseline scenario, where a decline of about 1.4% was observed, as shown in Figure 5. Similarly, labor demand, investment, wages, and consumption improve substantially relative to the baseline simulation, with RoT households benefiting the most. However, as can be seen in the third column of the last row, paying out subsidies instead of transfers is cheaper fiscally (the lump-sum transfer to households even increases relative to baseline due to the much more favorable developments of the tax bases for consumption, labor income and capital gains taxes). As we will see below, however, this is only true for the price path being fixed. It no longer holds when the gas supply is exogenously given.

Finally, Figure 6 shows the average quarterly impact on sectoral output of the three scenarios over the first five years of the simulation horizon.[20] For each row, the left and

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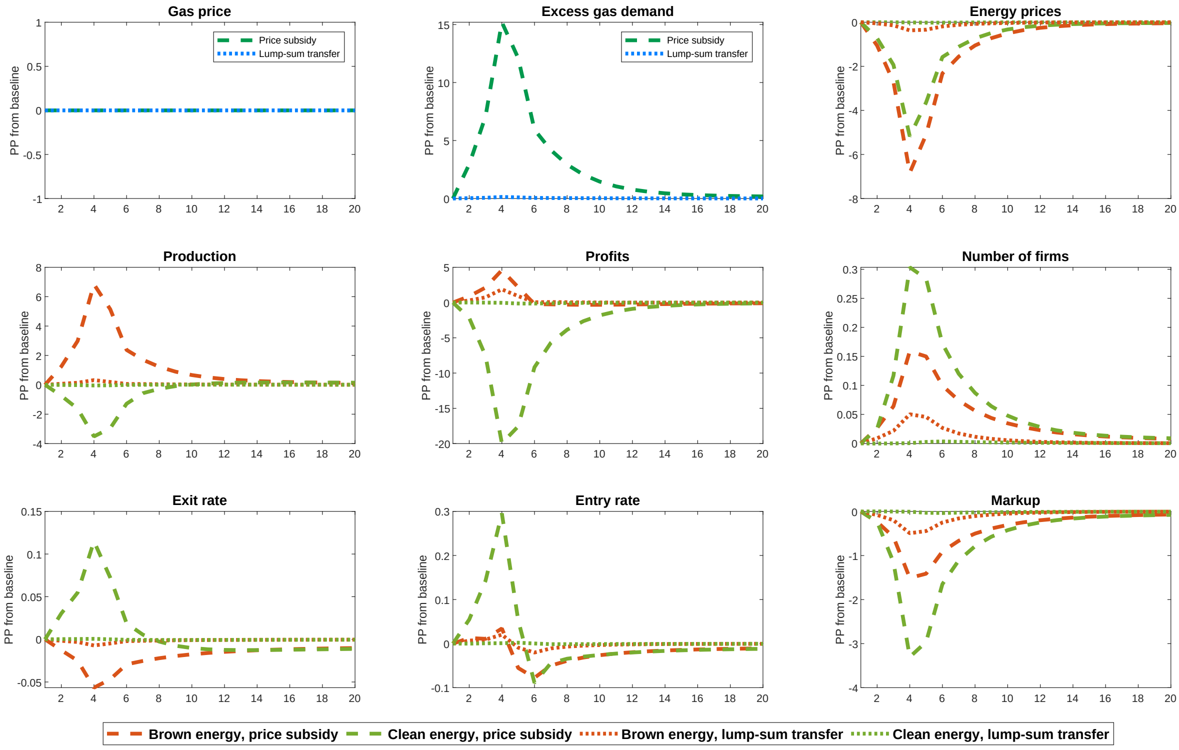
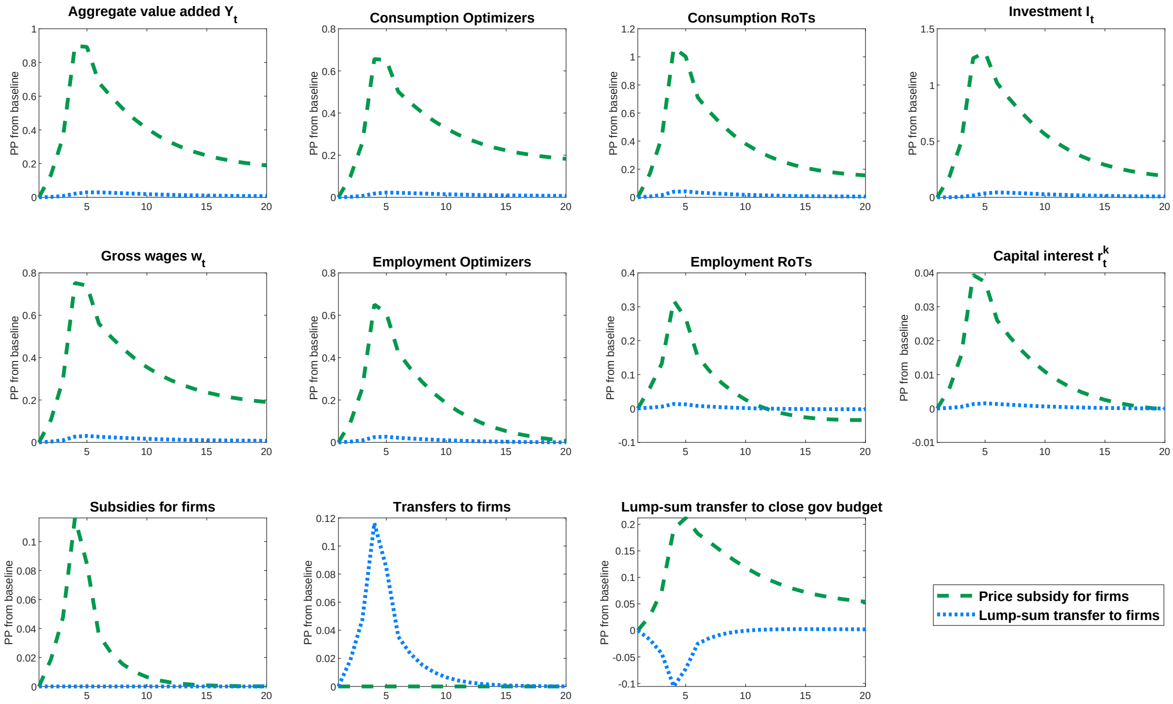
[20] The average quarterly effect is calculated by taking the cumulative effect over a twenty-quarter period and dividing by the number of quarters considered.

Figure 4: Implications of mitigation schemes for energy sectors.



Notes: Figure shows exogenous gas price increase and (endogenous) excess gas demand in percentage point deviation from baseline. The price subsidy for firms is depicted by the green dashed line. The dotted blue line represents the lump-sum transfer to firms. Moreover, figure plots (projected) implications resulting from mitigation schemes for the energy sectors. The dashed (dotted) light green line shows effects of the price subsidy (lump-sum transfer) on the clean energy sector. The dashed (dotted) brown lines show effects of the price subsidy (lump-sum transfer) on the brown energy sector.

Figure 5: Implications of mitigation schemes for macroeconomic variables and government budget.

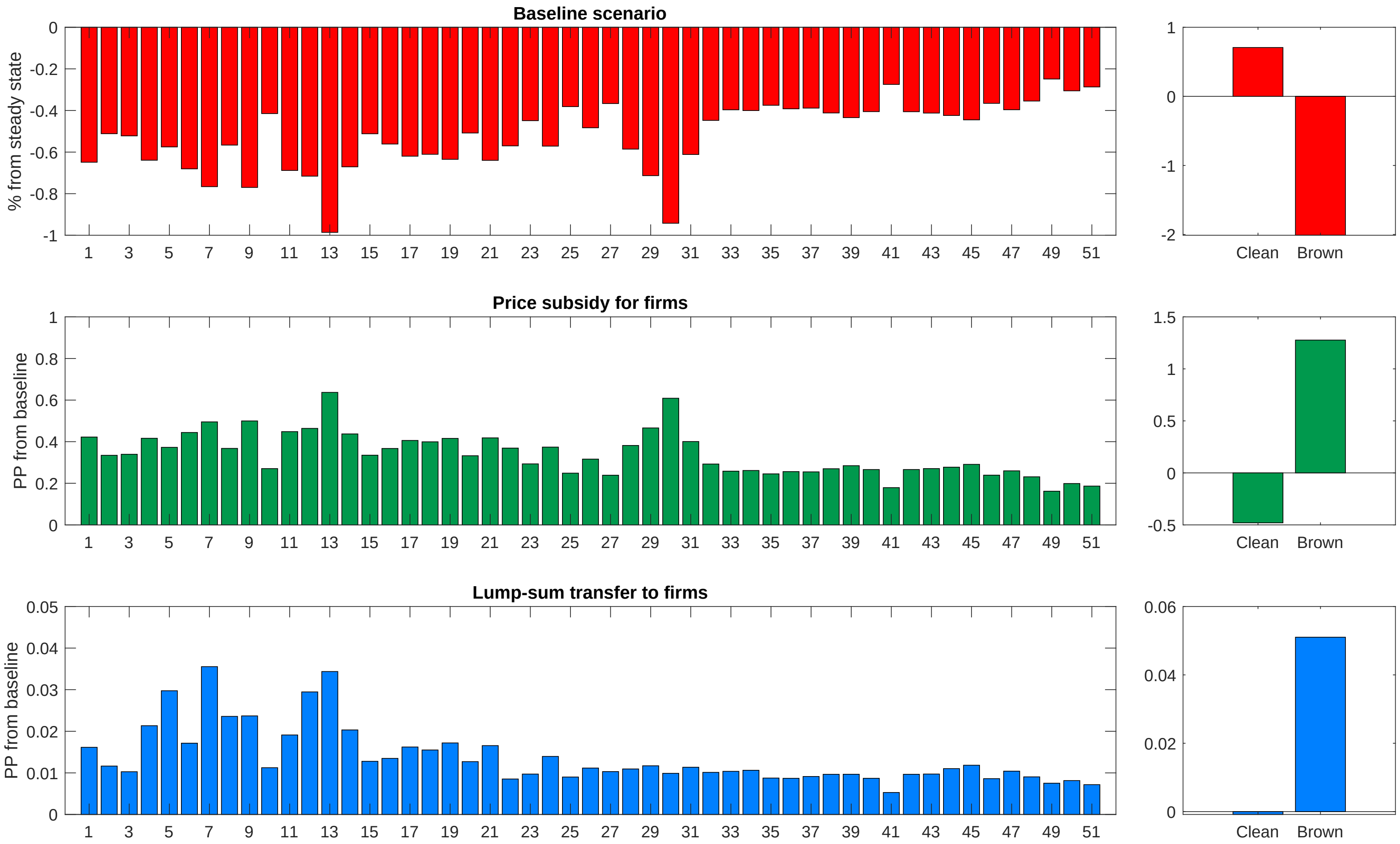


Notes: Figure plots (projected) implications resulting from policy interventions for key macroeconomic variables in percentage point deviations from baseline. The price subsidy for firms is depicted by the green dashed line. The dotted blue line represents the lump-sum transfer to firms.

right columns show the impact on the non-energy and energy sectors, respectively. The top row shows the sectoral effects of the baseline scenario as percentage deviations from steady state. The middle and bottom rows show the effects of the two policies relative to the baseline scenario. In addition to the large quantitative differences between the two policies, Figure 6 shows that the impact at the sectoral level differs across the two policies. Not surprisingly, the non-energy producing sectors that are worst off in the baseline simulation are also those that benefit most from the price subsidy. The worst-performing sectors in the baseline simulation are 13 (*Manufacture of basic metals*), 30 (*Air transportation*), 9 (*Manufacture of chemicals and chemical products*), and 7 *(Manufacture of paper and paper products*). Notably, these sectors are not necessarily those that consume the most gas, but those that consume the most brown energy: Through production linkages, the price increase in the brown energy sector, which consumes a lot of gas, also affects these sectors. This transmission mechanism is also reflected in the lower panel, where the *Air transportation* sector 30 benefits much less than the other sectors, since its gas consumption is not as high and therefore the transfers are lower compared to the metal, paper and textile and leather producing sectors 13, 7, and 5, respectively. The production of the clean energy sector even decreases slightly as a result of the price subsidy, while its production remains roughly unaffected by direct transfers to firms. This is because, although the clean sector does not receive any transfers, the production of brown energy does not expand as much as with the gas price subsidy.

As shown in Appendix B, the large quantitative differences between the two policies and the effects on different types of households are also reflected in the welfare gains. The price subsidy generates much larger effects compared to the transfers, with the RoT households benefiting more compared to optimizers.

Figure 6: Short-run changes in total sectoral output implied by gas price rise and various mitigation schemes.



Notes: Figure plots (projected) cumulative percentage deviations of total sectoral output from initial steady state values induced by gas price change (red). Moreover, it shows cumulative percentage point deviations from baseline for the price subsidy (green) and the lump-sum transfer (blue) to firms. Sector numbers in line with Table A.3.

5.2.2 Variable gas price, fixed gas supply

The results look very different when there is an actual shortage in the quantity of an essential input, as shown in Figures 7 and 8. As before, the vertical axes measure the percentage point deviation from the baseline. Figure 7 shows the impact on the energy sectors and on the gas price, conditional on the exogenously specified gas consumption taken from the benchmark simulation.

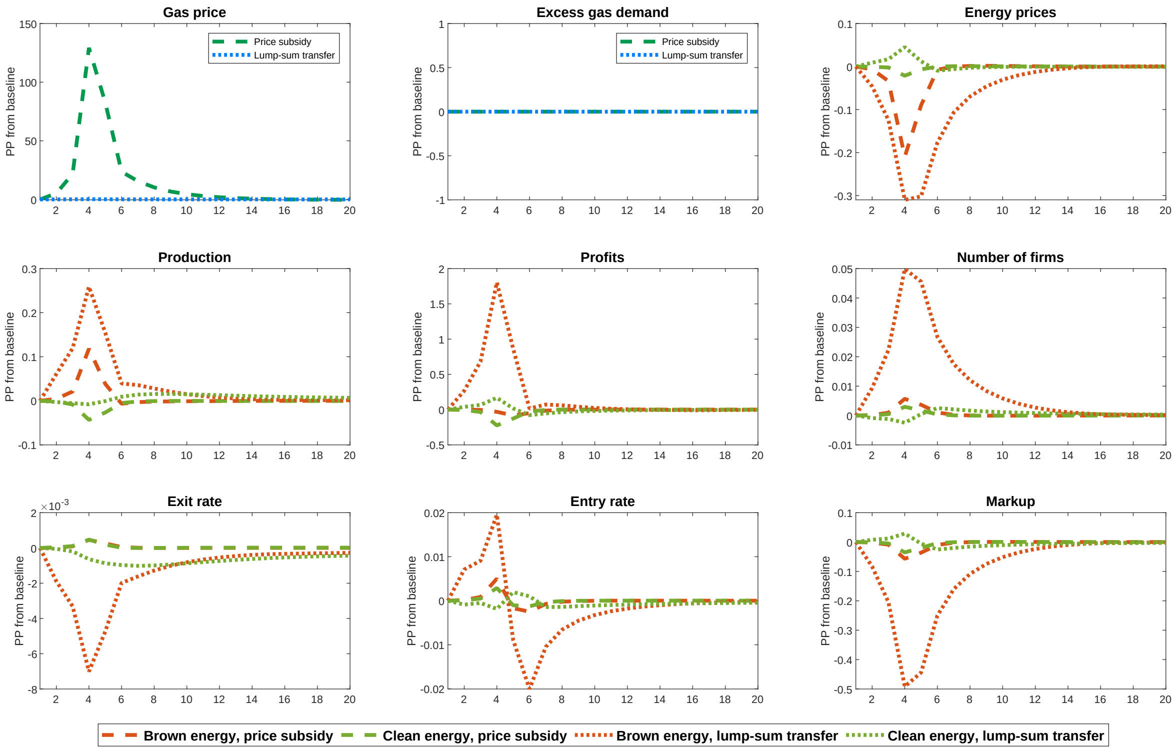
The left panel in the top row shows that under the subsidy policy, the (pre-subsidy) gas price P_t^O increases dramatically in the case of a quantity restriction. This is because the subsidy reduces the effective (cum-subsidy) price $P_{s,t}^{O,\text{eff}}$, which increases the demand for gas. However, since the supply of gas is fixed, this drives up P_t^O. The increased expenditures resulting from the subsidies for the higher gas price are borne by the optimizing households.

Compared to the no-policy baseline, the gas price subsidy still reduces energy prices. However, this effect is only a fraction of the price decrease in the brown power sector compared to the simulation in which quantities were allowed to adjust. This is because, in the latter case, the price subsidy strongly stimulates gas demand, as shown in the middle panel of the top row of Figure 4. This, in turn, stimulates production and consumption in the economy and produces large positive effects. When gas is rationed, however, this channel is not available. In contrast, the policy may actually worsen the shock if the subsidy drives the pre-subsidy gas price to a level that results in an excessive burden on optimizing households and/or the fiscal authority (as shown by the evolution of lump-sum transfers in Figure 8).

According to our analysis, direct transfers to firms are the more advisable policy compared to subsidies when essential inputs are rationed. Figure 7 shows that the stimulus in the brown energy sector is larger in terms of output, profits per firm, and number of firms. This also affects macroeconomic aggregates and welfare, as shown in Figure 8 (for welfare, see Appendix B). Now, direct transfers to firms generate relatively larger macroeconomic effects compared to the price subsidy, although the stimulative effects are small – especially given the large negative effects observed in the baseline simulation.

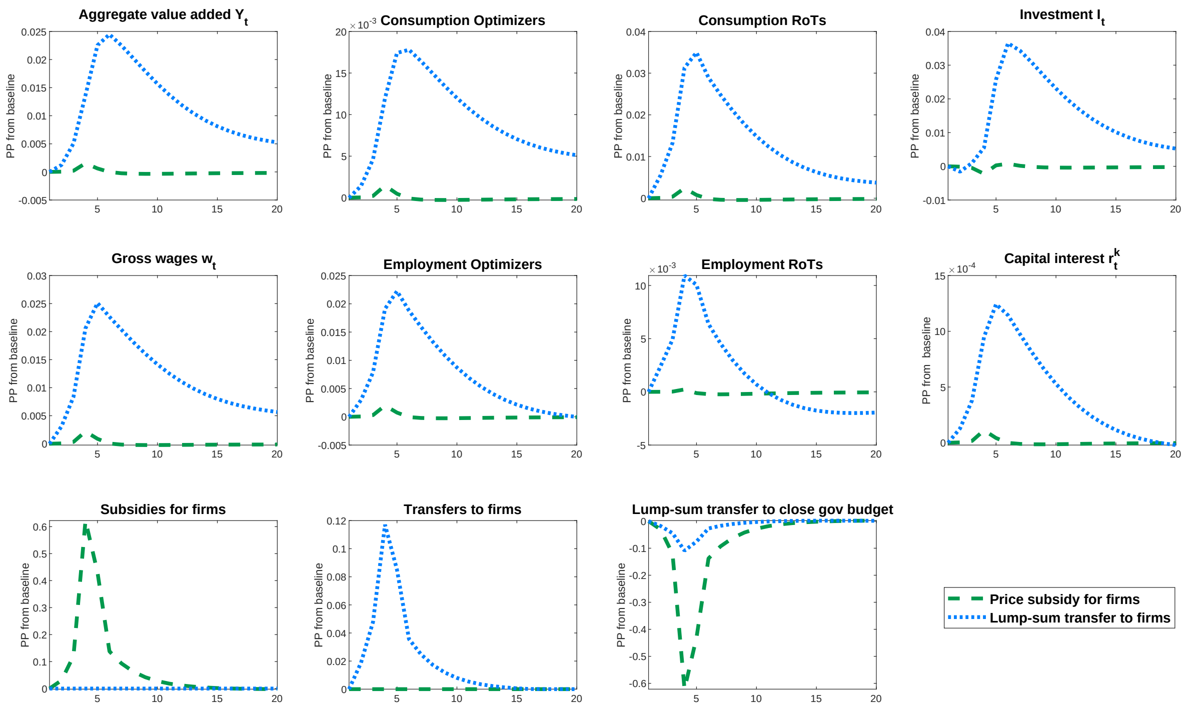
On the sectoral level, the subsidy may even decrease output, as shown in Figure 9. This particularly affects those sectors that purchase a relatively large amount of energy and relatively little gas - such as the *Air transportation* sector (sector 30). Gas-intensive sectors like the brown energy sector, on the other hand, gain slightly from the price subsidy. By contrast, direct transfers stimulate all sectors. Again, those sectors with a high gas consumption benefit the most from the policy.

Figure 7: Implications of mitigation schemes for energy sectors with fixed gas supply.



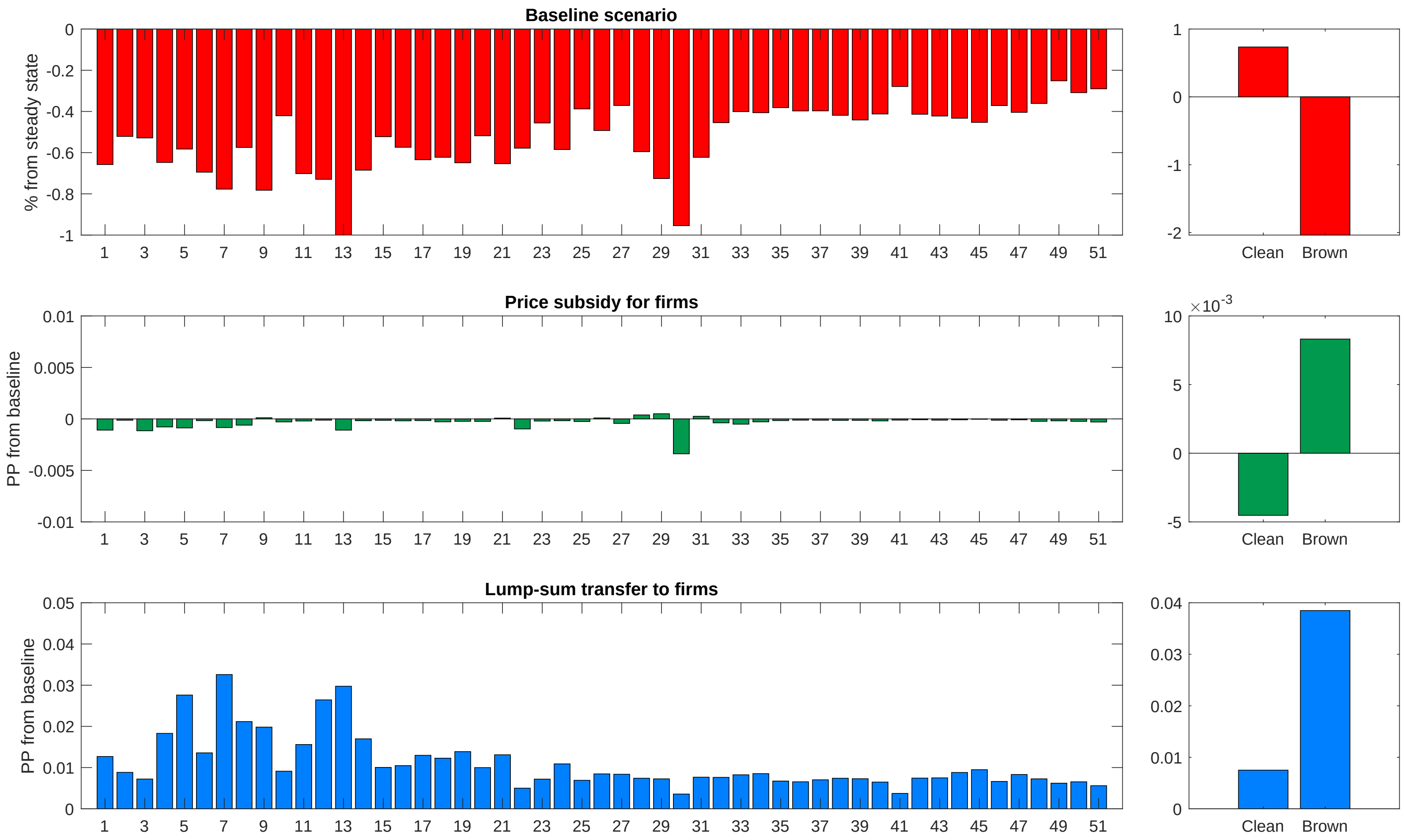
Notes: Figure shows endogenous price increase and exogenous excess gas demand in percentage point deviation from baseline under the assumption that gas supply is fixed at baseline values. The price subsidy for firms is depicted by the green dashed line. The dotted blue line represents the lump-sum transfer to firms. Moreover, figure plots (projected) implications resulting from mitigation schemes for the energy sectors. The dashed (dotted) light green line shows effects of the price subsidy (lump-sum transfer) on the clean energy sector. The dashed (dotted) brown lines show effects of the price subsidy (lump-sum transfer) on the brown energy sector.

Figure 8: Implications of mitigation schemes for macroeconomic variables and government budget with fixed gas supply.



Notes: Figure plots (projected) implications resulting from policy interventions for key macroeconomic variables in percentage point deviations from baseline under the assumption that gas supply is fixed at baseline values. The price subsidy for firms is depicted by the green dashed line. The dotted blue line represents the lump-sum transfer to firms.

Figure 9: Short-run changes in total sectoral output implied by gas price rise and various mitigation schemes with fixed gas supply.



Notes: Figure plots (projected) cumulative percentage deviations of total sectoral output from initial steady state values induced by gas price change (red). Moreover, it shows cumulative percentage point deviations from baseline for the price subsidy (green) and the lump-sum transfer (blue) to firms under the assumption that gas supply is fixed at baseline values. Sector numbers in line with Table A.3.

5.3 Discussion

In the following, we discuss the robustness of our results and the impact of different modeling assumptions. Our benchmark model assumes that gas enters directly into the production function of all sectors. However, it may also be interesting to consider the effects of gas entering only the brown energy sector. Overall, we find that the policy measures have analogous effects in such a model. The difference, however, is that in this case the subsidies accrue only to the brown energy producing sector. The remaining sectors benefit only indirectly from cheaper brown energy (because production costs in this sector are lower as a result of the subsidy).

In such a model, it may be reasonable to assume that the (brown) energy price/use is subsidized instead of the import price of gas in order to help all sectors and not just the brown energy sector (for transfers to firms, of course, energy use instead of gas is the basis for the transfer). Again, we can show that the results presented in the main text hold. It is noteworthy, however, that the marginal cost subsidy is more beneficial relative to the transfers to firms in this model version, even in the simulation where the gas supply path is fixed. This is because other types of energy can now more easily substitute for gas, which can change the ranking of policies.

On the fiscal side, we assume that the government closes the budget by using lump-sum taxes levied only on optimizers. While this can be interpreted as the fiscal cost of the policy measure, such an instrument is of course not really available. The government must use taxes or cut other expenditures, which most likely generate distortions. Already when using consumption taxes to close the budget, we find that the marginal cost subsidy works rather poorly in the case of a fixed gas supply. In fact, because of the extreme gas price hike, using consumption taxes may even generate a greater recession, with the expected effects on optimizers' and RoTs' consumption and welfare levels. Allowing for debt financing alleviates and stretches the consumption tax increase. Nevertheless, it does not prevent negative welfare effects. Although the magnitude of the feedback of the policy measure on the gas price in these simulations is likely to be considerably larger than those observed in the real world, it transparently highlights the effects of the subsidy on the domestic economy due to the large burden placed on financing the measure in combination with the lack of a stimulating effect on the economy that is driven by the gas shortage.

6 Conclusions

This article examines the effectiveness of policy measures designed to mitigate the adverse economic implications of an abrupt surge in the price of an essential production input or its rationing. The sudden escalation in gas prices due to the Russian war of aggression that began in the first quarter of 2022 serves as the primary focus, although the results may also apply to other resources such as rare earths or microchips. The two policy interventions explored in depth are lump-sum transfers and marginal cost subsidies to firms.

Using a dynamic model that incorporates multiple interconnected production sectors and endogenous firm entry and exit, we find that neither of the strategies is universally superior. Rather, the choice hinges on the availability of the essential input. If the input's price rises but it can still be supplied at the escalated price, the subsidy emerges as the preferred policy measure as it directly addresses the distortion. However, if the input has to be rationed, the subsidy exacerbates the situation by further inflating the price without providing additional quantities. In such a scenario, direct transfers to firms prove to be a more effective policy intervention. This is due to the fact that fewer firms exit the market, leading to a higher number of operational firms and increased competition, while the mark-ups are reduced. Nevertheless, the quantitative impact of transfers is relatively minor as they do not directly address the root of the crisis.

References

Alessandri, P. and A. G. Gazzani (2023). Natural Gas and the Macroeconomy: Not All Energy Shocks Are Alike. Available at SSRN 4549079.

Amaglobeli, D., J. Guilhoto, S. Jahan, S. Khalid, R. Lam, G. Legoff, B. Meyer, X. S. Sheng, P. Smietanka, S. Waddell, and D. Weitz (2024). Firms' Resilience to Energy Shocks and Response to Fiscal Incentives: Assessing the Impact of 2022 Energy Crisis. Technical report, IMF Working Papers, forthcoming.

Anil, A., N. Arregui, S. Black, O. Celasun, D. Iakova, A. Mineshima, V. Mylonas, I. Parry, I. Teodoru, and K. Zhunussova (2022). Surging Energy Prices in Europe in the Aftermathof the War: How to Support the Vulnerable and Speed up the Transition Away from Fossil Fuels. Technical report, IMF Working Papers, 152, 1.

Antoszewski, M. (2019). Wide-range Estimation of Various Substitution Elasticities for CES Production Functions at the Sectoral Level. Energy Economics 83(C), 272–289.

Atalay, E. (2017). How Important Are Sectoral Shocks? American Economic Journal: Macroeconomics 9(4), 254–280.

Auclert, A., H. Monnery, M. Rognlie, and L. Straub (2023, August). Managing an Energy Shock: Fiscal and Monetary Policy. Working Paper 31543, National Bureau of Economic Research.

Bachmann, R., D. Baqaee, C. Bayer, M. Kuhn, A. Löschel, B. McWilliams, B. Moll, A. Peichl, K. Pittel, M. Schularick, and G. Zachmann (2022). How It Can Be Done. Policy brief no. 034, ECONtribute.

Bachmann, R., D. Baqaee, C. Bayer, M. Kuhn, A. Löschel, B. Moll, A. Peichl, K. Pittel, and M. Schularick (2022). What if? The Economic Effects for Germany of a Stop of Energy Imports from Russia. Policy brief no. 028, ECONtribute.

Baqaee, D. and E. Farhi (2019). Networks, Barriers, and Trade. NBER Working Papers 26108, National Bureau of Economic Research, Inc.

Baqaee, D. R. (2018). Cascading Failures in Production Networks. Econometrica 86(5), 1819–1838.

Bayer, C., A. Kriwoluzky, G. J. Müller, and F. Seyrich (2023). Hicks in HANK: Fiscal Responses to an Energy Shock. Discussion Paper 2056, DIW Berlin.

Bilbiie, F. O., F. Ghironi, and M. J. Melitz (2012). Endogenous Entry, Product Variety, and Business Cycles. Journal of Political Economy 120(2), 304–345.

Bilbiie, F. O., F. Ghironi, and M. J. Melitz (2019, October). Monopoly Power and Endogenous Product Variety: Distortions and Remedies. American Economic Journal: Macroeconomics 11(4), 140–74.

Bouakez, H., O. Rachedi, and E. Santoro (2023). The Government Spending Multiplier in a Multi-Sector Economy. American Economic Journal: Macroeconomics 15(1), 209–239.

Cavallari, L. (2015). Entry Costs and the Dynamics of Business Formation. Journal of Macroeconomics 44, 312–326.

Coenen, G., R. Straub, and M. Trabandt (2013). Gauging the Effects of Fiscal Stimulus Packages in the Euro Area. Journal of Economic Dynamics and Control 37(2), 367–386.

Cooley, T. and E. Prescott (1995). Economic Growth and Business Cycles. In T. Cooley (Ed.), Frontiers in Business Cycle Research, pp. 1–38. Princeton University Press, Princeton University, NJ.

Corsatea, T. D., S. Lindner, I. Arto, M. V. Roman, J. M. Rueda-Cantuche, A. V. Afonso, A. F. Amores, F. Neuwahl, et al. (2019). World Input-Output Database Environmental Accounts. Update 2000-2016. Technical report, Publications Office of the European Union, Luxembourg.

Dhawan, R., K. Jeske, and P. Silos (2010). Productivity, Energy Prices and the Great Moderation: A New Link. Review of Economic Dynamics 13(3), 715–724.

Dullien, S. and I. M. Weber (2022). Mit einem Gaspreisdeckel die Inflation bremsen. Wirtschaftsdienst 102(3), 154–155.

Ernst, A., N. Hinterlang, A. Mahle, and N. Stähler (2023). Carbon Pricing, Border Adjustment and Climate Clubs: Options for International Cooperation. Journal of International Economics 144(103772).

Eurostat (2008). NACE Rev. 2 – Statistical classification of economic activities in the European Community. Methodologies and working papers, Eurostat.

Gadatsch, N., K. Hauzenberger, and N. Stähler (2016). Fiscal Policy During the Crisis: A Look on Germany and the Euro Area with GEAR. Economic Modelling 52(PB), 997–1016.

Gadatsch, N., N. Stähler, and B. Weigert (2016). German Labor Market and Fiscal Reforms 1999-2008: Can They Be Blamed For Intra-Euro Area Imbalances? Journal of Macroeconomics 50(Supplement C), 307–324.

Gali, J., J. D. Lopez-Salido, and J. Valles (2007). Understanding the Effects of Government Spending on Consumption. Journal of the European Economic Association 5(1), 227–270.

Gavin, W. T., B. D. Keen, and F. E. Kydland (2015). Monetary Policy, the Tax Code, and the Real Effects of Energy Shocks. Review of Economic Dynamics 18(3), 694–707.

Geerolf, F. (2022). The "Baqaee-Farhi approach" and a Russian gas embargo. Revue de l'OFCE 4(179), 2–23.

Ghironi, F. and M. J. Melitz (2005). International Trade and Macroeconomic Dynamics with Heterogeneous Firms. The Quarterly Journal of Economics 120(3), 865–915.

Gornemann, N., S. Hildebrand, and K. Kuester (2022). Limited energy supply, sunspots, and monetary policy. ECONtribute.

Greenwood, J., Z. Hercowitz, and G. W. Huffman (1988). Investment, Capacity Utilization, and the Real Business Cycle. American Economic Review 78(3), 402–417.

Hinterlang, N., A. Martin, O. Röhe, N. Stähler, and J. Strobel (2022). Using energy and emissions taxation to finance labor tax reductions in a multi-sector economy. Energy Economics 115(C).

Hinterlang, N., A. Martin, O. Röhe, N. Stähler, and J. Strobel (2023). The Environmental Multi-Sector DSGE Model EMuSe: A Technical Documentation. Technical Paper 03/2023, Deutsche Bundesbank.

IEA (2021). World energy balances. Technical report, International Energy Agency, https://www.iea.org/reports/world-energy-balances-overview.

Jaimovich, N. and M. Floetotto (2008). Firm dynamics, markup variations, and the business cycle. Journal of Monetary Economics 55(7), 1238–1252.

Jaimovich, N. and S. Rebelo (2009). Can News about the Future Drive the Business Cycle? American Economic Review 99(4), 1097–1118.

Kim, I.-M. and P. Loungani (1992). The Role of Energy in Real Business Cycle Models. Journal of Monetary Economics 29(2), 173–189.

King, R. G., C. I. Plosser, and S. T. Rebelo (1988). Production, growth and business cycles: I. the basic neoclassical model. Journal of Monetary Economics 21(2), 195–232.

Krebs, T. (2022). Auswirkungen eines Erdgasembargos auf die gesamtwirtschaftliche Produktion in Deutschland. IMK Studies 79-2022, IMK at the Hans Boeckler Foundation, Macroeconomic Policy Institute.

Langot, F. and A. G. Gazzani (2023). The Macroeconomic and Redistributive Effects of Shielding Consumers from Rising Energy Prices: the French Experiment. Technical report, CEPREMAP.

Lucas, R. E. (2003). Macroeconomic Priorities. American Economic Review 93(1), 1–14.

Mitchell, P. R., J. E. Sault, and K. F. Wallis (2000). Fiscal policy rules in macroeconomic models: principles and practice. Economic Modelling 17(2), 171–193.

Moll, B., M. Schularick, and G. Zachmann (2023). The power of substitution: The great german gas debate in retrospect. Brookings Papers on Economic Activity.

OECD (2023). Aiming Better: Government Support for Households and Firms During the Enery Crisis. Technical report, OECD Economic Policy Paper, No. 32.

Röhe, O. and N. Stähler (2020). Demographics and the decline in firm entry: Lessons from a life-cycle model. Discussion Papers 15/2020, Deutsche Bundesbank.

Sgaravatti, G., S. Tagliapietra, C. Trasi, and G. Zachmann (2023). National Fiscal Policy Responses to the Energy Crisis. Datasets, Bruegel.

Stähler, N. and C. Thomas (2012). FiMod - A DSGE model for fiscal policy simulations. Economic Modelling 29(2), 239–261.

Timmer, M. P., E. Dietzenbacher, B. Los, R. Stehrer, and G. J. De Vries (2015). An illustrated user guide to the world input–output database: the case of global automotive production. Review of International Economics 23(3), 575–605.

Appendix A: Calibration details

This section provides tables with details on the calibration, i.e. it summarizes the general parameters, describes the sectoral split and summarizes sector-specific variables.

Table A.1: Baseline calibration of general parameters

Variable/Parameter	Symbol	Value
Discount factor	β	0.992
Elasticity of intertemporal substitution	σ	2.000
GHH parameter	γ	0.050
Inverse of Frisch elasticity of lab. supply	ζ	2.000
Labor disutility scaling	κ^N	6.331
Capital depreciation rate	δ^k	0.025
Capital adjustment costs	κ^I	25.00
Fixed cost	ϕ_s	0.150
Consumption tax rate	$\bar{\tau}^c$	0.190
Labor tax rate	$\bar{\tau}^n$	0.300
AR(1) coefficient fiscal instruments	ρ^x	0.900
Share of non-energy consumption	ψ_C	0.962
Steady state mark up rel. parameters	$\bar{\mu}_s$	1.300
EOS within sub-sectoral goods	τ_s^f	0.949
EOS across sub-sectoral goods	ω_s^f	0.001
Shape parameter of Pareto distribution	κ^{ex}	1.500

Notes: The table shows calibrated values for general parameters as described in the main text.

Table A.2: Baseline calibration of parameters determining the elasticity of substitution (EOS)

Symbol	Value	EOS	Determines EOS between...
σ_C	-2.704	0.270	*NE* & *E* consumption bundles
$\sigma_{C^{NE}}$	-0.100	0.909	*NE* consumption goods
σ_{C^E}	0.600	2.500	*E* consumption goods
σ_I	-0.332	0.751	investment goods
ν_N	2.000	-1.000	labor across sectors
ν_K	2.000	-1.000	capital across sectors
$\sigma_{H,s}$	-9.000	0.100	*NE* & *E* intermediate input bundles
$\sigma_{NE,s}$	-2.333	0.300	*NE* intermediate inputs
$\sigma_{E,s}$	0.600	2.500	*E* intermediate inputs

Notes: The table shows calibrated values for the parameters determining the EOS as described in the main text. *NE* and *E* refer to non-energy and energy, respectively. The EOS reported in column three is computed as $1 - 1/\sigma$, where $\sigma \in \{\sigma_C, \sigma_{C^{NE}}, \sigma_{C^E}, \sigma_I, \nu_N, \nu_K, \sigma_{H,s}, \sigma_{NE,s}, \sigma_{E,s}\}$.

Table A.3: Baseline calibration of sector-specific parameters

	$\alpha_{N,s}$	$\alpha_{H,s}$	$\alpha_{O,s}$	$\alpha_{NE,s}$	$\psi_{E,s,53}$	N_s/N	K_s/K	$\psi_{C^{NE},s}/\psi_C$ or $\psi_{C^E,s}/(1-\psi_C)$	$\psi_{I,s}$	$\bar{\delta}_s^N$
1) Crop and animal production, hunting and related service activities	0.804	0.327	0.002	0.951	0.960	0.014	0.015	0.006	0.002	0.025
2) Forestry and logging	0.677	0.443	0.001	0.981	0.324	0.001	0.001	0.002	0.000	0.025
3) Fishing and aquaculture	0.658	0.516	0.001	0.939	0.996	0.000	0.000	0.000	0.000	0.025
4) Manufacture of food products, beverages and tobacco products	0.769	0.229	0.011	0.988	0.478	0.022	0.006	0.084	0.001	0.019
5) Manufacture of textiles, wearing apparel and leather products	0.775	0.337	0.020	0.975	0.531	0.004	0.001	0.010	0.002	0.034
6) Manufacture of wood and of products of wood and cork, except furniture; MF of articles of straw and plaiting materials	0.794	0.271	0.003	0.967	0.238	0.003	0.001	0.002	0.015	0.019
7) Manufacture of paper and paper products	0.640	0.281	0.021	0.955	0.509	0.004	0.002	0.004	0.000	0.024
8) Printing and reproduction of recorded media	0.640	0.405	0.013	0.984	0.524	0.004	0.001	0.003	0.000	0.032
9) Manufacture of chemicals and chemical products	0.565	0.306	0.014	0.950	0.755	0.008	0.008	0.009	0.002	0.016
10) Manufacture of basic pharmaceutical products and pharmaceutical preparations	0.359	0.511	0.008	0.986	0.610	0.003	0.006	0.006	0.001	0.016
11) Manufacture of rubber and plastic products	0.667	0.361	0.011	0.967	0.712	0.010	0.003	0.004	0.003	0.011
12) Manufacture of other non-metallic mineral products	0.656	0.368	0.032	0.949	0.455	0.006	0.002	0.003	0.002	0.017
13) Manufacture of basic metals	0.670	0.214	0.021	0.932	0.760	0.006	0.003	0.001	0.004	0.016
14) Manufacture of fabricated metal products, except machinery and equipment	0.743	0.425	0.009	0.982	0.657	0.022	0.004	0.004	0.032	0.016
15) Manufacture of computer, electronic and optical products	0.604	0.467	0.003	0.987	0.773	0.008	0.006	0.004	0.012	0.018
16) Manufacture of electrical equipment	0.655	0.420	0.002	0.986	0.861	0.012	0.004	0.008	0.024	0.018
17) Manufacture of machinery and equipment n.e.c.	0.692	0.391	0.004	0.991	0.695	0.027	0.010	0.004	0.112	0.013
18) Manufacture of motor vehicles, trailers and semi-trailers	0.552	0.315	0.002	0.993	0.736	0.020	0.017	0.047	0.067	0.015
19) Manufacture of other transport equipment	0.676	0.335	0.005	0.992	0.591	0.003	0.002	0.000	0.008	0.015
20) Manufacture of furniture; other manufacturing	0.762	0.460	0.003	0.986	0.757	0.010	0.002	0.013	0.026	0.019
21) Repair and installation of machinery and equipment	0.881	0.400	0.002	0.989	0.831	0.006	0.001	0.001	0.029	0.020
22) Water collection, treatment and supply	0.375	0.598	0.001	0.881	0.959	0.001	0.006	0.007	0.000	0.013
23) Sewerage; waste collection, treatment and disposal activities materials recov.; remediation act. & other waste managem. serv.	0.430	0.449	0.001	0.980	0.764	0.005	0.024	0.023	0.001	0.013
24) Construction	0.777	0.437	0.001	0.983	0.911	0.058	0.005	0.006	0.439	0.022
25) Wholesale and retail trade and repair of motor vehicles and motorcycles	0.711	0.678	0.007	0.968	0.781	0.020	0.004	0.029	0.022	0.021
26) Wholesale trade, except of motor vehicles and motorcycles	0.710	0.580	0.003	0.974	0.805	0.045	0.010	0.022	0.028	0.025
27) Retail trade, except of motor vehicles and motorcycles	0.877	0.527	0.007	0.976	0.700	0.077	0.009	0.129	0.008	0.031
28) Land transport and transport via pipelines	0.568	0.496	0.001	0.942	0.971	0.022	0.009	0.022	0.001	0.032
29) Water transport	0.179	0.303	0.001	0.941	1.000	0.001	0.005	0.000	0.000	0.029
30) Air transport	0.738	0.250	0.001	0.852	0.999	0.002	0.002	0.010	0.000	0.035
31) Warehousing and support activities for transportation	0.549	0.383	0.001	0.979	0.876	0.015	0.026	0.002	0.001	0.022
32) Postal and courier activities	0.924	0.470	0.002	0.982	0.885	0.011	0.001	0.003	0.000	0.048
33) Accommodation and food service activities	0.833	0.469	0.004	0.982	0.686	0.043	0.005	0.067	0.000	0.035
34) Publishing activities	0.592	0.465	0.002	0.992	0.821	0.006	0.001	0.013	0.000	0.028
35) Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities	0.475	0.560	0.001	0.990	0.010	0.003	0.002	0.009	0.013	0.028
36) Telecommunications	0.325	0.413	0.001	0.989	0.010	0.003	0.006	0.032	0.004	0.033

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continued from previous page	$\alpha_{N,s}$	$\alpha_{H,s}$	$\alpha_{O,s}$	$\alpha_{NE,s}$	$\psi_{E,s,53}$	N_s/N	K_s/K	$\psi_{C^{NE},s}/\psi_C$ or $\psi_{C^{E},s}/(1-\psi_C)$	$\psi_{I,s}$	$\bar{\delta}_s^N$
37) Computer programming, consultancy and related activities; information service activities	0.697	0.612	0.001	0.988	0.010	0.017	0.004	0.003	0.046	0.039
38) Financial service activities, except insurance and pension funding	0.678	0.456	0.002	0.995	0.538	0.016	0.010	0.037	0.001	0.016
39) Insurance, reinsurance and pension funding, except compulsory social security	0.498	0.349	0.002	0.997	0.501	0.004	0.006	0.038	0.000	0.013
40) Activities auxiliary to financial services and insurance activities	0.498	0.453	0.001	0.996	0.681	0.008	0.000	0.001	0.000	0.026
41) Real estate activities	0.048	0.764	0.001	0.989	0.877	0.011	0.526	0.222	0.013	0.019
42) Legal and accounting activities; activities of head offices; management consultancy activities	0.890	0.586	0.001	0.989	0.010	0.031	0.005	0.001	0.007	0.032
43) Architectural and engineering activities; technical testing and analysis	0.711	0.597	0.001	0.989	0.010	0.016	0.002	0.002	0.042	0.028
44) Scientific research and development	0.506	0.646	0.001	0.979	0.010	0.005	0.008	0.000	0.000	0.036
45) Advertising and market research	0.429	0.566	0.001	0.993	0.010	0.006	0.000	0.000	0.000	0.043
46) Other professional, scientific and technical activities; veterinary activities	0.551	0.543	0.001	0.984	0.010	0.005	0.000	0.007	0.000	0.035
47) Administrative and support service activities	0.538	0.612	0.005	0.991	0.523	0.072	0.028	0.012	0.011	0.035
48) Public administration and defence; compulsory social security	0.802	0.657	0.005	0.984	0.629	0.061	0.076	0.011	0.004	0.017
49) Education	0.884	0.768	0.012	0.983	0.519	0.057	0.033	0.018	0.000	0.044
50) Human health and social work activities	0.789	0.689	0.010	0.984	0.504	0.126	0.047	0.042	0.000	0.017
51) Other service activities	0.666	0.677	0.005	0.981	0.736	0.052	0.024	0.056	0.004	0.051
52) Clean energy	0.328	0.385	0.001	0.700	0.020	0.004	0.012	0.145	0.009	0.042
53) Brown energy	0.325	0.088	0.039	0.665	0.886	0.003	0.009	0.855	0.001	0.042

Notes: The table shows calibrated values for sector-specific parameters as described in the main text. The values were computed by the authors based on the World Input-Output Database and Environmental Accounts for the year 2014. Exit rates stem from Destatis.

Table A.4: Input-Output Matrix, Non-energy Inputs, $\psi_{H,s,j}$

	Consumer s																										
Producer j	1)	2)	3)	4)	5)	6)	7)	8)	9)	10)	11)	12)	13)	14)	15)	16)	17)	18)	19)	20)	21)	22)	23)	24)	25)	26)	27)
1)	8.1	7.5	0.0	25.2	0.5	0.0	0.1	0.0	0.2	0.3	1.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.2	0.1
2)	0.3	37.9	0.0	0.0	0.0	10.4	0.8	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.1	0.0	0.0	0.0
3)	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4)	18.6	0.2	0.5	20.6	0.8	0.3	0.2	0.2	3.9	2.1	0.4	0.3	0.3	0.2	0.5	0.3	0.2	0.1	0.2	0.4	0.3	0.1	0.1	0.3	0.2	0.3	0.2
5)	0.2	0.1	13.0	0.1	16.0	0.1	0.1	0.1	0.1	0.2	1.0	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.9	0.1	0.1	0.1	0.2	0.1	0.1	0.1
6)	0.3	6.2	1.5	0.2	0.3	29.8	2.3	0.1	0.4	0.3	0.5	0.5	0.2	0.5	0.5	0.2	0.5	0.2	1.3	10.1	0.4	0.3	0.2	3.3	0.1	0.2	0.2
7)	0.2	0.3	1.8	1.8	1.9	1.2	40.9	24.8	1.6	1.9	1.2	1.0	0.2	0.5	1.5	0.8	0.3	0.1	0.3	1.3	0.4	0.2	0.1	0.2	0.1	0.7	1.1
8)	0.2	0.4	1.3	0.3	2.0	0.7	1.6	33.2	0.5	0.7	0.6	0.5	0.4	0.5	1.3	0.7	0.5	0.4	0.4	1.5	0.5	0.7	1.0	0.2	2.1	1.0	5.0
9)	6.8	2.3	1.7	1.0	9.9	6.9	4.3	3.1	32.1	9.7	25.5	3.6	3.1	1.8	3.1	1.2	1.4	1.6	1.2	1.8	1.1	1.5	0.8	1.8	0.8	0.6	0.5
10)	0.2	0.1	0.1	0.1	0.3	0.1	0.1	0.1	0.6	6.6	0.4	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
11)	1.1	0.6	0.6	1.9	2.4	1.2	3.6	0.9	2.1	2.3	15.9	1.4	0.4	2.0	2.2	2.2	4.2	4.5	2.0	4.3	3.4	1.2	1.3	6.1	4.7	0.7	1.5
12)	1.9	2.4	0.2	0.6	1.4	5.9	0.3	0.1	1.0	1.5	1.3	21.7	1.7	1.1	2.1	1.1	0.6	0.9	0.6	1.6	1.5	0.9	0.6	11.6	0.7	0.1	0.1
13)	0.3	0.3	0.2	0.1	0.3	0.4	0.5	0.1	1.4	0.3	1.0	0.5	37.5	16.6	2.6	5.2	6.0	4.1	5.8	1.9	6.4	1.1	0.2	1.3	1.0	0.2	0.2
14)	1.5	1.8	6.4	0.8	1.7	1.9	0.4	0.3	1.6	1.3	3.2	1.3	3.7	36.4	5.2	5.6	12.4	6.4	13.1	7.8	11.3	3.4	4.1	7.1	5.1	0.4	0.4
15)	0.5	0.4	1.0	0.5	0.7	0.4	0.4	0.7	0.5	0.5	0.5	0.6	0.7	0.6	5.3	1.9	1.1	0.4	1.1	1.4	1.5	0.5	0.4	0.6	0.3	0.4	0.4
16)	0.6	0.5	0.8	0.4	0.7	0.4	0.4	0.3	0.6	0.4	0.7	1.1	1.6	1.7	3.9	30.2	5.8	2.7	3.1	1.9	7.9	2.6	0.7	7.7	1.4	0.4	0.3
17)	2.0	3.3	1.7	0.6	1.2	0.4	0.6	1.3	0.8	0.5	1.1	1.1	1.8	3.5	2.2	2.9	22.4	3.9	5.4	1.7	7.5	4.0	2.0	1.7	1.1	0.4	0.4
18)	1.3	0.6	0.3	0.2	0.4	0.2	0.2	0.2	0.4	1.4	0.7	0.9	0.8	1.4	1.0	1.2	5.5	42.5	2.4	2.2	10.3	0.9	0.6	0.6	15.6	0.3	0.8
19)	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1	13.8	0.1	2.4	0.1	0.0	0.0	0.0	0.0	0.0
20)	0.2	0.2	0.3	0.1	1.2	0.3	0.1	0.1	0.2	0.3	0.3	0.2	0.3	0.6	2.2	0.4	0.3	0.4	0.8	9.4	0.9	0.1	0.1	0.2	0.2	0.1	0.1
21)	0.3	0.3	0.6	0.5	0.8	0.5	1.0	0.6	1.4	0.2	0.6	1.6	3.5	2.0	1.8	0.8	1.8	0.8	6.2	1.2	3.4	0.9	0.2	0.3	0.1	0.1	0.2
22)	0.8	0.1	0.9	0.4	0.5	0.2	1.2	0.2	0.7	0.7	0.4	0.9	0.9	0.3	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.9	1.1	0.1	0.3	0.1	0.2
23)	1.4	0.4	0.6	0.8	1.5	1.1	6.4	0.2	2.8	7.7	1.9	3.0	6.8	0.2	0.1	0.2	0.2	0.1	0.1	0.4	0.1	6.3	12.6	0.2	0.3	0.2	0.6
24)	2.1	2.8	6.2	1.1	1.7	1.1	1.1	1.6	1.4	1.9	1.1	2.0	1.5	1.1	1.4	0.9	1.2	0.6	1.0	1.0	1.1	15.2	12.0	14.0	2.6	1.1	2.3
25)	1.2	0.7	0.0	0.2	0.3	0.6	0.3	0.3	0.2	0.3	0.2	0.8	0.2	0.3	0.3	0.3	0.8	5.2	1.5	0.4	1.5	1.2	1.7	0.5	4.6	0.6	3.4
26)	10.7	8.1	26.5	12.0	15.7	8.9	6.5	2.5	6.6	7.3	8.0	9.9	10.0	6.9	14.6	11.8	7.2	3.3	6.8	13.2	7.3	4.4	5.1	8.8	2.3	6.4	3.4
27)	2.5	1.1	5.0	2.7	14.7	3.7	2.3	0.6	1.3	3.5	1.6	2.1	0.8	1.3	5.2	2.1	1.6	0.9	1.7	6.4	2.0	0.7	0.6	2.8	0.8	0.6	0.6
28)	1.0	1.7	0.8	3.0	1.1	4.4	4.9	0.7	3.5	0.9	3.3	9.7	6.2	1.4	3.1	1.7	1.8	1.9	4.3	3.9	1.3	2.3	0.4	0.6	1.1	17.5	3.7
29)	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
30)	0.1	0.1	0.0	0.1	0.4	0.3	0.4	0.2	0.4	0.4	0.3	0.4	0.2	0.2	0.6	0.3	0.3	0.2	0.4	0.3	0.4	0.2	0.2	0.1	0.2	0.3	0.2
31)	0.4	0.4	8.2	4.4	1.2	1.7	0.9	0.4	1.6	0.6	2.2	3.4	1.2	1.3	3.1	1.5	2.1	1.8	0.7	1.8	1.4	1.2	0.5	0.7	1.8	28.2	3.1
32)	0.1	0.1	0.0	0.2	0.5	0.1	0.2	0.5	0.7	1.1	0.4	0.3	0.2	0.5	1.2	0.8	0.6	0.2	0.2	0.7	0.6	1.1	0.5	0.1	0.9	1.6	11.3
33)	0.1	0.1	0.8	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.2	0.5	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.3	0.5	0.3
34)	0.1	0.2	0.1	0.2	0.3	0.1	0.2	0.3	0.4	0.6	0.2	0.3	0.2	0.2	0.5	0.3	0.2	0.2	0.3	0.3	0.2	0.8	1.3	0.1	0.5	0.4	1.3
35)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.4
36)	0.3	0.8	0.0	0.3	0.7	0.7	0.6	0.8	0.7	0.8	0.9	1.1	0.4	0.9	1.6	1.1	0.8	0.4	0.7	0.6	0.8	1.8	1.5	0.7	0.9	1.1	1.2
37)	0.1	0.1	0.0	0.3	0.5	0.4	0.7	1.1	1.2	1.6	0.6	0.9	0.7	1.0	2.4	1.1	1.0	0.6	1.3	0.8	1.1	2.7	3.5	0.4	1.0	1.1	1.4
38)	3.4	3.0	0.9	1.4	1.8	1.7	1.6	1.9	1.6	2.0	1.8	2.0	1.7	1.9	2.1	1.6	1.7	1.2	1.6	1.8	1.8	3.0	2.2	3.4	5.7	2.9	4.3
39)	1.8	0.5	0.8	0.4	0.2	0.9	0.7	0.7	0.9	0.4	0.7	0.9	0.2	0.2	0.3	0.2	0.3	0.2	0.3	0.5	0.3	2.4	2.2	0.6	1.2	0.5	1.6
40)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41)	2.0	0.7	0.8	3.0	4.5	3.9	3.4	6.1	3.3	4.1	3.9	3.8	2.8	3.5	4.7	3.3	2.9	3.4	3.5	3.2	3.0	3.9	4.9	10.6	22.2	12.8	23.1
42)	0.6	0.2	0.7	3.0	1.0	1.1	1.9	2.7	3.9	3.4	3.5	3.9	2.6	1.6	4.8	6.0	6.2	2.9	2.5	1.9	5.3	2.3	2.9	1.3	4.8	4.0	5.4
43)	1.1	0.3	0.0	0.4	0.1	1.3	1.4	0.1	2.4	2.2	2.7	4.2	1.0	1.5	3.4	3.2	1.6	0.8	3.9	0.6	2.9	10.9	13.9	1.3	0.1	0.3	0.4
44)	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.3	2.4	14.7	1.3	1.7	0.5	0.1	2.1	0.9	0.3	1.0	5.4	0.3	2.6	0.0	0.0	0.0	0.0	0.1	0.0
45)	0.4	0.3	1.1	5.9	1.5	0.4	0.8	0.4	4.5	6.0	1.9	1.5	0.3	0.7	2.9	1.2	0.8	1.5	0.6	3.6	0.9	2.0	1.2	0.1	7.6	2.7	4.7
46)	1.5	0.0	0.0	0.2	4.5	0.1	0.3	0.5	0.7	0.5	0.4	0.6	0.2	0.3	0.9	0.5	0.5	0.4	0.3	2.1	0.4	0.7	0.9	0.1	0.6	0.5	0.6
47)	22.6	10.4	4.1	3.3	2.8	4.9	4.4	9.4	6.9	5.6	4.9	7.6	3.5	3.5	5.7	3.9	3.5	2.6	3.3	4.0	3.5	10.6	13.3	8.3	5.1	8.7	11.7
48)	0.5	1.9	1.5	0.5	0.6	0.6	0.6	0.6	0.9	0.9	0.7	1.2	0.5	0.4	0.6	0.5	0.3	0.3	0.3	0.5	0.4	3.8	1.7	0.9	0.6	0.4	0.6
49)	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.1	0.2	0.3	0.2	0.3	0.4	0.1	0.5	0.1	0.1	0.0	0.0	0.0	0.0
50)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
51)	0.7	0.5	1.8	0.7	1.0	0.5	0.6	1.6	0.8	1.6	0.5	0.8	0.6	0.4	1.3	0.6	0.4	0.3	0.4	0.8	0.4	2.1	2.8	0.6	0.8	0.8	2.4

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	Consumer s																									
Producer j	28)	29)	30)	31)	32)	33)	34)	35)	36)	37)	38)	39)	40)	41)	42)	43)	44)	45)	46)	47)	48)	49)	50)	51)	52)	53)
1)	0.1	0.2	0.1	0.2	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.5	0.3	0.2	0.8	0.3	0.1	0.2
2)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4)	0.1	1.2	0.2	0.1	0.0	24.1	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.1	1.8	1.3	8.6	0.5	0.2	0.7
5)	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1
6)	0.1	0.0	0.0	0.1	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.1	0.0	0.2	0.1	0.2	0.3	0.1	1.7	0.7	0.5
7)	0.1	0.0	0.1	0.1	0.1	0.2	1.7	0.1	0.1	0.5	0.1	0.0	0.0	0.0	0.2	0.5	0.4	0.2	0.8	0.2	0.2	0.2	0.3	0.2	0.2	0.7
8)	0.5	0.1	0.2	0.2	5.7	0.3	21.9	7.0	2.4	4.2	1.4	0.5	0.1	0.2	2.1	2.0	1.5	1.7	3.0	1.8	2.0	1.9	0.4	1.0	0.5	0.5
9)	0.5	0.5	1.3	0.2	0.3	0.8	0.5	0.3	0.3	0.9	0.2	0.1	0.1	0.2	0.3	0.4	1.4	0.2	0.8	1.0	0.8	0.6	1.4	1.2	1.1	6.0
10)	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.0	0.3	0.1	0.1	0.1	2.9	0.2	0.1	0.1
11)	0.9	0.1	0.1	0.3	0.2	0.4	0.1	0.1	0.2	0.2	0.1	0.0	0.0	0.1	0.3	0.3	0.3	0.2	0.5	0.3	0.5	0.1	0.5	0.3	1.2	0.7
12)	0.2	0.1	0.1	0.2	0.1	0.5	0.0	0.0	0.5	0.1	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.0	0.1	0.2	0.4	0.2	0.3	0.7	2.6	2.1
13)	0.6	0.1	0.2	0.2	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	1.3	1.0
14)	0.9	0.1	0.2	0.7	0.2	0.4	0.1	0.2	0.4	0.3	0.1	0.0	0.0	0.3	0.1	0.2	0.5	0.1	0.2	0.3	1.2	0.3	0.4	0.4	2.1	3.3
15)	0.3	0.2	0.5	0.1	0.4	0.6	0.6	0.5	1.6	1.6	0.2	0.1	0.1	0.1	0.2	0.3	0.8	0.2	0.4	0.3	0.4	0.4	0.6	0.4	0.6	1.0
16)	0.9	0.2	0.6	0.3	0.4	0.7	0.3	0.3	0.8	0.8	0.1	0.1	0.1	0.2	0.1	0.3	0.8	0.1	0.3	0.3	0.4	0.2	0.4	1.0	6.3	1.3
17)	0.7	0.3	0.7	0.2	0.2	0.6	0.3	0.5	0.6	0.7	0.1	0.1	0.1	0.2	0.1	0.2	0.8	0.1	0.3	0.2	0.4	0.2	0.6	0.2	1.8	3.0
18)	3.5	0.1	0.4	1.5	0.2	0.2	0.2	0.1	0.2	0.5	0.1	0.1	0.1	0.1	0.1	0.2	1.7	0.1	0.2	0.4	1.4	0.4	0.3	0.2	0.5	0.4
19)	0.2	0.0	4.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	2.0	0.0	0.1	0.0	0.1	0.3
20)	0.1	0.0	0.1	0.1	0.0	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.3	0.1	0.1	0.3	3.4	0.2	0.2	0.3
21)	1.5	1.0	3.1	0.2	0.1	0.1	0.1	1.9	1.2	0.2	0.0	0.0	0.0	0.5	0.1	0.1	0.2	0.0	0.5	0.1	0.4	0.1	0.6	0.1	2.7	5.3
22)	0.2	0.0	0.0	0.1	0.2	0.9	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.2	0.2	0.2	0.1	0.3	0.2	0.5	1.1	0.6	1.0	1.2	0.5
23)	0.2	0.0	0.0	0.2	0.2	0.7	0.1	0.1	0.1	0.2	0.1	0.1	0.0	0.1	0.2	0.2	0.3	0.1	0.3	0.4	2.5	0.3	0.8	0.3	0.4	1.0
24)	2.7	0.7	0.7	3.6	2.6	3.2	1.2	1.8	2.4	2.3	1.2	0.6	1.2	28.7	1.9	1.9	1.9	1.5	3.4	2.2	7.9	5.3	5.6	3.4	11.3	4.1
25)	4.2	0.1	0.1	4.3	0.9	0.5	0.3	0.3	0.4	0.3	0.1	0.1	0.2	0.0	0.2	0.2	0.4	0.2	0.4	0.7	0.6	0.4	0.3	0.3	0.4	0.4
26)	2.3	2.9	4.8	1.2	2.0	13.3	2.6	1.4	3.9	5.0	0.5	0.3	0.4	0.2	1.2	2.2	4.0	1.3	3.0	2.1	3.0	3.2	8.0	4.1	4.3	12.2
27)	0.7	0.5	1.2	0.3	0.4	2.3	0.6	0.5	1.6	0.9	0.1	0.1	0.1	0.1	0.3	0.6	1.0	0.4	1.0	0.4	0.9	1.0	4.2	1.4	1.1	1.8
28)	10.6	6.1	2.8	30.5	1.7	0.2	3.1	0.4	0.1	0.6	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.7	0.3	0.5	12.5	0.1	0.6	10.1	13.4
29)	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
30)	0.1	0.1	1.6	0.1	1.1	0.0	0.5	0.9	0.1	1.0	0.5	0.3	0.1	0.0	0.6	0.8	1.4	0.4	1.8	0.5	1.0	0.1	0.1	0.7	0.1	0.6
31)	26.8	70.7	32.2	35.0	20.1	0.7	0.5	0.1	0.4	0.3	0.1	0.0	0.1	0.1	0.3	0.3	0.2	0.3	1.0	0.4	0.2	0.7	0.1	0.2	1.2	3.8
32)	1.3	0.0	0.2	0.5	30.4	0.7	1.6	0.8	9.3	0.9	0.9	1.0	2.8	0.3	1.2	1.3	1.0	0.8	1.6	0.7	2.6	0.2	0.9	0.9	1.0	0.4
33)	0.5	0.0	1.3	0.1	0.1	0.1	0.2	0.4	0.3	0.3	0.3	0.2	0.2	0.1	0.2	0.2	0.3	0.1	0.3	0.2	0.6	0.1	0.3	0.6	0.1	0.2
34)	0.4	0.1	0.1	0.2	0.4	1.2	9.3	1.2	0.6	2.1	0.6	0.4	0.5	0.2	2.5	5.2	7.2	3.0	5.8	1.9	2.7	4.6	0.9	2.0	0.4	0.3
35)	0.0	0.0	0.1	0.0	0.0	6.7	1.2	37.7	2.5	0.8	0.6	0.9	0.0	0.2	1.1	1.1	0.0	51.3	1.7	0.6	0.3	0.9	1.3	1.1	0.2	0.1
36)	1.1	0.2	0.6	0.9	10.1	2.6	6.4	13.0	36.0	4.2	2.2	1.1	1.9	0.8	1.2	1.2	2.7	5.2	1.6	2.5	2.1	0.7	1.6	2.3	0.8	1.2
37)	1.9	0.1	0.6	1.7	3.6	0.6	8.4	2.1	4.6	34.8	3.1	1.2	1.7	0.3	2.2	2.7	11.8	2.0	4.0	1.8	2.3	2.8	2.4	1.3	1.1	0.9
38)	3.3	0.9	1.2	1.8	2.6	4.0	1.5	1.5	2.6	3.3	37.0	4.3	28.4	17.1	3.4	4.4	1.6	3.1	6.8	2.7	4.4	2.3	4.9	8.8	3.1	3.7
39)	8.1	0.2	0.4	2.1	0.4	0.6	0.3	0.3	0.3	0.6	1.3	13.5	24.2	0.2	0.5	0.5	0.5	0.4	0.8	1.5	2.6	4.4	0.9	0.9	2.6	0.7
40)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	12.8	48.8	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0
41)	2.6	0.3	0.4	3.4	2.3	14.3	3.3	3.0	11.5	4.6	9.2	4.6	4.0	19.5	10.7	14.2	5.4	6.3	12.5	4.5	8.0	3.4	8.8	4.2	4.0	5.6
42)	2.0	0.1	0.2	0.6	1.1	1.0	3.6	1.8	2.4	7.0	12.6	10.1	4.3	20.0	47.6	30.1	2.2	6.9	21.4	11.8	3.0	0.6	2.8	1.9	3.1	5.7
43)	4.0	0.2	0.6	1.7	0.2	0.3	0.3	0.1	0.5	1.6	0.7	0.2	0.4	1.7	1.3	6.8	8.7	1.1	2.1	1.3	1.9	0.7	1.2	0.7	5.6	2.0
44)	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.1	17.2	0.0	0.0	0.6	12.7	2.8	0.6	0.1	0.0	0.3
45)	1.1	0.1	0.5	0.2	2.4	0.4	5.1	1.7	2.4	1.5	1.4	1.3	0.1	0.1	0.9	0.8	0.2	0.6	1.2	1.2	0.7	0.2	0.2	1.1	1.0	3.3
46)	0.5	0.0	0.0	0.1	0.2	0.3	6.1	1.4	0.7	1.4	1.8	1.9	3.3	0.9	2.8	2.7	0.8	2.3	4.4	1.5	0.8	0.2	1.9	0.4	0.7	0.6
47)	11.9	11.9	36.2	5.6	7.8	10.0	9.9	6.0	5.2	7.7	6.8	6.4	9.4	3.7	6.9	9.2	6.1	4.6	6.9	50.6	8.0	6.2	9.3	11.8	9.9	6.5
48)	0.8	0.1	0.1	0.3	0.3	0.5	0.3	0.4	0.3	1.2	0.3	0.2	0.1	1.9	2.6	3.5	3.2	1.9	1.3	1.4	4.1	0.7	0.9	1.2	12.2	1.5
49)	0.8	0.0	0.7	0.2	0.6	0.0	0.2	0.1	0.2	2.9	1.0	0.2	0.2	0.6	0.1	0.0	9.3	0.1	0.3	0.3	4.1	33.6	0.4	0.7	0.1	0.2
50)	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.1	1.3	0.6	15.0	0.4	0.0	0.0
51)	0.8	0.2	0.5	0.8	0.3	2.6	6.9	11.4	1.8	3.3	1.9	0.9	0.6	0.4	5.5	3.8	2.5	2.7	5.6	1.2	7.7	3.1	3.5	38.4	1.6	1.4

Notes: This table reports the share of total intermediates (in expenditure terms and %) used by the consuming sector that comes from the producing sector. (For example, 7.5% of the total intermediates used by the second sector stem from the first sector.) The shares were computed by the authors based on the World Input-Output Database for the year 2014.

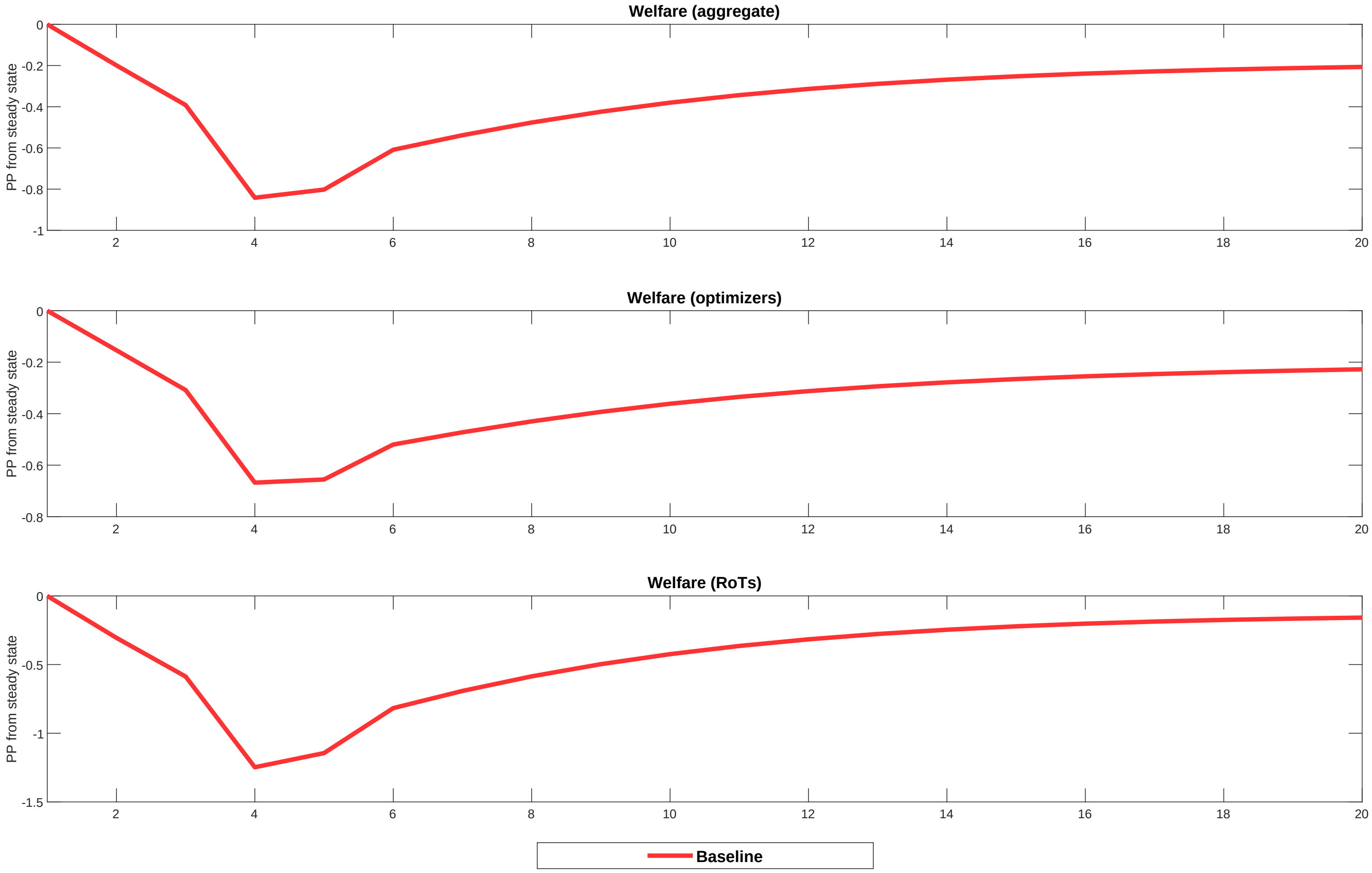
Appendix B: Welfare effects

In order to measure the welfare effects of the policy measures, we compute the lifetime consumption-equivalent gain of the representative household in line with Lucas (2003) as a result of the policy measure. The welfare function is given by equation (1). The alternative welfare function is given by

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\left((1+ce_i) \cdot \bar{C}_i - \kappa_{i,N} \bar{N}_i^{\zeta} \cdot \bar{X}_i \right)^{1-\sigma} - 1}{1-\sigma} \right], \quad \text{where } i = o, r$$

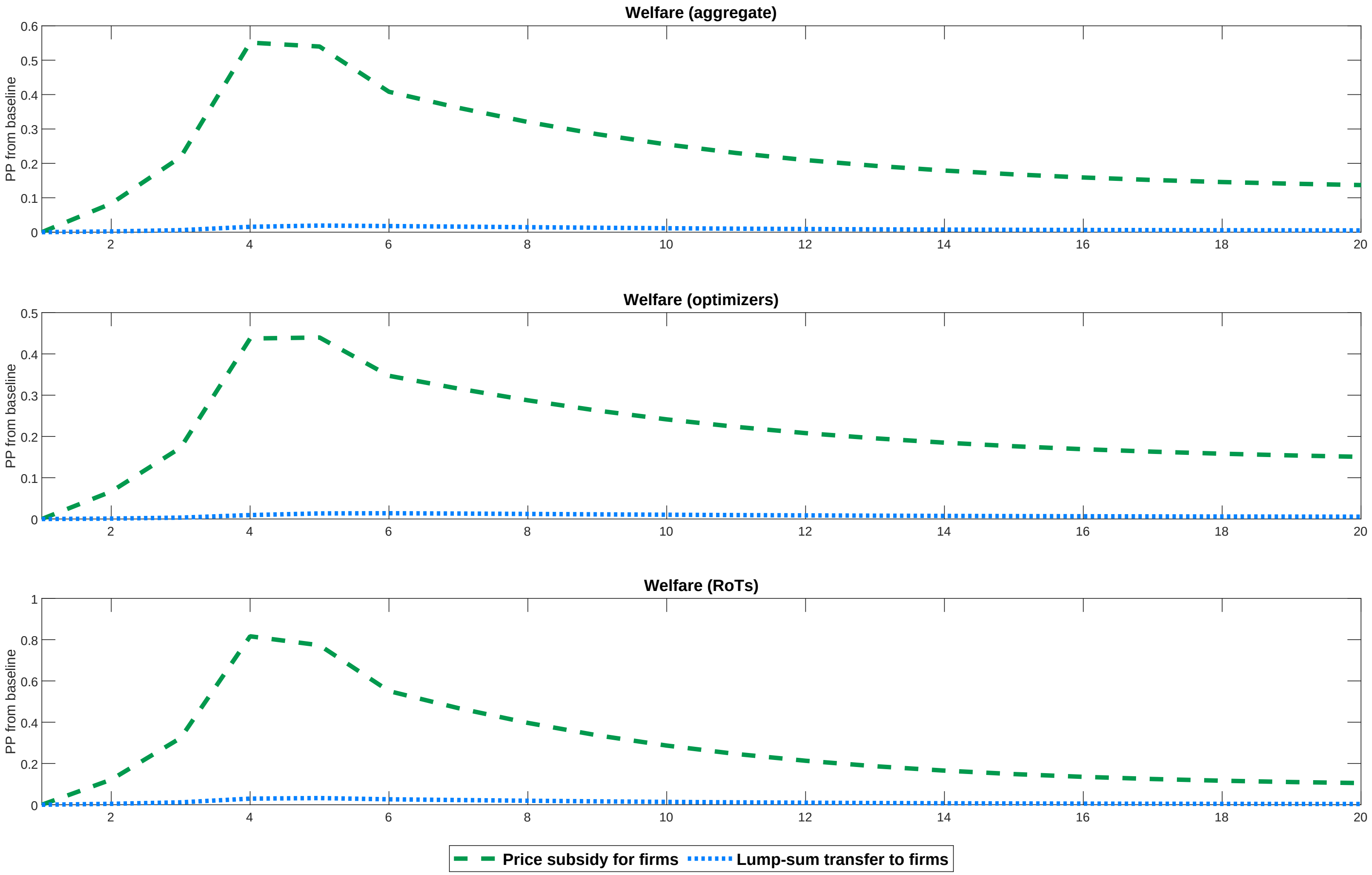
where the bar indicates steady-state values. If we equate this equation with equation (1), we can extract the corresponding lifetime consumption-equivalent gain ce_i. The aggregate consumption-equivalent gain ce is computed as the weighted sum of the two types of household. The results of this exercise are summarized in Figures B.1 - B.3, which plots the consumption-equivalent gains for the baseline simulation, for the exogenous price increases and for the scenario in which gas is in short supply.

Figure B.1: Welfare effects implied by gas price rise.



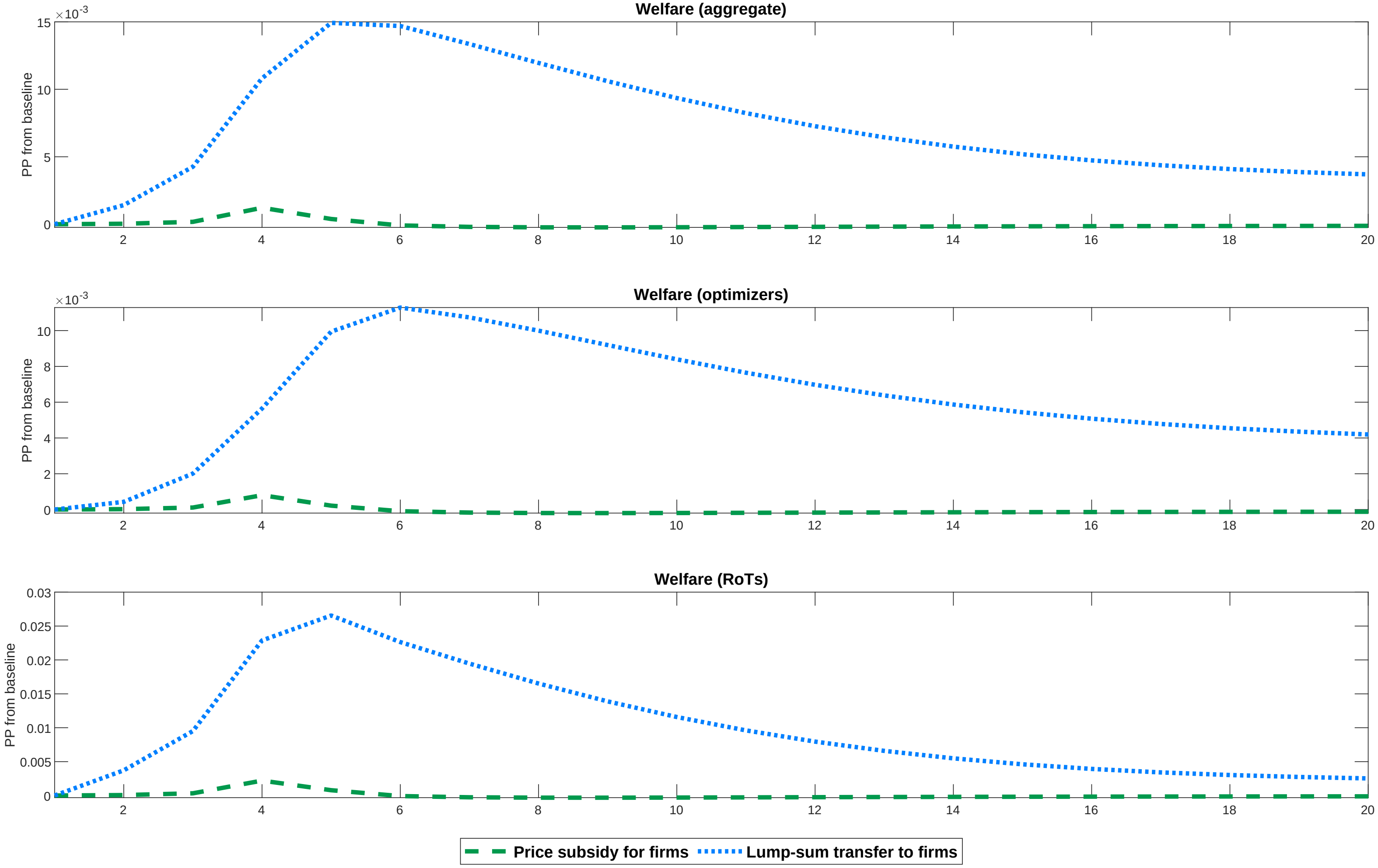
Notes: Figure plots (projected) cumulative percentage deviations of total welfare (measured as steady-state consumption equivalents) for optimizers, rule-of-thumb households and the average aggregate household.

Figure B.2: Welfare effects implied by mitigation schemes.



Notes: Figure plots (projected) cumulative percentage point deviations from baseline of total welfare (measured as steady-state consumption equivalents) for optimizers, rule-of-thumb households and the average aggregate household. The price subsidy for firms is depicted by the green dashed line. The dotted blue line represents the lump-sum transfer to firms.

Figure B.3: Welfare effects implied by mitigation schemes with fixed gas supply.



Notes: Figure plots (projected) cumulative percentage point deviations from baseline of total welfare (measured as steady-state consumption equivalents) for optimizers, rule-of-thumb households and the average aggregate household under the assumption that gas supply is fixed at baseline values. The price subsidy for firms is depicted by the green dashed line. The dotted blue line represents the lump-sum transfer to firms.