To Cap or Not to Cap? Energy Crises in a Currency Union

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Abstract

Considering the recent energy crisis and the divergent price cap policies in the Euro Area, this paper investigates the implications of energy price caps in a two-country currency union model with an exogenous energy supply. I find that policy makers face a Prisoner's Dilemma: The cooperative outcome is when neither country imposes a price cap, since the cap is a costly market distortion. However, a capped country avoids the crisis while an uncapped country bears the negative spillovers. Under non-homothetic preferences, the negative spillovers are so large that it outweighs the costs of a price cap: The equilibrium outcome is a price cap in both countries. I show that the price cap contributed to 40% (20%) of energy (headline) inflation in the uncapped Euro Area countries in 2022Q1. Moreover, targeted transfers are a cheaper and more effective way to boost consumption of the poor, while not creating divergence within the union.

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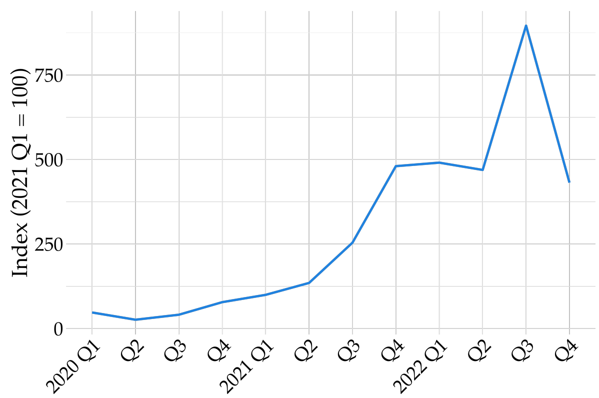
1 Introduction

The Euro Area, and more generally Europe as a whole, experienced a large energy crisis in 2022. The price of gas skyrocketed after the Russian invasion of Ukraine in early 2022, as shown in Figure 1.[1] The huge increase in the gas price triggered energy price cap decisions from governments within the Euro Area. This paper investigates the effects of an energy price cap in a subset of countries in currency union during an energy crisis, focusing on international spillovers and how they could affect policy decisions.

Figure 1: Gas price in the European Union



Data source: IMF Data (2024)

In 2022, France and Germany, among others, decided to impose an energy price cap,[2] whereas other countries including The Netherlands and Italy did not.[3] Figure 2a shows how the energy inflation in countries without an energy price cap was about 30 percentage points higher than in the capped countries in 2022Q3. The price cap policies did not only affect divergence of energy inflation: Figure 2b shows that headline inflation divergence also increased to unprecedented levels in 2022.[4] This paper finds that high (energy) inflation in uncapped countries is an important

[1]Since wholesale electricity prices move jointly with the gas prices, also electricity prices soared in Europe in 2022. As in any competitive market, the highest marginal cost of production determines the electricity price, and currently, gas-powered plants are the highest-cost producers (Pescatori & Steurmer, 2022).

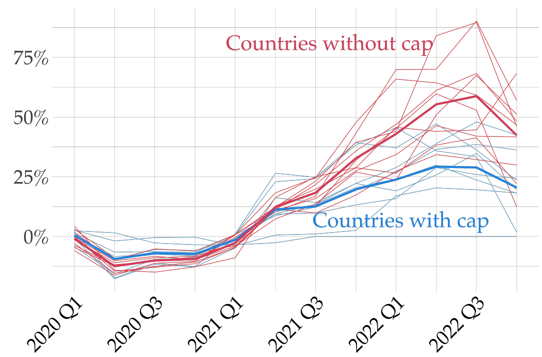
[2]Within the countries that introduced a price cap there are differences in terms of the size, the duration, and other details. See Sgaravatti et al. (2023) for more details.

[3]Some countries, including the Netherlands, introduced an energy price cap later in 2023. The analysis of paper focuses on 2022, when the inflation divergence was the largest.

[4]The decomposition of the variance of headline inflation across countries is in Figure 15 in Appendix C and shows that energy inflation contributes to inflation divergence only in 2022.

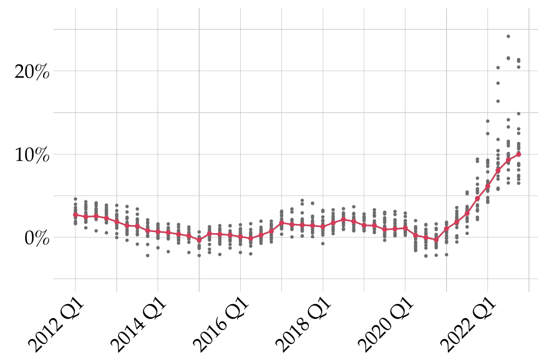
spillover of an energy price cap in another part of the union.

Figure 2: Inflation in the Euro Area



(a) Energy inflation rates 2020 – 2022

Note: Countries with an energy price cap in 2022 are Austria, Estonia, France, Germany, Luxembourg, Malta, Portugal, Slovakia, Slovenia, Spain. Countries without are Belgium, Cyprus, Finland, Greece, Ireland, Italy, Latvia, Lithuania, The Netherlands. Bold lines are weighted averages for each group. Data source: Eurostat.



(b) Headline inflation rates 2012 – 2022

Note: Gray dots represent annualized inflation rates for each quarter in each country in the Euro Area. Red dots are the weighted average values for the Euro Area as a whole. Data source: Eurostat.

First, I examine the effects of an adverse energy supply shock to the currency union. Eurostat (2023a) reports that in 2021 the European Union imported 55.5% of its energy, with a significant part from Russia.[5] Hence, stopping the dependency on Russian gas lead to a large negative energy supply shock in the European Union. With a two-country New Keynesian model of a currency union, and in the absence of energy price caps, I find that the adverse energy supply shock acts like a cost-push shock: A decline in the exogenous supply of energy depresses output while increasing inflation. I introduce non-homothetic preferences as in Boppart (2014) to reflect the fact that households spend a higher share of their income on energy when their income is low. Without price caps, non-homothetic preferences merely amplify the effect of the energy shock. However, they play an important role when analyzing spillovers and policy decisions, and when estimating the model.

Second, the paper studies the effect of an adverse energy supply shock to a two-country currency union when only one of the countries imposes an energy price cap. I define the energy price cap as a policy that fixes energy price. The government then pays the difference between the actual price of energy and its retail price.

[5] Russia used to supply 50% of the Union's gas imports. The global gas market is highly fragmented because of the pipeline infrastructure, and therefore it is hard to substitute away from Russian gas (Moll et al., 2023; Pescatori & Steurmer, 2022).

The differing cap policies cause divergence within the union: I find that the capped country avoids the crisis by maintaining its energy consumption. On the contrary, the uncapped country experiences a double-size decline in energy consumption and a double-size cost-push shock compared to the case of no price caps in the entire union. So, the price cap causes negative spillovers to uncapped countries. A shared energy supply, as is the case in Europe for Russian gas, is a crucial assumption of this result. Moreover, I analyze the challenge that the divergence within the currency union poses to the common central bank.

For policy makers facing the decision – to cap or not to cap – there is a trade-off between the cost of the price cap and the magnitude of the spillovers. In a setup with two countries and two decisions available for each country, the policy makers face a classic Prisoner's Dilemma, as in Table 1. The cooperative outcome after an adverse energy supply shock arises when neither of the countries imposes a price cap, [–1 for both countries]: Since there is an exogenous supply of energy, a price cap is a market distortion and a cost for the government without increasing utility, [–2 for both countries]. However, countries have an incentive to deviate from the cooperative strategy. Given one country does not impose an energy price cap, the other country can take advantage by imposing the cap. In that case, the capped country avoids the energy crisis, [1], while the uncapped country bears the negative spillovers, [–3].

Table 1: Price caps during energy crises as a classic Prisoner's Dilemma

		Country B	
	Welfare	Cap	No cap
Country A	Cap	$(-2, -2)$	$(1, -3)$
	No cap	$(-3, 1)$	$(-1, -1)$

Note: The numbers are cardinal and purely for illustrative purposes.
The bigger the number, the higher welfare.

Given one country imposing a price cap, should the remaining country also impose the cap? On the one hand, when both countries introduce a price cap, the cost of the price cap becomes a high: Energy is scarce, but both countries try to maintain their energy consumption. On the other hand, incurring negative spillovers while not capping the energy price is also costly. When preferences are sufficiently non-homothetic, the negative spillovers become large enough such that the policy makers prefer to also impose a price cap despite its costs. So, the only scenario in which both countries do not have an incentive to deviate is the one in which they both introduce an energy price cap. This outcome is worse than when none of the countries impose the price cap, the cooperative case.

Third, I provide counterfactual exercises of price cap policies in Europe in 2022. I add an energy production sector to the model and estimate it with macroeconomic data. After estimating the elasticity of substitution between the exogenous supply of gas and domestically produced energy, I perform a historical shock decomposition of the energy and headline inflation rates in which the energy price cap is one of the shocks. I find that the energy price cap contributed 40% to energy inflation and 20% to headline inflation in the uncapped countries in 2022Q1. Moreover, the inflation rates in the capped countries would not have been much higher without the energy price cap, the cooperative case.

Last, I introduce a version of the model with hand-to-mouth households to compare the energy price cap with targeted transfers. Targeted transfers are a cheaper and more effective way to boost the consumption of the poor during an energy crisis. Moreover, because targeted transfers do not distort the energy market in the union, there is no divergence between countries within the union whether they implement the transfers or not.

The contributions of this paper are both general, on international policy coordination, and specific to the European energy crisis in 2022: First, I show that in a decision game of two countries and two cap options, the degree of non-homotheticity determines the magnitude of the spillovers, and hence the incentives for policy makers to implement the price cap. Second, I quantify the model by estimating it with European data. I confirm the general result that the negative spillovers from the capped to uncapped country are much larger than the benefits the capped country experiences by implementing the cap.

Related Literature. This paper contributes to two strands of the literature. First, it builds onto the vast literature on monetary and fiscal policy in a currency union. Beetsma et al. (2001), Beetsma and Jensen (2005), Ferrero (2009), and Galí and Monacelli (2008) are pioneers of this strand of literature and explore the optimal joint conduct of monetary and fiscal policy as stabilization tools under asymmetric shocks. Other authors like Anderson (2007) and Keen and Konrad (2013) focus on strategic interactions of regulatory policies, like taxes, trade policies, and industrial regulation. Later, papers on this topic consider long-term coordination, with the sovereign debt crises in mind (Chang, 2015; Trichet, 2013). In this paper, I analyze the international coordination in energy price cap policy during a union-wide energy shock. This paper focuses the determinants of the magnitude of the cap's spillovers, and finds that fiscal coordination between countries is favorable. However, I show that under non-homothetic preferences, countries do not always have the incentives to cooperate.

Second, this paper contributes to the rapidly expanding the literature on energy crises. This paper is closest to Bayer et al. (2023), who also evaluate different fiscal responses to an energy shock in a currency union. They compare two types of energy price caps and the trade-off between stabilization of the domestic economy and costly spillovers to abroad. Auclert et al. (2023) and Chan et al. (2023) study the macroeconomic effects of an energy price shock and look at the coordination of fiscal policies and optimal monetary policy, respectively. This paper approaches the topic with a novel angle: I adopt a simple, game-theoretic approach to determine the cooperative energy price cap policy as well as the equilibrium that arises when countries have their own incentives.

The rest of this paper contains the following sections: Section 2 outlines the baseline model, the price cap setup, and the model calibration. Section 3 discusses the results of the baseline model, including the magnitude of the spillovers and its effect on the Prisoner's Dilemma. I also analyze the trade-offs between headline and core-inflation targeting. Then, in Section 4 I estimate an extended version of the model and quantify the contribution of the energy price cap to (energy) inflation in 2022. Lastly, in Section 5 I investigate targeted transfers by adding hand-to-mouth households to the model.

2 Baseline model

The model considers a currency union with two countries, Home and Foreign $\{H, F\}$, and incomplete financial markets. The relative size of the Home country is $\Theta \in (0, 1)$ and hence of the Foreign is $1 - \Theta$. Energy supply to the union is exogenous which follows from the high dependency of Europe on imported energy (Eurostat, 2023a). In the extended models, I include domestic energy production. The energy market clears with a single price for the whole union reflecting the well-integrated energy market in Europe (Pescatori & Steurmer, 2022). This setup for the energy market is similar to the one introduced by Bayer et al. (2023). Households consume energy as part of their consumption basket and firms use energy as one of their input factors. Households have non-homothetic preferences for energy, which ensure that they prefer to consume a higher share of energy when their income decreases. Firms in both countries produce tradable goods under monopolistic competition. The law of one price holds for those goods and there is home bias. Since the Home and Foreign country are symmetric, I explain only the Home-side of the union, unless otherwise stated. Foreign variables are denoted with an *. Appendix A provides a more detailed description of the model, including a list of relevant equilibrium conditions and the steady state.

2.1 Households

2.1.1 Preferences

Households derive utility from two types of goods: Energy goods, E_t^h, and non-energy ("rest") goods, C_{Rt}. Preferences of the households are non-homothetic as introduced by Boppart (2014). In this specification of preferences, the total nominal expenditure of the household, defined as $exp_t = P_{Et}E_t^h + P_{Rt}C_{Rt}$, matters for the share of expenditure spent on energy and the rest goods. P_{Et} and P_{Rt} are prices for energy and rest goods respectively. The indirect utility function of the representative household with non-homothetic preferences is:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{\varepsilon_1} \left[\left(\frac{exp_t}{P_{Rt}} \right)^{\varepsilon_1} - 1 \right] - \frac{\alpha_{ENG}}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Rt}} \right)^{\varepsilon_2} - 1 \right] \right\} \tag{1}$$

where $0 \leq \varepsilon_1 \leq \varepsilon_2 < 1$ are parameters that govern the degree of non-homotheticitiy in consumption as explained below. $\alpha_{ENG} > 0$ is the share of energy consumption in the steady state and β is the discount factor.

Choice between energy and rest goods. The relative demand for energy and rest goods obtained using Roy's identity reads as:[6]

$$C_{Rt} = \frac{1 - \alpha_{ENG}\varpi_t}{\alpha_{ENG}\varpi_t} \frac{P_{Et}}{P_{Rt}} E_t^h \tag{2}$$

[6] See Appendix A for a detailed derivation of the first order conditions.

where

$$\varpi_t = \left(\frac{P_{Rt}}{exp_t}\right)^{\varepsilon_1} \left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2} \tag{3}$$

is the energy expenditure share wedge. This wedge increases when the total expenditure decreases or when the price of energy increases, both relative to the price of the rest goods. Consequently, the consumption choice is non-homothetic in income since the share of expenditure on energy, $\alpha_{ENG}\varpi_t$, increases when the household becomes poorer. When $\varepsilon_1 = \varepsilon_2 = 0$, Eq. (2) simplifies to $C_{Rt} = \frac{1-\alpha_{ENG}}{\alpha_{ENG}} \frac{P_{Et}}{P_{Rt}} E_t^h$, which is the standard Cobb-Douglas result. In this case, the expenditure elasticity for both types of goods are equal to unity.

Choice between Home and Foreign goods. The consumption of non-energy goods is a composite index, bundling consumption of Home-produced goods C_{Ht} and Foreign-produced goods C_{Ft}:

$$C_{Rt} = \left[(1-\alpha_{IMP})^{1/\gamma} (C_{Ht})^{(\gamma-1)/\gamma} + (\alpha_{IMP})^{1/\gamma} (C_{Ft})^{(\gamma-1)/\gamma}\right]^{\gamma/(\gamma-1)} \tag{4}$$

where $\alpha_{IMP} \in (0,1)$ is the share of imported goods in the consumption basket and γ is the elasticity of substitution between Home and Foreign goods. Since the preferences between Home and Foreign-produced goods are homothetic, the intratemporal consumption choice between Home and Foreign goods are standard:

$$\frac{C_{Ht}}{C_{Ft}} = \frac{1-\alpha_{IMP}}{\alpha_{IMP}} \left(\frac{P_{Ht}}{P_{Ft}}\right)^{-\gamma} \tag{5}$$

where P_{Ht} and P_{Ft} are the price indices of Home and Foreign goods respectively. The aggregate expenditure on rest consumption is then:

$$\int_0^1 P_{Ht}(i)C_{Ht}(i)di + \int_0^1 P_{Ft}(i)C_{Ft}(i)di = P_{Ht}C_{Ht} + P_{Ft}C_{Ft} = P_{Rt}C_{Rt} \tag{6}$$

where P_{Rt} is the aggregate price index for non-energy goods:

$$P_{Rt} = \left[(1-\alpha_{IMP})P_{Ht}^{1-\gamma} + \alpha_{IMP}P_{Ft}^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \tag{7}$$

2.2 Intertemporal choices

The representative household makes intertemporal choices since it can trade in one-period bonds B_t with gross interest rate R_t. The household's income sources are from labor N_t for a nominal wage W_t per unit and from profits of domestic firms, D_t, and energy sellers, D_t^E.[7] The nominal budget constraint of the households is the following:

$$exp_t = P_{Et}E_t^h + P_{Rt}C_{Rt} = W_tN_t + D_t + D_t^E + R_{t-1}B_{t-1}^h - B_t^h - HC_t - T_t \tag{8}$$

where $HC_t = \frac{\tilde{\nu}}{2}(B_t^h - \bar{B}^h)^2$ are the portfolio adjustment costs of the household and T_t lump-sum taxes. The government uses those taxes to finance energy price caps. When the household maximizes their utility function (1) subject to the constraint, the Euler equation becomes:

$$\left(\frac{\mathbb{E}_t\left[exp_{t+1}\right]}{exp_t}\right)^{1-\varepsilon_1} = \beta\frac{R_t}{1 + P_{Rt}\tilde{\nu}(b_t^h - \bar{b}^h)}\mathbb{E}_t\left[\left(\frac{1}{\Pi_{R,t+1}}\right)^{\varepsilon_1}\right] \tag{9}$$

where $b_t^h = \frac{B_t^h}{P_t}$ denotes real bond holdings and $\Pi_{Rt} = \frac{P_{Rt}}{P_{R,t-1}}$ gross inflation of the rest goods. P_t is the aggregate price index, explained below. Households supply labor inelastically, such that $N_t = \bar{N}\ \forall t$.

2.3 Firms

The country has a continuum of $i \in [0,1]$ firms who produce the (non-energy) rest goods under monopolistic competition. They use both labor N_t and energy E_t^f as production inputs in their Constant Elasticity of Substitution (CES) production function:

$$Y_t(i) = A_t\left[\left(\alpha^f\right)^{1/\theta^f}\left(E_t^f(i)\right)^{(\theta^f-1)/\theta^f} + \left(1-\alpha^f\right)^{1/\theta^f}\left(N_t(i)\right)^{(\theta^f-1)/\theta^f}\right]^{\theta^f/(\theta^f-1)} \tag{10}$$

where α^f is the share of energy used in production and θ^f is the elasticity of substitution between input factors energy and labor. A_t is the total factor productivity which follows an AR(1) shock process. The firms face adjustment costs à la Rotemberg

[7] As in Bayer et al. (2023), households earn profits determined by deviations from steady state when selling energy.

(1982), so their profit maximization problem is:

$$\max_{P_{Ht}(i),N_t(i)} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{t+1} \left[\frac{P_{Ht}(i)}{P_{Ht}} Y_t(i) - \frac{W_t}{P_{Ht}} N_t(i) - P_{Et} E_t^f(i) - Y_t FC_t \right] \tag{11}$$

subject to

$$\text{demand curve} \quad Y_t(i) = \left(\frac{P_{Ht}(i)}{P_{Ht}} \right)^{-\epsilon} Y_t \tag{12}$$

$$\text{price adjustment costs} \quad FC_t(i) = \frac{\xi}{2} \left(\frac{P_{Ht}(i)}{P_{H,t-1}(i)} - 1 \right)^2 \tag{13}$$

where $\Lambda_{t+1} = \beta \left(\frac{C_{t+1}}{C_t} \right)$ is the stochastic discount factor and $\int_0^1 P_{Ht}(i) = P_{Ht}$ the average price of Home-produced goods.[8] ξ governs the level of price adjustment costs.[9] The firm's profits reads:

$$D_t = P_{Ht} Y_t (1 - FC_t) - W_t N_t - P_{Et} E_t^f \tag{15}$$

2.4 Market clearing

Goods market clearing. The goods market clears for the Home country when the production in that country is equal to the demand for consumption goods produced in that country. Hence, the market clearing condition includes the demand for Home-produced goods in the Foreign country:

$$Y_t = C_{Ht} + C_{Ht}^* + HC_t + FC_t \tag{16}$$

$$= (1 - \alpha_{IMP}) \left(\frac{P_{Ht}}{P_{Rt}} \right)^{-\gamma} C_{Rt} + \alpha_{IMP}^* \left(\frac{P_{Ht}}{P_{Rt}^*} \right)^{-\gamma} C_{Rt}^* + HC_t + FC_t \tag{17}$$

[8]The first-order condition with respect to $P_{Ht}(i)$ leads to the standard New Keynesian Philips Curve (NKPC). See Appendix A for detailed derivations. In log-linear form, the NKPC reads:

$$\hat{\pi}_{Ht} = \beta \mathbb{E}_t \hat{\pi}_{H,t+1} + \kappa \hat{\mu}_t \tag{14}$$

where $\kappa = \frac{\epsilon}{\xi \mathcal{M}}$ and $\mathcal{M} = \frac{\epsilon}{1-\epsilon}$. $\hat{\mu}_t$ is the real marginal cost. As in Aoki (2001), the relative price of energy shows up as a shift of the NKPC, like a cost-push shock, when re-writing the NKPC in terms of headline inflation.

[9]Since energy is an exogenous supplied good, Rotemberg (1982) and Calvo (1983) pricing are identical up to first order, unlike conventional two-sector models.

where C^*_{Ht} is the consumption of Home-produced goods in Foreign, and C^*_{Rt} is the consumption of rest goods (both Home and Foreign-produced) in Foreign.

Energy market clearing. The energy market clears when the demand for energy by households and firms from both countries equals the supply. As mentioned, the supply of energy E_t is exogenous:

$$E_t = E_t^h + E_t^f + E_t^{h*} + E_t^{f*} \tag{18}$$

2.5 Current account and the dynamics of net foreign assets

I derive the dynamics of net foreign assets, and hence the current account, by consolidating households' and firms resource constraints, (8) and (15):

$$B_t^h - B_{t-1}^h = r_{t-1}B_{t-1}^h + P_{Ht}Y_t\left(1 - FC_t\right) - P_{Rt}C_{Rt} - HC_t \tag{19}$$

where $r_t = R_t - 1$ is the net nominal interest rate set by the monetary authority. Since the right-hand side of the equation is the current account I can express the above equation as the following:

$$CA_t = b_t^h - b_{t-1}^h \tag{20}$$

$$CA_t = r_{t-1}b_{t-1}^h + \frac{P_{Ht}}{P_t}Y_t\left(1 - FC_t\right) - \frac{P_{Rt}}{P_t}C_{Rt} - \frac{1}{P_t}HC_t \tag{21}$$

where $b_t^h = \frac{B_t^h}{P_t}$ is real bond holdings. Since the union is a closed economy, to ensure mutual consistency of current accounts $CA_t = CA_t^*$ needs to hold.

2.6 Monetary policy

The monetary authority targets the headline inflation of the two countries, Home and Foreign, with a Taylor rule set accordingly to their respective size. So, the Taylor rule for the nominal interest rate R_t is:

$$R_t = \frac{1}{\beta}\left(\frac{\Pi_t^W}{\bar{\Pi}^W}\right)^{\phi_\pi}\exp(\nu_t) \tag{22}$$

where superscript W indicates a union-wide variable, defined as:

$$\Pi_t^W = (\Pi_t)^{\Theta}(\Pi_t^*)^{1-\Theta} \tag{23}$$

The monetary authority only targets inflation, and no output gap, because the mandate of the European Central Bank is price stability. The inflation that the central bank targets is:

$$\Pi_t = (\Pi_{Et})^{\alpha_{ENG}}(\Pi_{Rt})^{1-\alpha_{ENG}} \tag{24}$$

which corresponds to the Consumer Price Index (CPI), or headline inflation in common literature and data sources.

2.7 Fiscal policy: The energy price cap

If the Home country introduces a cap on energy prices, the fiscal policy and the government budget constraint of the country become relevant. With an energy price cap in the Home country, the effective energy price becomes:

$$P_{Et}^{eff} = \begin{cases} P_{Et} & \text{without cap} \\ \bar{P}_E & \text{with cap} \end{cases} \tag{25}$$

Hence, under the cap, the effective price for energy for the households and firms is equal to the steady state price of energy, $\bar{P}_E$. Consequently, when the fiscal authority introduces the price cap, the price of energy in households' and firms' equilibrium conditions is given by the effective price of energy $P_{Et}^{eff} = \bar{P}_E$. The government runs a balanced budget and finances the cap by a lump-sum tax, such that the government budget constraint reads:[10]

$$COST_t(E_t^h + E_t^f) = T_t \tag{26}$$

where $COST_t = P_{Et} - \bar{P}_E$ denotes the cost of the cap per unit of energy for the government.

[10]Ricardian Equivalence holds in this model, such that it does not matter whether the government finances the cap by taxes or debt.

2.8 Calibration

The model is calibrated at quarterly frequency. In the extended model, I perform a Bayesian estimation of some of the model parameters. Table 2 provides an overview of the baseline calibration values. The countries are identical except for their relative sizes.

Table 2: Baseline calibration of parameters

Parameter	*Description*	*Value*
Households		
α_{IMP}	Share of imports in consumption	0.25
α_{ENG}	Share of energy in consumption	0.066
γ	Elasticity of substitution between Home and Foreign goods	6
ϵ	Elasticity of substitution within goods	9
ε_1	Non-homotheticity parameter	0.77
ε_2	Non-homotheticity parameter	0.77
$\tilde{\nu}$	Adjustment cost for bonds	0.001
β	Discount factor	0.99
Firms		
α^f	Share of energy in production	0.011
θ^f	Elasticity of substitution between energy and labor	0.2
ξ	Price-adjustment cost	15.84
Monetary policy		
ϕ_π	Taylor-coefficient on inflation	1.5
α^{CB}	Share of energy for central bank's consideration	0.066
Currency union		
Θ	Relative size Home country (with cap)	2/3

On the household side, Eurostat (2023b) reports that in 2022, the share of internationally traded goods and services relative to GDP was 25%. Hence, the share of imports in consumption, α_{IMP}, is 0.25. The share of energy in total consumption expenditure is on average 6.6%, so I set α_{ENG} as 0.066.[11]. The elasticity of substitution within different varieties of Home and Foreign, ϵ, is 9, in line with standard literature. The adjustment cost for bond-holdings, $\tilde{\nu}$, is 0.001, to match the canonical work by Schmitt-Grohé and Uribe (2003). The discount factor β is 0.99 as is standard in the literature. I perform a data matching exercise at the end of the subsection to calibrate the non-homotheticity parameters ε_1 and ε_2.

For the firms, I set the share of energy in production, α^f, to 1.1% to target the steady-state energy expenditure of the industry as share of total production value of 1%.[12] The elasticity of substitution of energy and labor, θ^f, is 0.2, following

[11] Eurostat data, online data code: hbs_str_t223.

[12] I calculate the steady-state energy expenditure as share of total production value with data from

Bachmann et al. (2024) and Bayer et al. (2023).[13] I calibrate the Rotemberg (1982) price-adjustment cost parameter, ξ, such that the slope of the New Keynesian Philips Curve matches that of the Calvo (1983) price rigidities for the Calvo parameter 0.5. This value implies an expected price duration of two quarters, which is more frequent than standard, to reflect the fast change in prices in 2022. The corresponding price-adjustment cost parameter is $\xi = [(\epsilon - 1)0.5]/[(1 - 0.5)(1 - 0.5\beta)] \approx 15.84$

Monetary policy follows a standard Taylor (1993) rule, with the coefficient on inflation ϕ_π as 1.5. The monetary authority targets headline inflation, following the official target of the European Central Bank (ECB, 2021).[14]

To get the relative size of the two countries, I calculate the GDP ratio of countries that introduced a cap in 2022 and that did not introduce a cap in 2022.[15] Since the sum of GDPs of countries with an energy price cap in 2022 was about 68% of the total of countries in the Euro Area, I set the size of the Home country $\Theta = 0.68$.

Non-homotheticity parameters. For the calibration of the non-homotheticity parameters ε_1 and ε_2, I conduct a data matching exercise. I take the gas inflation data for France and the Netherlands from Eurostat from 2019 to 2022, and feed it into the model as perfect foresight energy price shocks, as shown Figure 3.[16] At the peak in 2022Q3, the Netherlands experienced a gas price inflation of about 30% in quarterly

European Commission et al. (2020) and Eurostat data (online data code: sbs_sc_ovw). The sectors included are selected manufacturing sectors, wholesale and retail trade, accommodation and restaurants, and information and communication, and the countries included are the 27 European Union members in 2020.

[13] Bachmann et al. (2024) show that when other production inputs are constant, the own-price elasticity maps directly to the elasticity of substitution. They estimate the own-price elasticity of energy to range from -0.15 to -0.20.

[14] Moreover, the press releases of the ECB monetary policy decisions between June 2022 and September 2023, when the ECB kept increasing interest rates, often mention energy prices as one of the key drivers of upwards pressures for inflation. The decision reports mention headline inflation figures to indicate how far the economy is off the 2% target (European Central Bank, 2024).

[15] Euro Area countries with an energy price cap in 2022: Austria, Estonia, France, Germany, Luxembourg, Malta, Portugal, Slovakia, Slovenia, Spain. Euro Area countries without an energy price cap in 2022: Belgium, Cyprus, Finland, Greece, Ireland, Italy, Latvia, Lithuania, The Netherlands. Croatia joined the Euro Area in 2023 and therefore excluded from the analysis in this paper.

[16] I manipulate the data from Eurostat (online data code: prc_hicp_manr) to get quarterly rates. I use the observations from 2020Q3 to 2021Q3 to compute the steady state to express all data in deviations from steady state. France and the Netherlands are one of the most extreme cases of inflation divergence within the Euro Area. The countries are relatively close geographically and socio-economically, which make them good candidates for this data exercise. Including all countries in the Euro Area makes this exercise less clear cut, since idiosyncrasies, like proximity to Ukraine or Russia, affect the price dynamics in different ways than this reduced form exercise can handle. In the Bayesian estimation of the extended model, I include all countries in the Euro Area.

rates (over 90% in annual rates). France, on the other hand, imposed a price cap on gas inflation which barely exceeded 10% in quarterly rates (about 30% in annual rates). The gas consumption data reflect the policies: In the Netherlands, the gas consumption decreased about 15 percentage points more than in France. I conduct a parameter search for ε_1 and ε_2, imposing $0 < \varepsilon_1 \leq \varepsilon_2 < 1$ as in Boppart (2014), to minimize the Mean Squared Error (MSE) between the model impulse responses for energy consumption and the realized gas consumption in 2020Q3 to 2022Q4 for both countries.[17] The results give 0.77 for both ε_1 and ε_2, implying a corner solution imposed by the model specification. I set the elasticity of substitution between Home and Foreign goods, γ, to 6, the upper bound of standard literature (Benigno, 2009), since the data exercise performs best under this calibration.

In the rightmost subfigure of Figure 3, I check that the dynamics of the model's CPI inflation rates and the inflation rates of rest goods match the dynamics of those of the data. I take the difference in CPI rates of Netherlands and France, and decompose it into the contribution from difference in gas inflation rates and inflation rates of other goods.[18] In the height of the energy crisis in 2022, you can see that in both the data and the model, the energy inflation was higher in the Netherlands, whereas France had higher inflation in other goods. This result implies that energy and other goods are complements, suggesting that the demand pressures for other goods were lower in the country where the energy crisis was worse. The model lacks slightly in magnitude, but in general tracks the CPI difference and its decomposition quite well over the sample period.

Shock specification. In the numerical analyses in the following sections, I shock the model with an adverse energy supply shock of 15% that lasts for 6 quarters. In this way, I capture the decline in the supply of Russian gas in summer 2022. and the expectations of governments that the shock would last until spring 2023. More con-

[17]The data is from Eurostat (online data code: nrg_c_gasm). With population data (intrapolated for the quarters), I get the gas consumption per capita. I seasonally adjust the data using X-13ARIMA-SEATS in R before taking quarterly data points and steady-state deviations from steady state.

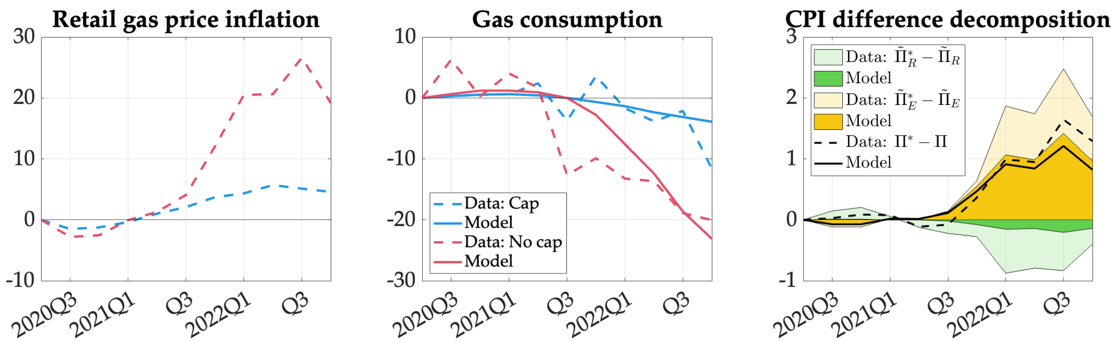
[18]In equation form, the CPI decomposition denotes:

$$\Pi_t^* - \Pi_t = \left[\left(1-\alpha^{ENG}\right)\Pi_t^{R*} + \alpha^{ENG}\Pi_t^{E*}\right] - \left[\left(1-\alpha^{ENG}\right)\Pi_t^{R} + \alpha^{ENG}\Pi_t^{E}\right] \tag{27}$$

$$= \left(\tilde{\Pi}_t^{R*} + \tilde{\Pi}_t^{E*}\right) - \left(\tilde{\Pi}_t^{R} + \tilde{\Pi}_t^{E}\right) = \left(\tilde{\Pi}_t^{R*} - \tilde{\Pi}_t^{R}\right) + \left(\tilde{\Pi}_t^{E*} - \tilde{\Pi}_t^{E}\right) \tag{28}$$

where $\tilde{\Pi}_t^R = \left(1-\alpha^{ENG}\right)\Pi_t^R$ and $\tilde{\Pi}_t^E = \alpha^{ENG}\Pi_t^E$ are contributions of rest goods and energy respectively to CPI inflation.

Figure 3: Data exercise to calibrate the non-homotheticity parameters



cretely, in July 2022 the European Union member states agreed to a gas consumption reduction target of 15% between August 2022 and March 2023, and another extension until March 2024, to prepare for possible supply disruptions (European Commission, 2023). Moreover, most countries that introduced an energy price cap did so in 2022 with the promise to keep it in place for 4-9 quarters, depending on the country.

3 Baseline results

In this section, I conduct a series of simulations with the dynamic model to investigate the effect of an adverse energy supply shock on a currency union. First, I show how an adverse energy supply shock affects the economy in absence of price caps. The shock causes an increase in the price of energy, and a cost-push shock in the economy. Second, I take the scenario of the Euro Area in 2022, and impose an energy price cap in the bigger country in the union. I find that the capped country can avoid most of the crisis, while the uncapped country experiences a cost-push double the size. The size of such negative spillovers depend on the degree of non-homotheticity of energy and affect policy decisions. Moreover, I discuss the consequences of headline and core targeting and the trade-offs they impose.

3.1 Energy crisis without energy caps

In this subsection, I discuss the economy's response to an adverse energy supply shock, when neither country implements an energy price cap. Moreover, I explain the role of non-homothetic preferences in the responses. The results are in Figure 4. As explained, the shock is a 15% shock to the energy supply of the currency union and lasts 6 quarters. In the Figure, the thin lines are the results with homothetic preferences, and the bold lines with non-homothetic preferences. Since there are no energy price caps in either country and the countries are otherwise symmetric, the responses for the two countries are the same. Hence, there is only one response per variable per preference type.

With homothetic preferences, the energy adverse energy supply shock triggers the energy inflation to go up by about 70%. The recessionary shock decreases inflation for other goods on impact. In the later periods, the rest-goods inflation increases since energy is one of the production inputs. Consumer Price Index (CPI) inflation, or headline inflation, is a weighted average of energy inflation and rest-goods inflation, and hence peaks when rest-goods inflation is highest. Production and consumption of rest goods decrease as a consequence of the energy supply declining.[19] Energy consumption by households decreases by about the same amount as the shock.[20] Since the energy shock increases CPI inflation while depressing output, the shock acts as a cost-push shock. The monetary authority conducts contractionary policy to dampen inflationary pressures, and returns to steady state together with CPI inflation.

Non-homothetic preferences amplify the responses to an adverse supply shock to the non-homothetic good, energy. Because energy is a necessity and more desired when income declines, the price of energy increases more, to above 200%.[21] Despite the high energy prices, energy consumption decreases less compared to the case with homothetic preferences. To compensate, the consumption of other goods decreases more, as seen in the output response. This mechanism is in line with the non-homotheticity of energy consumption in income: When (real) income decreases, households spend more of their income on energy and less other goods. With homothetic preferences, the elasticity of demand for both goods are the same. Under non-homothetic preferences there is a bigger need for energy, and hence the adverse supply shock has a bigger effect on the macroeconomic variables, increasing the CPI

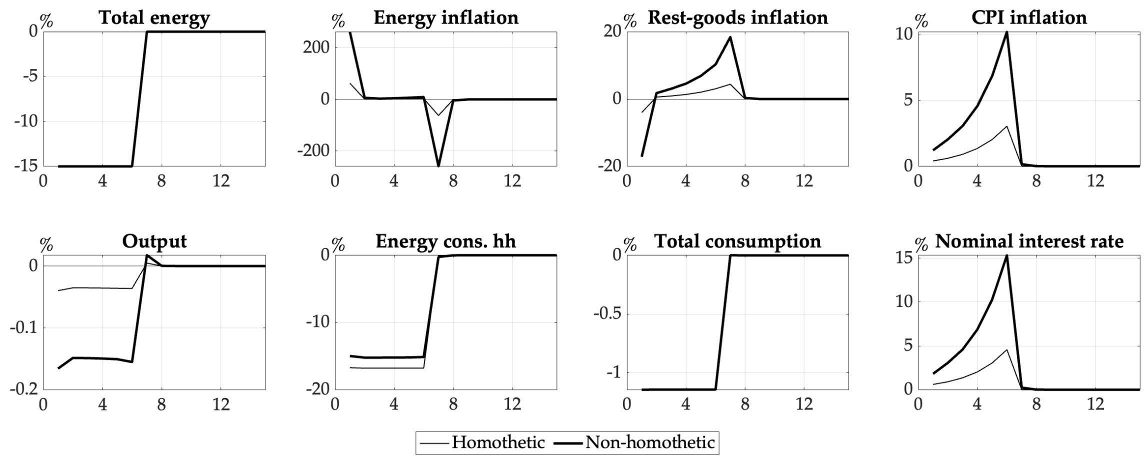
[19]Shown in the Output panel, since output is the production of rest goods, which is equal to the consumption of rest goods.

[20]The firms decrease their energy use by less than 15%, hence the energy consumption by households reduces by slightly more than 15%.

[21]When estimating the model in the next section, I add a domestic energy production sector to dampen the effect of the adverse supply shock and to inflation responses closer to the data.

inflation more and decreasing output more. In accordance, the response of the monetary authority is also stronger.

Figure 4: Responses to an adverse energy supply shock | No caps



Note: Inflation and interest rates are annualized.

3.2 Energy crisis: Large spillovers from cap to no cap

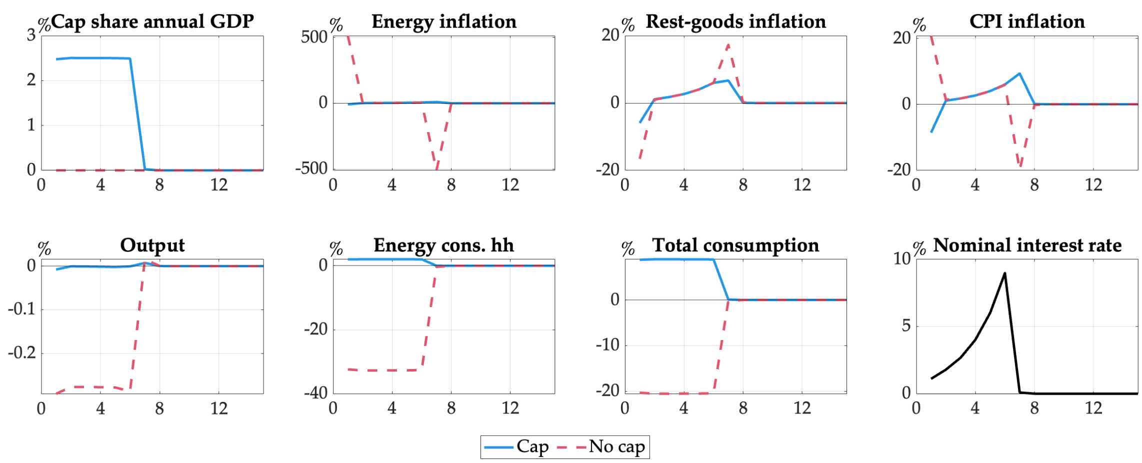
Now consider the case in which the the larger country introduces a price cap on the energy price, such that the retail energy price stays constant. Figure 5 shows the impulse responses for the economy when households have non-homothetic preferences. When the energy supply decreases by 15%, the bigger country (blue solid lines) introduces an energy price cap which costs about 2.5% of the annual GDP for the government. In the uncapped country (red dotted lines) the adverse energy supply shock is essentially doubled compared to the case without any price caps, since the capped country's share of the shock spills over.

In the capped country the economy avoids most of the energy crisis. Because their energy prices do not increase, households in this country have more purchasing power than households in the uncapped country. Therefore, they consume more of the rest goods produced in their own country, but also more of the ones produced in the uncapped country. Moreover, the goods from the uncapped country have become relatively cheaper because of the large recession in that country (terms-of-trade appreciation). Hence, total consumption in the capped country increases.

In the country without the cap the energy price increase doubles compared to the previous case without any caps, because of the spillovers from the capped country. Since the capped country does not decrease their energy consumption, energy is an even scarcer good in the uncapped country. Households in this country absorb most of the adverse energy supply shock by doubling their decrease in energy consumption compared to the case when the other country also did not introduce the energy price cap. Since the energy supply shock is essentially double the size and the terms-of-trade depreciation leads to increased exports of the rest goods, the total consumption in the uncapped country declines drastically.

The common monetary policy adopts a less contractionary stance than when neither of the countries implemented the energy price cap, in Figure 4. Because the country with the cap is larger, the weighted union-wide CPI inflation is lower for the case with a capped and uncapped country. Hence, the nominal interest rate is not sufficiently high for the uncapped country.

Figure 5: Responses to an adverse energy supply shock | Cap vs. no cap



Note: Preferences are non-homothetic. Inflation and interest rates are annualized.

3.2.1 Implications for policy decisions and welfare

In this subsection, I analyze the welfare implications for each combination of policy strategies (cap and no cap, for both countries) and show the decision game is a classic Prisoner's Dilemma when the preferences are sufficiently non-homothetic.

Policy outcomes under fiscal union. Table 3 summarizes the results under non-homothetic preferences. I calculate the welfare gains and losses in terms of consumption equivalence compared to the steady state of the economy.[22] First, focus on the cells on the diagonal where the policies are symmetric (cap-cap and no cap-no cap), which is the fiscal union benchmark. Since the currency union is a closed economy, the fiscal union benchmark is equivalent to the closed economy case. In this closed economy case, the adverse energy supply shock causes a welfare loss of 1% without an energy price cap and 15% with the cap. When the economy is closed off, households cannot consume resources from abroad. Hence, government expenditure is at the expense of household consumption. Since government expenditure does not increase utility, it is optimal to keep it at a minimum and not impose any price caps. Another way to explain this result is to see the price cap as a market distortion. The government distorts the price-clearing process by imposing a price cap on energy. Hence, welfare is lower compared to the case without any distortions.

Table 3: Welfare gains/losses after energy supply shock

Non-homothetic preferences

		1/3 of union	
	%	Cap	No cap
2/3 of union	Cap	$(-15, -15)$	$(8, -17)$
	No cap	$(-16, 6)$	$(-1, -1)$

Policy outcomes without fiscal union. When the countries are not in a fiscal union, is the cooperative, non-distortionary no-cap strategy the Nash equilibrium? As the circles around the welfare values indicate in Table 3, the cooperative case is not the Nash equilibrium. Instead, as in the classic Prisoner's Dilemma, the non-cooperative decision, imposing the price cap, is the dominant strategy for both fiscal authorities.

First, *given 1/3 of the union does not impose an energy price cap*, does the rest, 2/3 of the union, have an incentive to deviate from the no-cap strategy? If they keep to the no-cap strategy, the union is in the cooperative case, in which both countries

[22]For consumption equivalence, I find χ which satisfies:

$$\mathbb{E}_t \sum_{t=0}^{6} \beta^t \left\{ \frac{1}{\varepsilon_1} \left[\left(\frac{exp_t}{P_{Rt}} \right)^{\varepsilon_1} - 1 \right] - \frac{\alpha_{ENG}}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Rt}} \right)^{\varepsilon_2} - 1 \right] \right\} = \mathbb{E}_t \sum_{t=0}^{6} \beta^t \frac{1}{\varepsilon_1} \left\{ [\overline{exp}(1+\chi)]^{\varepsilon_1} - 1 \right\} \quad (29)$$

So, χ is the fraction of total expenditure, i.e. total consumption, that the household would be willing to forgo in the economy in steady state (right-hand side) to live in the economy with the energy supply shock, as evaluated by the left-hand side of the equation. Since all model variables return to steady state one period after the shock dissipates, I only take the sum of seven periods.

experience a welfare loss of 1%. However, the country representing 2/3 of the union has an incentive to deviate to the cap policy, which improves the welfare in that country (8%) at the expense of the no-cap country (–17%). This result is a summary of the impulse responses in Figure 5, with large spillovers from the capped to the uncapped country.

Second, *given 2/3 of the union imposes an energy price cap*, does the rest, 1/3 of the union, also have an incentive to impose the price cap? The large, negative spillovers are very costly for the uncapped country; They cause a welfare loss of 17%. Hence, the country has an incentive to also impose the price cap, even though both countries imposing the cap causes a welfare loss of 15%. The loss is relatively big because when both countries implement an energy price cap, the cost for the cap spirals upwards: The only benefit from the price cap emerges from creating spillovers to the other country, which is not possible when both countries impose the cap.

The above argument also applies when the small and large countries switch: For both countries, it is better to impose the energy price cap when the other does, despite the large cost of the distortion, rather than bearing the negative spillovers.[23] Hence, imposing an energy price cap is the dominant strategy for both countries, leading to a Prisoner's Dilemma: Both countries can gain from cooperating, but it is not rational to do so.

Policy outcomes under homothetic preferences. How much do these results depend on the non-homotheticity of energy? Here, I illustrate that the above results do highly depend on the degree of non-homotheticity. The welfare table for homothetic preferences is in Table 4. The degree of non-homotheticity does not affect the values on the diagonal of the fiscal union benchmark. Again, the non-cooperative case when both countries impose a cap are much worse (–15%) than in the cooperative case without any caps (–1%) due to the market-distorting price cap.

Table 4: Welfare gains/losses after energy supply shock

Homothetic preferences

		1/3 of union	
	%	Cap	No cap
2/3 of union	Cap	$(-15, -15)$	$(2, -6)$
	No cap	$(-4, 0)$	$(-1, -1)$

[23]The externalities are smaller when the smaller country implements the energy price cap. However, not small enough to break symmetry in the preferred strategies in Table 3.

However, non-homotheticity of preferences affects the magnitude of the spillovers significantly. Under the homothetic case, the externalities of the price cap are not as large, because energy is not a necessity. Hence, when the counterpart country implements a cap, the welfare losses associated with negative spillovers are not as large: −6% for the larger country and −4% for the smaller country. So, implementing the price cap is not worth the cost when the other country also has the cap. Thus, in the case of homothetic preferences, there is no dominant strategy for neither of the fiscal authorities. There are two Nash equilibria, with one country implementing the price cap and not the other country.

Recall that parameters ε_1 and ε_2 govern the degree of non-homotheticity of energy. Welfare outcomes under the baseline calibration with non-homothetic preferences, $\varepsilon_1 = \varepsilon_2 = 0.77$, are in Table 3: One Nash equilibrium which is a price cap in both countries. Welfare outcomes in the homothetic case, $\varepsilon_1 = \varepsilon_2 = 0$, are in Table 4: Two Nash equilibria for differing cap policies. The magnitude of the spillovers are crucial in determining the size of the negative spillovers to the uncapped country and depend on the degree of non-homotheticity. The value for ε_1 and ε_2 for which the smaller country is indifferent about imposing a cap or not, when the bigger country has imposed a cap, is $\varepsilon_1 = \varepsilon_2 = 0.72$.

3.2.2 Headline vs. core-inflation targeting

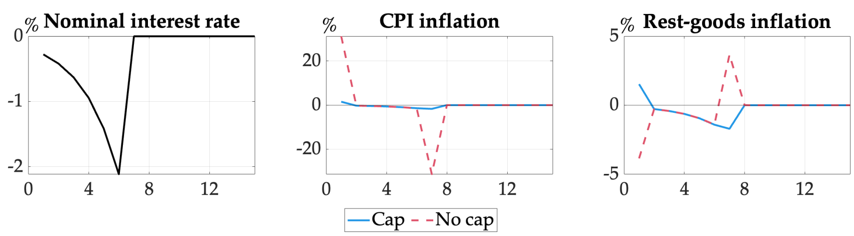
In this subsection, I explore the different implications for the monetary authority when targeting Consumer Price Index (CPI) inflation, i.e. headline inflation, or rest-goods inflation, i.e. core inflation.[24] I show that there is a trade-off between targeting headline and core inflation.

In the baseline analysis, the monetary authority targets headline inflation in its Taylor rule. In that case, Figure 5 shows that the monetary authority conducts contractionary monetary policy to stabilize union-wide headline inflation, which is the weighted average of the headline inflation rates of the two countries. However, under headline inflation targeting, there are large fluctuations in the core sector in both countries, but worse for the uncapped country. On top of the adverse energy supply shock, a contractionary monetary policy worsens the cost-push shock in the core sector of the economies.

[24] In the literature, core inflation refers to CPI inflation excluding food and energy inflation. Since my model does not have food inflation, I refer to CPI inflation excluding energy inflation as core inflation.

Figure 6 present the responses of the interest rates and inflation rates with a central bank that targets core inflation in its Taylor rule. The figure shows that the central bank conducts expansionary policy in this case. Because the adverse energy supply shock is a cost-push shock to the core-goods sector, a central bank that targets core-goods inflation decreases its rates to stabilize the fluctuations in that sector. As expected, the expansionary monetary policy comes at the cost of a higher headline inflation.

Figure 6: Responses to an adverse supply shock | Core-inflation targeting



All in all, a central bank with a target for rest-goods inflation should conduct relatively expansionary policy during an energy crisis with heterogeneous cap policies. When the target is for headline inflation, a more contractionary monetary policy mitigates the inflationary pressures from the high energy inflation in the uncapped country, reducing the headline inflation fluctuations.

3.2.3 Flexible nominal exchange rates

I briefly discuss an alternative setup of the model in which the two countries are not in a currency union and therefore have a flexible nominal exchange rate. Figure 16 in Appendix C shows that with a capped and uncapped country, the responses are slightly larger than in the flexible exchange rate model than the union model. So, under flexible nominal exchange rates, the larger country benefits more from the cap and the spillovers to the uncapped country are a slightly bigger than under the union model.

Moreover, Table 8 in Appendix C presents the welfare table in the non-union setup. As expected, the larger country benefits more when it has an energy price cap and the spillovers to the smaller country are bigger. However, in the opposite case, when the smaller country has the energy price cap, the benefits of the cap are smaller and the spillovers are also smaller compared to union case. So, going from a union to a flexible exchange rate regime, I find that the bigger country benefits while the smaller country loses out. In reverse, smaller countries benefit more from joining the union. This finding is in line with the optimal currency area literature as in Alesina and Barro (2002).

4 Results with domestic energy production

So far, the analysis uses the baseline model which only has an exogenous source of energy. This setup is useful in investigating the dynamics of the economies and its spillovers. However, during the European energy crisis in 2022 total energy consumption per capita did not decrease. When the supply of gas fell, other energy sources substituted out for gas, such that total energy consumption stayed roughly constant.[25] Therefore, to estimate the model, I add a domestic energy production sector to both countries. There is still an exogenous supply of gas which the two countries in the union share.

With the extended model, I perform a Bayesian estimation of the parameters and a historical shock decomposition. I show that the domestic production of energy dampens the negative spillovers of the energy price cap, such that there are two Nash equilibria with differing cap policies for the countries. Moreover, I demonstrate that the energy price cap contributed to 50% of energy inflation and 30% of CPI inflation in the first quarter of 2022 in the uncapped countries.

4.1 Energy sector and energy market clearing in the model

To make sure there is a substitute for the exogenous supply of gas, I add energy firms to both countries in the union. Unless otherwise stated, all other equations in the model stay unchanged from the baseline specification.

Energy firms only use labor, N_{Et}, as their input in their production Y_{Et}:

$$Y_{Et} = A_{Et} N_{Et}^{\eta} \tag{30}$$

where A_{Et} is the total factor technology in the energy sector. η determines the share of profits from total revenue. The production function uses a diminishing-return

[25] Shown in figures later.

technology, as in Ferrero and Seneca (2019), to match the oligopolies in the energy sector.

The representative energy producer takes the wages as given. I assume that the energy firms sell any quantity of energy at the prevailing price. This assumption reflects the findings by Zakeri et al. (2022) who find that the European electricity prices depend highly on natural gas prices. The energy firm's problem is

$$\max_{N_{Et}} P_{Et} Y_{Et} - W_t N_{Et} \tag{31}$$

subject to the production function (30). The first-order conditions are in Appendix A.5.

Energy market clearing. Energy supply comes from the exogenous, union-wide gas supply GAS_t^W and the domestically produced energy. Hence, the market clearing conditions for energy are:

$$E_t^h + E_t^f = \left[(1-\alpha_{GAS})^{1/\zeta} (Y_{Et})^{(\zeta-1)/\zeta} + \alpha_{GAS}^{1/\zeta} (GAS_t)^{(\zeta-1)/\zeta} \right]^{\zeta/(\zeta-1)} \tag{32}$$

$$E_t^{h*} + E_t^{f*} = \left[(1-\alpha_{GAS}^*)^{1/\zeta} (Y_{Et}^*)^{(\zeta-1)/\zeta} + {\alpha_{GAS}^*}^{1/\zeta} (GAS_t^*)^{(\zeta-1)/\zeta} \right]^{\zeta/(\zeta-1)} \tag{33}$$

$$GAS_t + GAS_t^* = GAS_t^W \tag{34}$$

where α_{GAS} is the share of gas in energy use and ζ governs the substitutability of gas and other energy.

4.2 Calibration and estimation of the parameters

In the model with domestic energy production, there are a few extra parameters to consider. Moreover, since the goal is to estimate the contributions of the energy price cap, I divert from the symmetric setup and calibrate some extra parameters differently for the capped and uncapped countries when there is distinguishing data. I calibrate the share of gas in energy use, α_{GAS} and α_{GAS}^*, the steady-state productivity of the energy sector, $\bar{A}_E$, and the share of profits, η, with data and matching targets. For the non-homotheticity parameters, $\varepsilon_1, \varepsilon_1^*, \varepsilon_2$ and ε_2^*, and the elasticity of substitution between gas and non-gas energy, ζ and ζ^*, I use Bayesian estimation.

4.2.1 Calibration.

For the share of gas in energy use, α_{GAS} and α^*_{GAS}, I use the Harmonized Index of Consumer Prices (HICP) item weights from Eurostat and set them to 0.18 and 0.22 respectively for the capped and uncapped countries.[26] Even though the data for estimation starts a decade earlier than 2022, I group the countries already into capped and uncapped countries, referring to the energy price cap policy in 2022. To set the steady-state productivity of the energy sector, $\bar{A}_E$, and the share of profits, η, I match the following targets: The share of workers in the energy sector of 3.66% in Europe[27] and the relative price of energy and rest goods of 1, as in the baseline model. The values that match the targets are $\eta = 0.19$ and $\bar{A}_E = 0.17$. These parameters are symmetric across the countries. Table 5 provides a summary.

Table 5: Extra parameters in model with domestic energy production

Parameter	*Description*	*Value*
α_{GAS}	Share of gas in energy, "Cap"	0.18
α^*_{GAS}	Share of gas in energy, "No cap"	0.22
η	Share of profits for energy firms	0.19
$\bar{A}_E$	Steady-state productivity energy sector	0.17
ε_1	Non-homotheticity parameter	0.25
ε_2	Non-homotheticity parameter	0.25
ζ	Elasticity of substitution between gas and non-gas energy, "Cap"	14.88
ζ^*	Elasticity of substituion between gas and non-gas energy, "No cap"	34.89

4.2.2 Estimation

I estimate the non-homotheticity parameters, $\varepsilon_1, \varepsilon^*_1, \varepsilon_2$ and ε^*_2, and the elasticity of substitution between gas and non-gas energy, ζ and ζ^*. Here, I outline the method used and steps taken for Bayesian estimation and present the outcome.

I use the Bayesian estimation techniques programmed in Dynare (Adjemian et al., 2024). I include the following shocks and measurement errors in the model: Total factor productivity (TFP) shocks for rest-goods and energy sector, demand shocks, cost-push shocks in the rest-goods sector, shocks to gas supply, monetary policy shock, and measurement errors for energy consumption and energy inflation. Those shocks

[26] Eurostat data, online data code: prc_ hicp_inw. I take the weighted average according to Eurostat's country weights (data code: prc_ hicp_cow) when calculating the values for capped and uncapped countries. The categorization of capped and uncapped countries is in Footnote 15.

[27] Own calculations from the World Energy Employment report in 2022 by the International Energy Agency (IEA, 2022) and Eurostat data.

and measurement errors are separate for the two countries in the union, except for the monetary policy shock and the energy inflation measurement error.[28]

First, I compute the mode of the posterior distribution with the Monte-Carlo based optimization routine. Second, the Metropolis-Hastings algorithm evaluates the marginal likelihood of the model and produces the posterior distributions of the parameters. This method closely follows the Bayesian estimation approach in Smets and Wouters (2007). More details on the estimation method are in Appendix B.

Prior distributions. I only estimate the parameters which have no direct counterpart in the data or a sensible target to match. The non-homotheticity parameter ε_1 is bounded by zero and one.[29] Hence, I use the Beta distribution as the prior distribution. The prior mean is set to 0.77 for all four parameters, the calibration value from the data exercise in the baseline model. For the elasticity of substitution between gas and non-gas energy, ζ and ζ^*, I use the Gamma distribution as the prior distribution. I set the prior mean to 2 with a loose standard error. Following Krause et al. (2008), all shock processes follow an AR(1) process. The prior means of all AR-coefficient parameters are 0.9 and the standard deviations are 0.01. The AR-coefficients are bounded by one and zero, so they follow a Beta distribution. The standard deviations follow an Inverse-gamma distribution.

Data. I use the following data series from 2008Q1 to 2019Q4 in the Bayesian estimation:[30] Energy inflation, gas inflation, CPI inflation, energy consumption, gas consumption, output, and the nominal interest rate. Since the union has an integrated energy market, and therefore also gas market, there is one energy and gas inflation rate each for the entire union. Moreover, since the model implies a shared supply of gas, the gas consumption is the same as well. All data are from Eurostat

[28] I add the measurement error for energy inflation with a tight prior to avoid stochastic singularity.

[29] I estimate with $\varepsilon_1 = \varepsilon_1^* = \varepsilon_2 = \varepsilon_2^*$. First, I assume that the "Cap" and "No cap" do not differ in their non-homotheticity to energy. Since the data series is not too long and the "Cap" and "No cap"-blocks only arose in 2022, I assume, as in the baseline calibration, that the countries are symmetric. The only exception I make is the elasticity of substitution between gas and non-gas, as explained in this paragraph. Second, I set $\varepsilon_1 = \varepsilon_2$. Boppart (2014) show that the preferences only work when $0 \leq \varepsilon_1 \leq \varepsilon_2 < 0$. Similarly to the data exercise, when I estimate the two parameters separately, ε_2 gives an estimate below ε_1. Therefore, I impose the corner solution $\varepsilon_1 = \varepsilon_2$.

[30] I deliberately omit the COVID-19 pandemic year to keep the observables stable. For the estimation of the shocks later, I cannot avoid the pandemic year. The sample starts in 2008Q1 due to data availability.

Data. I seasonally adjust the data and detrend them to get the cyclical component. More details are in Appendix B.

Estimation results. Table 6 presents the results of the Bayesian estimation. The non-homotheticity parameters, ε_1, and therefore also ε_1^*, ε_2, and ε_2^*, are 0.27.[31] Moreover, the substitutability of gas and non-gas energy, ζ and ζ^*, are 15.21 and 35.31 respectively. Interestingly, the country-bloc that in 2022 implements an energy price cap have a much lower elasticity of substitution between gas and non-gas energy. This policy decision seems to make sense given the relatively low ability to substitute away from gas. The parameters are well-identified because I use both gas and energy inflation rates and gas and energy consumption for the estimation.[32] The posterior distributions plots and some more details about the estimation results are in Appendix B.

Table 6: Priors and posteriors

Parameter	Prior dist.	Prior mean	Prior std.	Post. mean	Post. std.	90% HPD interval
ε_1	Gamma	0.8	0.1	0.27	0.07	[0.165,0.380]
ζ	Beta	2	1	15.21	1.86	[12.190,18.265]
ζ^*	Beta	2	1	35.31	3.31	[29.981,40.802]

4.3 Results

In this subsection, I first show the simulation results of the extended model with parameter values from the calibration and the estimation, as summarized in Table 5. I show that domestic energy production dampens the effect of the gas supply shock on the economy. Then, I conduct a historical shock decomposition to quantify the contribution of the energy price cap in 2022 to the energy and CPI inflation levels in both the capped and uncapped countries.

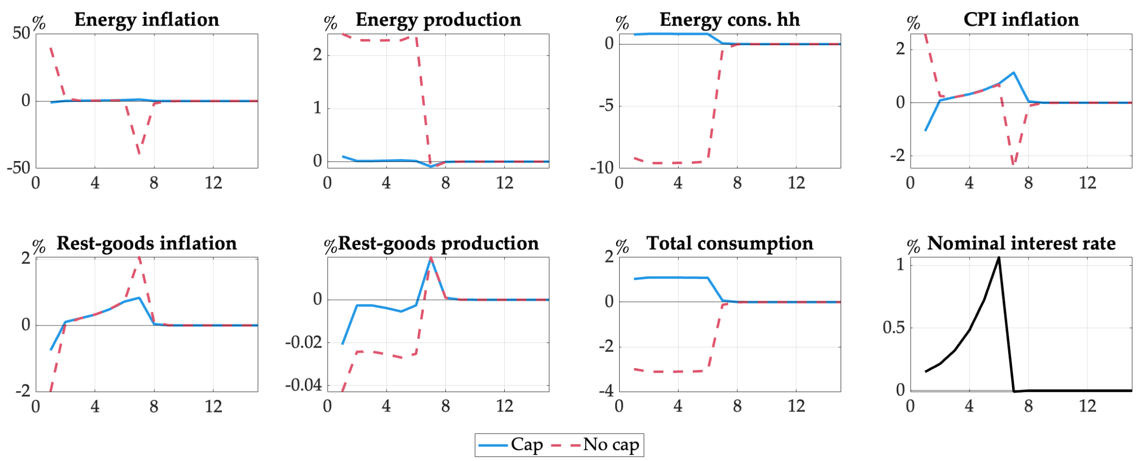
[31]The estimated non-homotheticity values, 0.27, are substantially lower than the values from the data exercise in the baseline model, 0.77. A couple reason to explain this difference: In the baseline model, the parameter captures the non-homotheticity of gas, whereas the extended model covers all energy. Moreover, the sample period of the data exercise was very short, 2020Q3 – 2022Q4, and not overlapping with the sample period of the estimation exercise. Despite the difference, the results of the extended model does not change qualitatively when I set the non-homotheticity parameter to 0.77 instead of 0.27.

[32]Since gas inflation/consumption is a fraction of energy inflation/consumption, the data implies inflation/consumption of non-gas energy.

4.3.1 Simulation results

Figure 7 shows the impulse responses to an adverse energy supply shock when one country implements an energy price cap, with the model that allows for domestic energy production. The energy production in the uncapped country dampens the negative spillovers from the capped to the uncapped country substantially. For example, energy consumption for the households only decreases by about 10% compared to about 20% in the case without energy production in Figure 5. The response of CPI inflation, about 2% on impact, is also much lower than the 20% in the previous case.

Figure 7: Responses to an adverse energy supply shock | Domestic energy production



Note: Inflation and interest rates are annualized.

The welfare outcomes for the combinations of price cap strategies are in Table 7. Because the energy sector dampens the effect of the exogenous gas supply shock, the loss from the gas supply shock is 0.5% instead of 1% in the baseline case, when there are no price cap policies in place. Moreover, when both countries impose a price cap, in the baseline case the losses rose to 15%. The domestic energy production dampens this effect to a loss of 5%, implying that the actual price of energy, and therefore the cost for the government to implement the cap, does not rise as high as in the baseline case. Importantly, Table 7 shows that imposing a price cap is not the dominant strategy as it was in the baseline case in Table 3. Under the extended model there are two Nash equilibra in which one country imposes the price cap and the other country does not. Because the energy sector dampen the negative spillovers of the energy price cap, imposing the cap when the opponent country also has one is not worth the cost. This outcome is the same as under the baseline model with homothetic preferences, as in Table 4, which also dampen the effect of the exogenous energy supply shock.

Table 7: Welfare gains/losses after energy supply shock

Model with domestic energy production

	%	1/3 of union: Cap	1/3 of union: No cap
2/3 of union	Cap	$(-5, -5)$	$(1, -3); -0.2$
	No cap	$(-1, 0); -0.7$	$(-0.5, -0.5)$

Note: The values outside the parentheses are weighted averages, i.e. union-wide welfare.

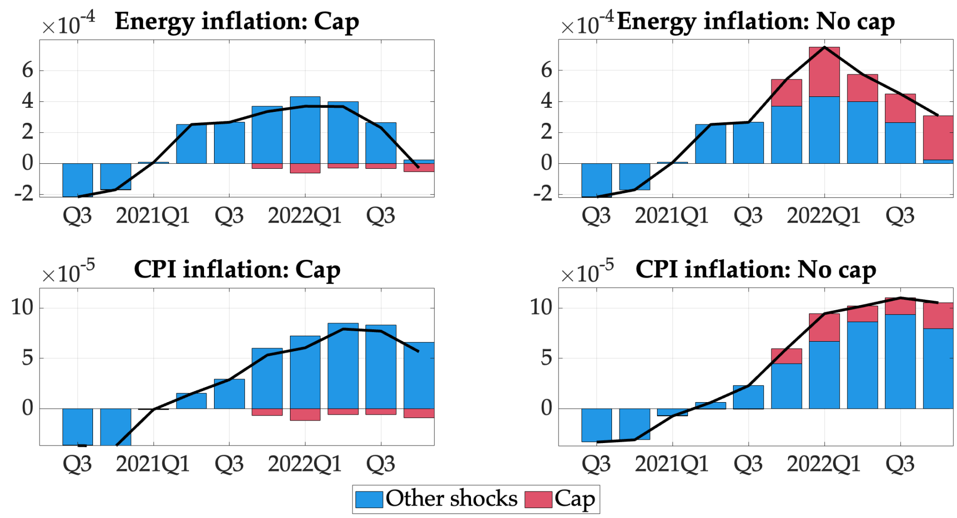
Table 7 also displays the union-wide welfare losses, outside of the parentheses in case of differing cap policies. The union-wide welfare loss is biggest when both countries impose the energy price cap, 5%, because the cost of imposing the cap is high for the government, and there is no other country to spillover to. Interestingly, the cooperative outcome when there are no price caps in the entire union has a bigger union-wide welfare loss, −0.5%, than when one of the countries impose the price cap, −0.2%. So, if the social planner solely cares about the union-wide welfare, they prefer a price cap policy in a part of the union. However, such a policy is at the cost for the uncapped part of the union.

4.3.2 Historical shock decomposition

Using the calibrated and estimated values in Table 5, I perform a historical shock decomposition for the period 2008Q1–2022Q4. Again, I use the Bayesian estimation techniques in Dynare (Adjemian et al., 2024). I use the same shock processes and data series as described for the estimation of the parameters. I add the energy price cap as an additional shock. As before, all shocks follow an AR(1) process and I estimate the coefficients for the shock in the same way as before. After the estimation of the shock processes, I perform a historical shock decomposition. More details on the data and estimation method are in Appendix B.

The historical shock decomposition decomposes the fluctuations in the data series into the contributions from the shocks. The results are in Figure 8. I group all shocks but the energy price cap in one (blue bars) and keep the contributions from the cap separate (red bars). The top-right graph in Figure 8 shows that the energy

Figure 8: Historical shock decomposition | Contributions from the energy price cap



Note: Quarterly log inflation rates in deviations from the sample mean. I detrend the data with the one-sided Hodrick-Prescott filter. More details are in Appendix B.

price cap contributed to about 40% of energy inflation in the uncapped countries in 2022Q1 when energy inflation was the highest. In the last quarter of 2022, the price cap was responsible for virtually all of energy inflation in the uncapped countries. Even though the spillovers that the price cap created were large, the top-left graph shows that in the countries with the cap the energy inflation would not have been much higher without it. If there were no energy price caps, the burden of the gas supply shocks would have been shared equally in the union. The partial substitution to non-gas energy mitigates the upward pressure on energy inflation across the entire union.

Similarly, the bottom graphs show that there were negative spillovers of the price cap to the uncapped countries, the upward pressure on CPI inflation: The price cap contributed to about 12–20% of CPI inflation in the uncapped countries, depending on the quarter. Moreover, the contribution increasing CPI inflation in the uncapped countries was a lot larger than the cap's contribution lowering inflation in the capped countries.

5 TANK results

In this section I compare the energy price cap with targeted transfers. I add poor hand-to-mouth to the model with domestic energy production, to which the transfers are targeted. Therefore, the model becomes a Two-Agent New Keynesian (TANK) model. I compare a country-wide energy price cap (to all households and firms) to a targeted transfer to a fraction of the households. I find that with much lower cost for the government, the targeted transfers achieve more favorable results in terms of boosting consumption for the poor. Moreover, since the transfer does not distort the energy market, there is barely any divergence within the union even if only one country implements the transfers.

5.1 Adding hand-to-mouth households to the model

In the two-agent version of the model, there are financially constrained households who represent share $\lambda \in [0,1]$ of the population, and unconstrained households who are share $1-\lambda$. Financially constrained households have no access to the one-period bonds. Moreover, they earn no profits from firms nor the energy sellers. The budget constraints of the constrained and unconstrained households are respectively:

$$exp_t^c = P_{Et}e_t^{h,c} + P_{Rt}c_{Rt}^c = W_t n_t^c + P_t\tau_t^c + \mathcal{T} - T_t^c \tag{35}$$

$$exp_t^u = P_{Et}e_t^{h,u} + P_{Rt}c_{Rt}^u = W_t n_t^u + \frac{1-\delta}{1-\lambda}D_t + \frac{1}{1-\lambda}D_t^E + R_{t-1}\frac{B_{t-1}}{1-\lambda} - \frac{B_t}{1-\lambda} - HC_t + P_{Rt}\tau_t^u - T_t^u \tag{36}$$

where superscript c refers to variables belonging to constrained households and u to unconstrained ones. τ_t are redisstributive transfers from the government explained below. $\mathcal{T}$ is a steady-state transfer from the constrained to unconstrained, to make sure their consumption is equal in steady state. I aggregate energy and rest-goods consumption and labor as:

$$\lambda e_t^{h,c} + (1-\lambda)e_t^{h,u} = E_t^h \tag{37}$$

$$\lambda c_{Rt}^c + (1-\lambda)c_{Rt}^u = C_{Rt} \tag{38}$$

$$\lambda n_t^c + (1-\lambda)n_t^u = N_t \tag{39}$$

Labor supply of constrained and unconstrained households are therefore identical to the firms.

Following Debortoli and Galí (2018) and Komatsu (2023), the fiscal authority redistributes the taxed profits from firms D_t as transfers to the constrained households, τ_t^c, and unconstrained households, τ_t^u, according to the rules:

$$\tau_t^c = (1 - \tau_0)\delta D_t \tag{40}$$

$$\tau_t^u = \left(1 + \frac{\tau_0 \lambda}{1 - \lambda}\right) \delta D_t \tag{41}$$

where δ is the tax rate on firms' profits, where τ_0 indicates how much of the profits go to (un)constrained households, using $\lambda \tau_t^c + (1 - \lambda)\tau_t^u = \delta D_t$. So, when τ_0 is equal to unity, all profits go back to the unconstrained households.

Calibration. The Household Finance and Consumption Survey (HFCS, 2022) collects household-level data in the Eurozone and estimate that credit-constrained households make up around 5-10% of the population. Hence, in the TANK version, the share of hand-to-mouth households, λ, is 0.1. For the redistribution of taxed firms' profits, I set the tax rate on firm's profits at $\delta = 0.215$, which was the average corporate tax rate in 2022 of European OECD countries (Bray, 2023). The redistribution rule, τ, is equal to unity, such that all profits go to unconstrained households. All other calibration values are identical to the baseline model and the model with domestic energy production.

Consumption response decomposition. In the next subsection I investigate the consumption responses of constrained and unconstrained households in detail. Hence, I perform an impulse response decomposition by rearranging the log-linearized equations. Hatted variables indicate log-linear deviations from steady state.

For constrained households, take total consumption as a sum of energy consumption and rest-goods consumption:

$$\hat{c}_t^c = \frac{\bar{e}^c}{\bar{c}^c} \hat{e}_t^c + \frac{\bar{c}_R^c}{\bar{c}^c} \hat{c}_{Rt}^c \tag{42}$$

Using the choice between energy and rest-goods, Eq. (2), the definition of the energy expenditure wedge, Eq. (3), and their budget constraint, Eq. (35), I decompose the consumption of the constrained households:

$$\hat{c}_t^c = \underbrace{\mathbf{A^c}\hat{e}_t^c + \mathbf{B}\hat{p}_t^{rel,ER}}_{\text{energy consumption}} + \underbrace{\mathbf{C}\hat{w}_t}_{\text{real wage}} - \underbrace{\mathbf{D}\hat{t}_t}_{\text{taxes}} \tag{43}$$

where $\mathbf{A^c} = \frac{1}{\bar{c}^c}\left(\bar{e}^c + \bar{c}_R^c\right)$, $\mathbf{B} = \frac{\bar{c}_R^c}{\bar{c}^c}\left[1 + \frac{1}{1-\alpha_{ENG}}\left(\frac{1}{\overline{exp}}\varepsilon_1 \bar{W}\bar{N}\alpha_{ENG} - \varepsilon_2\right)\right]$, $\mathbf{C} = \frac{\bar{c}_R^c}{\bar{c}^c}\frac{1}{(1-\alpha_{ENG})\overline{exp}}\varepsilon_1 \bar{W}\bar{N}$, and $\mathbf{D} = \frac{\bar{c}_R^c}{\bar{c}^c}\frac{1}{(1-\alpha_{ENG})\overline{exp}}\varepsilon_1\lambda$.

Analogously for unconstrained households, decompose total consumption using the choice between energy and rest-goods, Eq. (2), the definition of the energy expenditure wedge, Eq. (3):

$$\hat{c}_t^u = \underbrace{\mathbf{A^u}\hat{e}_t^u + \mathbf{E}\hat{p}_t^{rel,ER}}_{\text{energy consumption}} + \underbrace{\mathbf{F}\hat{exp}_t}_{\text{consumption smoothing}} \tag{44}$$

where $\mathbf{A^u} = \frac{1}{\bar{c}^u}\left(\bar{e}^u + \bar{c}_R^u\right)$, $\mathbf{E} = \frac{\bar{c}_R^u}{\bar{c}^u}\left(1 - \frac{1}{1-\alpha_{ENG}}\varepsilon_2\right)$, and $\mathbf{F} = \frac{\bar{c}_R^u}{\bar{c}^u}\frac{1}{1-\alpha_{ENG}}\varepsilon_1$. I call the last term "consumption smoothing", since the Euler equation (9) determines the total nominal expenditures of the unconstrained household, $\hat{exp}_t$.

5.2 Results: Price cap vs. targeted transfers

The TANK impulse responses after an adverse gas supply shock with one capped and one uncapped country are quantitatively and qualitatively similar to the representative-agent model in Figure 7.[33] So, the analysis of the macroeconomic responses and welfare in the previous section still applies to the TANK model.

To investigate the consumption responses for constrained and unconstrained in detail, I decompose the consumption responses for the constrained and unconstrained as in Eq. (43) and (44). The results are in Figure 9. For the uncapped country, I decompose the aggregate consumption response into contributions from constrained and unconstrained households.

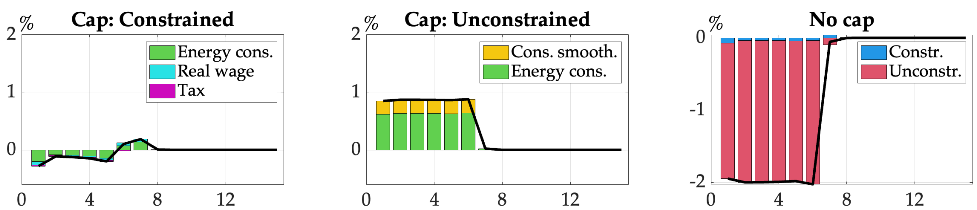
In the capped country, the consumption of the unconstrained increases, whereas the consumption of the constrained decreases. The unconstrained households increase their consumption both by increasing their energy consumption and from consumption smoothing. Recall the mechanism through which households benefit from the energy price cap in the baseline model: Households increase their con-

[33]The responses for the TANK model are in Figure 17 in Appendix C.

sumption because they consume cheap goods from the uncapped country, i.e. the capped country consumes more than it produces. This mechanism is *intertemporal*, since the capped country temporarily runs a current account deficit and borrows from abroad while the energy shock takes place. In the two-agent version, only unconstrained households make *intertemporal* decisions. Hence, unconstrained households can increase their consumption, whereas constrained households cannot.

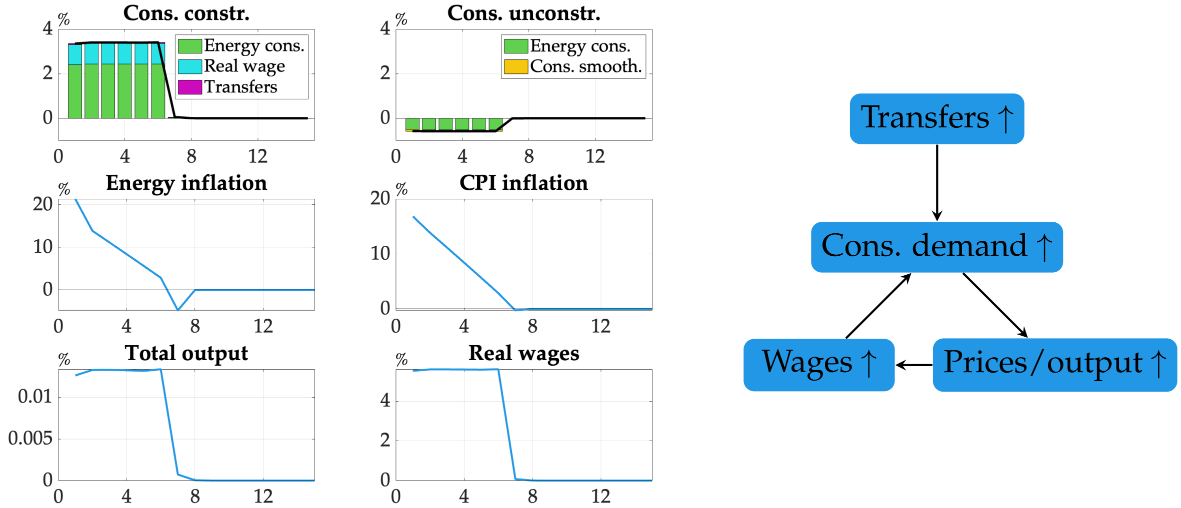
The rightmost graph displays the large spillovers from the capped to uncapped country, similar to previous versions of the model. Because the price cap distorts the energy market in the union, it creates spillovers to the uncapped country. Next, I analyze whether targeted transfers are more effective in helping poorer, constrained households, and whether they create less distortions and spillovers.

Figure 9: Consumption response decomposition | Cap and no cap



Targeted transfers. For easy comparison with the price cap, I set the targeted transfers to the same per person government expenditure, but only for the constrained households. Since they are 10% of the population, the specified targeted transfer only costs 10% of the cost of the price cap. The responses are in Figure 10a. The upper graphs show that the targeted transfers are effective in increasing the constrained household's consumption, while not lowering the consumption of the unconstrained too much. However, the decomposition shows that the gains for constrained households are not just from the transfers. To investigate further the lower four graphs in Figure 10a give more explanation. It seems that the general equilibrium effects of the transfers are much stronger than the direct effect: Transfers increase the consumption of the constrained households, which increases demand for goods. The increased demand for goods puts upward pressure on prices and increases output. Through this increased demand, real wages also increase. Since constrained households are sensitive to real wage changes, their consumption demand increases even more. Figure 10b summarizes the amplification mechanism.

Figure 10: Responses to an adverse energy supply shock | Transfers



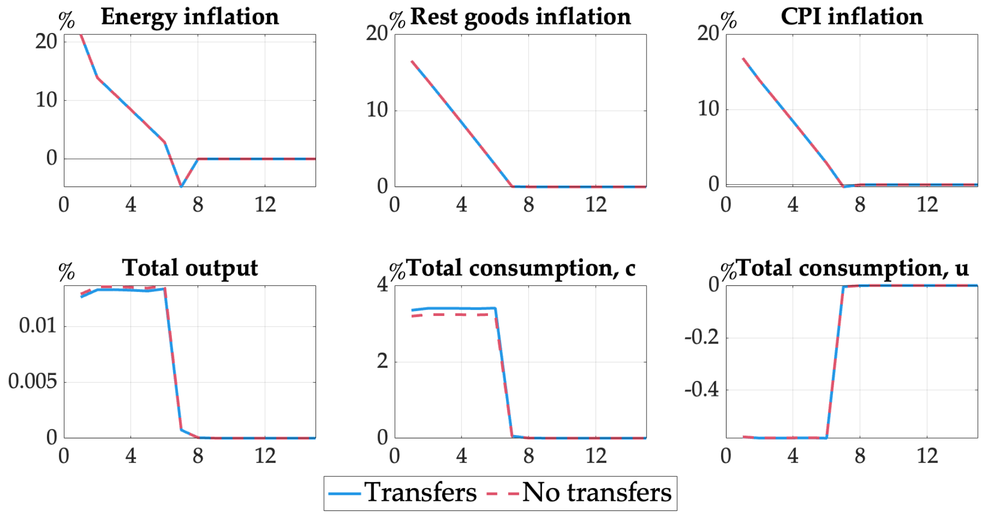
(a) Responses and decompositions (b) Amplification mechanism

So, targeted transfers seem much more effective in helping out poorer households during the energy crisis, for a much lower cost. One drawback is the larger upwards pressure on inflation compared to the price caps. However, targeted transfers, because they do not distort the integrated energy market in the currency union, do not create much divergence within the union, as shown in Figure 11. Since the energy market clears with one price in the entire union, the general equilibrium effects of the transfers also seem to pass through to the country without the transfers. Hence, the CPI inflation in the union is relatively high. However, because of the upwards pressure on prices and output and therefore wages, the constrained households in the country without the transfers also increase their consumption. Moreover, the inflation responses of the rest-goods and CPI inflation co-move. So, the common central bank can conduct aggressive contractionary monetary policy without trade-offs to stabilize inflation rates.

6 Conclusion

This paper investigates the implications of an energy price cap in a currency union during an energy crisis. With a New Keynesian model of a two-country currency union with an exogenous energy supply, I show that an adverse energy supply

Figure 11: Responses to an adverse energy shock | Transfers vs. no transfers



shock causes high energy inflation and a cost-push shock in the non-energy, core sector. Non-homothetic preferences towards energy, i.e energy as a necessity good, amplify the effect of the shock. When one country imposes an energy price cap but the other country does not, there are negative spillovers from the capped to the uncapped country: The capped country avoids the crisis while the uncapped country experiences a double-size crisis.

The magnitude of those spillovers determine the preferred policy decisions – To cap or not to cap? On the one hand, a price cap ensures that households can maintain energy consumption levels. On the other hand, a cap is a cost to the government, and therefore ultimately the households. When one country imposes a price cap, the uncapped country incurs negative spillovers. So, there is a trade-off between paying for the cap and the paying for the negative spillovers. With sufficiently high degree of non-homotheticity, the energy price cap is always worth it, because the spillovers become large. Therefore, countries have an incentive to impose an energy price cap, even though the cooperative outcome is to not have price caps in any country.

To bring the model closer to the data, I then add an energy sector in both the countries. Energy production dampens the effect of the energy shock and of the spillovers, especially when the elasticity of substitution between exogenous energy and domestically produced energy is high. I estimate this parameter using Bayesian techniques and perform a historical shock decomposition to quantify the contribution of the energy price cap on inflation. I find that the energy price cap contributed to about 40% to energy inflation and 20% to headline inflation in the first quarter of 2022 when energy inflation was at its peak.

Last, to compare the energy price cap with targeted transfers, I add hand-to-mouth households to the model. I find that targeted transfers to those households is cheaper and more effective in boosting consumption of the poor. I show that general equilibrium effects play a big role in increasing the hand-to-mouth consumption. Moreover, because the transfers do not distort the energy price, there is no divergence within the union.

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Appendices

A Model

In this section, I expand on the Household and Firm's side of the model. The market clearing, monetary and fiscal policy parts are as described in the main text.

A.1 Households

A.1.1 Preferences

Indirect utility function with non-homothetic preferences as in Boppart (2014):[34]

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{\varepsilon_1} \left[\left(\frac{exp_t}{P_{Rt}} \right)^{\varepsilon_1} - 1 \right] - \frac{\alpha_{ENG}}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Rt}} \right)^{\varepsilon_2} - 1 \right] \right\} \tag{45}$$

where $0 \leq \varepsilon_1 \leq \varepsilon_2 < 1$ and $\alpha_{ENG} > 0$. The utility assumes an inelastic labor supply and a per-period utility of the form $v = \frac{1}{\varepsilon_1} \left[\left(\frac{exp_t}{P_{Rt}} \right)^{\varepsilon_1} - 1 \right] - \frac{\alpha_{ENG}}{\varepsilon_2} \left[\left(\frac{P_{Et}}{P_{Rt}} \right)^{\varepsilon_2} - 1 \right]$. exp_t is the total nominal expenditure of the household on Energy and non-energy (Rest) goods, defined as $exp_t = P_{Et} E_t^h + P_{Rt} C_{Rt}$.

Choice between energy and non-energy rest goods. Marshallian demand functions obtained with Roy's identity:

$$E_t^h = -\frac{\partial v / \partial P_{Et}}{\partial v / \partial exp_t} = \frac{\alpha_{ENG} \left(\frac{P_{Et}}{P_{Rt}} \right)^{\varepsilon_2 - 1}}{\left(\frac{exp_t}{P_{Rt}} \right)^{\varepsilon_1 - 1}} \tag{46}$$

$$C_{Rt} = -\frac{\partial v / \partial P_{Rt}}{\partial v / \partial exp_t} = \frac{\left(\frac{exp_t}{P_{Rt}} \right)^{\varepsilon_1} - \alpha_{ENG} \left(\frac{P_{Et}}{P_{Rt}} \right)^{\varepsilon_2}}{\left(\frac{exp_t}{P_{Rt}} \right)^{\varepsilon_1 - 1}} \tag{47}$$

[34]Indirect utility function $v(p, exp)$: Household's maximal attainable utility when faced with vector p of goods prices and an amount of expenditure e. $v(p, exp) = u(x(p, exp))$. Recall Roy's identity:

$$E^h = -\frac{\partial v / \partial P_E}{\partial v / \partial exp} \qquad c_R = -\frac{\partial v / \partial P_R}{\partial v / \partial exp}$$

Rearrange to express C_{Rt} in terms of E_t^h to get relative demand:[35]

$$C_{Rt} = \frac{\left(\frac{exp_t}{P_{Rt}}\right)^{\varepsilon_1} - \alpha_{ENG}\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2}}{\left(\frac{exp_t}{P_{Rt}}\right)^{\varepsilon_1 - 1}} = \frac{1 - \alpha_{ENG}\left(\frac{P_{Rt}}{exp_t}\right)^{\varepsilon_1}\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2}}{\frac{P_{Rt}}{exp_t}} = \frac{1 - \alpha_{ENG}\varpi_t}{\frac{P_{Rt}}{exp_t}} \tag{52}$$

$$= \frac{1 - \alpha_{ENG}\varpi_t}{\alpha_{ENG}\varpi_t}\frac{P_{Et}}{P_{Rt}}E_t^h \tag{53}$$

where

$$\varpi_t = \left(\frac{P_{Rt}}{exp_t}\right)^{\varepsilon_1}\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2} \tag{54}$$

is the energy expenditure share wedge. When $\varepsilon_1 = \varepsilon_2 = 0$ (Cobb-Douglas case), then $C_{Rt} = \frac{1-\alpha_{ENG}}{\alpha_{ENG}}\frac{P_{Et}}{P_{Rt}}E_t^h$. Define relative total expenditure as:

$$exp_t^{rel} \equiv \frac{exp_t}{P_{Rt}} = \frac{P_{Et}}{P_{Rt}}E_t^h + C_{Rt} \tag{55}$$

Choice between Home and Foreign goods. The non-energy goods are bundled in a composite index:

$$C_{Rt} = \left[(1 - \alpha_{IMP})^{1/\gamma}(C_{Ht})^{(\gamma-1)/\gamma} + (\alpha_{IMP})^{1/\gamma}(C_{Ft})^{(\gamma-1)/\gamma}\right]^{\gamma/(\gamma-1)} \tag{56}$$

where $\alpha_{IMP} \in (0,1)$ is the share of imported goods in the consumption basket and γ is the elasticity of substitution between Home and Foreign goods. C_{Ht}, C_{Ft} are

[35] Another way to rearrange the Marshallian demands:

$$E_t^h = \alpha_{ENG}\frac{exp_t}{P_{Et}}\varpi_t = \alpha_{ENG}\frac{exp_t}{P_{Et}}\left(\frac{P_{Rt}}{exp_t}\right)^{\varepsilon_1}\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2} \tag{48}$$

$$C_{Rt} = \frac{exp_t}{P_{Rt}}(1 - \alpha_{ENG}\varpi_t) = \frac{exp_t}{P_{Rt}}\left[1 - \alpha_{ENG}\left(\frac{P_{Rt}}{exp_t}\right)^{\varepsilon_1}\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2}\right] \tag{49}$$

- With $\varepsilon_1 > 0$, the expenditure elasticity of demand is positive, but strictly smaller than unity for energy and larger than unity for Rest. With $\varepsilon_1 = 0$, they are both equal to unity.
- The expenditure elasticity of demand for energy is $1 - \varepsilon_1$.

The expenditure shares of the two types of goods are:

$$\eta_{Et} = \frac{P_{Et}E_t^h}{exp_t} = \alpha_{ENG}\varpi_t = \alpha_{ENG}\left(\frac{P_{Rt}}{exp_t}\right)^{\varepsilon_1}\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2} \tag{50}$$

$$\eta_{Rt} = \frac{P_{Rt}C_{Rt}}{exp_t} = 1 - \alpha_{ENG}\varpi_t = 1 - \alpha_{ENG}\left(\frac{P_{Rt}}{exp_t}\right)^{\varepsilon_1}\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2} \tag{51}$$

consumption indices of H-produced and F-produced goods respectively:

$$C_{Ht} \equiv \left[\int_0^1 C_{Ht}(i)^{(\varepsilon-1)/\varepsilon} di\right]^{\varepsilon/(\varepsilon-1)} \qquad C_{Ft} \equiv \left[\int_0^1 C_{Ft}(i)^{(\varepsilon-1)/\varepsilon} di\right]^{\varepsilon/(\varepsilon-1)} \tag{57}$$

where ϵ is the elasticity of substitution between different varieties within Home and Foreign goods. The intratemporal consumption choice between different varieties of H-produced and F-produced non-energy goods is:[36]

$$C_{Ht}(i) = \left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\varepsilon} C_{Ht} \qquad C_{Ft}(i) = \left(\frac{P_{Ft}(i)}{P_{Ft}}\right)^{-\varepsilon} C_{Ft} \tag{60}$$

where P_{Ht}, P_{Ht} are indices of prices of of H-produced and F-produced goods respectively:

$$P_{Ht} \equiv \left(\int_0^1 P_{Ht}(i)^{1-\varepsilon} di\right)^{1/(1-\varepsilon)} \qquad P_{Ft} \equiv \left(\int_0^1 P_{Ft}(i)^{1-\varepsilon} di\right)^{1/(1-\varepsilon)} \tag{61}$$

From Eq. (60) and (61), aggregate expenditure on H-produced and F-produced goods respectively:

$$\int_0^1 P_{Ht}(i) C_{Ht}(i) di = P_{Ht} C_{Ht} \qquad \int_0^1 P_{Ft}(i) C_{Ft}(i) di = P_{Ft} C_{Ft} \tag{62}$$

Intratemporal concumption choice between H-produced and F-produced goods bundle:[37]

$$C_{Ht} = (1-\alpha_{IMP}) \left(\frac{P_{Ht}}{P_{Rt}}\right)^{-\gamma} C_{Rt} \qquad C_{Ft} = \alpha_{IMP} \left(\frac{P_{Ft}}{P_{Rt}}\right)^{-\gamma} C_{Rt} \tag{63}$$

[36]Solutions to the following problems:

$$\min_{C_{Ht}(i)} \int_0^1 P_{Ht}(i) C_{Ht}(i) di \quad \text{s.t.} \quad \left[\int_0^1 C_{Ht}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \geq C_{Ht} \tag{58}$$

$$\min_{C_{Ft}(i)} \int_0^1 P_{Ft}(i) C_{Ht}(i) di \quad \text{s.t.} \quad \left[\int_0^1 C_{Ft}(i)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}} \geq C_{Ft} \tag{59}$$

[37]Solution to the following problem:

$$\min_{C_{Ht}, C_{Ht}} P_{Ht} C_{Ht} + P_{Ft} C_{Ft} \quad \text{s.t.} \quad \left[(1-\alpha)^{\frac{1}{\gamma}} C_{Ht}^{\frac{\gamma-1}{\gamma}} + \alpha^{\frac{1}{\gamma}} C_{Ft}^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}} \geq C_{Rt}$$

where P_{Rt} is the aggregate price index for non-energy goods:

$$P_{Rt} = \left[(1-\alpha_{IMP})P_{Ht}^{1-\gamma} + \alpha_{IMP}P_{Ft}^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \tag{64}$$

Combining the intratemporal consumption choice between Home and Foreign goods, I get:

$$\frac{C_{Ht}}{C_{Ft}} = \frac{1-\alpha_{IMP}}{\alpha_{IMP}}\left(\frac{P_{Ht}}{P_{Ft}}\right)^{-\gamma} \tag{65}$$

From Eq. (63) and (64), aggregate expenditure on non-energy consumption is:

$$\int_0^1 P_{Ht}(i)C_{Ht}(i)di + \int_0^1 P_{Ft}(i)C_{Ft}(i)di = P_{Ht}C_{Ht} + P_{Ft}C_{Ft} = P_{Rt}C_{Rt} \tag{66}$$

A.1.2 Intertemporal consumption choices and labor supply

Nominal budget constraint:

$$exp_t = P_{Et}E_t^h + P_{Rt}C_{Rt} = W_tN_t + D_t + D_t^E + R_{t-1}B_{t-1} - B_t - HC_t - T_t \tag{67}$$

where D_t is the nominal profit paid by the domestic firms to the representative domestic household and D_t^E the profits from the energy sellers given by:

$$D_t^E = \frac{P_{Et}}{\bar{P}_E}\left(E_t^h + E_t^f\right) \tag{68}$$

HC_t are the portfolio adjustment costs of the household:

$$HC_t = \frac{\tilde{\nu}}{2}(B_t - \bar{B})^2 \tag{69}$$

where B_t is nominal bond holdings of the household. T_t are lump-sum taxes for the government to finance the energy price cap.

$$\mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{1}{\varepsilon_1}\left[\left(\frac{exp_t}{P_{Rt}}\right)^{\varepsilon_1} - 1\right] - \frac{\alpha_{ENG}}{\varepsilon_2}\left[\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2} - 1\right] \right.$$
$$\left. + \lambda_t\left[W_tN_t + D_t + D_t^E + R_{t-1}B_{t-1} - B_t - HC_t - exp_t\right]\right\} \tag{70}$$

$$\frac{\partial \mathcal{L}}{\partial exp_t}: \quad exp_t^{\varepsilon_1 - 1} P_{Rt}^{-\varepsilon_1} - \lambda_t = 0 \tag{71}$$

$$\frac{\partial \mathcal{L}}{\partial B_t}: \quad \lambda_t = \beta R_t \mathbb{E}_t[\lambda_{t+1}] \tag{72}$$

Euler equation:

$$\left(\frac{\mathbb{E}_t\left[exp_{t+1}\right]}{exp_t}\right)^{1-\varepsilon_1} = \beta \frac{R_t}{1 + P_t \tilde{\nu}(b_t - \bar{b})} \mathbb{E}_t\left[\left(\frac{1}{\Pi_{R,t+1}}\right)^{\varepsilon_1}\right] \tag{73}$$

where $b_t = \frac{B_t}{P_t}$ is real bond holdings and $\Pi_{Rt} = \frac{P_{Rt}}{P_{R,t-1}}$ is gross inflation. Inelastic labor means $N_t = \bar{N}$.

A.2 Firms

There is monopolistic competition among firms producing the rest of consumption goods. They face adjustment costs à la Rotemberg (1982).

Cost minimization

$$\min_{N_t(i), E_t^f(i)} W_t N_t(i) + P_{Et} E_t^f(i) \tag{74}$$

$$\text{s.t. demand curve} \quad Y_t(i) = \left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\epsilon} Y_t \tag{75}$$

$$\text{production function} \quad Y_t(i) = A_t \left[\left(\alpha^f\right)^{1/\theta^f} \left(E_t^f(i)\right)^{(\theta^f-1)/\theta^f} + \left(1-\alpha^f\right)^{1/\theta^f} \left(N_t(i)\right)^{(\theta^f-1)/\theta^f}\right]^{\theta^f/(\theta^f-1)} \tag{76}$$

First order condition w.r.t. $N_t(i)$ and $E_t^f(i)$:[38]

$$W_t = \left(1-\alpha^f\right)^{1/\theta^f} \mu_t^{nom} \left(\frac{Y_t(i)}{N_t(i)}\right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \tag{77}$$

$$P_{Et} = \left(\alpha^f\right)^{1/\theta^f} \mu_t^{nom} \left(\frac{Y_t(i)}{E_t^f(i)}\right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \tag{78}$$

[38]The Lagrange multiplier on the demand curve μ_t^{nom} is the nominal marginal cost.

Combining these equations, we get that the relative price of the production inputs determine the trade-off between them:

$$\frac{E_t^f(i)}{N_t(i)} = \frac{\alpha^f}{1-\alpha^f}\left(\frac{P_{Et}}{W_t}\right)^{-\theta^f} \tag{79}$$

The total factor productivity:

$$\ln(A_t) \equiv a_t = \rho_a a_{t-1} + \varepsilon_t^a \tag{80}$$

Price setting

$$\max_{P_{Ht}(i),N_t(i)} \mathbb{E}_0 \sum_{t=0}^{\infty} \Lambda_{t+1}\left[\frac{P_{Ht}(i)}{P_{Ht}}Y_t(i) - \frac{W_t}{P_{Ht}}N_t(i) - P_{Et}E_t^f(i) - Y_t FC_t\right] \tag{81}$$

$$\text{s.t. demand curve} \quad Y_t(i) = \left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\epsilon} Y_t \tag{82}$$

$$\text{price adjustment costs} \quad FC_t(i) = \frac{\xi}{2}\left(\frac{P_{Ht}(i)}{P_{H,t-1}(i)} - 1\right)^2 \tag{83}$$

where $\Lambda_{t+1} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}$ is the stochastic discount factor and $\int_0^1 P_{Ht}(i) = P_{Ht}$ the average price of H goods. First order condition w.r.t. $P_{Ht}(i)$:[39]

$$\begin{aligned}(1-\epsilon)\left(\frac{P_{Ht}(i)}{P_{Ht}}\right)^{-\epsilon}\frac{1}{P_{Ht}}Y_t - \xi\left(\frac{P_{Ht}(i)}{P_{H,t-1}(i)} - 1\right)\frac{1}{P_{H,t-1}(i)}Y_t \\ + \mu_t \epsilon P_{Ht}(i)^{-\epsilon-1}\left(\frac{1}{P_{Ht}}\right)^{-\epsilon} Y_t + \mathbb{E}_t\left[\Lambda_{t+1}\xi\left(\frac{P_{H,t+1}(i)}{P_{Ht}(i)} - 1\right)Y_{t+1}\left(\frac{P_{H,t+1}(i)}{P_{Ht}(i)^2}\right)\right] = 0\end{aligned} \tag{84}$$

Aggregate price adjustment costs:

$$FC_t = \int_0^1 FC_t(i)di \tag{85}$$

Aggregate nominal profits:

$$D_t = P_{Ht}Y_t(1 - FC_t) - W_t N_t - P_{Et}E_t^f \tag{86}$$

[39]The Lagrange multiplier on the demand curve μ_t is the real marginal cost.

A.3 Summary of model equations

Relative prices

$$P_{Rt} = \left[(1-\alpha_{IMP})P_{Ht}^{1-\gamma} + \alpha_{IMP}P_{Ft}^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \tag{A.1}$$

$$P_{Rt}^{*} = \left[\alpha_{IMP}^{*}P_{Ht}^{1-\gamma} + (1-\alpha_{IMP}^{*})P_{Ft}^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \tag{A.2}$$

$$P_t = \alpha_{ENG}\log P_{Et} + (1-\alpha_{ENG})\log P_{Rt} \tag{A.3}$$

$$P_t^{*} = \alpha_{ENG}\log P_{Et}^{*} + (1-\alpha_{ENG})\log P_{Rt}^{*} \tag{A.4}$$

$$S_t = \frac{P_{Ft}}{P_{Ht}} \tag{A.5}$$

$$P_t^{rel,ER} = \frac{P_{Et}}{P_{Rt}} \tag{A.6}$$

$$P_t^{rel,ER*} = \frac{P_{Et}^{*}}{P_{Rt}^{*}} \tag{A.7}$$

$$P_{Et} = P_{Et}^{*} \tag{A.8}$$

Households.

$$C_t = E_t^h + C_{Rt} \tag{A.9}$$

$$C_t^* = E_t^{h*} + C_{Rt}^* \tag{A.10}$$

$$C_{Rt} = \left[(1-\alpha_{IMP})^{1/\gamma}(C_{Ht})^{(\gamma-1)/\gamma} + (\alpha_{IMP})^{1/\gamma}(C_{Ft})^{(\gamma-1)/\gamma}\right]^{\gamma/(\gamma-1)} \tag{A.11}$$

$$C_{Rt}^* = \left[(1-\alpha_{IMP}^*)^{1/\gamma}(C_{Ft}^*)^{(\gamma-1)/\gamma} + (\alpha_{IMP}^*)^{1/\gamma}(C_{Ht}^*)^{(\gamma-1)/\gamma}\right]^{\gamma/(\gamma-1)} \tag{A.12}$$

$$\frac{C_{Ht}}{C_{Ft}} = \frac{1-\alpha_{IMP}}{\alpha_{IMP}}\left(\frac{P_{Ht}}{P_{Ft}}\right)^{-\gamma} = \frac{1-\alpha_{IMP}}{\alpha_{IMP}}S_t^{\gamma} \tag{A.13}$$

$$\frac{C_{Ht}^*}{C_{Ft}^*} = \frac{1-\alpha_{IMP}^*}{\alpha_{IMP}^*}\left(\frac{P_{Ht}}{P_{Ft}}\right)^{-\gamma} = \frac{1-\alpha_{IMP}^*}{\alpha_{IMP}^*}S_t^{\gamma} \tag{A.14}$$

$$C_{Rt} = \frac{[1-\alpha_{ENG}\varpi_t]}{\alpha_{ENG}\varpi_t}P_t^{rel,ER}E_t^h \tag{A.15}$$

$$C_{Rt}^* = \frac{[1-\alpha_{ENG}\varpi_t^*]}{\alpha_{ENG}\varpi_t^*}P_t^{rel,ER*}E_t^{h*} \tag{A.16}$$

$$\varpi_t = \left(\frac{P_{Rt}}{exp_t}\right)^{\varepsilon_1}\left(\frac{P_{Et}}{P_{Rt}}\right)^{\varepsilon_2} = \left(exp_t^{rel}\right)^{-\varepsilon_1}\left(P_t^{rel,ER}\right)^{\varepsilon_2} \tag{A.17}$$

$$\varpi_t^* = \left(\frac{P_{Rt}^*}{exp_t^*}\right)^{\varepsilon_1}\left(\frac{P_{Et}^*}{P_{Rt}^*}\right)^{\varepsilon_2} = \left(exp_t^{rel*}\right)^{-\varepsilon_1}\left(P_t^{rel,ER*}\right)^{\varepsilon_2} \tag{A.18}$$

$$exp_t^{rel} = P_t^{rel,ER}E_t^h + C_{Rt} \tag{A.19}$$

$$exp_t^{rel*} = P_t^{rel,ER*}E_t^{h*} + C_{Rt}^* \tag{A.20}$$

$$N_t = \bar{N} \tag{A.21}$$

$$N_t^* = \bar{N} \tag{A.22}$$

$$\left(\frac{\mathbb{E}_t\left[exp_{t+1}^{rel}\right]}{exp_t^{rel}}\right)^{1-\varepsilon_1} = \beta\frac{R_t}{1+P_{Rt}\tilde{\nu}(b_t-\bar{b})}\mathbb{E}_t\left[\Pi_{R,t+1}^{-1}\right] \tag{A.23}$$

$$\left(\frac{\mathbb{E}_t\left[exp_{t+1}^{rel*}\right]}{exp_t^{rel*}}\right)^{1-\varepsilon_1} = \beta\frac{R_t}{1+P_{Rt}^*\tilde{\nu}(b_t^*-\bar{b})}\mathbb{E}_t\left[\left(\Pi_{R,t+1}^*\right)^{-1}\right] \tag{A.24}$$

Firms.

$$Y_t = A_t \left[\left(\alpha^f\right)^{1/\theta^f} \left(E_t^f\right)^{(\theta^f-1)/\theta^f} + \left(1-\alpha^f\right)^{1/\theta^f} \left(N_t\right)^{(\theta^f-1)/\theta^f} \right]^{\theta^f/(\theta^f-1)} \tag{A.25}$$

$$Y_t^* = A_t^* \left[\left(\alpha^f\right)^{1/\theta^f} \left(E_t^{f*}\right)^{(\theta^f-1)/\theta^f} + \left(1-\alpha^f\right)^{1/\theta^f} \left(N_t^*\right)^{(\theta^f-1)/\theta^f} \right]^{\theta^f/(\theta^f-1)} \tag{A.26}$$

$$\ln(A_t) \equiv \hat{a}_t = \rho_a \hat{a}_{t-1} + \varepsilon_t^a \tag{A.27}$$

$$\ln(A_t^*) \equiv \hat{a}_t^* = \rho_a \hat{a}_{t-1}^* + \varepsilon_t^{a*} \tag{A.28}$$

$$\frac{W_t}{P_t} = \left(1-\alpha^f\right)^{1/\theta^f} \mu_t \left(\frac{Y_t}{N_t}\right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \tag{A.29}$$

$$\frac{W_t^*}{P_t^*} = \left(1-\alpha^f\right)^{1/\theta^f} \mu_t^* \left(\frac{Y_t^*}{N_t^*}\right)^{1/\theta^f} \left(A_t^*\right)^{(\theta^f-1)/\theta^f} \tag{A.30}$$

$$\frac{P_{Et}}{P_t} = \left(\alpha^f\right)^{1/\theta^f} \mu_t \left(\frac{Y_t}{E_t^f}\right)^{1/\theta^f} A_t^{(\theta^f-1)/\theta^f} \tag{A.31}$$

$$\frac{P_{Et}}{P_t^*} = \left(\alpha^f\right)^{1/\theta^f} \mu_t^* \left(\frac{Y_t^*}{E_t^{f*}}\right)^{1/\theta^f} \left(A_t^*\right)^{(\theta^f-1)/\theta^f} \tag{A.32}$$

$$\left(\Pi_{Ht}-1\right)\Pi_{Ht} = \frac{\epsilon}{\xi}(\mu_t - \bar{\mu}) + \beta \mathbb{E}_t \left[\left(\Pi_{H,t+1}-1\right)\Pi_{H,t+1} \frac{Y_{t+1}}{Y_t} \right] \tag{A.33}$$

$$\left(\Pi_{Ft}-1\right)\Pi_{Ft} = \frac{\epsilon}{\xi}(\mu_t^* - \bar{\mu}) + \beta \mathbb{E}_t \left[\left(\Pi_{F,t+1}-1\right)\Pi_{F,t+1} \frac{Y_{t+1}^*}{Y_t^*} \right] \tag{A.34}$$

Goods market clearing.

$$Y_t = \left(1-\alpha_{IMP}\right) \left(P_{Ht}^{rel}\right)^{-\theta} C_{Ht} + \alpha_{IMP} \left(P_{Ht}^{rel*}\right)^{-\theta} C_{Ht}^* + AC_t + FC_t + T_t \tag{A.35}$$

$$Y_t^* = \alpha_{IMP} \left(P_{Ft}^{rel}\right)^{-\theta} C_{Ft} + \left(1-\alpha_{IMP}\right) \left(P_{Ft}^{rel*}\right)^{-\theta} C_{Ft}^* + AC_t^* + FC_t^* \tag{A.36}$$

Energy market clearing.

$$E_t = E_t^h + E_t^{h*} + E_t^f + E_t^{f*} \tag{A.37}$$

$$E_t = E_{t-1}^{\rho_e} \bar{E}^{1-\rho_e} \exp(\varepsilon_t^e) \tag{A.38}$$

Bonds market clearing.

$$CA_t = r_{t-1}b^h_{t-1} + P_{Ht}Y_t\left(1 - FC_t\right) - P_{Rt}C_{Rt} - HC_t \tag{A.39}$$

$$CA^*_t = r_{t-1}b^{h*}_{t-1} + P_{Ft}Y^*_t\left(1 - FC^*_t\right) - P^*_{Rt}C^*_{Rt} - HC^*_t \tag{A.40}$$

$$\left(CA_t\right)^{\Theta} = -\left(CA^*_t\right)^{1-\Theta} \tag{A.41}$$

$$\left(b^h_t\right)^{\Theta} = -\left(b^{h*}_t\right)^{1-\Theta} \tag{A.42}$$

Monetary policy.

$$R_t = \frac{1}{\beta}\left(\frac{\Pi^W_t}{\bar{\Pi}^W}\right)^{\phi_\pi}\left(\frac{Y^W_t}{\bar{Y}^W_t}\right)^{\phi_y}\exp(\nu_t) \tag{A.43}$$

$$\nu_t = \rho^{\nu}\nu_{t-1} + \varepsilon^{\nu}_t \tag{A.44}$$

Fiscal policy.

$$P^{eff}_{Et} = P_{Et} - CAP_t \tag{A.45}$$

$$CAP_t = P_{Et} - \bar{P}_E \tag{A.46}$$

$$CAP_t(E^h_t + E^f_t) = T_t \tag{A.47}$$

$$CAP^{exp}_t = \frac{CAP_t\left(E^h_t + E^f_t\right)}{Y_t} \tag{A.48}$$

A.4 Steady state

This section characterizes the steady state of the Home economy. The Foreign economy is identical. In steady state, the prices are constant. Hence, the inflation rates are all equal to unity.

$$\bar{\Pi} = 1 \tag{B.1}$$

$$\bar{\Pi}_E = 1 \tag{B.2}$$

$$\bar{\Pi}_R = 1 \tag{B.3}$$

I take $\bar{P}_R = 1$ as the numeraire. With the below calculations, I get the exogenous level of energy $\bar{E}$ which sets the steady-state price of energy also equal to unity, so $\bar{P}_E = 1$.

Demand side. Taking the Euler equation in steady state, I can express the steady state nominal interest rate as a function of the discount factor:

$$\bar{R} = \frac{1}{\beta} \tag{B.4}$$

Moreover, I assume that the energy expenditure wedge ϖ_t is unity in steady state, so that the expenditure shares of energy and the rest of consumption goods are the same as in the benchmark Cobb-Douglas case:

$$\bar{\varpi} = 1 \tag{B.5}$$

Then, since prices are equal to unity in steady state, I obtain that steady-state total expenditure of the household from the food expenditure wedge equation:

$$e\bar{x}p = \bar{\varpi}^{1/\varepsilon_1} \tag{B.6}$$

From the Marhsallian demands from Footnote 35, derive the steady-state values for energy and rest goods consumption:

$$\bar{E}^h = \alpha_{ENG} e\bar{x}p\bar{\varpi} \tag{B.7}$$

$$\bar{C}_R = (1 - \alpha_{ENG}\bar{\varpi})e\bar{x}p \tag{B.8}$$

Then, from the goods market clearing condition, get the steady-state output value:

$$Y = (1 - \alpha_{IMP})\bar{C}_R + \alpha^*_{IMP}\bar{C}^*_R \tag{B.9}$$

Supply side. From the price-setting equation of the firms, get the steady-state real marginal cost:

$$\bar{\mu} = \frac{\epsilon - 1}{\epsilon} \tag{B.10}$$

Since $\exp(\bar{a})$ scales the economy, I set the total factor productivity $\bar{a}$ such that $\exp(a) = 1$:

$$\bar{a} = 0 \tag{B.11}$$

From the energy demand equation of the firms, get the steady-state value for the firms' energy use:

$$\bar{E}^f = \alpha^f (\bar{\mu})^{\theta f} \bar{Y} \tag{B.12}$$

Then, from the production function, obtain the steady-state value for labor:

$$\bar{N} = \left[\frac{Y - \left(\alpha^f\right)^{1/\theta^f} \left(\bar{E}^f\right)^{(\theta^f-1)/\theta^f}}{(1-\alpha^f)^{1/\theta^f}} \right]^{(\theta^f)/(\theta^f-1)} \tag{B.13}$$

Using the steady-state values for labor, output and marginal cost, get the real wage:

$$\bar{W}^{real} = \left(1-\alpha^f\right)^{1/\theta^f} \bar{\mu} \left(\frac{\bar{Y}}{\bar{N}}\right)^{1/\theta^f} \tag{B.14}$$

The profits in steady state are:

$$\bar{D} = Y - \bar{W}^{real}\bar{N} - \bar{E}^f \tag{B.15}$$

Check supply and demand side are consistent. From the budget constraint of the household, check that the following equation holds:

$$e\bar{x}p = \bar{W}^{real}\bar{N} + \bar{D} + \bar{E}^h + \bar{E}^f \tag{B.16}$$

For the two-agent version, check that the aggregate budget constraint (constrained and unconstrained household holds combined) holds:

$$e\bar{x}p = \bar{W}\bar{N} + (1-\delta)\bar{D} + \bar{E}^h + \bar{E}^f + \lambda\tau_t^c + (1-\lambda)\tau_t^u \tag{B.17}$$

A.5 Domestic energy production sector

The oligopolistic energy firm's problem is

$$\max_{N_{Et}} P_{Et}Y_{Et} - W_t N_{Et} \tag{B.18}$$

$$\text{s.t. production fucntion } Y_{Et} = A_{Et}N_{Et}^{\eta} \tag{B.19}$$

The first-order condition gives rise to the labor demand:

$$N_{Et} = \left(\eta A_{Et}\frac{P_{Et}}{W_t}\right)^{\frac{1}{1-\eta}}, \tag{B.20}$$

which determines the energy production:

$$Y_{Et} = A_{Et}^{\frac{1}{1-\eta}} \left(\eta \frac{P_{Et}}{W_t} \right)^{\frac{\eta}{1-\eta}} \tag{B.21}$$

and the profits of the energy firm:

$$D_{Et} = (1-\eta) P_{Et} Y_{Et} \tag{B.22}$$

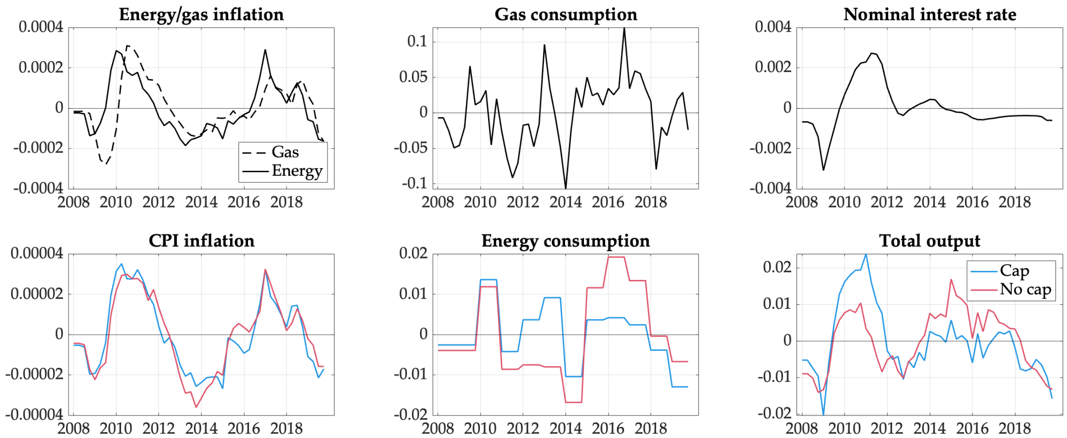
B Bayesian estimation: Details on data used and results

In this section, I describe and present the data used for Bayesian estimation. For the first estimation, to estimate the parameters, I use data from before the COVID-19 pandemic, so 2008Q1 – 2019Q4. For the second estimation, to perform a historic shock decomposition of the shock, I use data up to 2022Q4. I seasonally adjust the all data series with X-13ARIMA-SEATS. When the data is monthly, I transform the data to get quarterly equivalents. To get the aggregates for "Cap" and "No cap" countries, I take weighted averages with country weights from Eurostat Data. Finally, I detrend the data with the one-sided Hodrick-Prescott filter and demean the series to match the model variables.

Pre-pandemic data for estimating parameters. The data used for the estimation parameters are in Figure 12.[40] Since the price cap policy only took place in 2022, the energy and gas inflation in the union is the same across countries. Using gas consumption as a common variable avoids stochastic singularity. Since I assume that the countries in the union share one supply of gas, when the gas price is the same across countries the gas consumption also needs to be the same. Nominal interest is the rate that the European Central Bank sets. Energy consumption is yearly data. Hence, I allow for measurement errors in the model to capture quarterly fluctuations.

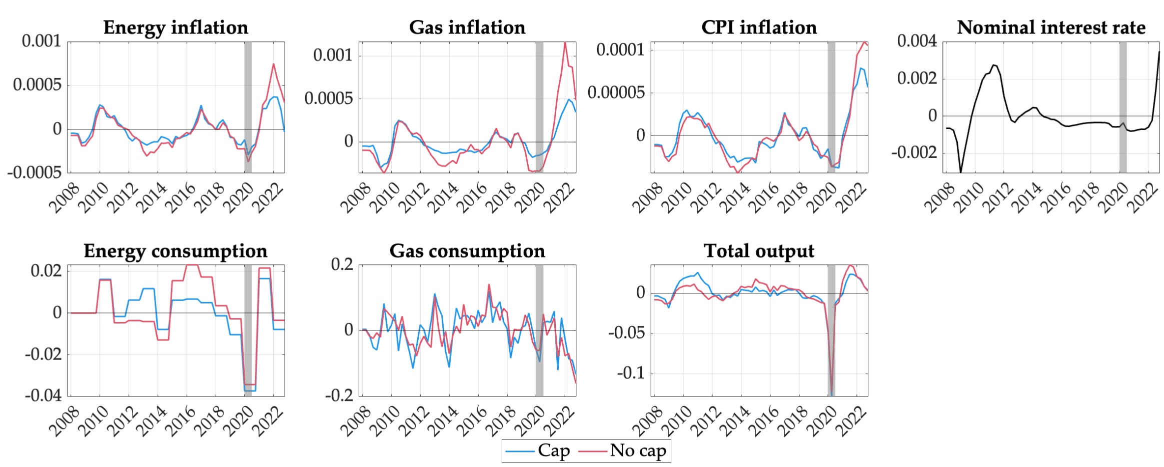
[40]Data sources: Energy, gas, and CPI inflation (Eurostat, prc_hicp_manr), gas consumption (Eurostat, nrg_cb_gasm), nominal interest rate (Eurostat, irt_st_q), total output (Eurostat, namq_10_pc), energy consumption (Our World in Data, Per capita primary energy consumption by source). When data are not per capita and they need to be, I use intrapolated population data (Eurostat, demo_pjan) to transform them to per capita variables.

Figure 12: Data used for estimation of parameters



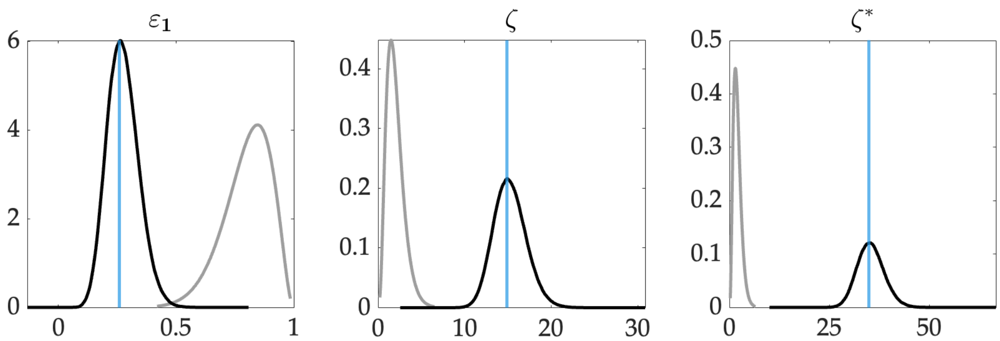
Data for historical shock decomposition. The data used for the historical shock decomposition are in Figure 13. The data sources are identical to those for the pre-pandemic data. However, since I detrend the data over a slightly longer sample, the values are somewhat different. Moreover, I only let the energy and gas inflation diverge in 2022. Before 2022, I take the weighted average of the two blocs, since there are no price caps in place. Figure 13 shows that the energy and gas inflation rates moved very closely between "Cap" and "No cap" countries before 2022.

Figure 13: Data used for historical shock decomposition



Note: Grey-shaded area are 2020Q1 and Q2, the quarters most affected by the COVID-19 pandemic.

Figure 14: Prior and posterior distributions



Estimation method. I use the Bayesian estimation approach built in Dynare Adjemian et al. (2024). For the estimation of the parameters, I use a slice optimizer to find the mode of the posterior distribution.[41] Then, the Metropolis-Hastings algorithm evaluates the marginal likelihood of the model and produces the posterior distributions. I use one million replications for each chain of the algorithm and four parallel chains. I check that the Monte Carlo Markov Chain converges and that the posterior chain for each parameter is stable. The posterior plots are in Figure 14. For the historical shock decomposition, I use the `shock_decomposition`-command in Dynare, which uses the Kalman smoother to decompose the historical fluctuations of the variables into contributions from each shock.

C Additional figures

Table 8: Welfare gains/losses after energy supply shock

(a) Union

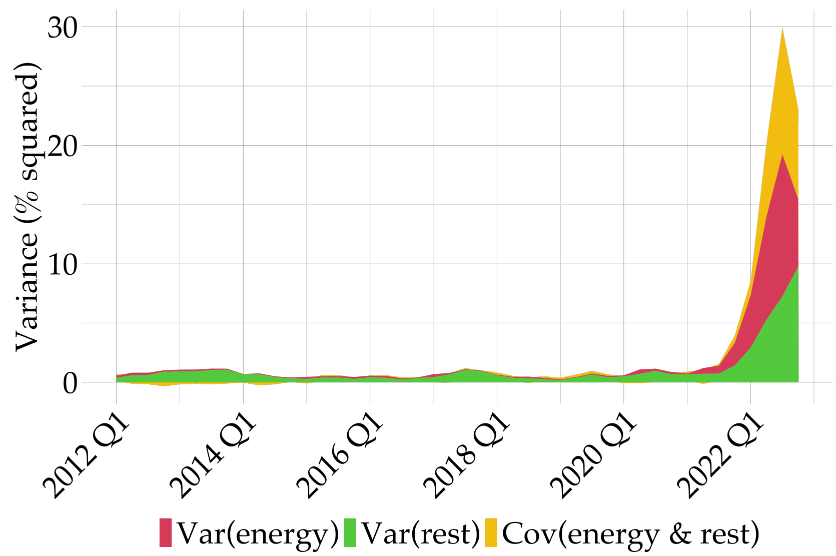
	%	1/3 of union Cap	 No cap
2/3	Cap	(−15.0, −15.0)	(7.7, −16.7)
	No cap	(−15.6, 6.1)	(−0.7, −0.7)

(b) Flexible nominal exchange rate

	%	1/3 of world Cap	 No cap
2/3	Cap	(−15.0, −15.0)	(8.1, −17.7)
	No cap	(−14.7, 5.6)	(−0.7, −0.7)

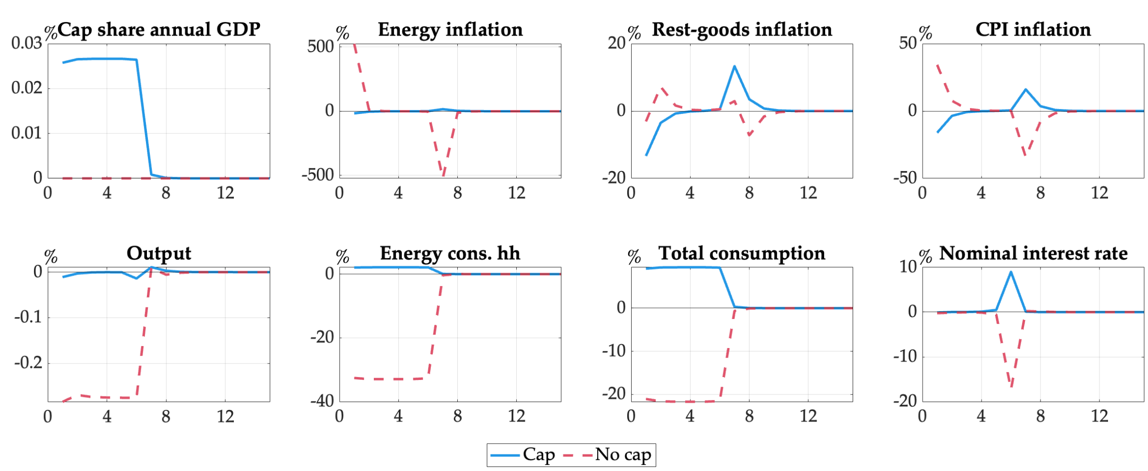
[41]Option 5 of the `mode_compute`-option in the `estimation`-command in Dynare.

Figure 15: Decomposition of the variance of headline inflation



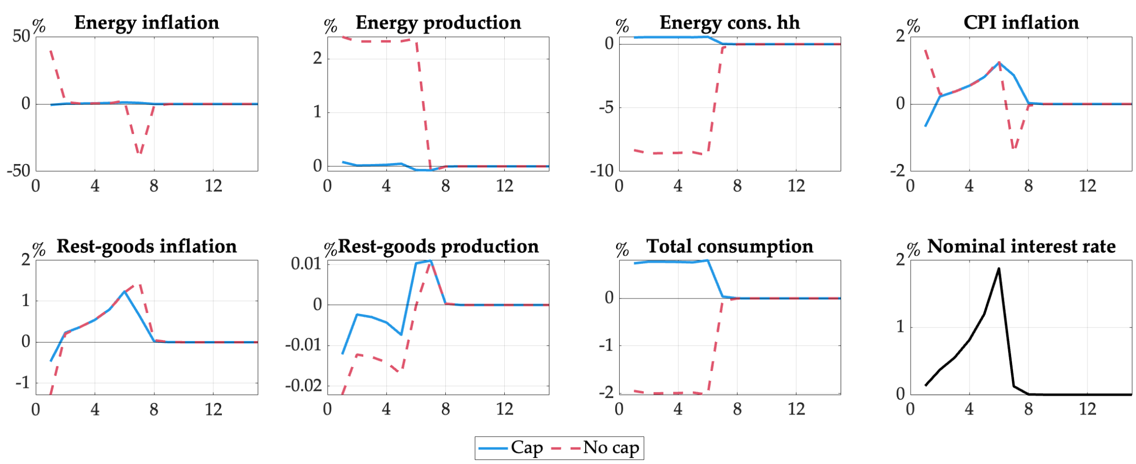
Note: The headline inflation in country i in quarter t is $\Pi_{it} = (1 - \alpha_{it}^{ENG})\Pi_{it}^{R} + \alpha_{it}^{ENG}\Pi_{it}^{E}$ where is α^{ENG} the share of energy in the consumption basket, Π_{it}^{E} and Π_{it}^{R} energy and rest inflation. The variance decomposition is across countries for each quarter, so $Var_t(\Pi_{it}) = Var_t\left[(1 - \alpha_{it}^{ENG})\Pi_{it}^{R} + \alpha_{it}^{ENG}\Pi_{it}^{E}\right]$. Data source: Eurostat.

Figure 16: Responses to an adverse energy supply shock in model with flexible nominal exchange rates | Cap vs. no cap



Note: Inflation and interest rates are annualized.

Figure 17: Responses to an adverse energy supply shock in TANK model | Cap vs. no cap



Note: Inflation and interest rates are annualized.