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

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Abstract

During the recent energy crisis some Euro Area countries introduced price caps on energy, while others did not, leading to about 30 percentage points higher energy inflation in uncapped countries. This paper investigates the trade-offs policymakers face with energy price caps in a two-country currency union model with shared energy supply. The cooperative, optimal outcome is for neither country to impose a price cap, since the cap is a costly market distortion. However, capping allows a country to avoid a crisis at the cost of negative spillovers on the uncapped country, characterized by high inflation and lower output. The quantitative model with non-homothetic preferences and substitutability of energy sources shows that the cost of the price cap exceeds the cost of such spillovers, explaining why some countries capped prices while others did not. Moreover, I show that the spillovers from price caps contributed to about 10 (0.5) percentage points of energy (headline) inflation in the uncapped Euro Area countries in 2022. Targeted transfers, an alternative policy to the price cap, is a cheaper and more effective way to boost consumption of the poor without creating divergence within the union.

JEL codes: E31, E63, F45, Q41

Keywords: Energy crisis, energy price cap, monetary union, international spillovers

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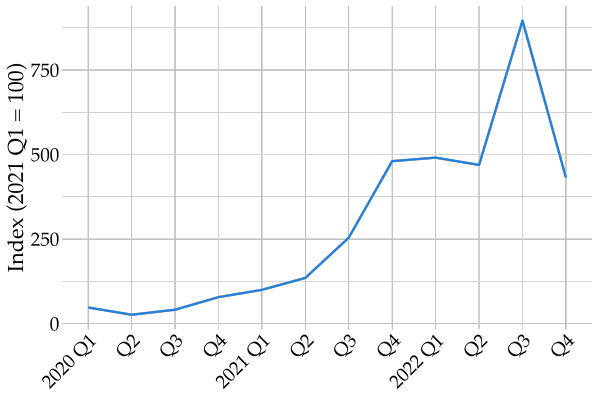
1 Introduction

The Euro Area, and Europe as a whole, experienced a large energy crisis in 2022. Energy prices began rising in mid-2021 and soared in 2022 after the Russian invasion of Ukraine, as shown in Figure 1. The increase in energy prices triggered energy price cap decisions from many, but not all governments. This paper investigates the effects of an energy price cap in a subset of countries in a currency union during an energy crisis, focusing on international spillovers and policy trade-offs of the price cap.

Figure 1: Natural gas price in Europe



Notes: The price index of the Title Transfer Facility (TTF) gas in the Netherlands. Most price setters use this price as the reference price and gas contracts are indexed to this price, the TTF price index is the standard gas price benchmark for Europe (Rogge, 2024).[2] For longer time series, see Figure 16 in Appendix C. Data source: IMF Data (2024).

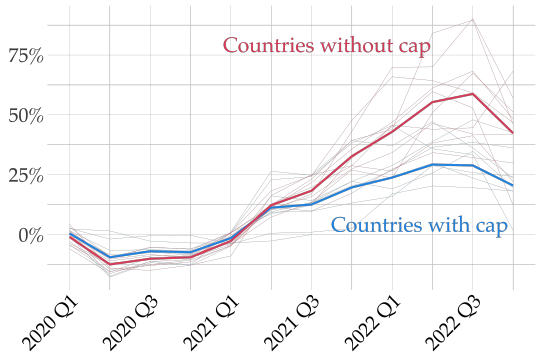
Inflation rates in uncapped countries were considerably higher than in capped countries, as shown in Figure 2. In 2022, France and Germany, among others, decided to impose an energy price cap, whereas other countries including The Netherlands and Italy did not. The energy inflation in countries without an energy price cap was about 30 percentage points higher than in the capped countries in 2022Q3, and for headline inflation the difference was about 5 percentage points. Figure 17 in Appendix C shows that the divergence of both energy and headline inflation in 2022 was at an unprecedented magnitude since the start of the Euro Area.

The paper uses a two-country currency union model with a shared energy supply to investigate the trade-offs of an energy price cap. In the absence of price caps, an

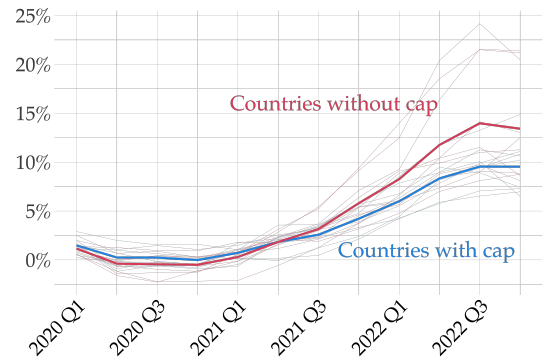
[2]Moreover, gas prices drive wholesale electricity prices as the highest marginal cost of energy production, so they are a good indicator for energy/electricity price movements (Pescatori & Steurmer, 2022).

Figure 2: Inflation in the Euro Area 2020 – 2022

(a) Energy inflation



(b) Headline inflation



Notes: Annualized energy and headline inflation rates in the Euro Area. Source: Eurostat. 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.

adverse energy supply shock not only reduces energy consumption, but also acts as a cost-push shock to an economy: a decline in the exogenous supply of energy depresses output while increasing inflation. The assumption of an exogenous energy supply reflects the high dependency of Europe on Russian gas before 2022 (Pescatori & Steurmer, 2022; Moll et al., 2023). Since the shock is essentially a relative price shock, it is a standard result in New Keynesian frameworks that it acts like a cost-push shock.

First, I find that capping the energy price allows a country to avoid the crisis while imposing negative spillovers on the uncapped country, causing divergence within the currency union. 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. This setup is somewhat stylized, because in reality most governments imposed a price cap that was less strict. However, this assumption is not overly restrictive, as the strictness of the price cap shifts the overall level of responses but does not alter the underlying mechanisms.

With the price cap, a country does not suffer from the energy supply shock: output does not suffer a fall and inflation does not soar. Moreover, households can maintain their energy consumption. On the contrary, the uncapped country experiences a larger cost-push shock compared to the case of no price caps in the entire union, and also a larger decline in energy consumption. A crucial assumption be-

hind these spillovers is the shared energy supply between the capped and uncapped countries, as is the case in Europe for Russian gas. During the adverse energy supply shock the capped country's energy consumption does not decrease because the price does not change. Then, the energy supply available in the uncapped country declines even more, which causes an even higher (energy) inflation and a lower welfare.

Second, the paper demonstrates that for policymakers facing the decision – to cap or not to cap – there is a trade-off between the cost of the price cap and the cost of the spillovers. I analyze the welfare implications of energy price caps in the two-country model, in which each country faces two policy decisions at the onset of an energy supply shock. The optimal, cooperative outcome occurs when both countries refrain from imposing a price cap. This outcome avoids market distortions, as energy prices reflect true scarcity during the crisis. However, because of the lack of cooperation between countries within the union, each country has an incentive to deviate from the cooperative strategy: if one country does not impose an energy price cap, the other country has an incentive to impose one to avoid the energy crisis as described above.

If one country imposes a price cap, should the other country follow suit? On one hand, imposing the price cap leads to inefficiencies and high costs, as artificially low prices in both countries encourage excessive energy consumption despite scarcity. On the other hand, not imposing the cap means bearing the negative spillovers from the first country's cap, which is also costly. In the quantitative model the cost of imposing the price cap are larger than the cost of these negative spillovers. Hence, the outcome of a static decision game is a price cap in one of the two countries, even though the cooperative strategy is for neither of the countries to impose the cap. This result explains why in reality some countries capped the energy price while others did not.

The key assumptions to this result are the type of household preferences and the substitutability of the energy source that is shared between the countries: they both affect the magnitude of the negative spillovers experienced by the uncapped country. The non-homothetic preferences are as in Boppart (2014): households spend a higher share of their income on energy when their income is low, which means they dislike reducing their energy consumption. These type of preferences are common in literature handling necessity goods like energy and food (Blanco & Diz, 2021; Olivi et al., 2023). Non-homothetic preferences amplify the negative spillovers, which

results in costs from spillovers exceeding the costs of implementing the price cap depending on the substitutability of the energy source.

Endogenous energy production dampens the spillovers and explains why a country might prefer to bear the negative spillovers from the price cap as an uncapped country rather than imposing a price cap themselves. During the European energy crisis in 2022, the elasticity of substitution between gas, subjected to the exogenous supply shock, and non-gas energy was crucial, since the total energy consumption per capita did not decrease (Energy Institute, 2024). In the quantitative model, I estimate this elasticity of substitution and find that with the estimated parameters the cost of bearing the spillovers is smaller than the cost of implementing a price cap.

Third, I provide counterfactual exercises of price cap policies in Europe in 2022. 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 to 10 percentage points of energy inflation and 0.5 percentage points to headline inflation in the uncapped countries in 2022. Moreover, the inflation rates in the capped countries would not have been much higher without the energy price cap, reinforcing the model result that the cooperative, optimal outcome involves no price caps.

Last, I introduce a version of the model with hand-to-mouth households to compare the energy price cap to targeted transfers as an alternative policy measure. Shielding low-income households from rising energy costs was a key priority for many governments (Sgaravatti et al., 2023). I show that 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, they do not cause large spillovers nor divergence within the union.

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 and the substitutability of the shared energy source determines the magnitude of the spillovers, and hence the incentives for policymakers 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), Galí and Monacelli (2008), Ferrero (2009), and Hjortsoe (2016) 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 (Trichet, 2013; Chang, 2015). In this paper, I introduce a new dimension of integration: a shared energy supply. I analyze the international coordination in energy price cap policies during a union-wide energy shock. The analysis focuses on the determinants of the magnitude of the cap's spillovers, and finds that fiscal coordination between countries is favorable. However, I show that countries do not always have the incentives to cooperate.

Second, this paper contributes to the rapidly expanding 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 abroad. Auclert et al. (2023) and Chan et al. (2024) study the macroeconomic effects of an energy price shock and look at the coordination of fiscal policies and optimal monetary policy, respectively. Moreover, Erceg et al. (2024) and Glocker and Wegmüller (2024) study the effectiveness of fiscal policies, including energy subsidies, in stabilizing inflation. This paper analyzes the trade-offs and the spillovers of the energy price cap in an international setting. I approach the topic with a novel angle: I adopt a tractable, 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 is organized as follows: Section 2 outlines the model with non-homothetic preferences, the price cap setup, and the model calibration. Section 3 discusses the results of the baseline model, including the magnitude of the spillovers. I also analyze the trade-offs between headline and core-inflation targeting. Then, in Section 4 I estimate the substitutability between the shared energy source (gas) and domestically produced energy (non-gas) and show that the costs of implementing a price cap are larger than the costs of bearing the negative spillovers. I also 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. Section 6 concludes.

2 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 $\in (0; 1)$ and hence of the Foreign is $1 - \quad$. Time is discrete and indexed by $t \in \{0; \ldots\}$. Both countries are inhabited by households, firms and a fiscal authority. There is one central bank setting monetary policy for the entire currency union.

Energy supply to the union is exogenous which follows from the high dependency of Europe on imported energy (Eurostat, 2023a). The energy market clears with a single price for the whole union reflecting the well-integrated energy market in Europe (Pescatori & Steurmer, 2022). When there is an energy price cap, the government pays for the difference between the actual price of energy and the retail price of energy. 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. Households have non-homothetic preferences for energy, which ensure that they consume a higher expenditure share of energy when their income decreases. Firms in both countries produce tradable goods under monopolistic competition, using energy and labor as inputs. 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 $\quad$. Appendix A provides a more detailed description of the model, including a list of relevant equilibrium conditions and the steady state.

This model includes non-homothetic preferences but not the substitutability of different energy sources. This version of the model is useful for understanding the core intuition and mechanics before introducing the substitutability of energy sources. In Section 4 I complete the model by adding domestic energy production and allowing for substitutability of the exogenous source of energy (gas) and domestically produced energy (non-gas).

2.1 Households

2.1.1 Preferences

Households derive utility from two types of goods: energy goods, E_t^h, and non-energy, other goods, C_{Ot}. 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 $exp_t = P_{Et}E_t^h + P_{Ot}C_{Ot}$, matters for the share of expenditure spent on energy and the other goods. P_{Et} and P_{Ot} are prices for energy and other goods respectively. The indirect utility function of the representative household with non-homothetic preferences is:[3]

$$E_0 \sum_{t=0}^{\infty} {}_t \frac{1}{"_1} \frac{exp_t}{P_{Ot}}^{"_1} - 1 - \frac{{}_E}{"_2} \frac{P_{Et}}{P_{Ot}}^{"_2} - 1 \tag{1}$$

where ${}_E > 0$ is the share of energy consumption in the steady state and is the discount factor. $"_1$ governs the expenditure elasticity of demand: when $"_1 > 0$, the expenditure elasticity of demand is strictly smaller than unity for energy and larger than unity for other goods. So, when total nominal expenditure, or total income available for consumption, decreases, the demand for energy decreases less than proportionally with income and the demand for other goods decreases more than proportionally. $"_2$ controls the elasticity of substitution between energy and other goods. In steady state, the elasticity of substitution between energy and other goods is $= 1 - "_2 - \frac{{}_E}{1 \quad {}_E}("_2 - "_1)$.[4][5]

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

$$C_{Ot} = \frac{1 - {}_E\$_t}{{}_E\$_t} \frac{P_{Et}}{P_{Ot}} E_t^h \tag{2}$$

[3] An indirect utility function $v(p; exp)$ expresses the household's maximal attainable utility when faced with vector p of goods prices and an amount of expenditure exp. In general, a direct utility counterpart of this indirect utility function does not exist.

[4] See Lemma 3 in Boppart (2014) for the derivation and Appendix A.4 for the steady state.

[5] Another commonly used non-homothetic preference specification is the Stone-Geary preferences, with which the consumer derives utility from consumption that exceeds the subsistence level. Under Stone-Geary preferences the expenditure share of energy does not increase after a price increase. Since in practice the household energy expenditure share increased in Europe in 2022, I chose to use the preferences from Boppart (2014) (OECD, 2023; European Commission, 2024).

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

where

$$\$_t = \frac{P_{Ot}}{\exp_t}^{"_1} \frac{P_{Et}}{P_{Ot}}^{"_2} \tag{3}$$

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 other goods. Consequently, the consumption demand is non-homothetic in income since the share of expenditure on energy, $_E\$_t$, increases when the household becomes poorer. When $"_1 = "_2 = 0$, Eq. (2) simpli es to $C_{Ot} = \frac{1 \quad _E}{_E}\frac{P_{Et}}{P_{Ot}}E_t^h$, which is the standard Cobb-Douglas result. In this case, the expenditure elasticity for both types of goods are equal to unity. Section 3.2.4 discusses the case under preferences with Constant Elasticity of Substitution (CES).

Relative demand 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}:

$$C_{Ot} = \left[(1 \quad _I)^{1=}(C_{Ht})^{(\quad 1)=} + (\quad _I)^{1=}(C_{Ft})^{(\quad 1)=}\right]^{=(\quad 1)} \tag{4}$$

where $_I$ 2 (0; 1) is the share of imported goods in the consumption basket and is the elasticity of substitution between Home and Foreign goods. Since the preferences between Home and Foreign-produced goods are homothetic, the intratemporal consumption demand between Home and Foreign goods are standard:

$$\frac{C_{Ht}}{C_{Ft}} = \frac{1 \quad _I}{_I}\frac{P_{Ht}}{P_{Ft}} \tag{5}$$

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

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

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

$$P_{Ot} = \left[(1 \quad _I)P_{Ht}^{1} + _I P_{Ft}^{1}\right]^{\frac{1}{1}} \tag{7}$$

2.1.2 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 pro ts of domestic rms, D_t, and energy sellers, D_t^E.[7] The nominal budget constraint of the households is the following:

$$\exp_t = P_{Et} E_t^h + P_{Ot} C_{Ot} = W_t N_t + D_t + D_t^E + R_{t\ 1} B_{t\ 1}^h \quad B_t^h \quad HC_t \quad T_t \tag{8}$$

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

$$\frac{E_t[\exp_{t+1}]}{\exp_t}^{1\ \ "_1} = \frac{R_t}{1 + P_t \sim (b_t^h \quad b^h)} E_t \quad \frac{1}{{}_{O;t+1}}^{"_1} \tag{9}$$

where $b_t^h = \frac{B_t^h}{P_t}$ denotes real bond holdings and ${}_{Ot} = \frac{P_{Ot}}{P_{O;t\ \ 1}}$ gross in ation of the other goods. P_t is the aggregate price index, explained below. Households supply labor inelastically, such that $N_t = N \ 8t$. In Section 3.2.4, I brie y discuss the results under elastic labor supply.

2.2 Firms

Final good producer. The nal good rms produce the nal consumption good, Y_t, using intermediate goods, $Y_t(i)$, according to:

$$Y_t = \int_0^1 Y_t(i)^{(1\ \ )=} di^{\ =(1\ \ )} \tag{10}$$

where $Y_t(i)$ is the output of the intermediate rm i and the elasticity of substitution between different varieties of the intermediate good. The rms produce in a competitive market and maximize pro ts given by $P_t Y_t \quad \int_0^1 P_t(i) Y_t(i) di$. The rst-order condition to the maximization problem gives the demand function of the intermedi-

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

ate good i:

$$Y_t(i) = \frac{P_{Ht}(i)}{P_{Ht}} \quad Y_t \tag{11}$$

and the price of the nal good Y_t:

$$P_{Ht} = \int_0^1 P_{Ht}(i)^{(1\quad)} \quad ^{1} \tag{12}$$

where $P_{Ht}(i)$ is the price of the intermediate good i.

Intermediate good producers. The country has a continuum of $i \ 2 \ [0;1]$ rms who produce the (non-energy) other 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:

$$Y_t(i) = A_t \quad ^{f \quad 1=\ f} \quad E_t^f(i)^{(\ f \quad 1)=\ f} + \ 1 \quad ^{f \quad 1=\ f} (N_t(i))^{(\ f \quad 1)=\ f} \quad ^{f\ =(\ f \quad 1)} \tag{13}$$

where ^{f} is the share of energy used in production and ^{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 rms face adjustment costs a la Rotemberg (1982), so their pro t maximization problem is: [8]

$$\max_{P_{Ht}(i);N_t(i)} E_0 \sum_{t=0}^{1} \quad \frac{P_{Ht}(i)}{P_{Ht}} Y_t(i) \quad \frac{W_t}{P_{Ht}} N_t(i) \quad P_{Et} E_t^f(i) \quad Y_t FC_t \tag{14}$$

subject to

$$\text{demand curve} \quad Y_t(i) = \frac{P_{Ht}(i)}{P_{Ht}} \quad Y_t \tag{15}$$

$$\text{price adjustment costs} \quad FC_t(i) = \frac{}{2} \quad \frac{P_{Ht}(i)}{P_{H;t \quad 1}(i)} \quad 1 \quad ^{2} \tag{16}$$

where governs the level of price adjustment costs.

The rst-order condition with respect to $P_{Ht}(i)$ leads to the standard New Keynesian Philips Curve (NKPC). See Appendix A for detailed derivations. As in Aoki

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

(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 in ation.

Since all intermediate goods are identical, $P_{Ht}(i) = P_{Ht}$ and $N_t(i) = N_t$. Aggregate rm's pro ts reads:

$$D_t = P_{Ht} Y_t (1 \quad FC_t) \quad W_t N_t \quad P_{Et} E_t^f \tag{17}$$

2.3 Monetary policy

The monetary authority targets the headline in ation 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:

$$R_t = \frac{1}{} \quad \frac{{}^{W}_{t}}{{}^{W}} \qquad \exp(\ _t) \tag{18}$$

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

$$ {}^{W}_{t} = (\quad _t) \ (\quad _t)^1 \tag{19}$$

The monetary authority only targets in ation, and no output gap, re ecting the European Central Bank's price stability mandate. The in ation that the central bank targets is:

$$ _t = (\quad _{Et}) \ ^{E} (\quad _{Ot})^1 \quad ^{E} \tag{20}$$

which corresponds to the Consumer Price Index (CPI), or headline in ation in common literature and data sources. The price level follows from the in ation term $ _t = P_t{=}P_{t \ 1}$.[9]

2.4 Fiscal policy: The energy price cap

If the Home country introduces a cap on energy prices, the scal policy and the government budget constraint of the country become relevant. With an energy price

[9]The main results are robust to changing the central bank's target from CPI to core in ation. In Section 3.2.3 I discuss the implications of core targeting on in ation rates.

cap in the Home country, the effective energy price becomes:

$$P_{Et}^{eff} = \begin{cases} P_E & \text{with cap and } P_{Et} > P_E \\ P_{Et} & \text{otherwise} \end{cases} \tag{21}$$

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

$$COST_t(E_t^h + E_t^f) = T_t \tag{22}$$

where $COST_t = P_{Et} \quad P_E$ denotes the cost of the cap per unit of energy for the government. Ricardian Equivalence holds in this model because consumption does not respond to changes in future expected taxes and government spending. Later, I introduce hand-to-mouth agents to the model as an extension in which case Ricardian Equivalence does not hold.

2.5 Equilibrium

The equilibrium of this economy is characterized by a sequence of prices $\{W_t; W_t^*; P_{Ht}; P_{Ft}; P_{Et}\}$ and allocations $\{E_t^h; E_t^{h*}; C_{Ht}; C_{Ft}; C_{Ht}^*; C_{Ft}^*; N_t; N_t^*; E_t^f; E_t^{f*}; b_t^h; b_t^{h*}\}$ such that the goods market is cleared for both Home and Foreign-produced goods, the energy market is cleared, the assets are in zero net supply between the countries, and the labor market is cleared in both countries. The full list of equilibrium conditions are in Appendix A.3.

2.5.1 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

[10] The results are robust to changing the price cap target from both household and rms to just households.

Foreign country:

$$Y_t = C_{Ht} + C_{Ht} + HC_t + FC_t \tag{23}$$

$$= (1 \quad {}_{I}) \frac{P_{Ht}}{P_{Ot}} \quad C_{Ot} + {}_{I} \frac{P_{Ht}}{P_{Ot}} \quad C_{Ot} + HC_t + FC_t \tag{24}$$

where C_{Ht} is the consumption of Home-produced goods in Foreign, and C_{Ot} is the consumption of other goods (both Home and Foreign-produced) in Foreign.

2.5.2 Energy market clearing.

The energy market is fully integrated across the two countries in the union. As in Bayer et al. (2023), I model the supply of energy E_t as exogenous. So, the supply of energy does not respond to price movements and the price of energy has to adjust for the market to clear. The energy market clears when the demand for energy by households and rms from both countries equals the exogenous supply:

$$E_t = E_t^h + E_t^f + E_t^h + E_t^f \tag{25}$$

2.5.3 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 rms resource constraints, (8) and (17):

$$B_t^h \quad B_{t\ 1}^h = r_{t\ 1} B_{t\ 1}^h + P_{Ht} Y_t (1 \quad FC_t) \quad P_{Ot} C_{Ot} \quad HC_t \tag{26}$$

where $r_t = R_t \quad 1$ 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:

$$CA_t = b_t^h \quad b_{t\ 1}^h \tag{27}$$

$$CA_t = r_{t\ 1} b_{t\ 1}^h + \frac{P_{Ht}}{P_t} Y_t (1 \quad FC_t) \quad \frac{P_{Ot}}{P_t} C_{Ot} \quad \frac{1}{P_t} HC_t \tag{28}$$

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 $CA_t = \quad CA_t$ needs to hold. Moreover, the assets are in zero net supply between countries.

2.6 Calibration

The model is calibrated at quarterly frequency. In the extended model, I perform a Bayesian estimation of some of the model parameters. Table 1 provides an overview of the baseline calibration values. The countries are identical except for their relative sizes.

Table 1: Baseline calibration of parameters

Parameter	Description	Value
Households		
$_{I}$	Share of imports in consumption	0.25
$_{E}$	Share of energy in consumption	0.066
	Elasticity of substitution between Home and Foreign goods	6
	Elasticity of substitution within goods	9
$"_1$	Non-homotheticity parameter	1
$"_2$	Non-homotheticity parameter	0.77
$\sim$	Adjustment cost for bonds	0.001
	Discount factor	0.99
Firms		
$_{f}$	Share of energy in production	0.011
$_{f}$	Elasticity of substitution between energy and labor	0.2
	Price-adjustment cost	15.84
Monetary policy		
	Taylor-coef cient on in ation	1.5
$_{CB}$	Share of energy for central bank's consideration	0.066
Currency union		
	Relative GDP size Home country (with cap)	0.68

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, $_{I}$, is 0.25. The share of energy in total consumption expenditure is on average 6.6%, so I set $_{E}$ as 0.066.[11]. The elasticity of substitution within different varieties of Home and Foreign, , is 9, in line with standard literature. The adjustment cost for bond-holdings, $\sim$, is 0.001, to match the canonical work by Schmitt-Groh é and Uribe (2003). The discount factor 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 $"_1$ and $"_2$.

For the rms, I set the share of energy in production, $_{f}$, 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, $_{f}$, is 0.2, following Bayer

[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

et al. (2023) and Bachmann et al. (2024).[13] I calibrate the Rotemberg (1982) price-adjustment cost parameter, , 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 re ect the fast change in prices in 2022. The corresponding price-adjustment cost parameter is = [(1)0:5]=[(1 0:5)(1 0:5)] 15:84

Monetary policy follows a standard Taylor (1993) rule, with the coef cient on in ation as 1.5. The monetary authority targets headline in ation, following the of cial target of the European Central Bank (ECB, 2021).[14]

To obtain 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 = 0 :68.[16]

Non-homotheticity parameters. For the calibration of the non-homotheticity parameters $"_1$ and $"_2$, I conduct a data matching exercise. I take the gas in ation 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.[17] At the peak in

Rademaekers 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 in ation. The decision reports mention headline in ation gures 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]The results are robust against a calibration with equal-sized countries, so = 0 :5.

[17]I manipulate the data from Eurostat (online data code: prc_hicp_manr) to obtain 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 in- ation 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.

2022Q3, the Netherlands experienced a gas price in ation of about 30% in quarterly rates (over 90% in annual rates). France, on the other hand, imposed a price cap on gas in ation which barely exceeded 10% in quarterly rates (about 30% in annual rates). The gas consumption data re ect the policies: in the Netherlands, the gas consumption decreased about 15 percentage points more than in France. I conduct a parameter search for $"_1$ and $"_2$, imposing $0 \quad "_1 \quad 1$ and $0 \quad "_1 \quad 1$ to minimize the Mean Squared Error (MSE) between the energy consumption from the model in which I feed in the gas in ation data, and the realized gas consumption in 2020Q3 to 2022Q4 for both countries.[18] The results give $"_1 = 1$ and $"_2 = 0{:}77$, which implies an elasticity of substitution between energy and other goods of 0.25 in steady state, which is in line with other literature on energy shocks like Bayer et al. (2023) and Chan et al. (2024). I set the elasticity of substitution between Home and Foreign goods, , to 6, the upper bound of standard literature (Benigno, 2009), since the data exercise gives the lowest error under this calibration.

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

Notes:The left panel shows the gas in ation of France (cap) and the Netherlands (no cap). I feed this data into the model and nd the parameters $_1$ and $_2$ that minimize the Mean Squared Error (MSE) between the gas consumption data (right panel, dotted) and the model-implied gas consumption (solid). Sources for data: Eurostat.

Shock speci cation. In the numerical analyses in the following sections, I shock the model with an adverse energy supply shock of 15% that lasts for six quarters. In this way, I capture the decline in the supply of Russian gas in summer 2022 and the

[18]The data is from Eurostat (online data code: nrg_c_gasm). With population data (intrapolated for the quarters), I obtain 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.

expectations of governments that the shock would last until spring 2023. More concretely, 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 introduced energy price caps lasting four to nine quarters in 2022.

3 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 nd that the capped country can avoid most of the crisis, while the uncapped country experiences a cost-push shock 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

The shock is a 15% shock to the energy supply of the currency union and lasts six quarters. 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, the results in Figure 4 show one response per variable.

The adverse energy supply shock pushes up on the energy in ation. The recessionary shock decreases in ation for other goods on impact. In the later periods, the other goods in ation increases since energy is one of the production inputs. Consumer Price Index (CPI) in ation, or headline in ation, is a weighted average of energy in ation and other goods in ation, and hence peaks when other goods in ation is highest. Production and consumption of other goods decrease as a consequence of the energy supply declining. [19] Energy consumption by households decreases by

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

about the same amount as the shock. Since the energy shock increases CPI in ation while depressing output, the shock acts as a cost-push shock. The monetary authority conducts contractionary policy to dampen in ationary pressures, and returns to steady state together with CPI in ation.

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

Notes:Impulse responses to a 15% decline in energy supply. Preferences are non-homothetic. Output is equal to the output gap. The y-axis is in terms of percentage deviations from steady state. The x-axis is in quarters. In ation and interest rates are annualized.

3.2 Energy crisis with one cap and one no-cap country

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 other goods produced in their own country, but also more of the ones produced in the uncapped country. Moreover, the other goods in ation responses show that

the goods from the uncapped country have become relatively cheaper because of the large recession in that country. 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. The energy scarcity is more severe due to the capped country not reducing their energy consumption. Since the capped country does not decrease their energy consumption, energy is an even scarcer good in the uncapped country. The adverse energy supply shock causes households in this country to reduce their energy consumption by twice as much relative to the case when the other country also did not introduce the energy price cap. The energy supply shock is essentially double the size in the uncapped country. Crucially, the other in ation uctuations in both countries imply a terms-of-trade depreciation for the uncapped country, because their other in ation decreases more than the one in the capped country. Since the terms of trade depreciates for the uncapped country, their purchasing power decreases. Imports become more expensive and exports to the households in the capped country increases, which decreases total consumption in the uncapped country drastically. [20] Despite the increased demand from the capped country for goods produced in the uncapped country, the output in the uncapped country decreases due to the large energy supply shock.

The common monetary policy adopts a less contractionary stance than when neither of the countries implemented the energy price cap, in Figure 4. The central bank targets the weighted-average headline in ation in its Taylor rule, which is the black line in the CPI in ation graph in Figure 5. Since the in ation rates of the capped and uncapped countries peak at different times, the weighted-average in ation does not increase as much as in the case without any price caps, which causes a milder response from the central bank.

3.2.1 Energy crisis with energy price caps

Figure 6 shows the responses when both countries impose an energy price cap. In this case, the price of energy stays constant in the entire union. Because of the distorted price, consumers try to maintain their energy and other goods consumption. However, since the supply of energy is exogenous, the supply side of the economy

[20] This result is similar to the terms-of-trade externality by for example Corsetti and Pesenti (2001), in which an expansionary scal policy causes a terms-of-trade appreciation for the country, hurting trading partners.

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

Notes: Impulse responses to a 15% decline in energy supply. Preferences are non-homothetic. The bigger country, of size imposes a price cap on the energy price (blue, solid) and the smaller country, of size 1 does not (red, dashed). The black solid lines show the union-wide variables. Output is equal to the output gap. Government expenditure on the price cap (Govt. exp. cap) is the cost of the cap as a share of annual total output of the country (GDP). The y-axis is in terms of percentage deviations from steady state. The x-axis is in quarters. In ation and interest rates are annualized.

cannot increase its production accordingly. Hence, there is high pressure on other goods in ation as well as the actual price of energy. Because the government pays the difference between the actual and retail price of energy, the price cap becomes a large cost for the government and ultimately for the consumers. Combined with the high other goods in ation, such high costs cause a big decline in the total consumption of the households.

3.2.2 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.

Policy outcomes under symmetric price cap policy. Table 2 summarizes the welfare results in a two-by-two matrix. The relevant metric is the consumption equiv-

Figure 6: Responses to an adverse energy supply shock; Caps

Notes: Impulse responses to a 15% decline in energy supply and a price cap in both countries. Preferences are non-homothetic. Output is equal to the output gap. The y-axis is in terms of percentage deviations from steady state. The x-axis is in quarters. In ation and interest rates are annualized.

alent welfare gains and losses relative to the steady state of the economy.[21] First, focus on the cells on the diagonal where the policies are symmetric (cap-cap and no cap-no cap), which is the symmetric benchmark. Since the currency union is a closed economy, the symmetric benchmark is equivalent to the closed economy case. In this closed economy case, the adverse energy supply shock causes a welfare loss of 0.1% without an energy price cap and 1% with the cap.

With an energy price cap in the entire union the welfare losses are a tenfold bigger. As discussed, such a scenario is detrimental for household consumption since the demand distortions under the price cap increases the scal cost for the government to nance the cap, ultimately born by households, and the in ation of other goods. The consumption equivalent welfare loss is 1% when both countries introduce an energy price cap.

[21] For the consumption equivalent, I nd which satis es:

$$E_t \sum_{t=0}^{1} {}_t \frac{1}{"_1} \frac{\exp_t}{P_{Rt}}^{"_1} 1 \quad \frac{E}{"_2} \frac{P_{Et}}{P_{Rt}}^{"_2} 1 = \sum_{t=0}^{1} {}_t \frac{1}{"_1} f[\exp(1+)]^{"_1} 1g \qquad (29)$$

So, 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.

Table 2: Welfare gains/losses after energy supply shock

Non-homothetic preferences

		1/3 of union	
	%	Cap	No cap
2/3 of union	Cap	(1.0 ; 1.0)	(0.5 ; 1:1)
	No cap	(1:1; 0.4)	(0:1; 0:1)

Notes: Welfare gains and losses after a 15% energy supply shock. Preferences are non-homothetic. The gains and losses are in terms of the consumption equivalent relative to the steady state. The circles are around the preferred policy choices (Cap or No cap) for the countries.

Policy outcomes under asymmetric price cap policy. When the countries do not have to cooperate, is the non-distortionary no-cap strategy still the Nash equilibrium? As the circles around the welfare values indicate in Table 2, 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 scal 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 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 (0.5%) at the expense of the no-cap country (1.1%). 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 1.1%. Hence, the country has an incentive to also impose the price cap, even though both countries imposing the cap causes a welfare loss of 1%. The loss is relatively big because when both countries implement an energy price cap, the cost for the cap spirals upwards: the only bene t 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. [22]

[22] The externalities are smaller when the smaller country implements the energy price cap. How-

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.

The Prisoner's Dilemma as the Nash equilibrium does not re ect the choices that policymakers made in reality. In the next section I introduce substitutability between energy sources, which is an important feature in energy crises, and show that the model achieves the Nash equilibria in which one country imposes an energy price cap and the other country does not.

Policy outcomes under homothetic preferences. How much do these results depend on the non-homotheticity of energy? Here, I illustrate that the above results are highly dependent on the degree of non-homotheticity. The welfare table for homothetic preferences is in Table 3. The degree of non-homotheticity does not affect the values on the diagonal of the symmetric cap policies. Again, the non-cooperative case when both countries impose a cap are much worse (1%) than in the cooperative case without any caps (0.1%) due to the market-distorting price cap.

Table 3: Welfare gains/losses after energy supply shock

Homothetic preferences

		1/3 of union	
	%	Cap	No cap
2/3 of union	Cap	(1:0; 1:0)	(0.1; 0.4)
	No cap	(0.3; 0.0)	(0:1; 0:1)

Notes:Welfare gains and losses after a 15% energy supply shock. Preferences are homothetic (Cobb-Douglas). The gains and losses are in terms of the consumption equivalent relative to the steady state. The circles are around the preferred policy choices (Cap or No cap) for the countries.

However, non-homotheticity of preferences affects the magnitude of the spillovers signi cantly. 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: 0.4% when the larger country imposes a cap and 0.3% when the smaller country imposes a cap. So, implementing the price cap is not worth the cost when the other country also has the cap. Thus, with homothetic preferences, there are two Nash equilibria, in which one country implements a price cap and the other does not. Although this re ects what occurred in reality, the assumption that energy is not a necessity is unrealistic. Instead of relying on homothetic preferences to dampen

ever, not small enough to break symmetry in the preferred strategies in Table 2.

spillovers, I show in the next section that introducing substitutability between energy sources can achieve the same effect, leading to the desired outcome.

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 2: 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 3: 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 $\varepsilon_1 = \varepsilon_2 = 0.72$.

3.2.3 Implications for the central bank: Headline vs. core in ation targeting

In this subsection, I explore the different implications for the monetary authority when targeting Consumer Price Index (CPI) in ation, i.e. headline in ation, or other goods in ation, i.e. core in ation. [23] I show that there is a trade-off between stabilizing different in ation rates. However, since the relative in ation rates between the capped and uncapped country are similar in either targeting regime, the magnitude of the spillovers do not change much.

In the baseline analysis, the monetary authority targets headline in ation in its Taylor rule. In that case, Figure 5 shows that the monetary authority conducts contractionary monetary policy to stabilize union-wide headline in ation, which is the weighted average of the headline in ation rates of the two countries. However, under headline in ation targeting, there are large uctuations 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.

Figure 7 present the responses of the interest rates and in ation rates with a central bank that targets core in ation in its Taylor rule. The gure 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 in ation decreases its rates to stabilize the uctuations in that sector. As

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

expected, the expansionary monetary policy comes at the cost of a higher headline in ation.

Figure 7: Responses to an adverse supply shock, Core in ation targeting

Notes: Impulse responses to a 15% decline in energy supply under core in ation targeting. Preferences are non-homothetic. The bigger country, of size imposes a price cap on the energy price (blue, solid) and the smaller country, of size 1 does not (red, dashed). The black solid lines show the union-wide variables. The y-axis is in terms of percentage deviations from steady state. The x-axis is in quarters. In ation and interest rates are annualized.

All in all, a central bank with a target for other goods in ation should conduct relatively expansionary policy during an energy crisis with heterogeneous cap policies. When the target is for headline in ation, a more contractionary monetary policy mitigates the in ationary pressures from the high energy in ation in the uncapped country, reducing the headline in ation uctuations. In Figure 18 in Appendix C I display the rest of the impulse responses, which show that for the magnitude of the spillovers, the targeting regime does not matter. This result arises because the relative in ation rates between the capped and uncapped country, which matters for the spillovers, is similar regardless of the targeting regime.

3.2.4 Robustness checks under alternative model speci cations

In this section I conduct robustness checks with alternative assumptions of the model: elastic labor supply, exible prices, exible exchange rates, and preferences with Constant Elasticity of Substitution (CES). Most alternative model speci cations con- rm the robustness of the main results.

Elastic labor supply dampens the negative spillovers, which gives result to a welfare table that is in-between the non-homothetic and homothetic case. To allow for hours worked to adjust in the model, I implement an ad-hoc approach to elastic labor supply by incorporating a labor disutility term into the utility function, devi-

ating from the preferences outlined by Boppart (2014).[24] Figure 20 and Table 8 in Appendix C.1 present the results for this alternative speci cation.

The impulse responses in Figure 20 imply that elastic labor supply does not change the in ation dynamics of the two countries. However, because rms can now increase their production by employing more labor, the output responses are different to the baseline case. As discussed earlier, due to the increased demand in purchasing power of households in the capped country, they import more goods from the uncapped country. Contrary to the baseline case, the rms in the uncapped country now scale up their production by hiring more labor, which is bene cial for households in the uncapped country. Those households do not decrease their consumption as much as in the baseline case because of the increased labor demand. Accordingly, Table 8 shows that the costs of implementing a cap are higher than the cost of bearing the spillovers as the uncapped country, which is a similar result to the homothetic case.[25]

Under exible prices the main results under the asymmetric price cap policies and the welfare table are robust. The results are in Appendix C.2. While the spillovers under asymmetric price cap policies are similar to the sticky price case, the symmetric cases shows some differences. Speci cally, output does not decline following the energy supply shock, since price exibility allows for ef cient adjustments. Firms can adjust prices immediately, enabling the economy to absorb the shock without reducing output.

The tables and gures in Appendix C.2, C.3, and C.4 show the results for the last two alternative assumptions, exible exchange rates and CES preferences. Even though the impulse responses are somewhat different, the welfare table is the same as under the baseline case. This result con rms that the crucial assumption to the mechanism is the shared energy supply, not the shared monetary authority. Moreover, CES preferences dampen the overall effect of the energy supply shock and the

[24] The utility function with labor disutility is:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{\varepsilon_1} \left(\frac{\exp_t}{P_{Rt}} \right)^{\varepsilon_1} - 1 - \frac{\varepsilon_E}{\varepsilon_2} \left(\frac{P_{Et}}{P_{Rt}} \right)^{\varepsilon_2} - 1 - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \tag{30}$$

where is the disutility of labor and $1=\varphi$ the Frisch labor elasticity. The calibration is $= \varphi = 1$, as is standard in the literature.

[25] In the reverse case, when the smaller country imposes the price cap and the bigger country does not, the positive effect on welfare from increased labor demand is not big enough to outweigh the costs of implementing the price cap.

price cap spillovers on the economy, because the expenditure share of energy remains constant and energy is not a necessity good.

4 Endogenous energy production

So far, the analysis uses the model which only has an exogenous source of energy. This setup is valuable for understanding the core intuition and mechanics, as well as investigating the dynamics of the economies and their 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 (Energy Institute, 2024). 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 rst perform a Bayesian estimation of the parameters. Then, I revisit the mechanism and the incentives about whether to cap or not. I show that the domestic production of energy dampens the negative spillovers of the energy price cap, such that Nash equilibria, with one capped and one uncapped country, matches the reality in 2022. Moreover, I demonstrate with a historical shock decomposition that the energy price cap contributed to 40% of energy in ation and 20% of CPI in ation in 2022Q3 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 rms to both countries in the union. Unless otherwise stated, all other equations in the model stay unchanged from the baseline speci cation.

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

$$Y_{Et} = A_{Et} N_{Et} \tag{31}$$

where A_{Et} is the total factor technology in the energy sector. determines the share of pro ts from total revenue. The production function uses a diminishing-return 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 rms sell any quantity of energy at the prevailing price. This assumption re ects the ndings by Zakeri et al. (2022) who nd that the European electricity prices depend highly on natural gas prices. The energy rm's problem is

$$\max_{N_{Et}} P_{Et} Y_{Et} \quad W_t N_{Et} \tag{32}$$

subject to the production function (31). The rst-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:

$$E_t^h + E_t^f = {}^{h}(1 \quad {}_G)^{1=} (Y_{Et})^{(\quad 1)=} + {}^{1=}_{G} (GAS_t)^{(\quad 1)=} {}^{i}{}^{=(\quad 1)} \tag{33}$$

$$E_t^h + E_t^f = {}^{h}(1 \quad {}_G)^{1=} (Y_{Et})^{(\quad 1)=} + {}_G{}^{1=} (GAS_t)^{(\quad 1)=} {}^{i}{}^{=(\quad 1)} \tag{34}$$

$$GAS_t + GAS_t = GAS_t^W \tag{35}$$

where ${}_G$ is the share of gas in energy use and 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, ${}_G$ and ${}_G$, the steady-state productivity of the energy sector, A_E, and the share of pro ts, , with data and matching targets. For the non-homotheticity parameters, $"_1$; $"_1$; $"_2$ and $"_2$, and the elasticity of substitution between gas and non-gas energy, and , I use Bayesian estimation.

4.2.1 Calibration

For the share of gas in energy use, $_G$ and $_G$, 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, A_E, and the share of pro ts, , 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 other goods of 1, as in the baseline model. The values that match the targets are $= 0:19$ and $A_E = 0:17$. These parameters are symmetric across the countries. Table 4 provides a summary.

Table 4: Extra parameters in model with domestic energy production

Parameter	Description	Value
$_G$	Share of gas in energy, "Cap"	0.18
$_G$	Share of gas in energy, "No cap"	0.22
	Share of pro ts for energy rms	0.19
A_E	Steady-state productivity energy sector	0.17
$"_1$	Non-homotheticity parameter	0.25
$"_2$	Non-homotheticity parameter	0.25
	Elasticity of substitution between gas and non-gas energy, "Cap"	14.88
	Elasticity of substitution between gas and non-gas energy, "No cap"	34.89

Notes: Calibration of the extra parameters in the model with energy production. All other variables are the same as in the baseline case as in Table 1.

4.2.2 Estimation

I estimate the non-homotheticity parameters, $"_1 = "_2$, and and the elasticity of substitution between gas and non-gas energy, and . 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 other goods and energy sector, demand shocks, cost-push shocks in the other goods sector, shocks to gas supply, monetary policy

[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.

shock, and measurement errors for energy consumption and energy in ation. Those shocks and measurement errors are separate for the two countries in the union, except for the monetary policy shock and the energy in ation 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 $"_1 = "_2$ 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, the calibration value from the data exercise in the baseline model. For the elasticity of substitution between gas and non-gas energy, and , 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-coef cient parameters are 0.9 and the standard deviations are 0.01. The AR-coef cients 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 in ation, gas in ation, CPI in ation, 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 in ation 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 in ation with a tight prior to avoid stochastic singularity.

[29] I estimate with $"_1 = "_1 = "_2 = "_2$. 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 $"_1 = "_2$ to keep tractability. When $"_1 = "_2$ the elasticity of substitution between energy and other goods is 1 $"_2$.

[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 5 presents the results of the Bayesian estimation. The non-homotheticity parameters, $"_1$, and therefore also $"_1$, $"_2$, and $"_2$, are 0.27.[31] Moreover, the substitutability of gas and non-gas energy, and , 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-identi ed because I use both gas and energy in ation 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 5: Priors and posteriors

Parameter	Prior dist.	Prior mean	Prior std.	Post. mean	Post. std.	90% HPD interval
$"_1$	Gamma	0.8	0.1	0.27	0.07	[0.165,0.380]
	Beta	2	1	15.21	1.86	[12.190,18.265]
	Beta	2	1	35.31	3.31	[29.981,40.802]

Notes:The prior distribution, mean, standard deviation, posterior mean and standard deviation, and the Highest Posterior Density (HPD) interval of the Bayesian estimation.

4.3 Results

In this subsection, I rst show the simulation results of the extended model with parameter values from the calibration and the estimation, as summarized in Table 4. I show that domestic energy production dampens the effect of the gas supply shock on the economy. Consequently, the negative spillovers are also smaller, which leads the costs of implementing the price cap exceeding the costs of bearing the spillovers.

[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 reasons 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 in ation/consumption is a fraction of energy in ation/consumption, the data implies in ation/consumption of non-gas energy.

Then, I conduct a historical shock decomposition to quantify the contribution of the energy price cap in 2022 to the energy and CPI in ation levels in both the capped and uncapped countries.

4.3.1 Simulation results

Figure 8 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 in ation, about 3% on impact, is also much lower than the 20% in the previous case.

Figure 8: Responses to an adverse gas supply shock; Energy production

Notes: Impulse responses to a 15% decline in gas supply, in a model with energy production. Preferences are non-homothetic. The bigger country, of size imposes a price cap on the energy price (blue, solid) and the smaller country, of size 1 does not (red, dashed). The black solid lines show the union-wide variables. The y-axis is in terms of percentage deviations from steady state. The x-axis is in quarters. In ation and interest rates are annualized.

The welfare outcomes for the combinations of price cap strategies are in Table 6. Because the energy sector dampens the effect of the exogenous gas supply shock, the loss from the gas supply shock is 0.02% instead of 0.1% 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 1%. The domestic energy production dampens this effect to a loss of 0.3%, 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 6 shows that imposing a price cap is not the dominant strategy as it was in the baseline case in Table 2. Under the extended model there are two Nash equilibra in which one country imposes the price cap and the other country does not, explaining the reality in 2022. Because the energy sector dampens the negative spillovers of the energy price cap, imposing the cap when the opponent country also has one is not worth the cost.

Table 6 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, 0.5%, because the cost of imposing the cap is high for the government, and there is no other country to spillover to. The cooperative outcome when there are no price caps in the entire union has the smallest union-wide welfare loss, 0.03%, compared to the weighted averages 0.03% (with higher precision) and 0.07%, when one of the countries impose the price cap. So, the Nash equilibra are not the optimal outcome for union-wide welfare, even if they bene t the bigger country.

Table 6: Welfare gains/losses after gas supply shock

Model with domestic energy production

		1/3 of union	
	%	Cap	No cap
2/3 of union	Cap	(0:5; 0:5)	(0.1; 0.3); 0:03
	No cap	(0.3; 0.1); 0:2	(0:03; 0:03)

Notes: Welfare gains and losses after a 15% gas supply shock, in a model with energy production. Preferences are non-homothetic. The gains and losses are in terms of the consumption equivalent relative to the steady state. The circles are around the preferred policy choices (Cap or No cap) for the countries. The values outside the parentheses are weighted averages, i.e. union-wide welfare.

To understand the forces behind the welfare gains and losses, I decompose the loss value 0:3 of the uncapped 1=3 of the union in Table 7. The welfare loss of the uncapped country when the countries sharing a gas supply are in a currency union (iii), is, with higher precision, 0:26. By computing the welfare losses in the cases of (i) two autarkies sharing a gas supply and (ii) two trading countries not in a currency union sharing a gas supply, the Table decomposes the total welfare loss of the uncapped country into three components: loss coming from energy price

distortions, loss coming from the terms-of-trade effect, and the loss coming from being in a currency union.

Table 7 shows that the welfare loss coming from the terms-of-trade effect is the largest. Energy price distortions, though they affect the in ation rates, do not seem to have a big contribution to the welfare losses. Lastly, being in a currency union does not seem to affect the welfare losses too much, as expected from the robustness checks in Appendix C.3.

Table 7: Decomposition of the welfare loss for uncapped country

%	(i) Autarkies ($_{I}$ = 0, indep. CBs)	(ii) Trade partners ($_{I}$ = 0:25, indep. CBs)	(iii) In union ($_{I}$ = 0:25, one CB)
Energy price	0.03	0.03	0.03
Terms of trade	-	0.23	0.23
Currency union	-	-	+0
Total loss	0.03	0.26	0.26

Notes: Decomposition of the welfare loss of the uncapped country after a 15% gas supply shock, in a model with energy production. Preferences are non-homothetic. The losses are in terms of the consumption equivalent relative to the steady state. The rst column indicates the welfare loss in the case in which the countries are autarkies, i.e. do not trade ($_{I}$ = 0) and have independent central banks. The second column relaxes the no-trading assumption ($_{I}$ = 0:25) but still assumes independent central banks. The third column is the full model, with countries trading and in a currency union.

4.3.2 Historical shock decomposition

Using the calibrated and estimated values in Table 4, 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 coef cients 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 uctuations in the data series into the contributions from the shocks. The results are in Figure 9. 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 9 shows that the energy price cap contributed to about 10 percentage points of energy in ation in the

Figure 9: Historical shock decomposition j Contributions from the energy price cap

Notes: Historical shock decomposition of the annual in ation rates in deviations from the sample mean. “Other shocks” consist of total factor productivity (TFP) shocks for other goods and energy sector, demand shocks, cost-push shocks in the other goods sector, shocks to gas supply, monetary policy shock, and measurement errors for energy consumption and energy in ation. Those shocks and measurement errors are separate for the two countries in the union, except for the monetary policy shock. Mean energy in ation is 2.15% and 2.72% for capped and no-cap countries respectively. Mean CPI in ation is 1.42% and 1.46% for capped and no-cap countries respectively. The red bars indicate the contributions from the energy price cap, whereas the blue bars aggregate all other shocks. More details are in Appendix B.

uncapped countries in 2022. In the last quarter of 2022, the price cap was responsible for virtually all of energy in ation 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 in ation 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 in ation 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 in ation: the price cap contributed to about 0.5 percentage points of CPI in ation in the uncapped countries, depending on the quarter. Moreover, the contribution increasing CPI in ation in the uncapped countries was a lot larger than the cap's contribution lowering in ation in the capped countries.

5 TANK results

In this section I compare the energy price cap with targeted transfers. Most national governments conducted transfers to vulnerable groups in 2022, since the energy crisis affected them the most (Sgaravatti et al., 2023). To create heterogeneity within households, I add poor hand-to-mouth to the model with domestic energy production. A targeted transfer is a transfer to just those hand-to-mouth households. Since labor income is the only source for hand-to-mouth households and hence an important model feature, this version of the model includes elastic labor supply as discussed in Section 3.2.4. Therefore, the model becomes a Two-Agent New Keynesian (TANK) model.

The TANK version of the model does not alter in the transmission mechanism and the spillovers of the price cap and the aggregate welfare results discussed in the previous sections hold. An interesting aspect of the TANK model is its potential for evaluating the effects of targeted policies, such as the transfer program, on different household groups: I compare a country-wide energy price cap (to all households and rms) to a targeted transfer to the hand-to-mouth households. Since low-income, hand-to-mouth households spend a larger share of their income on energy, an adverse energy supply shock is particularly burdensome for them (Bayer et al., 2023). I nd 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 nancially constrained households who represent share 2 [0; 1] of the population, and unconstrained households who are share 1 . Financially constrained households have no access to the one-period bonds. Moreover, they earn no pro ts from rms nor the energy sellers. The budget constraints of the constrained and unconstrained households are respectively:

$$\exp_t^c = P_{Et} e_t^{h;c} + P_{Rt} c_{Rt}^c = W_t n_t^c + P_t \;{}_t^c + T \quad T_t^c \tag{36}$$

$$\exp_t^u = P_{Et} e_t^{h;u} + P_{Rt} c_{Rt}^u = W_t n_t^u + \frac{1}{1} D_t + \frac{1}{1} D_t^E + R_t \;{}_1 \frac{B_{t\;1}}{1} \quad \frac{B_t}{1} \quad HC_t + P_{Rt} \;{}_t^u \quad T_t^u \tag{37}$$

where superscript c refers to variables belonging to constrained households and u to unconstrained ones. $_t$ are redistributive transfers from the government explained below. T is a steady-state transfer from the constrained to unconstrained, to make sure their consumption is equal in steady state. The preferences are the same for both households and include the disutility for labor supply as in 3.2.4.

I aggregate energy and other goods consumption and labor as:

$$e_t^{h;c} + (1 \quad)e_t^{h;u} = E_t^h \tag{38}$$

$$c_{Rt}^c + (1 \quad)c_{Rt}^u = C_{Rt} \tag{39}$$

$$n_t^c + (1 \quad)n_t^u = N_t \tag{40}$$

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

Following Debortoli and Galí (2018) and Komatsu (2023), the scal authority redistributes the taxed pro ts from rms D_t as transfers to the constrained households, $_t^c$, and unconstrained households, $_t^u$, according to the rules:

$$_t^c = (1 \quad _0) D_t \tag{41}$$

$$_t^u = \quad 1 + \frac{_0}{1} \quad D_t \tag{42}$$

where is the tax rate on rms' pro ts, where $_0$ indicates how much of the pro ts go to (un)constrained households, using $_t^c + (1 \quad) \; _t^u = D_t$. So, when $_0$ is equal to unity, all pro ts 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, , is 0.1.[33] For the redistribution of taxed rms' pro ts, I set the tax rate on rm's pro ts at $= 0{:}215$, which was the average corporate tax rate in 2022 of European OECD countries (Bray, 2023). The redistribution rule, , is equal to unity, such that all pro ts go to unconstrained households. All other calibration values are identical to the baseline model and the model with do-

[33] 5-10% is the share of so-called "poor" hand-to-mouth households. When including the share of "wealthly" hand-to-mouth households, who own illiquid assets, the share of hand-to-mouth households rises to about 30%.

mestic 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 other goods consumption:

$$\hat{c}^c_t = \frac{e^c}{c^c}\hat{e}^c_t + \frac{c^c_R}{c^c}\hat{c}^c_{Rt} \tag{43}$$

Using the choice between energy and other goods, Eq. (2), the de nition of the energy expenditure wedge, Eq. (3), and their budget constraint, Eq. (36), I decompose the consumption of the constrained households:

$$\hat{c}^c_t = \underbrace{A^c\hat{e}^c_t + B\hat{p}^{rel;ER}_t}_{\text{energy consumption}} + \underbrace{C\hat{w}_t}_{\text{real wage}} \quad \underbrace{D\hat{t}_t}_{\text{taxes}} \tag{44}$$

where $A^c = \frac{1}{c^c}(e^c + c^c_R)$, $B = \frac{c^c_R}{c^c}\left(1 + \frac{1}{1\quad_E}\frac{1}{\exp}\right)''_1 WN\quad_E\quad''_2$, $C = \frac{c^c_R}{c^c}\frac{1}{(1\quad_E)\exp}''_1 WN$, and $D = \frac{c^c_R}{c^c}\frac{1}{(1\quad_E)\exp}''_1$.

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

$$\hat{c}^u_t = \underbrace{A^u\hat{e}^u_t + E\hat{p}^{rel;ER}_t}_{\text{energy consumption}} + \underbrace{F\hat{\exp}_t}_{\text{consumption smoothing}} \tag{45}$$

where $A^u = \frac{1}{c^u}(e^u + c^u_R)$, $E = \frac{c^u_R}{c^u}\left(1\quad\frac{1}{1\quad_E}\right)''_2$, and $F = \frac{c^u_R}{c^u}\frac{1}{1\quad_E}''_1$. 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 repre-

sentative agent model in Figure 8.[34] 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. (44) and (45). The results are in Figure 10. 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 bene t from the energy price cap in the baseline model: households increase their consumption 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 de cit 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.

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 speci ed targeted transfer only costs 10% of the cost of the price cap. The consumption responses are in Figure 11. The left graph shows that the targeted transfers are effective in increasing the constrained household's consumption, while not lowering the consumption of the unconstrained too much. Moreover, the spillovers to the country without transfers substantially smaller than under the cap.

The responses of some other macroeconomic variables for both the country with

[34] The responses for the TANK model are in Figure 19 in Appendix C.