

# Managing an Energy Shock: Fiscal and Monetary Policy

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## Abstract

This paper revisits the macroeconomic effects of energy price shocks in energy-importing economies. In standard representative-agent models, increases in energy prices trigger a boom in aggregate demand by reallocating spending towards domestic production. In heterogeneous-agent models, by contrast, we show that they cause a recession by pushing down on real wages and therefore on consumer spending, provided that the elasticity of substitution between energy and domestic goods is realistically low. Imported energy inflation can spill over to wage inflation through a wage-price spiral, without mitigating the real wage decline. Monetary policy tightening has limited effect on imported inflation when done in isolation, but can be powerful when done in conjunction with other energy importers by lowering world energy demand. Fiscal policy, especially energy price subsidies, can isolate individual energy importers from the shock, but it has large negative externalities on other economies.

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# 1 Introduction

At least since the Russian invasion of Ukraine in February 2022, many advanced economies have had to cope with unprecedented price increases for various types of energy, including natural gas, crude oil, and electricity.<sup>1</sup> In many European countries and beyond, this has caused eight salient patterns to emerge: (i) levels of energy and CPI inflation not seen since the 1980s; (ii) plummeting real wages despite (iii) rising nominal wage inflation; (iv) deteriorating trade balances; and (v) softening aggregate demand and (vi) a forecasted recession, despite (vii) several fiscal relief programs and (viii) an accommodative monetary policy stance, when judged by the level of the short-term real interest rate.

In this paper, we ask: Which models can account for those eight facts? What are the implications for monetary and fiscal policy? How do these policies spill over across borders? And, how can countries design a coordinated policy mix that limits economic damage among all energy importers?

The starting point of our paper is the observation that standard complete-markets, small open economy representative-agent (RA) New-Keynesian models à la Galí and Monacelli (2005) are inconsistent with the facts presented above. The reason for this is that, absent an aggressive monetary response pushing up real interest rates, energy price shocks cause expenditure switching towards domestic production in RA models; this raises aggregate demand and causes an economic boom. The strength of this channel is governed by the elasticity of substitution between energy and domestically produced goods,  $\chi$ . There is little trade-off for monetary policy: contractionary monetary policy is unambiguously the right tool to use to limit the boom and lean against elevated inflation.

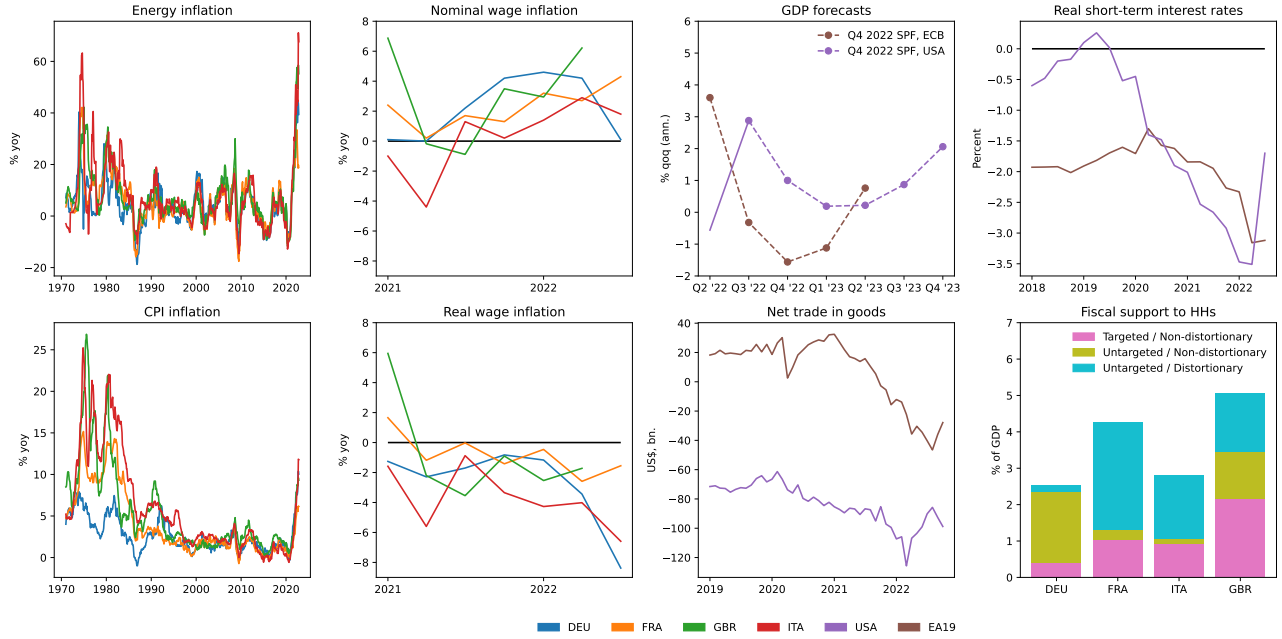
We contrast this result to the prediction of a small open economy heterogeneous-agent (HA) New-Keynesian model, as in Auclert, Rognlie, Souchier and Straub (2021b). We show that, because it features high marginal propensities to consume, the HA model implies a markedly different propagation of energy price shocks. Even in the presence of a wage-price spiral, real wages collapse in response to the shock, weighing down on consumer spending and aggregate demand. For a realistically low elasticity  $\chi$ , we show that this real-wage channel more than offsets the expenditure-switching channel, leading to an economic contraction. Wage-price spirals raise nominal wage inflation and CPI inflation, without mitigating the contraction or the real wage decline. Since this all happens without any upward movement in real interest rates, one can think of this shock as a combination of a cost-push shock and a negative aggregate demand shock.

Our HA model thus suggests that the energy shock poses a worse trade-off for monetary policy than a standard cost-push shock would. What are the options for individual energy importers' central banks? The natural reaction of an inflation-targeting central bank to an inflationary shock is to raise interest rates to limit inflation, even if that means a weakening of economic activity. Our model suggests two important caveats of such a policy. First, when the underlying shock itself

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<sup>1</sup>See, for example, Celasun, Mineshima, Arregui, Mylonas, Ari, Teodoru, Black, Zhunussova, Iakova and Parry (2022).

Figure 1: Motivating evidence



The leftmost panels show both (headline) CPI inflation and the energy component of CPI inflation are at their highest in decades. For nominal wages, we use measures of average labor cost per hour. In all cases, we see nominal wages are rising, while real wages are falling. The real GDP growth forecasts show a decline well below the long run average for both the Euro area and the USA, with a contraction forecasted in Europe. The net trade in goods has fallen sharply in European economies through the last year. Real short-term interest rates, computed as nominal short-term rates minus expected inflation, have also become even more accommodative over this period. Finally, we show an IMF breakdown of government support measures for 2022 and 2023 that target households. Distortionary measures are price suppressing policies, while non-distortionary measures take the form of income support. n.b. Here 'targeted' means targeted towards low-income households, in contrast to our policy in section 5.

already weakens aggregate demand, the additional contractionary effects from monetary tightening are significantly more costly than when the shock itself only causes inflationary pressure. Second, a shock that is caused by rising energy prices at the world level is hard to counteract with contractionary monetary policy by an individual energy importer, as the effect on world energy prices is bound to be limited. The only remaining way to affect domestic energy prices is via an exchange rate appreciation, but the effects of monetary policy on exchange rates are likely too weak to materially affect inflation.<sup>2</sup>

Tightening domestic monetary policy does tame domestic energy demand. This suggests that monetary policy has positive externalities on other countries. Indeed, we find that when all energy importers in our model coordinate and tighten monetary policy together, there is a material reduction in world energy prices and domestic energy inflation. In other words, in the wake of an energy price shock, monetary policy among energy importing countries suffers from a free-rider problem: each central bank may find it individually optimal to keep a loose stance, while all central banks hiking together could materially limit world energy inflation.

Interestingly, we find the exact opposite pattern for common types of fiscal policy. We consider

<sup>2</sup>A back-of-the-envelope calculation, using the uncovered interest-rate parity condition, shows that monetary tightening of 1 pp. for one year only causes the nominal exchange rate to appreciate by 1 percent.

three types of fiscal policy measures: energy price subsidies; untargeted lump-sum transfers; and targeted lump-sum transfers, proportional to households' exposure to the energy shock. All policies are deficit-financed and repaid at the same rate across policies by raising income taxes. We first study these policies when used by an individual energy importing country in isolation; then we consider externalities across countries.

We show that, when used by an individual country, fiscal policy can all but eliminate the negative effects of the energy shock. This is easiest to do using energy subsidies. When households are insulated from higher energy prices, there is no real wage loss, and no associated reduction in aggregate demand. Instead, by moving the shock from private balance sheets to its own balance sheet, the government is able to smooth out the impact of the shock over time. Transfers are also able to mitigate the effects of the shock, albeit somewhat less effectively. They mostly support consumer spending and hence aggregate demand. Inflation is higher when transfers are being used, as wage inflation increases with higher aggregate demand. All three kinds of fiscal policy reduce consumption inequality—a measure of welfare inequality—in response to the shock.

In stark contrast to its domestic benefits, we find that fiscal policy imposes strongly negative externalities on other countries. This is most salient for energy price subsidies. Since these subsidies limit incentives to substitute away from energy, world energy prices increase in response. The policy of any individual country only causes a small increase in world prices, but when all energy importers employ price subsidies, world energy demand becomes almost price inelastic, requiring a sharp rise in prices to clear the world energy market. This makes subsidies largely self-defeating: they are unable to effectively insulate countries from the shock, and cause such a burden on government balance sheets that even the smoothed out tax plan to finance initial deficits becomes sufficiently aggressive to significantly deepen the recession. Transfers also cause negative externalities on other energy importers, albeit to a lesser extent.

In summary, our paper suggests that any *individual* country's monetary tightening is costly and of limited use in fighting inflation after an energy price shock; but that it comes with positive externalities on other energy importers. Vice versa, fiscal policy can be very powerful in cushioning the effects of energy price shocks, but tends to have negative externalities on other countries. In light of these results, a promising combination of monetary and fiscal policy could be one that focuses on aggressive, coordinated monetary tightening combined with targeted fiscal relief and, crucially, avoids energy price subsidies.

**Literature.** Our paper is, to the best of our knowledge, the first to analyze an import price shock in an open economy New-Keynesian macro model with household heterogeneity. As such, it relates to an emerging literature that brings household heterogeneity a la [Bewley \(1977\)](#)-[Aiyagari \(1994\)](#) into New-Keynesian small open economy models a la [Galí and Monacelli \(2005\)](#), which has focused on different kinds of shocks.<sup>3</sup> For example, our result showing equivalence between RA

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<sup>3</sup>See the early work by [de Ferra, Mitman and Romei \(2020\)](#), as well as [Aggarwal, Auclert, Rognlie, Straub et al. \(2022\)](#), [Guo, Ottonello and Perez \(2021\)](#), [Oskolkov \(2021\)](#), [Zhou \(2020\)](#).

and HA economies under a Cole-Obstfeld parameterization ( $\chi = 1$ ) is related to a similar result in [Auclert et al. \(2021b\)](#), but is derived for a terms of trade shock as in [Cole and Obstfeld \(1991\)](#)’s seminal paper.

Several papers study supply shocks, e.g. to energy, in closed economy New-Keynesian models with household heterogeneity. [Guerrieri, Lorenzoni, Straub and Werning \(2020\)](#) emphasize how incomplete markets among households can lead to negative demand spillovers from adverse supply shocks. [Kaenzig \(2021b\)](#) studies the macroeconomic effects of carbon pricing in a closed economy set-up with tractable heterogeneity a la [Bilbiie \(2019\)](#) and [Bilbiie, Känzig and Surico \(2019\)](#). [Pieroni \(2022\)](#) analyzes the effects of an energy shock in a full-blown closed-economy heterogeneous-agent New-Keynesian model a la [Kaplan, Moll and Violante \(2018\)](#) and [Auclert, Rognlie and Straub \(2018\)](#).<sup>4</sup> Absent monetary tightening, aggregate demand for labor is a lot more likely to increase in a closed economy setting, even with heterogeneity, since higher energy prices increase real income in a closed economy, all else equal.

An established literature exists around the propagation of oil price shocks in open-economy representative-agent models. A vexing question in this literature has been why oil price shocks empirically have such large negative effects on GDP.<sup>5</sup> [Rotemberg and Woodford \(1996\)](#) argued that this is caused by endogenously increasing markups. [Bernanke, Gertler, Watson, Sims and Friedman \(1997\)](#) argued that it is mostly contemporaneous monetary tightening. [Blanchard and Gali \(2007b\)](#) substantiate this point using a model with real wage rigidities. In the model, the real interest rate required to stabilize nominal wage inflation rises sharply in response to an oil shock, inducing a strong recession when inflation is stabilized. [Bodenstein, Erceg and Guerrieri \(2011\)](#) present a two-country representative agent model with incomplete markets. They do find wealth effects on consumer spending to matter, under the assumption of (essentially) permanent shocks. However, even with monetary tightening, hours increase in their baseline simulation in response to a negative oil shock (their figure 8). Our paper shows that, once one allows for household heterogeneity, even temporary energy shocks can lead to significant contractions in real GDP.

Our results on policy spillovers are reminiscent of the literature on currency wars and competitive easing (e.g. [Caballero, Farhi and Gourinchas 2015](#)), which regarded monetary easing as having negative externalities across countries at the zero lower bound. Our results emphasize that, in times of high energy prices, the flip-side—positive externalities—holds for monetary tightening. A closely connected paper in this literature is the recent work by [Fornaro and Romei \(2022\)](#), which finds the opposite spillover from us: monetary tightening has negative externalities on other countries so that countries tighten too aggressively relative to what is socially optimal. Fiscal policy externalities have previously been analyzed in [Gourinchas, Kalemli-Ozcan, Penciakova and Sander \(2021\)](#), [Aggarwal et al. \(2022\)](#) and [Devereux, Gente and Yu \(2020\)](#), though not with regard to energy related policies or spillovers via energy prices.

Finally, a recent literature has investigated the propagation of oil and energy price shocks in

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<sup>4</sup>[Kuhn, Kehrig and Ziebarth \(2021\)](#) analyzes an energy shock in a similar model, but with flexible prices.

<sup>5</sup>See [Hamilton \(1983\)](#), [Barsky and Kilian \(2004\)](#), [Kilian \(2009\)](#), [Baumeister and Hamilton \(2019\)](#), [Kaenzig \(2021a\)](#) for empirical evidence on the macroeconomic effects of oil price shocks.

input-output networks. [Baqaee and Farhi \(2019b\)](#) find large effects of oil price shocks on world GDP. However, as long as productive efficiency and exogenous factor supplies are assumed, real GDP of any given country is entirely unaffected by foreign shocks such as adverse shocks to energy supplied by another country. This follows directly from theorem 1 in [Baqaee and Farhi \(2019a\)](#). [Bachmann, Baqaee, Bayer, Kuhn, Löschel, Moll, Peichl, Pittel, Schularick et al. \(2022\)](#) apply the [Baqaee and Farhi \(2019a\)](#) framework to Germany to argue that a cut in imported energy from Russia has a modest negative effect on gross national expenditure.

## 2 Model

Our model builds on the open-economy heterogeneous-agent (HA) New-Keynesian model in [Auclert et al. \(2021b\)](#), extended with an eye towards energy shocks.<sup>6</sup> The extension allows for: an energy good; a small continuum of energy importers; and a real-wage stabilization motive. We focus on the effects of energy price shocks on the demand side of the economy, initially leaving the supply side intact. We argue in section 3.4 that energy entering the supply side causes very similar behavior.

### 2.1 Model setup

Time is discrete and the horizon is infinite. We consider a nested small open economy environment. The world consists of a mass-one two-dimensional continuum of countries, e.g.  $[0, 1]^2$ , of which a 1-dimensional subset of length 1, e.g.  $\{0\} \times [0, 1]$ , labels all energy-importing countries. We make the simplifying assumptions that these country are the sole purchasers and consumers of energy in the world; and that energy is supplied entirely by the rest of the world.

We first focus on one representative such energy-importing country, “home”, and then turn to the set of energy-importing countries as a whole to explore coordinated policy responses. We denote variables corresponding to the entire world economy with a star superscript.

We consider perfect-foresight impulse responses to shocks starting from a steady state without aggregate uncertainty (“MIT shocks”). We use the sequence-space jacobian method from [Auclert, Bardóczy, Rognlie and Straub \(2021a\)](#) and linearize with respect to these shocks. By certainty equivalence, these impulse responses are the same as those from the model with aggregate risk.

There are three goods in the economy. The “home” good,  $H$ , is domestically produced and can be exported. The energy good,  $E$ , and “foreign” good,  $F$ , are produced abroad and imported.

**Domestic households.** The economy is populated by a unit mass of households. Each household is subject to idiosyncratic income risk, driven by productivity shocks  $e_{it}$ , which follow a first-order Markov chain with mean  $\mathbb{E}e_{it} = 1$ . Households can invest their assets in a domestic mutual fund, but cannot insure their idiosyncratic risk. A household with asset position  $a$  and

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<sup>6</sup>The [Auclert et al. \(2021b\)](#) model itself is a combination of the canonical [Galí and Monacelli \(2005\)](#) model with the closed-economy heterogeneous-agent framework in [Auclert, Rognlie and Straub \(2018\)](#).

productivity level  $e$  at time  $t$  optimally chooses her consumption  $c$  and saving  $a'$  by solving the dynamic programming problem

$$\begin{aligned} V_t(a, e) &= \max_{c, a'} U(c, N_t) + \beta \mathbb{E}_t [V_{t+1}(a', e')] \\ \text{s.t.} \quad &c + a' = (1 + r_t) a + e Z_t \\ &a' \geq \underline{a} \end{aligned} \quad (1)$$

Here  $r_t$  denotes the ex-post mutual fund return in units of the consumer price index  $P_t$ ;  $W_t$  is the nominal wage;  $N_t$  denotes labor supplied by households, determined by union demand as specified below;  $Z_t$  is aggregate labor income,

$$Z_t \equiv \frac{W_t}{P_t} N_t; \quad (2)$$

and  $\underline{a} \leq 0$  parametrizes the borrowing constraint agents face. The utility function, which is common across households, is separable and takes the form

$$U(c, N_t) = u(c) - v(N_t)$$

where

$$u(c) = \frac{c^{1-\sigma}}{1-\sigma}, \quad v(N) = v_\varphi \frac{N^{1+\varphi}}{1+\varphi}$$

The parameter  $\sigma > 0$  is the inverse elasticity of intertemporal substitution,  $\varphi > 0$  the inverse Frisch elasticity of labor supply.  $v_\varphi > 0$  is a normalization constant.

The household's consumption basket,  $c$ , is formed by a CES combination of energy consumption  $c_E$  and non-energy consumption  $c_{HF}$ , where the non-energy bundle results from a CES combination of home consumption  $c_H$ , and foreign consumption  $c_F$ ,

$$\begin{aligned} c &= \left[ \alpha_E^{1/\eta_E} c_E^{(\eta_E-1)/\eta_E} + (1 - \alpha_E)^{1/\eta_E} c_{HF}^{(\eta_E-1)/\eta_E} \right]^{\eta_E/(\eta_E-1)} \\ c_{HF} &= \left[ \alpha_F^{1/\eta} c_F^{(\eta-1)/\eta} + (1 - \alpha_F)^{1/\eta} c_H^{(\eta-1)/\eta} \right]^{\eta/(\eta-1)} \end{aligned} \quad (3)$$

Here  $\eta > 0$  is the elasticity of substitution between home and foreign goods, and  $\eta_E > 0$  is the elasticity of substitution between energy and non-energy goods. The consumer price index for these preferences is

$$\begin{aligned} P &= \left[ \alpha_E P_E^{1-\eta_E} + (1 - \alpha_E) P_{HF}^{1-\eta_E} \right]^{\frac{1}{1-\eta_E}} \\ P_{HF} &= \left[ \alpha_F P_F^{1-\eta} + (1 - \alpha_F) P_H^{1-\eta} \right]^{\frac{1}{1-\eta}} \end{aligned} \quad (4)$$

Here,  $P_{Et}$  and  $P_{Ft}$  are the nominal price of energy and foreign goods, respectively, in domestic



currency units, and  $P_{Ht}$  is the price of domestic goods.

Households differ in their level of spending but have the same consumption basket and price index. Defining  $\alpha \equiv \alpha_E + (1 - \alpha_E) \alpha_F$ , by standard two-step budgeting arguments, a household in state  $(a, e)$ , with consumption  $c_t(a, e)$ , splits her purchases between energy, foreign, and home goods according to

$$c_{Et}(a, e) = \alpha_E \left( \frac{P_E}{P} \right)^{-\eta_E} c_t(a, e) \quad (5)$$

$$c_{Ft}(a, e) = (1 - \alpha_E) \alpha_F \left( \frac{P_F}{P_{HF}} \right)^{-\eta} \left( \frac{P_{HF}}{P} \right)^{-\eta_E} c_t(a, e) \quad (6)$$

$$c_{Ht}(a, e) = (1 - \alpha) \left( \frac{P_H}{P_{HF}} \right)^{-\eta} \left( \frac{P_{HF}}{P} \right)^{-\eta_E} c_t(a, e) \quad (7)$$

**Foreign households.** Foreign households in other energy importing countries face the same problem as domestic households. Households in the rest of the world, who fully account for the demand for home exports, face an almost identical problem, except that they do not consume energy. These households consume an exogenous and constant quantity  $C^*$  of worldwide goods, and spread their own consumption of foreign goods across all foreign countries, with an elasticity of substitution across countries of  $\gamma > 0$ . Denoting by  $P_{Ht}^*$  the foreign-currency price of domestically produced goods, export demand for home goods is given by

$$C_{Ht}^* = \alpha^* \left( \frac{P_{Ht}^*}{P^*} \right)^{-\gamma} C^* \quad (8)$$

We assume that the law of one price holds for home goods, so that  $P_{Ht}^*$  is equal to the cost  $P_{Ht}/\mathcal{E}_t$  of a domestic good in foreign currency units:

$$P_{Ht}^* = \frac{P_{Ht}}{\mathcal{E}_t} \quad (9)$$

where  $\mathcal{E}_t$  is the nominal exchange rate. With this convention, an increase in  $\mathcal{E}_t$  indicates a nominal depreciation.

Monetary policy abroad keeps the price of foreign goods in foreign currency constant,  $P_{Ft}^* = P_t^* = 1$ . The world nominal interest rate,  $i^*$ , is constant.

**Production of home goods.** We allow for energy to be used as an input in production, though our main results concern the version of the model in which labor is the only input.<sup>7</sup> Output is produced from domestic intermediates and import energy. The intermediate inputs to be used in

<sup>7</sup>This is mostly for simplicity. See section 3.4 for an argument that an economy with energy in the production function behaves very similar to one with energy in consumption.



home goods production are produced by a continuum of monopolistically competitive firms each using the technology

$$Y_t = A_N N_t \quad (10)$$

where  $N_t$  is labor, and  $A_N$  is the constant level of TFP. Let  $\epsilon$  denote the elasticity of substitution between intermediates. We assume that prices are fully flexible, so that the price of labor for production is set at a constant markup  $\mu$  over nominal marginal costs,

$$P_t^I = \mu \frac{W_t}{A_N}$$

where  $\mu = \epsilon / (\epsilon - 1)$ . Total real dividends generated by domestic firms are then equal to

$$D_t = \frac{P_t^I Y_t - W_t N_t}{P_t} \quad (11)$$

Firms have a unit mass of shares outstanding, with end-of-period price  $j_t$ .

Home goods are produced competitively from domestic intermediates and energy with the constant returns to scale production function,

$$\bar{Y}_t = \left[ (1 - \zeta_E)^{\frac{1}{\nu}} Y_t^{\frac{\nu-1}{\nu}} + \zeta_E^{\frac{1}{\nu}} E_t^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \quad (12)$$

where  $E_t$  is energy used in production (the  $\zeta_E = 0$  case corresponds to the case without energy in production). The price is then set equal to the marginal cost

$$P_{Ht} = \left[ (1 - \zeta_E) \left( \mu \frac{W_t}{A_N} \right)^{1-\nu} + \zeta_E P_{Et}^{1-\nu} \right]^{\frac{1}{1-\nu}} \quad (13)$$

Real GDP is always equal to  $Y_t$  in this economy.

**Energy suppliers.** Energy is supplied to the energy-importing countries by a measure one of price-taking firms. These energy suppliers each have a claim to a source of energy that by default costlessly generates  $\bar{E}_t$  in each period  $t$ . A firm  $i$  can pull supply forward by a single period by extracting additional energy today, at some cost, leaving less energy to be costlessly extracted tomorrow. Similarly it can delay extraction, facing a symmetric cost. Call the “inventory”,  $I_{it}^E$ , of energy the cumulative shortfall of extraction relative to the default path  $\{\bar{E}_t\}$ . So

$$I_{i,t+1}^E = I_{i,t}^E + (\bar{E}_t - E_{it})$$

Then the amount of energy that can be costlessly extracted by firm  $i$  at  $t$  is then  $I_{i,t}^E + \bar{E}_t$ . The value of an energy supplier is the present discounted value of their dividends

$$\sum_{j=0}^{\infty} \left( \frac{1}{1+r^*} \right)^j \left[ P_{E,t+j}^* E_{i,t+j} - C \left( E_{i,t+j} - \bar{E}_{t+j} - I_{i,t+j}^E \right) \right]$$

where the adjustment cost paid is

$$C \left( E_{i,t} - \bar{E}_t - I_{i,t}^E \right) = \frac{\Gamma}{2} \left( E_{i,t} - \bar{E}_t - I_{i,t}^E \right)^2$$

Then the energy “inventory” carried over from period  $t$  to  $t+1$  is

$$I_{i,t+1}^E = \frac{\left( \frac{1}{1+r^*} \right) P_{E,t+1}^* - P_{E,t}^*}{\Gamma}$$

**Financial sector.** We assume frictionless capital flows across countries. At home, an unconstrained, risk-neutral mutual fund issues claims to households, with aggregate real value  $A_t$  at the end of period  $t$ . The mutual fund may invest in nominal bonds and firms, both at home and abroad. Its objective is to maximize the (expected) real rate of return on its liabilities  $r_{t+1}$ . In equilibrium, this implies that expected returns on all these assets are equal.

Equating returns from the nominal bonds, we get the standard uncovered interest parity (UIP) condition,

$$1 + i_t = (1 + i_t^*) \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \quad (14)$$

Define the ex-ante real interest rate as

$$1 + r_t^{\text{ante}} \equiv (1 + i_t) \frac{P_t}{P_{t+1}} \quad (15)$$

And define the real exchange rate as

$$Q_t \equiv \frac{\mathcal{E}_t}{P_t} \quad (16)$$

We can combine (14), (15), and (16) to obtain a real version of the UIP condition

$$1 + r_t^{\text{ante}} = (1 + i_t^*) \frac{Q_{t+1}}{Q_t} \quad (17)$$

Since the ex-ante returns are equated, the initial mutual fund portfolio is indeterminate, and the ex-post return for all dates  $t \geq 1$  is independent of the portfolio,  $r_{t+1} = r_t^{\text{ante}}$ . To determine  $r_0$ , we assume that coming into date 0, the mutual fund holds the entire stock of the home good firms. So we can write

$$1 + r_{t+1} = \frac{j_{t+1} + D_{t+1}}{j_t}$$

where the end-of-period share price of domestic firms is the present discounted value of dividends,

$$j_t = \frac{D_{t+1} + j_{t+1}}{1 + r_t^{\text{ante}}}. \quad (18)$$

We define the net foreign asset position to be the difference between the value of assets accumulated domestically,  $A_t$ , and the total value of assets in net supply domestically, i.e.

$$\text{nfa}_t \equiv A_t - j_t \quad (19)$$

**Unions.** We assume a formulation for sticky wages with heterogeneous households, similar to [Auclert, Rognlie and Straub \(2018\)](#). A union employs all households for an equal number of hours  $N_t$ , and is in charge of setting nominal wages by maximizing the welfare of the average household. Relative to the Phillips curve in [Auclert, Rognlie and Straub \(2018\)](#), we assume here that the union puts an extra weight on stabilizing real wages relative to the steady state real wage, incorporating the ideas of [Blanchard and Galí \(2007a\)](#). We show in appendix [A.1](#) that this problem leads to the wage Phillips curve

$$\pi_{wt} = \kappa_w \left( \frac{v'(N_t) / u'(C_t)}{\frac{1}{\mu_w} (W_t / P_t)^{1+\zeta_{BG}}} - 1 \right) + \beta \pi_{wt+1} \quad (20)$$

where  $\pi_{wt}$  denotes nominal wage inflation,

$$\pi_{wt} \equiv \frac{W_t}{W_{t-1}} - 1$$

Here,  $\zeta_{BG} \geq 0$  is the parameter characterizing the extent of the real wage stabilization motive. When  $\zeta_{BG} = 0$ , the wage Phillips curve has the standard form (e.g. [Erceg, Henderson and Levin 2000](#)), with wage inflation rising when the marginal rate of substitution (numerator) exceeds the marked-down after-tax real wage, now or in the future.<sup>8</sup> If we derive this equation from a Calvo specification where the probability of keeping the wage fixed is  $\theta_w$ , then  $\kappa_w = \frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w}$ . When  $\zeta_{BG} > 0$ , unions are averse to departures of real wages from their steady state value.

**Monetary policy.** The monetary authority sets the nominal interest rate according to a monetary rule. For the analytical results that we develop in the paper, our baseline is a specification in which monetary policy holds the real interest rate constant,

$$i_t = r_{ss} + \pi_{t+1} + \epsilon_t \quad (21)$$

This is a CPI-based Taylor rule with a coefficient of 1 on expected inflation. This monetary rule achieves a middle ground between standard CPI-based Taylor rules with responsiveness larger than 1, and zero-lower-bound specifications with a fixed nominal interest rate, and is widely used in the literature as a device to partial out the effects of monetary policy in the study of the effects of shocks to aggregate demand (e.g. [Woodford 2011](#), [McKay, Nakamura and Steinsson 2016](#), [Auclert, Rognlie and Straub 2018](#)). In the context of energy-price shocks, the rule (21) can be thought of

<sup>8</sup>In [Auclert, Rognlie and Straub \(2018\)](#)'s formulation of the union problem, the consumption level that enters the Phillips curve in (20) is equal to a consumption aggregator  $\bar{C}_t \equiv (u')^{-1} (\mathbb{E} [e_{it} u' (c_{it})])$  that takes into account inequality in labor earnings. Here we opt for the simpler formulation in (20), because it helps streamline some of our analytical results.

as a “neutral” monetary policy stance, in which monetary policy hikes nominal interest rates just enough to keep up with inflation. We consider alternative monetary rules in section 4.

**Equilibrium.** We are now ready to define two different notions of equilibrium. We define an (*uncoordinated*) *small open economy (SOE) equilibrium* as follows.

**Definition.** Given sequences of foreign energy price shocks  $\{P_{Et}^*\}$  and monetary shocks  $\{\epsilon_t\}$ , an initial wealth distribution  $\mathcal{D}_0(a, e)$ , and an initial portfolio allocation for the mutual fund, a *SOE equilibrium* is a path of policies  $\{c_{Ht}(a, e), c_{Ft}(a, e), c_{Et}(a, e), c_t(a, e), a_{t+1}(a, e)\}$  for households, distributions  $\mathcal{D}_t(a, e)$ , prices  $\{\mathcal{E}_t, Q_t, P_t, P_{Ht}, P_{Ft}, P_{Et}, W_t, p_t, i_t, r_t, r_t^p\}$ , and aggregate quantities  $\{C_t, C_{Ht}, C_{Ft}, C_{Et}, Y_t, \bar{Y}_t, A_t, D_t, nfa_t\}$ , such that all agents optimize, firms optimize, and the domestic goods market clears:

$$C_{Ht} + C_{Ht}^* = \bar{Y}_t \quad (22)$$

where  $C_{Ht} \equiv \sum_e \pi_e \int c_{Ht}(a, e) \mathcal{D}_t(a, e)$  denotes aggregate consumption of home goods, and  $C_t, C_{Ft}, C_{Et}, A_t$  are defined similarly. We focus on equilibria in which the long-run exchange rate returns to its steady state level,  $Q_\infty = Q_{ss}$ .

We also consider (*coordinated*) *world equilibria*, in which total energy demand must be met by total energy supply.

**Definition.** A coordinated equilibrium is an uncoordinated equilibrium in which the path of world energy prices  $\{P_{Et}^*\}$  is chosen such that energy demand  $C_{Et}$  equals energy supply in each period  $t$ .

**Further equilibrium objects.** In equilibrium, the *current account identity* holds:

$$nfa_t = NX_t + (1 + r_{t-1}^{\text{ante}}) nfa_{t-1} + (r_t - r_{t-1}^{\text{ante}}) A_{t-1} - (r_t^H - r_{t-1}^{\text{ante}}) j_{t-1} \quad (23)$$

where  $NX_t \equiv \mathcal{E}_t \frac{P_{Ht}^*}{P_t} C_{Ht}^* - \mathcal{E}_t \frac{P_{Ft}^*}{P_t} C_{Ft} - \mathcal{E}_t \frac{P_{Et}^*}{P_t} C_{Et}$  is the value of net exports in units of the CPI. The last two terms capture a balance of valuation effects.  $r_t^H$  is the ex-post return on the home good producing firms. These valuation terms are zero for all  $t \geq 1$ .

We consider a *steady state* with no inflation and no initial gross positions across borders. That is, the domestic mutual fund owns all stocks issued by home-good-producing firms and the net foreign asset position is zero.<sup>9</sup> We normalize foreign demand such that  $\alpha^* = \alpha + \frac{\xi_E}{1-\xi_E}$ . Then, we can normalize prices to 1 in this steady state, implying that  $P_{Hss}, P_{Fss}, P_{Ess}, P_{ss}, P_{Hss}^*, \mathcal{E}_{ss}, Q_{ss}$  are all equal to 1. Moreover, we normalize domestic GDP  $Y_{ss}$  as well as consumption  $C_{ss}$  and  $C^*$  to 1, implying output  $\bar{Y}_{ss} = \frac{1}{1-\xi_E}$ .

Following the same arguments as in Auclert et al. (2021b) the unique  $Q_\infty = 1$  steady state, to which the economy returns after transitory shocks, also has no net foreign asset position and

<sup>9</sup>Note that the steady state value of the importing firms is zero.

$C_\infty = Y_\infty = 1$ . Hence, our heterogeneous-agent model is stationary without the need for a debt-elastic interest rate, as in [Schmitt-Grohé and Uribe \(2003\)](#) or the large literature that followed.

**Complete-market representative-agent model (“RA model”).** We also consider the canonical representative-agent model of [Galí and Monacelli \(2005\)](#), in which there are complete markets across households and across countries. Following the same arguments as in [Auclert et al. \(2021b\)](#), in that model, the consumption behavior of the representative domestic household is described by the Backus-Smith condition

$$Q_t C_t^{-\sigma} = C_{ss}^{-\sigma} \quad (24)$$

**Calibration.** We calibrate the model at a quarterly frequency. Table 1 summarizes our calibration parameters, which are aimed at capturing a large European energy-importing country. We follow the calibration in [Auclert et al. \(2021b\)](#). We assume discount factor heterogeneity in order to match aggregate wealth. We consider permanent heterogeneity, with a three point distribution at  $\{\beta - \frac{\Delta}{2}, \beta, \beta + \frac{\Delta}{2}\}$  and a third of agents in each. We set  $\beta$  to achieve an annualized real interest rate of  $r = 4\%$  in steady state. We set the initial steady state net foreign asset position to 0, with all mutual fund assets invested in domestic stocks. We consider standard values of  $\sigma^{-1} = 1$  for the elasticity of intertemporal substitution, and  $\varphi^{-1} = 0.5$  for the Frisch elasticity of labor supply.

We target an import-to-GDP ratio of 30%.<sup>10</sup> So we set  $\alpha_F$  to achieve  $\alpha = 0.3$ . We set the energy share,  $\alpha_E$ , at 4% of GDP.<sup>11</sup> As in [Bachmann et al. \(2022\)](#), we consider a low elasticity of substitution between energy and non-energy goods equal to 0.1. We set the elasticity of substitution between home and foreign goods,  $\eta$ , equal to that between varieties of foreign goods,  $\gamma$ . We set these such that  $\chi$ , defined in (30), equals 0.3. We do not explicitly model delayed substitution, but we focus our analysis on the short run, and so choose low elasticities in line with [Boehm, Levchenko and Pandalai-Nayar \(2020\)](#). We set the real wage stabilization parameter to  $\zeta_{BG} = 5$ .<sup>12</sup> We set  $\theta_w$  so that peak nominal wage inflation matches the EA19 peak of 3.9%. [Auclert et al. \(2021b\)](#) argue that the implied  $\theta_F$  estimated for Italy and the UK are 0.94 and 1.00, respectively, although lower in

<sup>10</sup>In 2021, imports to GDP across the five largest European energy-importing countries were as follows: U.K. 28%, Italy 30%, France 32%, Spain 33%, Germany 42%. Overall, our economies are slightly less open than in [Galí and Monacelli \(2005\)](#), where  $\alpha = 0.4$ .

<sup>11</sup>We take data on complete energy balances from Eurostat, and consider the EU27 in 2021. We measure energy consumption by gross available energy (GAE), which combines production, net imports, and rundown of stocks. We use the TTF price for natural gas, the Brent crude oil price for oil and petroleum products, and IHS Northwest European coal prices for solid fossil fuels. Together, GAE for these three fuels makes up 2.9% of EU27 GDP. In common energy units, they account for 69% of total GAE and over 95% of energy imports. A simple extrapolation to the remaining energy sources would yield  $\alpha_E \approx 2.94\%/0.69 = 4.3\%$ .

Also in common energy units, 41% of GAE is domestically produced. In value weighted terms, the 2021 figure is likely lower since oil and gas (both largely imported) prices were already rising.

We price the remaining fuels – the largest two being nuclear and renewables – at the (unweighted) mean of the three known prices. This gives an energy share of 4.1% of which 35% is domestically produced. In most of section 3, we will assume this is entirely imported as this simplifies the analytic results. However, we additionally consider the case where some energy is produced domestically, and this is the case we use in our quantitative model.

<sup>12</sup>If we eliminate the nominal wage rigidity in our model, our assumption of  $\zeta_{BG} = 5$  lies squarely between the two values in [Blanchard and Galí \(2007a\)](#), 1.5 and 9. We show this in appendix A.2.

Parameter	Benchmark model	Parameter	Benchmark model
$\sigma$	1	$r$	0.01
$\varphi$	2	$\beta$	0.95
$\eta_E$	0.1	s.s. nfa	0
$\eta$	0.51	$\zeta_{BG}$	5
$\gamma$	0.51	$\theta_w$	0.938
$\alpha_E$	0.04	$\theta_E$	0.65
$\alpha_F$	0.27	$\theta_F$	0.9
$\mu$	1.03	$\rho_e$	0.96

Table 1: Calibration parameters

other cases. We set  $\theta_F = 0.9$ . Finally, we set  $\theta_E = 0.65$  making the pass through on impact around 40%.

For the energy shock itself, we let  $P_E^*$  follow an AR(1), with persistence giving a half-life of 16 quarters, and with an initial impact of 100%.

## 2.2 Intertemporal MPCs

An important part of our analysis is to analyze household spending behavior in energy-importing countries. To do so, we summarize aggregate consumption behavior in terms of a function  $\mathcal{C}_t$  that maps sequences of ex-ante real interest rates  $\{r_s^{\text{ante}}\}$  and real aggregate income  $\{P_{Hs}/P_s \cdot Y_s\}$  into the sequence of aggregate consumption  $\{C_t\}$ . We describe this function for the case where energy only appears in consumption,  $\zeta_E = 0$ . The map works in two steps:

First, it maps ex-ante interest rates and real income into ex-post returns  $\{r_s\}$ . For all  $s > 0$ , this map is simply given by  $r_s = r_s^{\text{ante}}$ . For  $s = 0$ ,  $r_0$  picks up a valuation effect, and is determined by

$$1 + r_0 = \frac{D_0 + j_0}{j_{ss}}$$

with  $D_t = \left(1 - \frac{1}{\mu}\right) \frac{P_{Ht}}{P_t} Y_t$  and  $j_t$  given by (18).

Second, it maps ex-post returns  $\{r_s\}$  and real income  $\{P_{Hs}/P_s \cdot Y_s\}$  into consumption. This works because the only two endogenous aggregates in (1) are ex-post returns and aggregate labor income  $Z_t = \frac{1}{\mu} \frac{P_{Ht}}{P_t} Y_t$ . Once the paths of these two aggregates are determined, all consumption and saving policies  $c_t(a, e)$ ,  $a_t(a, e)$  and the evolution of the distribution  $\Psi_t(a, e)$  (assuming the initial distribution is at the steady state) can be solved for, so aggregate consumption can be written as

$$C_t = \int c_t(a, e) d\Psi_t(a, e) = \mathcal{C}_t(\{r_s^{\text{ante}}, P_{Hs}/P_s \cdot Y_s\}_{s=0}^{\infty})$$

Finally, since we initially focus on an economy in which ex-ante real interest rates are kept con-

stant, we will write consumption simply as function of aggregate real income,

$$C_t = \mathcal{C}_t (\{P_{Hs}/P_s \cdot Y_s\}_{s=0}^{\infty}) \quad (25)$$

Intuitively,  $\mathcal{C}_t$  captures spending behavior in response to arbitrary paths of aggregate real income. Aggregate real income here affects spending in two ways. First, it reprices outstanding assets, as dividends are a given fraction of aggregate real income; and the associated capital gains lead to a spending response of households. Second, it increases aggregate labor income, which again results in a spending response.

As in previous work, e.g. [Auclert et al. \(2018\)](#), we linearize (25) around the steady state, and express changes in spending over time, stacked as the vector  $d\mathbf{C} \equiv (dC_0, dC_1, \dots)$ , as a function of changes in real income  $d\left(\frac{\mathbf{P}_H}{\mathbf{P}}\mathbf{Y}\right) \equiv \left(d\left(\frac{P_{H0}}{P_0}Y_0\right), d\left(\frac{P_{H1}}{P_1}Y_1\right), \dots\right)$ ,

$$d\mathbf{C} = \mathbf{M} \cdot d\left(\frac{\mathbf{P}_H}{\mathbf{P}}\mathbf{Y}\right) \quad (26)$$

Here,  $\mathbf{M}$  is the *sequence-space Jacobian* of  $\mathcal{C}_t$  defined as the collection of partial derivatives

$$M_{ts} \equiv \frac{\partial \mathcal{C}_t}{\partial (P_{Hs}/P_s \cdot Y_s)}$$

around the steady state. We call the entries of  $\mathbf{M}$  *intertemporal marginal propensities to consume*, or *iMPCs*. iMPCs are a richer set of moments than standard marginal propensities to consume, in that they capture both the entire dynamic response of consumption to unanticipated (aggregate) income changes—the entries in the first column ( $M_{\cdot,0}$ ) of  $\mathbf{M}$ —as well as the entire dynamic response of consumption to anticipated income changes—the entries in column  $s$ , ( $M_{\cdot,s}$ ), for an anticipated income change at date  $s > 0$ .

### 3 Energy price shocks and heterogeneity

We begin by studying the response of one individual energy importer to a (first order) shock to the world price of energy  $P_{Et}^*$ , denoted by  $dP_{Et}^*$ . We assume that the shock follows an AR(1), that is,

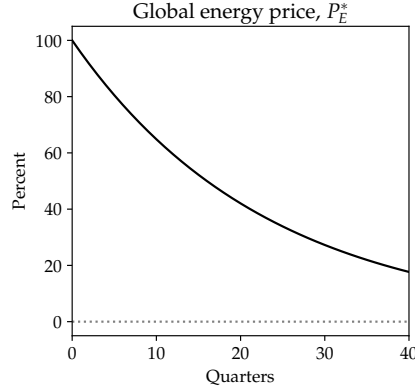
$$dP_{Et}^* = dP_{E0}^* \cdot \rho_e^t$$

where  $\rho_e \in (0,1)$  is the persistence of the shock. We choose a baseline persistence of  $\rho_e = 0.96$  and normalize the shock such that  $dP_{E0}^* = 1$ . The shock path is shown in figure 2. As described above, we assume that, for now, the ex-ante real interest rate is kept constant by monetary policy. We study alternative monetary policy rules in section 4 below. Up until section 3.4 below, we do not consider energy usage in production and keep  $\xi_E = 0$ .

Our analysis is centered around the home goods market clearing condition (22). After substituting in the demands (7)-(8) and the price-setting condition for PCP (9), we can write this



Figure 2: The energy price shock



Note: AR(1) shock to  $P_{Et}^*$  with persistence 0.96. This represents a doubling of energy prices on impact, with a half-life of four years.

condition as

$$Y_t = (1 - \alpha) \left( \frac{P_{Ht}}{P_{Hft}} \right)^{-\eta} \left( \frac{P_{Hft}}{P_t} \right)^{-\eta_E} C_t + \alpha \left( \frac{P_{Ht}}{\mathcal{E}_t} \right)^{-\gamma} C^* \quad (27)$$

Aggregate demand for home goods, the right hand side of (27), is influenced by the shock either due to changing relative prices  $\frac{P_{Ht}}{P_{Hft}}$ ,  $\frac{P_{Hft}}{P_t}$ ,  $\frac{P_{Ht}}{\mathcal{E}_t}$ , or due to changing domestic spending  $C_t$ . We next explore how a representative-agent model behaves in response to the shock; then we will compare that to a heterogeneous-agent model.

### 3.1 Representative agent

In the complete-markets representative-agent model, aggregate consumption remains constant,  $C_t = C_{ss}$ . This is easiest to see from combining the Backus-Smith condition (24) with the real UIP condition (17). Since ex-ante real interest rates are kept constant, the real exchange rate is constant as well,  $Q_t = Q_{ss}$ , and so is consumption. With this, we can characterize equilibrium output and consumption as follows.

**Proposition 1.** *In the complete-market representative-agent model with real interest rate rule (21), the linearized deviations from steady state consumption over output,  $dC_t = (C_t - C_{ss}) / Y_{ss}$  and output  $dY_t = (Y_t - Y_{ss}) / Y_{ss}$  in response to shocks to the world energy price  $dP_{Et}^* = (P_{Et}^* - P_{E,ss}^*) / P_{E,ss}^*$  are given by*

$$dC_t = 0 \quad (28)$$

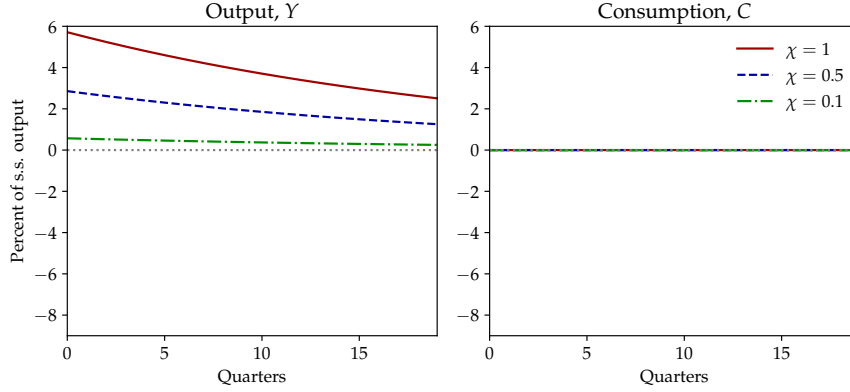
$$dY_t = \frac{\alpha_E}{1 - \alpha} \cdot \chi \cdot dP_{Et}^* \quad (29)$$

where  $\chi$  is a weighted average elasticity of substitution,

$$\chi \equiv (1 - \alpha) (\alpha_F \eta + (1 - \alpha_F) \eta_E) + \alpha \gamma. \quad (30)$$

Proposition 1 shows that the output response in the RA economy is proportional to the en-

Figure 3: Output and consumption responses to an energy price shock in the RA model



Note: Impulse responses in the representative-agent model to the energy price shock  $P_{Et}^*$  displayed in figure 2.  $\chi$  is the average substitution elasticity between energy and domestically produced goods. It is defined in (30).

ergy price shock. Its scale is determined by two factors: the share of energy in consumption,  $\alpha_E$ , relative to home consumption,  $1 - \alpha$ ; and an appropriately weighted average of the elasticities of substitution in the economy,  $\chi$ . Crucially, the output response (29) is always positive in response to a positive energy price shock. This can be explained by consumers substituting away from imported energy towards domestically produced goods, causing a boom in economic activity in the domestic economy. In fact, as consumer spending remains constant, the entire output response is driven by expenditure switching. We plot impulse responses in figure 3 for various substitution elasticities  $\chi$ .

Proposition 1 should not be interpreted as saying that there can never be a bust after an energy price shock in RA models, though. Instead, when there is a bust (e.g. as in Bodenstein et al. 2011), it has to be because of monetary tightening in response to the shock, rather than the shock itself. In terms of the textbook three-equation New-Keynesian model (Galí 2008), proposition 1 implies that a suitable interpretation of an energy shock in an RA model is one of a cost-push shock, paired with a positive aggregate demand shock.

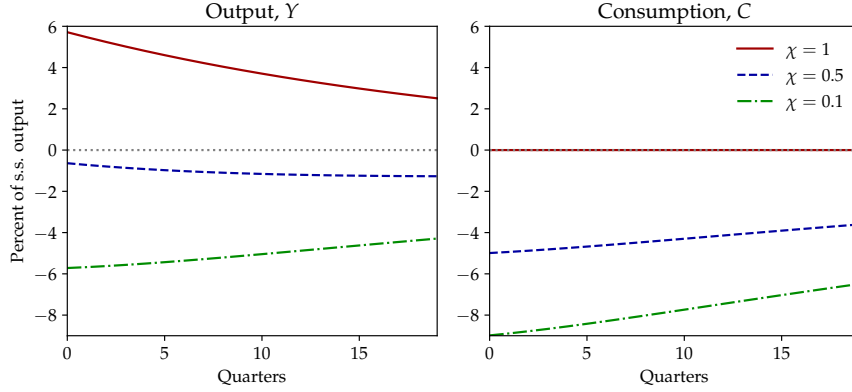
Going forward, it will be convenient to express impulse responses as vectors, just like in (26). With this notation, (28)–(29) become  $d\mathbf{C} = 0$  and  $d\mathbf{Y} = \frac{\alpha_E}{1-\alpha} \cdot \chi \cdot d\mathbf{P}_E^*$ .

### 3.2 Heterogeneous agents

In light of our discussion in section 2.2, one way to explain the RA result is to point out that, with complete markets across countries, a RA model essentially behaves like a model with zero iMPCs,  $\mathbf{M}^{RA} = 0$ . In other words, the complete-markets RA model features no real income effect on consumption.<sup>13</sup> This is the key difference to our heterogeneous-agent economy, where we find the following result for output and consumption.

<sup>13</sup>We analyze an incomplete-markets RA model in section 3.4 and show that it implies quantitatively very small real income effects.

Figure 4: Output and consumption responses to an energy price shock in the HA model



Note: Impulse responses in the heterogeneous-agent model to the energy price shock  $P_{Et}^*$  displayed in figure 2.  $\chi$  is the average substitution elasticity between energy and domestically produced goods. It is defined in (30).

**Proposition 2.** *With a real interest rate rule and a matrix of intertemporal MPCs  $\mathbf{M}$ , the impulse responses of consumption and output following an energy price shock are given by*

$$d\mathbf{C} = - \underbrace{\frac{\alpha_E}{1-\alpha} \mathbf{M} \cdot d\mathbf{P}_E^*}_{\text{Real income channel}} + \underbrace{\mathbf{M} \cdot d\mathbf{Y}}_{\text{Multiplier}} \quad (31)$$

$$d\mathbf{Y} = \underbrace{\frac{\alpha_E}{1-\alpha} \chi d\mathbf{P}_E^*}_{\text{Exp. switching channel}} - \underbrace{\frac{\alpha_E}{1-\alpha} \mathbf{M} \cdot d\mathbf{P}_E^*}_{\text{Real income channel}} + \underbrace{(1-\alpha) \mathbf{M} \cdot d\mathbf{Y}}_{\text{Multiplier}} \quad (32)$$

Proposition 2 shows that the impulse responses of consumption and output now also depend on the matrix of intertemporal MPCs  $\mathbf{M}$ . Equation (31) finds that there are two ways in which real income  $\frac{P_{Ht}}{P_t} Y_t$ , and hence consumption  $d\mathbf{C}$ , are affected by an energy shock  $d\mathbf{P}_E^*$ . First, increased energy prices increase the consumer price index (CPI)  $P_t$  relative to the price of home goods  $P_{Ht}$ . This reduces real income all else equal, leading agents to cut consumption by  $\mathbf{M} \times \frac{\alpha_E}{1-\alpha} d\mathbf{P}_E^*$ . We refer to this as the *real income channel* of energy price shocks. Second, the energy price shock will, indirectly, also affect the path of output  $d\mathbf{Y}$ , which also enters real income and changes consumption by  $\mathbf{M} \times d\mathbf{Y}$ . This is a standard (Keynesian) *multiplier* effect.

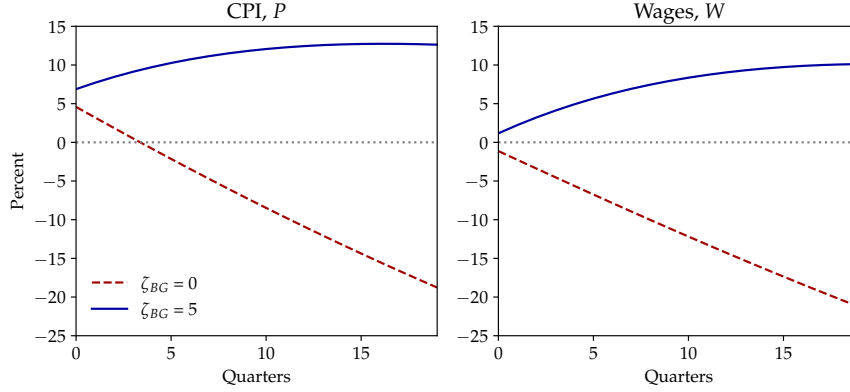
Linearizing goods market clearing (27) and substituting in (31), we obtain equation (32), whose form is like that of a standard Keynesian cross, where the relevant multiplier is the product of MPCs  $\mathbf{M}$  by the degree of home bias  $(1-\alpha)$ . Including expenditure switching, there are altogether three distinct channels that jointly determine the output response to any given shock. The next proposition derives the general solution to (32).

**Proposition 3.** *Assuming  $\mathbf{M} \geq 0$ , the equilibrium output response is unique and given by*

$$d\mathbf{Y} = \frac{\alpha_E}{1-\alpha} \chi d\mathbf{P}_E^* + \alpha_E (\chi - 1) \mathbf{M} \cdot (\mathbf{I} - (1-\alpha) \mathbf{M})^{-1} d\mathbf{P}_E^* \quad (33)$$

*In particular, if  $\chi = 1$ , all aggregate quantities and prices are the same as in the RA model, including*

Figure 5: Wage-price spiral with real wage stabilization motive



Note: Impulse responses in the heterogeneous-agent model to the energy price shock  $P_{Et}^*$  displayed in figure 2.  $\zeta_{BG}$  is the weight on the [Blanchard and Galí \(2007a\)](#) real-wage stabilization motive.

$dY = dY^{RA}$ . Moreover, provided that  $\mathbf{M} > 0$ , for an energy shock  $dP_E^* \geq 0$ , we have

$$dY \leq dY^{RA} \quad \text{and} \quad dC \leq 0 \quad \Leftrightarrow \quad \chi \leq 1$$

Proposition 3 solves the Keynesian cross fixed point in (32) for  $dY$ . Similar to [Auclert et al. \(2021b\)](#), it establishes a formal neutrality result for  $\chi = 1$ , showing that the RA and HA models have identical implications for aggregate quantities and prices. When the substitution elasticity lies below one, however,  $\chi < 1$ , the output response in the HA model is more muted relative to the RA model. The intuition for this result is that when  $\chi = 1$ , the real income and multiplier channels in (32) exactly offset each other, and  $dY$  is entirely driven by expenditure switching, as in the RA model. Reducing  $\chi$  below 1 leads to smaller expenditure switching channel, and hence also a smaller multiplier effect, making the HA output response fall below the RA one.

We illustrate proposition 3 in figure 4, plotting the output and consumption responses to the energy shock for various choices of  $\chi$ . While the responses are identical to those for the RA model (figure 3) when  $\chi = 1$ , output turns negative for modest substitution elasticities around  $\chi \approx 0.5$ . With realistic energy substitution elasticities of around  $\chi = 0.1$ , the shock causes a sizable contraction.

### 3.3 Wage-price spirals

Our result in proposition 3 characterizes the quantity response to the energy shock. What about prices and wages?

A useful starting point is the real wage  $w_t \equiv W_t/P_t$ . Given flexible prices, we can write

$$d \log w_t = d \left( \frac{P_{Ht}}{P_t} \right) = -\frac{\alpha_E}{1-\alpha} dP_{Et}^* \quad (34)$$

The real wage is directly determined by the shock, independent of the nominal wage Phillips

curve. Given the responses of the real wage, output (or equivalently, hours), and consumption, the nominal wage Phillips curve (20) then pins down the behavior of nominal wages, and by (34), the behavior of the price level. This separation, which allows us to first solve the “real economy”, including real wages, before solving for nominal objects is a useful consequence of the combination of a real interest rate monetary policy rule, sticky nominal wages and flexible prices.<sup>14</sup>

Figure 5 plots prices and wages as implied by the nominal wage Phillips curve (20) without the real wage stabilization motive (red, dashed) and with the real wage stabilization (blue, solid). Without the real wage stabilization motive, an initial jump up in the price level is actually followed by a sustained decline in prices, even below their original level. This is because wages start declining as households’ consumption and hours fall with the shock, raising their willingness to work. With the real wage stabilization motive, unions attempt to raise nominal wages to counteract declining real wages.

Interestingly, our economy is one in which the real wage stabilization motive is entirely self-defeating, and does not succeed in pushing up real wages (34). Higher average nominal wages  $W_t$  lead to higher domestic prices  $P_{Ht}$ , a higher price index  $P_t$ , and ultimately a depreciated exchange rate  $\mathcal{E}_t$ . The depreciated exchange rate  $\mathcal{E}_t$  leads to higher import prices, so that altogether, the entire CPI bundle becomes more expensive, in line with the increases in  $W_t$  (see appendix D.2). A wage-price spiral emerges.

Going forward, we work with the model that features a wage-price spiral.

### 3.4 Extensions

We consider six extensions to our analysis of the baseline HA model.

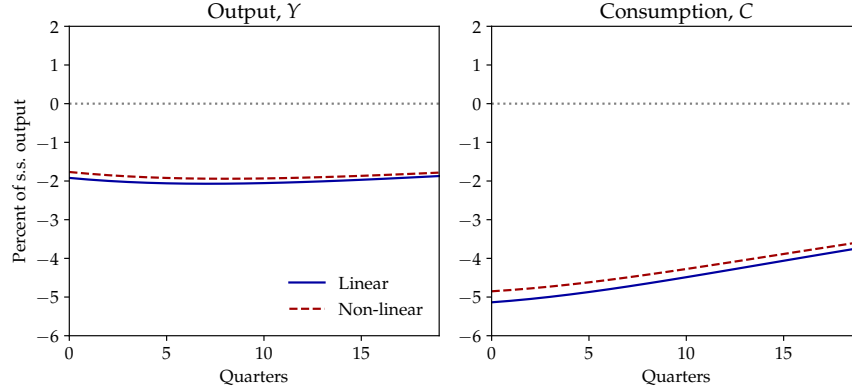
**Large shocks.** Our analysis has assumed small, first-order shocks thus far. The energy shocks we are seeing in the world in 2022 seem anything but first order, however. Figure 6 compares a nonlinear MIT shock with a first order one. We see that our model does not imply a hugely nonlinear impulse response.

**RA model with incomplete markets across countries.** Our RA model benchmark is assumed to come from an RA model with complete markets across countries. A natural question is how different that is from an RA model with incomplete markets across countries. Figure 7 redoes figure 3 but with incomplete markets. Comparing the figures, we see that incomplete markets do not change the response by a significant amount. The main reason for this is that rather than  $\mathbf{M}^{RA} = 0$ , the incomplete-markets RA model has positive, but very small intertemporal MPCs.

With very persistent shocks, the MPC will rise in the RA model with incomplete markets. However, as we show in Figure 8, this model struggles to generate substantial contractionary

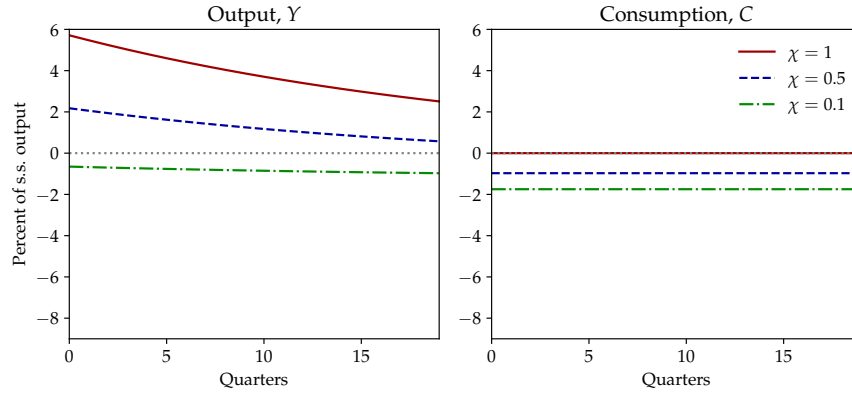
<sup>14</sup>See Auclert et al. (2018), Auclert et al. (2021b), Aggarwal et al. (2022) for recent applications of this idea. We have explored in Auclert et al. (2021b) that the main consequences learned in this environment still hold up with alternative monetary policy rules and sticky prices in addition to sticky wages.

Figure 6: First-order vs. higher order MIT shocks



Note: Impulse responses in the heterogeneous-agent model to the energy price shock  $P_{Et}^*$  displayed in figure 2. The figure compares the first-order impulse response with the nonlinear “MIT shock” (perfect foresight) solution.

Figure 7: Output and consumption responses to an energy price shock in the RA model with incomplete markets



Note: Impulse responses in a representative-agent model with incomplete markets to the energy price shock  $P_{Et}^*$  displayed in figure 2.  $\chi$  is the average substitution elasticity between energy and domestically produced goods. It is defined in (30).

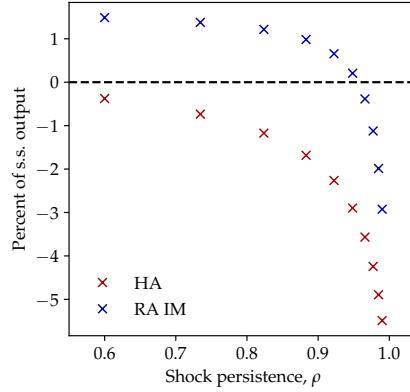
effects without very long-lived shocks.

**Two-agent model.** A natural next extension is to compare our HA model with a model with simplified heterogeneity with just two types, a la [Campbell and Mankiw \(1989\)](#), [Galí, López-Salido and Vallés \(2007\)](#), and [Bilbiie \(2008\)](#). We make such a comparison in appendix C.

**Energy in production.** One natural question is whether the response in our RA model of GDP and consumption would look different if energy were used in production rather than consumption. The answer is no:

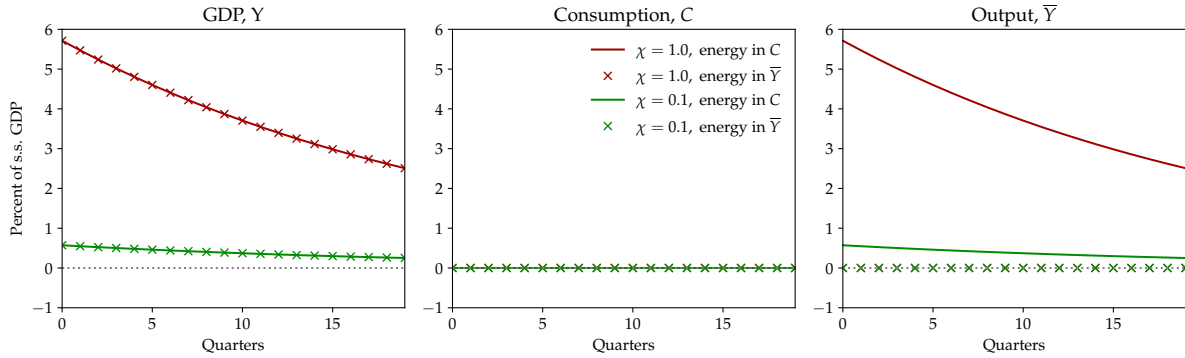
**Proposition 4.** *In the economy in which energy enters production but not consumption,  $\xi_E > 0$  and  $\alpha_E = 0$ , the response of GDP is given by*

Figure 8: Date-0 output response to an energy price shock in the RA-IM and HA models



Note: Impact response of output in a representative-agent model with incomplete markets and in a heterogeneous-agent model to the energy price shock  $P_{Et}^*$  displayed in figure 2. Here we set  $\chi = 0.3$  as in our baseline calibration.

Figure 9: Energy in consumption versus production in the RA model



Note: Impulse responses in a representative-agent model. 'Energy in C' refers to energy directly entering the household's consumption bundle. 'Energy in  $\bar{Y}$ ' indicates that energy is instead used in production of the Home good.  $\chi$  is the average substitution elasticity between energy and domestically produced goods in the 'energy in C' case. It is defined in (30).

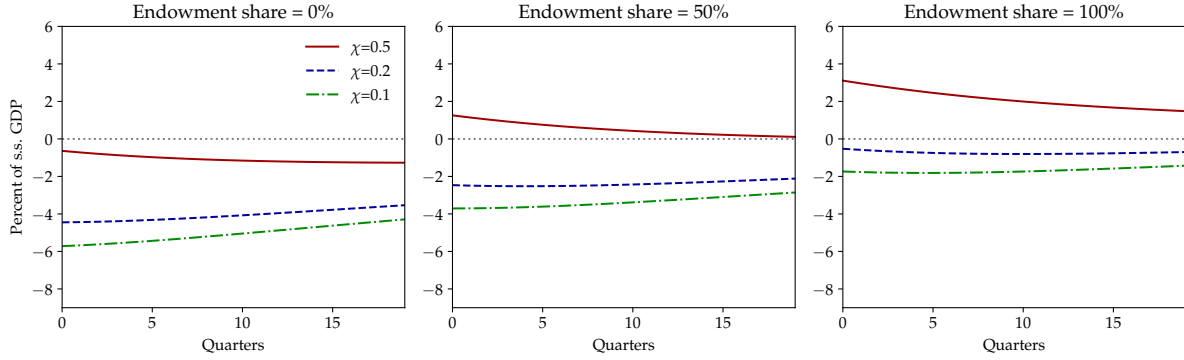
$$d\mathbf{Y} = \underbrace{\frac{\xi_E}{1 - \xi_E} \nu d\mathbf{P}_E^*}_{\text{Exp. switching channel}} - \underbrace{(1 - \alpha_F) \xi_E \mathbf{M} \cdot d\mathbf{P}_E^*}_{\text{Real income channel}} + \underbrace{(1 - \xi_E) (1 - \alpha_F) \mathbf{M} \cdot d\mathbf{Y}}_{\text{Multiplier}} \quad (35)$$

In particular, when setting  $\xi_E$ ,  $\alpha_F$ , and  $\nu$  in the "energy in production model" to be equal to  $(1 - \alpha_E) \alpha_F$ ,  $\frac{\alpha_E}{1 - (1 - \alpha_E) \alpha_F}$ , and  $\chi$  in the "energy in consumption" model, the GDP response  $d\mathbf{Y}$  to an arbitrary  $d\mathbf{P}_E^*$  shock with energy in production is exactly the same as the GDP response with energy in consumption shown in proposition 3.

Figure 9 illustrates the proposition. Where before it was households that switch their expenditure from imported energy to domestically produced goods, it is now firms that make the same substitution. Under the condition stated in proposition 4, the response of GDP will be identical. The condition is intuitive: It simply ensures that the effective spending shares on the three goods,  $H, F, E$ , by domestic households are the same in the two models.



Figure 10: Response of Home production to an energy shock in the HA model with energy endowments



Note: Impulse responses for  $\bar{Y}$  – production of the Home good – in the heterogeneous-agent model to the energy price shock  $P_{Et}^*$  displayed in figure 2. Under the baseline (endowment share = 0%), no energy is produced domestically, and all energy for consumption is imported. We also show the results when domestic energy production is equal to 50% and 100% of domestic energy consumption, respectively.

**Endowment of energy.** In our baseline model, energy-importing countries do not produce any energy themselves. Here we allow for energy to be produced at Home. This energy is produced and sold by energy suppliers, exactly as described above. These firms are entirely owned by domestic households, and they sell energy at the global price,  $P_{Et}^*$ . In figure 10, we vary the endowment of energy between zero and the level of total energy consumption. Increasing the energy share mitigates the hit to employment and home production,  $\bar{Y}$ . However, even with a 100% energy share, if  $\chi$  is low enough we still see a decline in  $\bar{Y}$  as the shock redistributes towards lower MPC agents.

**Markup shocks** In appendix D.3, we show that under a real rate rule, modeling the energy shock as a markup shock fails to generate a decline in output. Under a Taylor rule, the markup shock generates a notably smaller recession. This demonstrates how the energy price shock presents a worse trade off for monetary policy than a cost push shock.

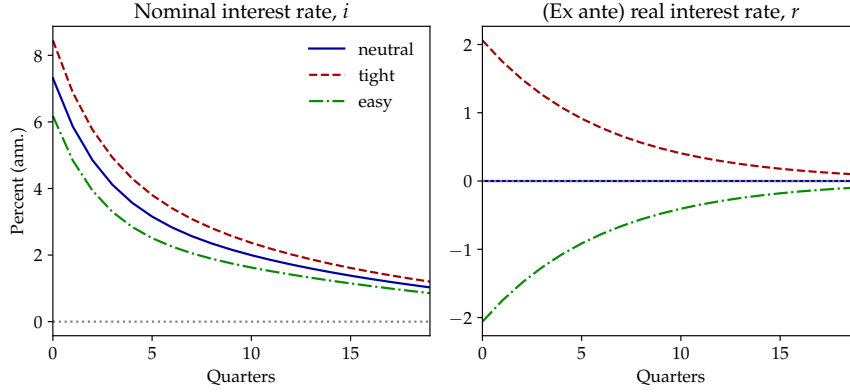
## 4 Monetary policy response

Our analysis so far has concentrated on a specific monetary policy rule, namely one that achieves a stable real interest rate path. A natural question is then to what extent a more active monetary policy stance can meaningfully bring down inflation or mitigate the recession.

In this section, we will compare three monetary policy responses to the shock: the neutral stance we have analyzed before, as well as an “easy” and a “tight” alternative response. We parameterize those alternatives as AR(1) paths for real interest rates that either start at plus or minus two percentage points (annualized). The shock as well as the induced nominal interest rate paths can be seen in figure 11.

One issue with our baseline model that can be seen in section 3.3 is that prices jump by a

Figure 11: Monetary policy scenarios in response to the energy price shock.



Note: This figure shows three scenarios for the monetary policy response to the energy price shock. The blue solid represents a monetary response that keeps the real interest rate constant. The red dashed represents a monetary response that raises the on impact real interest rate by 2 percentage points (annual), and then follows an AR(1) trajectory back to the original real rate (persistence = 0.85). The dot-dashed green line does the opposite.

significant margin at date 0, implying an unreasonably large inflation response on impact. To solve this issue, we first introduce slow pass-through of world prices into consumer prices, and then study the effects of monetary policy.

#### 4.1 The quantitative model

**Slow pass-through** We allow for slow pass-through of import prices of both  $F$  and  $E$  goods into consumer prices.<sup>15</sup> This implies that local currency prices for  $E$  and  $F$ , denoted  $P_{Et}$  and  $P_{Ft}$ , are no longer simply equal to converted world prices  $\mathcal{E}_t P_{Et}^*$  and  $\mathcal{E}_t P_{Ft}^*$ .

There is a continuum of monopolistically competitive firms that import the foreign good. Each importer produces their variety of the foreign import at unit real cost  $\frac{\mathcal{E}_t P_{Ft}^*}{P_t}$ . The importing firms are also subject to a Calvo friction, and can only adjust their price each period with probability  $1 - \theta_F$ . The foreign imports are combined by a competitive sector using CES aggregation. We focus on the case where these imports are highly substitutable, with the steady state gross markup going to 1, and generating the foreign good Phillips curve

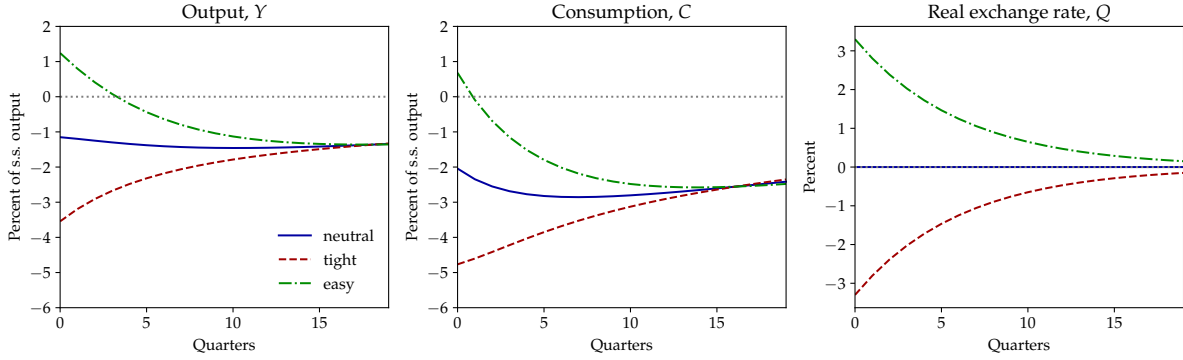
$$\pi_{F,t} = \kappa_F \left[ \frac{\mathcal{E}_t P_{Ft}^*}{P_{F,t}} - 1 \right] + \frac{1}{1 + r_{t+1}} \pi_{F,t+1}$$

where  $\kappa_F = \frac{(1-\theta_F)(1-\frac{\theta_F}{1+r_{ss}})}{\theta_F}$  and  $r_{ss}$  denotes the steady-state interest rate. The foreign good importers pay out total dividends

$$D_{Ft} = \left( \frac{P_{Ft} - \mathcal{E}_t P_{Ft}^*}{P_t} \right) C_{Ft}$$

<sup>15</sup>Since there is immediate passthrough of the exchange rate to export prices but slow passthrough to import prices, this is analogous to what the U.S. experiences in the “Dollar Currency Pricing” paradigm (DCP). We think of this as reasonable to model Europe, with many imports and exports goods priced in Euros.

Figure 12: Effect of monetary policy on output and consumption



Note: This figure shows the output and consumption responses to an energy price shock across the three monetary policy scenarios detailed in figure 11.

The energy good is imported in the same manner. The equations governing energy price inflation  $\pi_{Et}$  and dividends of energy firms  $D_{Et}$  are the direct analogue of those for  $\pi_{Ft}$  and  $D_{Ft}$ . A high  $\kappa_E$  corresponds to the case where world energy price or exchange rate changes rapidly pass through to domestic energy prices.

In order not to distort the steady state of the model with the introduction of slow pass-through, we assume that importers of  $E$  and  $F$  goods are owned by foreigners. This changes our expression of net exports in section 2 to

$$NX_t \equiv \frac{\mathcal{E}_t P_{Ht}^*}{P_t} C_{Ht}^* - \mathcal{E}_t \frac{P_{Ft}}{P_t} C_{Ft} - \mathcal{E}_t \frac{P_{Et}}{P_t} C_{Et}$$

All other equilibrium conditions are left untouched by this addition.

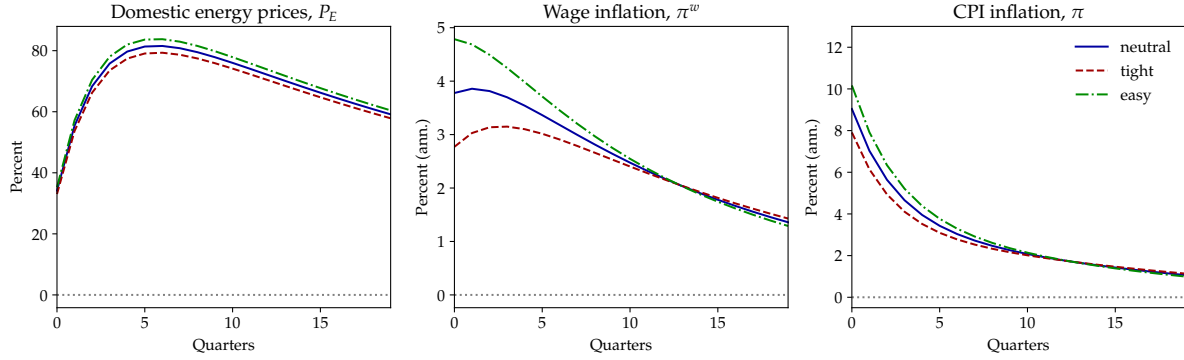
**Domestic energy production** Another feature we include in our numerical model is an energy endowment, as discussed in section 3.4. Introducing an energy endowment makes the response to the energy price shock less contractionary and more inflationary in our model. It also emphasizes the importance of heterogeneous agents; as we allow for domestic energy production, the RA-IM is increasingly unable to generate a sizable recession in response to the shock.

We retain the share of energy consumption in GDP at  $\alpha_E = 0.04$ , but now suppose that a third of this is domestically produced. (See footnote 11 for details.)

## 4.2 Effects of monetary policy on output and inflation

Figure 12 shows the effects of the two alternative monetary policy responses on output and consumption. As one would expect, monetary easing ameliorates the recession induced by the energy shock; monetary tightening deepens the recession. There is a small reversal a few quarters out, tighter monetary policy actually aids the recovery. This emerges as households see higher interest rates as an incentive to save more and improve their balance sheet position, increasing their ability

Figure 13: Effect of monetary policy on inflation



Note: This figure shows the price and wage inflation responses to an energy price shock across the three monetary policy scenarios detailed in figure 11.

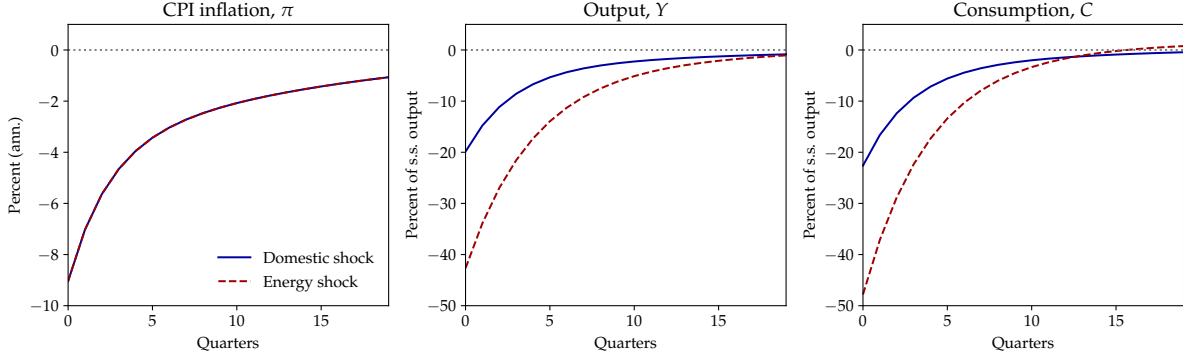
to spend down the road. This effect was noticed by Auclert et al. (2021b) and does not occur in standard heterogeneous-agent closed economy environments.

We plot the response of inflation and domestic energy prices to the alternative monetary policy responses in figure 13. We see that wage inflation reacts significantly to changes in monetary policy, but since domestic energy prices move very little, it is very hard to reduce CPI inflation in a meaningful way given the large initial increase in inflation. This is largely coming from the fact that the shock to CPI inflation is large, and monetary policy primarily affects inflation via wage inflation, which is relatively sticky. Crucially, any small energy importer's monetary policy is unable to affect world energy prices, implying that it cannot move the price that lies at the origin of the shock at all. We return to this point below, in section 6.

### 4.3 Effectiveness of monetary policy by source of the shock

In this section, we explore in what sense importing this inflationary shock can be a worse problem than dealing with a domestic inflationary shock. To do so, we ask what decline in output would be required to achieve zero inflation in the presence of downward nominal wage rigidity. We show the results in figure 14. With the energy price shock we have considered throughout, monetary policy stabilizes the CPI by raising rates to (1) appreciate the currency, lowering  $P_E$  and  $P_F$ , and (2) contract output, lowering  $W$  and so  $P_H$ . With downward nominal wage rigidity, the second channel is shut down, and the central bank must cause a bigger recession to sufficiently appreciate the currency. We contrast this with a “domestic shock” that generates the same path for CPI. In this case, wages pull up the CPI, and so the downward nominal wage rigidity does not bind. As such, monetary policy is more effective in fighting domestically generated inflation.

Figure 14: Different inflation-output tradeoffs for foreign and domestic shocks



Note: This plot shows the *change* in inflation, output, and consumption required to offset the degree of inflation generated by the energy price shock, given two different sources of the shock, and in the presence of downward nominal wage rigidity.

## 5 Fiscal policy response

An important component of the actual policy response to the energy shocks in 2022 and 2023 has been fiscal support programs. We now consider the effects of three such policies. To introduce them, we first extend the model to allow for a government. We keep slow pass-through and the energy endowment, which we introduced above in section 4.1.

### 5.1 Government

The government runs three possible programs: it can subsidize energy domestically, and it can send targeted or untargeted transfers to households. It finances those programs with deficits initially, which are ultimately repaid with labor income taxes.

*Energy subsidies.* The government may subsidize the real energy price that households face

$$\frac{P_{Et}^{hh}}{P_t} = (1 - \tau^E) \frac{P_{Et}}{P_t} + \tau^E \frac{P_{E,ss}}{P_{ss}}$$

Here,  $P_{Et}^{hh}$  denotes the nominal price paid by households after the subsidy. Before the subsidy, the price is still denoted by  $P_{Et}$ . It is important to subsidize real energy prices such that permanent shifts in the price level as a result of the shock do not lead to permanent subsidies.

*Targeted transfers.* The government may make targeted transfers to households, indexed to their counterfactual level of energy consumption absent the shock. Under a targeted transfer, household  $i$  in idiosyncratic state  $(a, e)$  with counterfactual energy consumption  $c_{i,ss}^E \equiv c_{E,ss}(a, e)$  receives a real transfer  $T_{i,t}$  that insures a fixed proportion  $\text{ins}^E$  of the net increase in energy costs,

$$T_{i,t} = \text{ins}^E \cdot c_{i,ss}^E \cdot \left( \frac{P_{Et}}{P_t} - \frac{P_{E,ss}}{P_{ss}} \right)$$

*Untargeted transfers.* The government may also make an untargeted (real) transfer, giving all

households an equal amount,  $T_t^{\text{unt}}$ . The level of  $T_t^{\text{unt}}$  is set so that the total subsidy is the same as in the targeted case.

*Labor income taxes.* The proportional labor income tax rate is denoted by  $\tau_t^L$ . We henceforth take  $Z_t$  to denote after-tax labor income. Replacing (2),  $Z_t$  is now given by

$$Z_t = (1 - \tau_t^L) \frac{W_t}{P_t} N_t$$

and the wage Phillips curve is now based on the after-tax wage  $(1 - \tau_t^L)W_t/P_t$ ,

$$\pi_{wt} = \kappa_w \left( \frac{v'(N_t)/u'(C_t)}{\frac{1}{\mu_w} [(1 - \tau_t^L) W_t/P_t] \cdot (W_t/P_t)^{\zeta_{BG}}} - 1 \right) + \beta \pi_{wt+1}$$

*Government budget constraint.* The government issues real bonds  $B_t$  to satisfy the government budget constraint

$$B_t = (1 + r_{t-1}^{\text{ante}}) B_{t-1} + \tau^E \left( \frac{P_{Et}}{P_t} - \frac{P_{E,ss}}{P_{ss}} \right) C_{Et} + \text{ins}^E \left( \frac{P_{Et}}{P_t} - \frac{P_{E,ss}}{P_{ss}} \right) C_{E,ss} + T_t^{\text{unt}} - \tau_t^L \frac{W_t}{P_t} N_t$$

The rate of income tax is proportional to the level of debt

$$\tau_t^L = \psi_B (B_{t-1} - B_{ss})$$

where  $\psi_B > 0$  parameterizes the speed with which debt is brought back to the steady state. The net foreign asset position is now given by

$$\text{nfa}_t \equiv A_t - j_t - B_t$$

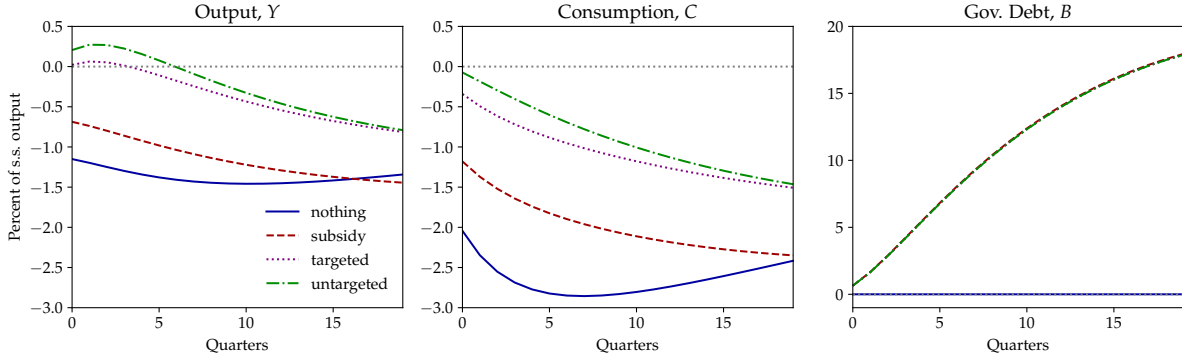
rather than (19).

*Calibration.* In order to keep the policies comparable, we set  $\tau^E = \text{ins}^E$ . We then set the untargeted transfer path to match the overall (ex-post) transfer in the targeted case. We explore the case of a 50% subsidy of deviations from the steady state price,  $\tau^E = 0.5$ . We set  $\psi_B = 0.04$ . In the absence of government spending, this implies a half-life of government debt of just under six years.

## 5.2 Effects of fiscal policy on output and inflation

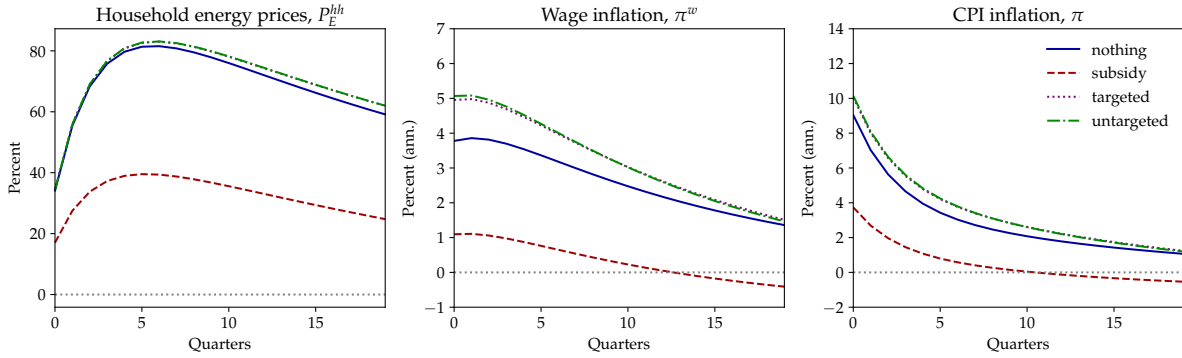
Figure 15 shows the effects of the three types of fiscal policies on output and consumption. It is clear that all three policies are able to significantly limit the real economic fallout of the energy shock. Both output and consumption are considerably higher under the policies. There is a very limited reversal 15-20 quarters out, which is due to the fact that labor income taxes start to become more salient at that point in order to bring down the additional debt that the government accumulated. We show in appendix D.5 that, if a government has less fiscal space and is therefore forced

Figure 15: Effect of fiscal policy on output and consumption



Note: This figure compares the output and consumption responses to an energy price shock under no fiscal policy with the three fiscal policy programs explained in section 5.1. All policies are financed by a deficit initially, and slowly paid for via increased proportional labor income taxes.

Figure 16: Effect of fiscal policy on inflation



Note: This figure compares the wage and price inflation responses to an energy price shock under no fiscal policy with the three fiscal policy programs explained in section 5.1. All policies are financed by a deficit initially, and slowly paid for via increased proportional labor income taxes.

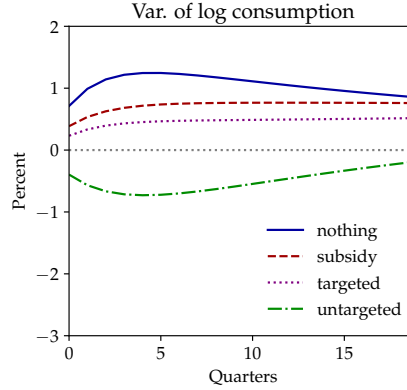
to run a balanced budget, the three policies are significantly less effective.

Where the three types of policies differ more is on their predictions for inflation (see figure 16). Targeted and untargeted transfers cause a significant uptick in CPI inflation, largely driven by a strong increase in wage inflation. This is to be expected, as deficit-financed transfers raise aggregated demand and stimulate the economy when MPCs are sizable (Farhi and Werning 2016, Auclert et al. 2018). Subsidies, on the other hand, are able to tame inflationary pressures in the economy to a large extent. By construction, energy prices faced by households come way down; this puts less pressure on real wages and therefore lessens the desire of unions to call for strong nominal wage increases; and ultimately CPI inflation only mildly overshoots its target.

Based on this discussion, energy subsidies appear to be a silver bullet: they tackle the shock at the root by bringing down energy prices, and therefore reduce the recessionary and inflationary forces in the economy. We return to this logic below, in section 6.



Figure 17: Fiscal policy and inequality after an energy shock



Note: This figure compares the inequality response to an energy price shock under no fiscal policy with the three fiscal policy programs explained in section 5.1. Since we have three household types (indexed  $g$ ), the variance of log consumption at date  $t$  is computed as  $\mathbb{E}_G [\text{Var} [\log (c_{it}) \mid i \in g]] - \text{Var}_G [\mathbb{E} [\log (c_{it}) \mid i \in g]]$ .

**Effects on inequality.** Our heterogeneous-agent model enables us to also study predictions on inequality across households, following the work of [Pieroni \(2022\)](#) and [Kuhn et al. \(2021\)](#). Figure 17 shows the evolution of the variance of log differences in consumption across households,  $\text{var}_{(a,e)}(\log c_t(a,e) - \log c_{ss}(a,e))$ . We see that inequality rises due to the shock itself (blue, solid line), but is significantly reduced by fiscal policy.

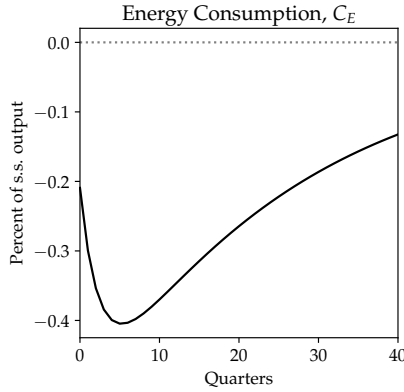
## 6 Role of policy coordination

So far we have limited our attention to an individual energy importer. Yet, all energy importers in our model face a similar situation and are likely to consider policy responses. In this section, we study the cross-border spillovers of fiscal and monetary policies implied by our model. To do so, we focus on a given energy importer and compare the macroeconomic effects of policies if the country is the only one engaging in the policy (“uncoordinated”) to a situation in which *all* energy importing countries engage in the same policy (“coordinated”).

We study coordinated policies by analyzing the world equilibrium, as defined in section 2, in which energy prices are endogenous. We choose the path of the energy supply shock  $\bar{E}_t$  to be such that when all countries follow a neutral monetary policy with no fiscal response, energy prices endogenously follow the same AR(1) path that we analyze in the single-country equilibrium (figure 2). This makes the coordinated world equilibrium comparable to the uncoordinated single-country equilibrium. We show the energy supply shock that we arrive at in figure 18.

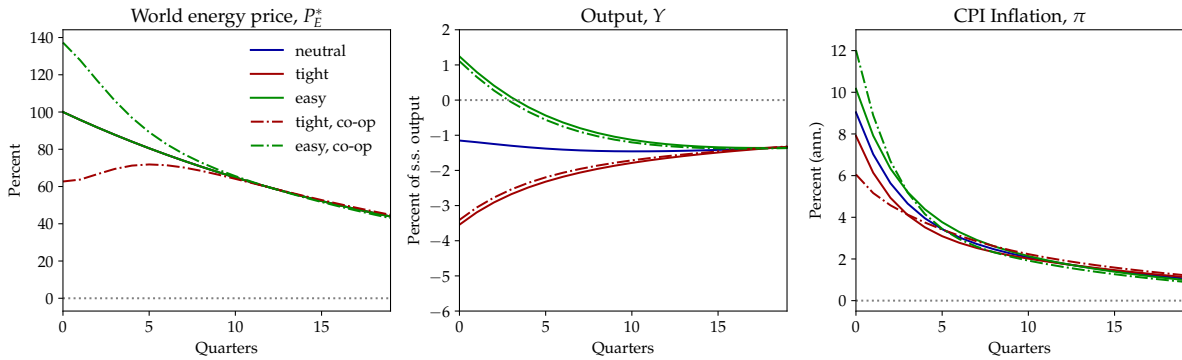
**Coordinated monetary policy.** Figure 19 compares uncoordinated with coordinated monetary policy. The key reason why coordinated monetary policy operates differently from uncoordinated policy is that coordinated policy is able to affect world energy prices. For example, coordinated tightening reduces world energy prices in the model by around 35 percentage points on impact.

Figure 18: The energy supply shock



Note: Shock path is chosen such that, if all countries follow a neutral monetary policy and have no fiscal response, world energy prices  $P_{Et}^*$  endogenously follow the AR(1) process shown in figure 2.

Figure 19: Coordinated vs uncoordinated monetary policy

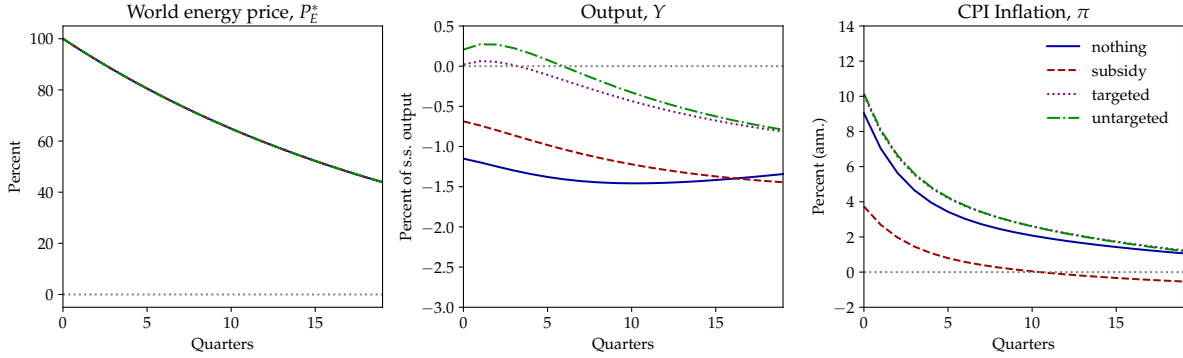


Note: This figure compares the output and inflation responses to an energy price shock across the three monetary policy scenarios detailed in figure 11. Solid simulates the case when only a single economy engages in the monetary policy scenarios. Dashed simulates the case when all economies use the same monetary policy.

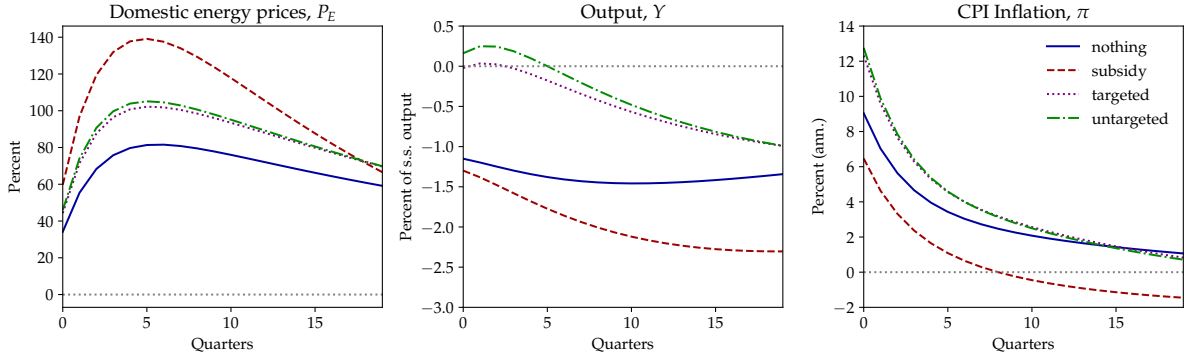
Even though pass through to consumer prices is slow, the reduction in world energy prices brings down CPI inflation by more than twice as much on impact. The associated output cost of tightening are also mitigated when all energy importers hike in a coordinated fashion, as real wages now fall by less. This discussion suggests that there are “positive externalities” from monetary tightening across energy importers, in the sense that one central bank’s tightening marginally reduces world energy prices for other countries.

**Coordinated fiscal policy.** Figure 20 compares uncoordinated with coordinated fiscal policy. Overall, the picture that emerges is one of “negative externalities” of fiscal support across countries. Targeted and untargeted transfers lead to an even greater uptick in inflation in the coordinated world equilibrium. And, most importantly, energy subsidies lead to a huge endogenous spike in world energy prices. This spike weakens the “insulating” role of energy subsidies, with CPI inflation almost rising to similar levels as without energy subsidies. The recession actually

Figure 20: Coordinated vs uncoordinated fiscal policy



(a) Without coordination (exogenous world energy price)



(b) With coordination (exogenous world energy supply)

Note: This figure compares the output and inflation responses to an energy price shock across the fiscal policy scenarios detailed in section 5.1 when (a) a single economy carries out the policy, and (b) all economies use the same fiscal policy.

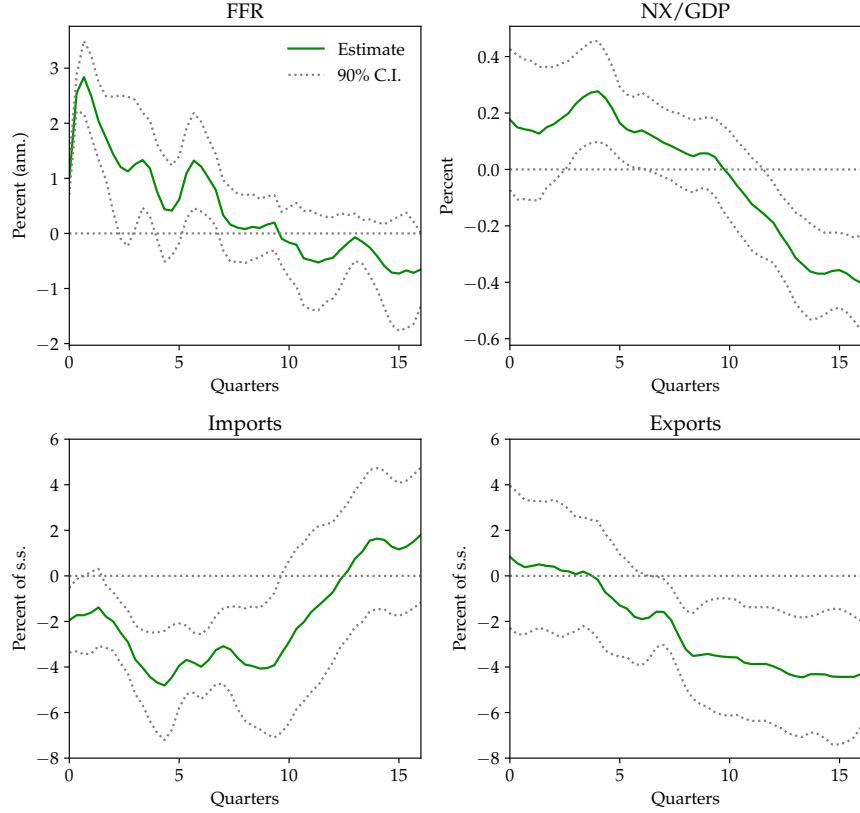
worsens in a world with coordinated energy subsidies, as governments need significant increases in labor income taxes to stem the fiscal cost of sustaining the energy subsidies.

## 6.1 Empirical evaluation of spillover channel

A key result in our model is the positive spillovers from coordinated monetary policy. This result contrasts with [Fornaro and Romei \(2022\)](#). As we show in appendix D.4, the spillover channel has the opposite effect on output in our model in the representative agent case.

In this section, we empirically explore the effect of monetary policy shocks on the trade balance, to verify our spillover channel is present in the data. We use the shocks constructed by [Romer and Romer \(2004\)](#) on their original sample (1969m3–1996m12). This exercise is therefore in a US context, but we use it to confirm our channel is present and calibrated reasonably. To obtain impulse responses, we use a [Jordà \(2005\)](#) projection. We collect quarterly data on exports, imports, net exports, and output, which we interpolate to monthly frequency. We then run a Jordà

Figure 21: Trade balance response to a monetary policy shock



Note: This figure shows our estimated set of impulse responses to an identified [Romer and Romer \(2004\)](#) monetary policy shock (solid green line), with 90% confidence intervals (dotted gray lines).

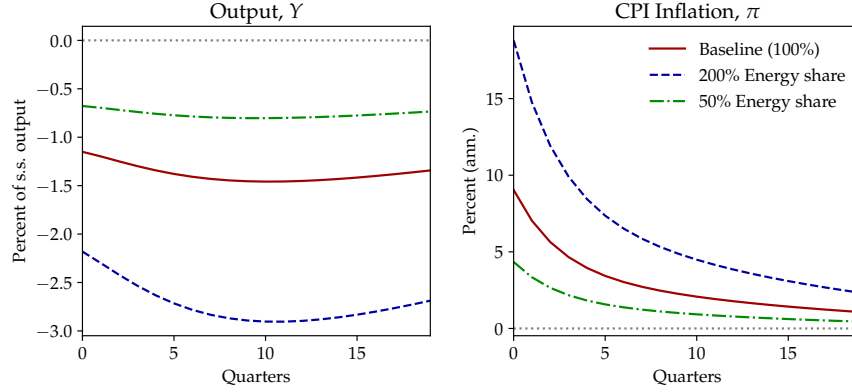
projection, which for a generic outcome  $Y_t$  reads

$$Y_{t+h} = J_h^Y \epsilon_t^m + \beta_h^Y X_t + \zeta_{t,h}^Y$$

separately for horizons  $h = 1, \dots, T$  up to  $T = 48$  months, where  $\epsilon_t^m$  is the Romer-Romer series, and  $\zeta_{t,h}^Y$  is a regression error term. To control for the potential endogeneity of  $\epsilon_t^m$  in practice, we include in  $X_t$  the set of controls that [Ramey \(2016\)](#) uses in her specification for figure 2, panel B: lags of industrial production, unemployment, the consumer price index and a commodity price index. We compute the standard deviation of  $\hat{J}_h^Y$  using a [Newey and West \(1987\)](#) correction for the autocorrelation in  $\zeta_{t,h}^Y$ .

The green lines in figure 21 display the impulse responses, with the dotted lines indicating confidence intervals. We see that in response to a 1 percentage point increase in the federal funds rate, net exports rise by around 0.2 percent of GDP. While in the long run, we appear to get the decline suggested by the expenditure switching channel, the short run appears to be dominated by a fall in imports consistent with a decline in domestic real income and low elasticities of substitution. Our model is targeted to the short run, and indeed the average change in net exports to

Figure 22: Responses to an energy price shock for different initial energy-in-GDP shares



Note: This figure compares the output and inflation responses to an energy price shock for different values of the energy-to-GDP ratio,  $\alpha_E$ .

GDP in the first six quarters after such a shock is 0.19 in both our model and the estimated IRFs.<sup>16</sup>

## 7 State dependence

An important question is whether we should expect the mechanisms documented in this paper to always be present, or whether they depend on the presence of certain pre-requisites. We now show that a crucial determinant of the presence of our mechanisms is the share of energy in an economy. To do so, we vary the share of energy in consumption between our baseline choice and double as well as half its value, i.e.  $\alpha_E^{\text{high}} = 2\alpha_E$  and  $\alpha_E^{\text{low}} = \frac{1}{2}\alpha_E$ . We leave the rest of the calibration entirely the same, including the assumption that one third of energy is being produced by the small open economy itself.

Figure 22 shows the responses of output and inflation to the energy shock across the three values of  $\alpha_E$ . We clearly see that higher values of  $\alpha_E$  leave an economy much more exposed to the energy shock. The responses are not entirely “scaled versions of each other” as the average elasticity  $\chi$  falls with a higher energy share, amplifying the effect of the shock.

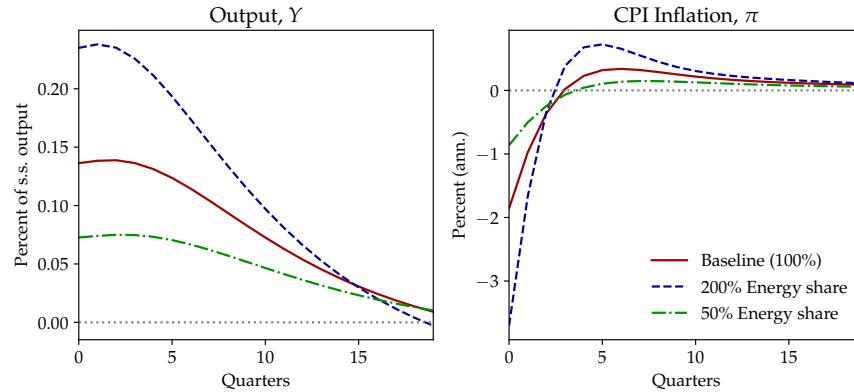
Figure 23 highlights that the magnitude of the spillover effect of monetary policy is also state dependent, and increases in the size of the energy share  $\alpha_E$ . This suggests that when examining the policies discussed above, the additional spillover channel of coordinated monetary tightening will play a particularly important role following a large, positive energy price shock.

## 8 Conclusion

In this paper, we propose to study energy price shocks in an open-economy heterogeneous-agent New-Keynesian model. We find that with low elasticities of substitution between energy and

<sup>16</sup>To compute this, we aggregate the nominal interest rate IRF to quarterly frequency, and feed this shock into our model.

Figure 23: Responses to a coordinated monetary policy shock for different initial energy-in-GDP shares



Note: This figure compares the output and inflation responses for different values of the energy-to-GDP ratio,  $\alpha_E$ . The shock is the world energy price path induced by all other energy-importing countries enacting the monetary policy tightening detailed in figure 11.

domestically produced goods, our model predicts “stagflationary” effects of an increase in world energy prices: a recession, paired with CPI and wage inflation. By contrast, we find that the same energy shock causes a boom in aggregate demand in a representative-agent model.

We then ask which policy options are on the table in the face of such a stagflationary shock. We distinguish between uncoordinated and coordinated, monetary and fiscal policies. Monetary policy helps regulate domestic demand in our model, which matters for wage inflation. With realistically sticky wages, however, an awful lot of monetary tightening, associated with a deeper recession, would be needed to offset the imported inflation in the consumer price index. For an individual country, monetary tightening is therefore an uphill battle. This is no reason against monetary tightening however: we find that tightening has positive spillovers across countries, as one country’s tightening lowers energy prices at the world level for everybody else. When all countries tighten their monetary policy together, inflation comes down by more than twice as much.

We find fiscal policy to work wonders when employed by a single country. Energy subsidies in particular are able to nearly fully insulate an individual energy importing country from the effects of higher world energy prices, bringing down imported and domestic inflation and mitigating the recession caused by plummeting real wages. However, it is precisely those subsidies that have the strongest negative externalities across energy importing countries. If all countries employ energy subsidies, very little substitution away from energy takes place since price incentives are largely muted. In an equilibrium with a fixed amount of energy supply, this generates strong price responses that undo the insulating role of energy subsidies and, by becoming a huge burden on the government budget, are able to worsen the recession caused by the energy shock. To the extent that not all countries have enough fiscal space, we would speculate that it is indeed the countries with the least fiscal space that would bear the main cost if those countries that have fiscal space engaged in aggressive energy subsidies.

What can we learn from our work on how countries presently ought to respond to the shock?

Clearly, energy subsidies seem like the wrong policies to lean on. Instead, one route that seems promising in light of our results is a combination of targeted energy subsidies on the one hand with aggressive and coordinated monetary tightening to suppress inflation and reduce world energy prices.



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## A Model details

### A.1 Derivation of the wage Phillips curve

In this section, we derive the wage Phillips curve with the real wage stabilization motive. At time  $t$ , union  $k$  sets its wage  $W_{kt}$  to maximize the utility of its average worker,

$$\sum_{\tau \geq 0} \beta^{t+\tau} \left( u(C_{t+\tau}) - v(N_{t+\tau}) - \frac{\psi_{nr}}{2} \left( \frac{W_{k,t+\tau}}{W_{k,t+\tau-1}} - 1 \right)^2 - \frac{\zeta_{BG}}{2} \frac{(\varepsilon - 1) N u'(C)}{\left( \frac{W}{P} \right)} \left( \frac{W_{k,t+\tau}}{P_{t+\tau}} - \frac{W}{P} \right)^2 \right)$$

Here  $\psi_{nr}$  parameterizes the degree of nominal rigidity, while  $\zeta_{BG}$  captures the real wage motive. The unions combine individual labor into tasks, which face demand

$$N_{kt} = \left( \frac{W_{kt}}{W_t} \right)^{-\varepsilon} N_t$$

where  $W_t = \left( \int W_{kt}^{1-\varepsilon} dk \right)^{\frac{1}{1-\varepsilon}}$  is the price index for aggregate employment services.

Each union is infinitesimal and therefore only takes into account its marginal effect on every household's consumption and labor supply. Household real earnings are

$$Z_t = \frac{1}{P_t} \int_0^1 W_{kt} \left( \frac{W_{kt}}{W_t} \right)^{-\varepsilon} N_t dk$$

By the envelope theorem, we can evaluate indirect utility by assuming all income from the union wage change is consumed immediately. Then  $\frac{\partial C_t}{\partial W_{kt}} = \frac{\partial Z_t}{\partial W_{kt}}$ , where

$$\frac{\partial Z_t}{\partial W_{kt}} = \frac{1}{P_t} N_{kt} (1 - \varepsilon)$$

On the other hand, total hours worked by household  $i$  are

$$N_{it} \equiv \int_0^1 \left( \frac{W_{kt}}{W_t} \right)^{-\varepsilon} N_t dk$$

which falls when  $W_{kt}$  rises according to

$$\frac{\partial N_{it}}{\partial W_{kt}} = -\varepsilon \frac{N_{kt}}{W_{kt}}$$

Therefore, the union's first order condition gives

$$\left( \frac{W_{k,t}}{W_{k,t-1}} - 1 \right) \frac{W_{k,t}}{W_{k,t-1}} = \frac{\varepsilon}{\psi_{nr}} \left[ N_{kt} v'(N_t) - \frac{\varepsilon - 1}{\varepsilon} \frac{N_{kt} W_{k,t}}{P_t} u'(C_t) - \zeta_{BG} \frac{N}{\frac{\varepsilon}{\varepsilon-1} \left( \frac{W}{P} \right)} u'(C) \left( \frac{W_{k,t}}{P_t} - \frac{W}{P} \right) \frac{W_{k,t}}{P_t} \right] + \beta \left( \frac{W_{k,t+1}}{W_{k,t}} - 1 \right)$$

In equilibrium, all unions set the same wage:  $W_{kt} = W_t$  and so  $N_{kt} = N_t$ . Define wage inflation as  $\pi^w \equiv \frac{W_t}{W_{t-1}} - 1$ . Then

$$\pi_t^w (1 + \pi_t^w) = \frac{\varepsilon}{\psi_{nr}} \left[ N_t v'(N_t) - \frac{1}{\mu_w} Z_t u'(C_t) - \frac{\zeta_{BG}}{\mu_w} u'(C) \frac{N}{N_t} \left( \frac{W_t}{P_t} - \frac{W}{P} \right) \frac{W_t}{P_t} / \frac{W}{P} \right] + \beta \pi_{t+1}^w (1 + \pi_{t+1}^w) \quad (\text{A.1})$$

with  $\mu_w = \frac{\varepsilon}{\varepsilon-1}$ . In the zero wage-inflation steady state

$$v'(N) = \frac{1}{\mu_w} u'(C) \frac{W}{P}$$

Linearizing (A.1) around this steady state,

$$d\pi_t^w = \frac{\varepsilon}{\psi_{nr}} N \left[ dv'(N_t) - \frac{1}{\mu_w} du'(C_t) \frac{W}{P} - (1 + \zeta_{BG}) \frac{1}{\mu_w} u'(C) d \left[ \frac{W_t}{P_t} \right] \right] + \beta d\pi_{t+1}^w$$

This also gives the first order dynamics (and the steady state) of (20) above, with  $\kappa_w = \frac{\varepsilon N v'(N)}{\psi_{nr}}$ .

## A.2 Comparison of the real wage targeting motive to Blanchard and Galí (2007a)

In Blanchard and Galí (2007a), the (log) real wage evolves according to

$$w_t = \gamma w_{t-1} + (1 - \gamma) \text{mrs}_t$$

Consider instead a modification of this equation, where the lagged real wage is replaced by the steady state value. Then, using hats to denote log deviations from steady state,

$$\hat{w}_t = (1 - \gamma) \hat{\text{mrs}}_t$$

Taking our wage equation (20) as  $\theta_w \rightarrow 0$ , gives

$$\mu_w \frac{v'(N_t)}{u'(C_t)} = (W_t/P_t)^{1+\zeta_{BG}}$$

Taking logs, and with  $\text{MRS}_t \equiv \frac{v'(N_t)}{u'(C_t)}$ ,

$$\hat{w}_t = \frac{1}{1 + \zeta_{BG}} \hat{\text{mrs}}_t$$

Blanchard and Galí (2007a) use values  $\gamma = 0.6$  and  $\gamma = 0.9$ . So to match this, we would set

$$\zeta_{BG} = \frac{\gamma}{1 - \gamma} \in \{1.5, 9\}.$$

Our value lies in between those two.

## B Proofs

### B.1 Proof of Proposition 2

In this section, we derive the “international Keynesian cross” shown in (32). To derive (32), we start from the general goods market clearing condition (27)

$$\bar{Y}_t = (1 - \alpha) \left( \frac{P_{Ht}}{P_{Hft}} \right)^{-\eta} \left( \frac{P_{Hft}}{P_t} \right)^{-\eta_E} C_t + \alpha^* \left( \frac{P_{Ht}}{\mathcal{E}_t} \right)^{-\gamma} C^* \quad (\text{A.2})$$

where we, at this point, still allow for energy in production,  $\zeta_E > 0$ . Consumption here can be written as an intertemporal consumption function (Auclert et al. 2018)

$$C_t = \mathcal{C}_t(\{r_0, r_s^{\text{ante}}, Z_s\}) \quad (\text{A.3})$$

where  $Z_s = \frac{W_s}{P_s} N_s$  denotes aggregate labor income (2). This follows directly from (1).

In (A.3), we have made explicit the fact that aggregate demand for consumption  $C_t$  depends only on the initial ex-post return  $r_0$ , reflecting valuation effects, the time path of ex-ante real interest rates  $r_s^{\text{ante}}$  for  $s \geq 0$  set by monetary policy (since  $r_{t+1} = r_t^{\text{ante}}$  for all  $t \geq 1$ ), and the path of real labor income  $Z_s$  for  $s \geq 0$ . We denote this general consumption function by  $\mathcal{C}_t$ .

We consider here the case of a constant real interest rate path,  $r_t^{\text{ante}} = \text{const} = r_{ss}$ , and will henceforth drop it from the consumption function (A.3). By the real UIP condition, (17) this also implies that

$$Q_t = Q_{ss}$$

and  $d \log P_t = d \log \mathcal{E}_t$ .

Next, we linearize (A.2), beginning with expressions for all relevant relative prices; then we linearize the left hand side, followed by the right hand side.

**Relative prices.** From (4), obtain

$$\begin{aligned} d \log P_{Hft} &= \alpha_F d \log P_F + (1 - \alpha_F) d \log P_H \\ d \log P_t &= \alpha_E d \log \mathcal{E}_t + \alpha_E d \log P_{Et}^* + (1 - \alpha_E) d \log P_{HF} \end{aligned}$$

Rearranging, we find

$$d \log \frac{P_{Ht}}{\mathcal{E}_t} = -\frac{\alpha_E}{1 - \alpha} d \log P_{Et}^* \quad (\text{A.4})$$

$$d \log \frac{P_{Ht}}{P_{Hft}} = -\frac{\alpha_E \alpha_F}{1 - \alpha} d \log P_{Et}^* \quad (\text{A.5})$$

$$d \log \frac{P_{Hft}}{P_t} = -\frac{\alpha_E}{1 - \alpha_E} d \log P_{Et}^* \quad (\text{A.6})$$

Moreover, log-linearizing (13), we obtain

$$d \log P_{Ht} = (1 - \zeta_E) d \log W_t + \zeta_E d \log P_{Et}^* + \zeta_E d \log \mathcal{E}_t$$

which lets us derive

$$d \log W_t - d \log P_{Et} = -\frac{1}{1 - \zeta_E} \frac{\alpha_E + 1 - \alpha}{1 - \alpha} d \log P_{Et}^* \quad (\text{A.7})$$

and

$$d \log \frac{W_t}{P_t} = -\frac{\alpha_E + \zeta_E (1 - \alpha)}{(1 - \zeta_E) (1 - \alpha)} d \log P_{Et}^* \quad (\text{A.8})$$

**Left hand side of (A.2).** We log-linearize the right hand side as follows,

$$d \log \bar{Y}_t = (1 - \zeta_E) d \log Y_t + \zeta_E d \log E_t$$

Energy demand by domestic firms is given by

$$d \log E_t = d \log Y_t + \nu (d \log W_t - d \log P_{Et})$$

so that we can write

$$d \log \bar{Y}_t = d \log Y_t + \zeta_E \nu (d \log W_t - d \log P_{Et})$$

Substituting in (A.7) and the steady state expression  $\bar{Y}_{ss} = \frac{1}{1 - \zeta_E}$ , we obtain for the left hand side of (A.2),

$$(1 - \zeta_E) d \bar{Y}_t = d Y_t - \frac{\zeta_E}{1 - \zeta_E} \frac{\alpha_E + 1 - \alpha}{1 - \alpha} \nu d \log P_{Et}^* \quad (\text{A.9})$$

**Relative prices on the right hand side of (A.2).** For the right hand side, we find

$$(1 - \alpha) \left( \frac{P_{Ht}}{P_{Hft}} \right)^{-\eta} \left( \frac{P_{Hft}}{P_t} \right)^{-\eta_E} C_t + \alpha^* \left( \frac{P_{Ht}}{\mathcal{E}_t} \right)^{-\gamma} C^*$$

$$d\bar{Y}_t = -(1-\alpha)\eta d\log \frac{P_{Ht}}{P_{Hft}} - (1-\alpha)\eta_E d\log \frac{P_{Hft}}{P_t} + (1-\alpha)dC_t - \alpha^*\gamma d\log \frac{P_{Ht}}{\mathcal{E}_t}$$

Substituting in (A.5), (A.6), (A.4), we arrive at

$$d\bar{Y}_t = \alpha_E (\alpha_F \eta + (1-\alpha_F)\eta_E) d\log P_{Et}^* + \alpha^*\gamma \frac{\alpha_E}{1-\alpha} d\log P_{Et}^* + (1-\alpha)dC_t \quad (\text{A.10})$$

**Consumption response on the right hand side of (A.2).** In order to express  $dC_t$  in terms of primitives, observe that the valuation equation for assets, combined with (11), implies that share prices are

$$p_t = \frac{D_{t+1} + p_{t+1}}{1+r_t} = PDV(\{(\mu-1)Z_s\}) \quad (\text{A.11})$$

so that the initial revaluation  $r_0^p$  also only depends on the path of labor income  $Z_s$ . Following Auclert et al. (2021b), we therefore can write the consumption function (A.3) simply as a function of  $Z_s$ ,

$$C_t = \mathcal{C}_t(\{Z_s\})$$

whose (sequence-space) Jacobian we denote by

$$M_{t,s} \equiv \frac{\partial \mathcal{C}_t}{\partial Z_s}$$

We stack the matrix as  $\mathbf{M} \equiv (M_{t,s})$ . The exact shape of  $\mathbf{M}$  is discussed in more detail in Auclert et al. (2021b). With this notation, we can write, in vector notation,

$$d\mathbf{C} = \mathbf{M} \cdot d\log \mathbf{Z} \quad (\text{A.12})$$

where, using (A.8),

$$d\log Z_t = dY_t + d\log \frac{W_t}{P_t} = dY_t - \frac{\alpha_E + \xi_E(1-\alpha)}{(1-\xi_E)(1-\alpha)} d\log P_{Et}^*$$

Thus,

$$d\mathbf{C} = -\frac{\alpha_E + \xi_E(1-\alpha)}{(1-\xi_E)(1-\alpha)} \mathbf{M} \cdot d\mathbf{P}_E^* + \mathbf{M} d\mathbf{Y} \quad (\text{A.13})$$

Equation (A.13) collapses to (31) in the special case of no energy usage in production,  $\xi_E = 0$ .

**Combining left and right hand sides.** Putting together (A.9), (A.10), (A.12), and the definition of  $\chi$  in (30) we obtain the following equation,

$$\begin{aligned} d\mathbf{Y} = & \left[ (1-\xi_E) \frac{\alpha_E}{1-\alpha} \chi + \frac{\xi_E}{1-\xi_E} \left( 1 + \frac{\alpha_E}{1-\alpha} \right) \nu + \xi_E \frac{\alpha_E}{1-\alpha} \gamma \right] d\log \mathbf{P}_E^* \\ & - (\alpha_E + \xi_E(1-\alpha)) \mathbf{M} \cdot d\mathbf{P}_E^* + (1-\xi_E)(1-\alpha) \mathbf{M} d\mathbf{Y} \end{aligned} \quad (\text{A.14})$$

Setting  $\xi_E = 0$ , and hence  $\alpha^* = \alpha$ , we find that this collapses to (32).

## B.2 Proof of Proposition 1

In the (complete-markets) representative-agent model, the Backus-Smith condition (24) holds. Since the real exchange rate  $Q_t$  is constant, consumption is, too. In other words,  $d\mathbf{C} = 0$ . Essentially,  $\mathbf{M} = 0$  for the (complete-markets) representative agent. This proves (28). (29) follows from (A.14) when we set  $\mathbf{M} = 0$  and  $\xi_E = 0$ .

### B.3 Proof of Proposition 3

Analogously to proposition 3 in Auclert et al. (2021b) we solve the fixed point (32) for  $d\mathbf{Y}$  to find

$$d\mathbf{Y} = \underbrace{\left( \sum_{k \geq 0} (1 - \alpha)^k \mathbf{M}^k \right)}_{=(\mathbf{I} - (1 - \alpha)\mathbf{M})^{-1}} \left( \frac{\alpha_E}{1 - \alpha} \chi d\mathbf{P}_E^* - \alpha_E \mathbf{M} \cdot d\mathbf{P}_E^* \right)$$

We can rearrange this to (33). The results that  $d\mathbf{Y} \leq d\mathbf{Y}^{RA}$  and  $d\mathbf{C} \leq 0$  are equivalent to  $\chi \leq 1$  follow directly from  $\mathbf{M} \geq 0$  and the assumption of a non-negative shock,  $d\mathbf{P}_E^* \geq 0$ .

### B.4 Proof of Proposition 4

For (4), we set  $\alpha_E = 0$  in (A.14). To get at the mapping between the “energy in production” and “energy in consumption” models, we denote by  $\tilde{\alpha}_F$  the share of consumption going towards good  $F$  in the “energy in production” model. We then have the following consumption shares in the two models, across the three goods, where we unpack the  $H$  good into labor and (if  $\xi_E > 0$ ) energy:

Table A.1: Consumption shares in the two models

Consumption share by good	“energy in production” model	“energy in consumption” model
domestic labor $N$	$(1 - \alpha_E)(1 - \alpha_F)$	$(1 - \xi_E)(1 - \tilde{\alpha}_F)$
$F$ goods	$(1 - \alpha_E)\alpha_F$	$\tilde{\alpha}_F$
$E$ goods	$\alpha_E$	$\xi_E(1 - \tilde{\alpha}_F)$

To equalize the shares, we define in the “energy in production” model,

$$\begin{aligned} \tilde{\alpha}_F &\equiv (1 - \alpha_E)\alpha_F \\ \xi_E &\equiv \frac{\alpha_E}{1 - \tilde{\alpha}_F} = \frac{\alpha_E}{1 - (1 - \alpha_E)\alpha_F} \end{aligned}$$

It is straightforward to check that the domestic labor consumption share is equalized, too. Notice that, with these definitions, we have that

$$\frac{\xi_E}{1 - \xi_E} = \frac{\alpha_E}{1 - \alpha}$$

Thus, if  $\nu = \chi$ , the Keynesian cross equation (35) with energy in production is equivalent to that with energy in consumption (32).

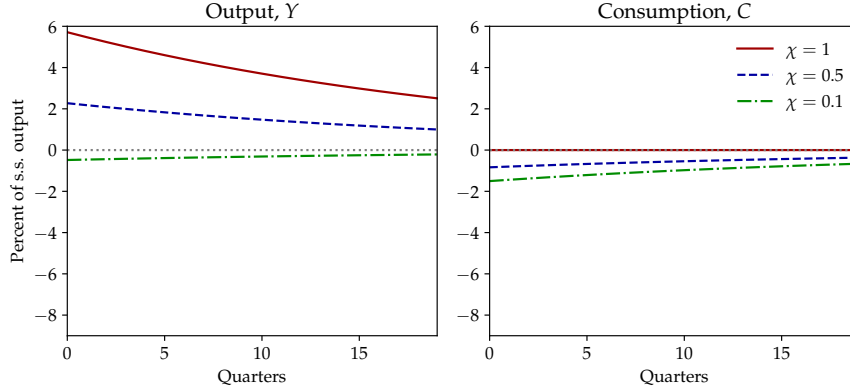
## C Comparison with a TANK model

For the two-agent complete-market model (“TA model”), we assume the household side of the model consist of a share  $1 - \lambda$  of agents with unconstrained access to financial markets, denoted by superscript  $u$ , and a share  $\lambda$  with no access to financial markets, denoted by superscript  $c$ . The unconstrained agents behave just like the representative agent in section 3.1. So, we can characterize their consumption with the Backus-Smith condition,

$$(c_t^u)^{-\sigma} = \frac{(c_{ss}^u)^{-\sigma}}{Q_t}$$



Figure A.1: Response to the energy price shock in TA model



Note: Impulse responses in a two-agent model to the energy price shock  $P_{Et}^*$  displayed in figure 2.  $\chi$  is the average substitution elasticity between energy and domestically produced goods. It is defined in (30).

The constrained agents consume their entire income each period,

$$c_t^c = Z_t$$

We suppose unions continue to split hours of work evenly between households. Aggregate consumption is the weighted average of these consumption responses,

$$C_t = (1 - \lambda) c_{ss}^u + \lambda c_t^c$$

And we set steady state aggregate asset holdings,  $A_{ss} = (1 - \lambda) A_{ss}^u$ , equal to those in the HA model. This gives rise to a household block characterized by the matrix of intertemporal MPCs,

$$\mathbf{M} = \lambda \mathbf{I}$$

From Proposition 2, the impulse response of consumption is then

$$d\mathbf{C} = - \underbrace{\frac{\alpha_E}{1 - \alpha} \lambda \cdot d\mathbf{P}_E^*}_{\text{Real income channel}} + \underbrace{\lambda \cdot d\mathbf{Y}}_{\text{Multiplier}}$$

$$d\mathbf{Y} = \underbrace{\frac{\alpha_E}{1 - \alpha} \chi \cdot d\mathbf{P}_E^*}_{\text{Exp. switching channel}} - \underbrace{\alpha_E \lambda \cdot d\mathbf{P}_E^*}_{\text{Real income channel}} + \underbrace{(1 - \alpha) \lambda \cdot d\mathbf{Y}}_{\text{Multiplier}}$$

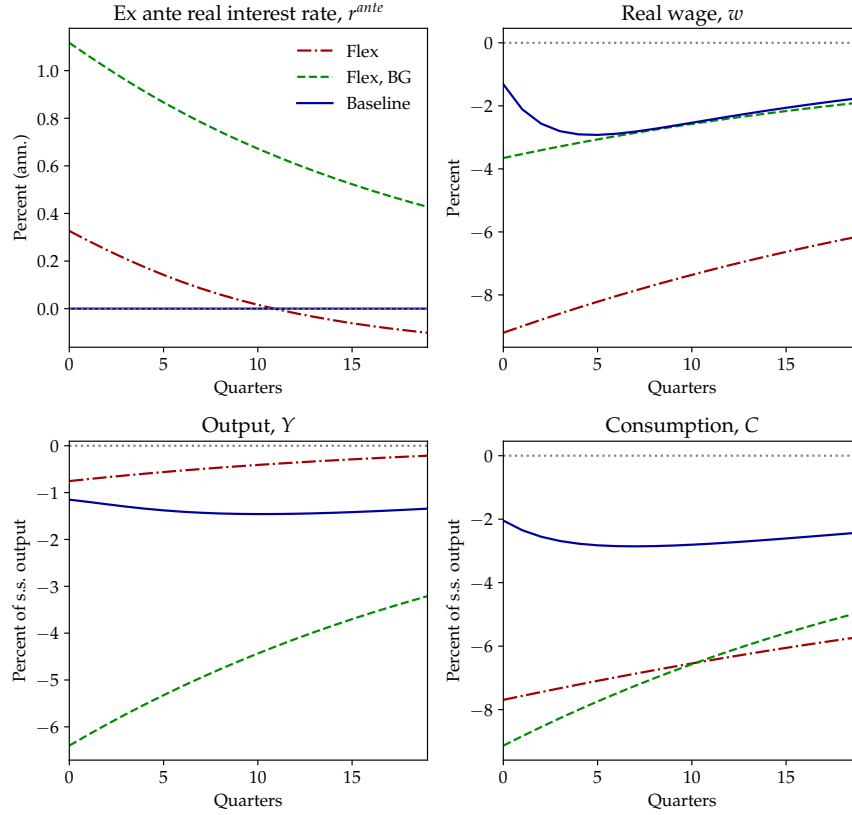
This has the solution

$$d\mathbf{Y} = \frac{\alpha_E}{1 - \alpha} \frac{\chi - (1 - \alpha) \lambda}{1 - (1 - \alpha) \lambda} \cdot d\mathbf{P}_E^*$$

$$d\mathbf{C} = \frac{\alpha_E}{1 - \alpha} \frac{\lambda (\chi - 1)}{1 - (1 - \alpha) \lambda} \cdot d\mathbf{P}_E^*$$

In figure A.1, we set  $\lambda = 0.25$  and plot the response to the energy price shock without importer frictions, as in section 3. We see that the potential for declines in output and consumption is much more limited in this model.

Figure A.2: Flexible price response to the energy price shock



Note: This figure shows the impulse responses to the energy price shock  $P_{Et}^*$  displayed in figure 2 for the baseline model, the flexible price model with the real wage friction (Flex, BG), and in the flexible price model without the real wage friction (Flex).

## D Additional model outcomes

### D.1 Flexible price allocation

In the section, we compare the response to the energy price shock in three cases: (1) the baseline case above, (2) the case with flexible prices but the real-wage stabilization motive, and (3) the case with flexible prices and no real-wage stabilization motive. The results are shown in figure A.2.

### D.2 Real Wage Stabilization with Taylor Rule vs Real Rate Rule

In the main text, we show the inflation response under a real rate rule, where

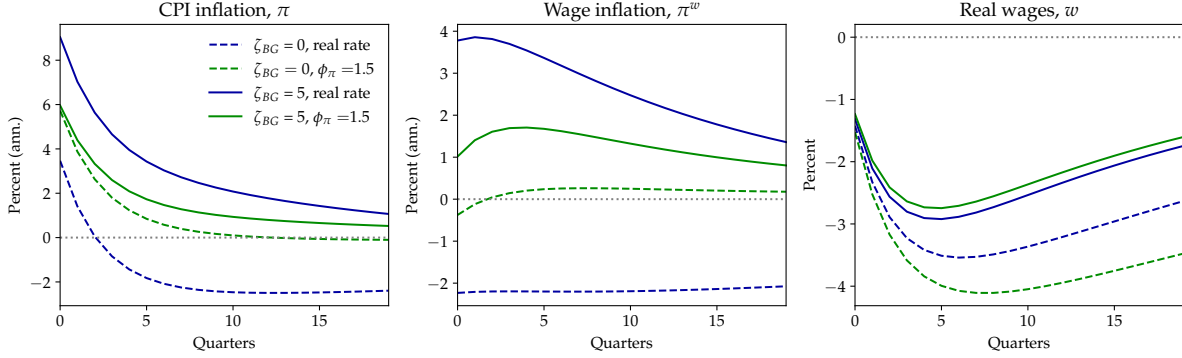
$$1 + i_t = (1 + r^*) (1 + \pi_{t+1})$$

In Figure A.3, we compare this to the response under the Taylor rule

$$1 + i_t = (1 + r^*) (1 + \phi_\pi \pi_t)$$

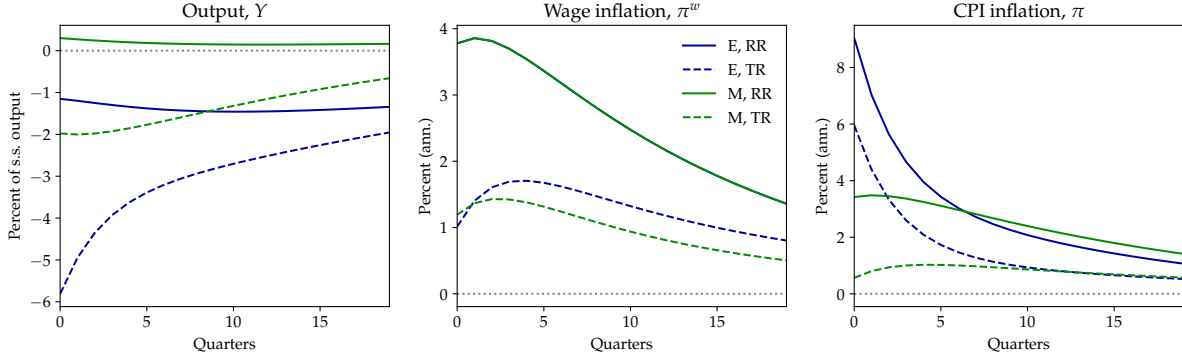
We see that the real wage stabilization motive is more effective at raising real wages under the Taylor rule. Under the real rate rule, the effect is smaller, and in the absence of energy importer frictions, it would be zero.

Figure A.3: Real wage stabilization with a Taylor rule vs a real rate rule



Note: This figure shows the responses of prices and wages to an energy price shock, with and without the real wage stabilization motive. It compares the response when the central bank follows a real rate rule against that when it follows a Taylor rule, with coefficient on current inflation  $\phi_\pi$ .

Figure A.4: Responses to an energy price shock and a markup shock under different monetary policy rules



Note: This figure contrasts the response to the original energy price shock (E) with that to a markup shock (M) that leads to equivalent wage inflation (under our baseline real rate rule). It plots the responses to each shock under a real rate rule (RR) and a Taylor rule (TR) for monetary policy.

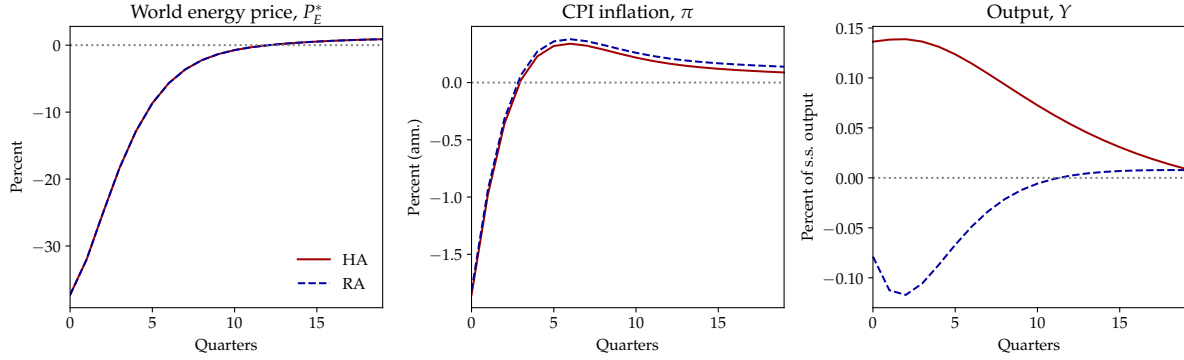
### D.3 Markup shocks versus energy shocks

We now ask whether the interpretation of an energy price shock as a markup shock retains the results of our model. We suppose a union markup shock that induces the same path for wage inflation as under our energy price shock. We then compare the results in figure A.4. Under a real rate rule, both shocks are inflationary, but only the energy price shock leads output to contract. While switching to a Taylor rule does generate a decline in output in both models, it is significantly worse under the energy price shock.

### D.4 Monetary spillover in different models

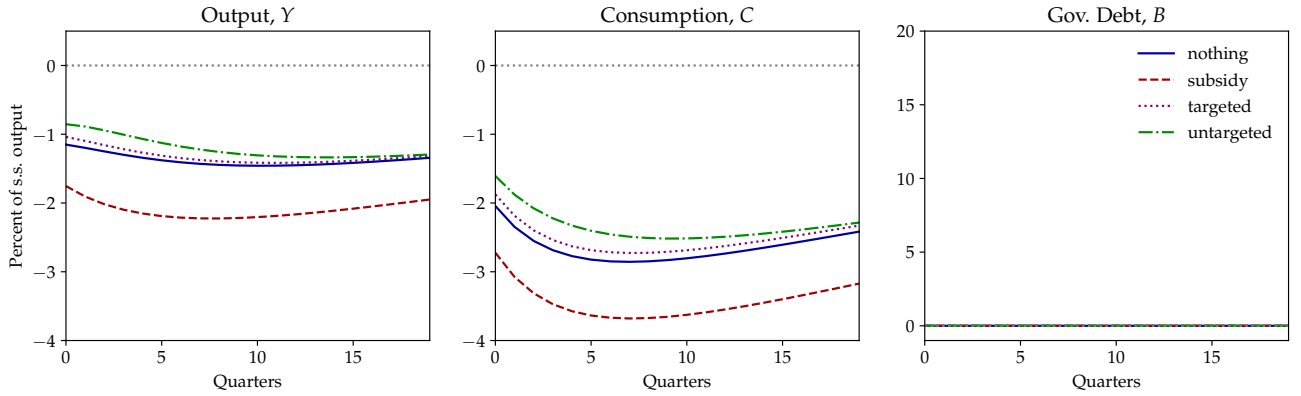
In this section, we consider the impact on Home of all other energy-importing countries tightening monetary policy, and thereby lowering the world energy price. That is, we isolate the spillover channel. In the HA model, as discussed above, this shock leads to lower inflation and a boost in output, driven by the real income channel. In the RA model, this same shock leads output to decline due to the expenditure switching channel. The results are shown in figure A.5.

Figure A.5: Spillover channel in the RA and HA models



Note: This figure shows the impact of all other energy importing countries tightening monetary as detailed in figure 11. It compares the response in the HA and RA models, for inflation and output.

Figure A.6: Fiscal policy with a balanced budget



Note: This figure compares the output and consumption responses to an energy price shock under no fiscal policy with the three fiscal policy programs explained in section 5.1, assuming a balanced budget throughout.

## D.5 Balanced budget fiscal policy

Here, we repeat the analysis in section 5, only now imposing a balanced budget at all dates:  $B_t = B_{ss} = 0$  for all  $t$ . As we see in figure A.6, the three fiscal policies are now less effective at cushioning the fall in output and consumption. However, it remains the case that the untargeted transfer is most effective, on this measure, and the subsidy the least.