Managing an Energy Shock: Fiscal and Monetary Policy

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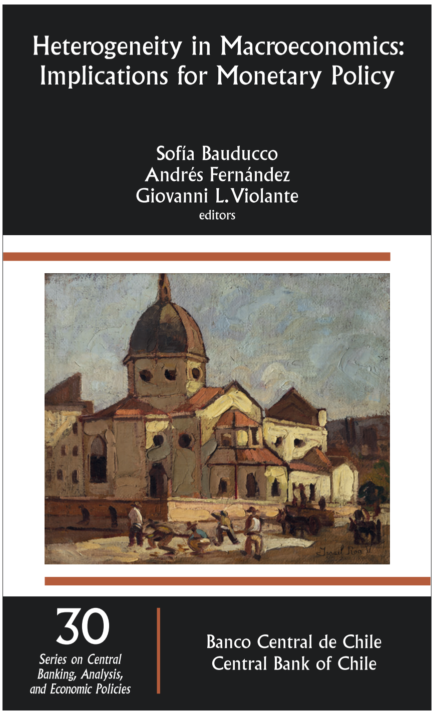

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In recent years, advanced economies have faced a large increase in the price of energy.[1] Prices for natural gas, crude oil, and electricity began to rise in 2021, then surged after the Russian invasion of Ukraine in February 2022 and, while they have fallen somewhat since, their future path remains uncertain. This sudden increase has

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1. See figure 1a.

Heterogeneity in Macroeconomics: Implications for Monetary Policy, edited by Sofía Bauducco, Andrés Fernández, and Giovanni L. Violante, Santiago, Chile.

led to debate about the appropriate response of monetary and fiscal policy—especially in Europe, where much energy is imported.

A key concern for policymakers has been the likely adverse impact of high energy prices on consumer demand. For instance, ECB chief economist Phillip Lane has argued that:[2]

> In addition to the direct and indirect impact of a surge in energy prices on inflation, it is necessary to recognize the adverse income and wealth effects of rising energy import prices on aggregate demand. Since the euro area is a large-scale net energy importer, an increase in the relative price of energy [implies] a net outward income transfer to the countries supplying energy to the euro area, [...] an adverse terms of trade movement, and a decline in real incomes, [...] with knock-on effects for consumption behavior.

This concern for knock-on effects on consumption motivated numerous fiscal packages, including direct transfers to households, VAT cuts, and other price regulations aimed at cushioning the impact of energy prices on real incomes.[3] Yet, in spite of a large literature on the macroeconomic effects of energy price shocks, standard theoretical models do not feature a direct link between high energy prices and aggregate demand.

Papers that study the supply-side effect of energy price shocks, such as Baqaee and Farhi (2019), Baqaee and Farhi (2022), and Bachmann and others (2022), find that rises in energy prices have a very limited effect on GDP, given realistic substitution elasticities. Since these papers abstract from nominal rigidities, they do not feature an aggregate demand channel. Yet, concerns about depressed aggregate demand appear to be well founded. For instance, the European GDP performance has been lackluster, at least compared to the United States,[4] with consumption playing a significant role in accounting for this difference. Moreover, research has found that the marginal propensity to consume (MPC) out of energy price increases is quite large.[5]

Papers that do feature an aggregate demand channel, such as New Keynesian models with oil, usually feature households that have a very low MPC out of energy, either because they use complete markets

2. See Inflation Diagnostics at the blog in the European Central Bank site, 25 November 2022.

3. See Ari and others (2022) and Sgaravatti and others (2023).

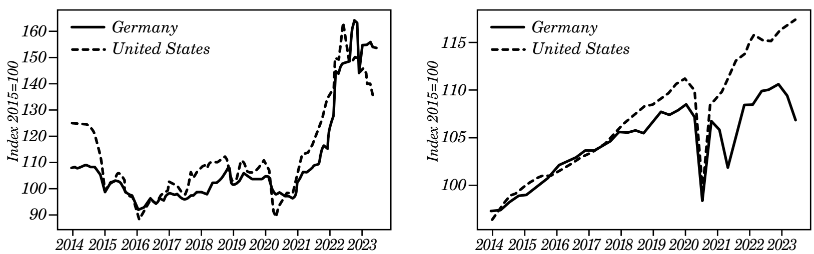
4. See Figure 1b.

5. See Gelman and others (2023).

to insure against changes in oil prices,[6] or because their permanent-income behavior leads them to smooth the effect of any price change on their consumption.[7] In these models, oil price shocks can cause a recession, but only because of the endogenous response of monetary policy to the inflation caused by the shock, rather than the direct effect of the shock on household real incomes and spending.[8,9] Yet it is this direct effect that seems to concern policymakers. Further, tightening of monetary policy in the euro area has lagged behind the United States, so that it is difficult to argue that the difference in figure 1b can be accounted for by more restrictive monetary policy in Germany.[10]

Figure 1. Energy Price Index and Real GDP in Germany vs. the United States

(*a*) *Price index for energy* (*b*) *Real GDP*



Source: Authors' calculations.
(a): Energy CPI in the U.S. (FRED: CPIENGSL) and energy HICP for Germany (Eurostat: EI_CPHI_M:CP-HIE).
(b): GDP in the U.S. (FRED:GDPC1) and in Germany (EEurostat:NAMQ_10_GDP:B1G). All indexed to 100 in 2015.

6. See Blanchard and Galí (2007a), and Soto and Medina (2005).

7. See Bodenstein and others (2011).

8. See Bernanke and others (1997), Leduc and Sill (2004), and Bodenstein and others (2013).

9. For empirical evidence that oil shocks can be expansionary at the ZLB, see Miyamoto and others (2023).

10. Instead, this differential performance of Germany relative to the U.S. is consistent with Phillip Lane's concerns about depressed aggregate demand, together with his observation that "the energy-related terms of trade sharply differentiates the current euro area and U.S. situations, since the U.S. is broadly balanced in its energy trade due to its large-scale domestic production of energy." (Inflation Diagnostics, cited above.)

This paper studies the macroeconomic effects of energy price shocks in a heterogeneous-agent New Keynesian model of a small open economy that imports energy, by adding an energy good to the model of Auclert and others (2021a). We show that, when MPCs are realistically large and the elasticity of substitution between energy and domestic goods is realistically low, this model does feature a direct link between high energy prices and aggregate demand: increases in energy prices depress real incomes and cause a recession, even if the central bank does not tighten monetary policy. We use our model as a laboratory to study potential monetary and fiscal policy responses to an energy shock, including their distributional effects.

To isolate the direct channel from energy price increases to aggregate demand, we begin by studying the case where monetary policy keeps the real interest rate constant in the face of energy shocks. We show analytically that the effect on aggregate GDP depends on a race between two effects: first, a substitution effect (when foreign energy is more expensive, consumers consume more domestically produced goods), which raises GDP and is governed by a certain elasticity of substitution χ, and second, a real-income effect (with real incomes depressed, consumers consume less of all goods), which lowers GDP and is governed by MPCs. Under a realistic calibration of substitution elasticities and MPCs, the second effect dominates, and energy price shocks cause a domestic contraction. This result contrasts with the predictions of a complete-market representative-agent model à la Blanchard and Galí (2007a) where, under this monetary policy, the substitution effect is the only effect, and the shock unambiguously causes an expansion; and also with the predictions of a representative-agent incomplete-market (RA-IM) model à la Bodenstein and others (2011), where the shock causes an expansion that is not offset by a real-income effect unless the shock is very persistent.

We then turn to the effect of the oil shock on price and wage inflation. Motivated by recent concerns about wage-price spirals in advanced economies, we ask whether the energy price shock can cause such a spiral, with nominal wages rising to catch up to nominal prices.[11] Under a standard parameterization of the wage Phillips curve, we find that, in fact, the answer is no: while the decline in purchasing power does lead households to desire higher wages, the recession caused by the shock makes them ask for lower wages, and the second force always dominates. However, we find that, when combining

11. See Blanchard (1986), Lorenzoni and Werning (2023b,a).

nominal rigidities with real-wage rigidities as in Blanchard and Galí (2007b), a spiral can occur: both wages and prices can rise after the energy price shock. Even in this case, the rise in nominal wages does not mitigate the real-wage decline caused by the shock: instead, the rise in nominal prices always outpaces the rise in nominal wages.

Next, we study alternative monetary policy responses to the shock. 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 an important caveat of such a policy: 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.[12]

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.

We then turn to fiscal policy. We study three types of fiscal 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 ultimately repaid by raising income taxes. As with monetary policy, we first study these policies when used by an individual energy-importing country in isolation, and then we consider externalities across countries.

We show that, when used by an individual country, fiscal policy can curtail the negative GDP effects of the energy shock. This is easiest to do by using energy subsidies. When households are insulated from higher energy prices, there is no real-wage loss and no associated

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

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 contrast to these 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 a smoothed tax plan significantly deepens 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. Inversely, 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 fiscal relief targeted to the poor—crucially avoiding energy price subsidies.

Our paper is one of 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 à la Bewley (1977)-Aiyagari (1994) into small open-economy New Keynesian models à la Galí and Monacelli (2005), which has focused on different kinds of shocks.[13] The paper builds in

13. See the early work of de Ferra and others (2020), as well as Guo and others (2023), Oskolkov (2023), Zhou (2022), and Aggarwal and others (2023), among others.

particular on Auclert and others (2021a), who studied exchange rate shocks. Import price shocks are different: for instance, as in the earlier paper, we derive an equivalence between representative-agent (RA) and heterogeneous-agent (HA) economies, but here this equivalence occurs for a parameterization with unitary elasticities and is therefore more closely related to 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 and others (2022) emphasize how incomplete markets among households can lead to negative demand spillovers from adverse supply shocks. Känzig (2023) studies the macroeconomic effects of carbon pricing in a closed-economy setup with tractable heterogeneity à la Bilbiie (2021) and Bilbiie and others (2022). Pieroni (2023) analyzes the effects of an energy shock in a full-blown closed-economy heterogeneous-agent New Keynesian model à la Kaplan and others (2018) and Auclert and others (2023).[14] 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 incomes in such a setting.

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.[15] Rotemberg and Woodford (1996) argued that this is caused by endogenously increasing markups. Bernanke and others (1997) argued that it is mostly contemporaneous monetary tightening. Blanchard and Galí (2007a) substantiate this point by 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 and others (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 nearly permanent shocks. However, even with monetary tightening, hours increase in their baseline simulation in response to a negative oil shock.[16] Our paper shows that, once one allows for

14. Kuhn and others (2021) analyzes an energy shock in a similar model, but with flexible prices.

15. See Hamilton (1983), Barsky and Kilian (2004), Kilian (2009), Baumeister and Hamilton (2019), and Känzig (2021) for empirical evidence on the macroeconomic effects of oil price shocks.

16. See their figure 8.

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.[17] This literature points out that monetary easing hurts other countries at the zero lower bound, stimulating the domestic economy at the expense of others. Our results emphasize that there is a related spillover via the world energy market since monetary easing boosts world energy demand, which hurts other energy importers. In Fornaro and Romei (2022), monetary policy does not internalize its impact on the world supply of tradable goods. Fiscal policy externalities have also previously been analyzed in Gourinchas and others (2021), Aggarwal and others (2023), and Devereux and others (2023), though not with regard to energy-related policies or spillovers via energy prices.

Finally, the recent surge in energy prices has led to many papers studying their implications for current policy. Lorenzoni and Werning (2023b), Blanchard and Bernanke (2023), and Gagliardone and Gertler (2023) find that energy prices can explain recent inflation developments. Kharroubi and Smets (2023) study their implications for the natural rate of interest when energy demand is non-homothetic. Closest to us, Chan, Diz, and Kanngiesser (2022), and Langot and others (2023) study the effects on aggregate demand in an open-economy heterogeneous-agent New Keynesian setting. Chan and others (2022) restrict heterogeneity by studying a two-agent model and are able to derive implications for optimal policy. Langot and others (2023) conduct a policy analysis for France, backing out the shocks that rationalize the data and then using the model for policy counterfactuals.

1. Model

Our model builds on the open-economy heterogeneous-agent New Keynesian model in Auclert and others (2021a), extended to study energy shocks.[18] This 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

17. See Caballero and others (2021).

18. The Auclert and others (2021a) model itself is a combination of the canonical Galí and Monacelli (2005) model with the closed-economy heterogeneous-agent framework in Auclert and others (2023).

economy, initially leaving the supply side intact. We argue in section 2.4 that energy entering the supply side causes very similar behavior.

1.1 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 one-dimensional subset of length 1, e.g. $\{0\} \times [0,1]$, labels all energy-importing countries. We make the simplifying assumptions that these countries 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 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 and others (2021b) 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 productivity level e at time t optimally chooses its consumption c and saving a' by solving the dynamic programming problem

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

Here r_t denotes the ex-post mutual-fund return in units of the consumer price index (CPI) 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,

$$Z_t \equiv \frac{W_t}{P_t} N_t, \tag{2}$$

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

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

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

The household's consumer basket, c, is formed by a constant-elasticity-of-substitution (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,

$$c = \left[\alpha_E^{1/\eta_E} c_E^{(\eta_E-1)/\eta_E} + (1-\alpha_E)^{1/\eta_E} c_{HF}^{(\eta_E-1)/\eta_E} \right]^{\eta_E/(\eta_E-1)} \tag{3}$$

$$c_{HF} = \left[\alpha_F^{\frac{1}{\eta}} c_F^{\frac{\eta-1}{\eta}} + (1-\alpha_F)^{\frac{1}{\eta}} c_H^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}.$$

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 CPI for these preferences is

$$P = \left[\alpha_E P_E^{1-\eta_E} + (1-\alpha_E) P_{HF}^{1-\eta_E} \right]^{\frac{1}{1-\eta_E}} \tag{4}$$

$$P_{HF} = \left[\alpha_F P_F^{1-\eta} + (1-\alpha_F) P_H^{1-\eta} \right]^{\frac{1}{1-\eta}}.$$

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 consumer 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 its purchases between energy, foreign, and home goods according to

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

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

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

Foreign households. Foreign households in other energy-importing countries face the same problem as domestic households. Households in the rest of the world, which 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

$$C^*_{Ht} = \alpha^* \left(\frac{P^*_{Ht}}{P^*}\right)^{-\gamma} C^*. \tag{8}$$

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:

$$P^*_{Ht} = \frac{P_{Ht}}{\mathcal{E}_t}, \tag{9}$$

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, $P^*_{Ht} = P^*_t = 1$. 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.[19] Output is produced from domestic intermediates and imported energy. The intermediate inputs to be used in home goods production are produced by a continuum of monopolistically competitive firms each using the technology

$$Y_t = A_N N_t, \tag{10}$$

where N_t is labor, and A_N is the constant level of TFP. Let ϵ 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 μ 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

$$D_t = \frac{P_t^I Y_t - W_t N_t}{P_t}. \tag{11}$$

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,

$$\bar{Y}_t = \left[(1-\xi_E)^{\frac{1}{v}} Y_t^{\frac{v-1}{v}} + \xi_E^{\frac{1}{v}} E_t^{\frac{v-1}{v}} \right]^{\frac{v}{v-1}}, \tag{12}$$

19. This is mostly for simplicity. See section 2.4 for an argument that an economy with energy in the production function behaves very similar to one with energy in consumption.

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

$$P_{Ht} = \left[(1 - \xi_E) \left(\mu \frac{W_t}{A_N} \right)^{1-\upsilon} + \xi_E P_{Et}^{1-\upsilon} \right]^{\frac{1}{1-\upsilon}}. \tag{13}$$

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, which are owned by foreign agents. 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', $I_{i\,t}^E$, of energy the cumulative shortfall of extraction relative to the default path $\{\bar{E}_t\}$. So

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

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

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

where the adjustment cost paid is

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

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,

$$1+i_t=\left(1+i_t^*\right)\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}. \tag{14}$$

Define the ex-ante real interest rate as

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

and define the real exchange rate as

$$Q_t\equiv\frac{\mathcal{E}_t}{P_t}. \tag{16}$$

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

$$1+r_t^{\text{ante}}=\left(1+i^*\right)\frac{Q_{t+1}}{Q_t}. \tag{17}$$

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 goods 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,

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

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.,

$$\text{nfa}_t \equiv A_t - j_t. \tag{19}$$

Unions. We assume a formulation for sticky wages with heterogeneous households, similar to Auclert and others (2023). 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 and others (2023), 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 (2007b). We show in appendix A.1 that this problem leads to the wage Phillips curve

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

where π_{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,[20] with wage inflation rising when the marginal rate of substitution (numerator) exceeds the marked-down after-tax real wage, now or in the future.[21] If we derive this equation from a Calvo specification where the probability of keeping the wage fixed is θ_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.

20. See Erceg and others (2000).

21. In Auclert and others (2023)'s formulation of the union problem, the consumption level that enters the Phillips curve in (20) is equal to a consumption aggregator $\overline{C_t} \equiv (u')^{-1}\left(\mathbb{E}\left[e_{it}u'(c_{it})\right]\right)$ 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.

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,

$$i_t = r_{ss} + \pi_{t+1} + \epsilon_t. \tag{21}$$

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.[22] In the context of energy price shocks, rule (21) can be thought of 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 3.

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 $\{\mathcal{E}_t, Q_t, P_t, P_{Ht}, P_{Ft}, P_{Et}, W_t, p_t, i_t, r_t, r^p_t\}$, and aggregate quantities $\{C_t, C_{Ht}, C_{Ft}, C_{Et}, Y_t, \overline{Y}_t, A_t, D_t, \text{nfa}_t,\}$, such that all agents optimize, firms optimize, and the domestic goods market clears:

$$C_{Ht} + C^*_{Ht} = \overline{Y}_t, \tag{22}$$

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.

22. See Woodford (2011), McKay and others (2016), Auclert and others (2023).

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

$$\text{nfa}_t = NX_t + \left(1 + r_{t-1}^{\text{ante}}\right)\text{nfa}_{t-1} + \left(r_t - r_{t-1}^{\text{ante}}\right)A_{t-1} - \left(r_t^H - r_{t-1}^{\text{ante}}\right)j_{t-1}, \tag{23}$$

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.[23] 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 $P_{\text{Hss}}, P_{Fss}, P_{Ess}, P_{ss}, P_{Hss}^*, \mathcal{E}_{ss}, Q_{ss}$ are all equal to 1. Moreover, we normalize domestic GDP Y_{ss} as well as consumption C_{ss} and C^* to 1, implying output $\overline{Y}_{ss} = \frac{1}{1-\xi_E}$.

Following the same arguments as in Auclert and others (2021a) the unique $Q_\infty = 1$ steady state, to which the economy returns after transitory shocks, also has no net foreign-asset position and $C_\infty = Y_\infty = 1$. 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 and others (2021a), in that model, the consumption behavior of the representative domestic household is described by the Backus-Smith condition

$$Q_t C_t^{-\sigma} = C_{ss}^{-\sigma}. \tag{24}$$

Calibration. We calibrate the model at a quarterly frequency. Table 1 summarizes our calibration parameters, which are aimed

23. Note that the steady-state value of the importing firms is zero.

at capturing a large European energy-importing country. We follow the calibration in Auclert and others (2021a). We assume discount factor heterogeneity in order to match aggregate wealth. We consider permanent heterogeneity, with a three-point distribution at $\left\{\beta - \frac{\Delta}{2}, \beta, \beta + \frac{\Delta}{2}\right\}$ and a third of agents in each. We set β to achieve an annualized real interest rate of $r = 4.0\%$ 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 percent.[24] So we set α_F to achieve $\alpha = 0.3$. We set the energy share, α_E, at four percent of GDP.[25] As in Bachmann and others (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, η, equal to that between varieties of foreign goods, γ. We set these such that χ, 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 and others (2023). We set the real-wage stabilization parameter to $\zeta_{BG} = 5$.[26] We set θ_w so that peak nominal-wage inflation matches the EA-19 peak of 3.9 percent.

24. 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 $\alpha = 0.4$.

25. We take data on complete energy balances from Eurostat and consider the EU-27 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 EU-27 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 2, 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.

26. 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 (2007b), 1.5 and 9. We show this in appendix A.2.

Auclert and others (2021a) argue that the implied θ_F estimated for Italy and the U.K. are 0.94 and 1.00, respectively, although lower in other cases. We set $\theta_F = 0.9$. Finally, we set $\theta_E = 0.65$, making the passthrough on impact around 40 percent.

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 percent.

1.2 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 $\left\{r_s^{\text{ante}}\right\}$ 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:

Table 1. Model Calibration

Parameter	*Benchmark model*	*Parameter*	*Benchmark model*
σ	1	r	0.01
φ	2	β	0.95
η_E	0.1	s.s. nfa	0
η	0.51	ζ_{BG}	5
γ	0.51	θ_w	0.938
α_E	0.04	θ_E	0.65
α_F	0.27	θ_F	0.9
μ	1.03	ρ_e	0.96

Source: Authors' calculations.

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 $r_s = r_{s-1}^{\text{ante}}$. 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

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

Finally, since we initially focus on an economy in which ex-ante real interest rates are kept constant, we will write consumption simply as a function of aggregate real income,

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

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 and others (2023), we linearize (25) around the steady state and express changes in spending over time, stacked as the vector $d\mathbf{C} \equiv (dC_0, dC_1, \ldots)$, as a function of changes in real income $d\left(\frac{\mathbf{P}_H}{\mathbf{P}}\mathbf{Y}\right) \equiv \left(d\left(\frac{P_{H0}}{P_0}Y_0\right), d\left(\frac{P_{H1}}{P_1}Y_1\right), \ldots\right)$,

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

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

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

around the steady state. We call the entries of **M** intertemporal marginal propensities to consume (iMPCs). iMPCs are a richer set of moments than standard MPCs, 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 **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 $s > 0$.

2. 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 is AR(1), that is,

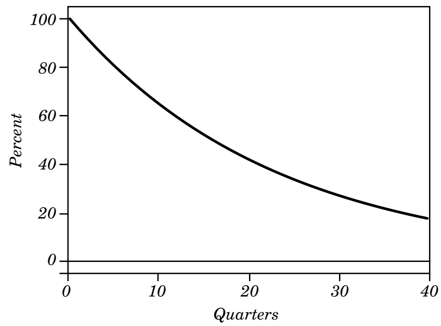
$$dP^*_{Et} = dP^*_{E0} \cdot \rho_e^t,$$

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 $P^*_{E0} = 1$. 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 3 below. Up until section 2.4 below, we do not consider energy usage in production and keep $\zeta_E = 0$.

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 condition as

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

Figure 2. The Energy Price Shock



Source: Authors' calculations.
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.

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.

2.1 Representative Agent

In the complete-market representative-agent model, aggregate consumption remains constant, $C_t = C_{ss}$. This is easiest to see by 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*

$$dC_t = 0 \tag{28}$$

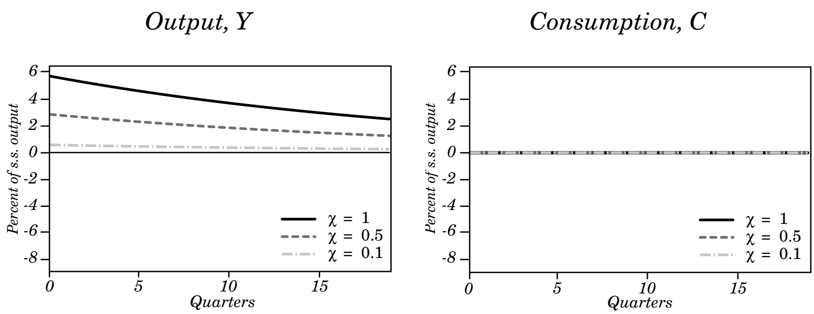
$$dY_t = \frac{\alpha_E}{1-\alpha} \cdot \chi \cdot dP^*_{Et}, \tag{29}$$

where χ is a weighted average elasticity of substitution,

$$\chi \equiv (1-\alpha)\left(\alpha_F \eta + (1-\alpha_F)\eta_E\right) + \alpha\gamma. \tag{30}$$

Proposition 1 shows that the output response in the RA economy is proportional to the energy price shock. Its scale is determined by two factors: the share of energy in consumption, α_E, relative to home consumption,1 – α, and an appropriately weighted average of the elasticities of substitution in the economy, χ. 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, thus 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 χ.

Figure 3. Output and Consumption Responses to an Energy Price Shock in the RA Model



Source: Authors' calculations.
Note: Impulse responses in the representative-agent model to the energy price shock P^*_{Et} displayed in figure 2. χ is the average substitution elasticity between energy and domestically produced goods. It is defined in (30).

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,[27] it has to be because of monetary tightening in response to the shock, in the sense of a rising real interest rate, rather than the shock itself. In terms of the textbook three-equation New Keynesian model,[28] 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 $d\mathbf{Y} = \frac{\alpha_E}{1-\alpha} \cdot \chi \cdot d\mathbf{P}_E^*$.

2.2 Heterogeneous Agents

In light of our discussion in section 1.2, one way to explain the RA result is to point out that, with complete markets across countries, an RA model essentially behaves like a model with zero iMPCs, $\mathbf{M}^{RA} = 0$. In other words, the complete-market RA model features no real-income effect on consumption.[29] This is the key difference from our heterogeneous-agent economy, where we find the following result for output and consumption.

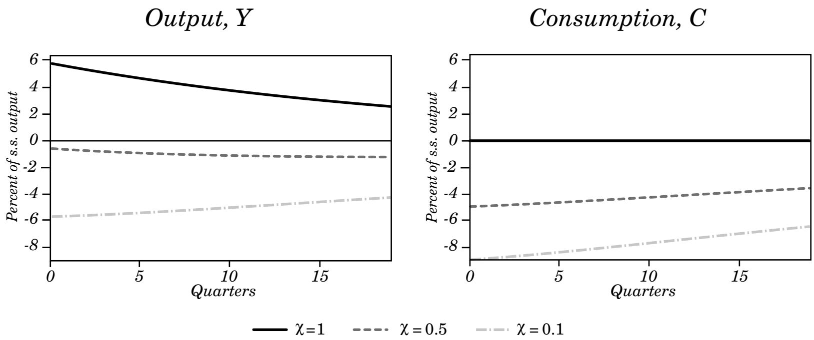
Proposition 2. *With a real interest rate rule and a matrix of intertemporal MPCs* $\mathbf{M}$*, the impulse responses of consumption and output following an energy price shock are given by*

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

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

27. See Bodenstein and others (2011).
28. See Galí (2008).
29. We analyze a RA-IM model in section 2.4 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



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

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 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*

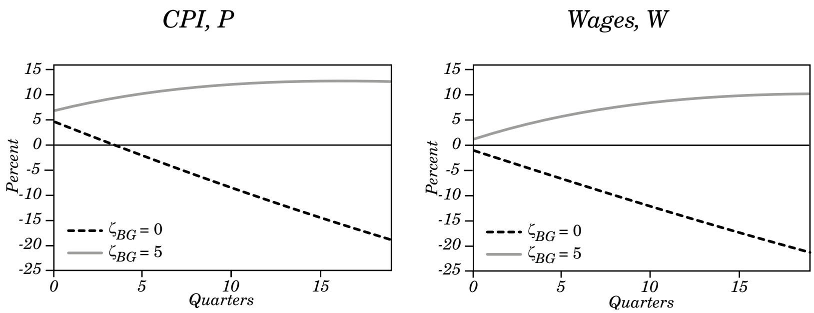
$$d\mathbf{Y}=\frac{\alpha_E}{1-\alpha}\chi d\mathbf{P}_E^*+\alpha_E(\chi-1)\mathbf{M}\cdot(\mathbf{I}-(1-\alpha)\mathbf{M})^{-1}d\mathbf{P}_E^*. \tag{33}$$

In particular, if $\chi = 1$*, all aggregate quantities and prices are the same as in the RA model, including* $d\boldsymbol{Y} = d\boldsymbol{Y}^{RA}$*. Moreover, provided that* $\boldsymbol{M} > 0$*, for an energy shock* $d\mathbf{P}_E^* \geq 0$*, we have*

$$d\mathbf{Y} \lesseqgtr d\mathbf{Y}^{RA} \text{ and } d\mathbf{C} \lesseqgtr 0 \Leftrightarrow \chi \lesseqgtr 1.$$

Proposition 3 solves the Keynesian cross fixed point in (32) for $d\boldsymbol{Y}$. Similar to Auclert and others (2021a), it establishes a formal neutrality result for $\chi = 1$, showing that the RA and HA models have identical implications for aggregate quantities and prices.[30] When the substitution elasticity lies below one ($\chi < 1$), however, 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 $d\boldsymbol{Y}$ is entirely driven by expenditure switching, as in the RA model. Reducing χ below 1 leads to a smaller expenditure switching channel, and hence also a smaller multiplier effect, making the HA output response fall below RA.

Figure 5. Wage-price Spiral with Real-Wage Stabilization Motive



Source: Authors' calculations.
Note: Impulse responses in the heterogeneous-agent model to the energy price shock P_{Et}^* displayed in figure 2. ζ_{BG} is the weight on the Blanchard and Galí (2007b) real-wage stabilization motive.

30. One important difference from Auclert and others (2021a), however, is that in (30), $\chi = 1$ is implied by all primitive elasticities being unity, as in Cole and Obstfeld (1991), whereas in Auclert and others (2021a), $\chi = 1$ requires primitive elasticities below unity.

We illustrate proposition 3 in figure 4, plotting the output and consumption responses to the energy shock for various choices of χ. 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.

2.3 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

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

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.[31]

Figure 5 plots prices and wages as implied by the nominal-wage Phillips curve (20) without the real-wage stabilization motive (dashed line) and with the real-wage stabilization (solid line). 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.

31. See Auclert et al. (2023), Auclert and others (2021a), Aggarwal and others (2023) for recent applications of this idea. We have found in Auclert and others (2021a) that the main results in this environment are robust to alternative monetary policy rules and sticky prices in addition to sticky 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.[32] A wage-price spiral emerges.

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

2.4 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.

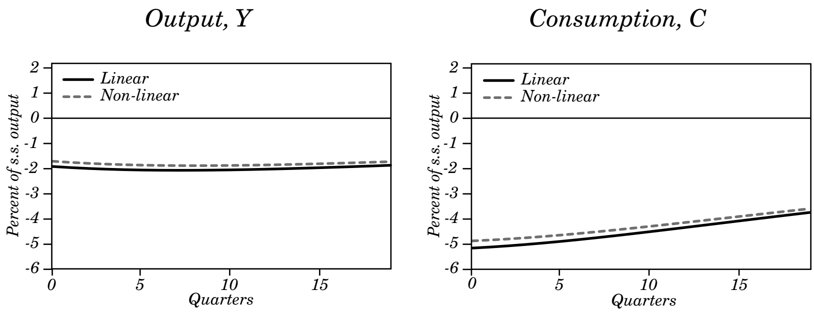
Representative-agent model with incomplete markets across countries. Our RA model benchmark assumes complete markets across countries. A natural question is what happens in a RA-IM model across countries. Figure 7 redoes figure 3 but with incomplete markets. Comparing the figures, we see that incomplete markets do not change the response by a significant amount. The main reason for this is that rather than $\mathbf{M}^{\mathrm{RA}} = 0$, the RA-IM model has positive, but very small intertemporal MPCs.

With very persistent shocks, the effective MPC rises in the RA model with incomplete markets. However, as we show in figure 8, this model struggles to generate substantial contractionary 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, à la Campbell and Mankiw (1989), Galí and others (2007), and Bilbiie (2008). We make such a comparison in appendix C.

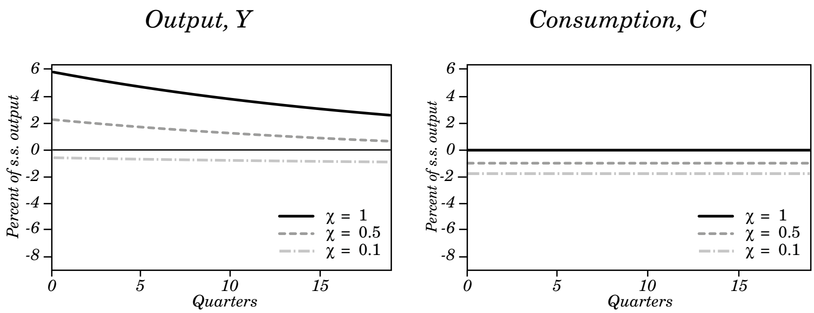
32. See appendix D.2.

Figure 6. First-Order vs. Higher-Order MIT Shocks



Source: Authors' calculations.
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



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

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.

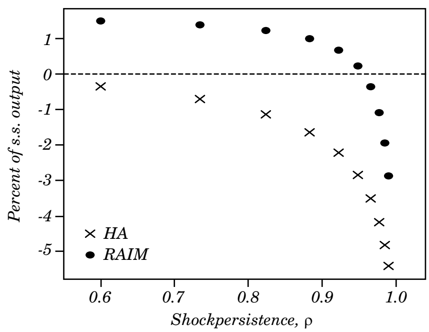
Proposition 4. *In the economy in which energy enters production but not consumption, $\xi_E > 0$ and $\alpha_E = 0$, the response of GDP is given by*

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

In particular, when setting ξ_E, α_F, and ν 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 χ in the "energy in consumption" model, the GDP response $d\boldsymbol{Y}$ to an arbitrary $d\boldsymbol{P}_E^*$ shock with energy in production is exactly the same as the GDP response with energy in consumption shown in proposition 3.

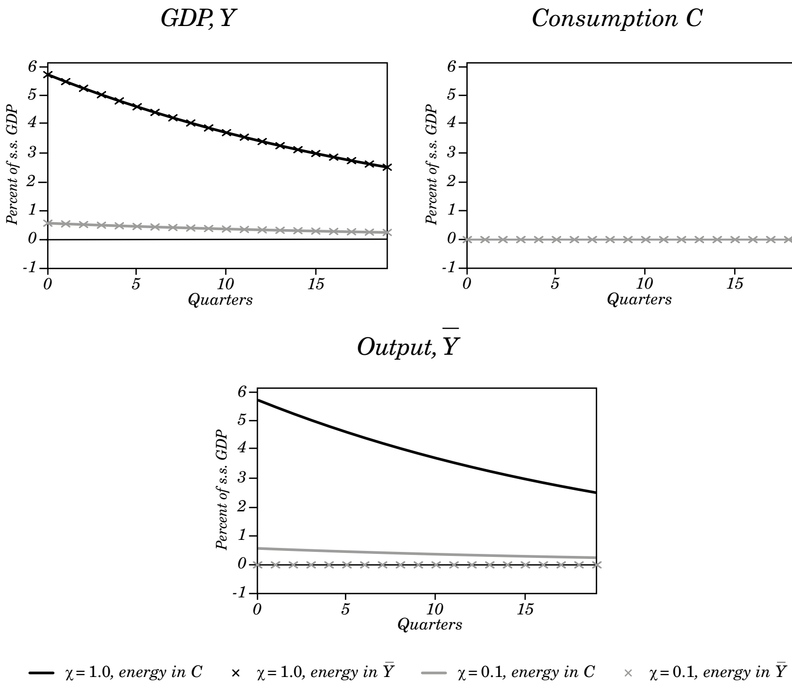
Figure 9 illustrates the proposition. Where before it was households that switched their expenditure from imported energy to domestically produced goods, it is now firms that make the same substitution. Under the condition stated in proposition 4, the response of GDP will be identical. The condition 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 8. Date-0 Output Response to an Energy Price Shock in the RA-IM and HA Models



Source: Authors' calculations.
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.

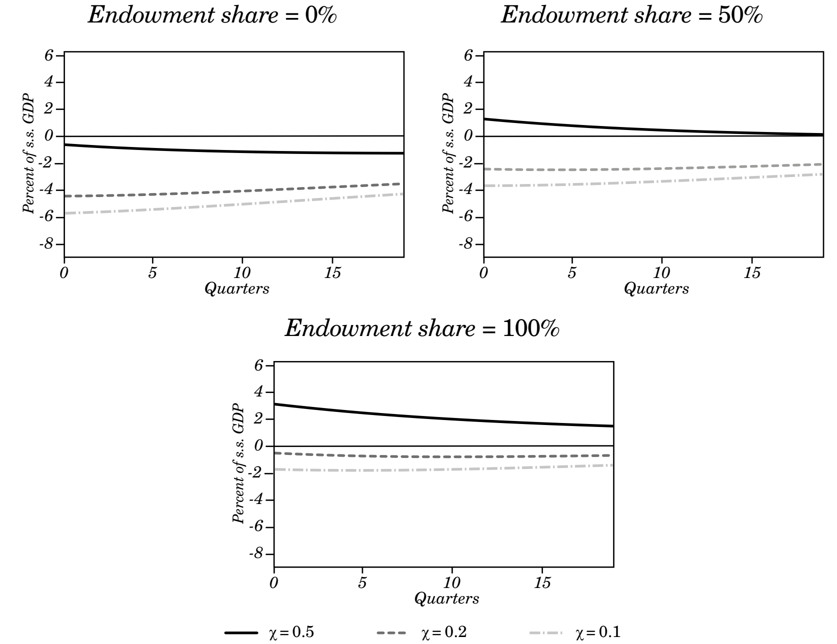
Figure 9. Energy in Consumption versus Production in the RA Model



Source: Authors' calculations.
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. χ is the average substitution elasticity between energy and domestically produced goods in the "energy in C" case. It is defined in (30).

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 percent energy share, if χ is low enough, we still see a decline in $\bar{Y}$ as the shock redistributes towards lower MPC agents.

Figure 10. Response of Home Production to an Energy Shock in the HA Model with Energy Endowments



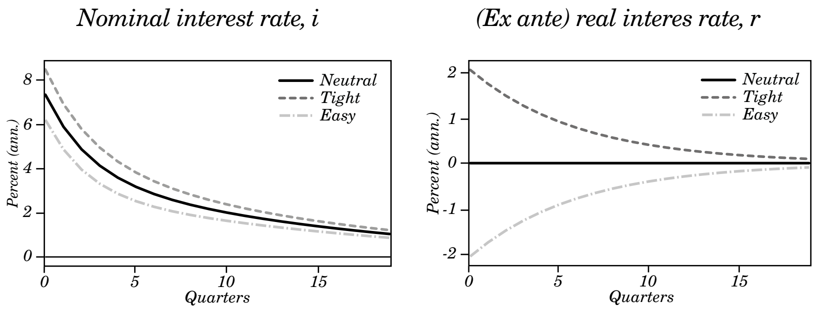
Source: Authors' calculations.
Note: Impulse responses for $\overline{Y}$—production of the home good—in the heterogeneous-agent model to the energy price shock P_{Et}^* displayed in figure 2. Under the baseline (endowment share = 0%), no energy is produced domestically, and all energy for consumption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

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 suggests that an energy price shock is a more difficult problem for monetary policy than a standard cost-push shock.

3. 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.

Figure 11. Monetary Policy Scenarios in Response to the Energy Price Shock



Source: Authors' calculations.
Note: This figure shows three scenarios for the monetary policy response to the energy price shock. The solid line represents a monetary response that keeps the real interest rate constant. The dashed line 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 line does the opposite.

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 2.3 is that prices jump by a significant margin at date 0, which implies an unreasonably large inflation response on impact. To solve this issue, we first introduce slow passthrough of world prices into consumer prices and then study the effects of monetary policy.

3.1 The Quantitative Model

Slow passthrough. We allow for a slow passthrough of import prices of both F and E goods into consumer prices.[33] 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 $\mathcal{E}_t P^*_{Ft}$.

33. 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.

There is a continuum of monopolistically competitive firms that import the foreign good. Each importer produces their variety of the foreign imports 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 $1 - \theta$. The foreign imports are combined by a competitive sector by 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 $\kappa_F = \dfrac{(1-\theta_F)\left(1 - \dfrac{\theta_F}{1 + r_{SS}}\right)}{\theta_F}$ and r_{SS} denote the steady-state interest rate. The foreign good importers pay out total dividends

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

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

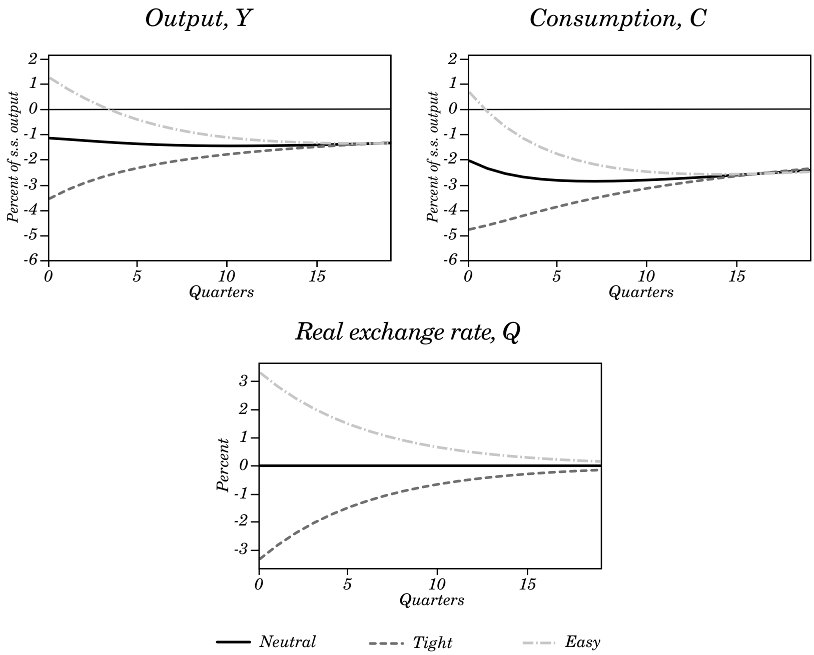
In order not to distort the steady state of the model with the introduction of a slow passthrough, we assume that importers of E and F goods are owned by foreigners. This changes our expression of net exports in section 1 to

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

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 2.4. 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.

Figure 12. Effect of Monetary Policy on Output and Consumption



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

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.[34]

3.2. Effects of Monetary Policy on Output and Inflation

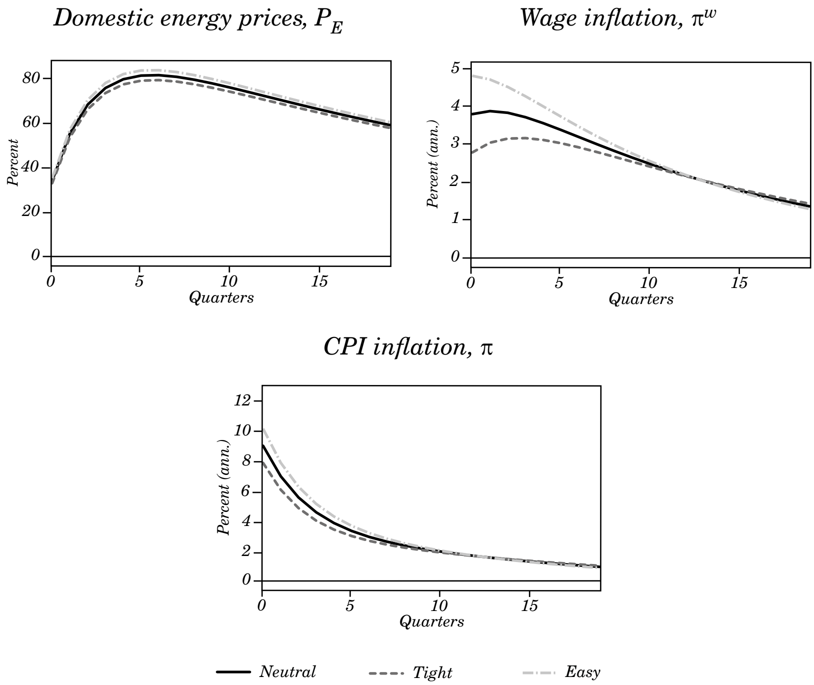
Figure 12 shows the effects of the two alternative monetary policy responses on output and consumption. As one would expect, monetary easing ameliorates the recession induced by the energy shock, while monetary tightening deepens the recession. There is a small reversal a few quarters out, as tighter 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,

34. See footnote 13 for details.

thus increasing their ability to spend later. This effect also appeared in Auclert and others (2021a) and does not occur in standard closed-economy heterogeneous-agent 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, which implies that it cannot move the price that lies at the origin of the shock at all. We return to this point below, in section 5.

Figure 13. Effect of Monetary Policy on Inflation



Source: Authors' calculations.
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.

3.3. Effectiveness of Monetary Policy by Source of the Shock

In this section, we explore how this imported inflationary shock can be more difficult for monetary policy than 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.

4. 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 a slow passthrough and the energy endowment, which we introduced above in section 3.1.

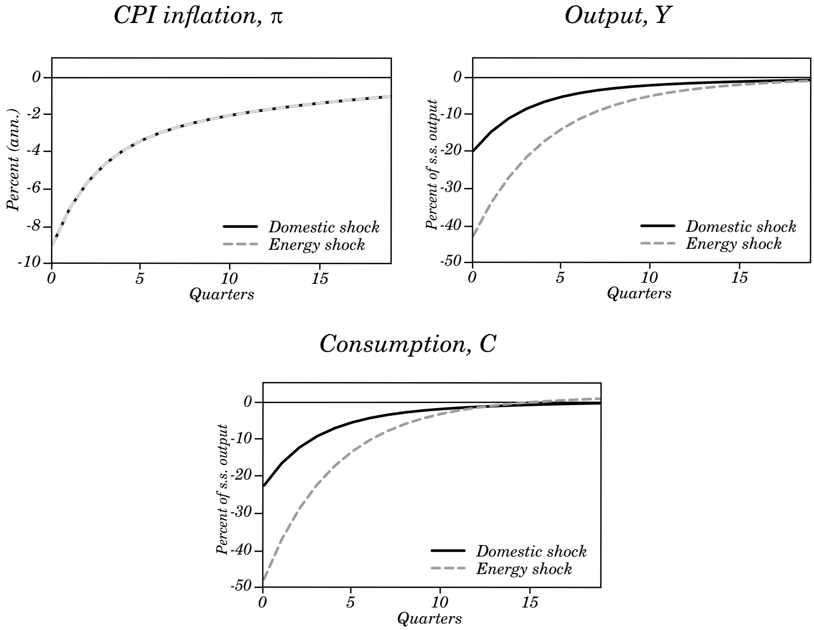
4.1 Government

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

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

Figure 14. Different Inflation-Output Tradeoffs for Foreign and Domestic Shocks



Source: Authors' calculations.
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.

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 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, by giving all households an equal amount, T_t^{unt}. The level of T_t^{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 τ_t^L. We henceforth take Z_t to denote after-tax labor income. Replacing (2), Z_t is now given by

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

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

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

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

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

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

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

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

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

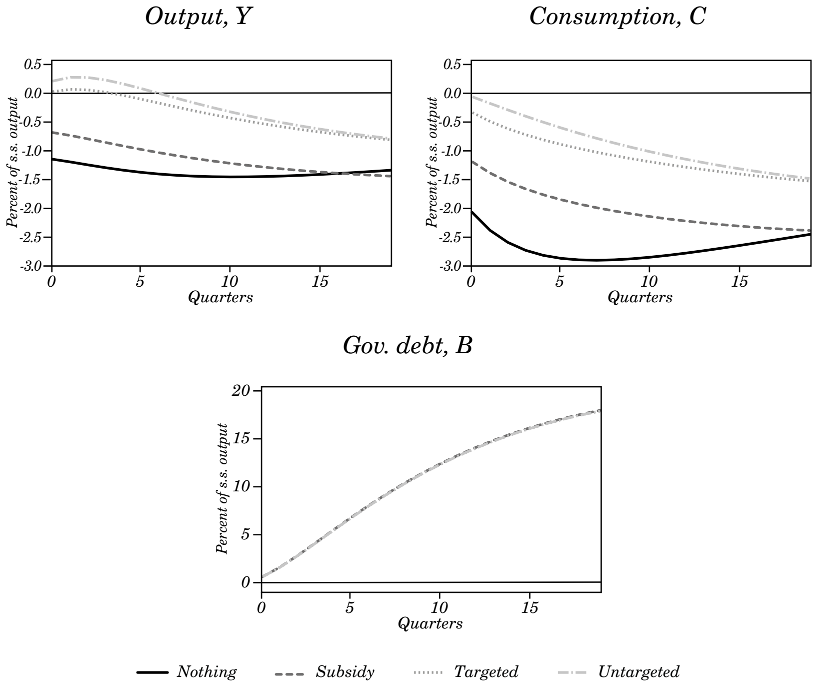
rather than (19).

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 percent 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.

4.2 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 labor income taxes being raised to bring down the additional debt that has been accumulated. We show in appendix D.5 that, if a government has less fiscal space and is therefore forced to run a balanced budget, the three policies are significantly less effective.

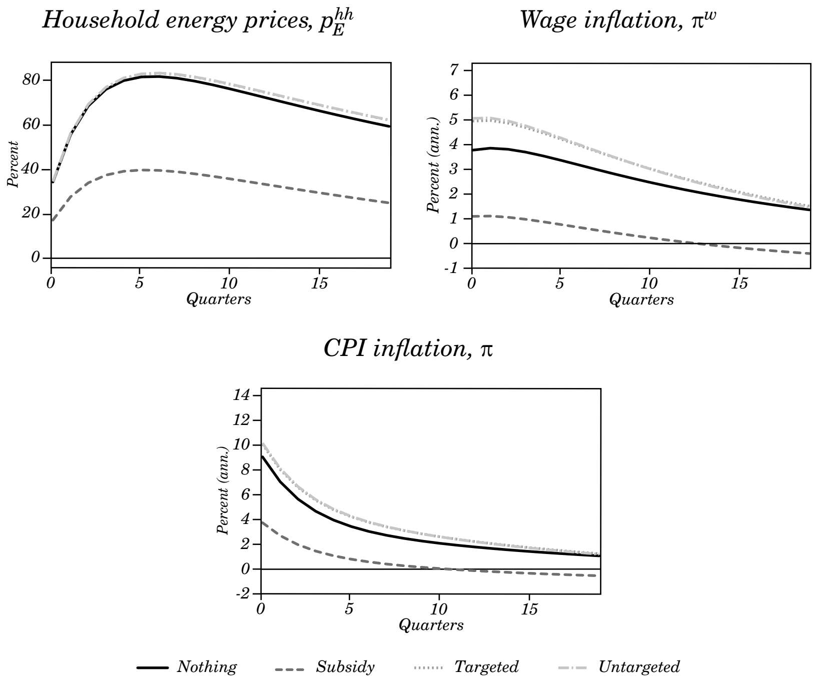
Figure 15. Effect of Fiscal Policy on Output and Consumption



Source: Authors' calculations.

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 4.1. 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

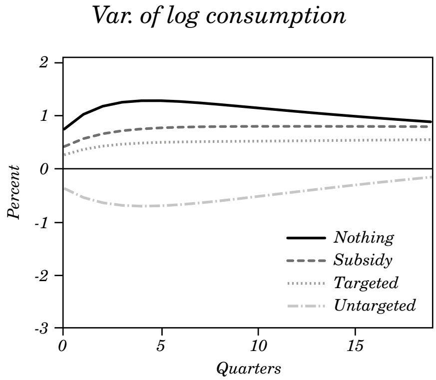


Source: Authors' calculations.
Note: This figure compares the wage and price inflation responses to an energy price shock under no fiscal policy with the three fiscal policy programs explained in section 4.1. All policies are financed by a deficit initially and slowly paid for via increased proportional labor income taxes.

Where the three types of policies differ more is in their predictions for inflation.[35] 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.[36] 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.

35. See figure 16.
36. See Farhi and Werning (2016), Auclert and others (2023).

Figure 17. Fiscal Policy and Inequality after an Energy Shock



Source: Authors' calculations.
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 4.1. Since we have three household types (indexed g), the variance of log consumption at date t is computed as $\mathbb{E}_G$ [Var[log (c_{it}) | $i \in g$]]-Var$_G$ [$\mathbb{E}$[log (c_{it}) | $i \in g$]].

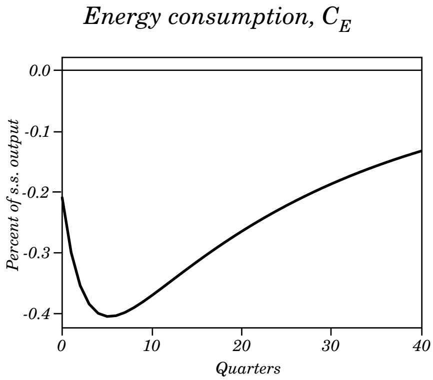
At the country level, therefore, energy subsidies appear to be a silver bullet: they tackle the shock at its root by bringing down energy prices and therefore reduce the recessionary and inflationary forces in the economy. We return to this logic below, in section 5.

Effects on inequality. Our heterogeneous-agent model enables us to also study predictions on inequality across households, as in the work of Pieroni (2023) and Kuhn and others (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 (solid line), but is significantly reduced by fiscal policy.

5. 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').

Figure 18. The Energy Supply Shock

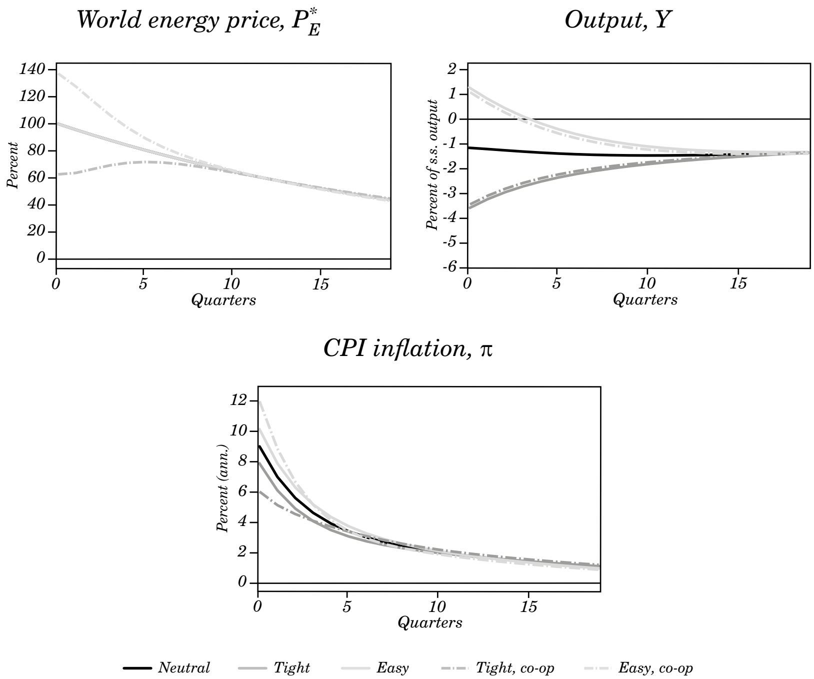


Source: Authors' calculations.
Note: Shock path is chosen such that, if all countries follow a neutral monetary policy and have no fiscal response, world energy prices P^*_{Et} endogenously follow the AR(1) process shown in figure 2.

We study coordinated policies by analyzing the world equilibrium, as defined in section 1, in which energy prices are endogenous. We choose the path of the energy supply shock $\overline{E}_t$ 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. Even though passthrough 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 is 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.

Figure 19. Coordinated vs. Uncoordinated Monetary Policy

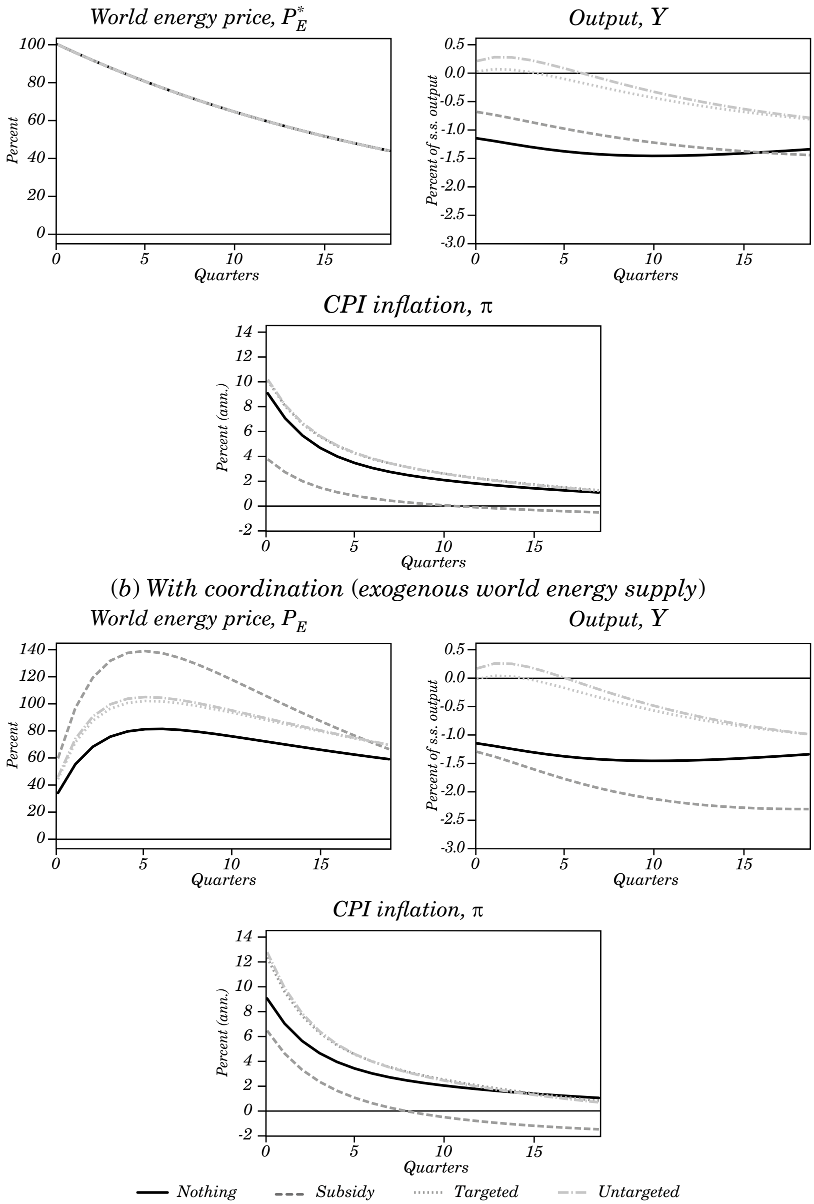


Source: Authors' calculations.
Note: This figure compares the output and inflation responses to an energy price shock across the three monetary policy scenarios detailed in figure 11. Solid lines simulate the case when only a single economy engages in the monetary policy scenarios. Dot-dashed lines simulate the case when all economies use the same monetary policy.

Coordinated fiscal policy. Figure 20 compares uncoordinated with coordinated fiscal policy. Overall, the picture that emerges is one of negative externalities. 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 large endogenous spike in world energy prices. This spike limits the insulating role of energy subsidies, with CPI inflation rising to similar levels as without energy subsidies. The recession actually 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.

Figure 20. Coordinated vs. Uncoordinated Fiscal Policy

(*a*) *Without coordination* (*exogenous world energy price*)



Source: Authors' calculations.

Note: This figure compares the output and inflation responses to an energy price shock across the fiscal policy scenarios detailed in section 4.1 when (a) a single economy carries out the policy and (b) all economies use the same fiscal policy.

Empirical evaluation of spillover channel. 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 (1969.3–1996.12). This exercise is therefore in a U.S. 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 Jordá projection, which for a generic outcome Y_t reads

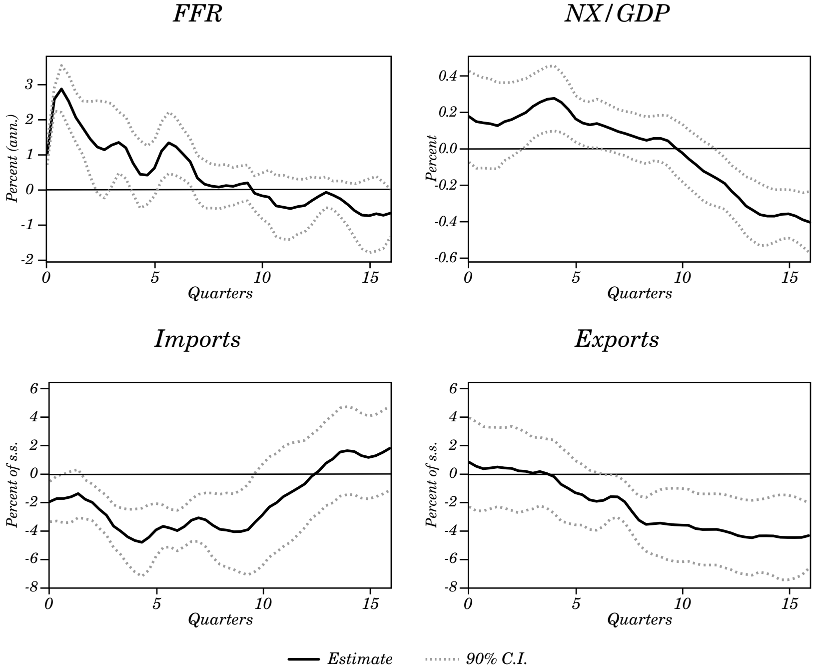
$$Y_{t+h} = J_h^Y \epsilon_t^m + \beta_h^Y X_t + \zeta_{t,h}^Y$$

separately for horizons $h = 1, \ldots, T$ up to $T = 48$ months, where ϵ_t^m is the Romer-Romer series, and $\zeta_{t,h}^Y$ is a regression error term. To control for the potential endogeneity of ϵ_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 CPI, 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 solid lines in figure 21 display the impulse responses, with the dotted lines indicating confidence intervals. We see that in response to a one 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 GDP in the first six quarters after such a shock is 0.19 in both our model and the estimated impulse-response functions (IRFs).[37]

37. To compute this, we aggregate the nominal interest rate IRF to quarterly frequency, and feed this shock into our model.

Figure 21. Trade Balance Response to a Monetary Policy Shock

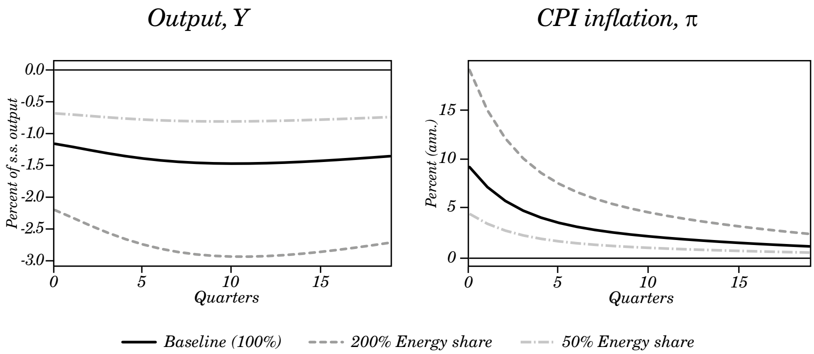


Source: Authors' calculations.
Note: This figure shows our estimated set of impulse responses to an identified Romer and Romer (2004) monetary policy shock (solid black line), with 90% confidence intervals (dotted gray lines).

6. State Dependence

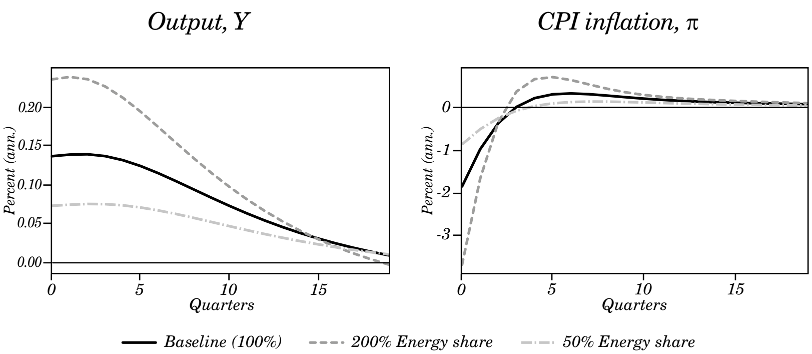
An important question is whether we should expect the mechanisms documented in this paper to always be present, or whether they depend on the presence of certain prerequisites. We now show that a crucial determinant of the presence of our mechanisms is the share of energy in an economy. To do so, we vary the share of energy in consumption between our baseline choice and double as well as half its value, i.e., $\alpha_E^{high} = 2\alpha_E$ and $\alpha_E^{low} = \frac{1}{2}\alpha_E$. 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. Responses to an Energy Price Shock for Different Initial Energy-in-GDP Shares



Source: Authors' calculations.
Note: This figure compares the output and inflation responses to an energy price shock for different values of the energy-to-GDP ratio, α_E.

Figure 23. Responses to a Coordinated Monetary Policy Shock for Different Initial Energy-in-GDP Shares



Source: Authors' calculations.
Note: This figure compares the output and inflation responses for different values of the energy-to-GDP ratio, α_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.

Figure 22 shows the responses of output and inflation to the energy shock across the three values of α_E. We clearly see that higher values of α_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 χ 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 α_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.

7. Conclusion

We study the macroeconomic effects of energy price shocks in energy-importing economies using a heterogeneous-agent New Keynesian model. When MPCs are realistically large and the elasticity of substitution between energy and domestic goods is realistically low, there is a direct link between high energy prices and aggregate demand: increases in energy prices depress real incomes and cause a recession, even if the central bank does not tighten monetary policy. When nominal- and real-wage rigidities are both present, imported energy inflation can spill over to wage inflation through a wage-price spiral; this, however, does not mitigate the decline in real wages. Our model constitutes a useful framework to evaluate monetary and fiscal policy responses to energy price shocks.

We find that monetary tightening has a limited effect on imported inflation when done in isolation, but can be powerful when done in coordination 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 raises world energy demand and prices, imposing large negative externalities on other economies.

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APPENDICES

Appendix 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,

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

Here ψ_{nr} parameterizes the degree of nominal rigidity, while ζ_{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

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

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

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

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,

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

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

A.2 Comparison of the Real-Wage Targeting Motive to Blanchard and Galí (2007b)

In Blanchard and Galí (2007b), 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,

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

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

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

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

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

Blanchard and Galí (2007b) 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.

Appendix 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)

$$\bar{Y}_t = (1-\alpha)\left(\frac{P_{Ht}}{P_{HFt}}\right)^{-\eta}\left(\frac{P_{HFt}}{P_t}\right)^{-\eta_E} C_t + \alpha^*\left(\frac{P_{Ht}}{\mathcal{E}_t}\right)^{-\gamma} C^*, \tag{B.1}$$

where we, at this point, still allow for energy in production, $\xi_E > 0$. Consumption here can be written as an intertemporal consumption function[1]

$$C_t = \mathcal{C}_t\left(\left\{r_0, r_s^{\text{ante}}, Z_s\right\}\right), \tag{B.2}$$

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

In (B.2), 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^{ante} for $s \geq 0$ set by monetary policy (since $r_{t+1} = r_s^{\text{ante}}$ 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, $r_s^{\text{ante}} = const = r_{ss}$, and will henceforth drop it from the consumption function (B.2). 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 (B.1), beginning with expressions for all relevant relative prices; then we linearize the left-hand side, followed by the right-hand side.

1. See Auclert and others (2023).

Relative prices. From (4), obtain

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

Rearranging, we find

$$d\log \frac{P_{Ht}}{\mathcal{E}_t} = -\frac{\alpha_E}{1-\alpha} d\log P^*_{Et} \tag{B.3}$$

$$d\log \frac{P_{Ht}}{P_{HFt}} = -\frac{\alpha_E \alpha_F}{1-\alpha} d\log P^*_{Et} C^*_{Ht} = \alpha^* \left(\frac{P^*_{Ht}}{P^*}\right)^{-\gamma} C^* \tag{B.4}$$

$$d\log \frac{P_{HFt}}{P_t} = -\frac{\alpha_E}{1-\alpha_E} d\log P^*_{Et}. \tag{B.5}$$

Moreover, log-linearizing (13), we obtain

$$d\log P_{Ht} = \left(1-\xi_E\right) d\log W_t + \xi_E d\log P^*_{Et} + \xi_E d\log \mathcal{E}_t,$$

which lets us derive

$$d\log W_t - d\log P_{Et} = -\frac{1}{1-\xi_E} \frac{\alpha_E + 1-\alpha}{1-\alpha} d\log P^*_{Et} \tag{B.6}$$

and

$$d\log \frac{W_t}{P_t} = -\frac{\alpha_E + \xi_E\left(1-\alpha\right)}{\left(1-\xi_E\right)\left(1-\alpha\right)} d\log P^*_{Et}. \tag{B.7}$$

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

$$d\log \bar{Y}_t = \left(1-\xi_E\right) d\log Y_t + \xi_E d\log E_t.$$

Energy demand by domestic firms is given by

$$d\log E_t = d\log Y_t + v\left(\mathrm{dlog} W_t - \mathrm{dlog} P_{Et}\right),$$

so that we can write

$$d\log \bar{Y}_t = d\log Y_t + \xi_E \upsilon\left(\mathrm{dlog}W_t - \mathrm{dlog}P_{Et}\right).$$

Substituting in (B.6) and the steady-state expression $\bar{Y}_{ss} = \dfrac{1}{1-\tilde{\zeta}_E}$, we obtain for the left-hand side of (A.2),

$$\left(1-\xi_E\right)d\bar{Y}_t = dY_t - \frac{\xi_E}{1-\xi_E}\frac{\alpha_E + 1 - \alpha}{1-\alpha}\upsilon d\log P^*_{Et}. \tag{B.8}$$

Relative prices on the right-hand side of (B.1). For the right-hand side, we find

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

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

Substituting in (B.4), (B.5), (B.3), we arrive at

$$d\bar{Y}_t = \alpha_E\left(\alpha_F\eta + \left(1-\alpha_F\right)\eta_E\right)d\log P^*_{Et} + \alpha^*\gamma\frac{\alpha_E}{1-\alpha}d\log P^*_{Et} + \left(1-\alpha\right)dC_t. \tag{B.9}$$

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 (B.10), implies that share prices are

$$p_t = \frac{D_{t+1} + p_{t+1}}{1+r_t} = \mathrm{PDV}\left(\left\{\left(\mu-1\right)Z_s\right\}\right), \tag{B.10}$$

so that the initial revaluation r_0^p also only depends on the path of labor income Z_s. Following Auclert and others (2021a), we therefore can write the consumption function (B.2) simply as a function of Z_s,

$$\mathcal{C}_t = \mathcal{C}_t\left(\left\{Z_s\right\}\right),$$

whose (sequence-space) Jacobian we denote by

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

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

$$d\mathbf{C} = \mathbf{M} \cdot d\log\mathbf{Z}, \tag{B.11}$$

where, using (B.7),

$$d\log Z_t = dY_t + d\log\frac{W_t}{P_t} = dY_t - \frac{\alpha_E + \xi_E\left(1-\alpha\right)}{\left(1-\xi_E\right)\left(1-\alpha\right)} d\log P^*_{Et}.$$

Thus,

$$d\mathbf{C} = -\frac{\alpha_E + \xi_E\left(1-\alpha\right)}{\left(1-\xi_E\right)\left(1-\alpha\right)}\mathbf{M} \cdot d\mathbf{P}^*_E + \mathbf{M}d\mathbf{Y}. \tag{B.12}$$

Equation (B.12) collapses to (31) in the special case of no energy usage in production, $\xi_E = 0$.

Combining left- and right-hand sides. Putting together (B.8), (B.9), (B.11), and the definition of χ in (30) we obtain the following equation,

$$d\mathbf{Y} = \left[\left(1-\xi_E\right)\frac{\alpha_E}{1-\alpha}\chi + \frac{\xi_E}{1-\xi_E}\left(1+\frac{\alpha_E}{1-\alpha}\right)\upsilon + \xi_E\frac{\alpha_E}{1-\alpha}\gamma\right] \tag{B.13}$$

$$d\log\mathbf{P}^*_E - \left(\alpha_E + \xi_E\left(1-\alpha\right)\right)\mathbf{M} \cdot d\mathbf{P}^*_E + \left(1-\xi_E\right)\left(1-\alpha\right)\mathbf{M}d\mathbf{Y}.$$

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

B.2 Proof of Proposition 1

In the (complete-market) 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-market) representative agent. This proves (28). (29) follows from (B.13) when we set $\mathbf{M} = 0$ and $\xi_E = 0$.

B.3 Proof of Proposition 3

Analogously to proposition 3 in Auclert and others (2021a) 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 $d\mathbf{Y} \lesseqgtr d\mathbf{Y}^{RA}$ and $d\mathbf{C} \lesseqgtr 0$ are equivalent to $\chi \lesseqgtr 1$ 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 (B.13). 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 B.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	α_E	$\xi_E(1 - \tilde{\alpha}_F)$

Source: Authors’ calculations.

To equalize the shares, we define in the "energy in production" model,

$$\tilde{\alpha}_F \equiv (1-\alpha_E)\alpha_F$$
$$\xi_E \equiv \frac{\alpha_E}{1-\tilde{\alpha}_F} = \frac{\alpha_E}{1-(1-\alpha_E)\alpha_F}.$$

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).

Appendix C. Comparison with a TANK Model

For the two-agent complete-market model ("TA model"), we assume the household side of the model consists of a share $1 - \lambda$ of agents with unconstrained access to financial markets, denoted by superscript u, and a share λ with no access to financial markets, denoted by superscript c. The unconstrained agents behave just like the representative agent in section 2.1. So, we can characterize their consumption with the Backus-Smith condition,

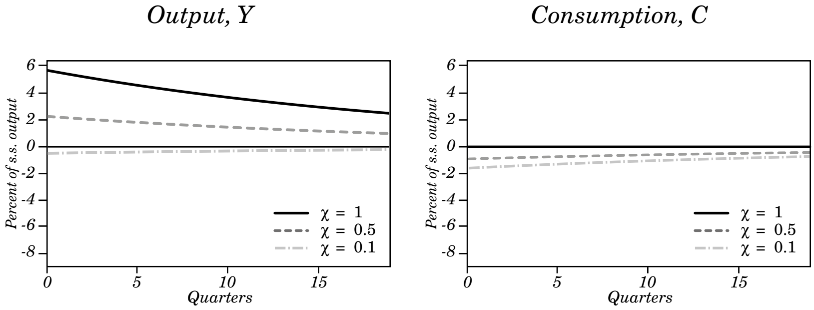
$$\left(c_t^u\right)^{-\sigma} = \frac{\left(c_{SS}^u\right)^{-\sigma}}{Q_t}.$$

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,

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

Figure C1. Response to the Energy Price Shock in TA Model



Source: Authors' calculations.
Impulse responses in a two-agent model to the energy price shock P^*_{Et} displayed in figure 2. χ is the average substitution elasticity between energy and domestically produced goods. It is defined in (30).

And we set steady-state aggregate asset holdings, $A_{ss} = (1-\lambda)A^u_{ss}$, 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

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

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

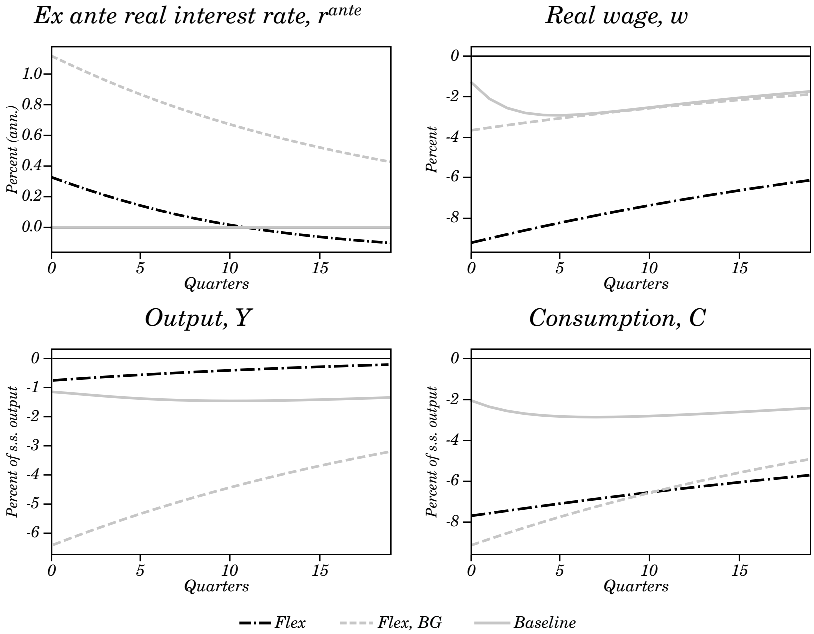
This has the solution

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

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

In figure C.1, we set $\lambda = 0.25$ and plot the response to the energy price shock without importer frictions, as in section 2. We see that the potential for declines in output and consumption is much more limited in this model.

Figure C2. Flexible Price Response to the Energy Price Shock



Source: Authors' calculations.
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).

Appendix 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 C.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

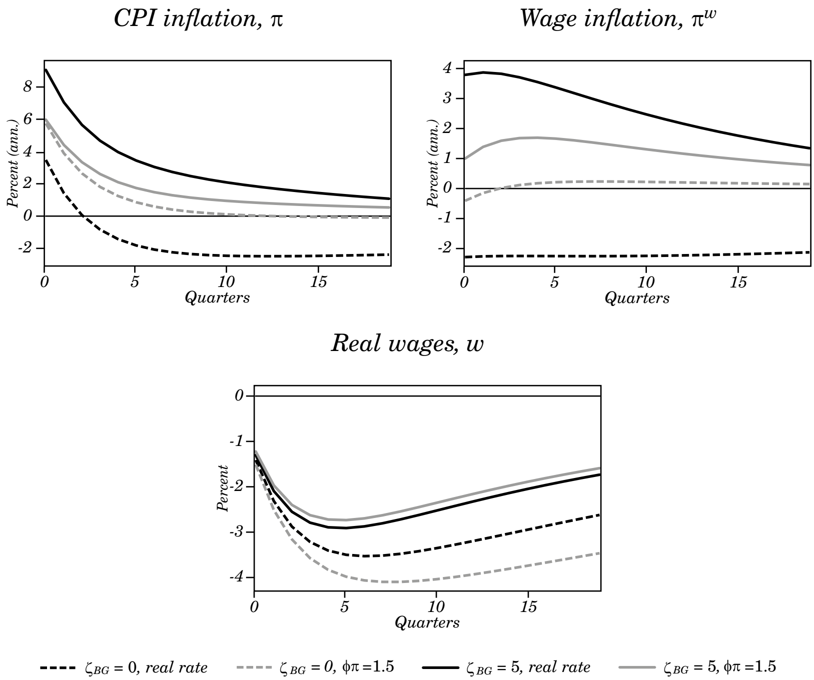
$$1+i_t=\left(1+r^*\right)\left(1+\pi_{t+1}\right).$$

In figure D.1, we compare this to the response under the Taylor rule

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

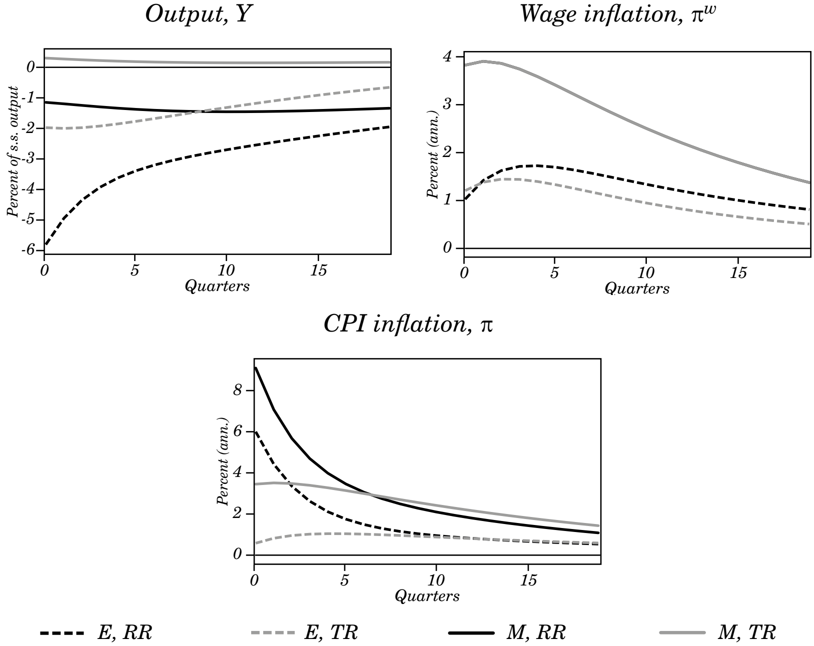
We see that the real-wage stabilization motive is more effective at raising real wages under the Taylor rule. Under the real rate rule, the effect is smaller, and in the absence of energy importer frictions, it would be zero.

Figure D1. Real-Wage Stabilization with a Taylor Rule vs. a Real Rate Rule



Source: Authors' calculations.
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 ϕ_π.

Figure D2. Responses to an Energy Price Shock and a Markup Shock under Different Monetary Policy Rules



Source: Authors' calculations.
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.

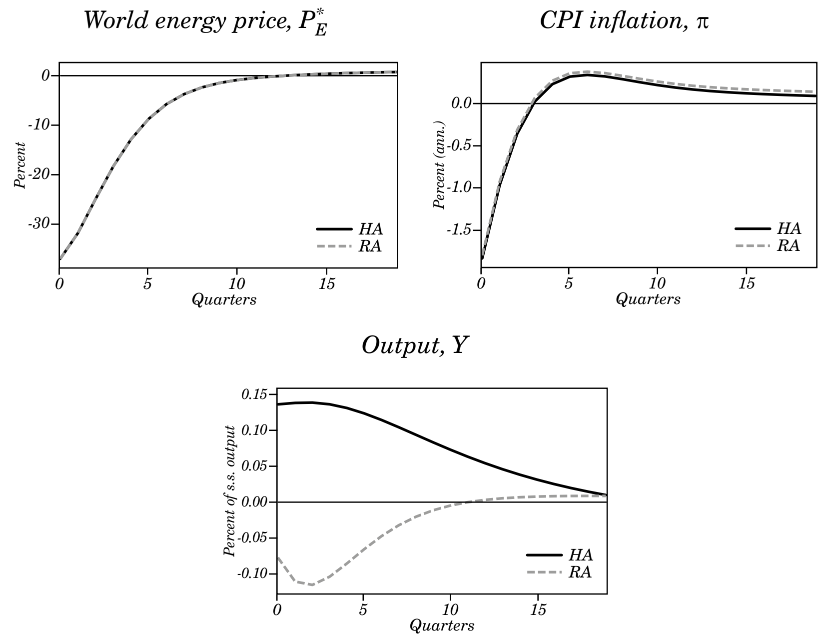
D.3 Markup shocks versus energy shocks

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 D.2. 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

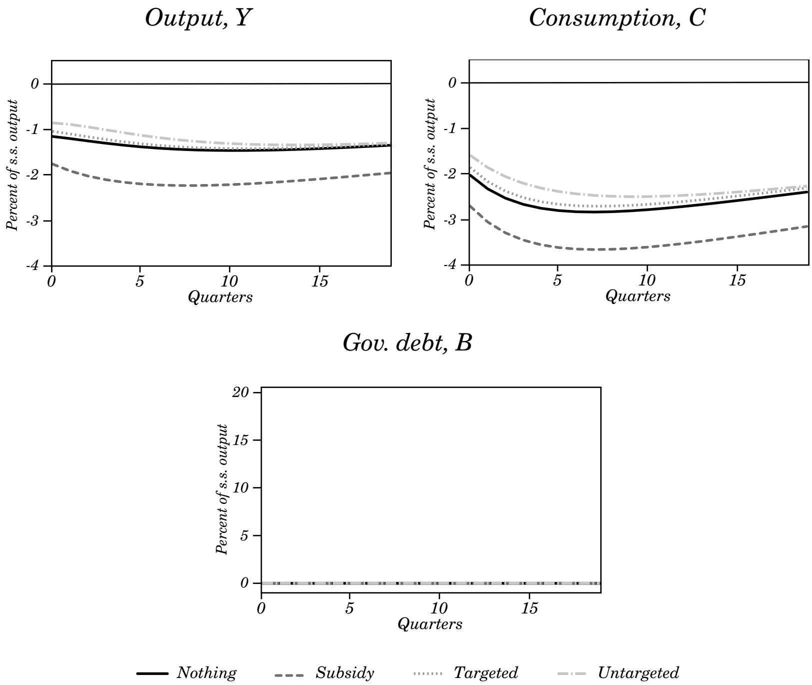
In this section, we consider the impact on home of all other energy-importing countries tightening monetary policy and thereby lowering the world energy price. That is, we isolate the spillover channel. In the HA model, as discussed above, this shock leads to lower inflation and a boost in output, driven 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 D.3.

Figure D3. Spillover Channel in the RA and HA Models



Source: Authors' calculations.
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 D4. Fiscal Policy with a Balanced Budget



Source: Authors' calculations.
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 4.1, assuming a balanced budget throughout.

D.5 Balanced Budget Fiscal Policy

Here, we repeat the analysis in section 4, only now imposing a balanced budget at all dates: $B_t = B_{ss} = 0$ for all t. As we see in figure D.4, 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.