What is a Fossil Fuel Embargo Shock?

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February 24, 2023

Abstract

In this paper, we focus on the impact of a occasionally binding quantity constraint on fossil fuel imports and compare the effects with those of an exogenous fossil fuel markup price shock. We show that while both shocks have similar responses to GDP and CPI inflation, they differ with respect to other macroeconomic components, such as consumption, exports, the trade balance and the functional income distribution.

Our findings are relevant for policymakers when determining the most effective fiscal stabilization policy. We compare different temporary fiscal stabilization policies, such as energy tax reduction, transfer to liquidity-constrained households, and a valued-added tax cut. We find that fiscal policies are less effective in the case of an embargo shock. In particular a reduction of the energy tax is completely ineffective when there is an embargo. In contrast, in the event of a price markup shock, an energy tax reduction is effective because it counteracts the price increase and allows companies to respond according to their energy demands.

In the case of an embargo, we show that transfer policies which redirect income to households receiving mostly labor income have good stabilization properties. However, this policy measure leads to a higher increase in all inflation rates which could widen the monetary policy trade-off between stabilizing output and inflation.

JEL: Q43, E63, F51

Keywords: Energy prices, embargo, general equilibrium model, fiscal policy

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1 Introduction

Economic sanctions are increasingly used in the global economy. They can take various forms such as imposing restrictions on financial transactions or restricting exports or imports of certain commodities. In the context of the Ukraine–Russia war an embargo on Russian fossil fuel (FF) imports is being discussed by economists and politicians in Europe as a way to limit the amount of Russia's revenues that can be allocated to fund war activities. Given the strong dependence of European countries on FF imports from Russia and the limited substitution possibilities in the short run, the possible macroeconomic costs of an embargo need to be assessed. It is also critical to determine which policy measures mitigate the negative effects of an embargo on the domestic economy.

A number of studies have investigated the quantitative effects of an FF embargo using various models. In an earlier contribution, Fishelson (1980) theoretically analyzes the economic effects of restrictions on energy purchases in the international market using the production function for the case of a small country. More recent studies model the reduction of the production/consumption share in FF as an increase in transportation cost or translate an FF embargo shock into a corresponding exogenous increase in FF price Bachmann et al. (2022), Deutsche Bundesbank (2022)). Exogenous FF price shocks have been studied intensively (e.g. Bernanke et al. (1997), Hamilton (2009), Blanchard and Riggi (2013)), mainly for oil. However, Kilian (2009) shows that not all oil price shocks are alike. He shows that only the Saudi Arabia's oil export embargo in the 1970s corresponds to what was previously understood as exogenous oil price shock. In contrast, a substantial number of the oil price shocks in the past are due to demand fluctuations. The recent strand of the literature investigates the economic consequences of FF price shocks using open-economy DSGE models that incorporates demand for and supply of oil and stabilization through monetary policy (e.g. Bodenstein et al. (2011), Bodenstein et al. (2012), Delpachitra et al. (2020)).

In this paper, we concentrate on supply-side driven shocks and compare the effects of an FF embargo with those of an exogenous FF price shock. The aim is to understand the transmission channel of an FF embargo. In the second part of the paper, we compare different fiscal stabilization policies that dampen the economic effects of an FF embargo. We contribute to the extant literature in three ways:

First, we contribute to the strand of literature dealing with the macroeconomic effects of energy shocks by uniquely identifying an FF embargo shock in a macroeconomic model and analyzing its economic impact. We introduce an FF embargo as an occasionally binding quantity constraint on FF imports. Typically in macroeconomic models, FF supply shocks are modelled as changes of the price markup. To make our embargo results comparable to the extant literature, we examine the effect of a FF price markup increase. We show that an embargo shock leads to a similar GDP and CPI inflation reaction as a FF price markup shock. However, both shocks differ significantly with respect to other macroeconomic components, such as consumption distribution, exports, trade balance, profits and real exchange rates. Furthermore, we show that an FF embargo leads to producer rents in the domestic economy. herefore, in addition to stabilizing the economy, economic policy must also correct distributional effects.

Second, we contribute to the part of the literature that examines appropriate stabilization instruments of energy shocks. Building on our findings, we compare different temporary fiscal stabilization policies, such as an energy tax reduction, a transfer to liquidity-constrained (LC) households and a value-added tax (VAT) reduction, in terms of dampening GDP losses, reducing price inflation, and correcting distributional effects. We find that fiscal policy is less effective in the case of an embargo shock. In particular, an energy tax cut is completely ineffective mitigating the negative effects of an embargo. In contrast, an energy tax cut proves effective when there is a FF price shock because it counteracts the price increase and allows firms to respond according to their energy demands. It also dampens the monetary policy trade-off between stabilizing output and inflation. Transfers to LC households have a stronger demand-stabilizing effect and correct negative distributional effects. However, this policy measure leads to a higher increase in all inflation rates, which could increase the monetary policy trade-off. A temporary reduction of the VAT on consumer goods stabilizes output and employment to a greater extent, and the distributional effects of an embargo are somewhat mitigated. However, the stabilization effect reverses when the tax is adjusted back to its original level. A majority of macroeconomic studies focus on the role of monetary policy and the trade-off between stabilizing inflation and output (e.g. Carlstrom and Fuerst (2006), Nakov and Pescatori (2010), Montoro (2012), Natal (2012)). More recent studies also analyze specific fiscal measures, such as energy taxes, in the wake of climate change policies (Golosov et al. (2014), Tumen et al. (2016), Hinterlang et al. (2022), Schreiner and Madlener (2022), Chan (2020), Pan et al. (2020)), but not in the wake of stabilizing temporary energy price shocks. Our analysis on the fiscal stabilization of an FF embargo within a dynamic macroeconomic framework provides an important contribution. A closer look at the impact of fiscal stabilization policies in the event of an embargo seems important, given the multibillion-currency relief packages imposed in many countries in the wake of high energy price inflation during 2022-2023.

Third, we also contribute to the literature of macro-energy modelling (Lippi and Nobili (2012), Nakov and Nuño (2013), Balke and Brown (2018), Branger et al. (2020), Bornstein and Krusell (2022)) by introducing the novel feature of an occasionally binding embargo constraints to producers into an open economy New Keynesian DSGE model. Furthermore, our model includes a labor market, trade, an integrated international financial market and a government sector and a sectoral structure. Thus, on the production side we distinguish between upstream (e. g. basic chemical products) and downstream (consumer goods) producers to capture the fact that FF is more intensively used in upstream sectors. This is an important feature because an embargo shock has different economic effects depending on the stage of the value chain at which it restricts demand for goods. We generate a comprehensive dataset of macro and energy market data to provide a solid empirical foundation for our model. We compile a set of empirical facts about the structure of the German economy and the energy intensity of production and consumption; some parameters are directly matched with these. The remaining model parameters are carefully calibrated based on a set of first-order moments for oil-related and macroeconomic variables. In addition, robustness analysis is performed with a min-max range for relevant parameters, both for the simulation of economic effects and for government stability policies. The aim of our model analysis is to employ a macroeconomic model that embeds the production function approach in Bachmann et al. (2022) while featuring the main channels through which an import or export embargo affects the importer's economy. We find that an import embargo of 10% reduces GDP by more than 1%. We can show that the severeness of an FF embargo is not only affected by the substitution elasticity but also by the trade elasticity, and nominal and real rigidity. Nominal rigidities amplify the negative impact of an import embargo, real rigidities in employment dampen it. However, high trade substitutability amplifies the negative GDP effect even.

The remainder of this paper is organized as follows: In Section 2, we briefly explain the DSGE model setup focusing on an FF embargo shock and how we find the relevant model parameters. In Section 3, we apply the model and compare an FF embargo with an FF price shock. We further analyze the sectoral differences and transmission channels. We then evaluate fiscal policy instruments that stabilize the macroeconomic and distributional effects of an FF embargo shock. In Section 4 we summarize and conclude our research.

2 Model

We build a two-country two-sector model, where country A represents the FF importer and country B represents the rest of the world producing and exporting FF and final goods. The final good is inelastically supplied while FF is supplied elastically at an exogenous price. The final good of country B is an imperfect substitute to the final good produced by country A. Thus country A imports both final goods and FF from country B and exports final goods to country B. In addition to goods, the two regions also trade financial assets and pursue independent monetary policies; thus, there is a flexible exchange rate.

To better understand how embargoes affect an economy depending on how they hit upstream and downstream production we distinguish between an upstream/intermediate goods production sector (X sector) and a downstream/consumption goods sector (C sector). The intermediate goods sector consists of $i \in (0,1)$ firms that produce different varieties of intermediate goods using domestic labor, capital input, and imported FF. These goods are sold to perfectly competitive firms which combine domestic intermediates to produce a final (upstream) good, using constant elasticity of substitution (CES) technology. In addition to being exported, this good is sold to the government, to intermediate firms (as an investment good), and to the downstream consumption goods sector. The consumption goods sector consists of $j \in (0,1)$ monopolistically competitive firms that produce different varieties of consumption goods. Firms in the consumption goods sector combine the final upstream good with the final imported good and with energy imports. Wages are set according to labor supply preferences of domestic households and are also subject to adjustment frictions.

2.1 Households

Households are divided into a fraction s^L of liquidity-constrained (LC) households (indexed by LC) and a fraction $1-s^L$ of Ricardian households (indexed by R). They have CES preferences over consumption varieties produced by firms in the consumption goods sector. Ricardian households are unconstrained and own capital and the firms. Both household types $l=R,LC$ optimize private consumption C_t^l and labor supply L_t according to the following utility function

$$U_0^l = \sum_{t=0}^{\infty} \beta^t \left(\log(C_t^l) - \frac{\omega}{1+\kappa} L_t^{1+\kappa} \right), \tag{1}$$

where L_t is the labor volume supplied by the household. κ is the inverse Frisch elasticity of (intensive and extensive) labor supply, ω denotes the relative preference for leisure and β measures the time preference of the households. For simplicity, we assume that the households do not differ with respect to the parameter values, but only with respect to their budget constraint. Consumers have CES preferences over consumption varieties j:

$$C_t^l = \left[\int_0^1 (C_{j,t}^l)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{2}$$

where ϵ is the intratemporal substitution elasticity between consumption varieties. Utility maximization for the Ricardian household is subject to the following budget constraint:

$$\begin{aligned}(1+\tau_t^{VAT})P_t^C C_t^R + B_t + E_t B_t^* + \left(1 + \frac{\gamma^K}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2\right) P_t^I I_t \\ = (1+i_t)B_{t-1} + (1+i_t^W)E_t B_{t-1}^* + \left(1 - ssc_t^{HH}\right) W_t L_t^R + R_t^k K_{t-1} + \Pi_t^X + \Pi_t^C - T_t + TR_t.\end{aligned} \tag{3}$$

Ricardian households receive labor income $W_t L_t^R$, capital income $R_t^k K_{t-1}$, profit income Π_t^X, Π_t^C from intermediate and consumption goods production, and public transfers Tr_t. They also receive income from financial net wealth, which consists of domestic government bonds B_t and internationally tradable bonds B_t^* and are denominated in RoW currency. Ricardian households buy the nominal composite consumption basket $P_t^C C_t^R$ and pay VAT, social security contributions $SSC_t^{HH} W_t L_t^R$, and lump-sum taxes T_t. The aggregate capital stock K_t evolve according to the following definition:

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

where I_t denotes private investments and δ is the physical depreciation rate. Capital accumulation is determined by capital adjustment costs $\frac{\gamma^K}{2}\left(\frac{I_t}{K_{t-1}} - \delta\right)^2$ and investment adjustment costs $\frac{\gamma^I}{2}\left(I_t - I_{t-1}\right)^2$.

LC households have identical CES preferences over consumption and labor and spend their total current income on consumer goods each period:

$$\left(1 + \tau_t^{VAT}\right) P_t^C C_t^{LC} = \left(1 - ssc_t^{HH}\right) L_t^{LC} W_t - T_t + Tr_t^{LC}, \tag{5}$$

where $W_t L_t^{LC}$ is labor income, T_t is the net amount of lump-sum tax and lump-sum transfer components of the government and T_t^{LC} is the transfer income of the LC household.

Total consumption is given by

$$C_t = s^L C_t^{LC} + (1 - s^L) C_t^R, \tag{6}$$

where s^L, $1 - s^L$ are the respective population shares of Ricardian and LC households.

2.2 Consumption goods sector (downstream good producers)

The consumption goods sector consists of $j \in (0,1)$ monopolistically competitive firms which supply households with different varieties of consumption goods. Given the household preferences, firm j faces a demand function of

$$C^{l}_{j,t} = \left(\frac{P^{C}_{j,t}}{P^{C}_{t}}\right)^{-\epsilon} C^{l}_{t}. \tag{7}$$

Consumption goods producers combine the domestic final good, and final goods import goods with FF imports O^C_t into a consumption aggregate C_t using a nested CES production function. We assume that consumption goods producers can more easily substitute between domestic and imported final upstream goods ($C^D_{j,t}$, $C^M_{j,t}$):

$$C^F_t = \left((s^D)^{\frac{1}{\sigma^C}} \left(C^D_{j,t}\right)^{\frac{\sigma^C-1}{\sigma^C}} + (s^M)^{\frac{1}{\sigma^C}} (C^M_{j,t})^{\frac{\sigma^C-1}{\sigma^C}} \right)^{\frac{\sigma^C}{\sigma^C-1}}, \tag{8}$$

but face strong complementarity between the final upstream aggregate $C_{j,t}$ and FF input $O^C_{j,t}$, expressed by $\sigma^O < \sigma^C$

$$C_t = \left((s^C)^{\frac{1}{\sigma^O}} \left(C^F_t\right)^{\frac{\sigma^O-1}{\sigma^O}} + (s^O)^{\frac{1}{\sigma^O}} (O^C_t)^{\frac{\sigma^O-1}{\sigma^O}} \right)^{\frac{\sigma^O}{\sigma^O-1}}, \tag{9}$$

where s^D is the consumption share of domestic produced goods and $s^M = 1 - s^D$ is the import share. σ^C is the intratemporal elasticity of substitution between domestically produced and imported final consumption goods. σ^O is the intratemporal elasticity of substitution between the upstream aggregate and imported FF input.

To facilitate aggregation we assume identical technologies across all consumption goods producers. Consumption goods producer j maximizes profits subject to technology constraint, price adjustment costs and an occasionally binding embargo constraint for FF, which restricts the demand so that $O^C_{j,t}$ does not exceed $\overline{O}^C_{j,t}$.

$$\sum_{t=0}^{\infty} \Pi^{t}_{k=0} \left(\frac{1}{1+r_k}\right) \left\{ \frac{P^C_{j,t+k}}{P^C_{t+k}} C_{j,t+k} - \frac{P^F_{t+k}}{P^C_{t+k}} C^F_{j,t+k} - \frac{(1+\tau^O) P^O_{t+k}}{P^C_{t+k}} O^C_{j,t+k} - ADJ^{PC}_{t+k} \right\}$$
$$\left\{ -\lambda_{i,t+k} \left(C_{i,t+k} - \left((s^C)^{\frac{1}{\sigma^O}} \left(C^F_{t+k}\right)^{\frac{\sigma^O-1}{\sigma^O}} + (s^O)^{\frac{1}{\sigma^O}} (O^C_{t+k})^{\frac{\sigma^O-1}{\sigma^O}} \right)^{\frac{\sigma^O}{\sigma^O-1}} \right) - \theta^C_{j,t+k} \left(O^C_{j,t+k} - \overline{O}^C_{j,t+k} \right) \right\} \tag{10}$$

The consumption goods producer sells variety j at price $P^{C,VAT}_{j,t+k} = P^C_{j,t+k}(1 + \tau^{VAT} t + k)$ to households and has to set the price $P^C_{j,t+k}$. Price adjustment costs associated with changing VAT might be smaller than price adjustment costs arising from changes in input prices. Therefore we calculate the adjustment cost as a weighted average of the sales price and the price excluding VAT, with weights of θ and $1-\theta$, respectively. If $\theta = 1$, price adjustment costs do not depend on the source of the price change. If $\theta = 0$, the firm faces no price adjustment costs due to VAT changes. For all cases in between, the firm faces positive but smaller price adjustment costs due to VAT changes.[1]

[1] See Clemens and Roeger (2021) for a detailed description.

$$ADJ^{PC}_{t+k} = \frac{\gamma^P}{2} C_{t+k} \left[\frac{\left(P^C_{j,t+k}\right)^{\theta}}{\Pi^{\alpha}_{t+k-1} \left(\Pi^T_{t+k}\right)^{1-\alpha} \left(\left(1+\tau^{VAT}_{t+k-1}\right) P^C_{j,t+k}\right)^{\theta}} - 1 \right]^2 \tag{11}$$

The adjustment cost function subtracts deviations of inflation from a weighted average of an inflation trend and past inflation. Using symmetry across consumption goods producers, optimization yields the following equation for consumer prices

$$\pi^C_t = \beta \pi^C_{t+1} + \left(\beta \left(\frac{\theta}{1+\overline{\tau}^{VAT}} \right) \left(\tau^{VAT}_{t+1} - \tau^{VAT}_t \right) - \left(\frac{\theta}{1+\overline{\tau}^{VAT}} \right) \left(\tau^{VAT}_t - \tau^{VAT}_{t-1} \right) \right) + \frac{\epsilon}{\gamma^P} MC^C_t, \tag{12}$$

with marginal costs given by

$$MC^C_t = \left[s^C \left(P^F_t\right)^{1-\sigma^O} + s^O \left((1+\tau^O) P^O_t + \theta^C_t \right)^{1-\sigma^O} \right]^{\frac{1}{1-\sigma^O}}. \tag{13}$$

If an embargo constraint binds, the Lagrange multiplier is $\theta^C_t > 0$. The binding embargo constraint acts like a (shadow) cost increase for $O^C_{j,t}$.[2] The price equation shows that an embargo yields positive profits for domestic consumer goods producers. This is a direct implication of the fact that with O^C_t fixed at $\overline{O}^C_t$, the production function has decreasing returns to scale during the period of an embargo. This in turn implies that the total of the income-accruing factors of production is less than total revenue. Profits in the consumption goods sector also include the scarcity rent as measured by the Lagrange multiplier of the embargo constraint (multiplied with $\overline{O}^C_t$). This shows that the higher marginal product of the constrained input is not reflected by a higher factor price.[3]

2.3 Final upstream good producer

Perfectly competitive firms produce a final upstream good Y_t using intermediate inputs X_{it} with a CES production function:

$$Y_t = \left[\int_0^1 (X_{it})^{\frac{\mu-1}{\mu}} di \right]^{\frac{\mu}{\mu-1}}. \tag{14}$$

This yields factor demand functions

$$X_{it} = s^X \left(\frac{P^X_{it}}{P^Y_t} \right)^{-\mu} Y_t, \tag{15}$$

where μ is the intratemporal substitution elasticity between intermediate inputs used in the production process of the final upstream good and s^X is the production share of the intermediate good.

[2] Since $\overline{O}^C_{j,t+k} > 0$ the existence of the marginal cost index does not present a problem, despite $\sigma^C < 1$.

[3] If an embargo is accompanied by an increase in the world market price for O, the profit in the Y sector is reduced or even eliminated. In this model, we ignore losses for a firm from underutilization of capital. The point on profits made above is only useful to highlight differences between an embargo and an increase in FF import prices.

2.4 Intermediate goods producer (upstream goods producer)

Each intermediate input is produced with a combined value-added factor and imported FF used in the production process in a similar fashion as in the final consumption goods sector.

$$X_{it} = \left((s^{VA})^{\frac{1}{\sigma^X}} VA_{it}^{\frac{\sigma^X - 1}{\sigma^X}} + (s^O)^{\frac{1}{\sigma^X}} \, (O_{it}^X)^{\frac{\sigma^X - 1}{\sigma^X}} \right)^{\frac{\sigma^X}{\sigma^X - 1}}, \tag{16}$$

where s^{VA} and s^O are the intermediate good shares of the combined value added and FF in production. σ^X is the substitution elasticity between both factors to produce the intermediate good. The combined value added factor itself is produced with labor and capital according to the Cobb-Douglas function:

$$VA_{it} = A_t L_{it}^{\alpha} K_{it}^{1-\alpha}. \tag{17}$$

In addition to the technology constraint, intermediate goods producers face a price adjustment cost friction (nominal rigidity), a labor adjustment cost friction (real rigidity), and an occasional embargo constraint on FF inputs. Each intermediate producer i solves the following maximization problem:

$$\sum_{t=0}^{\infty} \Pi_{k=0}^{t} \left(\frac{1}{1+r_k} \right) \left(\frac{P_{it}^X}{P_t^X} \right) X_{it} - \left(\frac{W_{t+j}(1+ssc_t)}{P_t^X} \right) L_{it}^X - r_t^K K_{it} - \left(\frac{(1+\tau^O) P_t^O}{P_t^X} \right) O_{i,t+j}^X - ADJ\left(P_{it}^X\right) - ADJ(K_{it})$$
$$- ADJ(L_{it}) - \lambda_{it} \left(X_{it} - \left((s^{VA})^{\frac{1}{\sigma^X}} VA_{it}^{\frac{\sigma^X - 1}{\sigma^X}} + (s^O)^{\frac{1}{\sigma^X}} (O_{it}^X)^{\frac{\sigma^X - 1}{\sigma^X}} \right)^{\frac{\sigma^X}{\sigma^X - 1}} \right) - \theta_{i,t}^X \left(O_{i,t}^X - \overline{O}_{i,t}^X \right), \tag{18}$$

where r_t is the interest rate at which the firm owner discounts future profits. ssc_t is the social security contribution rate that a firm pays on the labor earnings of its employees. $ADJ\left(P_{it}^X\right) = \frac{\gamma^{PX}}{2}\left(P_{it}^X - P_{it-1}^X\right)^2$ and $ADJ(K_{it}) = \frac{\gamma^K}{2}(K_{it} - K_{it-1})^2$ are quadratic price and capital adjustment costs with adjustment cost parameters γ^{PX} and γ^K. We further introduce quadratic employment adjustment costs $\frac{\gamma^L}{2}(L_t - L_{t-1})^2$ to account for costs that firms incur when they change their labor demand. Employment adjustment costs must be distinguished from labor hoarding. An economy without employment adjustment costs that has a labor hoarding scheme cannot avoid the decline of labor input (hours worked), and therefore cannot avoid GDP loss. The labor hoarding scenario only differs from the scenario without labor adjustment costs due to the generosity of compensation for short-time work relative to unemployment benefits. We assume that all intermediate firms produce with the same production technology and face identical marginal costs. Therefore, we can derive the aggregate price Phillips curve:

$$\left(1 - \frac{1}{\epsilon} - \gamma^{PX}\left(\beta\pi_{t+1}^X - \pi_t^X\right) + \iota\left(\beta\pi_t^X - \pi_{t-1}^X\right) \right) P_t^X \left(1 + \gamma^L(L_t - L_{t-1}) - \frac{1}{1+r_t}\gamma^L(L_{t+1} - L_t) \right) = MC_t^X. \tag{19}$$

The intermediate producer price inflation π_t^X is determined by the expected inflation rate π_{t+1}^X, the strength of labor adjustment costs and marginal costs which are affected by the factor prices and factor shares:

$$MC_t^X = \left[s^{VA} \left(\left(\frac{W_t(1+SSC_t)}{\alpha} \right)^{\alpha} \left(\frac{r_t^K}{1-\alpha} \right)^{1-\alpha} \right)^{1-\sigma^X} + s^{OX} \left((1+\tau^O) P_t^{OX} + \theta_t^X \right)^{1-\sigma^X} \right]^{\frac{1}{1-\sigma^X}} . \quad (20)$$

If an embargo constraint binds, the Lagrange multiplier $\theta_t^X > 0$. As in the consumption goods sector, an embargo yields positive profits for domestic intermediate goods producers. We can derive the factor demand functions of intermediate goods producers:

$$VA_{it} = s^{VA} \left(\frac{p_t^{vax}}{p_t^{xy}} \right)^{-\sigma^X} X_{it}. \quad (21)$$

The demand for FF is given by

$$\left(\frac{(1+\tau^O) P_t^O}{P_t^X} \right) \left(1 + \theta_{i,t}^X \right) = (1+\tau^O) P_t^{OX} \left(1 + \theta_{i,t}^X \right) = \lambda_t (s^L)^{\frac{1}{\sigma^X}} \left(\frac{X_t}{O_t^X} \right)^{\frac{1}{\sigma^X}} . \quad (22)$$

The binding embargo constraint acts like a price increase for O_t^X. Since no price deflator P^X is required in the model, the Lagrange multiplier $\theta_{i,t+j}^X$ only appears in the demand equation for O^X.

2.5 Monetary and fiscal policy

Monetary policy is conducted by the central bank according to the following rule:

$$i_t = \left(\frac{1-\beta}{\beta} \right) e_t^{ZLB} + \left(1 - e_t^{ZLB} \right) \left(\max \left[\underline{i}, (1-\phi^i) \left(\bar{r} + \phi^{\pi} \pi_t^C + \phi^{dy} (Y_t - Y_{t-1}) + \phi^y \frac{Y_t}{\overline{Y}} \right) + \phi^i i_{t-1} + e_t^i \right] \right), \quad (23)$$

where ϕ^{π}, ϕ^y and ϕ^{dy} denote the weights for the central bank's targets for CPI inflation (π_t^C), output gap $\left(Y_t/\overline{Y}\right)$, and growth $(Y_t - Y_{t-1})$. If the interest rate is above the lower bound $\underline{i}$, the central bank follows the Taylor rule in which the nominal interest rate i_t responds to its lagged value, the current inflation rate, output gap and output growth. We include a binary variable e_t^{ZLB} which equals 1 if we consider the announcement of a constant interest rate policy for period t.

For the government we assume a simplified budget function in real terms, where the government spends a constant fraction of steady-state GDP $G_t = gY_t$, pays lump-sum transfers to LC households Tr_t^L, and finances its expenditures either with new debt $B_t - B_{t-1}$ or different taxes on value added τ^{VAT} and FF τ^O, social security contributions of households and firms SSC_t and a lump-sum tax T_t or transfer if negative. Furthermore, the government pays interest rates on issued debt $r_{t-1}^B B_{t-1}$:

$$B_t = G_t + (1 + r_{t-1}) B_{t-1} - T_t + s^L Tr_t^L - \tau_t^{VAT} C_t - w_t^R ssc_t L_t + \tau^O (O_t^X + O_t^C). \quad (24)$$

The government follows a fiscal debt rule, where lump-sum taxes are set according to the recent debt-to-GDP ratio and new issued debt.

$$T_t = \phi_T T_{t-1} + (1 - \phi_T) \left(\phi_{by} \left(\frac{B_t}{y_t} - \frac{\overline{B}}{\overline{y}} \right) + \phi_b \left(B_t - \overline{B} \right) \right), \quad (25)$$

where ϕ_T is a persistence parameter of the fiscal rule, and ϕ_{by} measures the responsiveness of the lump-sum tax to deviations in the debt-to-GDP ratio from its target value. Furthermore, the responsiveness of new issued debt is weighted by ϕ_b within the fiscal rule.

2.6 National and international equilibrium

We assume that the supply of the imported final good and FF prices (in foreign currency) are exogenous and the foreign central bank pursues price-level targeting. There is a flexible exchange rate and nearly perfect capital mobility up to small risk premium related to foreign debt. The domestic economy exports final goods EX_t to the rest of the world and imports consumption goods C_t^M and FF O_t. The price elasticities between these goods are different, while final goods are substitutes to imports, FF is a complement ($\sigma^C > 1 > \sigma^O$). Nominal GDP of the domestic economy is given by the sum of value added in the consumption goods sector and the intermediate goods sector

$$Y_t^{nom} = \left(P_t^C C_t - P_t^Y Y_t^C - P_t^O O_t^C\right) + \left(P_t^X X_t - P_t^O O_t^X\right), \tag{26}$$

The equilibrium condition for final real output states that Y is used as input in the consumption good production sector Y_t^C, government consumption G_t, private investments I_t and exports EX_t.

$$Y_t = Y_t^C + G_t + I_t + EX_t. \tag{27}$$

Intermediate goods are supplied to the Y sector and exported $X_t = X_t^Y$. The export demand function of the home economy can be expressed as:

$$EX_t = RER_t^{\sigma^C} \overline{Y}_t^*, \tag{28}$$

where the real exchange rate is defined as $RER_t = \frac{E_t P_t^{Y*}}{P_t^Y}$. The export demand reacts only to exogenous global demand shocks $\overline{Y}_t^*$ and endogenously via relative price changes. The current account equation can be expressed as

$$RER_t B_t^* = \left(1 + i_{t-1}^* - \pi_t^Y\right) RER_t B_{t-1}^* + TB_t, \tag{29}$$

where B_t^* is the international net financial asset position. TB_t denotes the trade balance from the perspective of the domestic country.

$$TB_t = X_t - RER_t C_t^M - p_t^{*oy} RER_t O_t \tag{30}$$

Here, not only imported consumption goods, but also total oil imports $O_t = O_t^C + O_t^X$ are subtracted from total export demand and price-adjusted by the real exchange rate. The interest parity condition can be derived as a financial market equilibrium condition, so that the real exchange rate dynamics is determined by the international interest rate difference and the net foreign asset position B_t^*:

$$1 + r_t = (1 + \bar{r}^*) \frac{RER_{t+1}}{RER_t} - B_t^* \gamma^B, \tag{31}$$

where $\gamma^B > 0$ is the risk premium on net foreign debt.

2.7 Calibration

The empirical validation of our model is provided by setting parameters so that the model's steady state fits empirical observations for the economy and the tax system in Germany in 2021. The empirical values and the calibration for Germany are summarized in Table 1 and 2 in the Appendix.

The time preference factor β is set to 0.996 to match a steady-state real interest rate of 1.6%. With a capital share of $\alpha = 0.32$, we can match the capital-to-output ratio of approximately 3. The parameter that determines the inverse Frisch elasticity of total labor volume ρ is set to 1.2 and the share of LC households n is 0.28.[4]. The quarterly depreciation rate for private investments δ is calibrated to 0.016 yielding a steady state investment expenditures per GDP $\overline{g}/\overline{y}$ of 19 % close to the observed value.

Capital, intermediate goods price, final goods price and wage adjustment costs are set to $\gamma^I = 15$, $\gamma^K = 20$, $\gamma^{PY} = 20$, $\gamma^{PC} = 10$ and $\gamma^W = 120$, respectively. The price and wage adjustment costs correspond to Calvo parameters of 0.79, 0.72 and 0.91, which are comparable to values found in the literature.[5]

Following Bachmann et al. (2022), we consider their preferred specification of the elasticity of substitution between O and X to be $\sigma = 0.1$, and consider a reduction of O by 10%. An embargo shock can affect sectors differently. In our model, we distinguish two different sectors that may be affected as a result of an FF embargo shock. For domestic manufacturing companies the intermediate goods producer (X sector) may be affected. The consumer demand (C sector) is directly affected since FF energy is imported by customers and consequently enters the household shopping basket separately from domestically produced goods.[6] The energy share of the intermediate product sector is significant. Here, imported FF is required for the production of intermediate products, for example in the chemical, automotive and other industries. The actual energy share in the production of industrial goods is approximately 2% of GDP. Households also demand FF directly to heat their homes, fuel their cars, and produce electricity. This consumption also accounts for approximately 2% of GDP, resuling in a total energy share of GDP of 4% assumed in the baseline scenario.

Monetary and fiscal policy parameters are chosen mainly according to the extant literature.[7] For the monetary policy rule, we assume central bank weights for interest rate smoothing of $\phi^i = 0.8$ and for the CPI inflation target $\phi^\pi = 1.5$. For the output gap and the output growth targets ϕ^y, ϕ^{dy}, we consider that the central bank does not counteract fiscal policy effects and set both weights equal to 0. In the fiscal sector, we calibrate the steady-state government debt-to-GDP ratio $\overline{b}/\overline{y}$ as equal to 60% on an annual basis. The steady-state VAT rate $\overline{\tau}^C$ and social security contribution rates are set equal to their respective empirically observed values at 17.5% and 19.5% for both firms and households. The remaining component of the fiscal budget $\overline{T}$, in the subsequent analysis defined as net lump-sum tax can be calculated as the difference between revenues and expenditures.

[4]See e.g. Kollmann et al. (2015) and Grabka and Halbmeier (2019)

[5]See e.g. Burgert et al. (2020).

[6]In the production of final consumer goods, imported FF is mainly used in the form of energy during the conversion process from intermediate product to final good. For example, in the retail sector, energy is consumed to provide storage and sales space. However, the energy share of the final product sector is negligible.

[7]Monetary policy assumptions are not important for assessing general equilibrium effects in a fully flexible price economy. If prices and wages react rigidly, monetary policy has to be specified. In our baseline scenario we assume that the central bank uses the Taylor rule and responds to both consumer price inflation and GDP growth. In an alternative scenario, we assume nominal rates at zero (zero lower bound, ZLB).

The steady-state VAT rate $\overline{\tau}^{vat}$ is equal to 0.175, which matches the average VAT rate.[8] The parameter ϕ_{by} captures the strength of the reaction of lump-sum taxes to deviations of total government debt level from the target and is set to 0.63. The parameter that accounts for issuing new debt ϕ_b is set to 0.06.

3 Results

3.1 Embargo vs. fossil fuel price shock

We compare the effects of a FF import embargo (blue line) to those of an FF import price markup shock (red line). We assume that an embargo reduces the import demand for O by 10%.[9] To compare both shocks, we simulate an FF import price shock of 160%, producing an identical energy import response. Figure 1 shows the impulse-responses for selected macroeconomic and fiscal indicators.

The GDP effect of an embargo and an FF price shock is highly similar, mainly differing in the response of domestic and external demand. This is due to the fact that a price increase leads to a higher loss of domestic income, and a higher number of exports to finance the higher price for price-inelastic FF imports. In contrast, an embargo improves the trade balance because of the decline of FF imports. Thus, an embargo reduces domestic demand less than a price hike for FF. Initially, an FF price increase shows a stronger inflation impact; however, the inflationary effect of an embargo is sizeable as well since the embargo constraint also increases marginal costs for producers. Since there is a stronger negative wealth effect associated with an FF price shock, wage inflation slows less under the FF price shock, therefore inflation is lower than under an FF embargo shock. The two shocks have different distributional effects, as can be seen from the movement of profits and the wage share. Constraining FF imports implies decreasing returns to scale; thus, the total income accruing to factors of production are less than the total revenue.[10] This increases profits and reduces the wage share. The opposite result emerges with an FF price increase. The FF input remains constant because of a rise in FF prices. This reduces profits, because firms only pass on a fraction of the higher FF costs to output prices because of price rigidities.

Another consequence of an embargo is that a quantity constraint on one input leads to a rising marginal cost (decreasing returns to scale of all unconstrained factors of production). This in turns leads to positive profits generated by the embargo for final goods producers. In other words, the efficiency loss is eventually borne by workers, while producers capture the embargo rent (increase of the marginal product of O for which the foreign suppler of O is n remunerated). This is shown through the evolution of C^R and C^L. Thus, irrespective of the eventual GDP effect, a policy response is necessary to correct the distributional impact of an embargo. An embargo imposes an efficiency loss for the economy. The negative effect of the efficiency loss on GDP can be minimized by stabilizing employment; however, the efficiency loss still manifests as lower wages.

[8] The VAT rate for most consumption goods is 19%. Some consumption goods, such as food and necessities, have reduced tax rates of 7%.

[9] This makes the scenarios comparable across different specifications. This is also the correct assumption for a comparison of scenarios with and without a stabilizing policy. Without a binding constraint, a policy is considered to be successful if the decline of C become less steep; this increases the demand for O (and O decreases less), which is similar to an FF price shock. However, if O is constrained to -10%, the Lagrange multiplier must be adjusted upwards to satisfy the embargo constraint.

[10] The marginal cost (**??**) shows that an embargo increases profits and (**??**) becomes a positive function of the Lagrange multiplier of the embargo constraint. The shadow cost accrues to the firm as additional income.

Due to the different distributional effects of both shocks, the consumption of LC households declines more under an embargo. In both cases the consumption of LC households falls more sharply than the consumption of the Ricardian households because they cannot substitute consumption intertemporally even if the FF demand shares of both household types are equivalent.

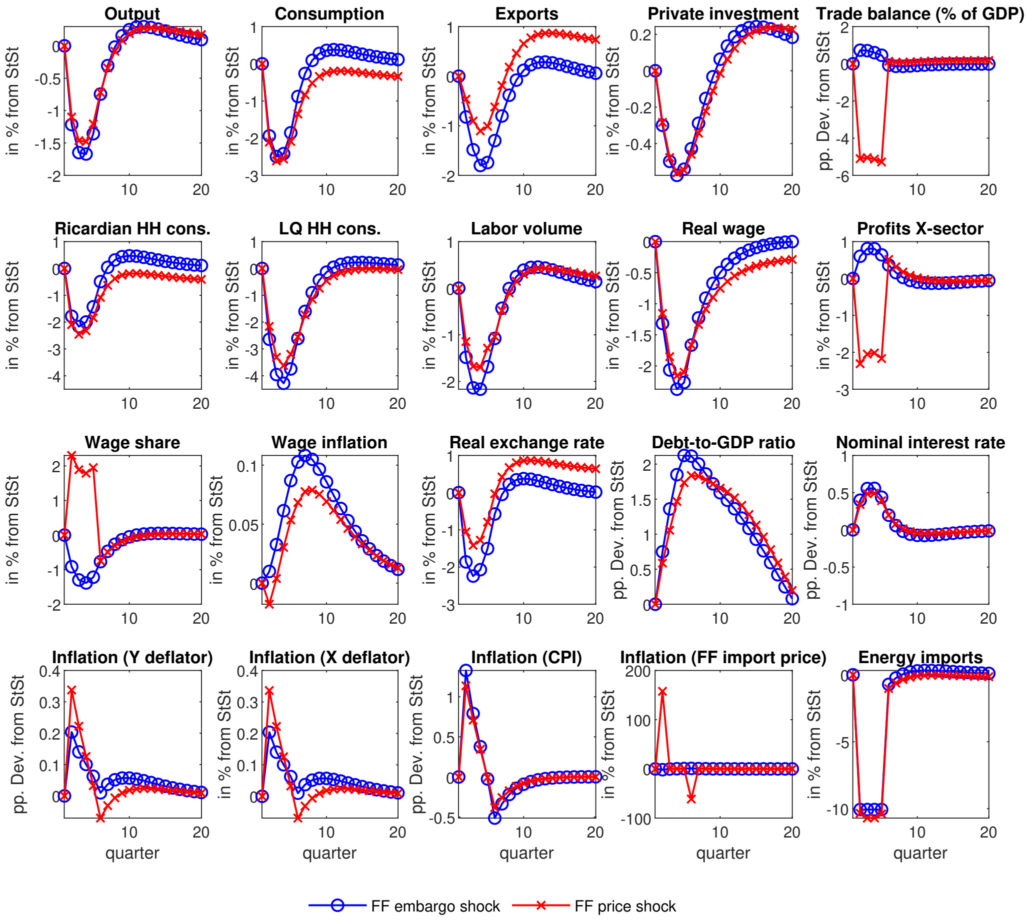

Figure 1: Impulse Response Functions to a 10% FF embargo shock (blue line) and a 160% FF price shock (red line)

Note: In order to compare both shocks we calibrate the FF price shock (red) to generate an equal immediate energy import reaction of 10%.

Although we are primarily interested in studying the economic effects of an embargo rather than in forecasting as accurately as possible, we briefly place our simulation results in the context of existing studies and forecasts. In our simulation, a 10% energy import freeze from Russia for one year causes GDP to decline by nearly 1.5%. Our simulation confirms the results of Bachmann et al. (2022), who expect a GDP decline of approximately 3% for an energy import embargo of 30%. The simulation of an import embargo shock neglects the fact that in the case of an embargo there is also a corresponding supply response of alternative FF exporters, which leads us to expect an increase in the price of imported FFs. However, a combination of the 160% FF import price shock and the 10% FF embargo shock do not lead to other significant results.

This analysis highlights the income and distributional effects of embargoes. In particular we show that there are distributional effects because embargoes generate rents for firms. Though there are safety nets in place which partially compensate income loss due to unemployment, an embargo – apart from a general loss of income – also leads to asymmetric income loss and reduces labor income relative to profit income.

3.2 Sectoral embargo shocks

We distinguish between upstream and downstream production sectors. This allows us to trace effects arising from demand and supply linkages. A shock hitting the upstream sector affects the rest of the economy via supply linkages: a cost increase in the upstream sector is transmitted to the downstream sector via an increase in the price of domestic intermediate inputs. In contrast, a positive cost shock hitting the downstream sector affects the upstream sector via a decline in the demand for intermediates.

We investigate the different effects of sectoral embargo shocks by simulating only the shock in the respective sector. We also set the energy shares of the other sectors to zero to establish a better comparability. However, unlike in previous simulations, this does not take into account the interdependence between sectors (*cascade effects*); for example, an embargo in the downstream sector would always have an impact on the energy demand of the X sector or households and vice versa. Because of this assumption, an embargo shock in sector j has no effect on the energy demand in other sectors. As a result the magnitude of the combined economic effects on GDP is smaller than in our baseline simulation (with cascade effects). Figure 2 shows the impulse response functions for sectoral embargo shocks.

An embargo shock hitting the downstream sector has a stronger negative effect than a shock hitting the upstream sector. This is a direct consequence of the presence of nominal rigidities, which amplify the negative effects of demand linkages. Thus, it does matter for aggregate output whether the downstream sector (red line) or the upstream sector (blue line) is affected by an embargo shock. Furthermore, the sum of both GDP effects without cascade effects is approximately 1.3% which is roughly 80% of the GDP effect in the baseline scenario with cascade effects between sectors.

Supply linkages matter mostly via the distribution of the input cost across sectors. In a perfectly competitive economy, the price for the final consumption good can be written as $P_t^C = f(s^X P_t^X, s^{OC} P_t^O)$, with $P_t^X = g(s^{VA} P_t^{VA}, s^{OX} P_t^O)$, where s^j with $j = X, OC, VA, OX$ are cost shares. The cost share for O^C and O^X includes the Lagrange multiplier of the embargo constraint $P_t^C = f\left(s^X \times g(s^{VA} P_t^{VA}, s^{OX} P_t^O), s^{OC} P_t^O\right)$. If $s^{OC} = s^{OX}$ and $s^X = (1 - s^{OC})$, then for s^{OX}, the cost share of O^X and O^C in final consumption do not differ much. The impact of a constraint on O^X on the price for final output/consumption would be smaller than the impact of a constraint on O^C. In addition, if the O^C sector could also substitute X via imports, then the cost share of X would decrease (if the elasticity of substitution is larger than 1), which would further reduce the impact of an embargo shock on O^X. A greater negative impact of an embargo shock in the upstream sector can only result from a large share of O in the production of X.

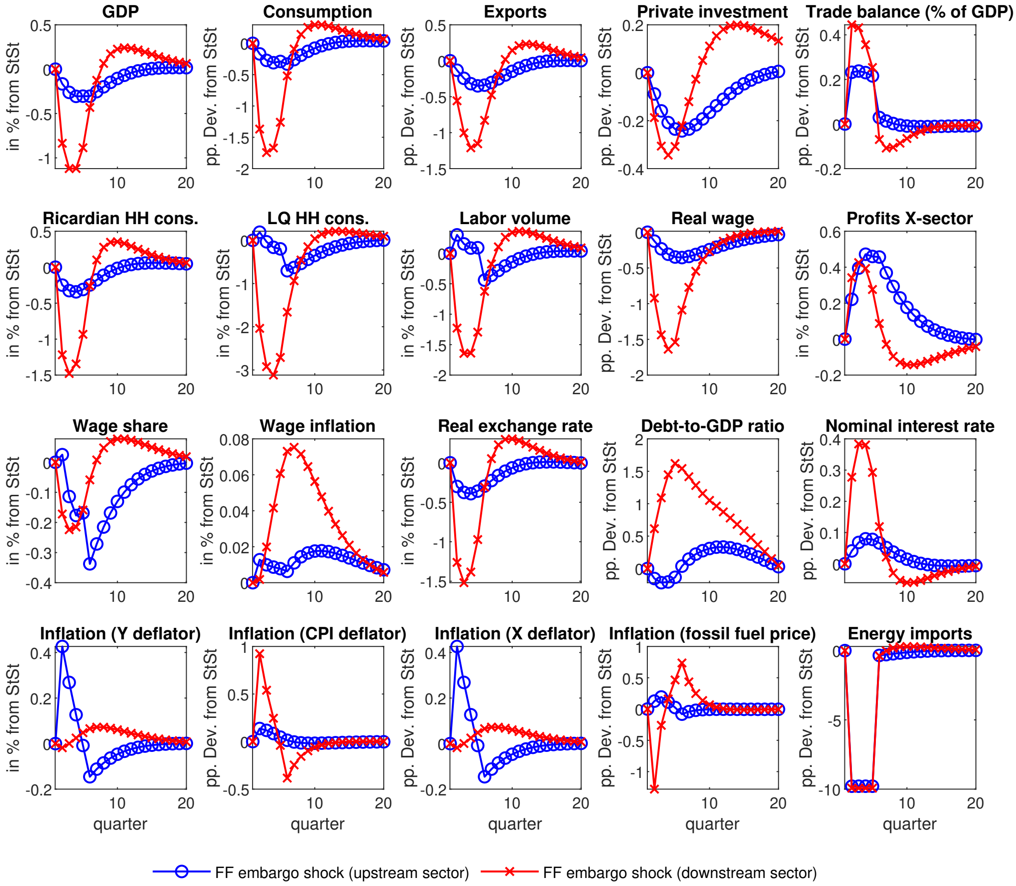

Figure 2: Impulse Response Functions to a 10% FF embargo shock in the upstream (blue line) and downstream sectors (red line)

Note: To compare the embargo sectoral shocks we calibrate the energy share of non-affected sectors to 0%.

Allowing for Keynesian effects further, reduces the impact of an embargo on O^X because the cost shock on X is mitigated by a reduction of the mark up in the X sector due to price rigidities. The cost increase (from higher prices for intermediates) also reduces the markup in the C sector. Keynesian effects in turn increase the negative impact of an embargo shock on O^C, since they reduce the demand for X, which in turn increases the mark up in the X sector.

3.3 Robustness

This section examines how the effects of an embargo change when the structural parameters fluctuate. The aim is to identify parameters that significantly influence the macroeconomic effect as a result of an embargo shock. We choose a range of realistic values from the literature for each parameter. Figure 2 summarizes the results. On the left-hand side, the GDP effect is shown for different parameter ranges for an active monetary policy, and on the right-hand side for a temporary passive monetary policy that leaves the interest rate constant for the duration of an embargo. The bars show the GDP effects for the lower and upper parameter limits. The respective parameter values are given in parentheses. The first parameter value in parentheses, for example 5 for labor supply elasticity, leads to the lower bound of the GDP effect (-0.8%). The second value, for example 0.5 for labor supply elasticity, leads to the upper limit of the GDP effect (0%).

We will discuss the transmission channels to highlight some fundamental trade-offs associated with an embargo shock. An energy embargo increases the marginal cost for the production of Y and therefore, the price of final goods. Since the final good enters the consumption basket of domestic households, its price is relevant to wages. How wages respond depends on the labor supply elasticity. If labor supply is inelastic, wages may not adjust and workers will be willing to accept a lower real consumption wage in order to keep employment constant. When labour supply is elastic, there will be both a negative employment and positive nominal wage response. This increases the production cost for domestic intermediate inputs, which reduces demand for domestic inputs by final goods producers. The decline of X is consequently determined by the labor supply elasticity.

However, irrespective of the labor supply elasticity, there is a loss of real (consumption) income for domestic workers since stable employment requires a decline in the real wage. This illustrates an important characteristic of an embargo, namely a decline in the marginal productivity of domestic factors of production. Thus, the *trade elasticity* σ^C is a relevant structural parameter. Countries whose imported and exported goods can be substituted internationally (high trade elasticity $\sigma^C = 7$) are more strongly affected by embargo-related price increases. This is because as foreign demand declines, exporting firms are more likely to use foreign inputs than domestic ones. However, this model does not take into account the fact that other countries are also hit by the embargo shock.

As expected, the most sensitive parameter is the *elasticity of substitution of FF* σ^X and σ^C for which we assume a range between 0.03 and 0.3. The more difficult it is to substitute FFs, the more GDP declines, because the factor cannot be replaced completely or only at higher cost. With a lower elasticity of substitution of 0.03, GDP falls by approximately 5%.[11] However, with an elasticity of substitution of 0.3, which is estimated in empirical studies as the long-run elasticity of substitution of FFs, GDP decreases by only 0.3%.[12]

Keynesian effects, which we broadly characterize as the presence of *price and wage adjustment frictions* γ^{PX} *and* γ^W leading to mark up fluctuations, are likely to amplify the negative effects. With price rigidity, additional negative feedback effects can be expected, since producers for X will find it optimal to respond to reduced demand from Y by reducing output/employment instead of reducing prices. Sluggish price and wage adjustment amplifies the negative effect of an embargo. Price adjustment costs increase the incentive for firms to adjust employment instead of prices for each individual firm as a response to falling demand for final goods producers. Similarly, trade unions must accept a decline in employment, instead of adjusting wages as a response to declining labor demand. This establishes a sequence of negative feedbacks starting from the final output sector, working through the intermediate input sector and eventually the labor market. Although the Keynesian equilibrium is characterized by lower employment, it limits the decline of the real consumption wage (relative to the efficient

[11]Studies expecting a higher GDP collapse than in our baseline also assume a lower elasticity of substitution. See e.g., Deutsche Bundesbank (2022)

[12]See e.g. Labandeira et al. (2017).

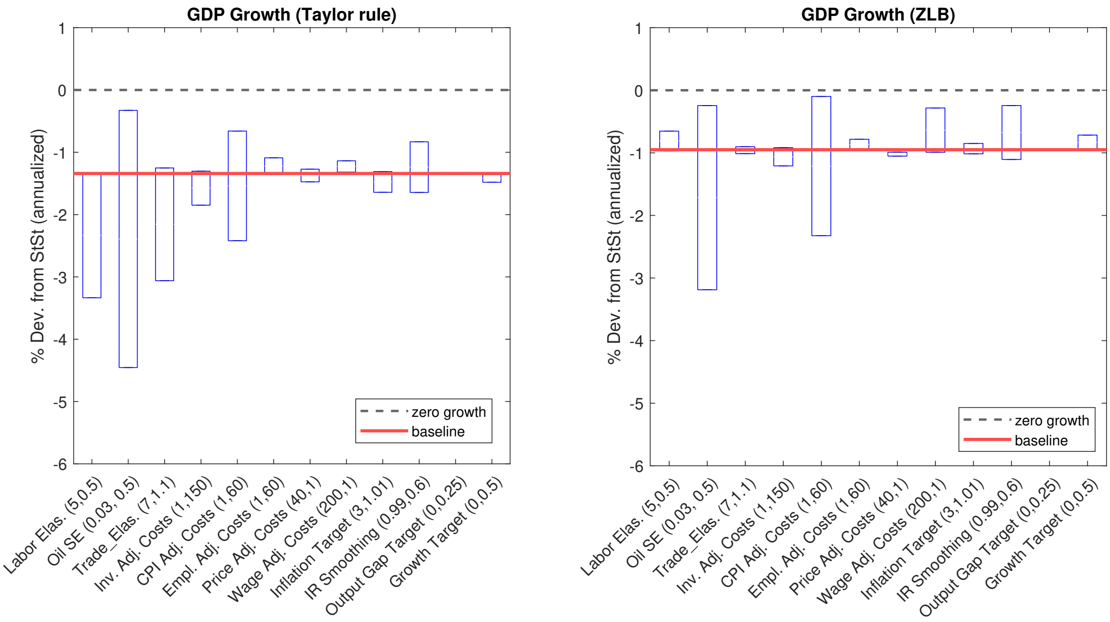

Figure 3: GDP effect after a 10% FF embargo shock under Taylor rule (LHS) and ZLB constraint (RHS)

Note: At (minimum value, maximum value) a higher parameter value leads to a smaller GDP reduction (e.g. for FF substitution elasticity, (0.03, 0.5), at 0.5 the GDP reduction is smaller). At (maximum value, minimum value) a higher parameter value leads to a greater GDP reduction (e.g. for trade elasticity, (7, 1.1), at 7, the GDP decreases more sharply).

economy). Nevertheless the real consumption of worker households (as measured by C^{LC}) declines relative to the economy without nominal frictions. Allowing for higher price and wage adjustment costs, significantly amplifies the effects, GDP now declines by almost 2% instead of the 1% found in our baseline simulation.

We show that additional real rigidities, namely *employment* γ^L *and investment adjustment costs* γ^I, mitigate the negative effects of price and wage rigidities. Given the importance of stabilizing employment to stabilize domestic GDP when there is an embargo on energy inputs, it is interesting to include employment adjustment frictions, which make it costly for firms to adjust employment when there are temporary shocks. These frictions stabilize the decline of employment and investments. The employment friction partially offsets the price-setting friction. Firms, facing both price and employment adjustment costs are confronted with the trade-off between keeping prices fixed (and suffering employment losses) and stabilizing employment (and facing a loss of profits from lowering prices). Thus, compared to the previous scenario, firms find it optimal to reduce prices more aggressively, and thereby stabilize employment. It is interesting to observe that the model with employment adjustment frictions improves upon the efficient economy in terms of distributional objectives, in particular by exhibiting the smallest decline in consumption of worker households.

Monetary policy is also affects the degree of the negative effect of an embargo. In principle, GDP declines slightly less when there is a temporary passive low-interest rate policy, both in the baseline calibration and across the different parameter ranges. This is due to the fact that the central bank does not respond to rising inflation expectations by raising interest rates in the short term. As a result, inflation is higher but output is more stabilized than under an active monetary policy (Taylor rule). Following the Taylor rule, the central bank stabilizes GDP with an output target ($\phi^y = 0.25$). A strong inflation ($\phi^\pi = 3$) or growth target ($\phi^{dy} > 0$) and with strong interest rate-smoothing ($\phi^i = 0.99$), reinforce the negative GDP effect, as the embargo shock creates a trade-off between output and inflation stabilization.

3.4 Stabilization Policy

The analysis in the previous section suggests policy measures which stabilize employment and correct for the distributional effects of an embargo. In this section, we compare possible policy measures: (1) a temporary VAT cut for non-durable goods, (2) a direct transfer for certain types of LC households, and (3) a temporary energy tax rate reduction.

We compare the effectiveness of these different policies using the GDP and consumption multiplier, the CPI, and the GDP deflator, and inflation reaction. The GDP and consumption multipliers are defined as the cumulative change of GDP and consumption divided by the cumulative change of specific revenues or transfer payments $\frac{\sum_{t=0}^{k} \Delta Z_{t+k}}{\sum_{t=0}^{k} \Delta X_{t+k}}$ in reaction to our baseline embargo shock, where $X_{t+k} = [\tau_t^{VAT}, \tau_t^{O}, T_t^{L}]$ and $Z_{t+k} = [Y_{t+k}, C_{t+k}]$. Figure 4 summarizes the results.[13] We distinguish between the first year effect ($k = 4$) of an embargo (LHS) and a price (RHS) shock. To compare the different policies, we normalize the policy reactions to a crisis shock so that they have an identical effect to the debt-to-GDP ratio. The debt-to-GDP ratio is the most important indicator for measuring the debt sustainability of a government within the fiscal stabilization framework of the EU. By selecting the debt-to-GDP ratio as normalization criterion, we ensure that all measures have the same effect on government finances and fiscal rules.

Since LC household consumption declines more than Ricardian household consumption, a targeted stabilization policy that takes distributional effects into account is needed. As an indicator for evaluating the policy instruments, we define the consumption gap as the difference between the consumption of Ricardian households and the consumption of LC households. A policy measure that reduces this gap accordingly also reduces the negative distributional effects of an embargo and a price shock.

Another important factor for an active monetary policy under the Taylor rule is the trade-off between stabilizing inflation and output. In our baseline specification, we assume that the central bank primarily pursues an inflation target, and that it responds to an embargo shock by raising interest rates, which consequently worsens the macroeconomic impact. Thus, a stabilizing fiscal policy can dampen the monetary policy trade-off by choosing an instrument that reduces inflation and increases the output gap.[14]

We find that no policy instrument generates multipliers greater than 1, no matter the FF shock; thus, crowding-out effects predominate.[15] One reason is that an embargo restriction reduces demand immediately, no matter

[13]Detailed impulse response functions of this analysis can be found in Figures 5-8 in the Appendix.

[14]With a passive central bank policy, the trade-off is irrelevant and the central bank does not react to price increases, allowing fiscal stabilization measures to have a different effect.

[15]This also holds under monetary policy with ZLB. We present the same comparison of fiscal instruments with ZLB in Figure 9 in the Appendix. A comparison of fiscal policy instruments under active and passive central bank policies shows that under temporary passive monetary policy, government transfers to LC households (yellow) and a reduction in VAT rates (green) are more effective than

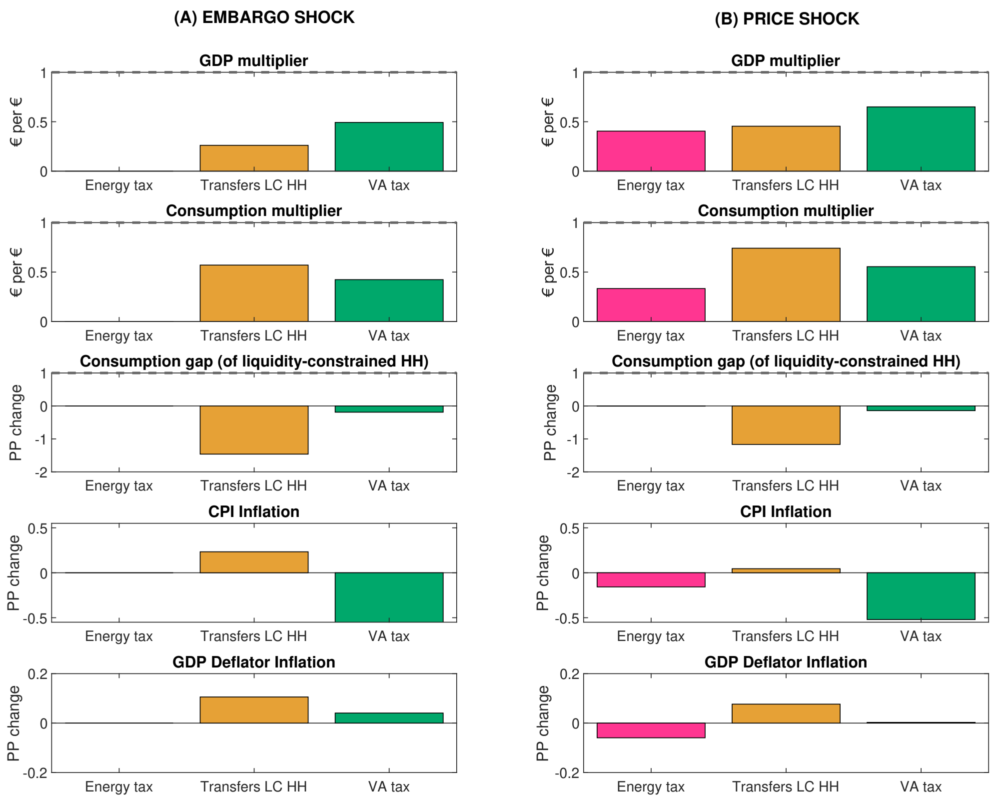

Figure 4: Multiplier, price and debt effects of selected fiscal stabilization policies after one year under FF embargo shock (LHS) and FF price shock (RHS)

Note: The GDP (Y) and consumption (C) multipliers are defined as the cumulative change of Y and C after four quarters divided by the cumulative change of specific revenues or transfer payments. The consumption gap is defined as percentage point difference between consumption loss of Ricardian households and LC households. CPI inflation, the GDP deflator (PY) inflation are defined as the percentage point change from the no-policy baseline after four quarters.

the tax rate or transfer. However, under an FF price shock, when the embargo constraint does not bind, the multipliers are smaller than 1 because FFs cannot be easily substituted by alternative factors. These policy measures cannot directly undo an embargo, and thus, they cannot increase O. This implies that any successful stabilization increases the quantity constraint on O. Furthermore, it also implies that the production of domestic goods which require a combination of O and domestic inputs in nearly fixed proportions cannot be stabilized either. Stabilization is only possible for goods which are substitutable for goods produced with O or for those goods where O can be substituted with domestic inputs. Comparing the fiscal stabilization under both shocks, we find a smaller fiscal multiplier for an embargo shock.

This becomes very clear with the reduction of the energy tax. This policy measure is completely ineffective

under active monetary policy. The main reason is that additional transfers to LC households or the reduction of the VAT rate can be financed via additional debt. When there is a constant interest rate this does not lead to additional lump-sum taxes to households, which would have been aroused to finance the higher interest expenditure of the government. Furthermore, under temporary constant interest rates, the real interest rate decreases in combination with additional transfer income or lower gross prices (through VAT reduction) and stabilizes employment and consumption of households.

when there is an embargo because a tax-reduced price discount does not lead to an increase in domestic energy demand, as this is limited by supply. However, a price reduction leads to higher profits and incomes, which are fully used to finance the tax reductions. An energy tax reduction is effective when there is a price shock because it counteracts the price increase and allows companies to respond according to their energy demands. Furthermore, it dampens the monetary policy trade-off, because it stabilizes GDP, consumption and employment, and reduces gross inflation rates (CPI and GDP deflator).

In contrast, higher transfers to LC households and a reduction in the VAT have a stabilizing effect on GDP, consumption and employment when there is an embargo or a price shock. However, for the aforementioned reasons, the effectiveness of an FF price shock is higher. Specifically, the instruments act through different channels.

LC households are most affected by embargoes. Their consumption falls by 1 percentage point more than Ricardian households in the baseline simulation. Transfers to LC households help correct for these distributional effects of an embargo. In an efficient economy, without frictions and rigidities, the transfer policy has only redistributive effects.[16] With frictions, transfers to LC households has consumption demand stabilization effects which are more pronounced than the supply side measures. However, transfers to LC households lead to a greater increase in all inflation rates, which could widen the monetary policy trade-off.

The temporary VAT reduction for non-durable consumption goods stabilizes output and employment to a greater extent. It reduces the gross consumer prices and thus dampens the CPI inflation rate compared to the no-policy baseline. This stabilizes consumer demand for Ricardian and LC households by approximately 1 percentage point each. Unlike with direct transfers to LC households, the distributional effects of an embargo are somewhat mitigated, but not corrected through a VAT reduction. It is nevertheless interesting to compare the GDP and the consumption multiplier of both, transfers and the VAT reduction. A VAT reduction stimulates consumption (of all households) and labor supply. It targets a shortfall of consumption demand and the reduction of labor demand, due to the falling marginal product of labor, which results from reduced FF input. In comparison, the transfers to LC households do not correct the negative supply effects of the shock, but instead target primarily distributional consequences of the shock. Due to its effect on labor supply, the GDP multiplier of a VAT reduction exceeds the transfer multiplier.

4 Conclusion

This paper examines at the policy implications of an FF embargo shock, which is implemented as a temporary quantity constraint on intermediate inputs. An FF embargo has similarities to a positive shock on FF prices for intermediates. Both measures reduce the use of intermediate inputs. However, an embargo differs from an FF price increase in two ways.

First, an FF embargo reduces the value of (intermediate) imports, while a price increase combined with a low

[16] There is a small feedback effect from redistribution on total consumption which affects aggregate labor supply decisions. However, these effects are negligible.

price elasticity for fossil fuel increases the value of imports. This mitigates the negative GDP effect of an embargo compared to a FF price increase. We show that it provides rents to producers, who use fossil fuels as input and have limited substitution possibilities. In this sense, an FF embargo is less detrimental to the domestic economy than an FF import price shock. Nevertheless, an embargo has substantial negative effects on domestic production and employment via demand linkages. Nominal rigidities amplify the negative effects on GDP.

Second, fiscal stabilization measures cannot undo the quantity constraint on intermediate imports. This reduces their multiplier effect because increased economic activity tightens the embargo constraint. Since an FF embargo has both negative GDP effects and distributive effects, policy measures which correct both effects are necessary. We show that transfer policies which redirect income from households receiving profit, capital, and labor income to households receiving mostly labor income have good stabilization properties. However, this policy measure leads to a higher increase in all inflation rates, which could widen the monetary policy trade-off between stabilizing output and inflation.

However, we also left open interesting questions for future research. For example, the question arises whether embargo shocks can be disentangled from corresponding price markup shocks even with appropriate sanction or embargo data sets and macroeconometric methods. Our model results provide a suitable identification, e.g. for vector autoregressive models (VAR) with sign restrictions. But also the question of optimal monetary and fiscal policy in the case of an embargo constraint can be investigated with our framework.

5 Appendix

5.1 Figures

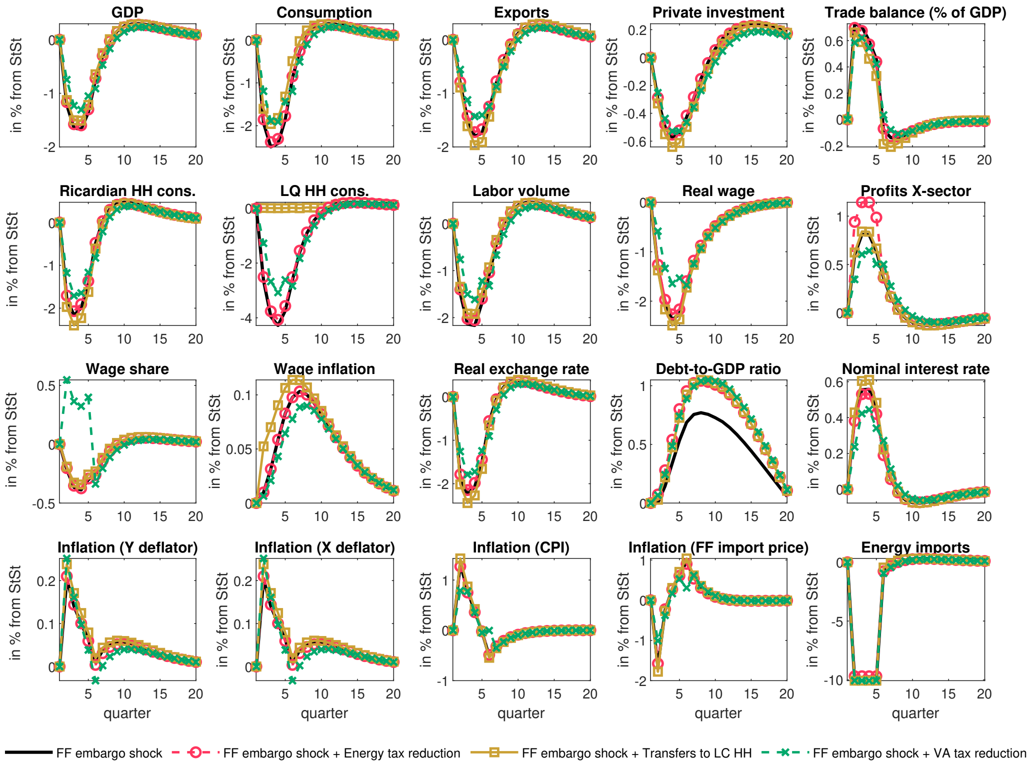

Figure 5: Impulse Response Functions to a 10% FF embargo shock and selected fiscal stabilization policies under Taylor rule

Note: In order to compare stabilization policies we assume a transfer path that fully stabilizes LC HH consumption. In a next step we choose an energy and VA tax path that generates an equal debt path.

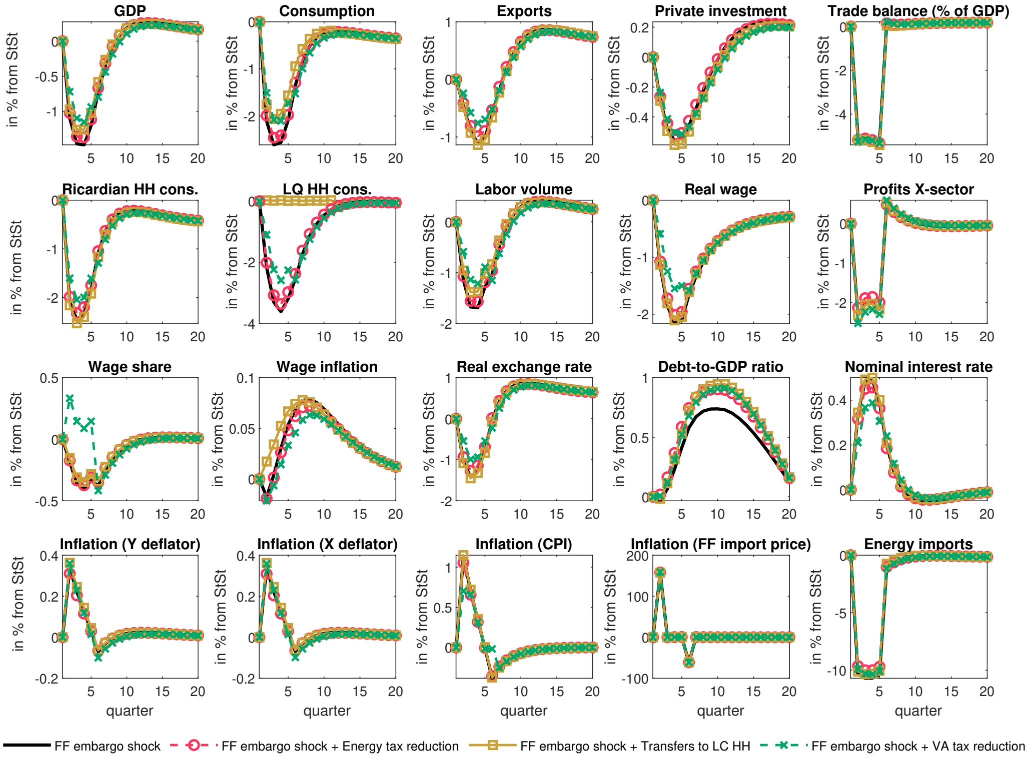

Figure 6: Impulse Response Functions to a 160% FF price shock and selected fiscal stabilization policies under Taylor rule

Note: In order to compare stabilization policies we assume a transfer path that fully stabilizes LC HH consumption. In a next step we choose an energy and VA tax path that generates an equal debt path. We calibrate the FF price shock such that it generates an equal immediate energy import reaction of 10%.

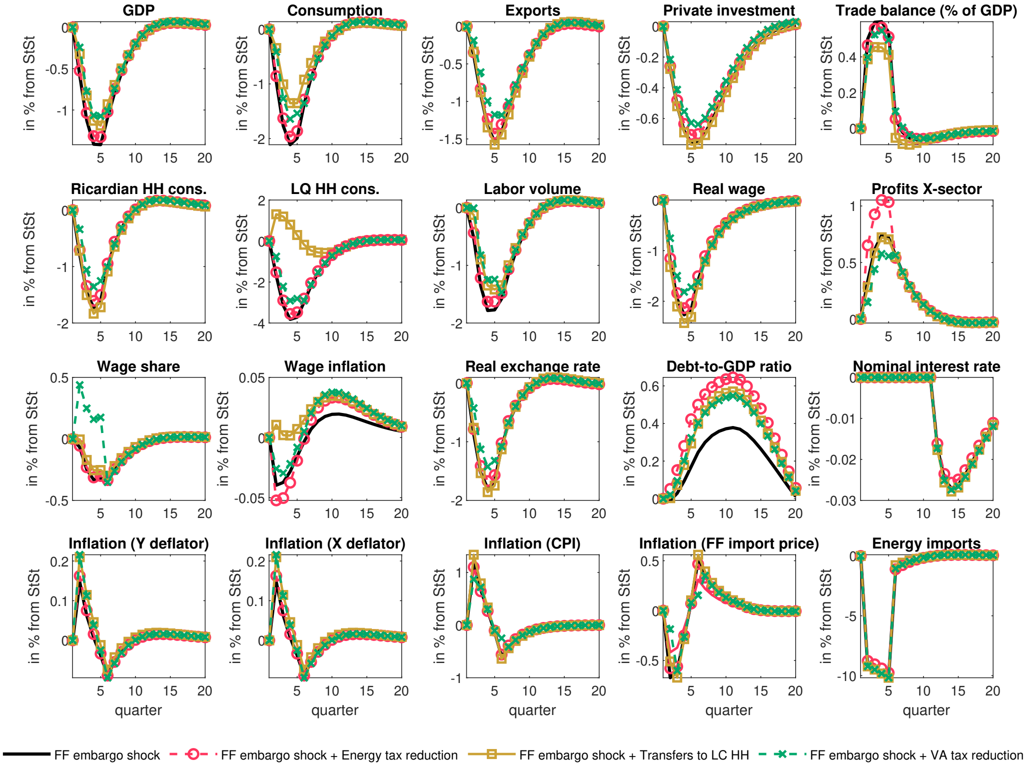

Figure 7: Impulse Response Functions to a 10% FF embargo shock and selected fiscal stabilization policies under ZLB

Note: In order to compare the the stabilization effects under Taylor and ZLB we assume the same shock magnitude as in the Taylor rule scenario.

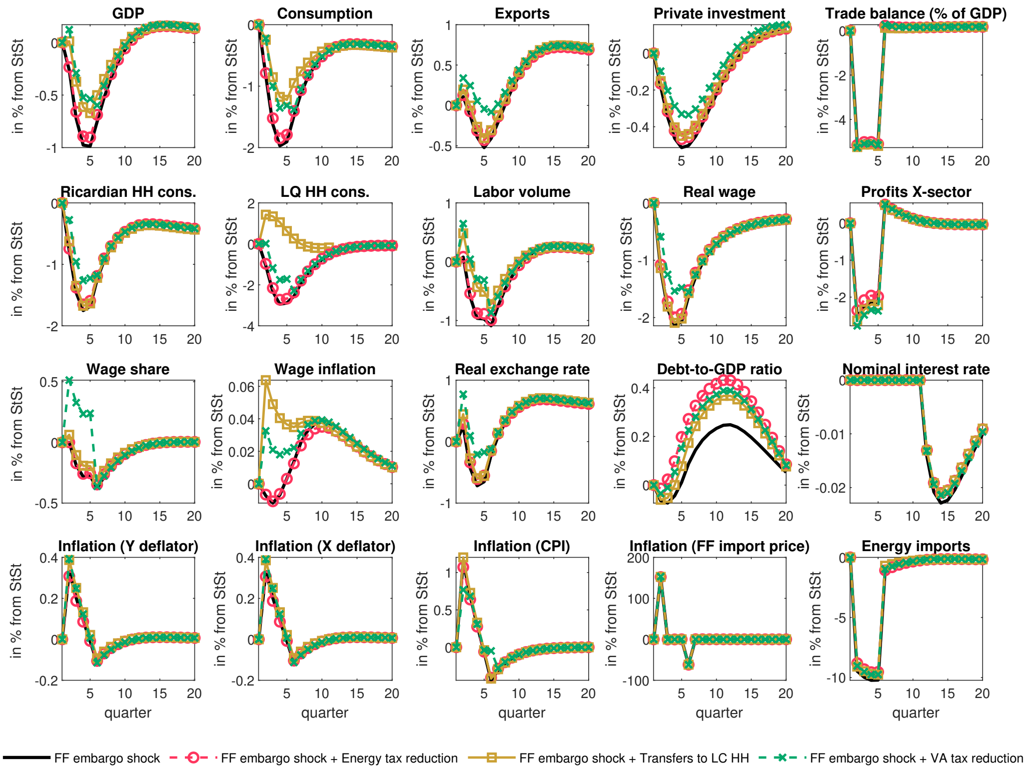

Figure 8: Impulse Response Functions to a 160% FF price shock and selected fiscal stabilization policies under ZLB

Note: In order to compare the the stabilization effects under Taylor and ZLB we assume the same shock magnitude as in the Taylor rule scenario. We calibrate the FF price shock such that it generates an equal immediate energy import reaction of 10%.

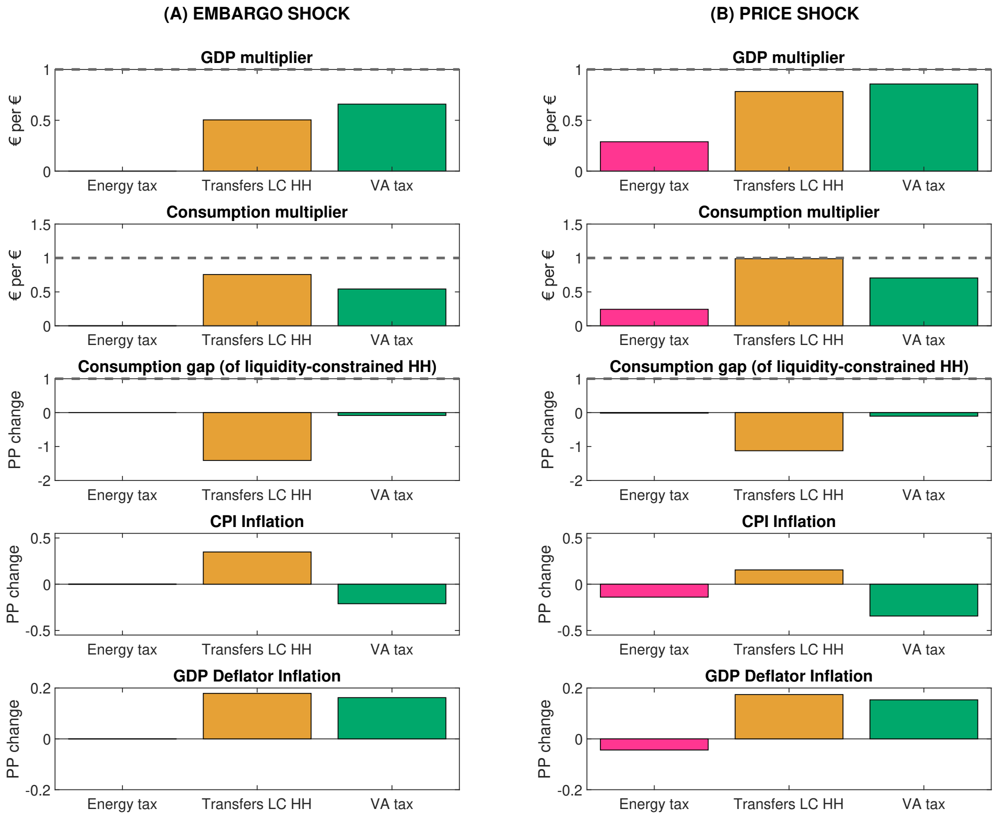

Figure 9: Multiplier, price and debt effects of selected fiscal stabilization policies after one year under FF embargo shock (LHS) and FF price shock (RHS), ZLB

Note: The GDP (Y), consumption (C) and employment (L) multipliers are defined as cumulative change of Y, C and L after 4 quarters divided by the cumulative change of specific revenues or transfer payments. The CPI inflation, GDP deflator (PY) inflation and debt per GDP effects are defined as PP change from the no-policy baseline after 4 quarters.

5.2 Model Equations

$RER_t = \frac{E_t P_t^{*Y}}{P_t^Y}$

Production function (Home)

$$Y_t = \left(s^{L\,\frac{1}{\sigma}} X_t^{\frac{\sigma-1}{\sigma}} + s^{O\,\frac{1}{\sigma}} O_t^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{32}$$

Energy share in production

$$S_t = p_t^{oy} \frac{O_t}{Y_t} \tag{33}$$

where $p_t^{oy} = P_t^O / P_t^Y$.

Energy embargo constraint

$$O_t = \min\left(\left(1 - 0.964 \times I_t^{EMB}\right), s^O \left(\frac{(1+\tau_t^O)\, p_t^{*oy} RER_t}{1+\tau_t^{VAT}} \left(1 + \frac{\gamma^M}{1+\tau_t^O} \left((O_t - O_{t-1}) - \beta(O_{t+1} - O_t)\right)\right)\right)^{-\sigma} Y_t \right) \tag{34}$$

Energy input demand

$$O_t = s^O \left(\frac{p_t^{*oy} RER_t}{\left(1 + LM_t^O\right)\left(1 + \tau_t^{VAT}\right)} \right)^{-\sigma} Y_t \tag{35}$$

Intermediate good demand

$$X_t = s^L \left(\frac{p_t^{xy}}{1 + \tau_t^{VAT}} \right)^{-\sigma} Y_t \tag{36}$$

where $p_t^{yc} = P_t^Y / P_t^C$.

Intermediate good production

$$X_t = A_t^X L_t \tag{37}$$

Current Account

$$B_t^* = \left(1 + i_{t-1} - \pi_t^Y\right) B_{t-1}^* + X_t - RER_t\, C_t^M - p_t^{*oy} RER_t O_t \tag{38}$$

Bond market clearing

$$1 + r_t = (1 + \bar{r}^*)\, \frac{RER_{t+1}}{RER_t} - B_t^*\, \gamma^B \tag{39}$$

Terms of Trade

$$TOT_t = p^{cy}{}_t = \left(s^D + s^M\, RER_t^{1-\sigma^C} \right)^{\frac{1}{1-\sigma^C}} \tag{40}$$

where $p_t^{cy} = P_t^C / P_t^Y$.

Domestic consumption

$$C_t^D = s^D \left(\frac{1}{p_t^{cy}} \right)^{-\sigma^C} \tilde{C}_t \tag{41}$$

Import demand

$$C_t^M = s^M \left(\frac{RER_t}{p_t^{cy}} \right)^{-\sigma^C} \tilde{C}_t \tag{42}$$

Total consumption

$$\tilde{C}_t = (1-n)\, C_t^R + nC_t^L \tag{43}$$

Budget constraint (LC HH)

$$\left(1+\tau_t^{VAT}\right) \frac{p_t^{cy}}{p_t^{xy}} C_t^L = L_t w_t^R - \tau_t - T_t + Z_t + T_t^L \tag{44}$$

Consumption euler (Ricardian HH)

$$C_{t+1}^R - hC_t^R = \frac{1+\tau_t^{VAT}}{1+\tau_{t+1}^{VAT}} \frac{(1+r_t)}{1+\rho} \left(C_t^R - hC_{t-1}^R\right) \tag{45}$$

Price inflation

$$w_t^R \left(1 + SSC_t + \gamma^L (L_t - L_{t-1}) - \frac{\gamma^L}{1+R_t} (L_{t+1} - L_t)\right) = A_t^X \left(1 - \left(\mu^P + \gamma^P \left(\frac{1}{1+\rho}\, \pi_{t+1}^X - \pi_t^X\right)\right)\right) \tag{46}$$

where $w_t^R = W_t / P_t^Y$.

Labor supply

$$w_t^R = \left(1+\tau_t^{VAT}\right) \left(1 + \mu^W + \gamma^W \left(\frac{1}{1+\rho}\, \pi_{t+1}^W - \pi_t^X\right)\right) \left(\frac{L_t}{\overline{L}}\right)^{\kappa} \frac{p_t^{cy}}{p_t^{xy}} \tilde{C}_t \tag{47}$$

Aggregate resource constraint (Home)

$$Y_t = X_t + C_t^D + G_t \tag{48}$$

Exports (Home) = Foreign demand

$$X_t = RER_t^{\sigma^C}\, \overline{Y}^* \tag{49}$$

Government budget

$$B_t = Z_t + G_t + (1+r_{t-1})\, B_{t-1} - T_t + n\, T_t^L - \tau_t^Y - \tau_t^{VAT}\, \tilde{C}_t - p^{xy}{}_t\, w^R{}_t SSC_t L_t \tag{50}$$

Transfer rule

$$T_t - T_{t-1} = \left(1 - I_t^B\right) \phi^T \left(B_t - \overline{B}\right) \tag{51}$$

CB Policy rate

$$i_t = \min\left(0.01, \left(\bar{i} \times I_t^i + (1 - I_t^i)\left(\left(1-\phi^i\right)\left(\rho + \phi^\pi \pi^C{}_t \phi^Y \left(\frac{Y_t}{Y_{t-1}} - 1\right)\right) + \phi^i\, i_{t-1}\right)\right)\right) \tag{52}$$

Labor costs

$$W_t^{R,Cost} = W_t^R\, (1 + SSC_t) \tag{53}$$

Real oil price (ROW)

$$p_t^{*oy} = 1 + e_t^\mu \tag{54}$$

Real oil price (Home)

$$p_t^{oy} = RER_t\, p_t^{*oy} \tag{55}$$

Oil price inflation

$$\pi_t^O = \pi_t^Y + \pi_t^{oy} \tag{56}$$

Real rate

$$i_t = r_t + \pi_{t+1}^Y \tag{57}$$

CPI inflation

$$1 + \pi_t^C = \frac{p_{t-1}^{cy}}{p_t^{cy}} \left(1 + \pi_t^Y\right) \tag{58}$$

PPI inflation

$$1 + \pi_t^Y = \frac{p_{t-1}^{xy}}{p_t^{xy}} \left(1 + \pi_t^X\right) \tag{59}$$

Real wage

$$w_t^C = \frac{w_t^R \frac{p_t^{xy}}{p_t^{cy}}}{1 + \tau_t^{VAT}} = \frac{W_t}{\left(1 + \tau_t^{VAT}\right) P_t^C} \tag{60}$$

Real wage dynamics

$$\pi_t^{w,C} = \frac{w_t^C}{w_{t-1}^C} - 1 \tag{61}$$

Wage inflation

$$\pi_t^w = \pi_t^Y + \pi_t^{w,C} + \left(\tau_{t+1}^C - \tau_t^C\right) \tag{62}$$

Gross real oil price

$$p_t^{o,cy} = P_t^{oy} \left(1 + \tau_t^O\right) \tag{63}$$

Relative oil price

$$p_t^{ox} = \frac{p_t^{oy}}{p_t^{xy}} \tag{64}$$

Wage share (Intermediate)

$$ws_t^X = \frac{L_t w_t^R}{X_t} \tag{65}$$

Wage share (Output)

$$ws^Y{}_t = \frac{p_t^{xy} w^R{}_t L_t}{1 + \tau^{VAT}{}_t Y_t} \tag{66}$$

Spending shock

$$G_t = \overline{G} + e_t^G \tag{67}$$

Transfer shock

$$Z_t = \overline{Z} + e_t^Z \tag{68}$$

VAT rate shock

$$\tau_t^{VAT} = \overline{\tau}^{VAT} + e_t^{\tau,C} \tag{69}$$

SSC rate shock

$$SSC_t = \overline{SSC} + e_t^{SSC} \tag{70}$$

LS Tax shock

$$\tau_t^Y = \bar{r}\bar{B} + \bar{G} + \bar{Z} + n\bar{T}^L - \bar{\tau}^{VAT}\bar{c} - \overline{SSC}\bar{w}^R\bar{L} + e_t^{\tau,Y} \tag{71}$$

Energy tariff shock

$$\tau_t^O = G_t^{\tau,O} + \rho^{\tau,O}\tau_{t-1}^O + e_t^{\tau,O} \tag{72}$$

Energy tariff shock II

$$G_t^{\tau,O} = \rho^{G,O}G_{t-1}^{\tau,O} + e_t^{G,O} \tag{73}$$

5.3 Calibration

Table 1: Parameter Values

Name	**Parameter**	**Value**	**Target**
Structural parameter			
SE Energy	σ	0.10	See Bachmann et al. (2022)
Value added share in production	s^{VA}	0.96	$1 - s^O$
Energy share in production	s^O	0.04	$\bar{O}/\bar{Y}$, see table 2
Time preference rate	ρ	0.004	annualized real interest rate$= 1.6\%$
Labor supply elasticity	κ	1.2	See Kollmann et al. (2015)
Price adj. costs	γ^P	20	See Burgert et al. (2020)
Price markup	μ^P	0.1	10% markup
Wage markup	μ^W	0.1	10% markup
Wage adj. costs	γ^W	120	See Burgert et al. (2020)
Share LC HH	n	0.28	See Grabka and Halbmeier (2019)
Export share	s^M	0.40	$\bar{X}/\bar{Y}$, see table 2
SE Import	σ^C	1.5	
Inflation target weight	ϕ^{pi}	1.5	Policy parameter
Output target weight	ϕ^Y	0.25	Policy parameter
Interest rate smoothing	ϕ^i	0.9	Policy parameter
Debt consolidation speed	ϕ^T	0.012	Policy parameter
Domestic absorption share	s^D	0.800	Policy parameter
Foreign bond adj. costs	γ^B	0.001	Policy parameter

Table 2: Matching to empirical values

Name	**Variable**	**Value**	**Empirical Match**
Ratios			
Debt-to-GDP target	$\overline{B}/4\overline{Y}$	2.4	2.4
Capital-output ratio	$\overline{K}/4\overline{Y}$	3	3
Private consumption share	$\overline{C^D}/\overline{Y}$	0.57	0.55
Private investment share	$\overline{I}/\overline{Y}$	0.19	0.18
Gov expenditure share	$\overline{G}/\overline{Y}$	0.22	0.22
Energy consumption share	$\overline{O}/\overline{Y}$	0.04	0.04
Export share (consumer goods)	$\overline{X}/\overline{Y}$	0.27	0.26
Import share (consumer goods)	$\overline{X}/\overline{Y}$	0.23	0.23
Trade balance per GDP (consumer goods)	$(\overline{X}-\overline{C}^M)/\overline{Y}$	0.03	0.03
Labour share	$\overline{WL}/\overline{Y}$	0.44	0.44
Transfer share	$\overline{Z}/\overline{Y}$	0.19	0.19
Value added tax rate	$\overline{\tau}^{VAT}$	0.175	0.175
VAT revenues per GDP	$\frac{\overline{\tau}^{VAT}}{\overline{Y}}$	0.10	0.11
SSC rate	$\overline{SSC}$	0.39	0.39
SSC per GDP	$\frac{\overline{SSC}}{\overline{Y}}$	0.17	0.17

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