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ESSAYS ON MONETARY AND FISCAL POLICY

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Abstract

Recent research unveiled the heterogeneous effects of rising energy prices for low-income and high-income households, as they tend to purchase distinct consumption baskets. In the first chapter, we explore the effects of energy inflation on consumption inequality in a Two-Agent New Keynesian (TANK) model featuring an exogenous energy sector and heterogeneous consumption baskets, and look for the optimal monetary policy response to an energy price shock. We find that rising energy prices widen consumption inequality through the expansions of inflation and income gaps. A Taylor rule targeting core inflation partially approximates the effects of a welfare-maximizing monetary policy.

The second chapter extends the analysis to fiscal policy responses to energy inflation by enriching the TANK framework with a range of fiscal instruments. We compare the effects of targeted transfers and energy subsidies directed to households under alternative financing schemes, and examine both optimal fiscal, and the optimal mix of monetary and fiscal policies. Targeted, price-suppressing instruments provide the best trade-off between output stabilization and inflation control, particularly when financed through distortionary taxes. While optimal fiscal policies improve the macroeconomic response to energy inflation, their marginal contribution over optimal monetary policy alone remains limited.

Contents

List of Figures

Chapter 1

Energy Inflation, Consumption Inequality and Monetary Policy

1.1 Introduction

The year 2021 marked the return of inflation in Europe. After a long period of stability, consumer prices began rising again, and by the end of 2022, the annual European Harmonised Index of Consumer Prices[1] (HICP) inflation, as reported by Eurostat data, had exceeded 10%, remaining persistently high in 2023. According to Gonçalves et al. (2022), the surge in the euro area HICPX inflation – HICP inflation excluding energy and food – during the third quarter of 2021 was initially driven primarily by supply-side factors, later accompanied by rising demand pressures. Also Menyhert et al. (2022) emphasized the central role of energy prices in driving EU inflation. As a net energy importer, the EU faced sharp increases in the cost of gas, electricity, fuel, and other energy products, especially after the Russian invasion of Ukraine in 2022. Energy inflation peaked at over 40% annually,

[1]The European Central Bank's (ECB) main task is to maintain price stability in the euro area and the indicator it uses for monitoring inflation is the Harmonised Index of Consumer Prices (HICP). Inflation is measured by the means of a consumer price index to compare current and past prices of goods and services. The HICP is calculated by Eurostat, the statistical office of the European Union, on the basis of a consumption bundle made up by goods and services that people typically purchase. For further information see: https://www.euro-area-statistics.org/.

significantly influencing prices of non-energy goods. Energy price shocks tend to cascade through the economy, as firms with market power pass on input costs to consumers, amplifying inflationary pressures (Kilian and Zhou, 2022).

From a household perspective, such price changes are perceived as exogenous shocks to real disposable income, as energy prices are taken as given when making consumption and saving decisions (Battistini et al., 2022). Inflation has thereby reduced the real income of European households, hitting low-income families the hardest. Ari et al. (2022) estimated that rising fossil fuel prices in 2022 increased the average household cost of living by approximately 7% of consumption, disproportionately burdening poorer households. This regressive impact of inflation, long recognized in the literature (e.g., Erosa and Ventura, 2002), stems from the higher share of essential goods – such as food and energy – in the consumption baskets of less affluent households. Corsello and Riggi (2023) highlight that the inflationary wave started in 2021, largely driven by energy and food prices, has exacerbated the regressive nature of inflation, as the most vulnerable households consume a much larger share of these primary goods compared to the wealthier ones. The idea that inflation affects different household types unevenly has a strong empirical foundation (e.g. Bach and Ando, 1957; Gürer and Weichenrieder, 2020; Ha et al., 2021). Seminal works by Michael (1979) and Hagemann (1982) revealed that low-income US households devote a relatively larger share of their income to the purchase of basic necessities, and are therefore more affected by the increase in prices of these goods and services. This heterogeneity has been confirmed in Europe as well. Using the Eurostat Household Budget Survey[2] (EU-BHS), Charalampakis et al. (2022) estimated the specific consumption basket of each income quintile group, discovering that the difference between the effective inflation rates experienced by households in the lowest and highest income quintiles has recently increased dramatically, from 0.1% in September 2021 to 1.9% in September 2022. They found that the effects of recent increases in HICP inflation in the euro area differ significantly for low- and high-income households, mainly for two reasons. The first lies in the price or inflation gap, that is the gap between the effective inflation rates experienced by low- and high-income households, determined by their different spending patterns. As a matter of

[2]The Household Budget Survey by Eurostat is a national survey that focuses on households' expenditure on goods and services and gives a picture of living conditions in the EU. It is carried out by each EU country and the results are used to make key macroeconomic indicators. For further information see: https://ec.europa.eu/eurostat/web/household-budget-surveys.

fact, they have heterogeneous consumption baskets: the former allocate a greater fraction of their consumption expenditure on basic necessities, including food, electricity, gas, and heating, while they spend a smaller share of their overall consumption in everything else, such as transportation, recreation, restaurants, and more. The second is the ability to amortize increases in the cost of living through savings. Low-income households tend, more often than high-income households, to consume a larger share of their income, and save less. Usually, they are unable to spread their consumption over time, for example by the means of financial markets, hence they have a reduced capacity to absorb inflation-driven increases in the cost of living. Battistini et al. (2022, 2023) confirmed that exposure to energy costs differs markedly by income group, observing that energy-intensive consumption[3] is nearly 35% for households in the bottom income quintile, but less than 10% for those at the top. On average, EU households spend about 25.4% of their budget on food and 13% on energy (Menyhert et al., 2022)[4].

This paper studies the distributional effects of energy inflation across households consumption, and look for the optimal monetary policy response to an energy price shock. We focus on energy inflation, one of the key drivers of recent consumer price surges in Europe, and examine its impact on consumption inequality, as consumption data better reflect the effect of inflation on families' consumption bundles, and the heterogeneous dynamics in the relative prices faced by low- and high-income households. An empirical investigation by Bettarelli et al. (2023) shows that energy inflation increases several measures of consumption inequality across a large panel of 129 economies over the period 1970-2013. We conduct a theoretical analysis developing a simplified model of the European economy, featuring two households types and an exogenous energy sector. We augment a standard Two-Agent New Keynesian (TANK) framework to include energy both as an input in production and as a consumption good, assuming the country is a net energy importer and the real price of energy follows an exogenous process – along the lines of Blanchard and Galí (2010). Households are either Savers or Hand-to-Mouth (HtM). The former receive labor income and dividends from firm ownership, and can smooth consumption through financial markets. The latter rely exclusively on labor income, consume their entire earnings each

[3]Energy-intensive consumption, which differs widely across income groups, measures the share of households' monthly income that goes on utilities and transport services, and represents an approximate indicator of their exposure to an energy price change.

[4]Calculations are based on EU-HBS and refer to the year 2022.

period, and don't have access to financial markets. In line with Corsello and Riggi (2023), the model features two distinct consumption baskets, consisting of a household-specific combination of energy and non-energy goods, where HtM devote a higher share of their consumption expenditure on energy than Savers. As a result, HtM consume a larger fraction of their income on energy goods, and are more vulnerable to energy price shocks.
Our work is twofold. First, we explore the effects of energy inflation on households consumption inequality. Second, we look for the optimal monetary policy response to an energy price shock. A rise in the real price of energy leads to higher headline inflation, prompting the Central Bank to raise the policy interest rate. This amplifies contractionary effects of the energy price shock. Firms cut production and maintain positive profits – due to decreasing wages – which are redistributed to Savers. Energy inflation widens the price or inflation gap, entering the households' price indexes, and disproportionately affecting the HtM due to their basket composition. Furthermore, the income gap broadens too, due to the distribution of profits to Savers in the form of dividends, amplifying the rise in the consumption gap between the two consumer types. Aggregate effects resemble a classic cost-push shock: rising inflation, while output, employment, and consumption decline. A welfare-maximizing monetary authority would respond looking through the shock, recognizing the asymmetric impact on households. A moderate rate hike reduces both macroeconomic losses and consumption inequality. This outcome can be approximated in a modified model where the Central Bank targets core inflation, a measure associate with price dispersion and, consequently, proving relevant from a welfare perspective.

Related literature. This paper is related to various strands of the literature. One of them is the extensive branch concerning the study of the effects of energy prices surge on the economy, which has evolved since the oil crises of the 1970s and whose foundations are laid in the articles by Bruno and Sachs (1985), Hamilton (1983) and Hamilton (1996), Hooker (1996), and Rotemberg and Woodford (1996), among others. There is a long tradition of papers employing New Keynesian models to explore this relationship. One of the pioneering contributions is that of Blanchard and Galí (2010), who modify a standard Dynamic Stochastic General Equilibrium (DSGE) model to explain the underlying causes of the different macroeconomic effects of variations in oil prices over time. First, they introduce oil both as an input in production and as a consumption good, assuming that the country is an oil importer, and that the real price of oil, in terms of domestic goods, follows an exogenous process; second, they allow for real wage rigidities along the lines of Blanchard and Galí (2007). They conclude that the effects of oil price shocks must have coincided in time with large shocks of different natures, and that they have changed over time for three possible reasons: a decrease in real wage rigidities, an increased credibility of monetary policy, and the decrease in the share of oil in consumption and in production. In their wake, Blanchard and Riggi (2013) estimate a modified version of the model for the United States (US) economy, while Vásconez et al. (2015) broaden it with capital accumulation. The former find that two major changes have taken place in the US economy since the 1970s: a large decrease of real wage rigidities and a substantial increase in the credibility of monetary policy and the anchoring of inflation expectations. The latter observe that an increase in energy efficiency significantly attenuates the effects of an oil shock, and that oil consumption and energy efficiency have been two major engines for US growth from the 1990s to the 2010s. We contribute to this branch of the literature investigating the implications of energy price shocks on households' consumption inequality. In particular, we draw inspiration from their oil modelling approach and apply it to the broader category of energy goods, within a framework featuring a tractable form of household heterogeneity à la Bilbiie (2008).

We also make our contribution to the domaine of the literature on inflation and inequality, focusing on the effect of energy inflation on consumption inequality, rather than income inequality. A number of works confirm that higher inflation raises income inequality (see, among others, Amble and Stewart, 1994; Bulir and Gulde, 1995; Garner et al., 1996). However, according to Bettarelli et al. (2023), consumption data better reflects the impact of rising prices on the consumption basket of households and different dynamics in the relative prices of goods consumed by rich and poor. They use a large panel of 129 advanced and developing economies during the period 1970-2013, showing that higher energy prices increase several measures of consumption inequality, including the Gini index of consumption inequality and the top/bottom ratios for the 10th and 20th income percentiles. They realize that higher energy prices reduce (increase) the share of consumption for households in the lower (higher) income deciles. We narrow the scope of analysis to Europe and leverage the empirical evidence to construct a theoretical model that can provide us with policy implications.

Another related segment of the literature is the one about the implications of household heterogeneity for macroeconomic dynamics. Indeed, we use specific features of models based on the concept of Limited Asset Market Participation (LAMP), as put forth by Campbell and Mankiw (1989), and subsequently employed in various articles, including Galí et al. (2007), Bilbiie (2008), Colciago (2011), and Albonico et al. (2019). We enhance this setting with an exogenous energy sector and study the optimal monetary policy response to an energy price shock.

Finally, we contribute to the literature that look into the consequences of diverse monetary policy reactions to energy price shocks. Auclert et al. (2023) study the macroeconomic effects of energy price shocks in energy-importing economies using an open-economy Heterogeneous-Agent New Keynesian (HANK) model. They notice that when marginal proprensieties to consume (MPCs) are realistically large and the elasticity between energy and domestic goods is realistically low, energy inflation reduces real incomes and induces a recession, even if the central banks does not tighten monetary policy. Moreover, monetary tightening has 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 raises world energy demand and prices, imposing large negative externalities on other economies. Gnocato (2023) studies the optimal conduct of monetary policy in a tractable HANK model with Search and Matching (S&M) frictions in the labor market and non-homotethic household preferences. He notes that rising energy prices induce a drag on aggregate demand and employment. The price shock acts endogenously as a cost-push term: it implies that the monetary authority optimally accommodates some core inflation so as to contain the rise in unemployment, and hence avoid households to become more exposed to the shock. Chan et al. (2022) build an open-economy TANK model, with labor and imported energy as complementary inputs in production, to analyze the demand side effects of an energy price shock. They conclude that, assuming production inputs are sufficiently difficult to substitute, or that prices are sufficiently flexible, an energy price shock has a negative impact on aggregate demand, i.e. the supply shock has a self-correcting effect, since the reduction in aggregate demand mitigates inflationary pressures. Furthermore, they look for the optimal response of monetary policy to an energy price shock: optimal monetary policy is contractionary in the baseline scenario, but can be expansionsary when the share of financially constrained families rises. We conduct a similar analysis: we study the effect of an energy price shock on consumption inequality and calculate the desirable monetary policy response, assuming, however, heterogeneous consumption baskets across households. The most similar to ours is the model in Corsello and Riggi (2023), who construct and estimate a closed-economy TANK model with imported energy for the Italian economy, concluding that the impact of the shock worsens when monetary policy responds aggressively to inflation. Similarly, we assume that each type of household derives utility from a basket of goods composed of a combination of energy and non-energy goods, where the former are imported, and the latter are domestically produced. Furthermore, in our model too, inspired by data on European households, the share of expenditure for energy is higher for low-income families, which in their case are represented by low-efficiency households. We extend the study to the European case and derive the optimal monetary policy response to an energy price shock.

The remainder of the chapter is organized as follows. Section 1.2 illustrates the model. Aggregate dynamics and results are respectively presented in Section 1.3 and 1.4. Section 1.5 is devoted to optimal monetary policy and Section 1.6 concludes.

1.2 Model

The model builds on the framework of Blanchard and Galí (2010) and Bilbiie (2008). Time is discrete and the horizon is infinite. It consists of a cashless, energy-importing economy populated by households, unions, firms, and a monetary policy authority. As in Bilbiie (2008) there are two types of households: Savers and Hand-to-Mouth (HtM). There are two types of consumption good, energy and non-energy goods, combined in a different consumption basket depending on the consumer type. Savers and HtM consume two different basket of goods, where the share of energy goods (non-energy goods) is relatively higher for HtM (Savers). In summary, Savers purchase a bundle of energy and non-energy goods, hold government bonds and firms shares, and supply labor to firms. HtM purchase another bundle of energy and non-energy goods, and supply labor to firms. Unions populate the monopolistically competitive labor market, setting wages according to a centralized fashion. Firms are distinguished in a continuum of monopolistically competitive intermediate goods firms, and a perfectly competitive final good firm. The former hire labor, purchase energy, and produce differentiated intermediate goods, the latter packages a final good which is sold to households. As for standard New Keynesian Dynamic Stochastic General Equilibrium (DSGE) models, staggered price setting à la Calvo (1983) is introduced in the goods market. Finally, the Central Bank is in charge of monetary policy, setting the short-term nominal interest rate.

1.2.1 Energy

We follow the approach by Blanchard and Galí (2010) for oil, introducing energy both as consumption good and as an input in production, assuming that the country is an energy importer and that the real price of energy, in terms of domestic final good, follows an exogenous process. Energy is imported from abroad at an exogenous world price, $P_{E,t}$, and energy imports are paid for with exports of output, with trade being balanced at every date – an assumption that allows us to consider the economic system as a closed economy. $P_{Q,t}$, represents the price of non-energy goods, i.e. final domestic goods, while the real price of energy in terms of domestic final good is given by

$$S_{E,t} = \frac{P_{E,t}}{P_{Q,t}} \tag{1.1}$$

The real price of energy follows an AR(1) process:

$$\ln S_{E,t} = \rho_{se}\, lnS_{E,t-1} + e_{se,t} \tag{1.2}$$

where $\rho_{se} \in (0,1)$, and $e_{se,t} \sim \mathcal{N}(0, \sigma_{se}^2)$ is an $i.i.d.$ energy price shock with zero mean and constant variance σ_{se}^2.

1.2.2 Households

The economy is populated by a continuum of infinitely-lived households of measure 1, all having the same utility function. A $1-\lambda$ time-invariant share of households is forward-looking and is able to smooth consumption, trading in all complete markets for state-contingent securities. From now on they will be referred to as Savers. The λ remaining share of consumers, henceforth Hand-to-Mouth (HtM), have no access to financial markets: they cannot smooth consumption and entirely consume their disposable income which comes from labor.

Savers

Savers are forward-looking optimizing agents, who smooth consumption, since they are able to trade in all markets for state-contingent securities. They invest in Government bonds and own firms, thus they receive dividends too[5]. Since markets are complete, they can perfectly insurance themselves. Savers maximize their expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t^s N_t^s)$$

where E_0 is the expectation operator conditional on time $t = 0$, $\beta \in (0, 1)$ is the Savers' subjective discount factor, N_t^s represents the Savers' hours of labor, and C_t^s their composite consumption index[6] defined by

$$C_t^s \equiv \left[(1 - \chi_s)^{\frac{1}{\eta}} (C_{Q,t}^s)^{\frac{\eta - 1}{\eta}} + (\chi_s)^{\frac{1}{\eta}} (C_{E,t}^s)^{\frac{\eta - 1}{\eta}} \right]^{\frac{\eta}{\eta - 1}}$$

$C_{Q,t}^s$ is an index of Savers' non-energy goods consumption given by the Constant Elasticity of Substitution (CES) Dixit and Stiglitz (1977) aggregator

$$C_{Q,t}^s \equiv \left(\int_0^1 C_{Q,t}^s(j)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$$

where $j \in [0, 1]$ denotes the generic non-energy variety, and $C_{E,t}^s$ the Savers' energy consumption. Note that η measures the elasticity of substitution between non-energy and energy goods, ϵ_p the elasticity of substitution among non-energy varieties, and $\chi_s \in [0, 1]$ captures the relative weight of energy in the Savers' consumption baskets.

To maximize their expected lifetime utility Savers are subject to a sequence of flow budget

[5] As in Bilbiie and Straub (2004), we do not model the equity market explicitly.
[6] When $\eta = 1$ the composite consumption index becomes $C_t^s = \frac{1}{(1-\chi_s)^{(1-\chi_s)} \chi_s^{\chi_s}} {C_{Q,t}^s}^{1-\chi_s} {C_{E,t}^s}^{\chi_s}$.

constraints of the form

$$\int_0^1 P_{Q,t}(j)C^s_{Q,t}(j)dj + P_{E,t}C^s_{E,t} + B_t \leq W_t N^s_t + R_{t-1}B_{t-1} + P^s_{C,t}D^s_t$$

for $t = 0, 1, 2...$ Where $P_{Q,t}(j)$ is the price of non-energy variety j, $P_{E,t}$ the price of the energy good in terms of domestic currency, B_t is the quantity of nominally riskless one-period bonds purchased in period t offering a nominal gross return, R_t, in period $t+1$, W_t is the nominal wage, and $P^s_{C,t}D^s_t$ are nominal dividends from the ownership of firms. Furthermore, Savers must satisfy the following solvency condition for all t

$$\lim_{T\to\infty} E_t\{B_T\} \geq 0$$

The saver's problem can be divided into three steps. First, he has to allocate his consumption expenditure among different non-energy good varieties. This means that he must maximize $C^s_{Q,t}$ for any given level of expenditures, $\int_0^1 P_{Q,t}(j)C^s_{Q,t}(j)dj$. The solution to this problem yields the Saver's demand schedule for the generic non-energy variety j

$$C^s_{Q,t}(j) = \left(\frac{P_{Q,t}(j)}{P_{Q,t}}\right)^{-\epsilon_p} C^s_{Q,t}$$

for all $j \in [0, 1]$, where

$$P_{Q,t} = \left(\int_0^1 P_{Q,t}(j)^{1-\epsilon_p} dj\right)^{\frac{1}{1-\epsilon_p}}$$

is the price index of non-energy goods, as we are going to see further on.

Second, the Saver must allocate his consumption expenditures between energy and non-energy goods. Therefore he maximizes his composite consumption basket, C^s_t, subject to the Saver's consumption expenditures constraint, $P^s_t C^s_t = P_{Q,t}C^s_{Q,t} + P_{E,t}C^s_{E,t}$. Solving this problem yields the Savers' demand schedules for non-energy and energy goods, respectively given by

$$C^s_{Q,t} = (1-\chi_s)\left(\frac{P_{Q,t}}{P^s_{C,t}}\right)^{-\eta} C^s_t \tag{1.3}$$

and

$$C^s_{E,t} = (\chi_s)\left(\frac{P_{E,t}}{P^s_{C,t}}\right)^{-\eta} C^s_t \tag{1.4}$$

where

$$P^s_{C,t} \equiv \left[(1-\chi_s)(P_{Q,t})^{1-\eta} + \chi_s(P_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{1.5}$$

is the Saver's Consumer Price Index (CPI^s)[7]. Hence Saver's total consumption expenditures are given by

$$P^s_{C,t}C^s_t = P_{Q,t}C^s_{Q,t} + P_{E,t}C^s_{E,t}$$

and his period budget constrain can be rewritten as

$$P^s_{C,t}C^s_t + B_t \leq W_t N^s_t + R_{t-1}B_{t-1} + P^s_{C,t}D^s_t$$

for $t = 0, 1, 2...$

Third, the saver must decide how much to consume, to work, and invest in Government one-period bonds. Solving the following maximization problem allows us to find the Saver's remaining optimality conditions. The intratemporal condition, i.e. his labor supply, is given by

$$-\frac{U_{ns,t}}{U_{cs,t}} = \frac{W_t}{P^s_{C,t}}$$

where $U_{ns,t}$ is Saver's marginal utility of labor, and $U_{cs,t}$ his marginal utility of consumption. The intertemporal condition, i.e. the Euler equation, is given by

$$\frac{1}{R_t} = \beta E_t\left\{\frac{U_{cs,t+1}}{U_{cs,t}}\frac{P^s_{C,t}}{P^s_{C,t+1}}\right\}$$

for $t = 0, 1, 2, ...$

Under the assumption of a Constant Relative Risk Aversion (CRRA) period utility function separable in consumption and hours worked in the form

$$U(C^s_t, N^s_t) = \frac{C^{s\,1-\sigma}_t}{1-\sigma} - \frac{N^{s\,1+\varphi}_t}{1+\varphi}$$

[7]In the particular case of $\eta = 1$, CPI^s becomes $P^s_{C,t} = {P_{Q,t}}^{1-\chi_s}{P_{E,t}}^{\chi_s}$.

the Saver's labor supply and Euler equation can be rewritten respectively as

$$C_t^{s\sigma} N_t^{s\varphi} = \frac{W_t}{P_{C,t}^s}$$

and

$$\frac{1}{R_t} = \beta E_t \left\{ \left(\frac{C_{t+1}^s}{C_t^s} \right)^{-\sigma} \frac{P_{C,t}^s}{P_{C,t+1}^s} \right\} \tag{1.6}$$

where σ measures relative risk aversion and φ is the inverse of Frisch labor supply elasticity. One can define the stochastic discount factor for nominal payoffs from t to $t+1$ as

$$\Theta_{t,t+1} = \beta \frac{\Theta_{t+1}}{\Theta_t} \equiv \beta \frac{U_{cs,t+1}}{U_{cs,t}} \frac{P_{C,t}^s}{P_{C,t+1}^s}$$

i.e.

$$\frac{1}{R_t} = E_t(\Theta_{t,t+1})$$

Consequently, the stochastic discount factor for nominal payoffs from t to $t+k$ is

$$\Theta_{t,t+k} = \beta^k \frac{\Theta_{t+k}}{\Theta_t} = \beta^k \frac{U_{cs,t+k}}{U_{cs,t}} \frac{P_{C,t}^s}{P_{C,t+k}^s}$$

Hand-to-Mouth

Hand-to-Mouth (HtM) are optimizing agents who consume each period their disposable income which comes from labor, and have no access to financial markets because of their constraints or myopic behavior[8], hence they cannot smooth consumption over time. The HtM maximizes his period utility function, $U(C_t^h, N_t^h)$, where N_t^h represents HtM's hours worked, C_t^h the HtM's composite consumption index[9] defined by

$$C_t^h \equiv \left[(1-\chi_h)^{\frac{1}{\eta}} (C_{Q,t}^h)^{\frac{\eta-1}{\eta}} + (\chi_h)^{\frac{1}{\eta}} (C_{E,t}^h)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

[8] They are often referred to as Non-Ricardian, Constrained or Rule-of-Thumb consumers.

[9] When $\eta = 1$ the composite consumption index becomes $C_t^h = \frac{1}{(1-\chi_h)^{(1-\chi_h)} \chi_h^{\chi^h}} {C_{Q,t}^h}^{1-\chi_h} {C_{E,t}^h}^{\chi_h}$.

where $C^h_{Q,t}$ is an index of HtM's consumption of non-energy goods given by the CES function

$$C^h_{Q,t} \equiv \left(\int_0^1 C^h_{Q,t}(j)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$$

where $j \in [0,1]$ denotes the generic non-energy variety, and $C^h_{E,t}$ HtM's consumption of energy goods. Note that $\chi_h \in [0,1]$ measures the share HtM energy consumption.
The period utility function is subject to the following period budget constraint

$$\int_0^1 P_{Q,t}(j) C^h_{Q,t}(j) dj + P_{E,t} C^h_{E,t} \leq W_t N^h_t$$

for $t = 0, 1, 2...$ HtM must allocate his consumption expenditures among different non-energy good varieties, and between energy and non-energy goods. Problems are analogous to the Saver's, and yield the aggregate HtM's consumption expenditures for non-energy goods

$$P_{Q,t} C^h_{Q,t} = \int_0^1 P_{Q,t}(j) C^h_{Q,t}(j) dj$$

the HtM's demand schedule for the generic non-energy variety

$$C^h_{Q,t}(j) = \left(\frac{P_{Q,t}(j)}{P_{Q,t}} \right)^{-\epsilon_p}$$

for all $j \in [0,1]$; and the HtM's optimal conditions related to the allocation of consumption between energy and non-energy goods

$$C^h_{E,t} = \chi_h \left(\frac{P_E, t}{P^h_{C,t}} \right)^{-\eta} C^h_t \tag{1.7}$$

and

$$C^h_{Q,t} = (1 - \chi_h) \left(\frac{P_Q, t}{P^h_{C,t}} \right)^{-\eta} C^h_t \tag{1.8}$$

where

$$P^h_{C,t} \equiv \left[(1 - \chi_h)(P_{Q,t})^{1-\eta} + \chi_h (P_{E,t})^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{1.9}$$

is the Consumer Price Index for Hand-to-Mouth (CPI^h)[10]. The HtM's total consumption expenditures are given by

$$P^h_{C,t}C^h_t = P_{Q,t}C^h_{Q,t} + P_{E,t}C^h_{E,t}$$

and his period budget constraint can be rewritten as

$$P^h_{C,t}C^h_t = W_t N^h_t \tag{1.10}$$

for $t = 0, 1, 2, ...$ HtM's remaining optimality conditions can be computed maximizing its period utility function subject to (1.10). The solution to this problem yields the HtM's optimal condition

$$-\frac{U_{nh,t}}{U_{ch,t}} = \frac{W_t}{P^h_{C,t}}$$

Assuming again a period utility function in the CRRA form

$$U(C^h_t, N^h_t) = \frac{{C^h_t}^{1-\sigma}}{1-\sigma} - \frac{{N^h_t}^{1+\varphi}}{1+\varphi}$$

yields the HtM labor supply

$${C^h_t}^{\sigma}{N^h_t}^{\varphi} = \frac{W_t}{P^h_{C,t}}$$

Aggregation

Aggregate consumption of non-energy and energy goods are respectively equal to

$$C_{Q,t} = (1-\lambda)C^s_{Q,t} + \lambda C^h_{Q,t}$$

and

$$C_{E,t} = (1-\lambda)C^s_{E,t} + \lambda C^h_{E,t}$$

Aggregate consumption in the economy is given by

$$P_{C,t}C_t = (1-\lambda)P^s_{C,t}C^s_t + \lambda P^h_{C,t}C^h_t \tag{1.11}$$

[10]When $\eta = 1$ CPI^h becomes $P^h_{C,t} = {P_{Q,t}}^{1-\chi_h}{P_{E,t}}^{\chi_h}$.

Aggregate hours worked are equal to

$$N_t = (1-\lambda)N_t^s + \lambda N_t^h \tag{1.12}$$

Finally, the aggregate Consumer Price Index (CPI) is

$$P_{C,t} = (1-\lambda)P_{C,t}^s + \lambda P_{C,t}^h \tag{1.13}$$

1.2.3 Unions

Following Galí et al. (2007), an alternative labor market structure is considered. An economy-wide union sets the wages according to a centralized fashion, and firms instead of households determine the hours worked, taking the wage as given. Assuming wages always higher than families' marginal rate of substitutions yields that labor demand from firms is always met. Firms allocate labor demand uniformly across different workers, independently of their household type. As a consequence, the union chooses an equal amount of hours worked for both Savers and HtM

$$N_t^s = N_t^h = N_t \tag{1.14}$$

for all $t = 0, 1, 2, ...$ The wage schedule is then given by

$$\left(\frac{1-\lambda}{C_t^{s\sigma} N_t^{\varphi}} \frac{W_t}{P_{C,t}^s} + \frac{\lambda}{C_t^{h\sigma} N_t^{\varphi}} \frac{W_t}{P_{C,t}^h}\right) = \frac{\epsilon_w}{\epsilon_w - 1}$$

where ϵ_w is the elasticity of substitution across different types of household. In real terms the result can be restated as

$$\left(\frac{1-\lambda}{C_t^{s\sigma} N_t^{\varphi}} \frac{W_{Q,t}^r P_{Q,t}}{P_{C,t}^s} + \frac{\lambda}{C_t^{h\sigma} N_t^{\varphi}} \frac{W_{Q,t}^r P_{Q,t}}{P_{C,t}^h}\right) = \mathcal{M}_w \tag{1.15}$$

where $\mathcal{M}_w \equiv \frac{\epsilon_w}{\epsilon_w - 1}$ is the (constant) wage markup set by unions, $W_{Q,t}^r$ the real product wage defined as

$$W_{Q,t}^r \equiv \frac{W_t}{P_{Q,t}}$$

The equilibrium conditions (1.14) and (1.15) replace the Saver and HtM labor supply schedules. This alternative labor market assumption allows to avoid type-dependent labor supply implications for inequality[11].

1.2.4 Firms

There is a continuum of monopolistically competitive firms indexed by $i \in [0, 1]$ producing differentiate intermediate goods. The latter are used as input by a perfectly competitive firm producing a homogeneous final domestic good.

Final Good Firm

The representative and perfectly competitive final good firm produces the final non-energy good with a CES production function given by

$$Q_t = \left(\int_0^1 Q_t(i)^{\frac{\epsilon_p - 1}{\epsilon_p}} di \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$$

where $Q_t(i)$ is the quantity of the intermediate non-energy good i used as an input, ϵ_p is the constant elasticity of substitution across intermediate non-energy goods. For simplicity no energy is needed to produce the final non-energy good. The final good firm chooses $Q_t(i)$ and Q_t in order to maximize profits, taking $P_{Q,t}(i)$ and $P_{Q,t}$ as given. The solution to its problem provides us the final good firm's demand schedule for the non-energy intermediate good i

$$Q_t(i) = \left(\frac{P_{Q,t}(i)}{P_{Q,t}} \right)^{-\epsilon_p} Q_t$$

where

$$P_{Q,t} = \left(\int_0^1 P_{Q,t}(i)^{1-\epsilon_p} di \right)^{\frac{1}{1-\epsilon_p}}$$

as at the equilibrium final good firm's profits must be equal to zero.

[11] See for instance, among others, Neri et al. (2023).

Intermediate Goods Firms

There is a continuum of intermediate goods firms indexed by $i \in [0, 1]$. Each of them hires a homogeneous type of labor and energy, and produces a differentiated good, exploiting the same technology represented by the following production function

$$Q_t(i) = \begin{cases} A_t E_t(i)^{\alpha} N_t(i)^{1-\alpha} - Fix, & A_t E_t(i)^{\alpha} N_t(i)^{1-\alpha} > Fix \\ 0, & otherwise \end{cases}$$

where $Q_t(i)$ is the quantity of non-energy variety produced by the generic firm i; A_t denotes the level of technology common to all firms, that evolves exogenously over time according to the following rule

$$\ln A_t = \rho_a \ln A_{t-1} + e_{a,t} \tag{1.16}$$

with $\rho_a \in (0, 1)$, and $e_{a,t} \sim \mathcal{N}(0, \sigma_a^2)$ is an $i.i.d.$ technology shock with zero mean and constant variance σ_a^2; $E_t(i)$ and $N_t(i)$ are the quantities of energy and labor used by the generic firm i as input in production, respectively; Fix is a fixed cost common to all intermediate good firms. Note that α and $1 - \alpha$ respectively represent the output elasticities to energy and hours worked.

Intermediate good firms solve a two-stage problem. First, they take input prices as given, and rent labor and energy in perfectly competitive factor markets to minimize costs. Second, they set their price with the aim of maximizing their expected real profits.

Cost minimization. The intermediate good firms take prices of energy, $P_{E,t}$, and labor, W_t, as given, since they are price-takers with respect to both inputs in production. Then they choose the quantity of energy and labor in order to minimize their costs subject to their production technology, with cost function, $Cost_t(i)$, represented by

$$Cost_t(i) = P_{E,t} E_t(i) + W_t N_t(i)$$

The problem's first-order conditions are

$$P_{E,t} = \Psi_t(i) \alpha A_t E_t(i)^{\alpha-1} N_t(i)^{1-\alpha} = \Psi_t(i) \alpha \frac{Q_t(i)}{E_t(i)}$$

and

$$W_t = \Psi_t(i)(1-\alpha)A_t E_t(i)^\alpha N_t(i)^{-\alpha} = \Psi_t(i)(1-\alpha)\frac{Q_t(i)}{N_t(i)}$$

where $\Psi_t(i)$ is the problem's Lagrange multiplier that represents the firm's i nominal marginal cost, since it measures the increase in the cost function as output, $Q_t(i)$, marginally increases. Combining the first-order conditions yields

$$\frac{P_{E,t}E_t(i)}{\alpha} = \frac{W_t N_t(i)}{1-\alpha}$$

Moreover, solving first-order conditions respectively for $E_t(i)$ and $N_t(i)$ allows to rewrite the production function as

$$Q_t(i) = A_t\left(\frac{\alpha\Psi_t(i)Q_t(i)}{P_{E,t}}\right)^\alpha\left(\frac{(1-\alpha)\Psi_t(i)Q_t(i)}{W_t}\right)^{1-\alpha}$$

Solving for Ψ_t

$$\Psi_t(i) = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\frac{P_{E,t}^\alpha W_t^{1-\alpha}}{A_t}$$

Noting that all intermediate firms face the same input prices and have access to the same production technology, it follows that the nominal marginal costs, $\Psi_t(i)$, are identical across firms

$$\Psi_t(i) = \Psi_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\frac{P_{E,t}^\alpha W_t^{1-\alpha}}{A_t}$$

Defining the real marginal cost as

$$MC_t \equiv \frac{\Psi_t}{P_{Q,t}}$$

it can be expressed as

$$MC_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\frac{S_{E,t}^\alpha W_t^{r\,1-\alpha}}{A_t} \tag{1.17}$$

Firm's i cost function can be restated as:

$$Cost_t(Q_t(i)) = \Psi_t(i)Q_t(i) = \Psi_t Q_t(i)$$

Profit maximization under flexible prices. Under flexible prices the intermediate good firms choose $P_{Q,t}(i)$, $Q_t(i)$, $N_t(i)$, and $E_t(i)$ in order to maximize their profits subject to the final good firm's demand schedule. The problem's first-orders condition is given by

$$P^*_{Q,t}(i) = \mathcal{M}_p \Psi_t$$

for all $i \in [0, 1]$, where $\mathcal{M}_p \equiv \frac{\epsilon_p}{\epsilon_p - 1}$ is the firms' (constant) markup under flexible prices or frictionless markup. Each intermediate good firm chooses the optimal price, $P^*_{Q,t}(i)$, for its differentiated non-energy variety as a constant markup over the nominal marginal cost, Ψ_t. However, both the frictionless markup and the nominal marginal cost do not depend on i, since they are identical across firms. For this reason, firm's i optimal price, $P^*_{Q,t}(i)$, is equal to $P^*_{Q,t}$, that is the optimal price for each i, thus

$$P^*_{Q,t} = \mathcal{M}_p \Psi_t$$

Optimal price setting. As mentioned above, intermediate good firms have to set the price, $P_{Q,t}(i)$, in order to maximize their profits. Prices are set à la Calvo (1983), hence each intermediate good firm may readjust its price with probability $1 - \theta$ with $\theta \in [0, 1]$ in any period t, independent of time passed from the last adjustment. This means that in any period a share of $1 - \theta$ of intermediate firms change their prices, while the remaining portion of measure θ keeps the price unchanged, since θ is constant and the law of large numbers holds. In the staggered price setting introduced by Calvo random price duration occurs, and the parameter θ can be thought as an index of price stickiness. All intermediate good firms readjusting their price are in front of the same optimization problem, therefore they are going to go for the same price, $P^*_{Q,t}(i) = P^*_{Q,t}$, for all $i \in [0, 1]$ and $t = 0, 1, 2, ...$ Similarly, all remaining intermediate good firms who are not readjusting their price, are going to maintain the same price of the period before. This means that one can write the following aggregate price level equation

$$P_{Q,t} = \left[(1 - \theta)(P^*_{Q,t})^{1-\epsilon_p} + \theta (P_{Q,t-1})^{1-\epsilon_p} \right]^{\frac{1}{1-\epsilon_p}} \tag{1.18}$$

since the distribution of prices among firms not adjusting in period t corresponds to the distribution of effective prices in period $t-1$ with total mass reduced to θ. In other words, because the adjusting firms were selected randomly in any previous period, the average price of non-adjusting firms is just the average price of all firms that prevailed in period $t-1$ adjusted by a proportionality factor θ.

The representative intermediate firm i that has the opportunity of readjusting its price at time t, i.e. the reoptimizing firm is going to choose the price, $P^*_{Q,t}$, as the problem does not depend on i, that maximizes the sum of expected future real profits subject to the final good firm demand schedule. The first-order condition for $P^*_{Q,t}$ is

$$E_t \sum_{k=0}^{\infty} (\theta\beta)^k \vartheta_{t+k} Q_{t+k} \Big[P^*_{Q,t} P^{\epsilon_p - 1}_{Q,t+k} - \frac{\epsilon_p}{\epsilon_p - 1} MC_{t+k} P^{\epsilon_p}_{Q,t+k} \Big] = 0$$

for all $k \geq 0$, where θ^k is the probability that the newly set price at time t is still in place at time $t+k$; $\vartheta_{t+k} = (C^s_{t+k})^{-\sigma}$, implicitly given by $\vartheta_{t,t+k}$, the stochastic discount factor from t to $t+k$ for real payoffs, defined as $\vartheta_{t,t+k} = \beta^k \frac{\vartheta_{t+k}}{\vartheta_t} \equiv \beta^k \frac{U_{cs,t+k}}{U_{cs,t}} = \beta^k \left(\frac{C^s_{t+k}}{C^s_t} \right)^{-\sigma}$; Q_{t+k} denotes non-energy production for intermediate firms at period $t+k$, and $MC_{t+k} = \frac{\Psi_{t+k}}{P_{Q,t+k}} = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} \frac{P^{\alpha}_{E,t+k} W^{1-\alpha}_{t+k}}{P_{Q,t+k} A_{t+k}}$ is the real marginal cost at time $t+k$. Solving the optimal condition for $P^*_{Q,t}$

$$P^*_{Q,t} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{E_t \sum_{k=0}^{\infty} (\theta\beta)^k (C^s_{t+k})^{-\sigma} MC_{t+k} P^{\epsilon_p}_{Q,t+k} Q_{t+k}}{E_t \sum_{k=0}^{\infty} (\theta\beta)^k (C^s_{t+k})^{-\sigma} P^{\epsilon_p - 1}_{Q,t+k} Q_{t+k}}$$

or

$$P^*_{Q,t} = \frac{\epsilon_p}{\epsilon_p - 1} \frac{Z_{N,t}}{Z_{D,t}} \tag{1.19}$$

where $Z_{N,t}$ and $Z_{D,t}$ are auxiliary variables we use to rewrite recursively the optimal price setting condition, which are respectively defined as

$$Z_{N,t} = E_t \sum_{k=0}^{\infty} (\theta\beta)^k (C^s_{t+k})^{-\sigma} MC_{t+k} P^{\epsilon_p}_{Q,t+k} Q_{t+k} = (C^s_t)^{-\sigma} MC_t P^{\epsilon_p}_{Q,t} Q_t + \theta\beta E_t Z_{N,t+1} \tag{1.20}$$

and

$$Z_{D,t} = E_t \sum_{k=0}^{\infty} (\theta\beta)^k (C_{t+k}^s)^{-\sigma} P_{Q,t+k}^{\epsilon_p - 1} Q_{t+k} = (C_t^s)^{-\sigma} P_{Q,t}^{\epsilon_p - 1} Q_t + \theta\beta E_t Z_{D,t+1} \tag{1.21}$$

Hence, intermediate reoptimizing firms choose an optimal non-energy good price that represents their optimal desired markup over a weighted average of current and expected future marginal costs.

1.2.5 GDP and GDP Deflator

Nominal value added or Gross Domestic Product (GDP) is defined as non-energy production minus energy imports

$$P_{Y,t} Y_t \equiv P_{Q,t} Q_t - P_{E,t} E_t \tag{1.22}$$

where Y_t is real GDP and $P_{Y,t}$ the GDP deflator, implicitly defined by

$$P_{Q,t} \equiv (P_{Y,t})^{1-\alpha} (P_{E,t})^{\alpha} \tag{1.23}$$

1.2.6 Monetary Policy

The Central Bank sets the nominal short-term interest rate by responding to deviations of inflation and output from their steady state values, according to the following Taylor-type interest rate rule

$$\frac{R_t}{R} = \left(\frac{\Pi_{C,t}}{\Pi_C}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y} U_t \tag{1.24}$$

where

$$\Pi_{C,t} \equiv \frac{P_{C,t}}{P_{C,t-1}} \tag{1.25}$$

is the aggregate (gross) CPI inflation between $t-1$ and t, and Π_C is its steady-state level, i.e. the monetary authority's inflation target; Y is the steady state level of GDP; ϕ_π and ϕ_y are the respectively non-negative inflation- and output-response coefficients set by the monetary authority; and U_t is an exogenous monetary policy shock that evolves according to the following AR(1) process

$$\ln U_t = \rho_u \ln U_{t-1} + e_{u,t} \tag{1.26}$$

with $\rho_u \in (0,1)$, and $e_{u,t} \sim \mathcal{N}(0, \sigma_u^2)$ is an $i.i.d.$ monetary policy shock with zero mean and constant variance σ_u^2.

1.2.7 Equilibrium

Market Clearing

At the equilibrium all economic agents solve their optimization problems and all markets clear. The non-energy goods market clearing condition is provided by the aggregate level of non-energy production, equal to

$$Q_t = \left(\int_0^1 Q_t(i)^{\frac{\epsilon_p - 1}{\epsilon_p}} di \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$$

Similarly, the energy goods and labor market clearing conditions are respectively given by

$$E_t = \int_0^1 E_t(i) di$$

and

$$N_t = \int_0^1 N_t(i) di$$

Moreover, at the equilibrium the intermediate good firms' nominal profits are

$$P_{Q,t} O_t = \int_0^1 P_{Q,t}(i) O_t(i) di$$

where they are equally rebated to savers under the form of dividends

$$P_{Q,t} O_t = (1 - \lambda) P_{C,t}^s D_t^s$$

Since markets are complete and consumers who have access to financial markets are identical, Government bonds are always in zero net supply

$$B_t = 0$$

for each $t = 0, 1, 2, ...$ Finally, the economy resource constraint is given by

$$P_{C,t}C_t = P_{Y,t}Y_t \tag{1.27}$$

Aggregation

An aggregate formulation for the intermediate firms' cost minimization condition in real terms is provided by

$$\frac{S_{E,t}E_t}{\alpha} = \frac{W_t^r N_t}{1-\alpha} \tag{1.28}$$

An expression for the intermediate firms' aggregate production function is given by

$$Q_t = \frac{A_t E_t^{\alpha} N_t^{1-\alpha} - F}{\zeta_t} \tag{1.29}$$

where

$$\zeta_t = \int_0^1 \left(\frac{P_{Q,t}(i)}{P_{Q,t}}\right)^{-\epsilon_p} di$$

is the price dispersion term, measuring the inefficiency due to the staggered price setting. As we mentioned above, in each period, a share of intermediate firms of measure θ keeps its price unchanged, while the remaining fraction $1-\theta$ changes its price. It follows that the price dispersion term can be rewritten as

$$\zeta_t = \int_0^{1-\theta} \left(\frac{P_{Q,t}^*}{P_{Q,t}}\right)^{-\epsilon_p} di + \int_{1-\theta}^1 \left(\frac{P_{Q,t-1}(i)}{P_{Q,t}}\right)^{-\epsilon_p} di$$

or, recursively

$$\zeta_t = (1-\theta)\left(\frac{P_{Q,t}^*}{P_{Q,t}}\right)^{-\epsilon_p} + \theta\zeta_{t-1} \tag{1.30}$$

Equilibrium Conditions

The competitive equilibrium is given by a set of processes for the following 30 variables $\left[C^s_{Q,t}, C^s_{E,t}, C^s_t, C^h_{Q,t}, C^h_{E,t}, C^h_t, C_t, N^s_t, N^h_t, N_t, P_{Q,t}, P^*_{Q,t}, P_{E,t}, P^s_{C,t}, P^h_{C,t}, P_{C,t}, P_{Y,t}, S_{E,t},\right.$ $\left.\Pi_{C,t}, MC_t, R_t, Q_t, E_t, W^r_t, \zeta_t, Y_t, A_t, U_t, Z^*_{N,t}, Z^*_{D,t}\right]$ that satisfy the system of non-linear equilibrium conditions including the equations from (2.1) to (2.30). In addition, there are the following 19 parameters $\left[\beta, \lambda, \chi_s, \eta, \epsilon_p, \sigma, \varphi, \chi_h, \epsilon_w, \mathcal{M}_w, \theta, \alpha, Fix, \mathcal{M}_p, \phi_\pi, \phi_y, \rho_{se},\right.$ $\left.\rho_u, \rho_a\right]$. Then, we rewrite the equilibrium conditions only in terms of relative prices and inflation, getting rid of price levels which could be non-stationary. We introduce six new variables: core inflation, $\Pi_{Q,t}$, defined as

$$\Pi_{Q,t} \equiv \frac{P_{Q,t}}{P_{Q,t-1}} \tag{1.31}$$

optimal core inflation

$$\Pi^*_{Q,t} \equiv \frac{P^*_{Q,t}}{P^*_{Q,t-1}} \tag{1.32}$$

relative CPI price and relative GDP deflator in terms of non-energy good price, given by, respectively

$$P_{CQ,t} \equiv \frac{P_{C,t}}{P_{Q,t}} \tag{1.33}$$

and

$$P_{YQ,t} \equiv \frac{P_{Y,t}}{P_{Q,t}} \tag{1.34}$$

relative Saver and HtM CPI price in terms of non-energy good price, given by, respectively

$$P^s_{CQ,t} \equiv \frac{P^s_{C,t}}{P_{Q,t}} \tag{1.35}$$

and

$$P^h_{CQ,t} \equiv \frac{P^h_{C,t}}{P_{Q,t}} \tag{1.36}$$

Finally, we express the auxiliary variables $Z_{N,t}$ and $Z_{D,t}$ in terms of core inflation respectively as

$$Z^*_{N,t} = (C^s_t)^{-\sigma} MC_t Q_t + \theta\beta E_t \Pi^{\epsilon_p}_{Q,t+1} Z^*_{N,t+1} \tag{1.37}$$

and

$$Z^*_{D,t} = (C^s_t)^{-\sigma} Q_t + \theta\beta E_t \Pi^{\epsilon_p - 1}_{Q,t+1} Z^*_{D,t+1} \tag{1.38}$$

We end up with a new competitive equilibrium given by a set of processes for the following 29 variables $\left[C^s_{Q,t}, C^s_{E,t}, C^s_t, C^h_{Q,t}, C^h_{E,t}, C^h_t, C_t, N^s_t, N^h_t, N_t, \Pi_{Q,t}, \Pi^*_{Q,t}, P_{CQ,t}, P_{YQ,t}, S_{E,t}, \Pi_t, MC_t, R_t, Q_t, E_t, W^r_t, \zeta_t, Y_t, A_t, U_t, P^s_{CQ,t}, P^h_{CQ,t}, Z^*_{N,t}, Z^*_{D,t}\right]$ that satisfy the system of 29 non-linear equilibrium conditions[12].

1.2.8 Steady State

The deterministic steady state is found evaluating the equilibrium conditions assuming all variable are constant and in the absence of shocks. Thus, we assume $S_E = A = U = 1$[13], and that steady-state inflation is zero, such that gross CPI inflation is equal to one, $\Pi_C = 1$. At the steady state, the relative Savers and HtM CPI prices are equal to one, $P^s_{CQ} = P^h_{CQ} = 1$, and consequently the aggregate relative CPI too, $P_{CQ} = 1$. The same applies to the relative GDP deflator, $P_{YQ} = 1$. From the definition of aggregate CPI inflation, (1.25), evaluated at the steady state, it follows that $\Pi_Q = 1$. Moreover, following the steady-state version of core inflation dynamics equation, (A.15), $\Pi^*_Q = 1$. Also the price dispersion converges to one, $\zeta = 1$. The Saver's Euler equation collapses to

$$\frac{1}{R} = \beta$$

Combining the auxiliary variable definitions, (A.17) and (A.18), and the optimal core inflation ratio, (A.16), evaluated at the steady state, yields that the steady-state real marginal cost is constant and equal to the inverse of the firms' desired markup

$$MC = \frac{1}{\mathcal{M}_p}$$

[12] See the Appendix

[13] Steady-state variables are denoted by the same letters as before, but without the subscript t.

Employing the equation for the real marginal cost, (A.14), one can find a steady-state expression for the real product wage, W_Q^r, given by

$$W_Q^r = \left[\alpha^\alpha (1-\alpha)^{(1-\alpha)} MC\right]^{\frac{1}{1-\alpha}}$$

From the equation (A.9) it follows that

$$N^s = N^h = N$$

Zero profits in the long-run are assumed. Following Bilbiie (2008), intermediate goods firms' fixed cost is set in order to get zero profits at the steady state. This means that st the steady state there is perfect insurance in consumption for the two types of households, i.e.,

$$C^s = C^h = C$$

Through the wage schedule, (A.4), and the HtM budget constraint, (A.8), we find his steady-state hours worked, N^h, and consumption, C^h, both equal to those of Savers, N^s and C^s, and to the aggregate steady-state levels, N and C. Substituting these results into the remaining households' steady-state conditions, we obtain the savers and HtM optimal demands for energy and non-energy goods. Moreover, on the supply side, steady-state energy imports and non-energy production are given respectively by

$$E = \frac{\alpha W_Q^r N}{1-\alpha}$$

and

$$Q = C + E$$

Real value added at the steady state is

$$Y = C$$

Finally, fixed cost Fix are given by

$$Fix = E^\alpha N^{1-\alpha} - Q$$

1.3 Aggregate Dynamics

1.3.1 The IS Equation

We derive the dynamic IS equation to analyze the effects of an energy price shock to the economy. First, we define the index of average consumption gap between Savers and HtM following Chan et al. (2022), as

$$C_{gap,t} \equiv \frac{C_t^s}{C_t^h}$$

which captures the consumption heterogeneity between the two types of household: the greater the consumption inequality, the greater $C_{gap,t}$. At the steady state perfect consumption insurance between families holds, ensuring $C^s = C^h$, hence $C_{gap} = 1$. Second, we log-linearise it around the zero-inflation steady state up to first order, as we do for the aggregate resource constraint of the economy, and the Saver's Euler equation. Finally, we combine them to obtain the dynamic IS equation[14]

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(r_t - E_t \pi^s_{C,t+1}) - E_t \pi_{C,t+1} + E_t \pi_{Y,t+1} + \lambda E_t \Delta c_{gap,t+1} \tag{1.39}$$

where lowercase letters are used to indicate log-linear variables, i.e. log-deviations from their steady-state levels, defined as: $x_t \equiv \ln\left(\frac{X_t}{X}\right)$. Notice that r_t represents the log-deviation of the gross nominal interest rate from its steady state, and $E_t \pi^s_{C,t+1}$ the expected log-linear gross CPI inflation for Savers, given by

$$E_t \pi^s_{C,t+1} = E_t p^s_{C,t+1} - p^s_{C,t}$$

The expectations of aggregate CPI and GDP deflator inflations are respectively given by

$$E_t \pi_{C,t+1} = E_t p_{C,t+1} - p_{C,t}$$

and

$$E_t \pi_{Y,t+1} = E_t p_{Y,t+1} - p_{Y,t}$$

[14] The derivations are included in the Appendix.

Finally, the expected change in the index of average consumption gap is

$$E_t \Delta c_{gap,t+1} = E_t c_{gap,t+1} - c_{gap,t}$$

Solving the dynamic IS equation forward and substituting for these results yields

$$y_t = -\frac{1}{\sigma} E_t \sum_{k=0}^{\infty} (r_{t+k} - \pi^s_{C,t+k+1}) + \left[(1-\lambda)\chi_s + \lambda\chi_h + \frac{\alpha}{1-\alpha} \right] \pi_{SE,t} - \lambda c_{gap,t} \quad (1.40)$$

where

$$\left[(1-\lambda)\chi_s + \lambda\chi_h + \frac{\alpha}{1-\alpha} \right] \pi_{SE,t} = \pi_{C,t} - \pi_{Y,t}$$

The mechanisms through which an energy price shock affects the economy can be summarized as follows. GDP dynamics depend on the expected evolution of three objects. First, the Saver's ex-ante real interest rate, given by the difference between the nominal interest rate and the Saver's expected inflation. Second, energy inflation, $\pi_{SE,t}$. Third, consumption inequality measured by the index of average consumption gap, $c_{gap,t}$. The first channel is triggered by the monetary authority. Following the increase in the price of imported goods and the resulting inflationary pressures, the Central Bank raises the nominal interest rate, which, in turn, leads to an increase in the real interest rate. This monetary policy tightening has a contractionary effect on the economy. The second channel operates through price dynamics. An increase in energy inflation leads to higher CPI inflation, but lower GDP deflator inflation. Given the aggregate resource constraint – up to a first order approximation – if aggregate consumption decreases, GDP must increase. Finally, the value added declines as the consumption gap rises, with the effect being stronger when the share of HtM in the economy is higher. As inequality between the two types of household increases, aggregate demand falls, as a larger share of resources must be allocated to energy spending. This channel, highlighted by Chan et al. (2022), captures the demand-side effects of the energy price shock.

1.3.2 The Consumption Gap

We now investigate the effects of the increase in the real price of energy on the consumption gap, in order to delve into the channels through which energy inflation contributes to household consumption inequality in the model economy. Consider the Saver's and the HtM's budget constraints, given respectively by

$$P^s_{C,t}C^s_t + B_t = W_t N^s_t + R_{t-1}B_{t-1} + P^s_{C,t}D_t$$

and

$$P^h_{C,t}C^h_t = W_t N^h_t$$

Solving them respectively for C^s_t and C^h_t, and noting that in equilibrium Government bonds are in zero net supply, allows to re-express the index of consumption gap as follows

$$C_{gap,t} = \frac{W_t N^s_t + P^s_{C,t}D_t}{P^s_{C,t}} \frac{P^h_{C,t}}{W_t N^h_t}$$

Following Corsello and Riggi (2023), we define the price gap between the two types as the ratio between the HtM's and the Saver's price indexes

$$P_{gap,t} \equiv \frac{P^h_{C,t}}{P^s_{C,t}} = \frac{[1-\chi_h + \chi_h (S_{E,t})^{1-\eta}]^{\frac{1}{1-\eta}}}{[1-\chi_s + \chi_s (S_{E,t})^{1-\eta}]^{\frac{1}{1-\eta}}}$$

and the income gap between the two types as

$$INC_{gap,t} \equiv \frac{W_t N^s_t + P^s_{C,t}D_t}{W_t N^h_t}$$

Thus, we can rewrite the index of consumption gap as

$$C_{gap,t} = P_{gap,t} INC_{gap,t}$$

or, in log-linear terms

$$c_{gap,t} = p_{gap,t} + inc_{gap,t}$$

In our setting, the effect of an energy price shock on consumption inequality is determined by movements in the the price gap and the income gap. The higher the price gap, the higher the index of consumption gap, and the same is true for the income gap. Let's go deeper into these two mechanisms.

The price gap. Log-linearizing $P_{gap,t}$ around the zero-inflation steady state up to first-order approximation yields

$$p_{gap,t} = (\chi_h - \chi_s)s_{e,t}$$

where

$$s_{e,t} \equiv p_{e,t} - p_{q,t}$$

is the log-linearised real price of energy in terms of domestic non-energy good. An energy price shock that raises the real price of energy, $s_{e,t}$, produces an expansion of the price gap, $p_{gap,t}$, as we assume that the HtM consume a larger share of energy goods than Savers ($\chi_h > \chi_s$), generating a growth in the index consumption gap, $c_{gap,t}$, hence increasing consumption inequality. The larger the real price of energy, the larger the differential between the consumption baskets' prices, thus the larger the impact on the differential between Savers' and HtM's consumption. Assuming identical consumption baskets for the two types of consumer shuts off this channel of consumption heterogeneity. Indeed, if $\chi_h = \chi_s = \chi$, it follows that $p_{gap,t} = 0$ for each $t = 0, 1, 2, ...$ As a consequence, the index of average consumption gap becomes coincident with the income gap.

The income gap. As $N_t^s = N_t^h = N_t$ the income gap becomes

$$INC_{gap,t} = 1 + \frac{P_{C,t}^s D_t^s}{W_t N_t}$$

Since nominal profits $P_{Q,t}O_t$ are entirely rebated from intermediate goods firms to Savers, at the equilibrium

$$P_{Q,t}O_t = (1-\lambda)P_{C,t}^s D_t$$

where

$$P_{Q,t}O_t = P_{Q,t}Q_t - W_t N_t - P_{E,t}E_t = \zeta_t(1 - MC_t)Q_t$$

Hence, the ratio between nominal dividends and aggregate labor income can be rewritten as

$$\frac{P_{C,t}^s D_t^s}{W_t N_t} = \frac{\zeta_t(1 - MC_t)Q_t}{(1-\lambda)\zeta_t(1-\alpha)MC_t Q_t} = \frac{1}{(1-\lambda)(1-\alpha)}\frac{1 - MC_t}{MC_t}$$

Defining the firms' average markup weighted by firms' input shares as the inverse of the real marginal cost, as $\mathcal{M}_t \equiv MC_t^{-1}$, the income gap can be rewritten as

$$INC_{gap,t} = 1 + \frac{\mathcal{M}_t - 1}{(1-\lambda)(1-\alpha)}$$

where

$$W_t N_t = \zeta_t (1-\alpha) MC_t Q_t$$

There is a positive relationship between the firms' average markup and the income gap. Notice that, denoting firm i's gross markup as $\mathcal{M}_t(i) = \frac{P_{Q,t}(i)}{\Psi_t(i)}$, and employing the intermediate firms' cost minimization conditions, we can write

$$S_{E,t}\mathcal{M}_t(i)E_t(i) = \alpha Q_t(i)\frac{P_{Q,t}(i)}{P_{Q,t}}$$

Since aggregate non-energy production is given by $Q_t = \left(\int_0^1 Q_t(i)^{\frac{\epsilon_p - 1}{\epsilon_p}} di\right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$, and the demand schedule facing firm i is $Q_t(i) = \left(\frac{P_{Q,t}(i)}{P_{Q,t}}\right)^{-\epsilon_p} Q_t$ it follows that

$$E_t = \frac{\alpha Q_t}{\mathcal{M}_t S_{E,t}}$$

Log-linearizing the result around the zero-inflation steady state up to first order yields

$$e_t = q_t - \mu_t - s_{e,t}$$

There is a negative relationship between firms' average markup – hence profits' share – and the real price of energy, ceteris paribus. This means that, in face of an increase in the real price of energy, for firms' average markup to rise while gross output decreases, a drastic reduction in energy imports is necessary.

1.4 Results

1.4.1 Calibration

The model is calibrated quarterly. Calibration is standard and summarised in Table 1.1, with some specific measures to tailor the model to the euro area economy. The Saver's subjective discount factor, β, is 0.99, consistent with an annualized real interest rate of approximately 4%. The utility function of both types of consumer is assumed logarithmic on consumption, i.e. risk aversion coefficient, σ, is set to 1. The same is true for the inverse of the Frisch labor supply elasticity, φ. The last two values are commonly adopted in the reference literature, providing a standardized benchmark that facilitates comparison with our results. This reasoning also applies for the Calvo parameter, θ, and the elasticity of substitution among differentiated non-energy varieties, ϵ_p, and across different types of households, ϵ_w, respectively fixed to 0.75, 6, and 6. θ is consistent with an average period of one year for price adjustments, ϵ_p and ϵ_w with frictionless price and wage markup both equal to 20% – hence $\mathcal{M} = 1.2$). In line with Auclert et al. (2023), which calibrate their model to capture a large European energy-importing country, we choose a low elasticity of substitution between energy and non-energy goods, η, of 0.1. Moreover, as they do, we assume a high energy shock persistence, ρ_{se}, equal to 0.96, and a share of energy in domestic production, α, equal to 4%. The Total Factor Productivity (TFP) shock has persistence, ρ_a, of 0.9, following Chan et al. (2022), among others; and the persistence of monetary policy shock, ρ_u, is 0.5, as in Galí (2007). The inflation and GDP response coefficients in the monetary policy rule, ϕ_π and ϕ_y, are standard and respectively equal to 1.5 and 0.125. The shares of energy consumption for Savers, χ_s, and HtM, χ_h, are parameterized on the basis of the EU-HBS data, and following the analysis by Corsello and Riggi (2023) and Battistini et al. (2022) for the euro area. The latter observe that the households' energy-intensive consumption, that is the share of their monthly income devoted on utilities and transport services, stands at around 35% for the lowest (i.e. poorest) and at 10% for the highest (i.e. richest) income quintiles. It follows that we set $\chi_s = 0.10$ and $\chi_h = 0.35$. The share of HtM households, λ, is calibrated to 0.20, matching the share of people at risk of poverty and social exclusion in EU in 2022.

Table 1.1: Baseline Calibration

Parameter	**Value**	**Description**
β	0.99	Subjective Discount Factor
λ	0.2	Share of HtM
χ_s	0.1	Share of Energy in Saver's Basket
χ_h	0.35	Share of Energy in HtM's Basket
η	0.1	Energy and Non-Energy Elasticity of Substitution
ϵ_p	6	Non-Energy Goods Elasticity of Substitution
ϵ_w	6	Households Elasticity of Substitution
σ	1	Risk Aversion Coefficient
φ	1	Inverse of Frisch Elasticity
θ	0.75	Calvo Parameter
α	0.04	Share of Energy in Production
Fix	0.132	Fixed Cost
$\mathcal{M}_p$	1.2	Steady-State Firms' Gross Markup
$\mathcal{M}_w$	1.2	Steady-State Wage Gross Markup
ϕ_π	1.5	Inflation Feedback Coefficient
ϕ_y	0.125	GDP Feedback Coefficient
ρ_a	0.9	Autoregressive Coefficient for Technology
ρ_u	0.5	Autoregressive Coefficient for Monetary Policy
ρ_s	0.96	Autoregressive Coefficient for Energy

1.4.2 Impulse Response Functions

Figures 1.1 and 1.2 illustrate the economy's dynamic response to a 25$\%$ increase in standard deviation of the real price of energy. The black line depicts the response of the baseline model, where the consumption baskets of the two household types differ. The blue line, on the other hand, shows the response of the alternative model, where both households share a single, homogeneous consumption basket. Let's begin with the analysis of the baseline case. On the supply side, an unexpected increase in the real price of energy leads intermediate goods firms to reduce their demand for energy inputs. As a result, imported energy falls sharply, and firms also cut domestic production – referred to as non-energy production or gross output. The decline in domestic production is substantial enough to outweigh the reduction in energy imports, leading to a contraction in GDP. The fall in gross output also reduces firms' demand for labor, resulting in lower employment. The decrease in labor demand puts downward pressure on wages, which drop enough to more than offset the increase in firms' production costs caused by the higher energy price. It follows that firms' real marginal cost declines. Consequently, intermediate goods firms' profits – distributed to Savers in the form of dividends – rise, thereby increasing income inequality between Savers and HtM households, as measured by the income gap. On the demand side, the combined decline in wages and employment reduces the aggregate demand: consumption by both Savers and HtM falls, leading to a contraction in aggregate consumption. However, the decline is not uniform across household types: HtM experience a disproportionately larger contraction in consumption. This is driven by two mechanisms. First, the price gap effect: since HtM consumption basket include a higher share of energy goods than those of Savers, they face higher effective inflation following the energy price shock. Second, the income gap effect: as firms' profits rise and are distributed as dividends to Savers, they partially offset their losses in labor income with capital income, while HtM, who rely solely on labor income, suffer a greater income loss. The impact of the shock on aggregate demand propagates through both supply and price channels, as energy is used both as a production input and a consumption good. The increase in CPI inflation prompts the Central Bank to tighten monetary policy, as reflected in a rise in the nominal interest rate. This, in turn, raises the ex-ante real interest rate, exacerbating the contractionary effects of the shock on output.

Turning to the one basket model, the increase in the real price of energy affects the CPI prices of both household types identically, so they experience the same inflation rate. Specifically, both Savers and HtM are assumed to allocate 15% of their total consumption expenditure to energy goods – the weighted average of their respective shares in the baseline. In response to the shock, all aggregate variables follow the same dynamics observed in the baseline. However, the distributional effects differ: the homogeneous basket model eliminates the price gap channel, leaving only the income gap. Consequently, the consumption gap between Savers and HtM is reduced and reflects solely the income gap, which remains positive as in the baseline. The Central Bank reacts similarly to the rise in CPI inflation by raising the policy interest rate, increasing the real interest rate, and reinforcing the recessionary effects of the shock.

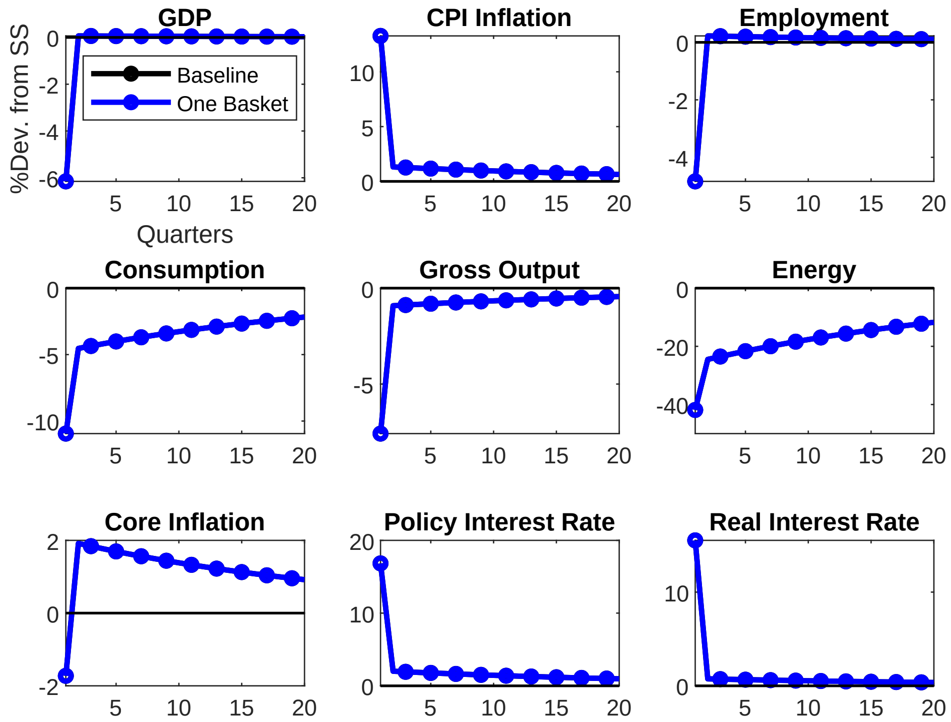

Figure 1.1: Dynamic Response to an Energy Price Shock: Baseline vs One Basket

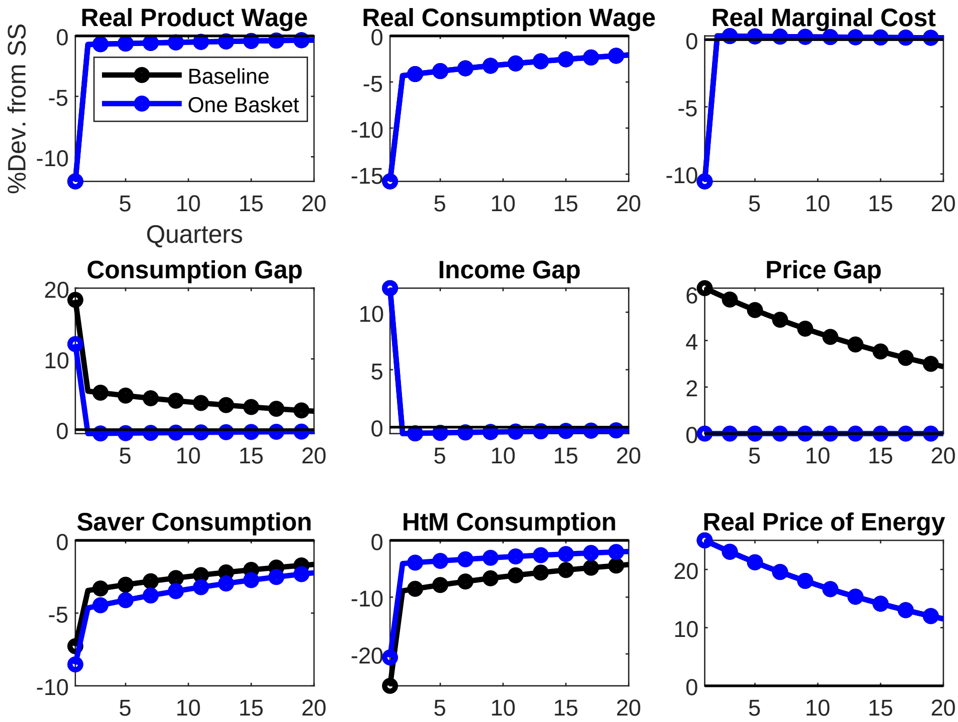

Figure 1.2: Dynamic Response to an Energy Price Shock: Baseline vs One Basket

1.5 Optimal Monetary Policy

This section investigates the optimal monetary policy response to an energy price shock, assuming a Ramsey planner sets monetary policy in a centralized fashion to maximize welfare. Following Bilbiie (2008), the planner maximizes a convex combination of the utilities of the two household types, weighted by their respective population shares, subject to the non-linear equilibrium conditions of the economy's private sector. A fiscal authority provides an optimal employment subsidy that neutralizes the monopolistic competition in goods and labor markets[15], ensuring an efficient and equitable steady state, meaning that the steady-state consumption gap is exactly zero.

Figures 1.3 and 1.4 compare the Ramsey economy's response – blue line – to a 25% increase in the standard deviation of the real price of energy with both baseline – black line – and a decentralized economy where the Central Bank targets core inflation, $\Pi_{Q,t}$ – light blue line. All three specifications feature two household types with heterogeneous consumption baskets, so both the price gap and the income gap channels are active. Let us first compare the Ramsey model to the baseline, where the Central Bank targets headline CPI inflation. The Ramsey economy exhibits a more muted response to the energy price shock: energy inflation leads to a reduction in energy imports and hours worked, causing a decline in domestic production and GDP, though these effects are less pronounced than in the decentralized model. Similar patterns are observed for real wages, marginal costs, profits, and dividends. As in the baseline case, the energy price shock depresses aggregate demand, leading to a decline in consumption that disproportionately affects HtM households, thereby widening the consumption gap. However, the magnitude of this effect differs: in the baseline model, the index of the consumption gap increases by almost 20%, while in the Ramsey model, the increase is approximately of 6%. Therefore, the optimal monetary policy response under the Ramsey planner clearly reduces the impact of energy inflation on consumption inequality. This outcome is driven by the markedly different monetary policy reactions: in the Ramsey model, the policy interest rate rises by only about 30 basis points (bp) annualized, whereas in the baseline by more than 16 percentage points. The stronger response in the baseline amplifies the contractionary impact of the energy price shock, an effect that is notably absent in the Ramsey model, where the declines in consumption and

[15] see Galí (2007), chapter 6.

GDP are significantly mitigated.

The response of a decentralized economy where the monetary policy target is core inflation instead of headline inflation offers further insights. In this specification, the economy's reaction closely resembles that of the Ramsey model. Targeting a measure of underlying inflation proves more effective in both containing consumption inequality and stabilizing the overall economy. This happens because, in this context, core inflation represents the welfare-relevant measure of inflation, given its association with price dispersion. According to Corsello and Riggi (2023), this modelling approach aligns with the ECB's medium-term monetary policy orientation, which allows policymakers to look through temporary shocks – such as exogenous energy price shocks – and thus avoid excessive volatility in interest rates and economic activity.

In summary, our analysis suggests that the optimal monetary policy response to an energy price shock is better approximated by a medium-term core inflation targeting framework rather than one focused on headline CPI inflation. More generally, it appears desirable for central banks to respond less aggressively to temporary shocks, while coordinated fiscal interventions can help the economy absorb these shocks more effectively.

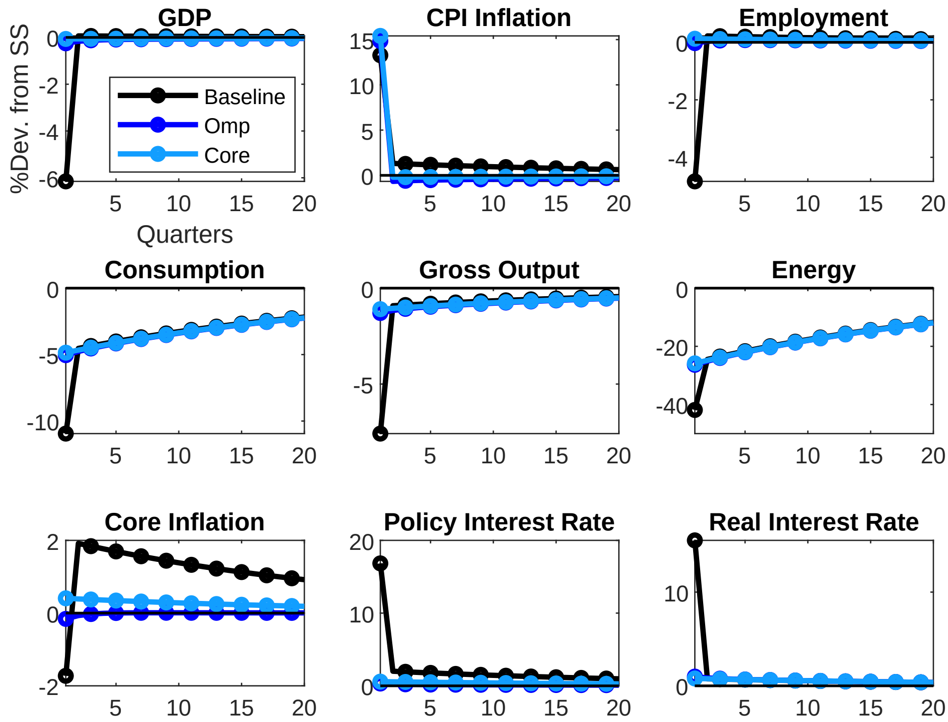

Figure 1.3: Dynamic Response to an Energy Price Shock: Baseline vs Omp vs Core Inflation

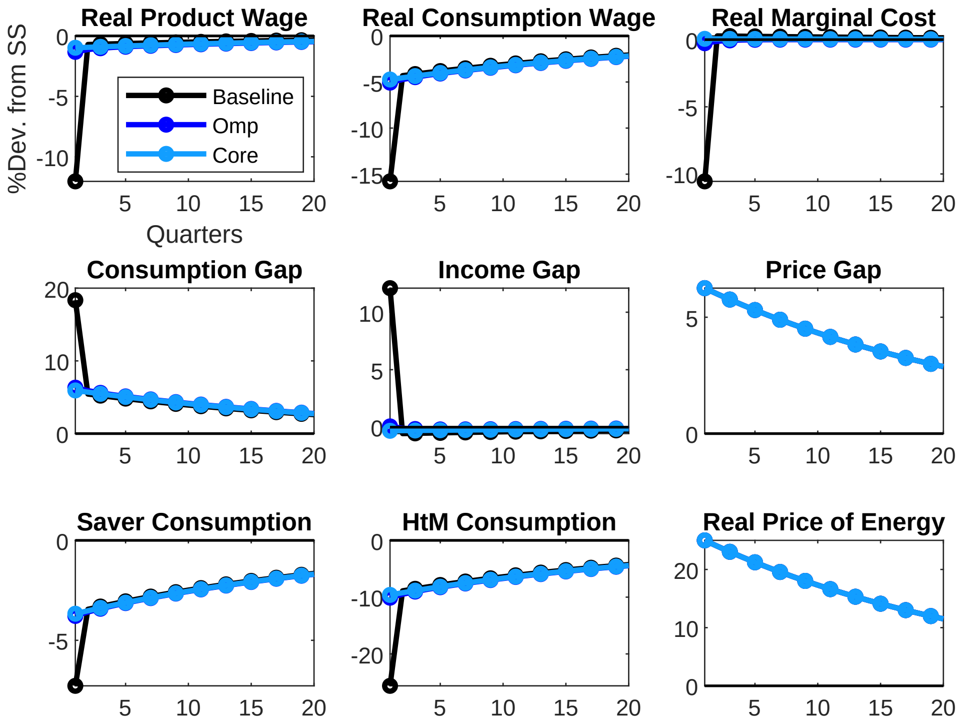

Figure 1.4: Dynamic Response to an Energy Price Shock: Baseline vs Omp vs Core Inflation

1.6 Conclusions

Recent research revealed that the resurgence of inflation – largely driven by spikes in energy prices – had a heterogeneous impact on low- and high-income European households, as tend to purchase distinct consumption baskets, and exhibits diverse abilities to smooth consumption over time. This paper analyzes the effects of energy inflation on consumption inequality, and explores the optimal monetary policy to an energy price shock, within a Two-Agent New Keynesian (TANK) model featuring an exogenous energy sector and heterogeneous consumption baskets.

Our findings indicate that an increase in the real price of energy drives up overall price level, prompting a strong reaction by the Central Bank: the policy rate raises significantly, thereby amplifying the contractionary effects of the energy price shock. In turn, firms sharply cut production but still maintain positive profits – partly due to wage reductions. Energy inflation directly affects households' consumption baskets, hence households' consumer price indexes, with a disproportionate impact on Hand-to-Mouth households due to the composition of their expenditures. Beyond the price or inflation gap effect, the income gap widens as well: profits generated by firms are distributed as dividends to Savers, further exacerbating consumption inequality between the two groups. At the aggregate level, the economy exhibits the typical features of a negative supply shock, with rising inflation and declines in output and employment.

Our analysis of the Ramsey optimal monetary policy shows that the Central Bank can adopt a more moderate stance in response to the imported energy price shock. By adjusting the policy rate less aggressively, the Central Bank mitigates the adverse effects on consumption inequality, while also reducing the declines in GDP and employment. Crucially, our results suggest that the welfare-maximizing monetary policy response can be approximated by a Central Bank targeting core inflation, the measure associated with price dispersion and proving relevant from a welfare perspective.

Chapter 2

Fiscal Policies and Energy Inflation

2.1 Introduction

In recent years, many countries have experienced a persistent increase in the growth rate of general price levels. From 2020 to 2022, global average annual inflation surged from 3.2 to 8.7 percent (Dao et al., 2023). While the post-pandemic recovery in 2021 led to widespread inflation across advanced economies, the February 2022 Russian invasion of Ukraine constituted an additional shock, driving most of the extraordinary inflation surge, especially in Europe. In the euro area, inflation rose above the 2% medium-term target in July 2021, and continued to climb throughout that year and most of the year after, peaking at 10.6% in October 2022 (Lane, 2024).

Following the energy crisis triggered by the Russian invasion of Ukraine, major Western central banks embarked on a solid and synchronized monetary policy tightening cycle. The US Federal Reserve (Fed) began its hiking cycle in March 2022, as year-on-year (y-o-y) headline inflation exceeded 8.5 percent. Over the next 14 months, the Fed raised the federal funds rate[1] by a total of 5 percentage points. Similarly, in July 2022, with 12-month headline inflation above 8%, the European Central Bank (ECB) initiated a series of hikes

[1]The US monetary policy stance is primarily set by establishing a target range for the federal funds rate, which is the interest rate at which banks can borrow reserves in private markets on an unsecured, overnight basis. The "stance" of monetary policy refers to whether policy is stimulating or constraining the labor market and inflation.

in its key interest rates, which continued until September 2023 and heightened the ECB policy interest rate[2] by cumulative 400 basis points.

At the same time, European Governments adopted several fiscal relief measures to cushion the impact of soaring energy prices on households and firms (Emiliozzi et al., 2025). A combination of transfers, energy subsidies, and tax cuts was put in place to contain the growth in energy prices, together with the reduction of dependency from Russian energy, and the search of an European price cap on gas (Altomare and Giavazzi, 2023). Between September 2021 and January 2023, European Union (EU) Member States collectively allocated and earmarked €646 billion (Sgaravatti et al., 2023a), while the euro area fiscal support was estimated to be around 1.9% of euro area GDP in 2022 and 1.8% in 2023 (Checherita-Westphal and Dorrucci, 2023), before dropping to 0.4% in 2024 (OECD, 2024). These measures underscored the severity of the energy crisis and reinforced calls for a coordinated EU energy policy and harmonized support schemes to protect the integrity of the European single market (Sgaravatti et al., 2023b).

For net energy-importing economies like the Eurozone or EU as a whole, responding to energy inflation with a persistently tight monetary policy is suboptimal (Ricciutelli, 2024). This is true if monetary policy target is represented by headline CPI inflation, and assuming that the Government does not implement some interventions to mitigate the effects of the energy price shock. This paper relaxes the last assumption to investigate the relationship between energy inflation and the subsequent monetary policy response, when fiscal policies come into play. We build a small-scale closed-economy Two-Agent New Keynesian (TANK) model with energy both as a production input and a consumption good, and with heterogeneous consumption baskets. The structural framework is used to quantify the economic and distributional impacts of each individual fiscal measure. In particular, a variety of scenarios are generated, assuming different alternative fiscal policy tools put in place with the objective of reducing households' consumption inequality. Then, we look at the macroeconomic effects of redistributive fiscal policies, and their interaction with monteray policy through the lens of a dynamic stochastic general equilibrium model of an energy-importing economy. After that, optimal fiscal and monetary-fiscal policies are outlined, in

[2]The ECB's primary policy interest rate is the deposit facility rate, that is the interest rate on deposit facilities, which banks may use to make overnight deposits with the Eurosystem. It represents one of the ECB's three key interest rates, the one through which the central bank steers its monetary policy stance.

response to an inflationary energy price shock.
We find that the effectiveness of non-price-suppressing fiscal instruments critically depends on whether they are targeted or not. Targeted transfers to Hand-to-Mouth households partially mitigate the contractionary impact of the energy price shock by supporting aggregate demand, albeit at the cost of higher inflation and a tighter monetary policy response. Price-suppressing instruments, such as energy subsidies, better mitigate output and employment losses, with their impact strongly influenced by the financing scheme. Subsidies funded through consumption taxes offer the best trade-off between output stabilization and price control. While optimal fiscal policies improve both macroeconomic and distributional outcomes, their gains over optimal monetary policy remain modest.

Related literature. This paper examines the effects of redistributive fiscal policy on economic activity in times of high energy inflation. The idea of fiscal policy as an instrument for a more equal distribution of income, hence with an increasing effect on propensity to consume, dates back to Keynes (1936). As pointed out by Galí (2018), modern New Keynesian economics can be interpreted as a synthesis between some key insights from Keynes' *General Theory*, and Real Business Cycle (RBC) theory and methodologies, developed from the influential work of Kydland and Prescott (1982). The evidence documented by Campbell and Mankiw (1989, 1990, 1991), passing through the *Savers-Spenders Theory of Fiscal Policy* of Mankiw (2000), has been formally integrated into the New Keynesian framework through the development of the so-called TANK model, notably by Galí et al. (2004, 2007), Bilbiie and Straub (2004), and Bilbiie (2008). Galí and coauthors demonstrate that the presence of a sufficient share of Rule-of-Thumbs – households who make consumption decisions based on simplified heuristics rather than perfectly rational optimization – leads to a positive consumption multiplier from Government expenditure. This framework has become a workhorse in the analysis of both monetary and fiscal policy and has been employed, as noted in Bilbiie (2020), to study time-varying fiscal multipliers (Bilbiie et al., 2008); the interaction between public debt and redistribution (Bilbiie et al., 2013; Mehrotra, 2014; Giambattista and Pennings, 2017); and fiscal multipliers under liquidity traps in currency unions (Farhi and Werning, 2016), among the other things.
In the past few years, this class of models has been extended for monetary and fiscal analysis during an energy crisis (see, among others, Corsello and Riggi, 2023 and Chan et al.,

2024 for monetary policy; Bartocci et al., 2024 and Erceg et al., 2024 for fiscal policy). Others conducted similar analyses using full-fledged Heterogeneous Agent New Keynesian (HANK) models (see Auclert et al., 2023; Pieroni, 2023; and Langot et al., 2023, among others). Erceg et al. (2024) use a TANK model with energy in both consumption and production to investigate the stabilizing and redistributive effects of energy subsidies to consumers, following an energy price shock. They find that the fiscal measure reduces first-round effects on headline inflation in response to an energy price spike, but it also causes the pre-subsidy energy price faced by firms to rise enough that the overall effect is a rise in core inflation. Furthermore, the subsidies reduce consumption inequality across households, but targeted transfers to Hand-to-Mouth (HtM) are more efficient as they achieve this goal with a better inflation-output trade-off. Bartocci et al. (2024) employ a two-country TANK to analyze the macroeconomic and distributional effects of several policy responses to a sudden increase in price of fossil fuels. They find that reducing excise taxes on fuel prices has a non-negligible impact on inflation, while it is not the case in the scenario where targeted transfers to HtM are raised. Moreover, the effects of both fiscal instruments on economic activity are relatively small. We contribute to this branch of the literature in several ways. First, we perform an original theoretical exercise, implementing redistributive fiscal policies designed to offset the inequality triggered by the energy crisis. Second, we extend the analysis of Erceg et al. (2024) by assuming heterogeneous consumption baskets between the two types of consumer. Third, we expand the work of Bartocci et al. (2024) generating scenarios under which fiscal measures are financed through distortionary taxes.
Furthermore, this work contributes to the literature on optimal policy design in general equilibrium models – particularly within New Keynesian frameworks with heterogeneity – focusing on both fiscal and joint monetary-fiscal interventions to counteract an energy price shock. The long-standing tradition of optimal policy analysis, rooted in the work of Ramsey (1927), and later developed by Lucas and Stokey (1983), Chamley (1986), Benigno and Woodford (2003) and Schmitt-Grohé and Uribe (2004), has more recently converged with heterogeneous agent models – both tractable and cOmputational – such as those in Courtoy (2022), McKay and Wolf (2023) and Bilbiie et al. (2024). This line of research has also been extended to the context of energy shocks, as in the flexible-price environment of Kharroubi and Smets (2024). They find that a budget-neutral fiscal policy which subsidises firms' energy consumption and low-income credit-constrained households but taxes

high-income unconstrained households, can replicate the first-best allocation. Assuming sticky prices, we begin by characterizing the optimal fiscal policy response for each instrument available to the Government; then, we extend the framework developed in Ricciutelli (2024) to derive the optimal mix of monetary and fiscal policy. The former, provides a benchmark for each scenario previously considered, while the latter sheds light on how the role of Central Bank evolves when fiscal authorities pursue welfare-maximizing interventions.

The remainder of the chapter is structured as follows. Section 2.2 outlines the model. Fiscal policy scenarios are presented in Section 2.3, while Section 2.4 embodies model calibration and numerical results. Section 2.5 is devoted to optimal policy and Section 2.6 concludes.

2.2 Model

The Two-Agent New Keynesian (TANK) model with energy from Ricciutelli (2024)[3] is extended by incorporating a framework suitable for analyzing various fiscal policy measures. Time is discrete and the horizon is infinite. The closed cashless economy is populated by households, unions, firms, a Central Bank, and a Government. There are two consumption goods, energy and non-energy, combined in a different consumption basket depending on the consumer type. Savers and Hand-to-Mouth consume two different baskets of goods, where the share of expenditure for energy (non-energy) is relatively higher for Hand-to-Mouth (Savers). Staggered price setting à la Calvo (1983) is introduced in the goods market. Next the different agents' objectives and constraints are described.

2.2.1 Energy

Following the approach by Blanchard and Galí (2010) for oil, energy is introduced both as a consumption good and an input in production, imported from abroad at an exogenous world price $P_{E,t}$, and paid for with exports of output, with trade being balanced at every date. Given the price of non-energy goods – i.e. the domestic final goods – $P_{Q,t}$, the real

[3] A standard TANK model à la Bilbiie (2008) enriched with an exogenous energy sector following Blanchard and Galí (2010).

price of energy is defined as

$$S_{E,t} \equiv \frac{P_{E,t}}{P_{Q,t}} \tag{2.1}$$

and follows the AR(1) process

$$\ln S_{E,t} = \rho_{se}\; lnS_{E,t-1} + e_{se,t} \tag{2.2}$$

where $\rho_{se} \in (0,1)$, and $e_{se,t} \sim \mathcal{N}(0, \sigma^2_{se})$ is an $i.i.d.$ energy price shock with zero mean and constant variance σ^2_{se}.

2.2.2 Households

The economy is populated by a continuum of infinitely-lived households of measure 1, all having the same utility function. A $1 - \lambda$ time-invariant share of households is forward-looking and is able to smooth consumption, trading in all complete markets for state-contingent securities. From now on they will be referred to as Savers. The λ remaining share of consumers, henceforth Hand-to-Mouth (HtM), have no access to financial markets, they cannot smooth consumption and entirely consume their disposable income which comes from labor.

Savers

Savers are forward-looking optimizing agents. They smooth consumption, since they are able to trade in all markets for state-contingent securities. They invest in Government bonds, own firms, and receive dividends. Since markets are complete they can perfectly insurance themselves. Savers purchase a bundle of energy and non-energy goods, hold Government bonds and firms shares, and supply labor to firms.
Savers maximize their expected lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C^s_t N^s_t)$$

where E_0 is the expectation operator conditional on time $t = 0$, $\beta \in (0,1)$ is the Saver's subjective discount factor, N^s_t represents their hours of labor, and C^s_t their composite consumption index[4] defined by

$$C_t^s \equiv \left[(1-\chi_s)^{\frac{1}{\eta}}(C_{Q,t}^s)^{\frac{\eta-1}{\eta}} + (\chi_s)^{\frac{1}{\eta}}(C_{E,t}^s)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

$C_{Q,t}^s$ is an index of Saver's non-energy goods consumption given by the Constant Elasticity of Substitution (CES) Dixit and Stiglitz (1977) aggregator

$$C_{Q,t}^s \equiv \left(\int_0^1 C_{Q,t}^s(j)^{\frac{\epsilon_p-1}{\epsilon_p}} dj\right)^{\frac{\epsilon_p}{\epsilon_p-1}}$$

where $j \in [0,1]$ denotes the generic non-energy variety, and $C_{E,t}^s$ the Saver's consumption of imported energy. Note that η measures the elasticity of substitution between non-energy and energy goods, ϵ_p the elasticity of substitution among non-energy varieties, and $\chi_s \in [0,1]$ captures the relative weight of energy in the Saver's consumption basket.

To maximize their expected lifetime utility Savers are subject to a sequence of flow budget constraints of the form

$$(1+\tau_{C,t})\left[\int_0^1 P_{Q,t}(j)C_{Q,t}^s(j)dj + (1-\tau_{E,t}^s)P_{E,t}C_{E,t}^s\right] + B_t + P_{C,t}^s T_t^s \leq W_t N_t^s + \\ + R_{t-1}B_{t-1} + P_{C,t}^s D_t^s + P_{C,t}^s Tr_t^s$$

for $t = 0, 1, 2...$ Where $\tau_{C,t}$ is the tax rate on consumption, $P_{Q,t}(j)$ the price of non-energy variety j, $\tau_{E,t}^s$ the energy bonus to Savers – a subsidy from Government on Saver's energy consumption – $P_{E,t}(j)$ the price of the energy good in terms of domestic currency, B_t the quantity of nominally riskless one-period bonds purchased in period t offering a nominal gross return, R_t, in period $t+1$, $P_{C,t}^s$ the Saver's Consumer Price Index CPI^s[5] (CPI^s) defined as

$$P_{C,t}^s \equiv \left[(1-\chi_s)(P_{Q,t})^{1-\eta} + \chi_s(P_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{2.3}$$

T_t^s are lump sum taxes to Savers, W_t is the nominal wage, D_t^s are real dividends from the ownership of firms, and Tr_t^s denotes lump sum transfers to Savers. Furthermore, Savers

[4] When $\eta = 1$ the composite consumption index becomes $C_t^s = \frac{1}{(1-\chi_s)^{(1-\chi_s)}\chi_s^{\chi^s}} {C_{Q,t}^s}^{1-\chi_s} {C_{E,t}^s}^{\chi_s}$.

[5] When $\eta = 1$ becomes $P_{C,t}^s = {P_{Q,t}}^{1-\chi_s} {P_{E,t}}^{\chi_s}$.

must satisfy the following solvency condition for all t

$$\lim_{T\to\infty} E_t\{B_T\} \geq 0$$

The Saver's problem can be divided into three steps. First, he has to allocate his consumption expenditures among different non-energy good varieties. This means that he must maximize $C^s_{Q,t}$ for any given level of expenditures, $\int_0^1 P_{Q,t}(j)C^s_{Q,t}(j)dj$. The solution to this problem yields the Saver's demand schedule for the generic non-energy variety j

$$C^s_{Q,t}(j) = \left(\frac{P_{Q,t}(j)}{P_{Q,t}}\right)^{-\epsilon} C^s_{Q,t}$$

for all $j \in [0, 1]$, where

$$P_{Q,t} = \left(\int_0^1 P_{Q,t}(j)^{1-\epsilon_p} dj\right)^{\frac{1}{1-\epsilon_p}}$$

is the price index of non-energy goods, as we are going to see further on.

Second, Savers must allocate their consumption expenditures between energy and non-energy goods. Therefore they maximize their composite consumption basket, C^s_t, subject to the their consumption expenditures constraint, given by

$$(1 + \tau_{C,t})P^s_{C,t}C^s_t = P_{Q,t}C^s_{Q,t} + (1 - \tau^s_{E,t})P_{E,t}C^s_{E,t} \tag{2.4}$$

Solving this problem yields the Saver's optimal choice for energy and non-energy goods

$$\left[\frac{P_{Q,t}}{(1 - \tau^s_{E,t})P_{E,t}}\right]^{-\eta} = \frac{\chi_s}{1 - \chi_s}\frac{C^s_{Q,t}}{C^s_{E,t}} \tag{2.5}$$

Hence Saver's period budget constrain can be rewritten as

$$(1 + \tau_{C,t})P^s_{C,t}C^s_t + B_t + P^s_{C,t}T^s_t \leq W_tN^s_t + R_{t-1}B_{t-1} + P^s_{C,t}D^s_t + P^s_{C,t}Tr^s_t$$

for $t = 0, 1, 2...$

Third, Savers must decide how much to consume, work, and invest in Government one-period bonds. Solving the following maximization problem allows us to find the Saver's remaining optimality conditions. The intratemporal condition, i.e. its labor supply, is given by

$$-\frac{U_{ns,t}}{U_{cs,t}} = \frac{W_t}{(1+\tau_{C,t})P^s_{C,t}}$$

where $U_{ns,t}$ is Saver's marginal utility of labor, and $U_{cs,t}$ its marginal utility of consumption. The intertemporal condition, i.e. the Consumption Euler equation, is given by

$$\frac{1}{R_t} = \beta E_t \left\{ \frac{U_{cs,t+1}}{U_{cs,t}} \frac{(1+\tau_{C,t})P^s_{C,t}}{(1+\tau_{C,t+1})P^s_{C,t+1}} \right\}$$

for $t = 0, 1, 2, ...$

Under the assumption of a Constant Relative Risk Aversion (CRRA) period utility function separable in consumption and hours worked in the form

$$U(C^s_t, N^s_t) = \frac{C^{s\,1-\sigma}_t}{1-\sigma} - \frac{N^{s\,1+\varphi}_t}{1+\varphi}$$

the saver's labor supply and Euler equation can be rewritten respectively as

$$C^{s\sigma}_t N^{s\varphi}_t = \frac{W_t}{(1+\tau_{C,t})P^s_{C,t}}$$

and

$$\frac{1}{R_t} = \beta E_t \left\{ \left(\frac{C^s_{t+1}}{C^s_t} \right)^{-\sigma} \frac{(1+\tau_{C,t})P^s_{C,t}}{(1+\tau_{C,t+1})P^s_{C,t+1}} \right\} \tag{2.6}$$

where σ measures relative risk aversion and φ is the inverse of Frisch labor supply elasticity. The intratemporal optimality condition is substituted by a wage schedule due to the presence of an economy-wide union. One can define the stochastic discount factor for nominal payoffs from t to $t+1$ as

$$\Theta_{t,t+1} = \beta \frac{\Theta_{t+1}}{\Theta_t} \equiv \beta \frac{U_{cs,t+1}}{U_{cs,t}} \frac{(1-\tau_{C,t})P^s_{C,t}}{(1-\tau_{C,t+1})P^s_{C,t+1}}$$

i.e.

$$\frac{1}{R_t} = E_t(\Theta_{t,t+1})$$

Consequently, the stochastic discount factor for nominal payoffs from t to $t+k$ is

$$\Theta_{t,t+k} = \beta^k \frac{\Theta_{t+k}}{\Theta_t} = \beta^k \frac{U_{cs,t+k}}{U_{cs,t}} \frac{(1-\tau_{C,t})P^s_{C,t}}{(1-\tau_{C,t+1})P^s_{C,t+k}}$$

Hand-to-Mouth

Hand-to-Mouth (HtM) are optimizing agents who consume each period their disposable income which comes from labor, and don't participate to asset markets because of their constraints or myopic behavior[6], hence they cannot smooth consumption over time. They purchase a different bundle of energy and non-energy goods, and supply labor to firms.
HtM maximize their period utility function $U(C^h_t, N^h_t)$, where N^h_t represents their hours worked, C^h_t their composite consumption index[7] defined by

$$C^h_t \equiv \left[(1-\chi_h)^{\frac{1}{\eta}}(C^h_{Q,t})^{\frac{\eta-1}{\eta}} + (\chi_h)^{\frac{1}{\eta}}(C^h_{E,t})^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$

where $C^h_{Q,t}$ is an index of HtM consumption of non-energy goods given by the CES function

$$C^h_{Q,t} \equiv \left(\int_0^1 C^h_{Q,t}(j)^{\frac{\epsilon_p-1}{\epsilon_p}} dj\right)^{\frac{\epsilon_p}{\epsilon_p-1}}$$

where $j \in [0,1]$ denotes the generic non-energy variety, and $C^h_{E,t}$ HtM consumption of energy goods. Note that $\chi_h \in [0,1]$ represents the share of energy in the HtM consumption basket. The period utility function is subject to the following period budget constraint

$$(1+\tau_{C,t})\left[\int_0^1 P_{Q,t}(j)C^h_{Q,t}(j)dj + (1-\tau^h_{E,t})P_{E,t}C^h_{E,t}\right] + P^h_{C,t}T^h_t \leq W_tN^h_t + P^h_{C,t}Tr^h_t$$

[6]They are often referred to as Non-Ricardian, Constrained or Rule-of-Thumb consumers.

[7]When $\eta = 1$ the composite consumption index becomes $C^h_t = \frac{1}{(1-\chi_h)^{(1-\chi_h)}\chi_h^{\chi^h}} {C^h_{Q,t}}^{1-\chi_h} {C^h_{E,t}}^{\chi_h}$.

for $t = 0, 1, 2...$ $\tau^h_{E,t}$ the energy bonus to HtM – a subsidy from Government on HtM energy consumption – , $P^h_{C,t}$ the HtM Consumer Price Index (CPI^h)[8] defined as

$$P^h_{C,t} \equiv \left[(1-\chi_h)(P_{Q,t})^{1-\eta} + \chi_h(P_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{2.7}$$

T^h_t and Tr^h_t respectively denote lump sum taxes and transfers to HtM. HtM allocate their consumption expenditures among different non-energy varieties, and between energy and non-energy goods. Problems are analogous to the Saver's case and yield the aggregate HtM consumption expenditures for non-energy goods

$$P_{Q,t}C^h_{Q,t} = \int_0^1 P_{Q,t}(j)C^h_{Q,t}(j)dj$$

the HtM demand schedule for the generic non-energy variety

$$C^h_{Q,t}(j) = \left(\frac{P_{Q,t}(j)}{P_{Q,t}}\right)^{-\epsilon}$$

for all $j \in [0, 1]$; and the HtM optimal condition related to the allocation of consumption between energy and non-energy goods

$$\left[\frac{P_{Q,t}}{(1-\tau^h_{E,t})P_{E,t}}\right]^{-\eta} = \frac{\chi_h}{1-\chi_h}\frac{C^h_{Q,t}}{C^h_{E,t}} \tag{2.8}$$

The HtM total consumption expenditures are given by

$$(1+\tau_{C,t})P^h_{C,t}C^h_t = P_{Q,t}C^h_{Q,t} + (1-\tau^h_{E,t})P_{E,t}C^h_{E,t} \tag{2.9}$$

and their period budget constraint can be rewritten as

$$(1+\tau_{C,t})P^h_{C,t}C^h_t + P^h_{C,t}T^h_t = W_tN^h_t + P^h_{C,t}Tr^h_t \tag{2.10}$$

for $t = 0, 1, 2, ...$

[8] When $\eta = 1$ CPI^h becomes $P^h_{C,t} = {P_{Q,t}}^{1-\chi_h}{P_{E,t}}^{\chi_h}$.

HtM remaining optimality conditions can be cOmputed maximizing their period utility function subject to (2.10). The solution to this problem yields the HtM optimal condition

$$-\frac{U_{nh,t}}{U_{ch,t}} = \frac{W_t}{(1+\tau_{C,t})P^h_{C,t}}$$

Assuming the same period utility function adopted for Savers in the CRRA form

$$U(C^h_t, N^h_t) = \frac{{C^h_t}^{1-\sigma}}{1-\sigma} - \frac{{N^h_t}^{1+\varphi}}{1+\varphi}$$

yields the HtM labor supply

$${C^h_t}^{\sigma}{N^h_t}^{\varphi} = \frac{W_t}{(1+\tau_{C,t})P^h_{C,t}}$$

A wage schedule due to the introduction of unionized wages substitute both Savers' and HtM labor supply schedules in the equilibrium conditions.

Aggregation

Aggregate consumption of energy and non-energy goods is respectively given by

$$(1-\tau_{E,t})C_{E,t} = (1-\lambda)(1-\tau^s_{E,t})C^s_{E,t} + \lambda(1-\tau^h_{E,t})C^h_{E,t} \tag{2.11}$$

and

$$C_{Q,t} = (1-\lambda)C^s_{Q,t} + \lambda C^h_{Q,t} \tag{2.12}$$

Aggregate consumption in the economy is given by

$$P_{C,t}C_t = (1-\lambda)P^s_{C,t}C^s_t + \lambda P^h_{C,t}C^h_t \tag{2.13}$$

is the tax rate on aggregate consumption. Analogously, the energy bonus on aggregate energy consumption is given by

$$\tau_{E,t} = (1-\lambda)\tau^s_{E,t} + \lambda\tau^h_{E,t} \tag{2.14}$$

Aggregate lump sum transfers and taxes are respectively given by

$$P_{C,t}Tr_t = (1-\lambda)P^s_{C,t}Tr^s_t + \lambda P^h_{C,t}Tr^h_t \tag{2.15}$$

and

$$P_{C,t}T_t = (1-\lambda)P^s_{C,t}T^s_t + \lambda P^h_{C,t}T^h_t \tag{2.16}$$

Aggregate hours worked are equal to

$$N_t = (1-\lambda)N^s_t + \lambda N^h_t \tag{2.17}$$

Finally, the aggregate Consumer Price Index (CPI) is given by

$$P_{C,t} = (1-\lambda)P^s_{C,t} + \lambda P^h_{C,t} \tag{2.18}$$

Unions

Following Galí et al. (2007) a monopolistically competitive labor market populated by a continuum of unions is assumed. Unions set the wages according to a centralized fashion, and firms instead of households determine the hours worked, taking the wage as given. Assuming wages always higher than families' marginal rate of substitutions yields that labor demand from firms is always met. Firms allocate labor demand uniformly across different workers, independently of their household type. As a consequence the union chooses an equal amount of hours worked for both Savers and HtM

$$N^s_t = N^h_t = N_t \tag{2.19}$$

for all t. The wage schedule is given by

$$\left(\frac{1-\lambda}{{C^s_t}^\sigma N^\varphi_t}\frac{W_t}{P^s_{C,t}} + \frac{\lambda}{{C^h_t}^\sigma N^\varphi_t}\frac{W_t}{P^h_{C,t}}\right) = \mathcal{M}_w \tag{2.20}$$

where $\mathcal{M}_w \equiv \frac{\epsilon_w}{\epsilon_w - 1}$ is the (constant) wage markup set by unions, and ϵ_w the elasticity of substitution across different types of household. Notice that the real product wage – wage in terms of unit of non-energy production – can be defined as

$$W^r_{Q,t} \equiv \frac{W_t}{P_{Q,t}} \tag{2.21}$$

Saver and HtM real consumption wages – i.e. wages in terms of unit of consumption – can respectively be defined as

$$W^{s,r}_{C,t} \equiv \frac{W_t}{P^s_{C,t}} \tag{2.22}$$

and

$$W^{h,r}_{C,t} \equiv \frac{W_t}{P^h_{C,t}} \tag{2.23}$$

Consequently, the aggregate real consumption wage is defined as

$$W^r_{C,t} \equiv \frac{W_t}{P_{C,t}} \tag{2.24}$$

The equilibrium conditions (2.19) and (2.20) replace the saver's and HtM's labor supply schedules. This labor market assumption allows to avoid type-dependent labor supply implications for inequality[9].

2.2.3 Firms

Firms are distinguished in a continuum of monopolistically competitive intermediate goods firms and a perfectly competitive final good firm. The former hire labor, purchase energy, and produce differentiated intermediate goods, the latter packages a final good which is sold to households. There is a continuum of monopolistically competitive firms indexed by $i \in [0, 1]$ producing differentiate intermediate goods. The latter are used as input by a perfectly competitive firm producing a homogeneous final domestic good.

[9] See for instance, among others, Neri et al. (2023)

Final Good Firm

The representative and perfectly competitive final good firm produces the final non-energy good with a CES production function given by

$$Q_t = \left(\int_0^1 Q_t(i)^{\frac{\epsilon_p - 1}{\epsilon_p}} di \right)^{\frac{\epsilon_p}{\epsilon_p - 1}}$$

where $Q_t(i)$ is the quantity of the intermediate non-energy good i used as an input, ϵ_p is the constant elasticity of substitution across intermediate non-energy goods. For simplicity no energy is needed to produce the final non-energy good. The final good firm chooses $Q_t(i)$ and Q_t in order to maximize profits, taking $P_{Q,t}(i)$ and $P_{Q,t}$ as given. The solution to its problem provides us the final good firm's demand schedule for the non-energy intermediate good i

$$Q_t(i) = \left(\frac{P_{Q,t}(i)}{P_{Q,t}} \right)^{-\epsilon_p} Q_t$$

for all $i \in [0, 1]$ where

$$P_{Q,t} = \left(\int_0^1 P_{Q,t}(i)^{1-\epsilon_p} di \right)^{\frac{1}{1-\epsilon_p}}$$

as at the equilibrium final good firm's profits must be equal to zero.

Intermediate Goods Firms

There is a continuum of intermediate goods firms indexed by $i \in [0, 1]$. Each of them hires a homogeneous type of labor and energy, and produces a differentiated good, exploiting the same technology represented by the following production function

$$Q_t(i) = \begin{cases} A_t E_t(i)^{\alpha} N_t(i)^{1-\alpha} - Fix, & A_t E_t(i)^{\alpha} N_t(i)^{1-\alpha} > Fix \\ 0, & otherwise \end{cases}$$

where $Q_t(i)$ is the quantity of non-energy variety produced by the generic firm i; A_t denotes the level of technology common to all firms, that evolves exogenously over time according to the following rule

$$\ln A_t = \rho_a \ln A_{t-1} + e_{a,t} \tag{2.25}$$

with $\rho_a \in (0,1)$, and $e_{a,t} \sim \mathcal{N}(0,\sigma_a^2)$ is an $i.i.d.$ technology shock with zero mean and constant variance σ_a^2; $E_t(i)$ and $N_t(i)$ are the quantities of energy and labor used by the generic firm i as input in production, respectively; Fix is a fixed cost common to all intermediate goods firms. Note that α and $1-\alpha$ respectively represent the output elasticities to energy and hours worked.
Intermediate goods firms solve a two-stage problem: first, they take input prices as given and rent labor and energy to minimize costs; second, they set their price with the aim of maximizing their expected real profits.

Cost minimization. The intermediate goods firms take prices of energy $P_{E,t}$ and labor W_t as given, since they are price-takers with respect to both inputs in production. Then they choose the quantity of energy and labor in order to minimize their costs subject to their production technology, with cost function $Cost_t(i)$ represented by

$$Cost_t(i) = P_{E,t}E_t(i) + (1-\tau_w)W_tN_t(i) + T_w$$

where τ_w represents an employment subsidy (constant) rate financed through lump sum taxes T_w[10]. The problem's first-order conditions are

$$P_{E,t} = \Psi_t(i)\alpha A_t E_t(i)^{\alpha-1}N_t(i)^{1-\alpha} = \Psi_t(i)\alpha\frac{Q_t(i)}{E_t(i)}$$

and

$$W_t = \Psi_t(i)(1-\alpha)A_tE_t(i)^{\alpha}N_t(i)^{-\alpha} = \Psi_t(i)(1-\alpha)\frac{Q_t(i)}{(1-\tau_w)N_t(i)}$$

where $\Psi_t(i)$ is the problem's Lagrange multiplier that represents the firm's i nominal marginal cost, since it measures the increase in the cost function as output $Q_t(i)$ marginally increases. Combining the first-order conditions yields

$$\frac{P_{E,t}E_t(i)}{\alpha} = \frac{(1-\tau_w)W_tN_t(i)}{1-\alpha}$$

[10]For the remainder of the decentralized economy analysis, both the employment subsidy rate τ_w and the lump sum taxes to intermediate goods firms T_w are assumed equal to zero. They will play a crucial role in ensuring the steady-state efficient allocation for the normative analysis.

Moreover, solving first-order conditions respectively for $E_t(i)$ and $N_t(i)$ allows to rewrite the production technology as

$$Q_t(i) = A_t\left(\frac{\alpha\Psi_t(i)Q_t(i)}{P_{E,t}}\right)^{\alpha}\left(\frac{(1-\alpha)\Psi_t(i)Q_t(i)}{(1-\tau_w)W_t}\right)^{1-\alpha}$$

Solving for $\Psi_t(i)$

$$\Psi_t(i) = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\frac{P_{E,t}^{\alpha}(1-\tau_w)^{(1-\alpha)}W_t^{(1-\alpha)}}{A_t}$$

Noting that all intermediate firms face the same input prices and have access to the same production technology, it follows that the nominal marginal costs $\Psi_t(i)$ are identical across firms

$$\Psi_t(i) = \Psi_t$$

Defining the real marginal cost as

$$MC_t \equiv \frac{\Psi_t}{P_{Q,t}}$$

the former can be expressed as follows

$$MC_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\frac{S_{E,t}^{\alpha}(1-\tau_w)^{(1-\alpha)}{W_{Q,t}^{r}}^{(1-\alpha)}}{A_t} \tag{2.26}$$

and firm's i cost function can be restated as

$$Cost_t(Q_t(i)) = \Psi_t Q_t(i) + T_w$$

Profit maximization under flexible prices. Under flexible prices the intermediate goods firms choose $P_{Q,t}(i)$, $Q_t(i)$, $N_t(i)$, and $E_t(i)$ in order to maximize their profits subject to the final good firm's demand schedule. The problem's first-orders condition is given by

$$P_{Q,t}^{*}(i) = \mathcal{M}_p\Psi_t$$

for all $i \in [0, 1]$, where $\mathcal{M}_p \equiv \frac{\epsilon_p}{\epsilon_p - 1}$ is the constant markup under flexible prices or firms' desired markup. Each intermediate goods firm chooses the optimal price $P^*_{Q,t}(i)$ for its differentiated non-energy variety as a constant markup over the nominal marginal cost Ψ_t. However, both the frictionless markup and the nominal marginal cost do not depend on i, since they are identical across firms. Then firm's i optimal price $P^*_{Q,t}(i)$ is equal to $P^*_{Q,t}$, that is the optimal price for each firm i

$$P^*_{Q,t} = \mathcal{M}_p \Psi_t$$

Optimal price setting. As mentioned above, intermediate good firms have to set the price $P_{Q,t}(i)$ in order to maximize their profits. Prices are set à la Calvo (1983), hence each intermediate goods firm may readjust its price with probability $1 - \theta$ with $\theta \in [0, 1]$ in any period t, independent of time passed from the last adjustment. This means that in any period a share of $1-\theta$ of intermediate goods firms change their prices, while the remaining portion of measure θ keeps their price unchanged, since θ is constant and the law of large numbers holds. In the staggered price setting introduced by Calvo random price duration occurs, and the parameter θ can be thought as an index of price stickiness. All intermediate good firms readjusting their price are in front of the same optimization problem, therefore they are going to go for the same price $P^*_{Q,t}(i) = P^*_{Q,t}$ for all $i \in [0, 1]$ and $t = 0, 1, 2, ...$ Similarly, all remaining intermediate good firms, who are not readjusting their price, are going to maintain the same price of the period before. This means that one can write the following aggregate price level equation:

$$P_{Q,t} = \left[(1-\theta)(P^*_{Q,t})^{1-\epsilon_p} + \theta(P_{Q,t-1})^{1-\epsilon_p} \right]^{\frac{1}{1-\epsilon_p}} \tag{2.27}$$

since the distribution of prices among firms not adjusting in period t corresponds to the distribution of effective prices in period $t-1$ with total mass reduced to θ. In other words, because the adjusting firms were selected randomly in any previous period, the average price of non-adjusting firms is just the average price of all firms that prevailed in period $t-1$ adjusted by a proportionality factor θ.

The representative intermediate goods firm i that has the opportunity of readjusting its price at time t, i.e. the reoptimizing firm, is going to choose the price $P^*_{Q,t}$ – as the problem does not depend on i – that maximizes the sum of expected future real profits subject to the final good firm demand schedule. The first-order condition for $P^*_{Q,t}$ is

$$E_t \sum_{k=0}^{\infty} (\theta\beta)^k \vartheta_{t+k} Q_{t+k} \left[P^*_{Q,t} P^{\epsilon_p - 1}_{Q,t+k} - \mathcal{M}_p MC_{t+k} P^{\epsilon_p}_{Q,t+k} \right] = 0$$

for all $k \geq 0$, where θ^k is the probability that the newly set price at time t is still in place at time $t+k$; $\vartheta_{t+k} = (C^s_{t+k})^{-\sigma}$, implicitly given by $\vartheta_{t,t+k}$, the stochastic discount factor from t to $t+k$ for real payoffs, defined as $\vartheta_{t,t+k} = \beta^k \frac{\vartheta_{t+k}}{\vartheta_t} = \beta^k \frac{U_{cs,t+k}}{U_{cs,t}} = \beta^k \left(\frac{C^s_{t+k}}{C^s_t} \right)^{-\sigma}$; and Q_{t+k} denotes non-energy production for intermediate firms at period $t+k$. Solving the optimal condition for $P^*_{Q,t}$

$$P^*_{Q,t} = \mathcal{M}_p \frac{E_t \sum_{k=0}^{\infty} (\theta\beta)^k (C^s_{t+k})^{-\sigma} MC_{t+k} P^{\epsilon_p}_{Q,t+k} Q_{t+k}}{E_t \sum_{k=0}^{\infty} (\theta\beta)^k (C^s_{t+k})^{-\sigma} P^{\epsilon_p - 1}_{Q,t+k} Q_{t+k}}$$

or

$$P^*_{Q,t} = \mathcal{M}_p \frac{Z_{N,t}}{Z_{D,t}} \tag{2.28}$$

where $Z_{N,t}$ and $Z_{D,t}$ are auxiliary variables we use to rewrite recursively the optimal price setting condition, which are respectively defined as

$$Z_{N,t} = E_t \sum_{k=0}^{\infty} (\theta\beta)^k (C^s_{t+k})^{-\sigma} MC_{t+k} P^{\epsilon_p}_{Q,t+k} Q_{t+k} = (C^s_t)^{-\sigma} MC_t P^{\epsilon_p}_{Q,t} Q_t + \theta\beta E_t Z_{N,t+1} \tag{2.29}$$

and

$$Z_{D,t} = E_t \sum_{k=0}^{\infty} (\theta\beta)^k (C^s_{t+k})^{-\sigma} P^{\epsilon_p - 1}_{Q,t+k} Q_{t+k} = (C^s_t)^{-\sigma} P^{\epsilon_p - 1}_{Q,t} Q_t + \theta\beta E_t Z_{D,t+1} \tag{2.30}$$

Hence, intermediate goods reoptimizing firms choose an optimal non-energy good price that represents their optimal desired markup over a weighted average of current and expected future marginal costs.

2.2.4 GDP and GDP Deflator

Nominal value added or Gross Domestic Product (GDP) is defined as domestic non-energy or gross production minus energy imports

$$P_{Y,t}Y_t \equiv P_{Q,t}Q_t - P_{E,t}E_t \tag{2.31}$$

where Y_t is real GDP and $P_{Y,t}$ the GDP deflator, implicitly defined by

$$P_{Q,t} \equiv (P_{Y,t})^{1-\alpha}(P_{E,t})^{\alpha} \tag{2.32}$$

2.2.5 Monetary Policy

The Central Bank is in charge of monetary policy and sets the nominal short-term interest rate by responding to deviations of inflation and output from their steady state values, according to the following interest rate Taylor-type rule

$$\frac{R_t}{R} = \left(\frac{\Pi_{C,t}}{\Pi_C}\right)^{\phi_\pi}\left(\frac{Y_t}{Y}\right)^{\phi_y}U_t \tag{2.33}$$

where

$$\Pi_{C,t} \equiv \frac{P_{C,t}}{P_{C,t-1}} \tag{2.34}$$

is the aggregate (gross) CPI inflation between $t-1$ and t, and Π_C is its steady state level i.e. the monetary authority's inflation target; Y is the steady state level of GDP; ϕ_π and ϕ_y are respectively the non-negative inflation- and output-response coefficients set by the monetary authority; and U_t is an exogenous monetary policy shock that evolves according to the following AR(1) process

$$\ln U_t = \rho_u \ln U_{t-1} + e_{u,t} \tag{2.35}$$

with $\rho_u \in (0,1)$, and $e_{u,t} \sim \mathcal{N}(0,\sigma_u^2)$ an $i.i.d.$ monetary policy shock with zero mean and constant variance σ_u^2.

2.2.6 Fiscal Policy

The Government raises lump sum taxes T_w on intermediate goods firms to finance the employment subsidy $\tau_w W_t N_t$[11]. Besides, the fiscal authority finances public expenditure $P_{C,t}G_t$, energy bonus $\tau_{E,t}P_{E,t}C_{E,t}$ and lump sum transfers to households $P_{C,t}Tr_t$, by raising the public debt B_t, taxes on consumption $\tau_{C,t}P_{C,t}C_t$, and lump sum taxes $P_{C,t}T_t$. Hence, the Government budget constraint is given by

$$R_{t-1}B_{t-1} + P_{C,t}G_t + \tau_{E,t}P_{E,t}C_{E,t} + P_{C,t}Tr_t + \tau_w W_t N_t = B_t + \tau_{C,t}P_{C,t}C_t + P_{C,t}T_t + T_w$$

for all $t = 0, 1, 2, ...$ where the real Government spending G_t evolves according to the AR(1) process

$$\ln G_t = \rho_g \ln G_{t-1} + e_{g,t}$$

with $\rho_g \in (0, 1)$, and $e_{g,t} \sim \mathcal{N}(0, \sigma_g^2)$ is a $i.i.d.$ Government spending shock with zero mean and constant variance σ_g^2.

The description of Government behavior in the modeled economy will be expanded in Section 2.3, where different endogenous fiscal policy rules will be introduced. These rules are designed to reduce the inequality caused by the sudden increase in the real price of energy $S_{E,t}$. The various fiscal measures will generate multiple economic scenarios, which will be compared to the baseline scenario, assuming no Government response to the energy price shock. In the baseline the following equilibrium conditions hold

$$G_t = 0 \tag{2.36}$$

$$\tau_{E,t}^s = \tau_{E,t}^h = 0 \tag{2.37}$$

$$\tau_{C,t} = 0 \tag{2.38}$$

$$T_t^s = T_t^h = 0 \tag{2.39}$$

$$Tr_t^s = Tr_t^h = 0 \tag{2.40}$$

for any period.

[11]For the decentralized economy analysis, both the employment subsidy rate τ_w and firms' taxes T_w are assumed equal to zero.

2.2.7 Equilibrium

Market Clearing

At the equilibrium all economic agents solve their optimization problems and all markets clear. The non-energy goods market clearing condition is provided by the aggregate level of non-energy production, equal to

$$Q_t = \left(\int_0^1 Q_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$$

Similarly, the energy goods and labor market clearing conditions are respectively given by

$$E_t = \int_0^1 E_t(i) di$$

and

$$N_t = \int_0^1 N_t(i) di$$

At the equilibrium the intermediate good firms' nominal profits are

$$P_{Q,t} O_t = \int_0^1 P_{Q,t}(i) O_t(i) di$$

with $P_{Q,t}(i)O_t(i) = P_{Q,t}(i)Q_t(i) - Cost_t(i)$, and where aggregate nominal profits are equally rebated to savers under the form of dividends

$$P_{Q,t} O_t = (1 - \lambda) P^s_{C,t} D^s_t$$

Since markets are complete and consumers who have access to financial markets are identical, Government bonds are always in zero net supply

$$B_t = 0 \tag{2.41}$$

for each $t = 0, 1, 2, ...$ Finally, as Government purchases G_t are set to zero, the economy resource constraint is given by

$$P_{C,t} C_t = P_{Y,t} Y_t \tag{2.42}$$

Aggregation

An aggregate formulation for the intermediate goods firms' cost minimization condition in real terms is provided by

$$\frac{S_{E,t}E_t}{\alpha} = \frac{(1-\tau_w)W^r_{Q,t}N_t}{1-\alpha} \tag{2.43}$$

An expression for the intermediate firms' aggregate production function is given by

$$Q_t = \frac{A_t E_t^{\alpha} N_t^{1-\alpha}}{\zeta_t} - \frac{Fix}{\zeta_t} \tag{2.44}$$

where

$$\zeta_t = \int_0^1 \left(\frac{P_{Q,t}(i)}{P_{Q,t}}\right)^{-\epsilon_p} di$$

is the price dispersion term, measuring the inefficiency due to the staggered price setting. As we mentioned above, in each period, a share of intermediate firms of measure θ keeps its price unchanged, while the remaining fraction $1-\theta$ changes its price. It follows that the price dispersion term can be rewritten as

$$\zeta_t = \int_0^{1-\theta} \left(\frac{P^*_{Q,t}}{P_{Q,t}}\right)^{-\epsilon_p} di + \int_{1-\theta}^{1} \left(\frac{P_{Q,t-1}(i)}{P_{Q,t}}\right)^{-\epsilon_p} di$$

or, recursively

$$\zeta_t = (1-\theta)\left(\frac{P^*_{Q,t}}{P_{Q,t}}\right)^{-\epsilon_p} + \theta\zeta_{t-1} \tag{2.45}$$

Equilibrium Conditions

The competitive equilibrium is given by a set of processes for the following 48 variables $\big[C^s_{Q,t}, C^s_{E,t}, C^s_t, C^h_{Q,t}, C^h_{E,t}, C^h_t, C_{E,t}, C_{Q,t}, C_t, N^s_t, N^h_t, N_t, \tau^s_{E,t}, \tau^h_{E,t}, \tau_{E,t}, \tau_{C,t}, Tr^s_t, Tr^h_t, Tr_t,$ $T^s_t, T^h_t, T_t, P_{Q,t}, P^*_{Q,t}, P_{E,t}, P^s_{C,t}, P^h_{C,t}, P_{C,t}, P_{Y,t}, S_{E,t}, \Pi_{C,t}, MC_t, R_t, Q_t, E_t, W_t, W^{s,r}_{C,t}, W^{h,r}_{C,t},$ $W^r_{C,t}, W^r_{Q,t}, \zeta_t, Y_t, B_t, A_t, U_t, G_t, Z^*_{N,t}, Z^*_{D,t}\big]$, that satisfy the system of non-linear equilibrium conditions including the 48 equations from (2.1) to (2.45). In addition, there are the following 20 parameters $\big[\beta, \lambda, \chi_s, \eta, \epsilon_p, \epsilon_w, \sigma, \varphi, \chi_h, \theta, \alpha, Fix, \mathcal{M}_p, \mathcal{M}_w, \phi_\pi, \phi_y,$ $\rho_{se}, \rho_a, \rho_u, \rho_g\big]$. Then, we rewrite the equilibrium conditions only in terms of relative prices and inflation, getting rid of price levels. We introduce the following new variables.

Core inflation $\Pi_{Q,t}$ defined as

$$\Pi_{Q,t} \equiv \frac{P_{Q,t}}{P_{Q,t-1}}$$

optimal core inflation

$$\Pi^*_{Q,t} \equiv \frac{P^*_{Q,t}}{P^*_{Q,t-1}}$$

relative savers and HtM CPI, respectively given by

$$P^s_{CQ,t} \equiv \frac{P^s_{C,t}}{P_{Q,t}} = [1 - \chi_s + \chi_s S^{1-\eta}_{E,t}]^{\frac{1}{1-\eta}} \tag{2.46}$$

and

$$P^h_{CQ,t} \equiv \frac{P^h_{C,t}}{P_{Q,t}} = [1 - \chi_h + \chi_h S^{1-\eta}_{E,t}]^{\frac{1}{1-\eta}} \tag{2.47}$$

relative aggregate CPI and relative GDP deflator in terms of price of the domestic good given by, respectively

$$P_{CQ,t} \equiv \frac{P_{C,t}}{P_{Q,t}} = (1 - \lambda) P^s_{CQ,t} + \lambda P^h_{CQ,t} \tag{2.48}$$

and

$$P_{YQ,t} \equiv \frac{P_{Y,t}}{P_{Q,t}}$$

savers and HtM CPI inflation, respectively defined as

$$\Pi^s_{C,t} \equiv \Pi_{Q,t} \frac{P^s_{CQ,t}}{P^s_{CQ,t-1}} \tag{2.49}$$

and

$$\Pi^h_{C,t} \equiv \Pi_{Q,t} \frac{P^h_{CQ,t}}{P^h_{CQ,t-1}} \tag{2.50}$$

and aggregate CPI inflation, defined as

$$\Pi_{C,t} \equiv \Pi_{Q,t} \frac{P_{CQ,t}}{P_{CQ,t-1}} \tag{2.51}$$

We end up with a new competitive equilibrium given by a set of processes for the following 48 variables $\big[C^s_{Q,t}, C^s_{E,t}, C^s_t, C^h_{Q,t}, C^h_{E,t}, C^h_t, C_{E,t}, C_{Q,t}, C_t, N^s_t, N^h_t, N_t, \tau^s_{E,t}, \tau^h_{E,t},$ $\tau_{E,t}, \tau_{C,t}, Tr^s_t, Tr^h_t, Tr_t, T^s_t, T^h_t, T_t, P^s_{CQ,t}, P^h_{CQ,t}, P_{CQ,t}, P_{YQ,t}, \Pi_{Q,t}, \Pi^*_{Q,t}, \Pi^s_{C,t}, \Pi^h_{C,t}, \Pi_{C,t}, R_t,$ $MC_t, Q_t, E_t, W^{s,r}_{C,t}, W^{h,r}_{C,t}, W^r_{C,t}, W^r_{Q,t}, \zeta_t, Y_t, B_t, Z^*_{N,t}, Z^*_{D,t}, S_{E,t}, A_t, U_t, G_t\big]$, that satisfy the system of 48 non-linear equilibrium conditions[12].

2.2.8 Steady State

The deterministic steady state is found evaluating the equilibrium conditions assuming all variable are constant and in the absence of shocks. Thus, we assume $S_E = A = U = G = 1$[13], and that steady-state inflation is zero, such that gross CPI inflation is equal to one, $\Pi_C = 1$. At the steady state, the relative savers and HtM CPI are equal to one, $P^s_{CQ} = P^h_{CQ} = 1$, and consequently the aggregate relative CPI too, $P_{CQ} = 1$. The same applies to the relative GDP deflator, $P_{YQ} = 1$. From the definition of aggregate CPI inflation, (2.51), evaluated at the steady state, it follows that $\Pi_Q = 1$. Moreover, following the steady-state version of core inflation dynamics equation, (**??**), $\Pi^*_Q = 1$. Also the price dispersion converges to one, $\zeta = 1$. The Saver's Euler equation collapses to

$$\frac{1}{R} = \beta$$

Combining the auxiliary variable definitions, (**??**) and (**??**), and the optimal core inflation ratio, (**??**), evaluated at the steady state, yields that the steady-state real marginal cost is constant and equal to the inverse of the firms' desired markup

$$MC = \frac{1}{\mathcal{M}_p}$$

Employing the equation for the real marginal cost, (**??**), one can find a steady-state expression for the real product wage, W^r_Q, given by

$$W^r_Q = \left[\alpha^\alpha (1-\alpha)^{(1-\alpha)} MC\right]^{\frac{1}{1-\alpha}}$$

[12] See the Appendix.

[13] Steady-state variables are denoted by the same letters as before, but without the subscript t.

From the equation (**??**) it follows that

$$N^s = N^h = N$$

Zero profits in the long-run are assumed. Following Bilbiie (2008), intermediate goods firms' fixed cost is set in order to get zero profits at the steady state. This means that st the steady state there is perfect insurance in consumption for the two types of households, i.e.,

$$C^s = C^h = C$$

Through the wage schedule, (**??**), and the HtM budget constraint, (**??**), we find his steady-state hours worked, N^h, and consumption, C^h, both equal to those of savers, N^s and C^s, and to the aggregate steady-state levels, N and C. Substituting these results into the remaining households' steady-state conditions, we obtain the savers and HtM optimal demands for energy and non-energy goods. Moreover, on the supply side, steady-state energy imports and non-energy production are given respectively by

$$E = \frac{\alpha W_Q^r N}{1-\alpha}$$

and

$$Q = C + E$$

Real value added at the steady state is

$$Y = C$$

Finally, fixed cost Fix are given by

$$Fix = E^{\alpha} N^{1-\alpha} - Q$$

2.3 Fiscal Policies and Energy Inflation

Several endogenous fiscal policy rules, designed to counteract the consumption inequality triggered by an energy price shock, are now introduced. Following Dao et al. (2023), fiscal measures are classified into price-suppressing versus non-price-suppressing, and targeted versus untargeted. Price-suppressing measures, represented by energy subsidies[14], directly suppress the energy good price in the consumers' basket. In turn, they can be targeted if addressed only to the HtM – the poorer category of consumers – or untargeted, if addressed to everyone. Non-price-suppressing measures are represented by lump sum transfers[15], and can be targeted or untargeted. Both price-suppressing and non-price-suppressing measures can be financed through lump sum or consumption taxes. The various fiscal schemes generate multiple economic scenarios, which are compared to the baseline, where no Government response to the energy price shock is assumed. The last-mentioned is isomorphic to the one in Ricciutelli (2024). Each scenario features a single price-suppressing or non-price-suppressing, targeted or untargeted fiscal instrument, financed by the means of lump sum or consumption taxes. Untargeted fiscal instruments are equally set for both household types, while targeted one or fully redistributive are addressed only to HtM, hence equal to zero for Savers.

The index of average consumption gap[16] between Savers and HtM is defined as

$$C_{gap,t} \equiv \frac{C_t^s}{C_t^h}$$

Solving the households' budget constraints for their respective consumption levels[17], allows to restate the index of consumption gap as follows

$$C_{gap,t} = \frac{(W_tN_t + P_{C,t}^sD_t^s + P_{C,t}^sTr_t^s - P_{C,t}^sT_t^s)}{(1+\tau_{C,t})P_{C,t}^s}\frac{(1+\tau_{C,t})P_{C,t}^h}{(W_tN_t + P_{C,t}^hTr_t^h - P_{C,t}^hT_t^h)}$$

[14] In the real world they have taken several forms, including energy retail price caps, excise duties or value-added tax rates cuts on energy products, block tariffs, etc.

[15] Lump sum energy vouchers, income tax credits, or cash transfers, in reality.

[16] It captures the consumption heterogeneity between the two types of households: the greater the consumption inequality, the greater $C_{gap,t}$. At the steady state, perfect consumption insurance between families holds, ensuring: $C^s = C^h$, hence $C_{gap} = 1$.

[17] Note that in equilibrium Government bonds are in zero net supply, hence $B_t = 0$ for each $t = 0, 1, 2, ...$

or

$$C_{gap,t} = P_{gap,t} INC_{gap,t}$$

where

$$P_{gap,t} \equiv \frac{P^h_{C,t}}{P^s_{C,t}}$$

and

$$INC_{gap,t} \equiv \frac{W_t N_t + P^s_{C,t} D^s_t + P^s_{C,t} Tr^s_t - P^s_{C,t} T^s_t}{W_t N_t + P^h_{C,t} Tr^h_t - P^h_{C,t} T^h_t}$$

The effect of an energy price shock on consumption inequality is determined by movements in the price and the income gaps. The higher the price gap, the higher the index of consumption gap, and the same is true for the income gap. In each of the following scenarios, the Government sets some fiscal schemes to achieve

$$C_{gap,t} = 1 \tag{2.52}$$

for $t = 0, 1, 2, ...$

2.3.1 Scenario I - Untargeted Lump Sum Transfers

Assume the Government raises lump sum taxes to finance lump sum transfers, i.e. a non-price-suppressing fiscal measure to households, according to the following budget constraint

$$P_{C,t} Tr_t = P_{C,t} T_t \tag{2.53}$$

for each $t = 0, 1, 2, ...$ where equations (**??**) and (**??**) hold. The fiscal authority sets some transfers policy to achieve

$$C_{gap,t} = \frac{(W_t N_t + P^s_{C,t} D^s_t + P^s_{C,t} Tr^s_t - P^s_{C,t} T^s_t)}{(W_t N_t + P^h_{C,t} Tr^h_t - P^h_{C,t} T^h_t)} \frac{P^h_{C,t}}{P^s_{C,t}} = 1$$

Assume that lump sum taxes are homogeneous for the two types of consumer

$$T^s_t = T^h_t = T_t \tag{2.54}$$

and that the same is true for transfers

$$Tr_t^s = Tr_t^h = Tr_t \tag{2.55}$$

Then, equation (2.52) can be expressed as

$$\frac{(W_t N_t + P_{C,t}^s D_t^s - P_{C,t}^s T_t + P_{C,t}^s Tr_t)}{(W_t N_t - P_{C,t}^h T_t + P_{C,t}^h Tr_t)} \frac{P_{C,t}^h}{P_{C,t}^s} = 1$$

Since $T_t = Tr_t$, the expression can be simplified to

$$P_{C,t}^h W_t N_t + P_{C,t}^h P_{C,t}^s D_t^s = P_{C,t}^s W_t N_t$$

Dividing both sides by $(P_{Q,t})^2$ and $P_{CQ,t}^h$, and rearranging terms yields

$$P_{CQ,t}^s D_t^s = -W_{Q,t}^r N_t \left(\frac{P_{gap,t} - 1}{P_{gap,t}} \right)^{18}$$

or, equivalently, in terms of HtM real consumption wage

$$D_t^s = -W_{C,t}^{h,r} N_t (P_{gap,t} - 1) \tag{2.56}$$

From this analytical result, several conclusions can be drawn. First, under Scenario I, there is no transfer policy able to erase the consumption gap, $C_{gap,t}$, since lump sum taxes and transfers cancel each other out. Second, the last expression clearly shows that consumption inequality would be eliminated if the price gap, $P_{gap,t}$, were equal to one in every period t, and Savers' real dividends, D_t^s, were always zero – two conditions that hold at the steady state. Finally, the equation also implies that $C_{gap,t}$ would vanish following a disturbance that induces a change in D_t^s exactly equal to the negative deviation of $P_{gap,t}$ from one – i.e., its steady-state level – multiplied by HtM real labor income, $W_{C,t}^{h,r} N_t$[19].

[19]Notice that, the price gap measures the deviation of the HtM from the Saver price index. When energy price rises, it incorporates the larger burden HtM suffer from facing a price index with a higher share of energy. In this context, $P_{gap,t} - 1$, represents the extent to which this deviation differs from its steady-state value. Thus, the right-hand side can be interpreted as the share of HtM labor income lost due to the presence of heterogeneous price indexes. Closing the consumption gap, requires an equally opposite movement in Savers' real dividends.

2.3.2 Scenario II - Targeted Lump Sum Transfers

Things change when transfers are fully redistributive. Assume again homogeneous lump sum taxes across households

$$T_t^s = T_t^h = T_t \tag{2.57}$$

but heterogeneous lump sum transfers

$$Tr_t^s \neq Tr_t^h$$

with

$$Tr_t^s = 0 \tag{2.58}$$

hence $Tr_t = \lambda Tr_t^h$. Then, equation (2.52) becomes

$$\frac{(W_t N_t + P_{C,t}^s D_t^s - P_{C,t}^s T_t)}{(W_t N_t - P_{C,t}^h T_t + P_{C,t}^h Tr_t^h)} \frac{P_{C,t}^h}{P_{C,t}^s} = 1$$

or, after some algebra

$$Tr_t^h = W_{C,t}^{h,r} N_t (P_{gap,t} - 1) + D_t^s \tag{2.59}$$

Real transfers to HtM that would fill the consumption gap are given by the sum of two objects. First, the share of labor income HtM lost due to the greater increase in their relative price index. Second, the amount of real dividends distributed to Savers.

2.3.3 Scenario III - Untargeted Energy Subsidies

Scenario IIIa. Assume the Government raises lump sum taxes to finance energy subsidies, i.e. energy price-suppressing bonus to households, according to the following budget constraint

$$\tau_{E,t} P_{E,t} C_{E,t} = P_{C,t} T_t \tag{2.60}$$

for each $t = 0, 1, 2, ...$ where equations (**??**), (**??**) and (**??**) hold. The index of average consumption gap, $C_{gap,t}$, can be rewritten in terms of non-energy and energy consumption as follows

$$C_{gap,t} = \frac{[C_{Q,t}^s + (1 - \tau_{E,t}^s) S_{E,t} C_{E,t}^s]}{[C_{Q,t}^h + (1 - \tau_{E,t}^h) S_{E,t} C_{E,t}^h]} \frac{P_{C,t}^h}{P_{C,t}^s} \tag{2.61}$$

Under scenario III, energy subsidies are homogeneous for both types, hence

$$\tau^s_{E,t} = \tau^h_{E,t} = \tau_{E,t} \tag{2.62}$$

and equation (2.61) can be re-expressed as

$$C_{gap,t} = \frac{[C^s_{Q,t} + (1-\tau_{E,t})S_{E,t}C^s_{E,t}]}{[C^h_{Q,t} + (1-\tau_{E,t})S_{E,t}C^h_{E,t}]}\frac{P^h_{C,t}}{P^s_{C,t}} \tag{2.63}$$

Setting (2.63) equal to one and solving for $\tau_{E,t}$, yields

$$\tau_{E,t} = \frac{P_{gap,t}C^s_{Q,t} + P_{gap,t}S_{E,t}C^s_{E,t} - C^h_{Q,t} - S_{E,t}C^h_{E,t}}{P_{gap,t}S_{E,t}C^s_{E,t} - S_{E,t}C^h_{E,t}}$$

or

$$1-\tau_{E,t} = \frac{P_{gap,t}C^s_{Q,t} - C^h_{Q,t}}{S_{E,t}C^h_{E,t} - P_{gap,t}S_{E,t}C^s_{E,t}} \tag{2.64}$$

where, $1-\tau_{E,t}$, denotes the effective or post-subsidy share of energy spending for households, which depends positively upon the difference between Savers and HtM non-energy consumption, and negatively upon the difference between HtM and Savers (pre-subsidy) energy expenditure, where in both differences Savers spending is adjusted for the price gap. Thus, a consumption-equalizing equilibrium requires that the untargeted energy subsidy, $\tau_{E,t}$ – which moves in the opposite way to the effective share of energy spending for households – decreases with the deviation in non-energy consumption between Savers and HtM, and increases with the deviation in energy expenditure between HtM and Savers. In particular, $\tau_{E,t}$ rises when the former deviation grows (shrinks) less (more) than the latter.

Scenario IIIb. If instead the Government finances energy subsidies with consumption taxes, according to the following budget constraint

$$\tau_{E,t}P_{E,t}C_{E,t} = \tau_{C,t}P_{C,t}C_t \tag{2.65}$$

for each $t = 0, 1, 2, ...$ assuming

$$\tau^s_{E,t} = \tau^h_{E,t} = \tau_{E,t}$$

and setting equation (2.63) equal to one, yields the same result as in equation (2.64). Despite this, the distortionary effect of consumption taxes produces different economic implications in response to the energy price shock[20], as will be seen in section 2.4.

2.3.4 Scenario IV - Targeted Energy Subsidies

Scenario IVa. Assume again the Government raises lump sum taxes to finance energy subsidies, according to equation (2.60). Moreover, assume

$$\tau^s_{E,t} \neq \tau^h_{E,t}$$

with

$$\tau^s_{E,t} = 0 \tag{2.66}$$

Setting (2.63) to one, yields

$$\tau^h_{E,t} = \frac{C^h_{Q,t} + S_{E,t}C^h_{E,t} - P_{gap,t}C^s_{Q,t} - P_{gap,t}S_{E,t}C^s_{E,t}}{S_{E,t}C^h_{E,t}}$$

or

$$1 - \tau^h_{E,t} = \frac{C^h_{Q,t} - P_{gap,t}C^s_{Q,t} - P_{gap,t}S_{E,t}C^s_{E,t}}{S_{E,t}C^h_{E,t}} \tag{2.67}$$

where, $1 - \tau^h_{E,t}$, denotes the effective or post-subsidy share of energy spending for HtM, which depends positively upon the difference between HtM non-energy consumption and Savers aggregate expenditure adjusted for the price gap, and negatively upon HtM energy spending. Thus, the consumption-equalizing targeted energy subsidy rises if the aforementioned deviation grows (shrinks) less (more) than HtM pre-subsidy energy spending.

Scenario IVb. Finally, assume the Government finances energy subsidies with consumption taxes, according to equation (2.65). Then, setting equation (2.63) equal to one yields the same result as in equation (2.67). As seen under Scenario III, distortionary taxation implies heterogeneous economic implications in response to the energy price shock.

[20]Here the focus is on energy inflation, but the same reasoning applies in response to other shocks.

2.4 Results

2.4.1 Calibration

The model is calibrated quarterly. The calibration, which follows Ricciutelli (2024), is standard and summarised in Table 2.1. Some parameters are set to tailor the model to the euro area economic context. Savers' subjective discount factor, β, is 0.99, consistent with an annualized real interest rate of around 4%. The utility function of both types of consumers is assumed logarithmic on consumption, i.e. risk aversion coefficient, σ, is set to 1. The same is true for the Frisch labor supply elasticity, φ, which is also equal to 1. The last two values are commonly adpoted in the reference literature, providing a standardized benchmark that facilitates direct comparison with our results. This reasoning also applies for the Calvo parameter, θ, and the elasticity of substitution among differentiated non-energy varieties, ϵ_p, and across different types of households, ϵ_w, respectively fixed to 0.75, 6, and 6. θ is consistent with an average period of one year for price adjustments, ϵ_p and ϵ_w with frictionless price and wage markup both equal to 20% – hence $\mathcal{M}_p = \mathcal{M}_w = 1.2$. In line with Auclert et al. (2023), who calibrate their model to capture a large European energy-importing country, we choose a low elasticity of substitution between energy and non-energy goods, η, of 0.1. Moreover, as they do, we assume a high energy shock persistence, ρ_{se}, equal to 0.96, and a share of energy in domestic production, α, equal to 4%. The Total Factor Productivity (TFP) shock has persistence, ρ_a, of 0.9, following Chan et al. (2022), among others; and the persistence of monetary policy shock, ρ_v, is 0.5, as in Galí (2007). The inflation and GDP response coefficients in the monetary policy rule, ϕ_π and ϕ_y, are standard and respectively equal to 1.5 and 0.125. The shares of energy consumption for Savers, χ_s, and HtM, χ_h, are parameterized on the basis of the EU-HBS data, and following the analysis by Corsello and Riggi (2023) and Battistini et al. (2022) for the euro area. The latter observe that the households' energy-intensive consumption, that is the share of their monthly income devoted on utilities and transport services, stands at around 35% for the lowest (i.e. poorest) and at 10% for the highest (i.e. richest) income quintiles. It follows that we set $\chi_s = 0.10$ and $\chi_h = 0.35$. The share of HtM households, λ, is calibrated to 0.20, matching the share of people at risk of poverty and social exclusion in EU in 2022.

Table 2.1: Baseline Calibration

Parameter	**Value**	**Description**
β	0.99	Subjective Discount Factor
λ	0.2	Share of HtM
χ_s	0.1	Share of Energy in Saver's Basket
χ_h	0.35	Share of Energy in HtM's Basket
η	0.1	Energy and Non-Energy Elasticity of Substitution
ϵ_p	6	Non-Energy Goods Elasticity of Substitution
ϵ_w	6	Households Elasticity of Substitution
σ	1	Risk Aversion Coefficient
φ	1	Inverse of Frisch Elasticity
θ	0.75	Calvo Parameter
α	0.04	Share of Energy in Production
Fix	0.132	Fixed Cost
$\mathcal{M}_p$	1.2	Steady-State Intermediate Firms' Gross Markup
$\mathcal{M}_w$	1.2	Steady-State Wage Gross Markup
ϕ_π	1.5	Inflation Feedback Coefficient
ϕ_y	0.125	GDP Feedback Coefficient
ρ_a	0.9	Autoregressive Coefficient for Technology
ρ_u	0.5	Autoregressive Coefficient for Monetary Policy
ρ_{se}	0.96	Autoregressive Coefficient for Energy
ρ_g	0.9	Autoregressive Coefficient for Government Spending

2.4.2 Impulse Response Analysis

Scenario I - Untargeted Lump Sum Transfers

Under Scenario I, the economy's response to the positive – thus contractionary – and persistent 25 standard deviation shock – 100 percentage point annualized – in the real price of energy, $S_{E,t}$, is equivalent to the baseline[21]. This outcome arises because untargeted lump sum transfers, Tr_t, are financed through untargeted lump sum taxes, T_t, with both instruments applied uniformly across household types. As a result, transfers and taxes exactly offset one another, leaving the economic dynamics unchanged relative to the baseline[22].

Scenario II - Targeted Lump Sum Transfers

Under scenario II, the Government responds to the energy price shock by collecting lump sum taxes, T_t, from households to finance targeted, non-price-suppressing measures – specifically lump sum transfers to HtM households, Tr_t^h. This fiscal scheme is explicitly designed to eliminate consumption inequality, as measured by the index of average consumption gap, $C_{gap,t}$.

Energy inflation and policy response. As shown in Figure 2.1, Consumer Price Index (CPI) inflation, $\Pi_{C,t}$, rises by approximately 14.70% annualized versus 13.27% in the baseline. This increase signals a higher average cost of living across households. The stronger inflationary pressure stems from the redistributive fiscal stimulus, which cushions the negative impact of the shock on demand for both energy and non-energy goods. As demand for non-energy goods contracts less sharply, core inflation, $\Pi_{Q,t}$, falls by only -0.30% on impact – much less than the -1.73 percentage points observed in the baseline. The policy interest rate, R_t, is raised more than in the baseline scenario – by 19.93% vis-a-vis 16.84% on an annual basis. Accordingly, the ex-ante real interest rate, $E_t R_{t+1}^r$, edges up by approximately 18.32% annualized, compared to 15.52% in the baseline. By stimulating HtM demand and intensifying upward price pressures, fiscal transfers prompt a more aggressive monetary tightening by the Central Bank in response to the energy price shock.

[21] See Subsection 2.4.2 et seq., or Ricciutelli (2024) for a more extensive discussion on the baseline.

[22] If instead lump-sum taxes were targeted, the economy would effectively resemble Scenario II. As shown below, in that case, the response to the shock diverges due to the asymmetric nature of the fiscal intervention.

Aggregate outcomes. Despite the stronger monetary policy reaction, targeted transfers help stabilize demand and cushion the contraction in output. Real GDP, Y_t, declines by -4.25%, a less severe fall than the -6.15% observed in the baseline. By reallocating resources to HtM, who have a higher marginal propensity to consume (MPC), the transfers policy bolsters demand for non-energy goods. This stimulates intermediate goods producers to maintain higher levels of gross or non-energy output, Q_t, resulting in smaller contraction in employment, N_t, and energy imports, E_t. Specifically, Q_t shrinks by -5.55% instead of -7.58%, N_t by -3.29% instead of -4.84%, and E_t by -36.86% instead of -41.87% on impact. As in the baseline, labor market structure ensures that employment losses are equally distributed across household types. The decline in the real product wage is more moderate at -8.58%, compared to -12.02% in the baseline. Similarly, the real consumption wage falls by -12.33% versus -15.78%. These smaller wage adjustments reflect the support to aggregate demand from fiscal transfers, allowing the union to negotiate less drastic wage reductions. Consequently, the real marginal cost decreases by -7.23%, instead of -10.55%, mitigating the fall in profits – and therefore in dividends – accruing to Savers. Aggregate consumption, C_t, falls by -9.04% from steady state, compared to -10.95% in the baseline.

Distributional outcomes. The moderation in C_t reflects a significantly smaller contraction in HtM consumption, C_t^h, which declines by -9.04%, instead of -25.62% in the baseline. By contrast, Savers consumption, C_t^s, falls by -9.04% compared to -7.28% under the baseline. Targeted transfers raise HtM disposable income, directly supporting their consumption and aligning it with that of Savers. In doing so, the policy expands (restricts) demand from HtM (Savers), softening the economy-wide consumption downturn and closing the gap between the two household types. As a result, consumption inequality, measured by the index of average consumption gap, $C_{gap,t}$, is completely eliminated – it increases by 18.34% in the baseline – due to the redistributive role of fiscal transfers to HtM. The price gap, $P_{gap,t}$, remains unchanged across scenarios, as HtM still bear a relatively higher energy inflation burden due to their consumption basket composition. However, the income gap, $INC_{gap,t}$, is reduced from 12.09% in the baseline to -6.25%, fully offsetting the inflation-driven decline in HtM purchasing power.

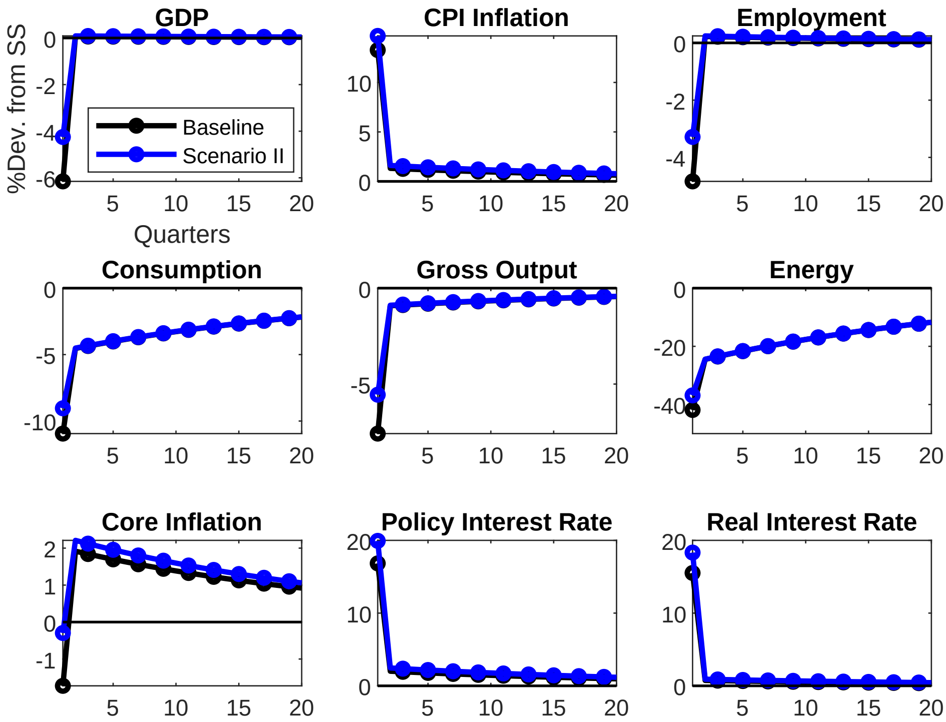

Figure 2.1: Dynamic Response to an Energy Price Shock: Baseline vs Scenario II

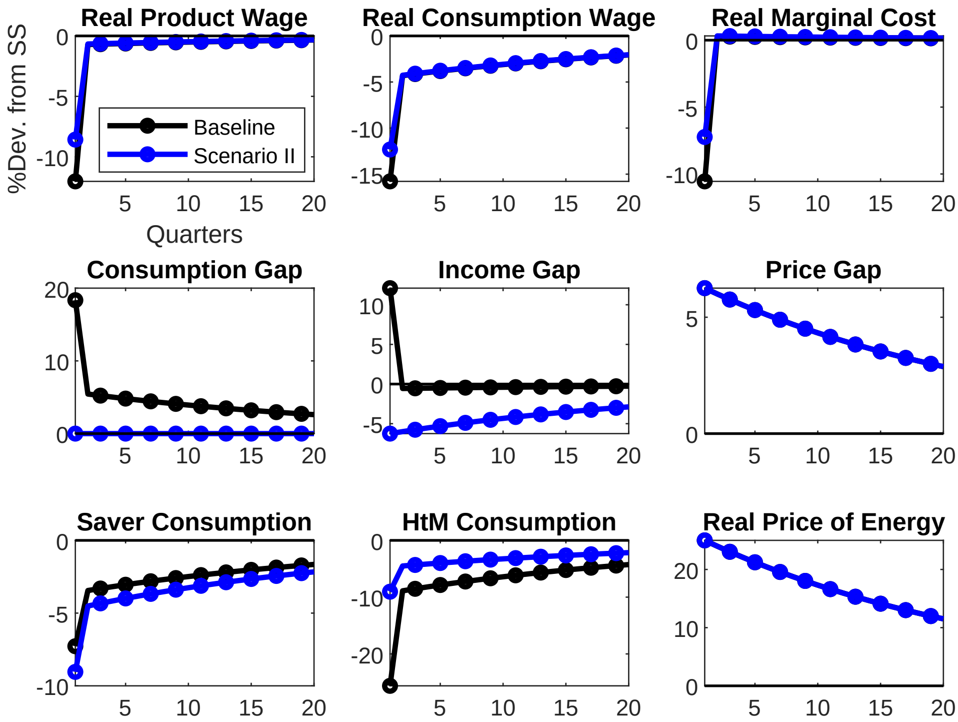

Figure 2.2: Dynamic Response to an Energy Price Shock: Baseline vs Scenario II

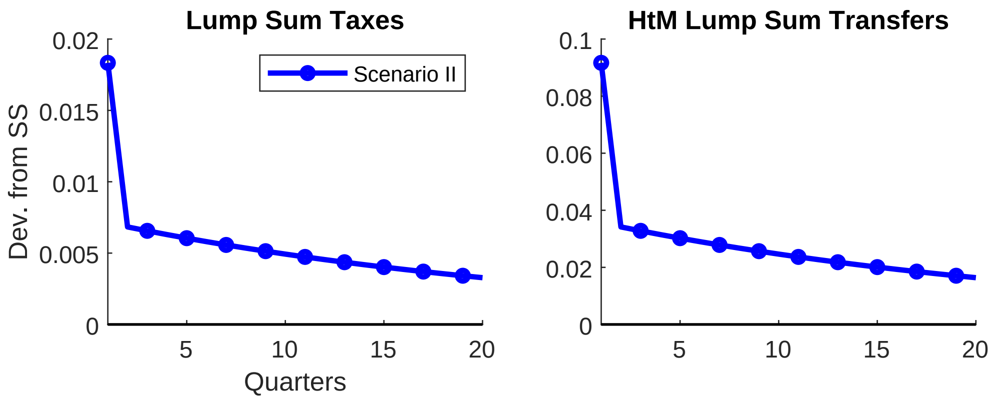

Figure 2.3: Dynamic Response to an Energy Price Shock: Scenario II

Scenario III - Untargeted Energy Subsidies

Scenario III explores the effects of an untargeted, price-suppressing fiscal measure – namely, an untargeted energy subsidy to households – implemented in response to a 25% positive – thus contractionary – and persistent energy price shock. Two variants are considered: Scenario IIIa, where the energy subsidy, $\tau_{E,t}$, is financed via lump sum taxation, T_t, and Scenario IIIb, where it is funded through consumption taxes, with $\tau_{C,t}$ denoting the consumption tax rate. As in previous scenarios, the fiscal intervention is designed to eliminate consumption inequality, measured by the index of average consumption gap, $C_{gap,t}$. In both variants, the energy subsidy and the corresponding tax instruments are reduced over time[23]. In practice, the Government raises funds by taxing energy consumption and redistributes them through lower lump sum taxes – Scenario IIIa – or reduced consumption taxes – Scenario IIIb. The latter can be interpreted as an unconventional fiscal policy measure, such as the temporary VAT cuts introduced in Germany during the COVID-19 pandemic (Bachmann et al., 2023)[24]. In both versions of Scenario III, Government intervention boosts demand and fuels inflationary pressures, more strongly so under distortionary taxation.

Energy inflation and policy response. Following the shock, CPI inflation rises by 14.70% annualized under Scenario IIIa, and 17.29% under Scenario IIIb, compared to 13.28% in the baseline. Core inflation, which declines by -1.72% in the baseline, falls only by -0.30% in IIIa and increases to 2.30% in IIIb. The monetary policy response is more aggressive under fiscal intervention: the policy interest rate is raised from 16.84% in the baseline to 19.93% in IIIa, and 25.05% in IIIb, while the expected real interest rate increases from 15.52% to 18.32% and 22.32%, respectively. These dynamics reflect stronger inflationary pressures in Scenario III, particularly under IIIb, where the stimulus from consumption tax cuts amplifies demand.

Aggregate outcomes. Untargeted energy subsidies substantially cushion the contractionary effects of the energy price shock. GDP declines by -6.15% in the baseline but

[23] To facilitate comparison across scenarios, and without loss of generality, all fiscal instruments are assumed to be zero in steady state. Any reduction thus entails a temporary move into negative territory – an artifact that disappears under positive steady-state values for taxes and subsidies.

[24] In the tradition of Shapiro (1991) and Correia et al. (2013), they define unconventional fiscal policy as the use of consumption tax changes to affect the price path and hence inflation dynamics.

only by -4.25% in IIIa and -1.78% in IIIb. Employment follows a similar pattern, contracting by -4.84% in the baseline but only by -3.29% in IIIa and -1.27% in IIIb. Gross output declines by -7.58% in the baseline, compared to -5.55% in IIIa and -2.92% in IIIb. The milder downturn in IIIb highlights the relatively lower contractionary impact of financing subsidies through consumption taxes, due to the consumption incentive triggered by distortionary taxation. The mechanism is also reflected in consumption and wage dynamics. Aggregate consumption drops by -10.95% in the baseline, -9.04% in IIIa, and -6.57% in IIIb. The real product wage falls by -12.03% without policy intervention, but only by -8.58% in IIIa and -4.09% in IIIb. A similar pattern is observed for the real consumption wage, with declines of -15.78%, -12.33%, and -7.84%, respectively. The stronger demand stimulus under Scenario IIIb, which leads to higher employment and smaller wage compression, implies that the real marginal cost decreases much less: from -10.55% in the baseline to -7.23% in IIIa and -2.93% in IIIb. These results indicate that energy subsidies financed via distortionary taxation mitigate the adverse effects of the shock more effectively than when financed via lump sum taxation. Notice that the aggregates' response to the energy price shock under Scenario IIIa is very close to that under Scenario II.

Distributional outcomes. The fiscal intervention in Scenario III fully eliminates the consumption gap observed in the baseline, ensuring equal consumption declines equally for Savers and HtM households. In the baseline, Saver consumption declines by -7.28%, while HtM consumption contracts by -25.62%. Under Scenario IIIa, both groups experience an equal decline of -9.04%, and in Scenario IIIb the drop is limited to -6.57%. While the price gap remains constant across scenarios, the income gap narrows from -12.09% in the baseline, to approximately -6.25% in IIIa and in IIIb. Savers real consumption wage falls by -14.53% in the baseline, -11.07% in IIIa, and -6.59% in IIIb, while HtM households experience shrinkages of -20.78%, -17.33%, and -12.84%, respectively. These outcomes confirm that financing energy subsidies via consumption tax reductions yields stronger aggregate demand effects relative to lump sum taxation.

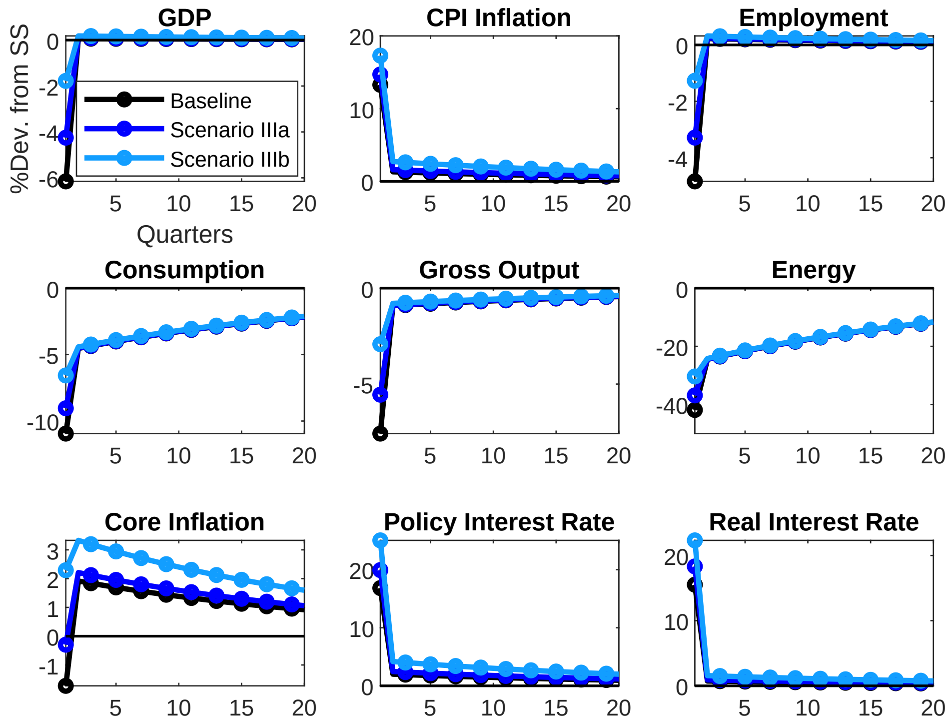

Figure 2.4: Dynamic Response to an Energy Price Shock: Baseline vs IIIa vs IIIb

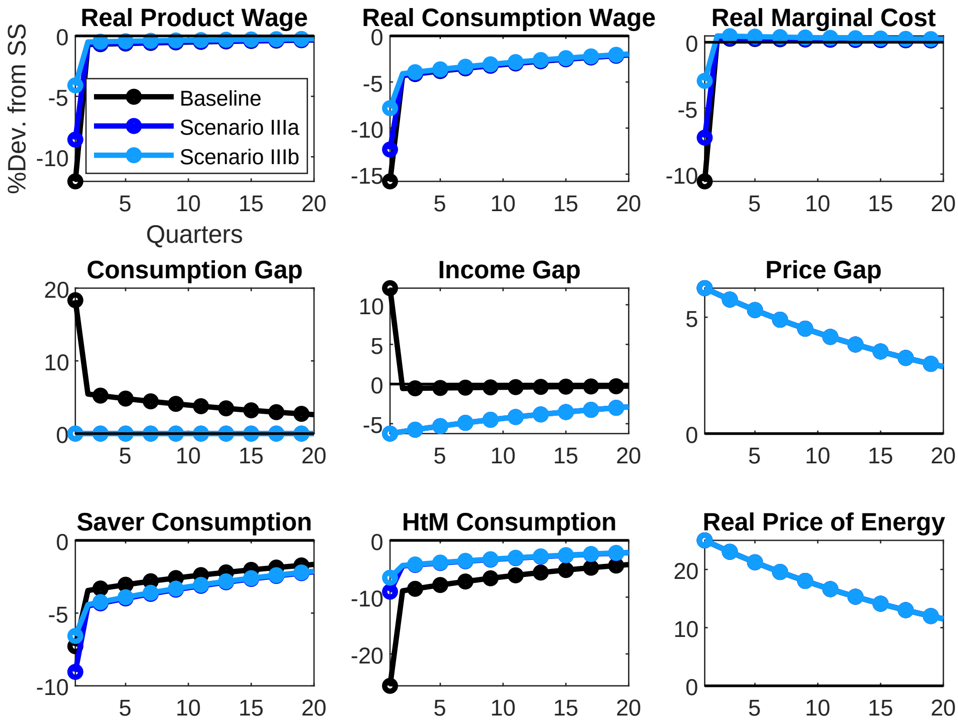

Figure 2.5: Dynamic Response to an Energy Price Shock: Baseline vs IIIa vs IIIb

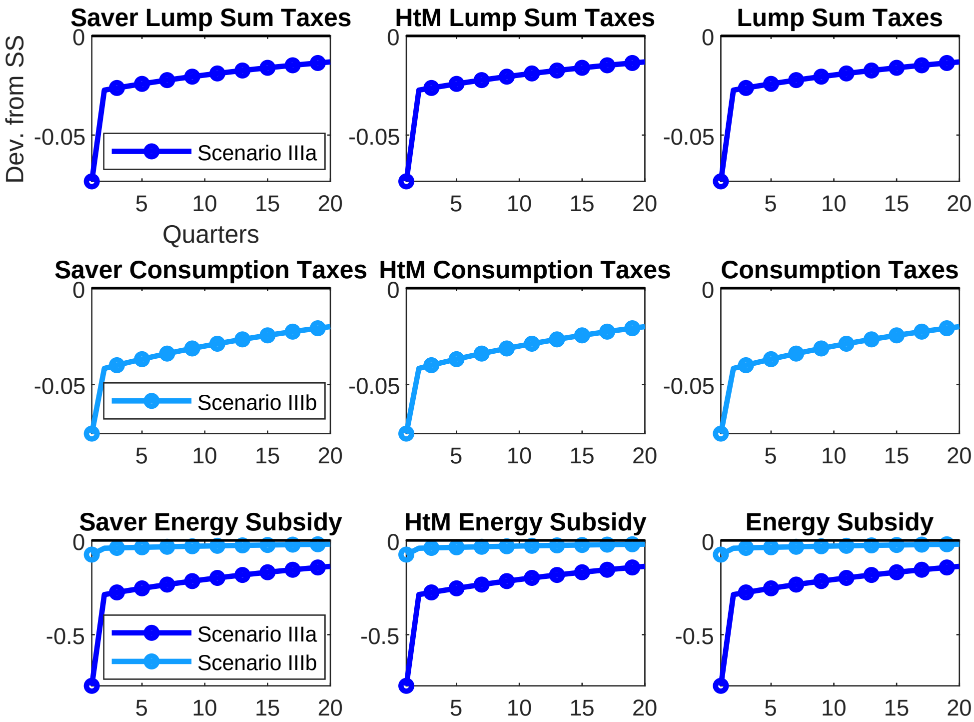

Figure 2.6: Dynamic Response to an Energy Price Shock: IIIa vs IIIb

Scenario IV - Targeted Energy Subsidies

Under scenario IV, a targeted, price-suppressing fiscal scheme – namely, an energy subsidy directed only to HtM – is implemented in response to a 25% positive and persistent energy price shock. As before, we distinguish between two versions of Scenario IV and compare their effects with the baseline. Under Scenario IVa, the targeted energy subsidy to HtM, $\tau^h_{E,t}$, which is calibrated to eliminate consumption inequality, is financed through lump-sum taxation, T_t. In Scenario IVb, the subsidy is instead financed via a consumption tax, with $\tau_{C,t}$ denoting the tax rate. As in Scenario III, the shock leads to a gradual decline in both taxation and the subsidy, which stimulates aggregate demand and increases inflationary pressures. Once again, the expansionary impact of fiscal intervention is stronger when the subsidy is financed through consumption taxes.

Energy inflation and policy response. Under Scenario IVa, inflation rises to 14.70%, while in IVb, it reaches 14.93%. Core inflation, $\Pi_{Q,t}$, declines only slightly in IVa by -0.30% and is nearly stable in IVb – -0.07%. In response to rising inflation, the policy interest rate is raised to 19.93% in IVa and 22.39% in IVb. The real interest rate follows a similar trajectory, climbing to 18.32% and 21.88%, respectively.

Aggregate outcomes. The targeted energy subsidy significantly mitigates the negative macroeconomic effects of the shock. GDP contracts -4.25% in IVa and falls further to -2.05% in IVb. Employment contracts by -3.29% in IVa, compared to -1.50% in IVb. Gross output exhibits similar dynamics, declining by -5.55% and -3.22%, respectively. Similarly to Scenario III, the relatively stronger stabilization in Scenario IVb suggests that financing the subsidy via a reduction in consumption taxes is less contractionary than using lump-sum taxation. As a result, aggregate consumption falls only by -9.04% in IVa and -6.84% in IVb. The real product wage contracts by -8.58% under IVa and -4.59% under IVb, while the real consumption wage by -12.33% and -8.34%, respectively.

Distributional outcomes. At the household level, Savers and HtM consumption declines by -9.04% in IVa and -6.85% in IVb. The income gap also narrows significantly, falling from 12.09% in the baseline to -6.25% under both Scenarios IVa and IVb.

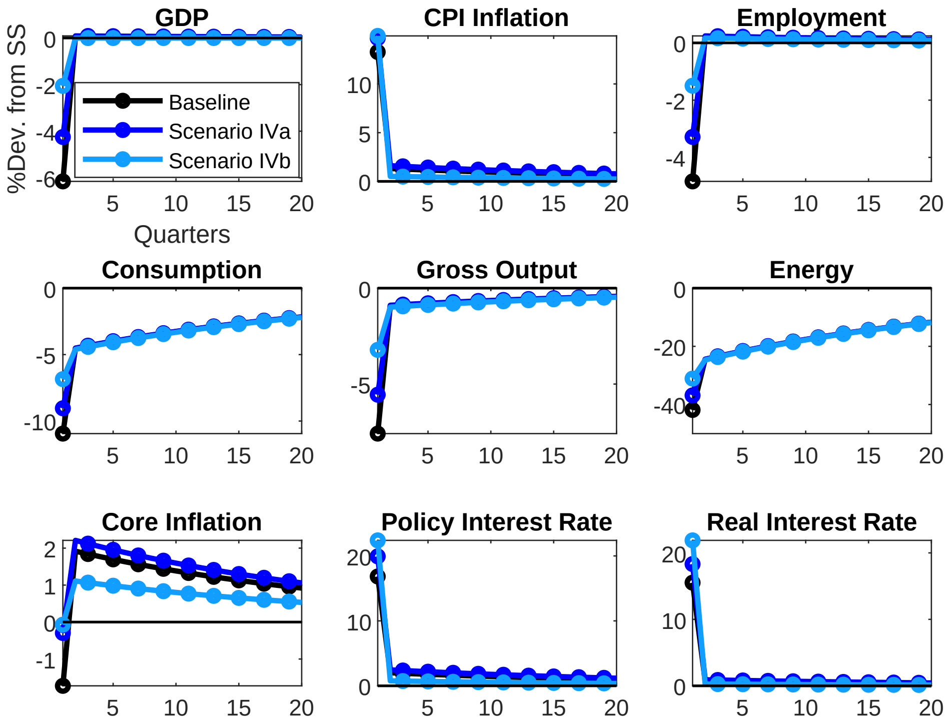

Figure 2.7: Dynamic Response to an Energy Price Shock: Baseline vs IVa vs IVb

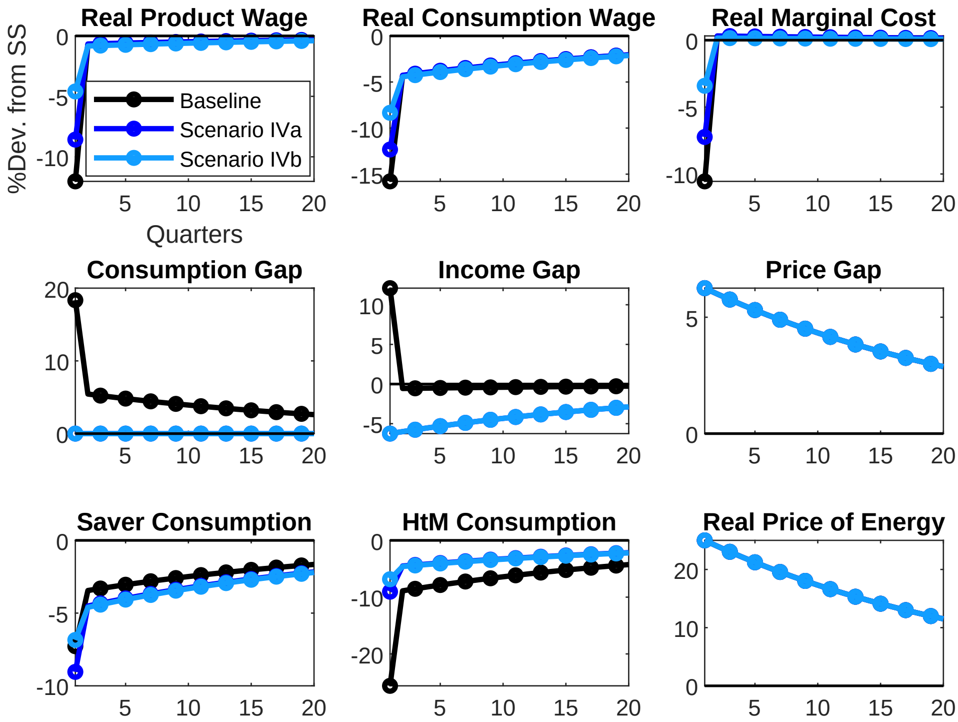

Figure 2.8: Dynamic Response to an Energy Price Shock: Baseline vs IVa vs IVb

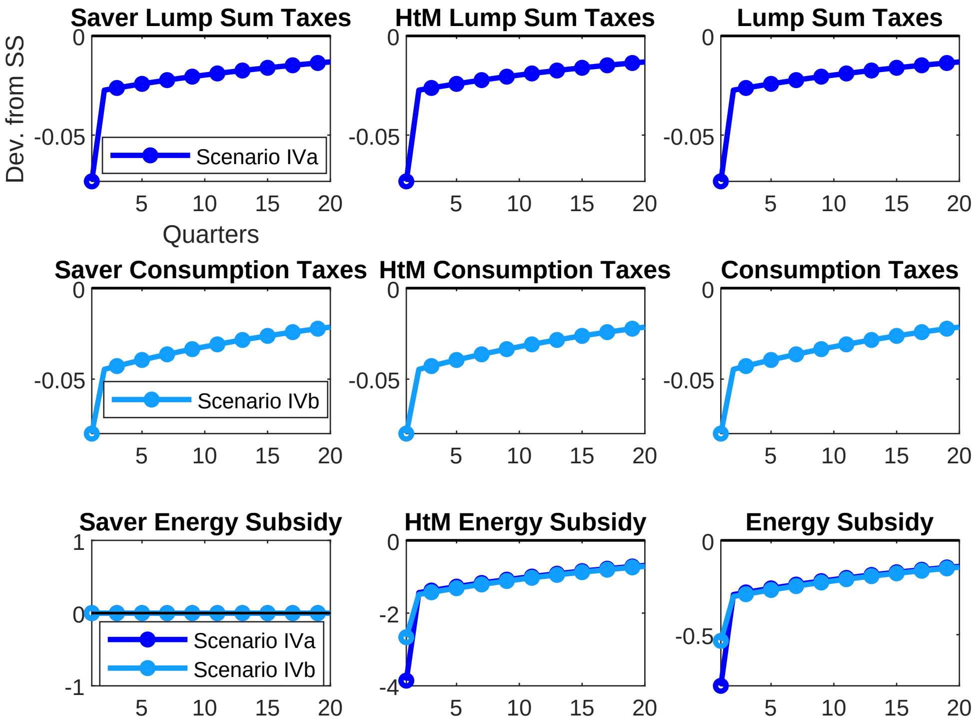

Figure 2.9: Dynamic Response to an Energy Price Shock: IVa vs IVb

Discussion on Scenario Analysis

The analysis confirms that untargeted, non-price-suppressing fiscal instruments – such as those implemented under Scenario I – do not improve upon the baseline response to energy price shocks. When the fiscal authority intervenes through transfers, their effectiveness depends critically on targeting. Under Scenario II, where transfers are directed toward poorer households, the energy price shock remains contractionary, reducing output, employment, and raising inflation. However, redistributive fiscal policy plays an important stabilizing role: by restoring consumption inequality to pre-shock levels, it supports aggregate demand and mitigates the adverse macroeconomic effects of the shock. This comes at the cost of higher inflation, which in turn triggers a stronger monetary policy tightening. The introduction of a price-suppressing instrument – such as an energy subsidy – even if untargeted, further alleviates the recessionary effects compared to Scenario II, as shown under Scenario III. Crucially, the financing mechanism plays a central role in shaping the macroeconomic outcome. When the subsidy is funded through consumption taxes – Scenario IIIb – the policy becomes more expansionary: it stimulates demand, cushions output and employment losses, but also generates higher inflation and a more forceful monetary tightening. Conversely, if financed through lump sum taxes – Scenario IIIb – the macroeconomic response resembles Scenario II, with limited additional stabilization. Under Scenario IVb, the energy subsidy is both targeted to HtM and financed via distortionary taxation – in contrast, Scenario IVa assumes lump sum financing. This setup achieves output stabilization comparable to Scenario IIIb, but with lower inflationary pressure. The more favorable trade-off arises because the targeted energy subsidy declines on impact, leading to a sharp contraction in HtM demand and thus dampening the upward pressure on prices. As a result, Scenario IVb delivers the most balanced trade-off between output stabilization and inflation control, highlighting the advantage of targeted, price-suppressing policies funded by distortionary taxation. Figures 2.10, 2.11, and 2.12 illustrate the economy's response under Scenarios II, IIIb, and IVb[25]. These figures underscore the trade-off between output and price stabilization that emerges between fiscal responses employing price-suppressing versus non-price-suppressing measures. The most effective trade-off is delivered by targeted, price-suppressing interventions aimed at supporting HtM households.

[25] Scenarios IIIa and IVa are neglected as their dynamics closely mirror those of Scenario II.

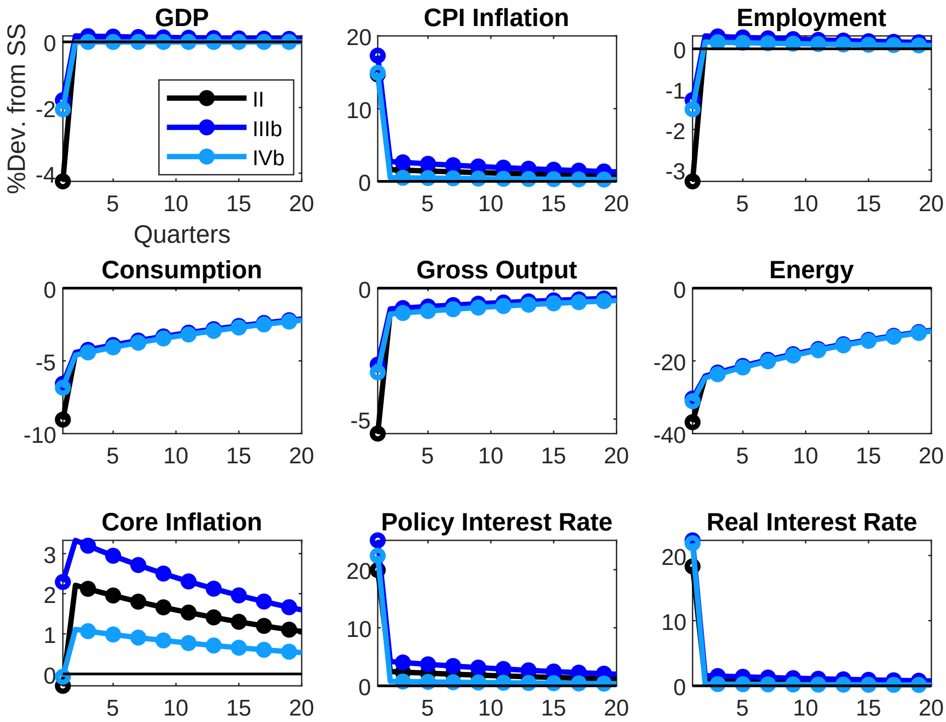

Figure 2.10: Dynamic Response to an Energy Price Shock: II vs IIIb vs IVb

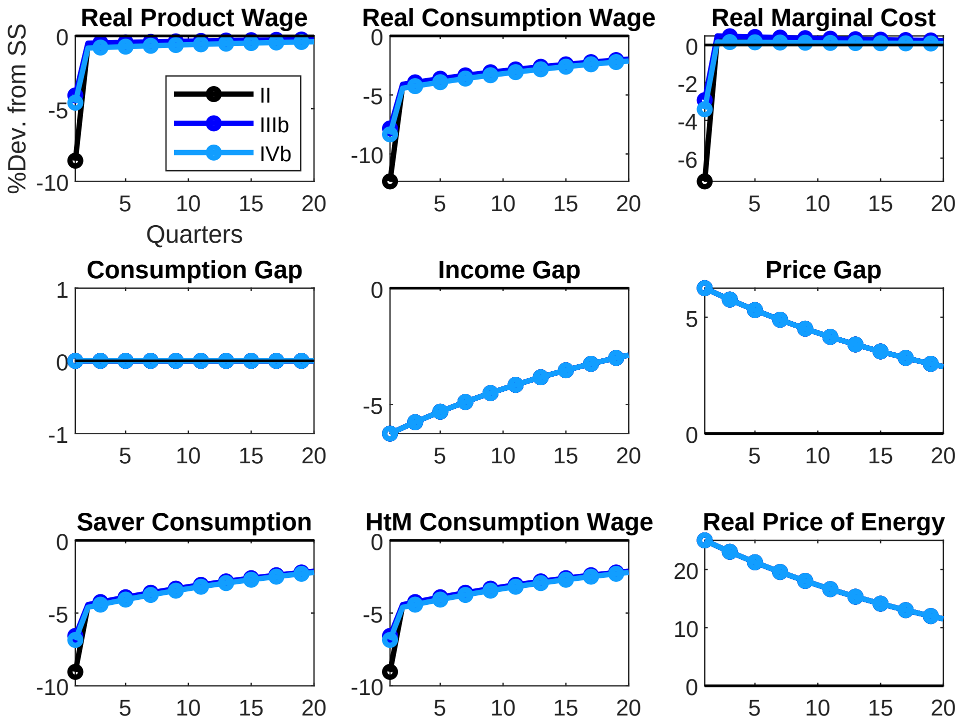

Figure 2.11: Dynamic Response to an Energy Price Shock: II vs IIIb vs IVb

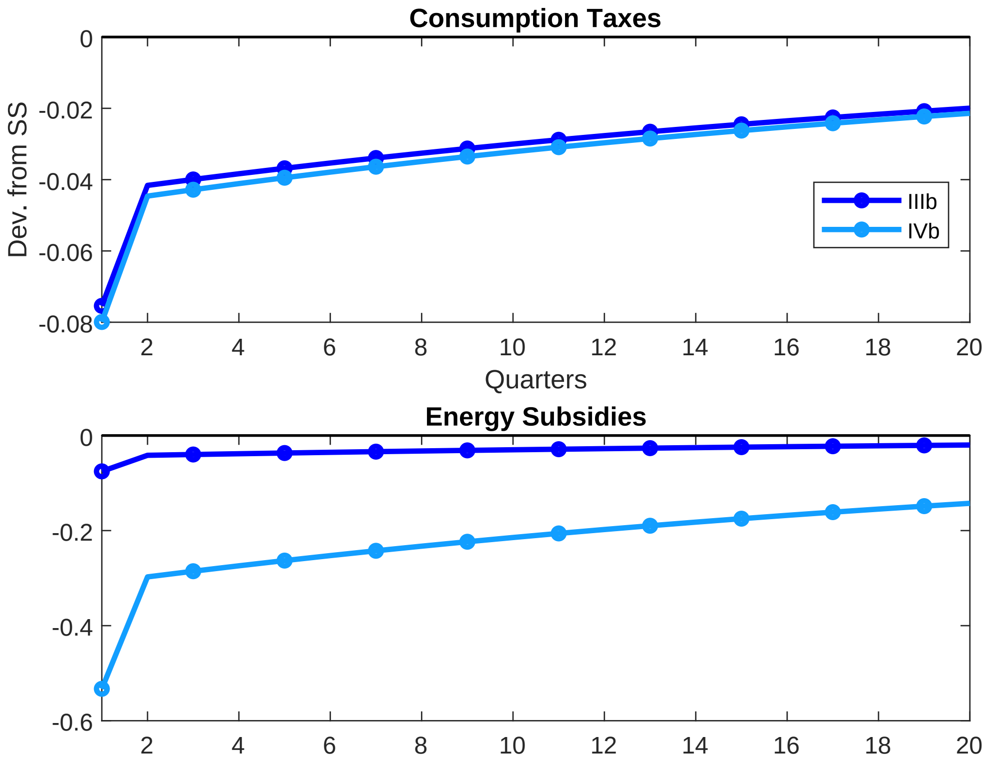

Figure 2.12: Dynamic Response to an Energy Price Shock: IIIb vs IVb

2.5 Energy Inflation and Optimal Policy

The normative implications for fiscal policy and for the combination of monetary and fiscal policies are now explored. In particular, we study the optimal fiscal and monetary-fiscal policies, following the timeless perspective approach in Woodford (2003). In other words, we look for the optimal fiscal and monetary-fiscal responses to an energy price shock under commitment, assuming a Ramsey planner set the maximizing welfare monetary policy in a centralized fashion.

Following the tradition of Lucas and Stokey (1983) and in line with Bilbiie (2008), the Ramsey planner maximizes aggregate welfare, given by a convex combination of households' utilities weighted by the mass of consumers of each type,

$$W_t = (1-\lambda)\left[\frac{C_t^{s\,1-\sigma}}{1-\sigma} - \frac{N_t^{s\,1+\varphi}}{1+\varphi}\right] + \lambda\left[\frac{C_t^{h\,1-\sigma}}{1-\sigma} - \frac{N_t^{h\,1+\varphi}}{1+\varphi}\right]$$

subject to the equilibrium conditions of the economy's private sector. A fiscal authority provides an optimal employment subsidy (see Galí, 2007[26]) that neutralizes the monopolistic competition in the goods and labor markets, ensuring the steady-state efficient allocation. Moreover, the steady state is "equitable", meaning that the steady-state consumption inequality is assumed zero.

2.5.1 Optimal Fiscal Policy

Assume that, following the occurrence of the same energy shock as in the previous analyses, a Ramsey planner is tasked with setting the fiscal instrument only, while monetary policy remains decentralized and governed by equation (2.33). The response of the Ramsey economy is compared to the baseline and the decentralized economy with fiscal measures aimed at reducing consumption inequality across households.

Optimal Targeted Transfers

Let's start by the optimal counterpart of Scenario II, where targeted transfers toward HtM, Tr_t^h, are the sole fiscal instrument.

[26] In particular, see chapter 6 of the cited textbook.

Policy response. Given that HtM cannot smooth consumption intertemporally, any income loss due to the shock translates into an immediate drop in their consumption, and hence welfare. The Ramsey planner therefore raises taxes and redistributes income toward these households, cushioning the impact of the shock. Compared to Scenario II, the fiscal stimulus under the optimal plan is more limited in magnitude and duration: it fades out within two quarters and then turns negative before gradually returning to its steady-state level. While CPI inflation, $\Pi_{C,t}$, rises across all scenarios, it increases slightly more under fiscal intervention – from 13.28% in the baseline to 14.70% in Scenario II, and further to 14.78% under the optimal policy. This in turn elicits a stronger response in the policy interest rate, R_t, which peaks at 19.93% and 21.10% in Scenario II and under the optimal plan, respectively, compared to 16.84% in the baseline. Under the Ramsey plan, fiscal support to HtM also moderates the fall in core inflation, $\Pi_{Q,t}$, by partially stabilizing consumption dynamics.

Aggregate outcomes. Relative to the baseline, targeted transfers in Scenario II attenuate the contraction in aggregate demand and employment, N_t, yielding improved macroeconomic outcomes: GDP, Y_t, falls by -4.25% vs -6.15%, consumption, C_t, by -9.04% vs -11.00%, and employment by -3.29% vs -4.84%. These gains are magnified under the optimal fiscal policy. The Ramsey planner limits the GDP decline to -2.17%, the contraction in employment to -1.59%, and the drop in consumption to -6.96%.

Distributional outcomes. The baseline scenario features a sharp increase in consumption inequality, with a consumption gap, $C_{gap,t}$, of 18.34% on impact. Scenario II is explicitly designed to close this gap through targeted transfers. The optimal policy reduces the consumption gap to a negligible 0.12% on impact, but allows it to rise again to nearly 13% after three quarters, suggesting that the planner finds it optimal to reduce inequality – at least in the periods immediately following the shock. The income gap, $INC_{gap,t}$, falls significantly, from 12.10% in the baseline to 3.97% under the optimal policy. This indicates that, under the optimal plan, a substantial share of inequality is addressed through the income gap channel.

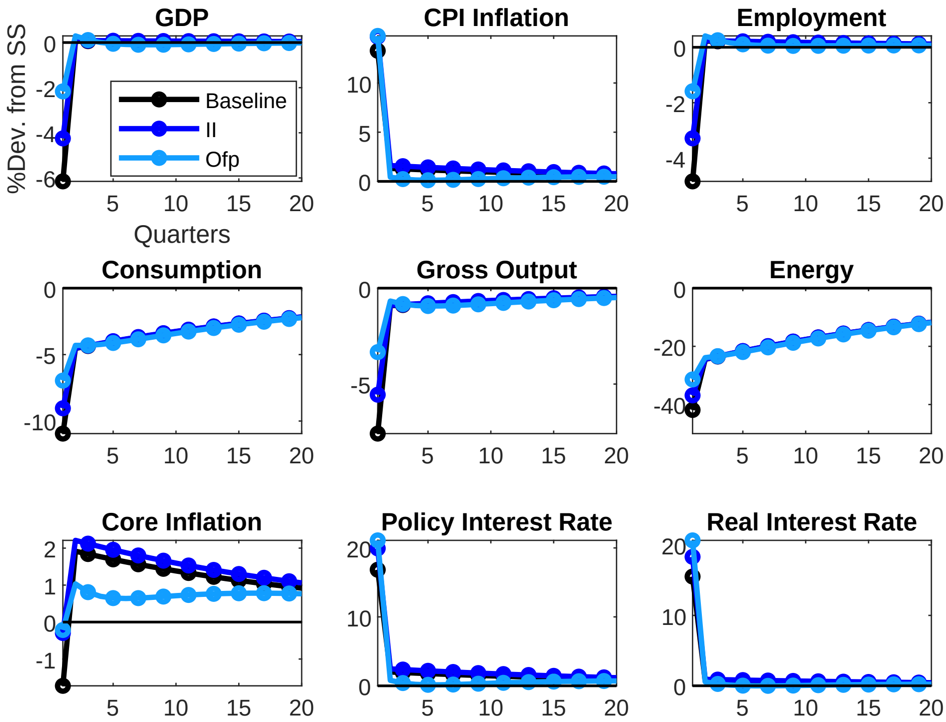

Figure 2.13: Dynamic Response to an Energy Price Shock: Baseline vs II vs Ofp

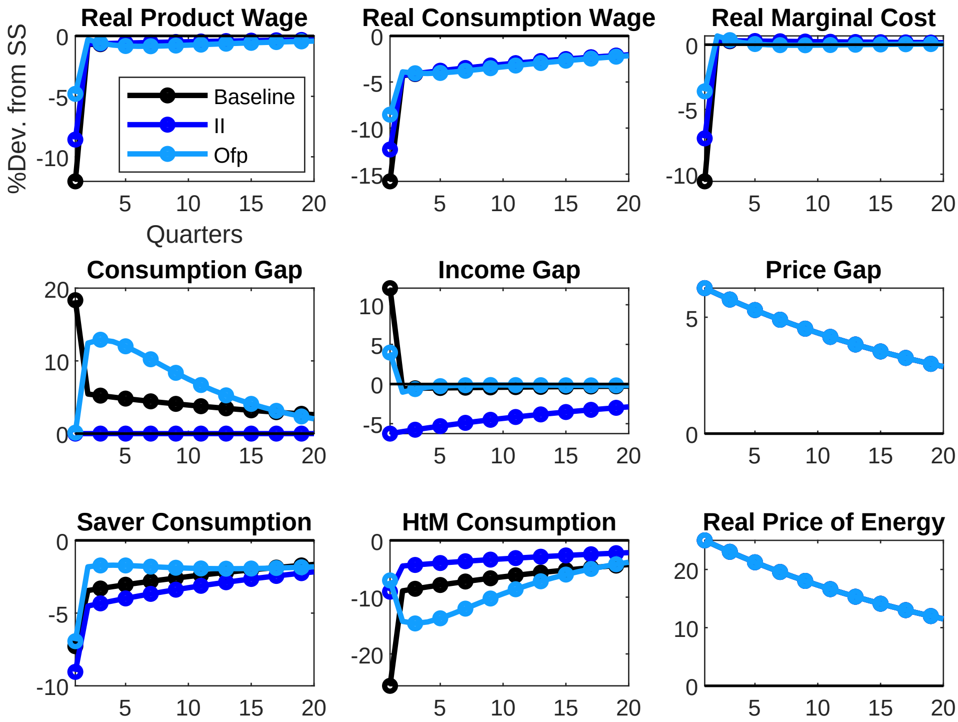

Figure 2.14: Dynamic Response to an Energy Price Shock: Baseline vs II vs Ofp

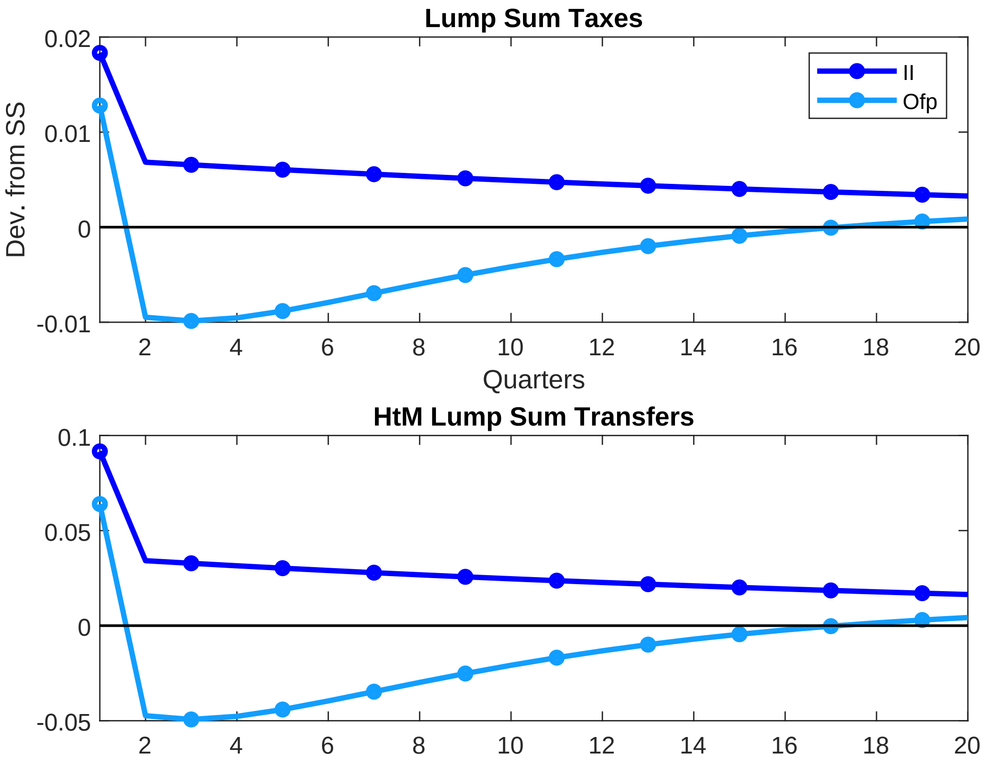

Figure 2.15: Dynamic Response to an Energy Price Shock: Scenario II vs Ofp

Optimal Untargeted Energy Subsidies

Now, let's move on to the Ramsey version of Scenario IIIb, where the fiscal tool is represented by untargeted energy subsidies, $\tau_{E,t}$.

Policy response. The planner, as the Government under Scenario IIIb, initially stimulates demand through a temporary reduction in consumption taxes. This unconventional measure lasts for one quarter only. Starting from the second quarter after the shock, consumption taxes are increased to finance the energy subsidy. Compared to the baseline, both fiscal interventions mitigate the contractionary effects of the shock. However, the optimal policy achieves a more effective trade-off between output stabilization and inflation control. CPI inflation peaks at 17.29% under Scenario IIIb, compared to 13.28% in the baseline and 14.90% under the optimal plan. These inflationary pressures trigger a strong monetary policy response: the nominal interest rate rises to 25.05% in Scenario IIIb and 22.10% under the optimal policy, both substantially above the 16.84% observed in the baseline. Core inflation falls only marginally under the optimal policy by -0.09%, compared to a rise of 2.29% under Scenario IIIb, and a decline of -1.72% in the baseline.

Aggregate outcomes. The benefits of untargeted energy subsidies are clearly visible in the performance of real macroeconomic indicators. Scenario IIIb and the optimal policy both lead to significantly improved outcomes relative to the baseline. GDP contracts by only -1.78% under Scenario IIIb and -0.51% under the optimal plan, as opposed to -6.15% in the baseline. Employment losses are similarly attenuated, amounting to -1.27% and -0.24%, respectively, compared to -4.84% in the baseline. Aggregate consumption falls by -11.00% in the baseline, but only -6.56% under Scenario IIIb and -5.30% under optimal policy.

Distributional outcomes. Under optimal policy, the consumption gap is reduced to 5.26% on impact, before edging up to around 9% in the following period and then gradually decreasing. As in the previous analysis, the planner finds it welfare-improving to narrow consumption inequality, while let some disparity persist over time. The income gap shrinks from 12.10% in the baseline to just 0.60% under the optimal plan.

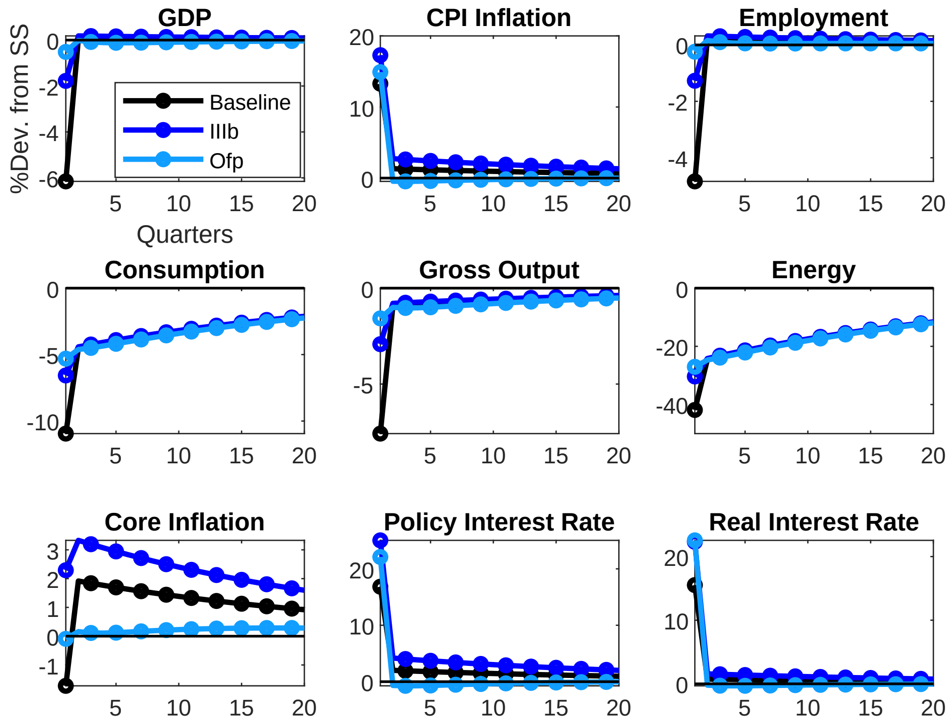

Figure 2.16: Dynamic Response to an Energy Price Shock: Baseline vs IIIb vs Ofp

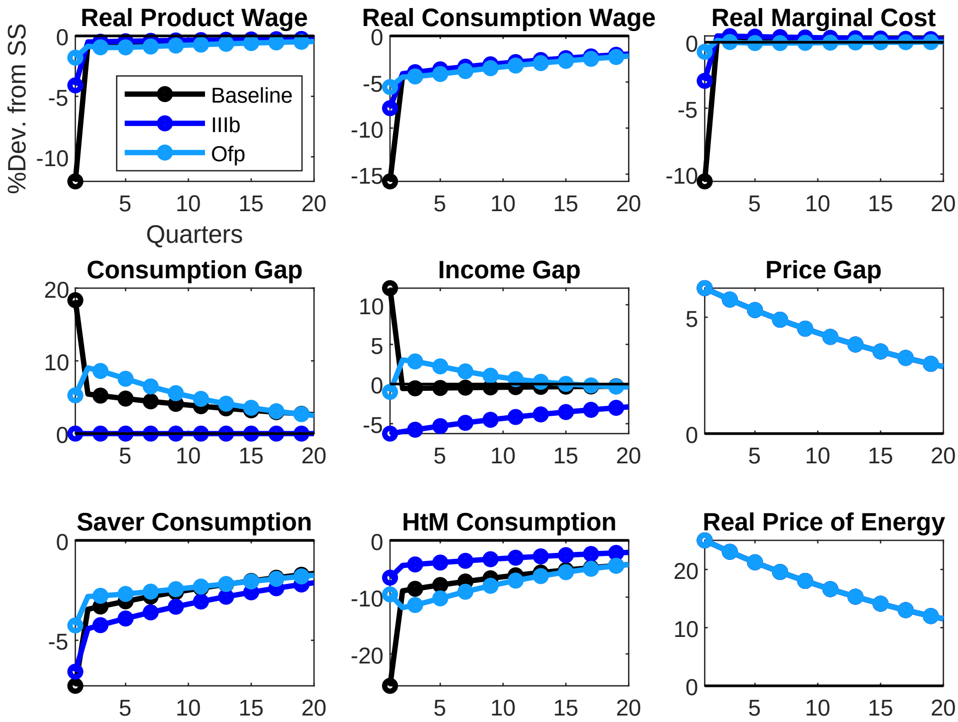

Figure 2.17: Dynamic Response to an Energy Price Shock: Baseline vs IIIb vs Ofp

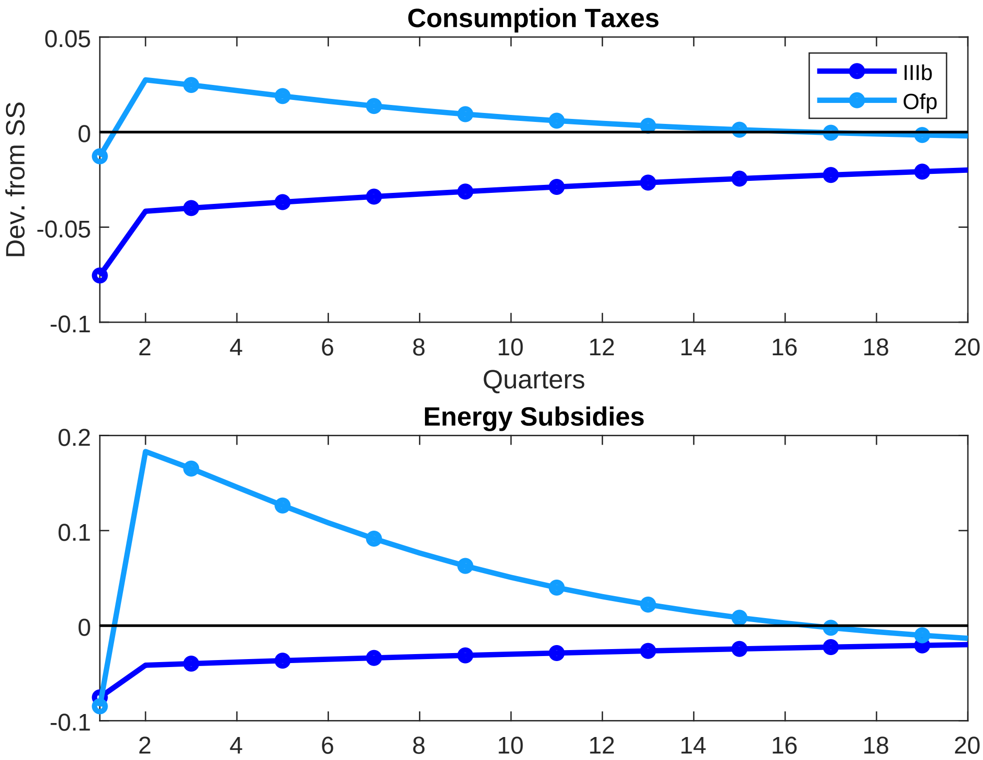

Figure 2.18: Dynamic Response to an Energy Price Shock: Scenario IIIb vs Ofp

Optimal Targeted Energy Subsidies

Finally, we examine the optimal counterpart of Scenario IVb, where the fiscal tool is a targeted energy subsidy, $\tau^h_{E,t}$, directed exclusively to HtM.

Policy response. The Ramsey planner adopts a strategy similar to that in the untargeted energy subsidies case: a one-off reduction in consumption taxes in response to the energy price shock, followed by higher consumption taxes to finance the targeted energy subsidy. CPI inflation peaks at 14.93% in Scenario IVb and 14.91% under the optimal plan—both slightly higher than the 13.28% observed in the baseline These inflationary dynamics elicit a strong monetary policy reaction, with the policy rate increasing by 22.39% in Scenario IVb and 22.10% under optimal policy on impact, again above the 16.84% in the baseline.

Aggregate outcomes. Targeted energy subsidies prove highly effective – to the same extent as untargeted ones – in stabilizing economic activity. GDP falls by only -2.05% in Scenario IVb and -0.51% under the optimal plan, compared to -6.15% in the baseline. Employment losses are also much smaller, amounting to -1.50% and -0.24%, respectively, versus -4.84%. Aggregate consumption contracts by -6.85% in Scenario IVb and -5.31% under the optimal policy – both significant improvements relative to the -11.00% drop in the baseline.

Distributional outcomes. Under optimal policy, the planner allows for a moderate consumption gap of 5.26% on impact, which rises temporarily before gradually declining over time. This reflects a welfare-based rationale: full equalization is not necessarily optimal. The income gap narrows from 12.10% in the baseline to 0.60% under the optimal policy.

Summary. The performance of optimal targeted and untargeted energy subsidies is nearly identical across most indicators. Both policies result in a GDP decline of just -0.51%, and employment losses of -0.24%. Inflation and interest rate dynamics are also the same, suggesting that the targeting of the subsidy has only marginal effects on aggregate stabilization and redistribution.

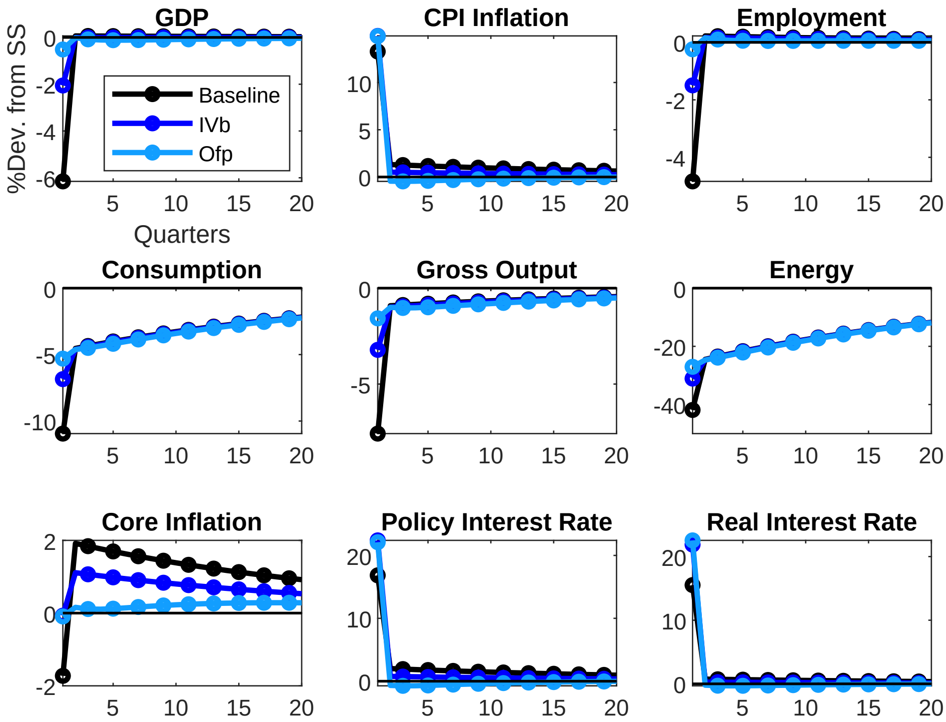

Figure 2.19: Dynamic Response to an Energy Price Shock: Baseline vs IVb vs Ofp

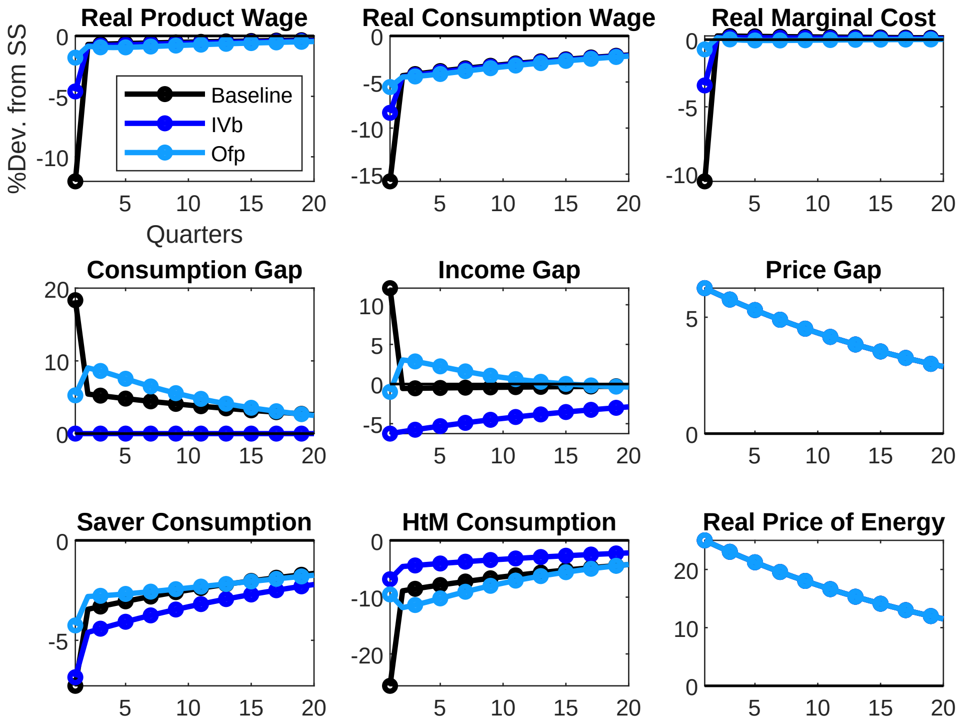

Figure 2.20: Dynamic Response to an Energy Price Shock: Baseline vs IVb vs Ofp

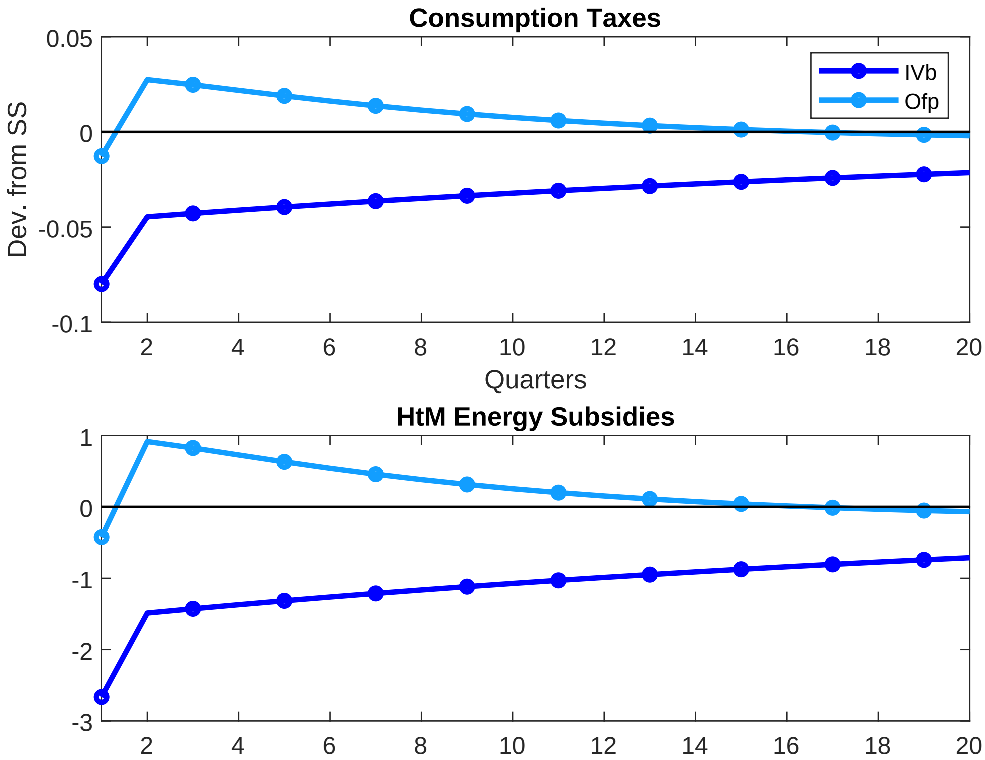

Figure 2.21: Dynamic Response to an Energy Price Shock: Scenario IVb vs Ofp

2.5.2 Optimal Monetary and Fiscal Policy

The joint optimal design of monetary and fiscal policy in response to an energy price shock is outlined. The goal of this exercise is to assess whether granting the Ramsey planner access to fiscal redistribution enhances aggregate and/or distributional outcomes beyond what can be achieved through monetary policy alone, and whether a trade-off between stabilization and redistribution remains. As usual, the Central Bank's instrument is represented by the policy interest rate, R_t. For simplicity, the Government has only non-price-suppressing instruments at its disposal, represented by lump sum transfers, Tr_t^s and Tr_t^h – financed through lump sum taxation levied on all consumers – where the former are set to zero, given our interest on the role of fully redistributive fiscal measures. The fiscal authority optimally decides whether to redistribute income toward HtM households or not. Results are compared to the optimal monetary policy analysis in Ricciutelli (2024), with policy interest rate as only instrument and no Government intervention assumed.

Energy inflation and policy response. The economy experiences a contractionary, persistent 25% standard deviation energy price shock, resulting in an unexpected increase in the real price of energy, $S_{E,t}$. Under both the optimal monetary (Omp) and optimal monetary-fiscal (Omfp) scenarios, the disturbance induces a rise in gross CPI inflation, $\Pi_{C,t}$, of 14.84% annualized – under the Omfp economy, the increase is marginally lower – since energy price is included in the consumer price indexes. The HtM consumption basket contains a larger share of energy goods compared to that of Savers, hence the poorers' CPI price experiences a more substantial rise. Consequently, HtM CPI inflation, $\Pi_{C,t}^h$, increases more sharply than for Savers, $\Pi_{C,t}^s$, implying a widening of the price gap, $P_{gap,t}$, which grows by 6.25% on impact, consistent with previous analyses. Core inflation, $\Pi_{Q,t}$, which tracks the dynamics of non-energy good price, follow an opposite trajectory, declining in both scenarios by approximately 16 basis points (bp) on an annualized basis – slightly more under the Omfp regime. In the Omfp economy, taxes are raised to finance targeted transfers to HtM – see Figure 2.24. Although the scale of the fiscal intervention is two orders of magnitude smaller than in the optimal targeted transfers scenario, the stimulus still lasts for two quarters before reversing and gradually returning to its steady-state level. As shown in Figure 2.22, the policy interest rate, R_t, is increased by 150 bp in annualized terms, compared to only about 30 bp in the Omp scenario. This results in an expected real interest rate that more than doubles in the Omfp case relative to the Omp one.

Aggregate outcomes. The macroeconomic responses in the two scenarios are very similar. GDP, Y_t, falls slightly more in Omfp scenario – -0.27% – than in Omp – -0.25% – as do employment, N_t, and consumption, C_t, which contract by -0.04% and-5.06% in Omfp, compared to -0.03% and -5.04% in Omp, respectively. Non-energy or gross production, Q_t, and energy imports also show marginally larger negative deviations in the Omfp scenario relative to Omp. This suggests that optimal fiscal redistribution entails a small cost in terms of aggregate stabilization when monetary policy is already optimized.

Distributional outcomes. On the distributional side differences between the two scenarios are small. However, at least on impact, they slightly favor the Omfp plan. The consumption gap, $C_{gap,t}$ decreases marginally under Omfp – 6.15% –compared to Omp – 6.32% – as a result of a slightly larger reduction in consumption by Savers, C_t^s, and a correspondingly smaller decline in consumption by HtM, C_t^h, supported by the income redistribution triggered by the shock. However, the subsequent trajectory of transfers leads to a modestly wider consumption gap in the Omfp scenario over the following quarters.

Discussion on Optimal Monetary and Fiscal Policy Analysis

Under Omp, the planner minimizes welfare losses using only the policy interest rate, keeping it close to zero on impact and thereby limiting monetary tightening in response to energy inflation, which is temporarily tolerated to avoid excessive real contractions. In contrast, in the Omfp case, the planner can also implement targeted transfers to HtM. Despite this additional tool, the policy rate response remains modest, and inflation dynamics are nearly unchanged relative to Omp. Thus, introducing a redistributive fiscal instrument alongside monetary policy in a Ramsey framework leads to very limited improvements in both aggregate and distributional outcomes. When the planner can already stabilize inflation and output efficiently with interest rates, the marginal benefit of adding targeted transfers is small. Although the difference is minimal, we observe slightly lower inflation under fiscal intervention. This result is consistent with the findings of Dao et al. (2024), who argue that unconventional fiscal policy measures, when coordinated with restrictive monetary policy, can help smooth inflation in the face of large transitory energy shocks.

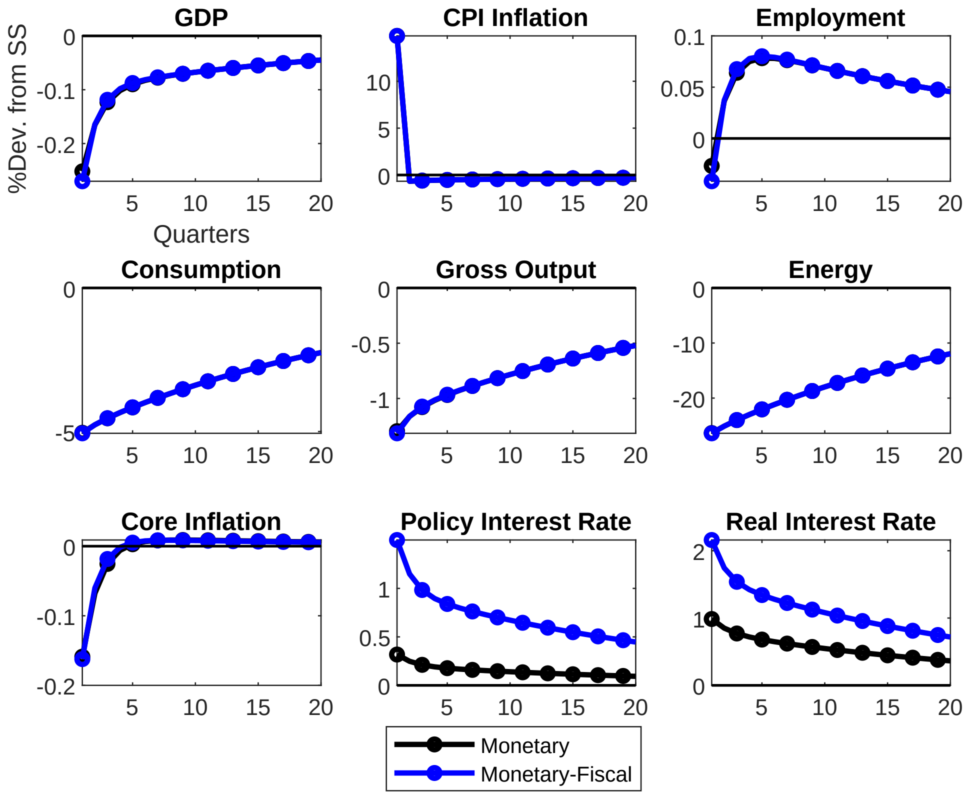

Figure 2.22: Dynamic Response to an Energy Price Shock: Omp vs Omfp

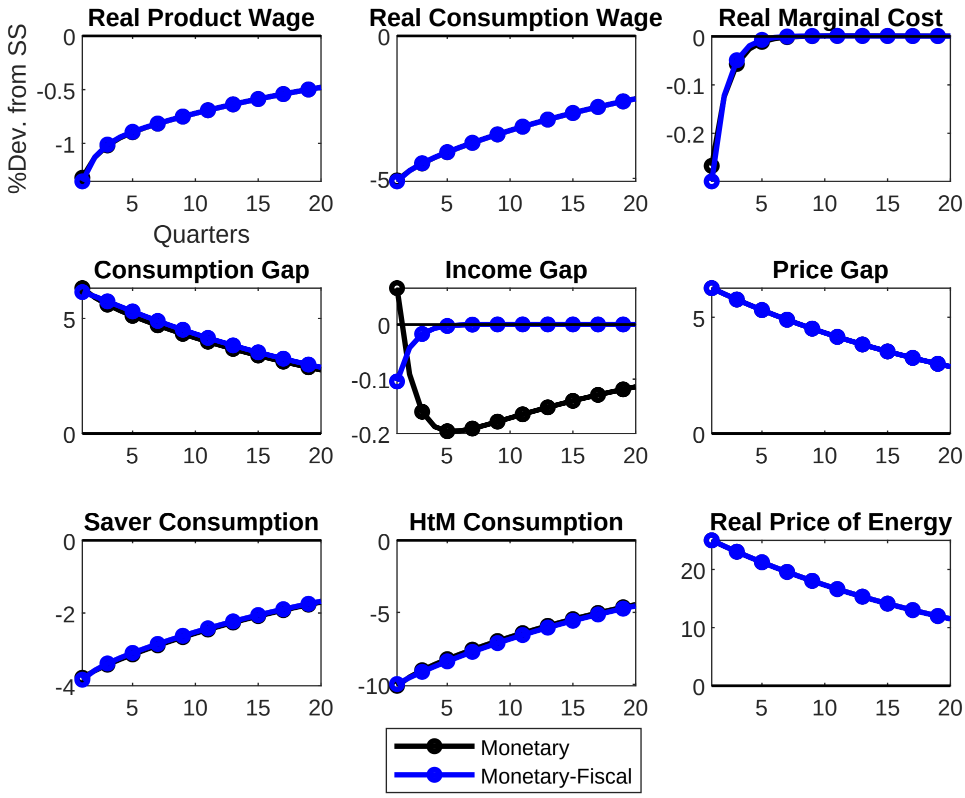

Figure 2.23: Dynamic Response to an Energy Price Shock: Omp vs Omfp

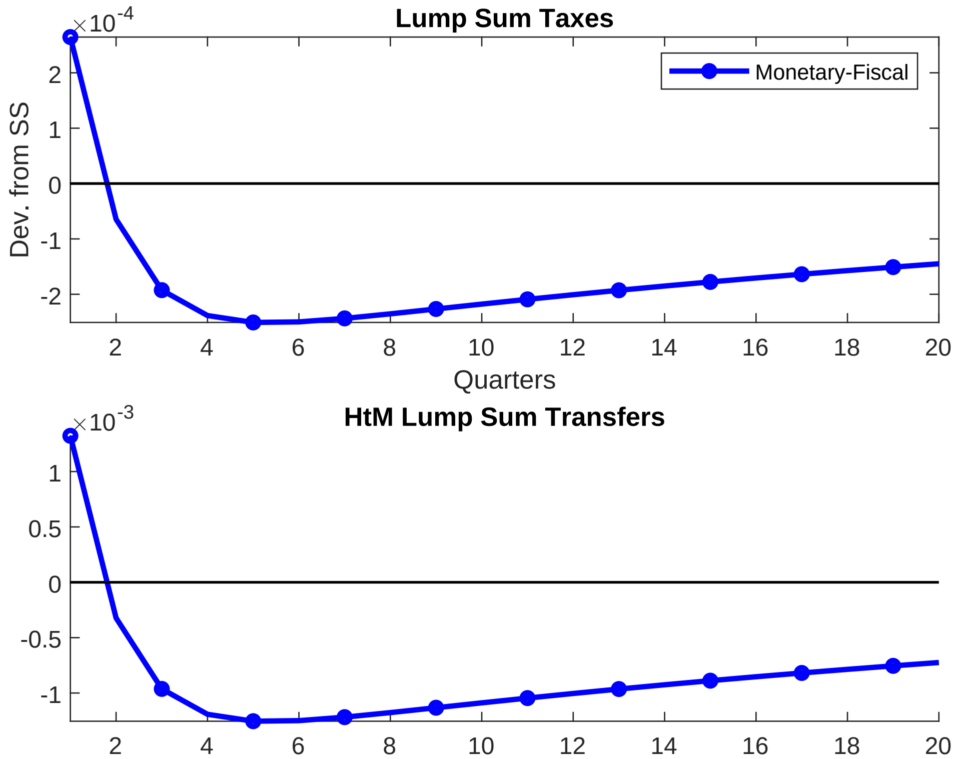

Figure 2.24: Dynamic Response to an Energy Price Shock: Omfp

2.6 Conclusions

The 2021-2022 global energy crisis was faced with a combination of restrictive monetary policy and expansionary fiscal policy. Central banks relied on a series of gradual and regular interest rate hikes, while governments pulled-out large-scale fiscal support packages. This paper investigates the role of various fiscal policy responses to energy price shocks through the lens of a Two-Agent New Keynesian model featuring heterogeneous consumption baskets in an energy-importing economy. In addition, the corresponding optimal fiscal policy, and the optimal mix of monetary and fiscal policy responses are explored.

When the fiscal authority intervenes by the means of lump sum transfers, the effectiveness of such measures is conditional on whether they are targeted or not. Under Scenario II, where transfers are directed toward Hand-to-Mouth households, the energy price shock remains contractionary, leading to declines in output and employment, and a rise in inflation. Nevertheless, the redistributive nature of the policy plays a substantial stabilizing role. By restoring consumption inequality to its pre-shock level, it sustains aggregate demand and mitigates the macroeconomic fallout of the shock. This stabilization, however, comes at the cost of increased inflationary pressures, which in turn elicit a more pronounced monetary tightening response. The deployment of a price-suppressing instrument – such as an energy subsidy – further attenuates the recessionary effects relative to Scenario II, even when the intervention is not targeted, as illustrated under Scenario III. Crucially, the financing mechanism of the subsidy is a key determinant of its overall macroeconomic impact. When the subsidy is financed through a consumption tax – Scenario IIIb – the policy becomes more expansionary: it stimulates aggregate demand, mitigates losses in output and employment, but also generates stronger inflationary pressures, which necessitate a more aggressive monetary policy response. By contrast, if the subsidy is financed via lump sum taxation – Scenario IIIa – the resulting macroeconomic dynamics closely resemble those in Scenario II, offering only marginal additional stabilization. Under Scenario IVb, the subsidy is both targeted to Hand-to-Mouth and financed through distortionary taxation, while Scenario IVa considers the same targeted subsidy funded by lump sum taxes. Scenario IVb achieves output stabilization effects comparable to those in Scenario IIIb, but with lower inflation. The configuration in Scenario IVb thus delivers the most favorable trade-off between output stabilization and inflation control, emphasizing the advantages of targeted, price-suppressing interventions financed through distortionary taxes. Our results depart from both Erceg et al. (2024), who find that subsidies reduce consumption inequality across households, but that targeted transfers to Hand-to-Mouth agents are more efficient, as they achieve similar distributional gains with a more favorable inflation-output trade-off; and Bartocci et al. (2024), who find that reducing excise taxes on fuel and implementing targeted transfers has only a limited effect on economic activity. The divergence from the former could arise from our assumption of heterogeneous consumption baskets across households, which makes price-suppressing fiscal policy instruments more efficient. The discrepancy with the latter stems from our introduction of distortionary taxation as a financing mechanism for public interventions, which plays a crucial role in shaping macroeconomic outcomes.

Across all optimal fiscal policy scenarios, aggregate outcomes systematically dominate those under their respective decentralized counterparts. The planner redistributes the burden of the energy price shock across household types – primarily by shifting resources toward poorer households – thereby stabilizing consumption while tolerating a modest increase in inflation. The comparison across centralized economies mirrors the findings of the scenario analysis: price-suppressing instruments are more effective in mitigating the contractionary effects of energy price shocks on output and employment, albeit at the cost of slightly higher inflation. By contrast, non-price-suppressing instruments, such as targeted transfers, are more successful in enhancing welfare by addressing consumption inequality, which declines more substantially under optimal policies involving targeted redistribution. Introducing redistributive fiscal instruments into a Ramsey framework alongside monetary policy, however, yields only modest incremental improvements in both aggregate and distributional outcomes. When the planner is already able to effectively stabilize inflation and output using interest rate policy alone, the marginal benefit of incorporating targeted fiscal transfers is limited. Nonetheless, inflation tends to be slightly lower in scenarios that include fiscal intervention. This finding is consistent with Dao et al. (2023), who argue that unconventional fiscal measures, when coordinated with restrictive monetary policy, can contribute to smoother inflation dynamics in response to large yet transitory energy price shocks. We leave further exploration of the design and interaction of such monetary and fiscal policy instruments to future research.

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Appendix A

Chapter 1

A.1 Model

Equilibrium Conditions

The new competitive equilibrium is given by a set of processes for the following 27 variables $\left[C^s_{Q,t}, C^s_{E,t}, C^s_t, C^h_{Q,t}, C^h_{E,t}, C^h_t, C_t, N^s_t, N^h_t, N_t, \Pi_{Q,t}, \Pi^*_{Q,t}, P_{CQ,t}, P_{YQ,t}, S_{E,t}, \Pi_{C,t}, MC_t, R_t, Q_t, E_t, W^r_t, \zeta_t, Y_t, A_t, U_t, P^s_{CQ,t}, P^h_{CQ,t}, Z^*_{N,t}, Z^*_{D,t}\right]$ that satisfy the following system of 29 non-linear equilibrium conditions.

$$\begin{gathered} \ln S_{E,t} = \rho_{se}\; lnS_{E,t-1} + e_{se,t} \\ \rho_{se} \in (0,1) \quad e_{se,t} \sim \mathcal{N}(0, \sigma^2_{se}) \end{gathered} \tag{A.1}$$

$$C^s_{Q,t} = (1-\chi_s)\left\{\frac{P_{Q,t}}{\left[1-\chi_s+\chi_s(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}}}\right\}^{-\eta} C^s_t \tag{A.2}$$

$$C^s_{E,t} = (\chi_s)\left\{\frac{P_{E,t}}{\left[1-\chi_s+\chi_s(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}}}\right\}^{-\eta} C^s_t \tag{A.3}$$

$$\left(\frac{1-\lambda}{C^{s\,\sigma}_t N^{\varphi}_t}\frac{W^r_{Q,t}}{P^s_{CQ,t}} + \frac{\lambda}{C^{h\,\sigma}_t N^{\varphi}_t}\frac{W^r_{Q,t}}{P^h_{CQ,t}}\right) = \mathcal{M}_w \tag{A.4}$$

$$\frac{1}{R_t} = \beta E_t \left\{ \left(\frac{C^s_{t+1}}{C^s_t} \right)^{-\sigma} \frac{1}{\Pi_{Q,t+1}} \frac{P^s_{CQ,t}}{P^s_{CQ,t+1}} \right\} \tag{A.5}$$

$$C^h_{Q,t} = (1-\chi_h) \left\{ \frac{P_{Q,t}}{\left[1-\chi_h+\chi_h(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}}} \right\}^{-\eta} C^h_t \tag{A.6}$$

$$C^h_{E,t} = (\chi_h) \left\{ \frac{P_{E,t}}{\left[1-\chi_h+\chi_h(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}}} \right\}^{-\eta} C^h_t \tag{A.7}$$

$$\left[1-\chi_h+\chi_h(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} C^h_t = W^r_t N^h_t \tag{A.8}$$

$$N^s_t = N^h_t \tag{A.9}$$

$$P_{CQ,t}C_t = (1-\lambda)\left[1-\chi_h+\chi_h(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} C^s_t + \lambda\left[1-\chi_h+\chi_h(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} C^h_t \tag{A.10}$$

$$N_t = (1-\lambda)N^s_t + \lambda N^h_t \tag{A.11}$$

$$P_{CQ,t} = (1-\lambda)\left[1-\chi_s+\chi_s(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} + \lambda\left[1-\chi_h+\chi_h(S_{E,t})^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{A.12}$$

$$\begin{aligned} \ln A_t &= \rho_a \; lnA_{t-1} + e_{a,t} \\ \rho_a \in (0,1) &\quad e_{a,t} \sim \mathcal{N}(0,\sigma_a^2) \end{aligned} \tag{A.13}$$

$$MC_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} \frac{S^\alpha_{E,t} W^{r\,1-\alpha}_t}{A_t} \tag{A.14}$$

$$\Pi_{Q,t} = \left[(1-\theta)(\Pi^*_{Q,t})^{1-\epsilon_p} + \theta \right]^{\frac{1}{1-\epsilon_p}} \tag{A.15}$$

$$\Pi^*_{Q,t} = \frac{\epsilon_p}{\epsilon_p - 1} \Pi_{Q,t} \frac{Z^*_{N,t}}{Z^*_{D,t}} \tag{A.16}$$

$$Z^*_{N,t} = (C^s_t)^{-\sigma} MC_t Q_t + \theta\beta E_t (\Pi_{Q,t+1})^{\epsilon_p} Z^*_{N,t+1} \tag{A.17}$$

$$Z^*_{D,t} = (C^s_t)^{-\sigma} Q_t + \theta\beta E_t (\Pi_{Q,t+1})^{\epsilon_p - 1} Z^*_{D,t+1} \tag{A.18}$$

$$P_{YQ,t} Y_t = Q_t - S_{E,t} E_t \tag{A.19}$$

$$1 = (P_{YQ,t})^{1-\alpha}(S_{E,t})^\alpha \tag{A.20}$$

$$\frac{R_t}{R} = \left(\frac{\Pi_{C,t}}{\Pi_C}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y} U_t \tag{A.21}$$

$$\Pi_{C,t} = \Pi_{Q,t} \frac{P_{CQ,t}}{P_{CQ,t-1}} \tag{A.22}$$

$$\begin{aligned} \ln U_t &= \rho_u \, lnU_{t-1} + e_{u,t} \\ \rho_u \in (0,1) \quad & e_{u,t} \sim \mathcal{N}(0, \sigma_u^2) \end{aligned} \tag{A.23}$$

$$P_{CQ,t} C_t = P_{YQ,t} Y_t \tag{A.24}$$

$$\frac{S_{E,t} E_t}{\alpha} = \frac{W_t^r N_t}{1-\alpha} \tag{A.25}$$

$$Q_t = \frac{A_t E_t^\alpha N_t^{1-\alpha} - F}{\zeta_t} \tag{A.26}$$

$$\zeta_t = (1-\theta)(\Pi_{Q,t}^*)^{-\epsilon_p} (\Pi_{Q,t})^{\epsilon_p} + (\Pi_{Q,t})^{\epsilon_p} \theta \zeta_{t-1} \tag{A.27}$$

$$P_{CQ,t}^s = \frac{P_{C,t}^s}{P_{Q,t}} \tag{A.28}$$

$$P_{CQ,t}^h = \frac{P_{C,t}^h}{P_{Q,t}} \tag{A.29}$$

A.2 Aggregate Dynamics

A.2.1 The IS Equation

We look for the dynamic IS equation to analyze the effects of an energy price shock to the economy. The aggregate resource constraint of the economy is given by (1.27). Its log-linearised counterpart around the zero-inflation steady state and up to first order approximation is

$$p_{C,t} + c_t = p_{Y,t} + y_t \tag{A.30}$$

where lowercase letters are used to indicate log-linear variables, i.e. log-deviations from their steady-state values, defined as $x_t \equiv \ln\left(\frac{X_t}{X}\right)$.

The index of average consumption gap between Savers and HtM is defined as

$$C_{gap,t} \equiv \frac{C_t^s}{C_t^h}$$

which captures the consumption heterogeneity between the two types of households: the greater the consumption inequality, the greater $C_{gap,t}$. At the steady state perfect consumption insurance between families holds, ensuring $C^s = C^h$, hence $C_{gap} = 1$. The log-linearised index of consumption gap around the zero-inflation steady state and up to first order approximation is given by

$$c_{gap,t} = c_t^s - c_t^h$$

Dividing both sides of (1.13) by C_t^s, $P_{Q,t}$, and substituting for $C_{gap,t}$ yields

$$\frac{P_{CQ,t}C_t}{C_t^s} = (1-\lambda)P_{CQ,t}^s + \frac{\lambda P_{CQ,t}^h}{C_{gap,t}}$$

Log-linearizing the expression around the zero-inflation steady state and up to first order approximation gives

$$p_{CQ,t} + c_t - c_t^s = (1-\lambda)p_{CQ,t}^s + \lambda p_{CQ,t}^h - \lambda c_{gap,t}$$

or

$$c_t = c_t^s - \lambda c_{gap,t}$$

since

$$p_{CQ,t} = (1-\lambda)p_{CQ,t}^s + \lambda p_{CQ,t}^h$$

Substituting this result into (A.30) yields

$$p_{C,t} + c_t^s - \lambda c_{gap,t} = p_{Y,t} + y_t \tag{A.31}$$

Next, we consider the log-linear Saver's Euler equation, given by

$$c_t^s = E_t c_{t+1}^s - \frac{1}{\sigma}(r_t - E_t \pi_{C,t+1}^s) \tag{A.32}$$

where r_t represents the log-deviation of the gross nominal interest rate from its steady state, and $E_t\pi^s_{C,t+1}$ the expected log-linear gross CPI inflation for Savers, given by

$$E_t\pi^s_{C,t+1} = E_t p^s_{C,t+1} - p^s_{C,t}$$

We substitute (A.32) into (A.31) to obtain

$$p_{C,t} + E_t c^s_{t+1} - \frac{1}{\sigma}(r_t - E_t\pi^s_{C,t+1}) - \lambda c_{gap,t} = p_{Y,t} + y_t \tag{A.33}$$

Moving the resuls forward at time $t+1$ we get

$$E_t p_{C,t+1} + E_t c^s_{t+1} - \lambda E_t c_{gap,t+1} = E_t p_{Y,t+1} + E_t y_{t+1} \tag{A.34}$$

Deriving $E_t c^s_{t+1}$ from (A.35) and substituting out the result into (A.33) gives

$$p_{C,t} + E_t p_{Y,t+1} + E_t y_{t+1} + \lambda E_t c_{gap,t+1} - E_t p_{C,t+1} - \frac{1}{\sigma}(r_t - E_t\pi^s_{C,t+1}) - \lambda c_{gap,t} = p_{Y,t} + y_t$$

Rearranging terms yields the dynamic IS equation

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(r_t - E_t\pi^s_{C,t+1}) - E_t\pi_{C,t+1} + E_t\pi_{Y,t+1} + \lambda E_t\Delta c_{gap,t+1} \tag{A.35}$$

where

$$E_t\pi_{C,t+1} = E_t p_{C,t+1} - p_{C,t}$$

$$E_t\pi_{Y,t+1} = E_t p_{Y,t+1} - p_{Y,t}$$

and

$$E_t\Delta c_{gap,t+1} = E_t c_{gap,t+1} - c_{gap,t}$$

Solving the dynamic IS equation forward yields

$$y_t = -\frac{1}{\sigma}E_t\sum_{k=0}^{\infty}(r_{t+k} - \pi^s_{C,t+k+1}) + \pi_{C,t} - \pi_{Y,t} - \lambda c_{gap,t} \tag{A.36}$$

But

$$\pi_{C,t} - \pi_{Y,t} = p_{C,t} - p_{C,t-1} - p_{Y,t} + p_{Y,t-1}$$

where

$$p_{C,t} = (1-\lambda)p^s_{C,t} + \lambda p^h_{C,t}$$

$$p^s_{C,t} = (1-\chi_s)p_{Q,t} + \chi_s p_{E,t}$$

and

$$p^h_{C,t} = (1-\chi_h)p_{Q,t} + \chi_h p_{E,t}$$

Hence

$$p_{C,t} = p_{Q,t} + (1-\lambda)\chi_s s_{E,t} + \lambda\chi_h s_{E,t}$$

Moreover

$$p_{Y,t} = p_{Q,t} - \frac{\alpha}{1-\alpha}s_{E,t}$$

Therefore

$$\pi_{C,t} - \pi_{Y,t} = \left[(1-\lambda)\chi_s + \lambda\chi_h + \frac{\alpha}{1-\alpha}\right]\pi_{SE,t}$$

Finally, we can rewrite the IS equation as

$$y_t = -\frac{1}{\sigma}E_t\sum_{k=0}^{\infty}(r_{t+k} - \pi^s_{C,t+k+1}) + \left[(1-\lambda)\chi_s + \lambda\chi_h + \frac{\alpha}{1-\alpha}\right]\pi_{SE,t} - \lambda c_{gap,t}$$

Appendix B

Chapter 2

B.1 Model

Equilibrium Conditions

The new competitive equilibrium is given by a set of processes for the following 48 variables $\big[C^s_{Q,t}, C^s_{E,t}, C^s_t, C^h_{Q,t}, C^h_{E,t}, C^h_t, C_{E,t}, C_{Q,t}, C_t, N^s_t, N^h_t, N_t, \tau^s_{E,t}, \tau^h_{E,t},$
$\tau_{E,t}, \tau_{C,t}, Tr^s_t, Tr^h_t, Tr_t, T^s_t, T^h_t, T_t, P^s_{CQ,t}, P^h_{CQ,t}, P_{CQ,t}, P_{YQ,t}, \Pi_{Q,t}, \Pi^*_{Q,t}, \Pi^s_{C,t}, \Pi^h_{C,t}, \Pi_{C,t}, R_t,$
$MC_t, Q_t, E_t, W^{s,r}_{C,t}, W^{h,r}_{C,t}, W^r_{C,t}, W^r_{Q,t}, \zeta_t, Y_t, B_t, Z^*_{N,t}, Z^*_{D,t}, S_{E,t}, A_t, U_t, G_t\big]$, that satisfy the following system of 48 non-linear equilibrium conditions.

$$P^s_{CQ,t} \equiv \frac{P^s_{C,t}}{P_{Q,t}} = [1 - \chi_s + \chi_s S^{1-\eta}_{E,t}]^{\frac{1}{1-\eta}} \tag{B.1}$$

$$P^h_{CQ,t} \equiv \frac{P^h_{C,t}}{P_{Q,t}} = [1 - \chi_h + \chi_h S^{1-\eta}_{E,t}]^{\frac{1}{1-\eta}} \tag{B.2}$$

$$P_{CQ,t} \equiv \frac{P_{C,t}}{P_{Q,t}} = (1-\lambda) P^s_{CQ,t} + \lambda P^h_{CQ,t} \tag{B.3}$$

$$P_{YQ,t} \equiv \frac{P_{Y,t}}{P_{Q,t}} \tag{B.4}$$

$$\Pi^s_{C,t} \equiv \Pi_{Q,t} \frac{P^s_{CQ,t}}{P^s_{CQ,t-1}} \tag{B.5}$$

$$\Pi^h_{C,t} \equiv \Pi_{Q,t} \frac{P^h_{CQ,t}}{P^h_{CQ,t-1}} \tag{B.6}$$

$$\Pi_{C,t} \equiv \Pi_{Q,t} \frac{P_{CQ,t}}{P_{CQ,t-1}} \tag{B.7}$$

$$(1+\tau_{C,t})P^s_{CQ,t}C^s_t = C^s_{Q,t} + (1-\tau^s_{E,t})S_{E,t}C^s_{E,t} \tag{B.8}$$

$$\left[\frac{1}{(1-\tau^s_{E,t})S_{E,t}}\right]^{-\eta} = \frac{\chi_s}{1-\chi_s}\frac{C^s_{Q,t}}{C^s_{E,t}} \tag{B.9}$$

$$\frac{1}{R_t} = \beta E_t \left\{ \left(\frac{C^s_{t+1}}{C^s_t}\right)^{-\sigma} \frac{(1+\tau_{C,t})}{(1+\tau_{C,t+1})\Pi^s_{C,t+1}} \right\} \tag{B.10}$$

$$\left[\frac{1}{(1-\tau^h_{E,t})S_{E,t}}\right]^{-\eta} = \frac{\chi_h}{1-\chi_h}\frac{C^h_{Q,t}}{C^h_{E,t}} \tag{B.11}$$

$$(1+\tau_{C,t})P^h_{CQ,t}C^h_t = C^h_{Q,t} + (1-\tau^h_{E,t})S_{E,t}C^h_{E,t} \tag{B.12}$$

$$(1+\tau_{C,t})P^h_{CQ,t}C^h_t + P^h_{CQ,t}T^h_t = W^r_{Q,t}N^h_t + P^h_{CQ,t}Tr^h_t \tag{B.13}$$

$$(1-\tau_{E,t})C_{E,t} = (1-\lambda)(1-\tau^s_{E,t})C^s_{E,t} + \lambda(1-\tau^h_{E,t})C^h_{E,t} \tag{B.14}$$

$$P_{CQ,t}C_t = (1-\lambda)P^s_{CQ,t}C^s_t + \lambda P^h_{CQ,t}C^h_t \tag{B.15}$$

$$\tau_{E,t} = (1-\lambda)\tau^s_{E,t} + \lambda\tau^h_{E,t} \tag{B.16}$$

$$P_{CQ,t}Tr_t = (1-\lambda)P^s_{CQ,t}Tr^s_t + \lambda P^h_{CQ,t}Tr^h_t \tag{B.17}$$

$$P_{CQ,t}T_t = (1-\lambda)P^s_{CQ,t}T^s_t + \lambda P^h_{CQ,t}T^h_t \tag{B.18}$$

$$N_t = (1-\lambda)N^s_t + \lambda N^h_t \tag{B.19}$$

$$N^s_t = N^h_t \tag{B.20}$$

$$\left(\frac{1-\lambda}{C^{s\,\sigma}_t N^\varphi_t} W^{s,r}_{C,t} + \frac{\lambda}{C^{h\,\sigma}_t N^\varphi_t} W^{h,r}_{C,t}\right) = \mathcal{M}_w \tag{B.21}$$

$$W^{s,r}_{C,t} = \frac{W^r_{Q,t}}{P^s_{CQ,t}} \tag{B.22}$$

$$W^{h,r}_{C,t} = \frac{W^r_{Q,t}}{P^h_{CQ,t}} \tag{B.23}$$

$$W^r_{C,t} = \frac{W^r_{Q,t}}{P_{CQ,t}} \tag{B.24}$$

$$MC_t = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)}\frac{S^{\alpha}_{E,t}(1-\tau_w)^{(1-\alpha)}{W^r_{Q,t}}^{(1-\alpha)}}{A_t} \tag{B.25}$$

$$\Pi_{Q,t} = \left[(1-\theta)(\Pi^*_{Q,t})^{1-\epsilon_p} + \theta\right]^{\frac{1}{1-\epsilon_p}} \tag{B.26}$$

$$\Pi^*_{Q,t} = \mathcal{M}_p \Pi_{Q,t}\frac{Z^*_{N,t}}{Z^*_{D,t}} \tag{B.27}$$

$$Z^*_{N,t} = (C^s_t)^{-\sigma} MC_t Q_t + \theta\beta E_t \Pi^{\epsilon_p}_{Q,t+1} Z^*_{N,t+1} \tag{B.28}$$

$$Z^*_{D,t} = (C^s_t)^{-\sigma} Q_t + \theta\beta E_t \Pi^{\epsilon_p-1}_{Q,t+1} Z^*_{D,t+1} \tag{B.29}$$

$$P_{YQ,t}Y_t = Q_t - S_{E,t}E_t \tag{B.30}$$

$$1 = (P_{YQ,t})^{1-\alpha}(S_{E,t})^{\alpha} \tag{B.31}$$

$$\frac{R_t}{R} = \left(\frac{\Pi_{C,t}}{\Pi_C}\right)^{\phi_\pi}\left(\frac{Y_t}{Y}\right)^{\phi_y}\upsilon_t \tag{B.32}$$

$$B_t = 0 \tag{B.33}$$

$$\tau^s_{E,t} = \tau^h_{E,t} = 0 \tag{B.34}$$

$$\tau_{C,t} = 0 \tag{B.35}$$

$$T^s_t = T^h_t = 0 \tag{B.36}$$

$$Tr^s_t = Tr^h_t = 0 \tag{B.37}$$

$$P_{CQ,t}C_t = P_{YQ,t}Y_t \tag{B.38}$$

$$\frac{S_{E,t}E_t}{\alpha} = \frac{(1-\tau_w)W^r_{Q,t}N_t}{1-\alpha} \tag{B.39}$$

$$Q_t = \frac{A_t E^{\alpha}_t N^{1-\alpha}_t}{\zeta_t} - \frac{Fix}{\zeta_t} \tag{B.40}$$

$$\zeta_t = (1-\theta)(\Pi^*_{Q,t})^{-\epsilon_p}(\Pi_{Q,t})^{\epsilon_p} + (\Pi_{Q,t})^{\epsilon_p}\theta\zeta_{t-1} \tag{B.41}$$

$$
\begin{aligned}
\ln S_{E,t} &= \rho_{se}\ lnS_{E,t-1} + e_{se,t} \\
\rho_{se} \in (0,1) &\quad e_{se,t} \sim \mathcal{N}(0, \sigma^2_{se})
\end{aligned} \tag{B.42}
$$

$$
\begin{aligned}
\ln A_t &= \rho_a\ lnA_{t-1} + e_{a,t} \\
\rho_a \in (0,1) &\quad e_{a,t} \sim \mathcal{N}(0, \sigma^2_a)
\end{aligned} \tag{B.43}
$$

$$
\begin{aligned}
\ln U_t &= \rho_u\ lnU_{t-1} + e_{u,t} \\
\rho_u \in (0,1) &\quad e_{u,t} \sim \mathcal{N}(0, \sigma^2_u)
\end{aligned} \tag{B.44}
$$

$$
\begin{aligned}
\ln G_t &= \rho_g\ lnG_{t-1} + e_{g,t} \\
\rho_g \in (0,1) &\quad e_{g,t} \sim \mathcal{N}(0, \sigma^2_g)
\end{aligned} \tag{B.45}
$$