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MONETARY AND FISCAL POLICY RESPONSES TO FOSSIL FUEL PRICE SHOCKS

by Anna Bartocci*, Alessandro Cantelmo*, Pietro Cova*,
Alessandro Notarpietro* and Massimiliano Pisani*

Abstract

We use a dynamic equilibrium model featuring different sources of energy to assess the macroeconomic effects, in the euro area, of a temporary reduction in excise taxes on fossil fuels and an increase in lump-sum transfers to the poorest ('hand-to-mouth') households, and of raising the monetary policy rate in response to a temporary increase in the global prices of fossil fuels. In the model, the central bank should raise the monetary policy rate to stabilize inflation even if excise taxes are lowered, in particular if price- and wage-setting decisions are not strongly anchored to the central bank's inflation target. Lump-sum transfers to hand-to-mouth households can stabilize their consumption with limited inflationary effects.

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Contents

* Bank of Italy, Directorate General for Economics, Statistics and Research.

1 Introduction[1]

Adverse shocks to the global supply of fossil fuels, by increasing their international prices, can have a non-trivial impact on net fossil fuel-importing regions, such as the euro area (EA). Since fossil fuel price shocks imply an increase in production costs for firms, they are akin to cost-push shocks, which induce an increase in inflation and a slowdown in economic activity. Moreover, they may affect consumer price dynamics through second-round effects, which occur when the direct and indirect cost-increasing effects of the energy shock are passed on to nominal wages and prices.[2] Finally, the shocks deteriorate the EA terms of trade, because the EA is a net fossil fuel-importing region and it is difficult to substitute non-fossil fuels for fossil fuels in the short term. Thus, positive shocks to fossil fuel prices negatively affect EA households' real income and their demand for consumption goods, the more so for poorer households (whose propensity to consume energy is higher).

The policy response to fossil fuel shocks is quite complex. The central bank faces a typical trade-off between inflation and output stabilization and could "look through" the supply-side shock, if the latter is deemed to be temporary and relatively small. However, if the energy shock is large and induces a significant increase in inflation, which the central bank does not stabilize by sufficiently raising the policy rate, there is a risk of second-round effects, which would amplify and prolong the increase in inflation. On the fiscal policy front, reductions in excise taxes on fossil fuels and (targeted) transfers to the most vulnerable households can be used to support aggregate demand.[3]

[1]The views expressed in this paper are those of the authors alone and should not be attributed to the Bank of Italy or the Eurosystem. We thank two anonymous referees, Fabio Busetti, Michele Caivano, Paolo Del Giovane, Stefano Neri and participants at the Working Group on Econometric Modelling for useful comments, and Gwyneth Schaefer for editorial assistance. All remaining errors are ours.

[2]Direct effects are those related to the immediate impact on the energy component of the consumer price index, while indirect effects capture the transmission of the shock to consumer prices of goods other than energy and services via the production and distribution chain.

[3]Signorini (2022) suggests that, aside from emergency measures taken to smooth temporary "bumps", public intervention aimed at mitigating the effects of the energy crisis should take the form of income relief for those most affected rather than fighting price increases, so as to leave the signal of relative prices to function to the extent reasonably possible. Celasun et al. (2022) report that European policymakers have mostly responded to the recent surge in international fossil fuel prices with broad-based price-suppressing measures, including subsidies, tax reductions, and price controls. Indeed the discretionary fiscal support enacted by EA governments in response to the recent energy crisis and ensuing high inflation have been sizeable. According to the most recent assessments (see Checherita-Westphal and Dorrucci, 2023) it is estimated to amount to around 1.8% of EA GDP in 2023 (down from 1.9% in 2022) and to drop steeply to 0.5% of GDP in 2024. Of these measures, only a limited share was targeted at vulnerable households and firms (approximately 0.4% of GDP in 2022, 0.2% in 2023, and less than 0.1% in 2024). In particular, measures targeted at lower income households mostly consisted of income support

In this paper, we assess the macroeconomic effects of monetary and fiscal policy measures to counteract the impact on the EA economy of a temporary but relatively persistent (three-year-long) abrupt rise in the international price of fossil fuels.[4] To this purpose, we simulate a two-country two-agent New Keynesian (TANK) model calibrated to the EA and the rest of the world (RW). Some households are "hand-to-mouth" (HTM) and consume their entire disposable (wage) income in every period on a consumption basket with a larger energy share compared to the basket of the other households ("optimizers"). Moreover, households cannot easily or readily reduce their demand for energy from fossil fuels in favor of energy from renewable sources and non-energy goods, because energy and non-energy goods are assumed to be hardly substitutable, in line with the empirical evidence. This assumption implies a strong negative income effect associated with the rise in energy prices.

The fiscal policy measures are assumed to be transitory, budget-neutral (financed by lump-sum taxes paid by the optimizers) and implemented by a hypothetical representative EA-wide fiscal authority.[5]

We simulate several illustrative scenarios. In all of them, a temporary increase in the international prices of fossil fuels associated with a decrease in their international supply hits the economy, giving rise to stagflationary effects.

In the first scenario, the EA central bank raises, according to a Taylor-type rule, the policy rate in response to the inflation increase due to the energy price shock, while the fiscal authority does not respond with specific measures to the energy shock. In the second scenario, the central bank raises the policy rate and a coordinated EA-wide fiscal intervention is implemented in a transitory and budget-neutral way. This intervention is based on a temporary reduction in excise taxes on fossil fuels to partially offset the spike in fuel prices. In the third scenario, differently from the second one, the fiscal intervention is based on lump-sum transfers targeted to the

measures, in the form of either one-off payments or supplements to existing benefit schemes (see Basso et al., 2023). See Sgaravatti et al. (2022) for an online dataset of the policies put in place by European governments to shield consumers from rising energy prices.

[4]Our aim is not to quantitatively evaluate the (specific) impact of the abrupt surge in fossil fuel prices in the EA following the Russian invasion of Ukraine. Our results are to be read as purely qualitative. As our scenarios are illustrative, we do not replicate the exceptionally large size of the shock that hit the EA economy nor the exact design of policy responses. Fiscal responses could be particularly relevant for macroeconomic stability in the case of exceptionally large and sudden energy price rises.

[5]We do not evaluate the macroeconomic impact of policy measures directly related to the green transition, such as a carbon tax or a (green) subsidy to renewable sources of energy. For an analysis of the macroeconomic effects of carbon tax and green subsidies in the EA, see Bartocci et al. (2022).

HTM. The third scenario is also simulated under the assumption of "untargeted" transfers, that is, transfers directed to both groups of households, the HTM and the optimizers, instead of being directed only to HTM, i.e., those households that are hit hardest by the energy shock because of their lower income and higher propensity to consume energy.

We also analyze the role of indexation to past inflation in price- and wage-setting decisions by formulating alternative assumptions. In our benchmark simulations, we calibrate the degree of indexation in line with available estimates. We then assess the impact of possible large second-round effects by simulating scenarios under the assumption that wages and prices are highly indexed to past inflation and that, correspondingly, the central bank inflation target (kept constant over time at 2% in annualized terms) affects price- and wage-setting only marginally. In addition, we also (alternatively) assume that price- and wage-setting decisions are largely based on the central bank inflation target, while indexation to past inflation plays a marginal role. Finally, we perform a sensitivity analysis by varying (i) the weight of energy in the HTM's consumption basket, and (ii) the share of HTM.

The main results are the following. The central bank has to raise the monetary policy rate to stabilize inflation even if excise taxes are lowered and, in particular, if price- and wage-setting decisions are not strongly anchored to the central bank inflation target. Higher lump-sum transfers to HTM can stabilize their consumption and have limited inflationary effects.

We contribute to the literature on energy shocks by simulating a general equilibrium model calibrated to the EA to analyze the stabilization properties of a combination of possible monetary and fiscal policy responses. Our analysis relates to Guiso and Visco (1988). The authors investigate from a theoretical perspective the macroeconomic impact of real and nominal shocks, like those in the 1970s and 1980s, under alternative tariff and monetary policy responses. They find that it is optimal that both tariffs and money supply respond to real shocks. Curci et al. (2022) use microsimulation tools for the Italian economy and show that, if evaluated on the basis of both their cost for the public finances and their impact on inequality, the strengthening of the electricity and gas social bonuses, targeted at less well-off households, was the most effective intervention, while untargeted price reductions (such as the decrease in VAT rates on gas tariffs or lower excise duties on fuel) were the least effective. Auclert et al. (2023) simulate an heterogeneous agent model and find that energy price shocks in energy-importing economies cause a recession by pushing down real wages and therefore consumer spending, provided that the elasticity of substitution between energy and domestic goods is realistically low. A monetary policy tightening has limited effect on imported inflation when done in isolation, but can be powerful when done in conjunction with other energy importers by lowering world energy demand. Fiscal policy, especially energy price subsidies, can isolate individual energy importers from the shock, but it has large negative externalities on other economies. Gnocato (2023) studies the optimal conduct of monetary policy in a tractable heterogeneous-agent New-Keynesian model with search and matching frictions in the labor market and non-homothetic household preferences. Rising energy prices induce a novel precautionary saving motive: the consumption losses upon unemployment are increased, strengthening the drag on aggregate demand. Households heterogeneous exposure to the shock induces an endogenous trade-off for monetary policy, whose optimal response involves partly accommodating core inflation so as to indirectly support employment and prevent workers from becoming even more exposed to the shock through unemployment. Coenen et al. (2023) use a DSGE model with a detailed energy sector to study transition policies aimed at reducing carbon emissions and show that undesirable distributional effects can be addressed by appropriately redistributing the fiscal revenues from a carbon tax increase across households. In our paper, different from Coenen et al. (2023), we do not consider a carbon tax but a temporary, exogenous and unexpected increase in energy prices. We also consider targeted transfers to a specific group of households, which in our case are not financed via the revenues from a carbon tax, but with a lump-sum-tax on Ricardian households. Corsello and Riggi (2023) study the effects of an energy price shock on inflation inequality, measured as the gap between consumer prices for households at the bottom and top of the household expenditure distribution, which is due to different consumption baskets. They show that, while monetary policy may contain inflation, less affluent households benefit relatively less than more affluent ones from these measures, given the relatively lower share of consumption spent on items whose prices are sensitive to cyclical conditions. Our analysis also considers households heterogeneity in energy consumption but focuses on how different fiscal policy measures interact with monetary policy in response to an energy shock.

Our paper also contributes to the analysis of the monetary policy response to an energy shock under alternative assumptions on inflation expectations formation. IMF (2022) highlights that more backward-looking expectations require a stronger and more frontloaded monetary tightening to reduce the risks of inflation expectations de-anchoring. According to Boissay et al. (2022), a key concern for central banks is the possible emergence of a wage-price spiral, as this could signal a shift to a regime of persistently higher inflation accompanied by a de-anchoring of inflation expectations. One trigger for such a shift in regime could be nominal wage increases beyond price increases and productivity gains. Such nominal wage increases could quicken as wage earners may seek to recoup losses in purchasing power and secure additional gains to guard against future inflation surprises. However, IMF (2022) argues that the risks of a wage-price spiral are limited, particularly when the central bank promptly tightens. In this paper, we (simply) consider the case of higher second-round effects and do not consider the case of wage-price spirals or the case of inflation coming from distributional conflict.[6]

The paper is organized as following. The next section briefly describes the simulated model. Section 3 illustrates the simulated scenarios. Section 4 presents and discusses the results. Section 5 concludes.

2 Main model features

2.1 Model setup

We develop a two-country two-agent New Keynesian (TANK) model calibrated to the EA economy and to the RW.[7] The calibration is in line with the existing literature and is reported in Tables 1 to 6. The main features of the model are as follows (see also Fig. 1).[8]

In the EA, oil-based energy is produced under perfect competition by combining capital, labour, and oil. Similarly, the production of energy using, alternatively, coal, gas, nuclear, and a renewable source (representative of hydro, solar, wind, and biomass) combines the specific source

[6]It cannot be excluded that temporary fiscal measures like those considered in this paper could, by favoring most vulnerable households purchasing power and reducing the peak in firms energy costs, reduce the risk of the wage-price spirals. As long as the measures are budget-neutral they would not deteriorate public finance conditions. On the possible relevance of distributional conflicts as potential inflation drivers, see Lorenzoni and Werning (2023).

[7]The EA is a modelled as a single bloc and not as a monetary union. In the description of the model we focus on the EA. Similar equations hold for the RW economy, unless explicitly stated.

[8]See the Appendix for details.

with capital and labour. The different energy types are then combined into an energy bundle, which is sold to domestic firms in the (non-energy) goods and services sector as a production input and to domestic households for final consumption. The EA imports fossil fuels (oil, coal, and gas) from the RW, whereas the nuclear fuel and the renewable sources are available domestically and are not internationally traded.

The energy price of a fossil fuel in the EA, paid by firms operating in the energy sector, has two components: the international price, set in US dollars, and the EA excise tax.[9] The two components are exogenously set. Specifically, we assume that the international supply of fossil fuels endogenously adjusts to meet demand at the given US dollar-price of the fossil fuel and that the excise tax is set by the representative EA-wide fiscal authority. The international price is converted in the EA currency through the nominal exchange rate, which endogenously adjusts to the given shock.

In the EA some households are of the HTM type, that is, in every period they consume their disposable wage income, which is earned by supplying labour. Moreover, the share of the energy component in their consumption basket is larger than the corresponding share in the consumption basket of the rest of the population and set to 12 percent; (we run a sensitivity analysis on alternative share values in Section 4.4). HTM receive targeted lump-sum transfers from the fiscal authority. The size of HTM is assumed to be 25% of the overall population, in line with existing macroeconomic studies for the EA (see Coenen and Straub, 2005).[10] The remaining households, labelled "optimizers", supply labour and smooth consumption over time by investing in riskless bonds and in physical capital. The share of energy in their consumption basket is set to 8 percent, so that the share of energy in the EA population-weighted average consumption basket, is 9 percent, consistent with empirical evidence.[11] It is also assumed, in line with the existing literature, that the parameter measuring the elasticity of substitution between non-energy consumption goods and energy is set to 0.2, a relatively low value.

Importantly, labor income is pooled within the household sector, whose members are therefore perfectly insured against idiosyncratic labor income risk. We maintain this assumption in order

[9] For simplicity we set the VAT rate to zero.

[10] In Section 4.5 we perform a sensitivity analysis by varying the share of HTM.

[11] For evidence on European countries showing that higher energy prices tend to be regressive, i.e., to hurt poorer households more than richer ones, see Celasun et al. (2022). For evidence on the EA and Italian economies, see Charalampakis et al. (2022) and Curci et al. (2022), respectively.

to keep the model relatively simple on the household sector, with the exception that we allow for differences in Ricardian and HTM consumption bundles. We do not allow for involuntary unemployment via, for example, search and matching frictions in the labor market. Introducing such frictions may allow for amplification effects of energy price shocks via precautionary savings, as illustrated by Gnocato (2023).

Labour and physical capital are supplied to domestic firms. Firms in each energy sector combine these with the sector-specific source of energy to produce energy under perfect competition. Firms producing intermediate goods combine labour, capital and energy inputs to produce intermediate (non-energy) goods. The latter are sold domestically and abroad to retail EA and RW firms that produce, under perfect competition, final non-tradable goods for consumption and investment purposes.

The model features nominal wage and price stickiness. Households and firms producing intermediate goods set nominal wages and prices, respectively, under monopolistic competition and subject to quadratic adjustment costs. Both wages and prices are indexed to previous-period consumer price inflation and to the central bank inflation target, with corresponding weights between 0 and 1 and adding up to 1.[12] Crucially, we capture possible second-round effects in the EA by raising the indexation of wages and prices to past inflation to a value close to one, so that inflation becomes highly persistent, while the central bank inflation target does not greatly affect wage- and price-setting decisions.[13]

The EA central bank changes the policy rate in a gradual way (interest rate smoothing), to stabilize across-households average consumer price inflation, and economic activity, according to a Taylor-type rule.

We assume there is a fictitious EA-wide (representative) fiscal authority that sets, among other fiscal items, the excise taxes on fossil fuels paid by all households and the lump-sum transfers targeted to HTM. The fiscal policy measures are assumed to be transitory and budget-neutral (financed by lump-sum taxes paid by the optimizers).

[12]Specifically, in the benchmark calibration we assume that prices and wages are indexed to a weighted average of previous-period inflation and the central bank inflation target, with weights equal to the same value, that is, 0.5.

[13]In such a case, we increase the weight assigned to previous-period inflation to 0.95 and correspondingly lower the weight attached to the central bank inflation target to 0.05.

The EA optimizers and the RW households trade a riskless bond denominated in the RW currency that pays the RW monetary policy rate. EA optimizers also trade a riskless bond denominated in domestic currency paying the EA policy rate. Thus, an uncovered interest parity condition holds for the EA households, linking the EA and RW policy rate differential to the expected depreciation of the nominal exchange rate of the EA currency vis-à-vis the RW currency.

The EA economy exports intermediate non-energy goods and services and imports not only fossil fuels but also intermediate non-energy goods and services. The latter are combined with EA intermediate goods to produce final investment goods and with EA intermediate goods and energy services to produce private final consumption goods. The public final consumption goods are made of domestic intermediate goods only.

In our simulations we assume that there is a representative household for each category of households (i.e., for optimizers and HTM) and a representative firm for each production sector (i.e., energy, intermediate-good, final-good sectors). In what follows we briefly illustrate the excise taxes and the HTM.

2.2 Excise taxes

Excise taxes are paid to use fossil fuels (oil, coal, gas) by firms that produce energy. The after-excise tax price of oil is:[14]

$$P_{oil,t} = \bar{P}_{oil,t} + t_{e,t}, \tag{1}$$

where $t_{e,t} > 0$ is the excise tax and $\bar{P}_{oil,t}$ is the before-excise tax price of oil in domestic currency, i.e., the international price of oil converted in domestic currency units by the nominal exchange rate. The excise tax affects the relative price of oil and thus, its demand. The same type of excise tax also applies to coal and gas, which are the other two "brown" sources of energy. It thus affects the dynamics of consumption prices through its impact on the energy component of non-energy goods' production costs and on the energy component of the consumption basket.

[14]The price of energy goods in the EA generally includes components determined by the fiscal or by a regulatory authority that do not depend on the before-tax price. E.g., fuels include a tax on volumes purchased (the excise tax), gas prices often include fixed cost components (in Italy, the so-called "oneri di sistema"). For simplicity, in this paper we label "excise taxes" any component of the final price that is set by a public authority and does not depend on the before-tax price.

Ceteris paribus, the lower the excise tax, the lower the after-excise tax relative price of fossil fuels and the higher the demand for brown-source-generated energy by firms producing non-energy intermediate goods and, thus, by households for consumption purposes.

2.3 HTM households

There is a representative HTM household whose weight in the population is $0 < s^{rot} < 1$. In every period the HTM household consumes its disposable income:

$$(1+\tau_{c,t})P_{C,t}^{HTM}C_{HTM,t} = (1-\tau_{w,t})W_t L_{HTM,t} + TR_t^{HTM}. \tag{2}$$

where $P_{C,t}^{HTM}$ is the consumption price deflator of HTM's consumption basket, $C_{HTM,t}$ is the consumption basket, W_t is the nominal wage, $L_{HTM,t}$ labor, $TR_t^{HTM} > 0$ are per capita lump-sum transfers to the HTM from the domestic government, $\tau_{c,t}$ and $\tau_{w,t}$ are taxes on consumption and labour, respectively.

The price deflator of the overall HTM's consumption basket is

$$P_{C,t}^{HTM} = \left[a_{c,manu}^{HTM} P_{manu,t}^{1-\rho_C} + \left(1 - a_{c,manu}^{HTM}\right) P_{EN,t}^{1-\rho_C}\right]^{\frac{1}{1-\rho_C}} \tag{3}$$

where $P_{manu,t}$ and $P_{EN,t}$ represent the price deflators of the (non-energy) goods and services and energy consumption baskets, respectively and the parameter $\rho_C > 0$ is the elasticity of substitution among the two types of goods. The parameter $0 < a_{c,manu}^{HTM} < 1$ measures the weight of the non-energy consumption basket in the overall HTM's consumption basket. Thus $1 - a_{c,manu}^{HTM}$ measures the weight of the energy consumption basket. The weight $a_{c,manu}^{HTM}$ is set to a smaller value than in the case of the corresponding optimizer's weight, so that, consistent with the existing evidence, the energy basket has a larger share in the HTM's consumption basket than in the optimizers' basket.

3 Scenarios

In all scenarios a negative transitory energy supply shock materializes: the international prices of fossil fuels (oil, coal and gas) suddenly rise by 10 per cent and stay at the new higher level during the initial three years. Each scenario is characterized by a specific policy response in the EA. The implemented fiscal measures are transitory and are financed by lump-sum taxes paid by the optimizers.[15]

We simulate the following deterministic scenarios (under the perfect-foresight assumption).[16] In the first scenario, the EA central bank raises, according to a Taylor-type rule, the policy rate in response to the inflation increase due to the energy price shock, while the fiscal authority does not respond with specific measures. In the second scenario, the central bank raises the policy rate and a coordinated EA-wide fiscal intervention is implemented in a transitory and budget-neutral way, based on a temporary reduction in the excise taxes on fossil fuels to counteract the spike in fuel prices. In the third scenario, differently from the second scenario, the budget-neutral fiscal intervention is based on lump-sum transfers targeted to the HTM.[17] The third scenario is simulated also under the assumption that transfers are not targeted to HTM but rather "untargeted", that is, directed to both HTM and optimizers. In the simulations, it is initially assumed that price- and wage-setting decisions display an equal degree of indexation to past inflation and the central bank target. Subsequently, we assess the impact of possible second-round effects by simulating the scenarios under the assumption of higher wage and price indexation to past inflation and, correspondingly, the central bank target does not greatly affect price- and wage-setting decisions. Moreover, we also consider the polar case of low indexation to past inflation and large "anchoring" of price- and wage-setting decisions to the central bank target. Finally, we consider alternative weights of energy in the consumption basket of HTM

[15] The simulated scenarios are illustrative and do not aim at quantitatively replicating the (extremely large) energy shock that effectively hit the EA economy in 2021-22 and the ensuing policy responses.

[16] All shocks but the initial ones are anticipated by households and firms. One could possibly consider stochastic simulations of the energy shock, i.e., repeated unexpected realizations of the energy shock. The latter would generate oscillations in energy prices, which would prompt a systematic monetary policy response (according to the Taylor rule) and a fiscal policy response. The advantage of our setup is that it allows for a clear analysis of (i) the transmission of an energy shock, (ii) the design of fiscal measures, (iii) the impact of alternative monetary/fiscal policy combinations in response to the shock. Such clarity would most likely vanish in a stochastic environment.

[17] Fiscal measures are budget-neutral as they are financed by an increase in lump-sum taxes paid by Ricardian households. We do not consider the case of deficit-financed measures. The latter, if persistent and sizeable, could negatively affect public finance conditions and may therefore likely have negative implications for financial stability and, in particular, may induce higher sovereign risk premia.

and a larger share of HTM households in the population.

4 Results

4.1 Energy shock and policy responses

Fig. 2 reports the results obtained by simulating the case of only the EA central bank responding, according to the Taylor rule, to the sudden increase in international prices of fossil fuels (black continuous line). In this scenario, the EA fiscal authority does not react (i.e., it does neither reduce excise taxes nor raises lump-sum transfers to HTM).[18]

The shock, which materializes in a sudden and unexpected way, has a stagflationary impact on the economy. Inflation increases and output decreases. Higher international fuel prices are, consistent with the empirical evidence, quickly passed-through to EA energy prices. EA consumer price inflation increases in the first period and then returns close to its baseline value (i.e., the central bank inflation target), consistent with the path of the inflation rate of its energy component. Households and firms face a sudden decrease in purchasing power and increase in production costs, respectively. They cannot easily reduce demand for energy from fossil fuels in favour of non-energy goods, because the two are assumed to be hardly substitutable, in line with the empirical evidence. Thus, households cut their overall demand for goods and services, while non-energy firms reduce production and input demand (in particular for labour, not reported) and raise prices. HTM greatly reduce consumption, because of the drop in labour income, which is their only source of income and to which their consumption is tightly linked (HTM consume in every period their available income, see Eq. 2). Moreover, their purchasing power is reduced to a relatively large extent also because the energy component has a relatively large share in their consumption basket (see Eq. 3). Consistently, the inflation rate effectively faced by the HTM increases more than the inflation rate faced by the optimizers.

The central bank gradually raises the monetary policy rate to stabilize inflation. The higher monetary policy rate induces optimizing households to reduce their demand for consumption and investment in physical capital, which in turn contributes to reducing the initial inflation increase.

[18] All results are reported relative to the baseline (the steady state of the model).

Fig. 2 also shows the results of two alternative scenarios where both the EA fiscal authority and the EA central bank respond to the higher fossil fuel prices. Specifically, the EA fiscal authority either reduces the excise tax on fossil fuels in the initial period to lower the peak of the after-tax price of energy, or raises, for two years, lump-sum transfers targeted to HTM.[19] At the same time, the EA central bank raises the monetary policy rate according to the Taylor-type rule, which responds to inflation and output fluctuations and thus takes into account the general equilibrium effects related to the implementation of fiscal measures.

In the case of a reduction in excise taxes (red-dashed line), the lower rise in after-tax fuel prices is reflected into a correspondingly smaller increase in energy prices and headline inflation compared to the case in which the fiscal authority does not respond to the shock. The peak of overall consumer price inflation, optimizers' inflation and inflation faced by HTM is lower and postponed by one quarter relative to the benchmark case. The central bank, as a consequence, raises the policy rate at a somewhat slower pace than in the benchmark case. The peak of the policy rate is the same as in the benchmark case, the subsequent decline is somewhat smaller. The initially milder monetary policy tightening somewhat mitigates the decline in optimizers' demand for consumption. HTM, whose purchasing power benefits from the excise tax reduction, reduce their consumption somewhat less in the initial period.

In the case of higher lump-sum transfers to HTM (blue line with plus sign), their consumption decreases much less than in the benchmark and excise tax-reduction cases, because the higher transfers raise their disposable income and, thus, their purchasing power. Since transfers are targeted to HTM, who constitute a relatively small share of the population, the impact of the fiscal measure on overall economic activity and inflation and, thus, on the monetary policy rate increase, is extremely contained.

A few remarks are in order. All the fiscal measures that we consider are financed via lump-sum taxes, which are non-distortionary. Moreover, both the excise reduction and (un)targeted transfers are very short-lived (between one and two years), and all measures are relatively small

[19] In all simulations, the overall size of each of the two fiscal measures is about 0.1% of the before-shock GDP. In the case of excise tax, the size is computed using the before-shock amounts of coal, oil, and gas demanded by firms and households. The size is such that the excise tax reduction roughly halves the inflation response to the energy shock on impact while reducing the peak by about a third. In order to fully offset the initial spike in consumer price inflation due to the energy shock, the reduction in excise taxes should be about 0.2% of the before-shock GDP. An increase in HTM-targeted transfers of the same amount would be sufficient to offset the impact drop in HTM households' consumption.

in size. The use of lump-sum instruments does not affect Ricardian households consumption, whose permanent income is barely affected, if at all, given the relatively small size and duration of the fiscal measures. To the contrary, HTM household consumption is affected to a non-negligible extent. All in all, the effects on economic activity are relatively small. The impact on inflation is non-negligible and mostly mechanical in the case of the excise reduction, while it is rather small in the case of higher transfers.

Fig. 3 reports the responses of the different sources of energy. Following the energy price shock, demand for energy generated by fossil fuels (coal, gas, oil) decreases somewhat, while energy services generated by the renewable source increase, because both firms and households substitute the latter, which has become cheaper, for the former. However, the increase in renewable energy is not large, because the elasticity of substitution among the different types of energy is set to a relatively low value.

The increase in the (after-excise tax) fossil fuel prices is overall lower than if there were no excise tax reduction, inducing a lower short-run reduction in the demand for fossil fuels, as both households and firms face a lower price-incentive to substitute cheaper green energy for more expensive brown energy. This does not happen if the fiscal authority introduces HTM-targeted lump-sum transfers.[20]

Overall, even if the excise tax dampens the energy price peak, the central bank has to raise the policy rate to stabilize inflation. The excise tax reduction alone, being temporary and aimed at lowering the peak of the fossil fuel price increase, somewhat reduces the incentive for households and firms to direct, in the short run, their demand in favour of energy sources other than fossil fuels. Lump-sum transfers targeted to HTM - those who do not have access to financial markets and cannot smooth their consumption - help to stabilize HTM's available income and, thus, their consumption without greatly affecting aggregate macroeconomic conditions and without favouring the consumption of higher polluting energy sources.

Concerning the timing assumptions for the fiscal interventions, a few words are in order. We have also simulated two additional scenarios: a reduction in excise taxes beyond the energy price peak period, and a more prolonged increase in targeted transfers to HTM compared to the

[20] Our simulations are illustrative. For an analysis of fiscal measures consistent with a green transition, see Bartocci et al. (2022).

benchmark case.[21] In the first case, (after-tax) inflation is less stable, i.e., there are undesirable oscillations. Changes in excise taxes in fact directly affect inflation. In the second case, the additional increase in HTM's consumption is instead mainly absorbed via higher production of goods and services, consistent with the assumption of short-term nominal rigidities, with negligible effects on inflation.

Finally, it is worth stressing that targeted lump-sum transfers, by cushioning the loss in disposable income, may also contribute to reducing the incentive for HTM to ask for higher nominal wage increases, which could trigger second-round effects. While we do not explicitly model such a direct link between the lower disposable income and the demand for higher wages, in Section 4.3 we analyze the transmission of the energy price shock and the related policy responses under the assumption that indexation to past inflation has a larger role than the central bank target in price- and wage-setting decisions. In this way we evaluate the role of possible second-round effects.

4.2 Untargeted transfers

Fig. 4 reports the case of transfers that are not targeted to HTM, but to both HTM and optimizers (purple line with triangles). Relative to the case of targeted transfers, the HTM's consumption improves to a lesser extent, because HTM now receive a lower (per capita) amount of transfers. Optimizers' consumption does not change, as it depends on their permanent income and, thus, is not affected by transitory transfers that they will have to pay back in the future. Aggregate consumption improves to a lesser extent as well. The impact on aggregate consumption is mild, because the share of HTM's consumption in total consumption is relatively small. Similarly, GDP and inflation do not change.

4.3 Second-round effects and the role of indexation

The results shown so far are based on the benchmark assumption that price- and wage-setting decisions react partly to past consumer price inflation and are partly indexed to the central bank target. To shed further light on this point and its role in driving the results, we simulate the

[21] Results are available upon request.

same two scenarios discussed above under the alternative assumption that wage- and price-setting decisions are mainly indexed to past EA average consumer price inflation (with the corresponding indexation weight equal to 0.95, instead of 0.5 as in the benchmark case), while the central bank target plays only a marginal role in price- and wage- setting mechanisms (the corresponding indexation weight being equal to 0.05).[22] Moreover, in order to provide a complete analysis of the role of price and wage indexation, we also consider the other polar case of indexation to past inflation being very low (0.05) and indexation to the central bank target being very high (0.95), which captures the case of price- and wage-setting decisions being quite firmly "anchored" to the target.

Fig. 5 compares the benchmark, high- and low-indexation responses to the energy shock. Under high wage and price indexation to past inflation and no-fiscal policy response (red-dashed line), the same energy shock has more persistent effects on inflation compared to the benchmark case and to the case of low indexation, in which the central bank target plays an increasingly larger role in wage- and price-setting decisions (black solid and blue-dotted lines, respectively). The reason is that firms and households respectively update their prices and wages by giving more weight to the observed (previous-period) inflation, which has largely increased following the energy shock, compared to the central bank inflation target, which instead is kept constant over time at 2% in annualized terms. Thus, relative to the case where price- and wage-setting decisions are more anchored to the central bank target, the central bank instead has to raise the monetary policy rate to a larger extent and more persistently to stabilize inflation. As a consequence, the loss in terms of economic activity needed to stabilize inflation is significantly larger than in the benchmark and low indexation cases. HTM face a larger drop in their disposable income, because firms reduce labor demand to a larger extent.

Fig. 6 contains the responses of the main macroeconomic variables under high indexation and different policy responses. A temporary cut in excise taxes can limit the initial rise in inflation but cannot greatly reduce the inflation persistence and the output loss (red-dashed lines). The central bank raises the monetary policy rate in a slightly slower way, reducing the decline in

[22]Importantly, we do not consider here the case of inflation expectations drifting away from the central bank target. The latter still influences price- and wage-setting decisions, although to a lesser extent compared to the analysis illustrated in the previous section. See Cogley and Sbordone (2008) for a discussion of trend inflation and indexation for the estimation of the New Keynesian Phillips curve.

optimizers' consumption and overall economic activity only to a limited extent. Consistent with the contained improvement in economic activity and labor demand and the limited reduction in the inflation rate, the improvement in HTM's disposable income, purchasing power, and, thus, consumption is contained as well.

Lump-sum transfers to HTM are more effective in limiting the fall in their purchasing power, even if the inflation increase and the decline in economic activity are essentially the same as in the case of no-fiscal responses (compare blue lines with cross and black solid lines).

Finally, consistent with the result reported in the previous section, the excise tax reduction, by directly and partially offsetting the relative price increase of brown energy, limits the drop in brown energy consumption, while higher transfers to HTM, which directly improve their purchasing power, do not (see Fig. 7).

Fig. 8 and 9 illustrate the responses of the main macroeconomic variables and energy sources under low indexation and different policy responses. As mentioned above, a larger role of the central bank inflation target implies a less persistent inflation response. The interest rate consequently increases by a smaller amount. The efficacy of the excise tax reduction is greater if compared to the case of high indexation. Targeted transfers to HTM remain preferable in terms of cushioning their consumption drop.

Overall, even if a reduction in the excise tax lowers the energy price peak to some extent, an energy price shock necessitates a larger increase in the monetary policy rate to stabilize inflation if price- and wage-setting decisions are not strongly indexed to the central bank inflation target, compared to the case when they are.[23] Transfers to HTM support HTM purchasing power, with limited effects on the aggregate variables and, different from the excise tax cut, on the reduction in brown energy consumption.[24]

[23] The response of monetary policy to higher energy prices would also be necessary in the case (not studied in this paper) of inflation expectations de-anchoring from the central bank's objective. See Visco (2022).

[24] To further investigate the role of wage- and price- setting decisions we have simulated the same two scenarios discussed above under the assumptions that wage and price inflation expectations are partially backward-looking instead of being fully forward-looking (that is, model-consistent), as in Busetti et al. (2021). Specifically, the next period wage inflation expectation is a weighted average, with weights equal to 0.5, of a model-consistent wage inflation expectation and of an adaptive wage inflation expectation, where the latter postulates that the expectation is equal to the observed (previous-period) wage inflation. A similar assumption holds for price inflation expectations. Moreover, as in the simulations reported in the main text, we assume that wage- and price- setting decisions are heavily indexed to previous-period inflation. Results are similar to those reported in the main text, obtained under the assumption of model-consistent expectation and high indexation to past inflation. They are available upon request.

4.4 The role of the energy weight in the HTM's consumption basket

Fig. 10 shows the results of simulating the energy shock, without fiscal responses, for different values of the energy weight in the HTM's consumption basket (the term $1 - a_{c,manu}^{HTM}$ in Eq. 3). We decrease its value from 0.28 (benchmark calibration) to 0.2 (the same value as the weight of energy in the optimizers' consumption basket) and, alternatively, we raise it to 0.45 (for illustrative purposes). In the former case, energy consumption, as a share of overall HTM's consumption, is equal in steady state to 9 percent (12 percent in the benchmark calibration), in the latter to 19 percent.[25]

As expected, HTM decrease their overall consumption to a larger extent when the energy weight in their consumption basket is higher, because their purchasing power drops by more compared to when the energy weight is lower. They decrease both energy and non-energy consumption, consistent with the complementarity among the two types of baskets. Moreover, the economy-wide inflation rate is higher when there is a larger weight of energy in the HTM's consumption basket, given that the former is a weighted average of the inflation rates faced by HTM and optimizers. Facing a larger increase in inflation, the central bank raises the policy rate to a larger extent, further weighing on optimizers' consumption. GDP decreases to a larger extent, given the larger drop in aggregate demand.

4.5 The role of the HTM's share

The share of HTM households is calibrated to 25%, in line with the evidence for the EA reported in Coenen and Straub (2005), as explained in Section 2.1. More recently, Albonico et al. (2019) estimate a 39% share of HTM in the EA in the European Monetary Union years (1993-2012). In order to shed light on the importance of the relative size of HTM, we simulate the energy shock and the two fiscal policy responses under the assumption of a 39% share of HTM. Fig. 11 shows the results for the main macroeconomic variables. Compared to the benchmark calibration (see Fig. 2), the drop in economic activity and aggregate consumption is larger, reflecting the larger share of HTM, though the individual consumption fall is not much different than to the one

[25]Note that, because of the CES aggregator, the share of energy consumption in steady state does not coincide with the energy weight in the aggregator.

observed under the benchmark calibration. The same holds true for the fall in the consumption by Ricardian households. The relative effectiveness of the excise tax reduction and HTM targeted transfers is overall qualitatively and quantitatively quite similar to the case of a 25% share of HTM.

5 Concluding remarks

We have simulated a general equilibrium model calibrated to the EA to assess the macroeconomic effects of monetary and fiscal policy responses to a transitory but persistent increase in the international price of fossil fuels. The central bank has to raise the monetary policy rate to stabilize inflation even if excise taxes are lowered, in particular if price- and wage-setting decisions are not strongly anchored to the central bank inflation target. Lump-sum transfers to HTM can stabilize their consumption levels and have limited inflationary effects. Finally, lower excise taxes reduce incentives to substitute renewable sources for fossil fuels.

Our analysis can be further extended. The excise tax reduction could complement other possible policy measures implemented to respond to high energy prices, such as measures aimed at diversifying energy supply or price caps on fuels imports in order to ensure secure and affordable energy supplies to the EA. Other policy measures may be needed and may be more effective in the case of a permanent price increase arising from an accelerating green transition. We leave these issues for future research.

References

Albonico, Alice, Alessia Paccagnini, and Patrizio Tirelli, "Limited Asset Market Participation And The Euro Area Crisis: An Empirical Dsge Model," *Economic Inquiry*, July 2019, *57* (3), 1302–1323.

Auclert, Adrien, Hugo Monnery, Matthew Rognlie, and Ludwig Straub, "Managing an Energy Shock: Fiscal and Monetary Policy," Working Paper 31543, National Bureau of Economic Research August 2023.

Bartocci, Anna, Alessandro Notarpietro, and Massimiliano Pisani, "Green fiscal policy measures and non-standard monetary policy in the euro area," Temi di discussione (Economic working papers) 1377, Bank of Italy, Economic Research and International Relations Area July 2022.

Basso, Henrique S., Maria Flevotomou, Maximilian Freier, Myroslav Pidkuyko, Antonio F. Amores, Simeon Bischl, Paola De Agostini, Silvia De Poli, Emanuele Dicarlo, Sofia Maier, and Garc, "Inflation, fiscal policy and inequality," Occasional Paper Series 330, European Central Bank October 2023.

Boissay, Frederic, Fiorella De Fiore, Deniz Igan, Albert Pierres Tejada, and Daniel Rees, "Are major advanced economies on the verge of a wage-price spiral?," BIS Bulletins 53, Bank for International Settlements May 2022.

Busetti, Fabio, Stefano Neri, Alessandro Notarpietro, and Massimiliano Pisani, "Monetary policy strategies in the New Normal: A model-based analysis for the euro area," *Journal of Macroeconomics*, 2021, *70* (C).

Celasun, Oya, Aiko Mineshima, Nicolas Arregui, Victor Mylonas, Anil Ari, Iulia Teodoru, Simon Black, Karlygash Zhunussova, Dora M Iakova, and Ian W.H. Parry, "Surging Energy Prices in Europe in the Aftermath of the War: How to Support the Vulnerable and Speed up the Transition Away from Fossil Fuels," IMF Working Papers 2022/152, International Monetary Fund July 2022.

Charalampakis, Evangelos, Bruno Fagandini, Lukas Henkel, and Chiara Osbat, "The impact of the recent rise in inflation on low-income households," ECB Economic Bulletin 7/2022, European Central Bank November 2022.

Checherita-Westphal, Cristina and Ettore Dorrucci, "Update on euro area fiscal policy responses to the energy crisis and high inflation," ECB Economic Bulletin 2/2023, European Central Bank 2023.

Coenen, Günter and Roland Straub, "Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Area," *International Finance*, December 2005, *8* (3), 435–470.

_ **, Matija Lozej, and Romanos Priftis**, "Macroeconomic effects of carbon transition policies: an assessment based on the ECBs New Area-Wide Model with a disaggregated energy sector," Working Paper Series 2819, European Central Bank May 2023.

Cogley, Timothy and Argia M. Sbordone, "Trend inflation and inflation persistence in the New Keynesian Phillips curve," *American Economic Review*, December 2008, *98* (5), 2101–2126.

Corsello, Francesco and Marianna Riggi, "Inflation is not equal for all: the heterogenous effects of energy shocks," Temi di discussione (Economic working papers) 1429, Bank of Italy, Economic Research and International Relations Area November 2023.

Curci, Nicola, Marco Savegnago, Giordano Zevi, and Roberta Zizza, "The redistributive effects of inflation: a microsimulation analysis for Italy," Questioni di Economia e Finanza (Occasional Papers) 738, Bank of Italy, Economic Research and International Relations Area December 2022.

Gnocato, Nicolo, "Energy Price Shocks, Unemployment Risk, and Monetary Policy," *mimeo*, 2023.

Guiso, Luigi and Ignazio Visco, "Shocks reali e nominali, tariffe pubbliche e politica monetaria," *Politica economica*, 1988, *4* (1), 99–120.

IMF, "World Economic Outlook. Countering the Cost-of-Living Crisis," Technical Report, International Monetary Fund October 2022.

Lorenzoni, Guido and Ivan Werning, "Inflation is Conflict," NBER Working Papers 31099, National Bureau of Economic Research, Inc April 2023.

Sgaravatti, Giovanni, Simone Tagliapietra, and Georg Zachmann, "National policies to shield consumers from rising energy prices," Technical Report 2022.

Signorini, Luigi Federico, "Sustainable investment choices: emergencies and transition," *Speech, Centesimus Annus Pro Pontifice Foundation, Venice, 11 June*, 2022.

Visco, Ignazio, "The interaction between monetary and fiscal policies in the pandemic crisis and beyond," *Remarks, The ECB and Its Watchers XXII, 17 March*, 2022.

Table 1: Main variables

	EA	RW
Macroeconomic variables		
Private consumption	61.0	61.0
Public consumption	21	20.6
Investment	18.0	18.8
Imports	21.0	4.0
Imports of consumption goods	14.4	2.9
Imports of investment goods	4.8	1.0
Imports of oil, coal, and gas	1.8	–
Share of world GDP	15.9	84.1
Inflation rate	2	2
Financial variables		
Nominal short-term rate	2.1	2.1
Nominal long-term rate	2.4	2.4
Long-term public debt	100	100
Short-term public debt	6	6
Net foreign asset position	0	0
Energy shares in total energy production		
Share of oil-based energy	34.4	34.4
Share of gas-based energy	22.4	22.4
Share of coal-based energy	14.4	14.4
Share of nuclear-based energy	13.4	13.4
Share of renewable-based energy	15.4	15.4
Energy shares		
Energy share in firms' production costs	9.8	11.9
Energy share in Ricardian households' consumption	8.2	9.2
Energy share in HTM households' consumption	12.2	9.2

Note: EA = euro area. RW= rest of the world. Macroeconomic variables are as % of GDP. Inflation and interest rates are in %, annualized term. Public debt as % of annualized GDP. Energy shares as %.

Table 2: Parameters: preferences, intermediate and final goods technology

Parameter	EA	RW
Ricardian households discount factor β_{ric}	0.9998	0.9998
Intertemporal elasticity of substitution $1/\sigma$	1.0	1.0
Habit hab	0.7	0.7
Inverse of Frisch elasticity of labour supply τ	2.0	2.0
Share of households in population		
Ricardian households λ_{ric}	0.75	0.75
ROT households s^{rot}	0.25	0.25
Intermediate goods		
Depreciation rate of capital δ	0.025	0.025
Elasticity subst. btw. factors in value added production	1.0	1.0
Bias towards capital $\gamma_{pr_{va,k}}$	0.29	0.29
Elasticity subst. btw. factors in output production ρ_Y	0.2	0.2
Bias towards value added $\gamma_{pr_{y,va}}$	0.7	0.7
Elasticity subst. among energy types ρ_{EN}	0.45	0.45
Bias towards oil $\gamma_{pr_{y,oil}}$	0.36	0.36
Bias towards gas $\gamma_{pr_{y,gas}}$	0.23	0.23
Bias towards coal $\gamma_{pr_{y,coal}}$	0.12	0.12
Bias towards nuclear energy $\gamma_{pr_{y,nuc}}$	0.13	0.13
Final consumption goods		
Elasticity subst. btw. manufacturing good and energy ρ_C	0.20	0.20
Bias towards manufacturing goods Ricardian households $a^{Ric}_{c,manu}$	0.80	0.76
Bias towards manufacturing goods HTM households $a^{HTM}_{c,manu}$	0.72	0.76
Elasticity subst. btw. dom. and imported manuf. goods η_T	1.50	1.50
Bias towards domestic tradable goods $a_{EA,C}$	0.85	0.90
Elasticity subst. among energy types ρ_{EN}	0.45	0.45
Bias towards oil energy a_{oil}	0.31	0.38
Bias towards gas energy a_{gas}	0.20	0.24
Bias towards coal energy a_{coal}	0.14	0.13
Bias towards nuclear energy a_{nuc}	0.13	0.10
Final investment goods		
Elasticity subst. btw. dom. and imported goods η_T	1.50	1.50
Bias towards domestic tradable goods $a_{EA,I}$	0.85	0.90

Note: EA = euro area. RW= rest of the world.

Table 3: Energy production technology

Parameter	EA	RW
Oil-based energy		
Elasticity subst. btw. factors of production $\rho_{EN_{oil}}$	0.25	0.25
Bias towards capital $\gamma_{oil,k}$	0.5	0.5
Bias towards oil $\gamma_{oil,source}$	0.4	0.4
Gas-based energy		
Elasticity subst. btw. factors of production $\rho_{EN_{gas}}$	0.25	0.25
Bias towards capital $\gamma_{gas,k}$	0.55	0.55
Bias towards gas $\gamma_{gas,source}$	0.35	0.35
Coal-based energy		
Elasticity subst. btw. factors of production $\rho_{EN_{coal}}$	0.25	0.25
Bias towards capital $\gamma_{coal,k}$	0.6	0.6
Bias towards coal $\gamma_{coal,source}$	0.3	0.3
Renewable-based energy		
Elasticity subst. btw. factors of production $\rho_{EN_{res}}$	0.25	0.25
Bias towards capital $\gamma_{res,k}$	0.8	0.8
Bias towards renewable source $\gamma_{res,source}$	0.01	0.01
Nuclear-based energy		
Elasticity subst. btw. factors of production$\rho_{EN_{nuc}}$	0.25	0.25
Bias towards capital $\gamma_{nuc,k}$	0.7	0.7
Bias towards nuclear $\gamma_{nuc,source}$	0.2	0.2

Note: EA = euro area. RW= rest of the world.

Table 4: Gross markups (elasticities of substitution)

	EA	RW
Intermediate goods	1.2 ($\theta_T = 6.0$)	1.2 ($\theta_T = 6.0$)
labour	1.2 ($\theta_L = 6.0$)	1.2 ($\theta_L = 6.0$)

Note: EA = euro area. RW= rest of the world.

Table 5: Adjustment costs

Parameter	EA	RW
Ricardian households		
Long-term sovereign bond ϕ_B	0.001	0.001
International bond ϕ_b	0.05	–
Firms		
Physical capital ϕ_I	6.0	6.0
Nominal wages κ_W	400	400
Intermediate tradable goods κ_{EA}	380	380
Price indexation to past inflation ind_{EA}, ind_{RW}	0.5	0.5
Wage indexation to past inflation ind_W	0.5	0.5

Note: EA = euro area. RW= rest of the world.

Table 6: Monetary policy rules, fiscal policy rules and steady-state taxes

Parameter	EA	RW
Monetary policy rule		
Lagged interest rate ρ_R	0.87	0.87
Inflation ρ_π	1.70	1.90
Output growth ρ_{RGDP}	0.10	0.10
Fiscal policy rule		
Lump-sum taxes sensitivity to public debt ϕ_G, ϕ_G^*	0.6	0.6
Taxes		
Consumption tax rate τ_c, τ_c^*	20.0	20.0
Labour income tax rate τ_w, τ_w^*	40.0	40.0
Capital income tax rate τ_k, τ_k^*	30.0	30.0

Note: EA = euro area. RW= rest of the world. "*" refers to RW. Tax rates are in %.

Figure 1: Energy and non-energy sectors

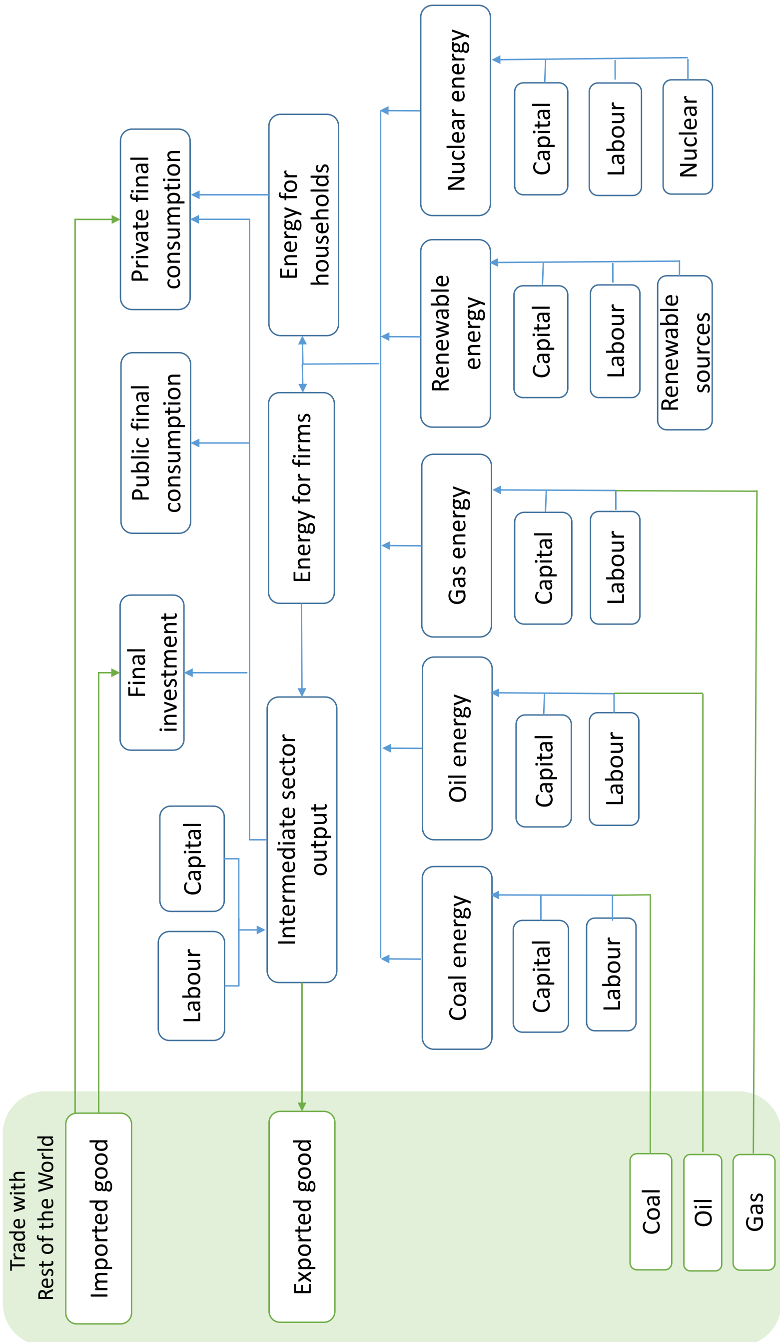
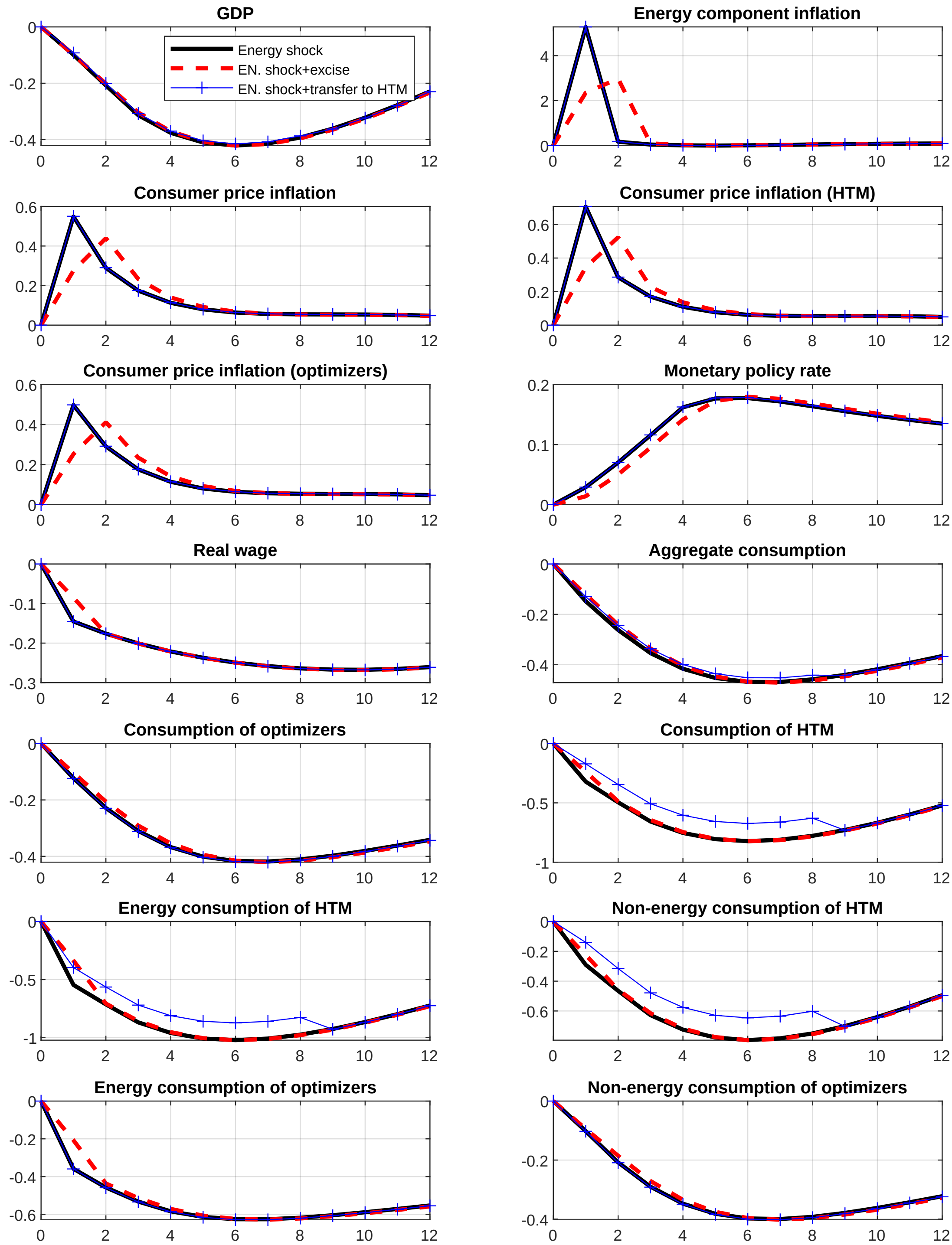
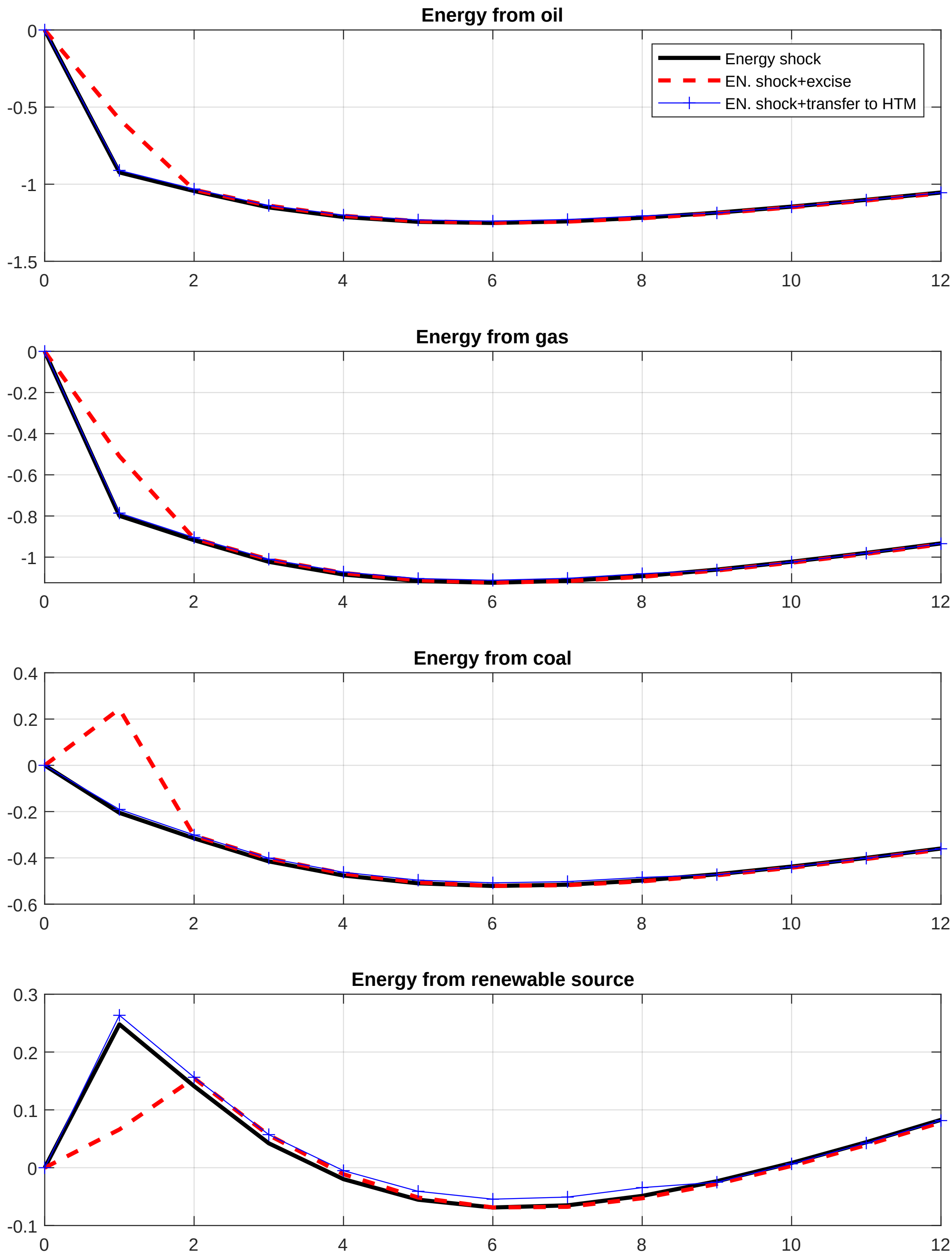


Figure 2: Energy shock and policy responses: macroeconomic variables



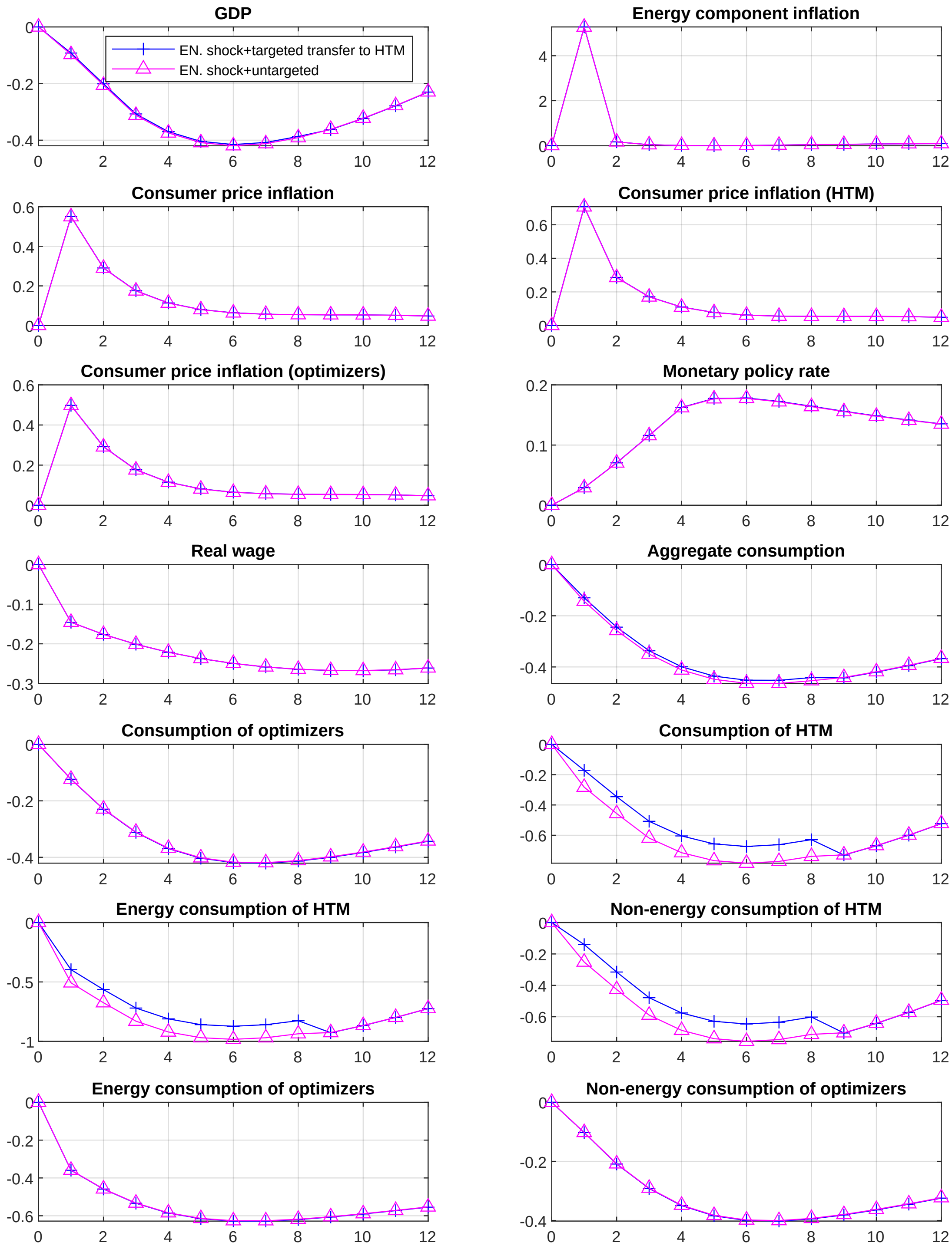
Note. Horizontal axis: quarters; vertical axis: real GDP and consumption in percent deviations from steady state; monetary policy rate and inflation rates: annualized percentage point deviations from steady state.

Figure 3: Energy shock and policy responses: energy variables



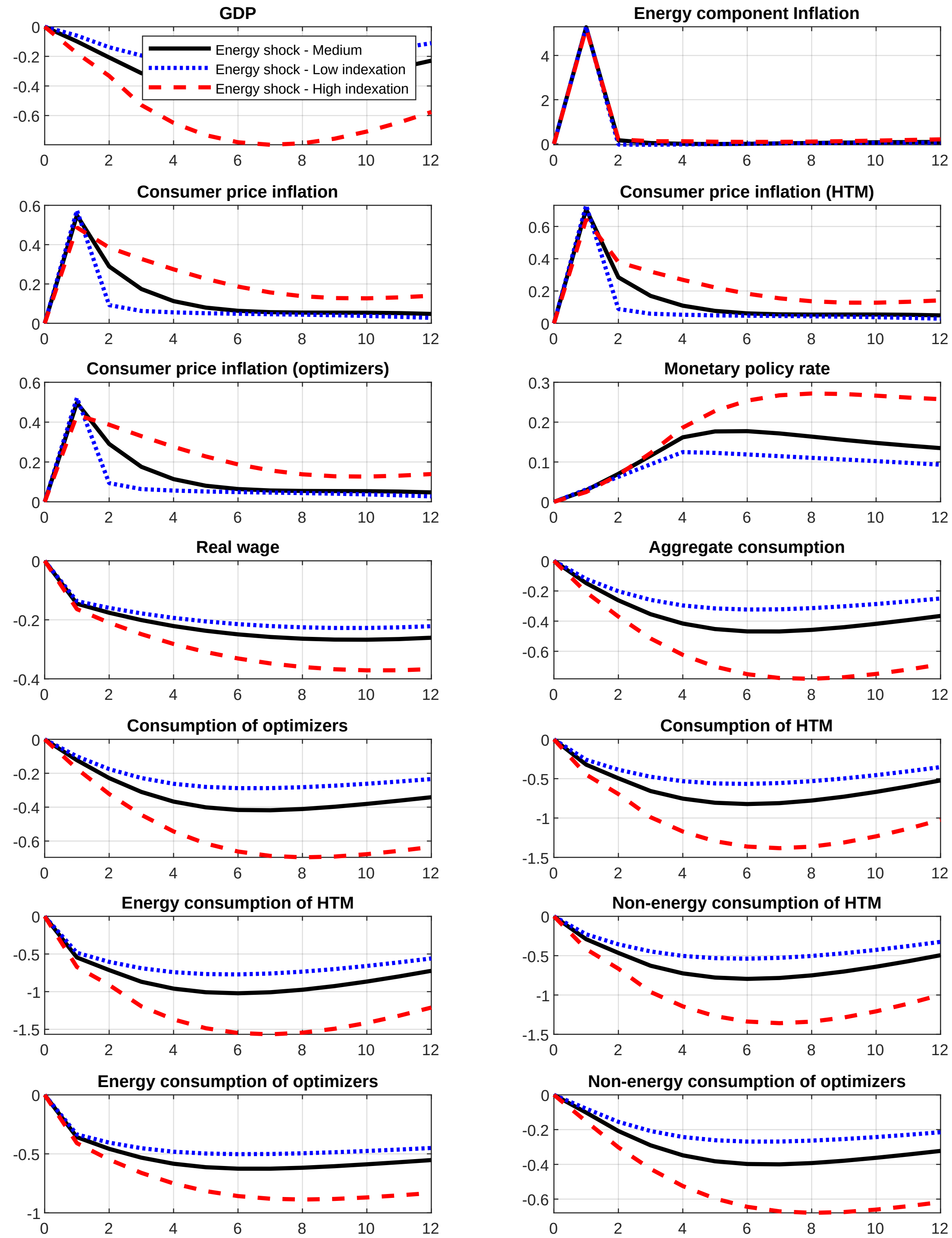
Note. Horizontal axis: quarters; vertical axis:percent deviations from steady state.

Figure 4: Energy shock and untargeted transfers: macroeconomic variables



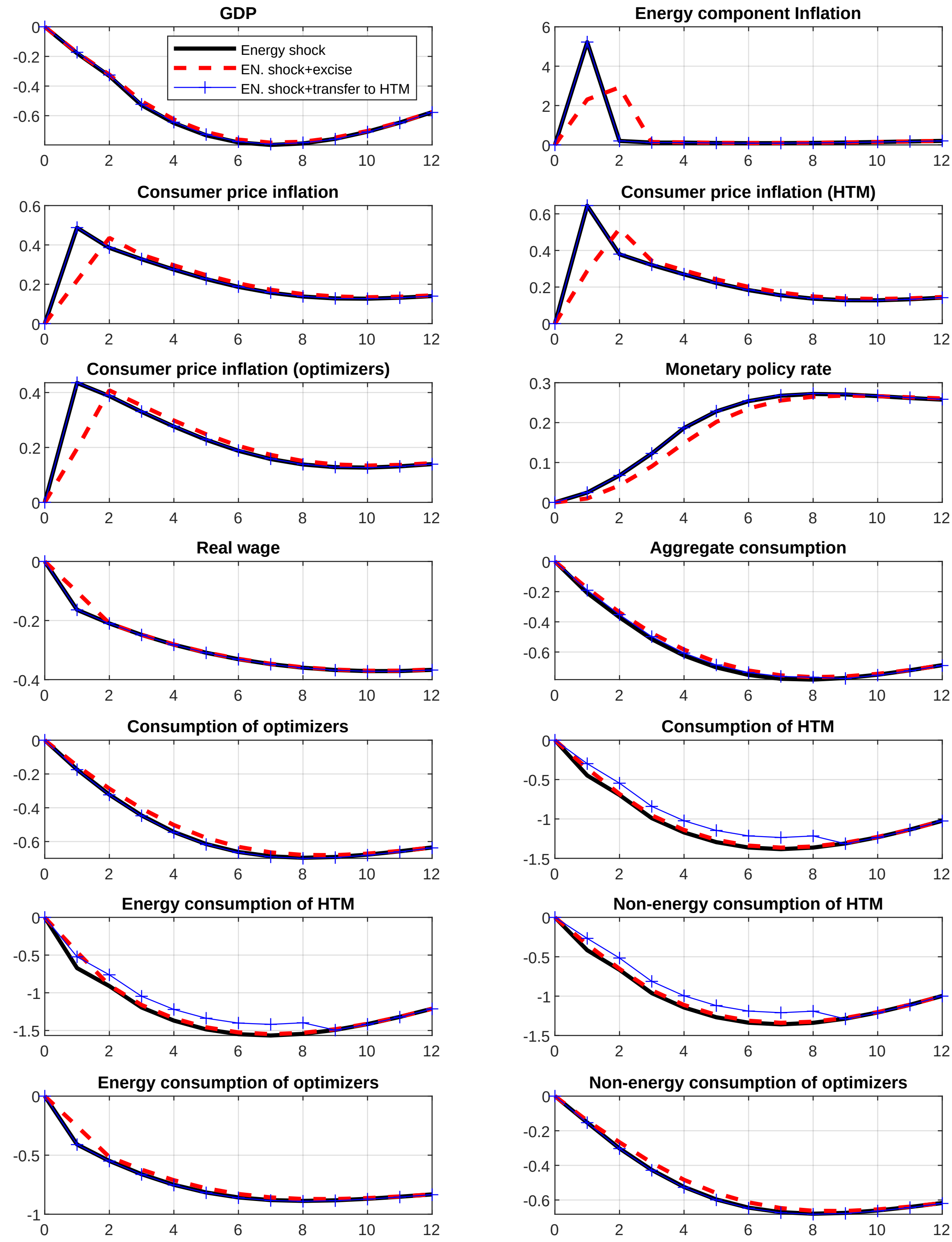
Note. Horizontal axis: quarters; vertical axis: real GDP and consumption in percent deviations from steady state; monetary policy rate and inflation rates: annualized percentage point deviations from steady state.

Figure 5: Benchmark, high and low indexation: macroeconomic variables



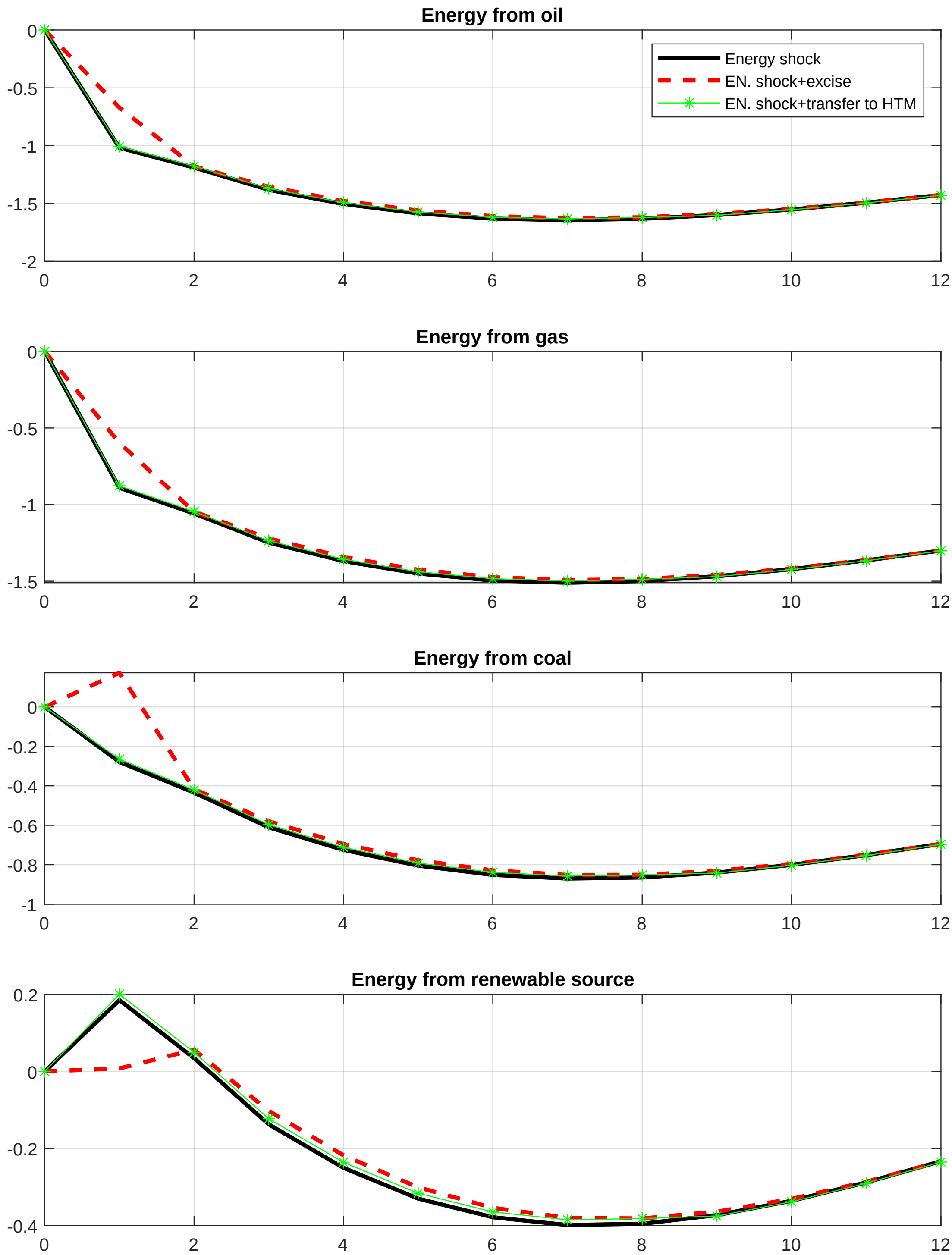
Note. Horizontal axis: quarters; vertical axis: real GDP and consumption in percent deviations from steady state; monetary policy rate and inflation rates: annualized percentage point deviations from steady state.

Figure 6: High indexation: macroeconomic variables



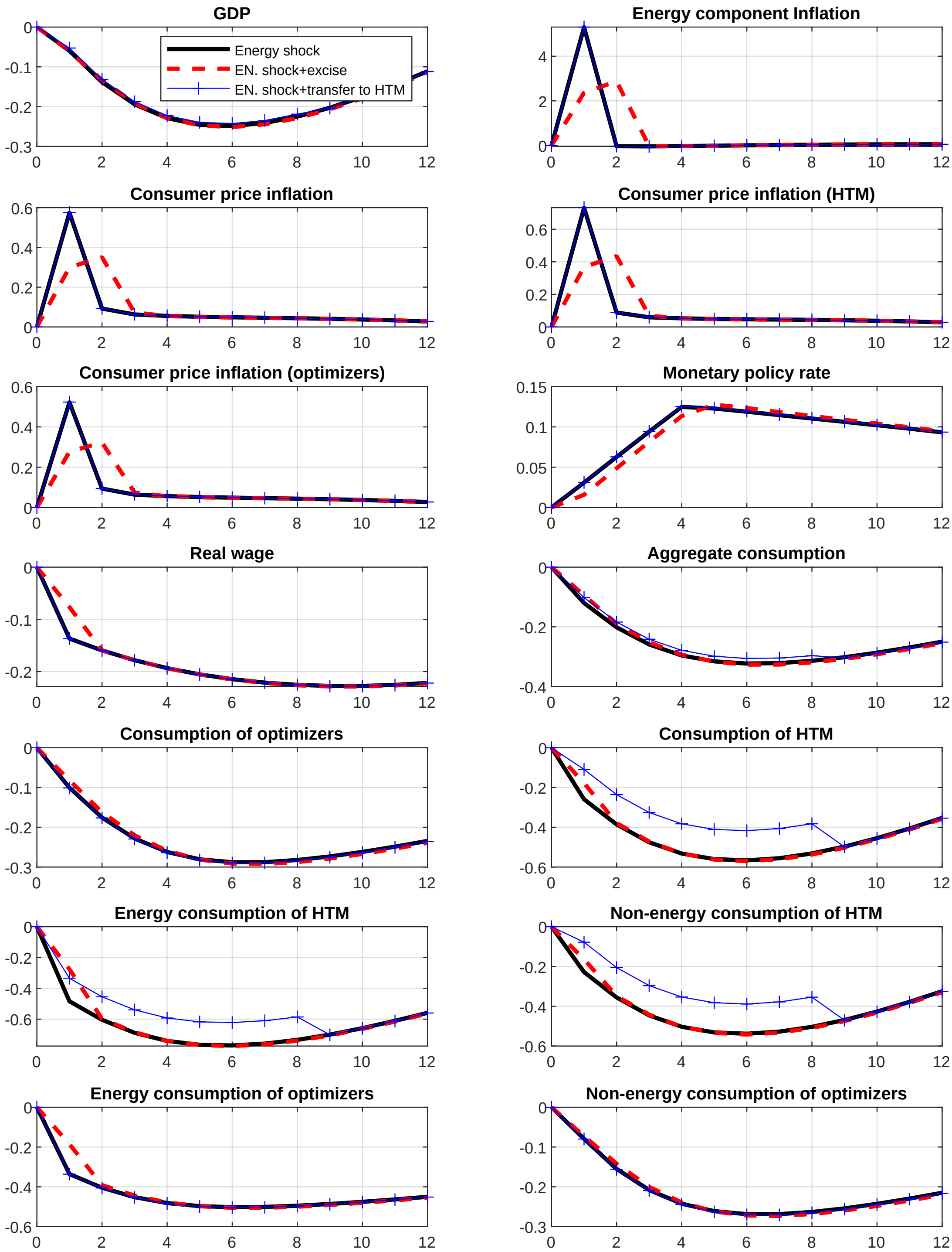
Note. Horizontal axis: quarters; vertical axis: real GDP and consumption in percent deviations from steady state; monetary policy rate and inflation rates: annualized percentage point deviations from steady state.

Figure 7: High indexation: energy variables



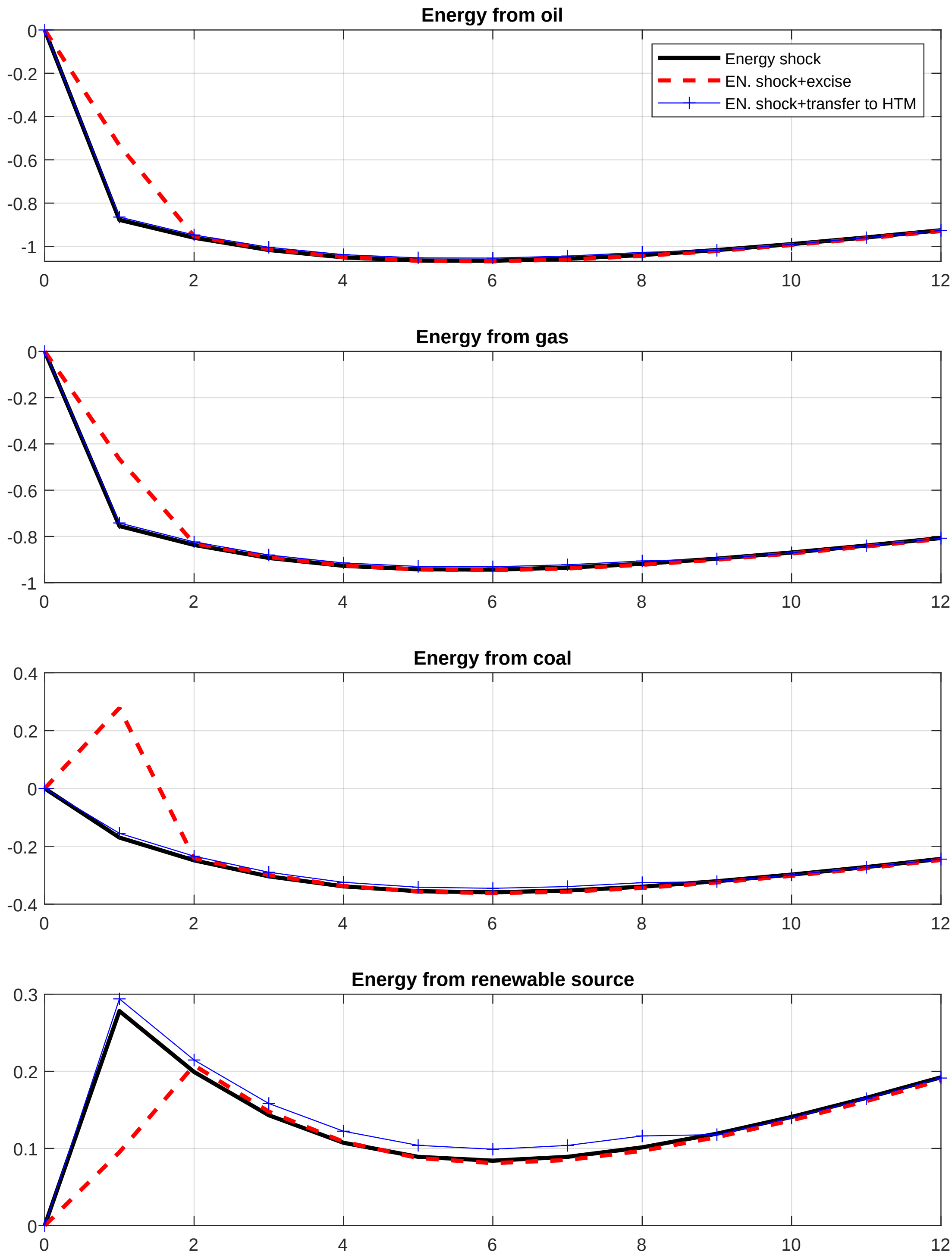
Note. Horizontal axis: quarters; vertical axis:percent deviations from steady state.

Figure 8: Low indexation: macroeconomic variables



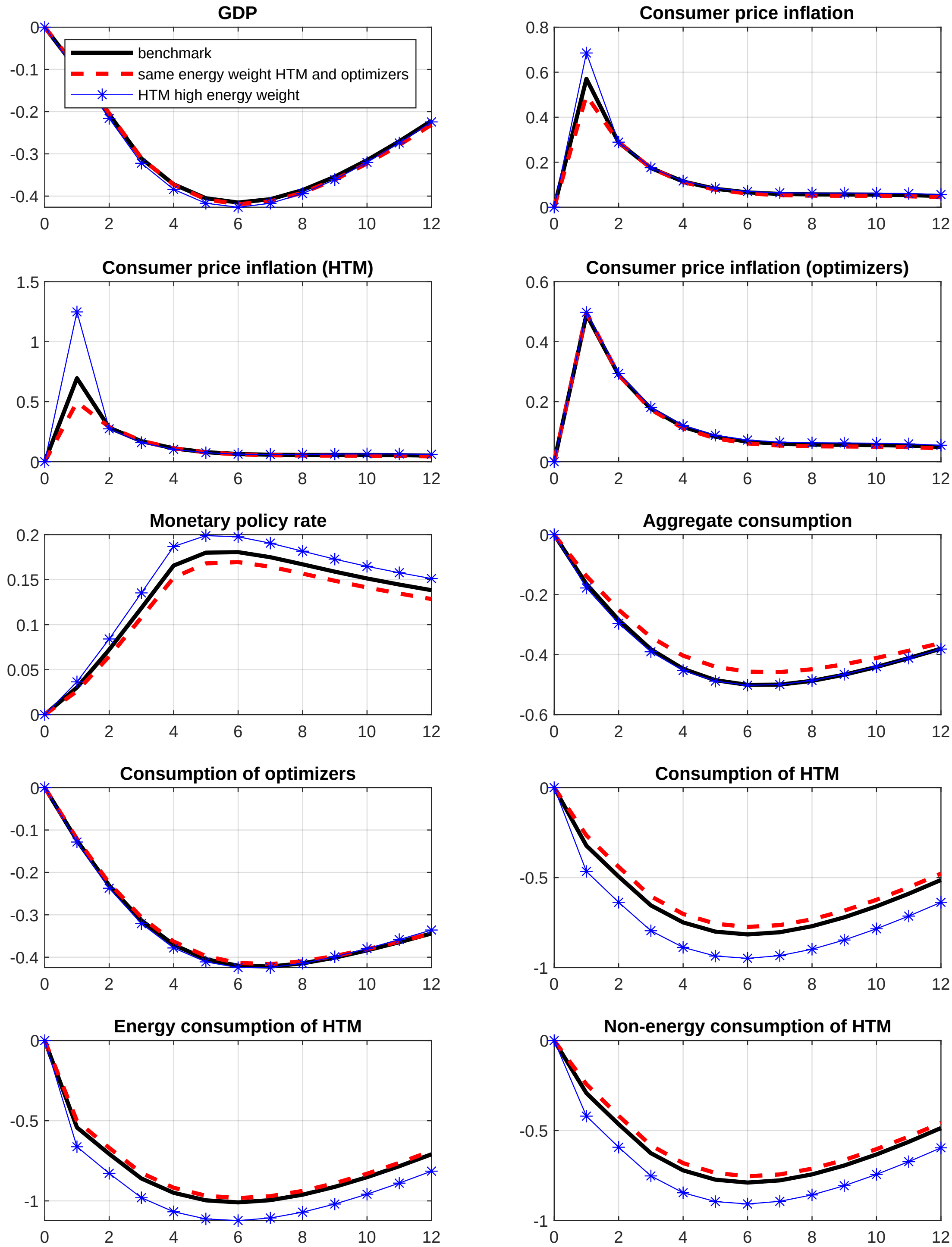
Note. Horizontal axis: quarters; vertical axis: real GDP and consumption in percent deviations from steady state; monetary policy rate and inflation rates: annualized percentage point deviations from steady state.

Figure 9: Low indexation: energy variables



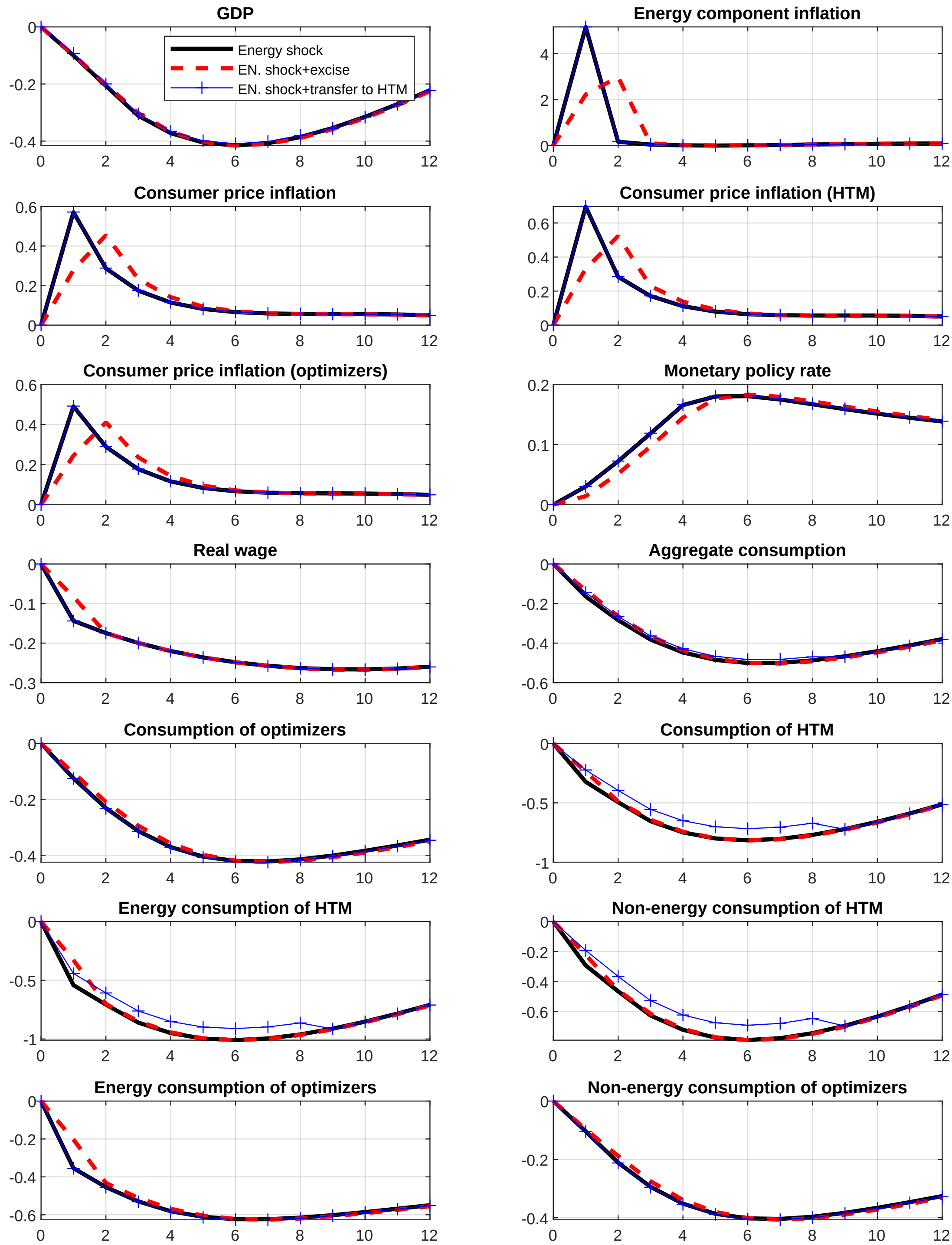
Note. Horizontal axis: quarters; vertical axis:percent deviations from steady state.

Figure 10: Alternative energy weights in the HTM's consumption basket



Note. Horizontal axis: quarters; vertical axis: real GDP and consumption in percent deviations from steady state; monetary policy rate and inflation rates: annualized percentage point deviations from steady state.

Figure 11: Larger share of HTM: macroeconomic variables



Note. Horizontal axis: quarters; vertical axis: real GDP and consumption in percent deviations from steady state; monetary policy rate and inflation rates: annualized percentage point deviations from steady state.

Model Appendix

A.1 Energy sector

A.1.1 Production of energy $EN_{oil,t}(o)$ from oil, coal and gas

- Production function

The generic firm o produces energy $EN_{oil,t}(o)$ using oil under perfect competition. It maximizes profits taking all prices and the technology constraint as given. The CES production function is

$$EN_{oil,t}(o)^{\frac{\rho_{EN_{oil}}-1}{\rho_{EN_{oil}}}} = \gamma_{oil,source}^{\frac{1}{\rho_{EN_{oil}}}} OIL_t(o)^{\frac{\rho_{EN_{oil}}-1}{\rho_{EN_{oil}}}} + \gamma_{oil,k}^{\frac{1}{\rho_{EN_{oil}}}} K_{oil,t}(o)^{\frac{\rho_{EN_{oil}}-1}{\rho_{EN_{oil}}}} + (1-\gamma_{oil,k}-\gamma_{oil,source})^{\frac{1}{\rho_{EN_{oil}}}} L_{oil,t}(o)^{\frac{\rho_{EN_{oil}}-1}{\rho_{EN_{oil}}}}, \quad (1)$$

where $OIL_t(o)$, $K_{oil,t}(o)$, and $L_{oil,t}(o)$ are oil, capital, and labour, respectively. The parameter $\rho_{EN_{oil}} > 0$ is the elasticity of intratemporal substitution among inputs. The parameters $0 < \gamma_{oil,source}, \gamma_{oil,k} < 1, \gamma_{oil,source} + \gamma_{oil,k} < 1$ are the weights of oil and capital in the production process, respectively.

The implied demands for oil, capital, and labour are reported in what follows.

- Demand for oil

$$OIL_t(o) = \gamma_{oil,source} \left(\frac{p_{oil,t+t_{eoil,t}}}{rmc_{enoil,t}} \right)^{-\rho_{EN_{oil}}} EN_{oil,t}(o) \quad (2)$$

where $p_{oil,t}$, $t_{eoil,t}$ and $rmc_{enoil,t}$ are the relative price of oil (in units of domestic consumption), the excise tax, and the real marginal cost of producing energy from oil, respectively.

- Demand for physical capital

$$K_{oil,t}(o) = \gamma_{oil,k} \left(\frac{r_{k,t}}{rmc_{enoil,t}} \right)^{-\rho_{EN_{oil}}} EN_{oil,t}(o) \quad (3)$$

where $r_{k,t}$ is the rental rate on capital

- Demand for labour

$$L_{oil,t}(o) = (1 - \gamma_{oil,k} - \gamma_{oil,source}) \left(\frac{w_t}{rmc_{enoil,t}} \right)^{-\rho_{EN_{oil}}} EN_{oil,t}(o) \tag{4}$$

where w_t is the real wage.

Similar equations hold for energy production from gas ($GAS_t(g)$) and coal ($COAL_t(co)$) produced by the generic firms g and co, respectively.

A.1.2 Production of energy $EN_{res,t}(r)$ from renewable sources

The generic firm r produces energy $EN_{res,t}(r)$ using a generic renewable source of energy $RES_t(r)$, capital, and labour.

- Production function

$$\begin{aligned} EN_{res,t}(r)^{\frac{\rho_{EN_{res}}-1}{\rho_{EN_{res}}}} &= \gamma_{res,source}^{\frac{1}{\rho_{EN_{res}}}} RES_t(r)^{\frac{\rho_{EN_{res}}-1}{\rho_{EN_{res}}}} + \gamma_{res,k}^{\frac{1}{\rho_{EN_{res}}}} K_{res,t}(r)^{\frac{\rho_{EN_{res}}-1}{\rho_{EN_{res}}}} \\ &+ (1 - \gamma_{res,k} - \gamma_{res,source})^{\frac{1}{\rho_{EN_{res}}}} L_{res,t}(r)^{\frac{\rho_{EN_{res}}-1}{\rho_{EN_{res}}}} \end{aligned} \tag{5}$$

- Demand for capital

$$K_{res,t}(r) = \gamma_{res,k} \left(\frac{r_{k,t}}{rmc_{enres,t}} \right)^{-\rho_{EN_{res}}} EN_{res,t}(r) \tag{6}$$

where $rmc_{enres,t}$ is the real marginal cost.

- Demand for renewable sources

$$RES_t(r) = \gamma_{res,source} \left(\frac{p_{res,t}}{rmc_{enres,t}} \right)^{-\rho_{EN_{res}}} EN_{res,t}(r) \tag{7}$$

where $p_{res,t}$ is the relative price (in units of domestic consumption) of the renewable source of energy.

- Demand for labour

$$L_{res,t}(r) = (1 - \gamma_{res,k} - \gamma_{res,source}) \left(\frac{w_t}{rmc_{enres,t}} \right)^{-\rho_{EN_{res}}} EN_{res,t}(r) \tag{8}$$

A.1.3 Production of energy $EN_{nuc,t}(n)$ from nuclear source

The generic firm n produces energy $EN_{nuc,t}(n)$ using the nuclear source of energy $NUC_t(n)$, capital, and labour. Equations are similar to those reported for the cases of oil-based and renewable-source-based productions of energy. Nuclear energy production is not subject to either tax or subsidy.

- Production function

$$\begin{aligned} EN_{nuc,t}(n)^{\frac{\rho_{EN_{nuc}}-1}{\rho_{EN_{nuc}}}} = \gamma_{nuc,source}^{\frac{1}{\rho_{EN_{nuc}}}} NUC_t(n)^{\frac{\rho_{EN_{nuc}}-1}{\rho_{EN_{nuc}}}} + \gamma_{nuc,k}^{\frac{1}{\rho_{EN_{nuc}}}} K_{nuc,t}(n)^{\frac{\rho_{EN_{nuc}}-1}{\rho_{EN_{nuc}}}} \\ + (1 - \gamma_{nuc,k} - \gamma_{nuc,source})^{\frac{1}{\rho_{EN_{nuc}}}} L_{nuc,t}(n)^{\frac{\rho_{EN_{nuc}}-1}{\rho_{EN_{nuc}}}} \end{aligned} \tag{9}$$

- Demand for capital

$$K_{nuc,t}(n) = \gamma_{nuc,k} \left(\frac{r_{k,t}}{rmc_{ennuc,t}} \right)^{-\rho_{EN_{nuc}}} EN_{nuc,t}(n) \tag{10}$$

where $rmc_{ennuc,t}$ is the real marginal cost of producing energy from nuclear source.

- Demand for nuclear source

$$NUC_t(n) = \gamma_{nuc,source} \left(\frac{p_{nuc,t}}{rmc_{ennuc,t}} \right)^{-\rho_{EN_{nuc}}} EN_{nuc,t}(n) \tag{11}$$

where $p_{nuc,t}$ is the relative price (in units of domestic consumption) of the nuclear source of energy.

- Demand for labour

$$L_{nuc,t}(n) = (1 - \gamma_{nuc,k} - \gamma_{nuc,source}) \left(\frac{w_t}{rmc_{ennuc,t}} \right)^{-\rho_{EN_{nuc}}} EN_{nuc,t}(n), \tag{12}$$

A.2 Intermediate goods sector

The generic firm h produces an intermediate good $Y_t(h)$ under monopolistic competition. It chooses inputs, i.e., labour, capital, and energy, to minimize the production costs taking as given the technology constraint and the input prices.

- Production function

$$Y_t(h)^{\frac{\rho_Y-1}{\rho_Y}} = \gamma_{pr_{y,va}}^{\frac{1}{\rho_Y}} VA_{y,t}(h)^{\frac{\rho_Y-1}{\rho_Y}} + (1-\gamma_{pr_{y,va}})^{\frac{1}{\rho_Y}} EN_{y,t}(h)^{\frac{\rho_Y-1}{\rho_Y}}, \tag{13}$$

where $VA_{y,t}(h)$ and $EN_{y,t}(h)$ are the value added and the energy bundle, respectively. The parameter $\rho_Y > 0$ is the elasticity of substitution among inputs and the parameter $0 < \gamma_{pr_{y,va}} < 1$ is the weight of value added in the production process.

- Value added

  The value added is a combination, according to a Cobb-Douglas technology, of physical capital and labour

$$VA_{y,t}(h) = K_{y,t}(h)^{\gamma_{pr_{va,k}}} L_{y,t}(h)^{1-\gamma_{pr_{va,k}}}, \tag{14}$$

where $K_{y,t}(h)$ and $L_{y,t}(h)$ are capital and labour, respectively, while the parameter $0 < \gamma_{pr_{va,k}}<1$ is the elasticity of value added with respect to capital.

- Energy bundle

  The energy bundle combines, according to a CES technology, the different types of energy obtained from oil ($EN_{oily,t}(h)$), coal ($EN_{coaly,t}(h)$), gas ($EN_{gasy,t}(h)$), nuclear source

$(EN_{nucy,t}(h))$, and renewable source $(EN_{resy,t}(h))$:

$$
\begin{aligned}
EN_{y,t}(h)^{\frac{\rho_{EN}-1}{\rho_{EN}}} &= \gamma_{pr_{y,oil}}^{\frac{1}{\rho_{EN}}} EN_{oily,t}(h)^{\frac{\rho_{EN}-1}{\rho_{EN}}} + \gamma_{pr_{y,coal}}^{\frac{1}{\rho_{EN}}} EN_{coaly,t}(h)^{\frac{\rho_{EN}-1}{\rho_{EN}}} \\
&+ \gamma_{pr_{y,gas}}^{\frac{1}{\rho_{Y}}} EN_{gasy,t}(h)^{\frac{\rho_{EN}-1}{\rho_{EN}}} + \gamma_{pr_{y,nuc}}^{\frac{1}{\rho_{EN}}} EN_{nucy,t}(h)^{\frac{\rho_{EN}-1}{\rho_{EN}}} \\
+(1-\gamma_{pr_{y,oil}} - \gamma_{pr_{y,coal}} &- \gamma_{pr_{y,gas}} - \gamma_{pr_{y,nuc}})^{\frac{1}{\rho_{EN}}} EN_{resy,t}(h)^{\frac{\rho_{EN}-1}{\rho_{EN}}},
\end{aligned}
\tag{15}
$$

where $\rho_{EN} > 0$ is the elasticity of substitution among the different types of energy, $0 < \gamma_{pr_{y,oil}} < 1$, $0 < \gamma_{pr_{y,coal}} < 1$, $0 < \gamma_{pr_{y,gas}} < 1$, $0 < \gamma_{pr_{y,nuc}} < 1$ ($\gamma_{pr_{y,oil}} + \gamma_{pr_{y,gas}} + \gamma_{pr_{y,coal}} + \gamma_{pr_{y,nuc}} < 1$) are the weights of energy obtained from oil, coal, gas, and nuclear source, respectively.

The implied demands for value added, energy bundle, capital, labour, and different types of energy, obtained by the cost minimization problem, are reported in what follows.

- Demand for value added

$$
VA_{y,t}(h) = \gamma_{pr_{y,va}} \left(\frac{p_{va,t}}{rmc_{y,t}} \right)^{-\rho_Y} Y_t(h) \tag{16}
$$

where $p_{va,t}$ is the relative price of the value added and $rmc_{y,t}$ is the real marginal production cost of the intermediate good.

- Demand for energy bundle

$$
EN_{y,t}(h) = (1 - \gamma_{pr_{y,va}}) \left(\frac{p_{en,t}}{rmc_{y,t}} \right)^{-\rho_Y} Y_t(h) \tag{17}
$$

where $p_{en,t}$ is the relative price of the energy bundle.

- Demand for capital

$$
K_{y,t}(h) = \gamma_{pr_{va,k}} \left(\frac{r_{k,t}}{p_{va,t}} \right)^{-1} VA_{y,t}(h) \tag{18}
$$

- Demand for labour

$$
L_{y,t}(h) = (1 - \gamma_{pr_{va,k}}) \left(\frac{w_t}{p_{va,t}} \right)^{-1} VA_{y,t}(h) \tag{19}
$$

- Demand for energy obtained from oil

$$EN_{oily,t}(h) = \gamma_{pr_{y,oil}} \left(\frac{rmc_{enoil,t}}{p_{en,t}} \right)^{-\rho_{EN}} EN_{y,t}(h) \tag{20}$$

Similar equations holds for demands for energy obtained from coal, gas, nuclear, and renewable sources.

- Optimal price of the EA intermediate good in the EA market

The generic firm h chooses the price of its good to maximize profits subject to the demand constraint and the quadratic costs to adjust the nominal price. Thus, the firm faces (short-term) nominal rigidities. We assume that EA and RW markets are exogenously segmented and the generic firm h price-discriminates across markets.

The implied first-order condition (i.e., optimal price of brand h in the EA market) is

$$\begin{aligned}(1-\theta_T)p_{EA,t}(h) + \theta_T rmc_{EA,t}(h) = \kappa_{EA} \left(\frac{P_{EA,t}(h)/P_{EA,t-1}(h)}{\pi_{EA,t-1}^{ind_{EA}} \pi_{target}^{1-ind_{EA}}} - 1 \right) \frac{P_{EA,t}/P_{EA,t-1}(h)}{\pi_{EA,t-1}^{ind_{EA}} \pi_{target}^{1-ind_{EA}}} \\ -\beta_{ric} \frac{\lambda_{ric,t+1}(j)\pi_{t+1}^{-1}}{\lambda_{ric,t}(j)} \kappa_{EA} \left(\frac{P_{EA,t+1}(h)/P_{EA,t}(h)}{\pi_{EA,t}^{ind_{EA}} \pi_{target}^{1-ind_{EA}}} - 1 \right) \frac{P_{EA,t+1}P_{EA,t+1}(h)/P_{EA,t}(h)^2 Y_{EA,t+1}}{\pi_{EA,t}^{ind_{EA}} \pi_{target}^{1-ind_{EA}} Y_{EA,t}}\end{aligned} \tag{21}$$

where $\theta_T > 1$ is the elasticity of substitution among different brands produced by firms belonging to the same sector, $\kappa_{EA} > 0$ is a parameter measuring the cost of adjusting the nominal price, $P_{EA,t}(h)$ is the nominal price of the intermediate good h, $\pi_{EA,t}$ is the gross inflation rate, and π_{target} is the central bank (gross) inflation target. The parameter $0 < ind_{EA} < 1$ measures indexation of current prices to previous-period inflation. Correspondingly, $1 - ind_{EA}$ measures indexation to the central bank target. Thus, the optimal price setting scheme is subject to a double indexation, i.e., to past inflation and to the central bank inflation target.

A similar equation holds for the price of good h in the Foreign market.

A.3 Final-good sectors

There are three sectors producing final goods: consumption goods for households, investment goods, and public sector consumption goods. Firms act under perfect competition. They choose inputs to maximize profits subject to the technology constraint and taking all prices as given.

A.3.1 Private consumption good

- Overall basket

The generic firm x produces the consumption good $C_t(x)$ according to the CES production function

$$C_t(x)^{\frac{\rho_C-1}{\rho_C}} = \alpha_{c,manu}^{\frac{1}{\rho_C}} C_{manu,t}(x)^{\frac{\rho_C-1}{\rho_C}} + (1-\alpha_{c,manu})^{\frac{1}{\rho_C}} C_{EN,t}(x)^{\frac{\rho_C-1}{\rho_C}} \tag{22}$$

where $\rho_C > 0$ is the elasticity of substitution among inputs, $C_{manu,t}(x)$ is the bundle of non-energy intermediate goods, $C_{EN,t}(x)$ is the energy bundle. The parameter $0 < \alpha_{c,manu} < 1$ is the weight of the non-energy consumption bundle. We allow it to assume different values for Ricardian and Hand-to-mouth (HTM) households. Specifically, we set $\alpha_{c,manu}^{HTM} > \alpha_{c,manu}^{Ric}$, such that the weight of the energy consumption bundle is larger for HTM than for Ricardian households.

- Basket of the manufacturing goods

The bundle of manufacturing goods is a CES function of domestic and imported consumption goods, $C_{EA,t}(x)$ and $C_{RW,t}(x)$, respectively:

$$C_{manu,t}(x)^{\frac{\eta_T-1}{\eta_T}} = a_{EA,C}^{\frac{1}{\eta_T}} C_{EA,t}(x)^{\frac{\eta_T-1}{\eta_T}} + (1-a_{EA,C})^{\frac{1}{\eta_T}} C_{RW,t}(x)^{\frac{\eta_T-1}{\eta_T}} \tag{23}$$

where the parameters $a_{EA,C}$, and $(1-a_{EA,C})$ ($0 < a_{EA,C} < 1$) are the weights of EA and

RW goods in the bundle ($C_{EA,t}$, and $C_{RW,t}$, respectively), while $\eta_T > 0$ is the elasticity of substitution among tradable goods.

- Basket of domestically-produced manufacturing good for consumption purposes $C_{EA}(x)$

  The domestically-produced manufacturing good for consumption purposes C_{EA} is a composite basket of a continuum of differentiated intermediate goods, each supplied by a different EA firm h operating in the intermediate sector. It is produced according to the following function:

$$C_{EA,t}(x) = \left[\left(\frac{1}{s^{EA}} \right)^{\theta_T} \int_0^{s^{EA}} C_{EA,t}(h, x)^{\frac{\theta_T - 1}{\theta_T}} \, dh \right]^{\frac{\theta_T}{\theta_T - 1}} \tag{24}$$

  where $\theta_T > 1$ is the elasticity of substitution among EA intermediate brands h used as inputs by the firms x, $C_{EA,t}(h, x)$, and s^{EA} is the size of the EA.[26]

- Basket of imported manufacturing goods $C_{RW}(x)$

  The basket of imported RW goods has a structure similar to that of EA goods, i.e.,

$$C_{RW,t}(x) = \left[\left(\frac{1}{1 - s^{EA}} \right)^{\theta_T} \int_{s^{EA}}^{1} C_{RW,t}(f, x)^{\frac{\theta_T - 1}{\theta_T}} \, df \right]^{\frac{\theta_T}{\theta_T - 1}} \tag{25}$$

  where $(1 - s^{EA})$ is the size of RW.

- Energy consumption bundle $C_{EN,t}(x)$

  The energy consumption bundle is a CES aggregator of the different types of energy produced using oil, gas, coal, nuclear source, and renewable source ($EN_{oilc,t}(x)$, $EN_{gasc,t}(x)$, $EN_{coalc,t}(x)$, $EN_{nucc,t}(x)$, and $EN_{resc,t}(x)$, respectively):

$$\begin{aligned} C_{EN,t}(x)^{\frac{\rho_{EN}-1}{\rho_{EN}}} &= \alpha_{oil}^{\frac{1}{\rho_{EN}}} EN_{oilc,t}(x)^{\frac{\rho_{EN}-1}{\rho_{EN}}} + \alpha_{gas}^{\frac{1}{\rho_{EN}}} EN_{gasc,t}(x)^{\frac{\rho_{EN}-1}{\rho_{EN}}} \\ &+ \alpha_{coal}^{\frac{1}{\rho_{EN}}} EN_{coalc,t}(x)^{\frac{\rho_{EN}-1}{\rho_{EN}}} + \alpha_{nuc}^{\frac{1}{\rho_{EN}}} EN_{nucc,t}(x)^{\frac{\rho_{EN}-1}{\rho_{EN}}} \\ &+ (1 - \alpha_{oil} - \alpha_{coal} - \alpha_{gas} - \alpha_{nuc})^{\frac{1}{\rho_{EN}}} EN_{resc,t}(x)^{\frac{\rho_{EN}-1}{\rho_{EN}}} \end{aligned} \tag{26}$$

[26] For each country, size refers to the overall population and to the number of firms operating in each sector.

where $\rho_{EN} > 0$ is the elasticity of substitution among the different types of energy, α_{oil}, α_{gas}, α_{coal}, α_{nuc} ($0 < \alpha_{oil}, \alpha_{gas}, \alpha_{coal}, \alpha_{nuc} < 1$, $\alpha_{oil} + \alpha_{gas} + \alpha_{coal} + \alpha_{nuc} < 1$) are the weights of the energy produced using oil, gas, coal, and nuclear source, respectively.

- Demand for energy services produced from oil source

$$EN_{oilc,t}(x) = \alpha_{oil} \left(\frac{rmc_{enoil,t}}{p_{en,t}} \right)^{-\rho_{EN}} C_{EN,t}(x) \tag{27}$$

Similar demand equations hold for energy services produced from coal, gas, nuclear and renewable sources.

- Demand for the generic brand h

Firm x demand for the generic brand h is

$$C_{EA,t}(h,x) = \frac{1}{s^{EA}} a_{EA,C} \alpha_{c,manu} \left(\frac{P_{EA,t}(h)}{P_{EA,t}} \right)^{-\theta_T} \left(\frac{P_{EA,t}}{P_{manu,t}} \right)^{-\eta_T} \left(\frac{P_{manu,t}}{P_t} \right)^{-\rho_C} C_t(x) \tag{28}$$

where

$$P_{EA,t} = \left[\int_0^{s^{EA}} P_{EA,t}(h)^{1-\theta_T} dh \right]^{\frac{1}{1-\theta_T}} \tag{29}$$

$$P_{manu,t} = \left[a_{EA,C} P_{EA,t}^{1-\eta_T} + (1 - a_{EA,C}) P_{RW,t}^{1-\eta_T} \right]^{\frac{1}{1-\eta_T}}, \tag{30}$$

$$P_{C,t} = \left[a_{c,manu} P_{manu,t}^{1-\rho_C} + (1 - a_{c,manu}) P_{EN,t}^{1-\rho_C} \right]^{\frac{1}{1-\rho_C}} \tag{31}$$

are the price deflators of EA goods' consumption bundle, non-energy consumption bundle, overall consumption bundle, respectively. An equation similar to the price deflator of the EA goods' consumption bundle holds for the price deflator of the imported (i.e., RW) goods. As shown in the main text, different values for $a_{c,manu}$ across Ricardian and HTM households imply difference consumption price deflators. Specifically, the price deflator of the HTM consumption bundle is defined as follows:

$$P_{C,t}^{HTM} = \left[a_{c,manu}^{HTM} P_{manu,t}^{1-\rho_C} + \left(1 - a_{c,manu}^{HTM}\right) P_{EN,t}^{1-\rho_C} \right]^{\frac{1}{1-\rho_C}} \tag{32}$$

A.4 Investment good

The sector producing final investment goods has a structure similar to one of the consumption goods' sector. The only difference is that the energy bundle does not enter the overall investment basket. Only non-energy (domestic and imported) intermediate goods do.

- Overall basket

  The generic firm i produces a basket (CES aggregator) of bundles of EA and imported (RW) goods, $I_{EA,t}$ and $I_{RW,t}$, respectively:

$$I_{T,t}(i) = \left[a_{EA,I}^{\frac{1}{\eta_T}} I_{EA,t}(i)^{\frac{\eta_T - 1}{\eta_T}} + (1 - a_{EA,I})^{\frac{1}{\eta_T}} I_{RW,t}(i)^{\frac{\eta_T - 1}{\eta_T}} \right]^{\frac{\eta_T}{\eta_T - 1}} \tag{33}$$

  where the parameter $0 < a_{EA,I} < 1$ is the weight of EA goods in the bundle, while $\eta_T > 0$ is the elasticity of substitution among tradable goods.

- Basket of domestic goods $I_{EA}(i)$

  The investment good I_{EA} is a composite basket of a continuum of differentiated domestic intermediate goods, each supplied by a different EA firm h. It is produced according to the following function:

$$I_{EA,t}(i) = \left[\left(\frac{1}{s^{EA}} \right) \int_0^{s^{EA}} I_{EA,t}(h,i)^{\frac{\theta_T - 1}{\theta_T}} dh \right]^{\frac{\theta_T}{\theta_T - 1}} \tag{34}$$

- Basket of imported goods $I_{RW}(i)$

The investment good I_{RW} is a composite basket of a continuum of differentiated domestic intermediate goods, each supplied by a different RW firm f. It is produced according to the following function:

$$I_{RW,t}(i) = \left[\left(\frac{1}{1-s^{EA}}\right)\int_{s^{EA}}^{1} I_{RW,t}(f,i)^{\frac{\theta_T-1}{\theta_T}}\, df\right]^{\frac{\theta_T}{\theta_T-1}} \tag{35}$$

Implied demand equations for generic brands and implied deflators are similar to corresponding equations for private consumption goods.

A.5 Public consumption good

- Overall basket

The public consumption good $C^g_{EA,t}$, produced by the generic firm g under perfect competition, is fully biased towards the intermediate domestic brands, i.e.,

$$C^g_{EA,t}(g) = \left[\left(\frac{1}{s^{EA}}\right)^{\theta_T}\int_{0}^{s^{EA}} C^g_{EA,t}(h,g)^{\frac{\theta_T-1}{\theta_T}}\, dg\right]^{\frac{\theta_T}{\theta_T-1}} \tag{36}$$

Implied demand equations for generic brands and implied deflators are similar to the corresponding equations for private consumption goods.

A.6 Households

A.6.1 Ricardian Households

In each country there is a continuum of Ricardian households j of mass s^{ric} $(0 < s^{ric} < 1)$.

- Preferences

Each household j maximizes its lifetime expected utility subject to the budget constraint. The lifetime expected utility, in consumption of goods C_{ric}, and labour L_{ric} is

$$E_0\left\{\sum_{t=0}^{\infty}\beta^t_{ric}\left[\frac{(C_{ric,t}(j) - habC_{ric,t-1})^{1-\sigma}}{(1-\sigma)} - \frac{L_{ric,t}(j)^{1+\tau}}{1+\tau}\right]\right\}, \tag{37}$$

where E_0 is period-0 expectation term, $0 < \beta_{ric} < 1$ the discount factor, $0 < hab < 1$ the (external) consumptions' habit parameter, $\sigma > 0$ the reciprocal of the intertemporal elasticity of substitution, and $\tau > 0$ the Frish elasticity of labour supply.

- Budget constraint

  The budget constraint is

$$
\begin{aligned}
& B_t^G(j) - B_{t-1}^G(j) R_{t-1}^G \\
& + S_t B_t^P(j) - S_t B_{t-1}^P(j) R_{t-1}^*(1 - \Gamma_{B^P,t-1}) \\
& + P_t^L B_{ric,t}^L(j) - R_t^L P_t^L B_{ric,t-1}^L(j) = \\
& (1 - \tau_{w,t}) W_t(j) L_{ric,t}(j) + \Pi_t^P(j) + \Pi_t^{prof}(j) - P_t(1 + \tau_t^c) C_{ric,t}(j) \\
& + TR_t(j) - \frac{\kappa_W}{2}\left(\frac{W_t(j)/W_{t-1}(j)}{\pi_{t-1}^{ind_W}\pi_{target}^{1-ind_W}} - 1\right)^2 W_t L_{ric,t} - \frac{\phi_B}{2}(P_t^L B_{ric,t}^L(j) - \bar{B}_{ric}^L)^2,
\end{aligned}
\tag{38}
$$

where: B_t^G is the end-of-period holdings of short-term (one-period) bonds issued by the domestic government, which pays the (gross) interest rate R^G; B_t^P is the bond exchanged with other domestic and RW Ricardian households, which pays the (gross) RW monetary policy rate R^* and denominated in RW currency (S_t is nominal exchange rate expressed as number of euro per unit of RW currency); the function $\Gamma_{B^P,t}$ captures the costs of undertaking positions in the international bond market;[27] $B_{ric,t}^L$ is the long-term sovereign bond issued by the domestic government; W_t is the nominal wage; $0 < \tau_{w,t} < 1$ is the labour income tax rate; Π_t^P are profits from ownership of domestic capital producers, rebated to Ricardian households is a lump-sum way; Π_t^{prof} are profits from ownership of domestic firms (other than capital producers), rebated to Ricardian households in a lump-sum way; P_t is the consumer price deflator; $0 < \tau_t^c < 1$ is the consumption tax rate; TR_t are lump-sum transfers from the government ($TR_t < 0$ are lump-sum taxes paid to the government); the

[27] The adjustment cost in the bond markets has the following functional form:

$$\Gamma_{B^P,t} \equiv \exp\left(\phi_b\left(\frac{S_t B_t^P}{P_t} - b^P\right)\right) \qquad \phi_b \geq 0.$$

The parameter $\phi_b > 0$ controls the speed of convergence to the non-stochastic steady state and b^p is the steady-state position. The adjustment cost is imposed to ensure the stationarity of the net foreign asset position.

last two terms are quadratic costs paid to adjust the nominal wage and the position in the long term sovereign bond, respectively. Specifically, $\kappa_W > 0$ is a parameter measuring the nominal wage stickiness; $0 < ind_W < 1$ is a parameter measuring the degree of indexation to previous-period inflation, π_{t-1} and, correspondingly, $1 - ind_W$ measures the indexation to the central bank target; in the bond adjustment cost, the term $\phi_B > 0$ is a parameter, while $\bar{B}^L_{ric}$ is the Ricardian household's steady-state position in the bond.

The long-term interest rate is

$$R^{long}_t = \frac{1}{P^{long}_t} + \kappa^{long} \tag{39}$$

In what follows we report the first order conditions implied by the household's utility maximization subject to the budget constraint.

- FOC with respect to consumption $C_{ric,t}(j)$

$$\lambda_{ric,t}(j)\,(1 + \tau^c_t) = (C_{ric,t}(j) - habC_{ric,t-1})^{-\sigma} \tag{40}$$

where $\lambda_{ric,t}$ is the consumption marginal utility.

- FOC with respect to domestic bond $B^G_t(j)$

$$\lambda_{ric,t}(j) \quad = \quad \beta_{ric} E_t \left(R^G_t \pi^{-1}_{t+1} \lambda_{ric,t+1}(j) \right) \tag{41}$$

where

$$\pi_t \equiv \frac{P_t}{P_{t-1}} \tag{42}$$

is the gross consumer price inflation rate.

- FOC with respect to foreign bond $B^P_t(j)$

$$\lambda_{ric,t}(j) \quad = \quad \beta_{ric} E_t \left(R_t (1 - \Gamma_{B^P_,t}) \pi^{-1}_{t+1} \frac{S_{t+1}}{S_t} \lambda_{ric,t+1}(j) \right) \tag{43}$$

- FOC with respect to long-term sovereign bond $B^L_{ric,t}(j)$

$$\lambda_{ric,t}(j)P^L_t\left(1+\phi_B\left(P^L_tB^L_{ric,t}(j)-\bar{B}^L_{ric}\right)\right)$$
$$=\beta_{ric}E_t\left(\left(1+\kappa_{long}P^L_{t+1}\right)\pi^{-1}_{t+1}\lambda_{ric,t+1}(j)\right) \quad (44)$$

- FOC with respect to nominal wage $W_t(j)$

The household supplies its labour variety under monopolistic competition; she sets the nominal wage taking into account of demand by domestic firms and subject to quadratic adjustment costs of setting nominal wages. The implied optimal wage setting equation is

$$\theta_L\frac{W_t(j)^{-\theta_L(1+\tau)-1}}{W_t^{-\theta_L(1+\tau)}}L^{\tau}_{ric,t}+(1-\theta_L)(1-\tau_{w,t})\frac{W_t(j)^{-\theta_L}}{W_t^{-\theta_L}}=\lambda_{ric,t}(j)\kappa_W\left(\frac{W_t(j)/W_{t-1}(j)}{\pi_{t-1}^{ind_w}\pi_{target}^{1-ind_w}}-1\right)\frac{W_t/W_{t-1}(j)}{\pi_{t-1}^{ind_w}\pi_{target}^{1-ind_w}}$$
$$-\beta_{ric}\lambda_{ric,t+1}(j)\kappa_W\left(\frac{W_{t+1}(j)/W_t(j)}{\pi_t^{ind_w}\pi_{target}^{1-ind_w}}-1\right)\frac{W_{t+1}W_{t+1}(j)/W_t(j)^2L_{ric,t+1}}{\pi_t^{ind_w}\pi_{target}^{1-ind_w}L_{ric,t}} \quad (45)$$

where the parameter $\theta_L>1$ measures the elasticity of substitution among different labour varieties supplied by households and π_{t-1} is the previous-period gross inflation rate. The parameter $0<ind_W<1$ measures indexation of current-period wage to previous-period inflation. Correspondingly, $1-ind_W$ measures indexation to the central bank target.

A.6.2 Hand-to-mouth households

There is a continuum of Hand-to-mouth households j'', with mass $0<s^{rot}<1$.[28] In each period the generic household consumes all the available wage income. The nominal wage and the labour supply are the same as the Ricardian household's corresponding variables.

- Budget constraint

$$(1+\tau_{c,t})P^{HTM}_{C,t}C_{HTM,t}(j'')=(1-\tau_{w,t})W_tL_{HTM,t}(j'')+TR^{HTM}_t. \quad (46)$$

[28] $s^{ric}+s^{rot}=1$.

A.7 Capital producers

The generic capital goods producer c produces private physical capital. It is owned by Ricardian households. Capital producers optimally choose the end-of-period capital K and investment I subject to the law of capital accumulation, the adjustment costs on investment, distortionary taxes on capital income levied by the domestic government, and taking all prices as given. Capital producers rent existing physical capital stock K in a perfectly competitive market at the nominal rate R^K to domestic firms producing intermediate goods.

- Capital accumulation law

$$K_t(c) = (1-\delta)K_{t-1}(c) + \left[1 - \frac{\phi_I}{2}\left(\frac{I_t(c)}{I_{t-1}(c)} - 1\right)^2\right] I_t(c) \tag{47}$$

where $0 < \delta < 1$ is the depreciation rate and investment is subject to a quadratic adjustment cost ($\phi_I > 0$ is a parameter);

- FOC with respect to the end-of-period capital $K_t(c)$

$$\begin{aligned} &\lambda_{ric,t} Q_t(c) \\ &= E_t\left(\beta_{ric}\lambda_{ric,t+1}\right) r^K_{t+1}\left(1-\tau_{k,t+1}\right) \\ &+ E_t\left(\beta_{ric}\lambda_{ric,t+1}\right)(1-\delta)Q_{t+1}(c) \end{aligned} \tag{48}$$

where: $\lambda_{ric,t}$ is the generic Ricardian household marginal utility of consumption, $Q(c)$ is the Tobin's Q (i.e., the multiplier of the capital accumulation law), and $0 < \tau_{k,t} < 1$ is the tax rate on the return of capital, r^K_t;

- FOC with respect to investment $I_t(c)$

$$\begin{aligned}
&\lambda_{ric,t}p_{I,t} \\
&= Q_t(c)\lambda_{ric,t} \times \\
&\left[1 - \frac{\phi_I}{2}\left(\frac{I_t(c)}{I_{t-1}(c)} - 1\right)^2 - \phi_I\left(\frac{I_t(c)}{I_{t-1}(c)} - 1\right)\frac{I_t(c)}{I_{t-1}(c)}\right] \\
&+\beta_{ric}\lambda_{ric,t+1}\phi_I\left[\left(\frac{I_{t+1}(c)}{I_t(c)} - 1\right)\frac{I_{t+1}^2(c)}{I_t^2(c)}\right]
\end{aligned} \tag{49}$$

A.8 Monetary policy

The central bank sets the (gross) quarterly policy rate R_t according to the Taylor rule.

- Taylor rule

$$\left(\frac{R_t}{\bar{R}}\right)^4 = \left(\frac{R_{t-1}}{\bar{R}}\right)^{4\rho_R}\left(\frac{\pi_{t,t-3}}{\pi_{target}^4}\right)^{(1-\rho_R)\rho_\pi}\left(\frac{RGDP_t}{RGDP_{t-1}}\right)^{(1-\rho_R)\rho_{RGDP}} \tag{50}$$

where $\pi_{t,t-3}$ is the annual gross inflation rate, $RGDP_t$ is the quarterly real gdp, $0 < \rho_R < 1$ is a parameter capturing inertial setting of the policy rate, $\rho_\pi > 0, \rho_{RGDP}$ measure responsiveness of the policy rate to inflation deviation from the central bank target π_{target} and to real gdp growth, respectively.

We also allow, in some simulations, the central bank to purchase long-term sovereign bonds for monetary policy purposes. The purchases are exogenously set.

A.9 Fiscal policy

In each country there is a fiscal authority.

- Budget constraint

$$B_t^G - B_{t-1}^G R_{t-1}^G + P_t^L B_t^{G,L} - R_t^L P_t^L B_{t-1}^{G,L} = P_{G,t} G_t + TR_t^{HTM} - TAX_t - T_t$$
$$-s^{EA} \times (t_{eoil,t} OIL_t + t_{egas,t} GAS_t + t_{ecoal,t} COAL_t) \tag{51}$$

where: $B^G > 0$ is the short-term (one-period) sovereign bond, which pays the gross interest rate R^G; $B_t^{G,L} > 0$ the long-term sovereign bond, paying the rate R_t^L and whose price is P_t^{long}; G_t is purchases of domestic goods, at the price $P_{G,t}$; TR_t^{HTM} are targeted lump-sum transfers to HTM households; $TAX_t > 0$ are lump-sum taxes paid by the Ricardian households; T_t are Total government revenues from distortionary taxation other than excise taxes; $t_{eoil,t}$,$t_{egas,t}$, $t_{ecoal,t}$ are the excise taxes on oil, gas, and coal, respectively.

- Total government revenues from distortionary taxation T_t other than excise taxes are equal to

$$T_t \equiv \tau_{w,t} W_t s^{EA} L_t + \tau_{k,t} s^{EA} r_t^K K_{t-1}$$
$$+\tau_{c,t} P_t s^{EA} (s^{ric} C_{ric,t} + \left(1 - s^{ric}\right) C_{HTM,t}) \tag{52}$$

where $0 < \tau_{w,t}, \tau_{k,t}, \tau_{c,t} < 1$ are tax rates on labour income, physical capital income, and consumption, respectively.

- Fiscal rule

The fiscal authority stabilizes the public debt as a ratio to GDP by setting the lump-sum taxes (as a ratio to GDP) tax_t according to the following fiscal rule:

$$\frac{tax_t}{\bar{tax}} = \left(\frac{b_{G,t}}{\bar{b}_G}\right)^{\phi_G} \tag{53}$$

where $\bar{tax}$ is the steady-state lump-sum-taxes-to-gdp ratio, $b_{G,t}$ the short-term public debt as a ratio to GDP, $\bar{b}_G$ its steady-state value, $\phi_G > 0$ a parameter measuring the responsiveness of taxes to the debt. Long-term sovereign debt is assumed to change proportionally to changes in the short-term debt. Thus the rule indirectly stabilizes also changes in the long-term sovereign debt.

A.10 Market clearing conditions

In what follows we report the market clearing conditions of goods and bonds holding in the EA. Similar equations hold for the RW.

- Labour market

$$\int_0^{s^{EA}s^{ric}} L_{ric,t}(j)\,dj + \int_{s^{EA}s^{ric}}^{s^{EA}} L_{HTM,t}(j'')\,dj'' =$$
$$\int_0^{s^{EA}} L_{y,t}(h)\,dh + \int_0^{s^{EA}} L_{oil,t}(o)\,do + \int_0^{s^{EA}} L_{coal,t}(co)\,dco$$
$$+\int_0^{s^{EA}} L_{gas,t}(g)\,dg + \int_0^{s^{EA}} L_{res,t}(r)\,dr + \int_0^{s^{EA}} L_{nuc,t}(n)\,dn \qquad (54)$$

- Capital

$$\int_0^{s^{EA}} K_t(c)\,dc = \int_0^{s^{EA}} K_{y,t}(h)\,dh + \int_0^{s^{EA}} K_{oil,t}(o)\,do + \int_0^{s^{EA}} K_{coal,t}(co)\,dco$$
$$+\int_0^{s^{EA}} K_{gas,t}(ga)\,dga + \int_0^{s^{EA}} K_{res,t}(r)\,dr + \int_0^{s^{EA}} K_{nuc,t}(n)\,dn \qquad (55)$$

- Oil market

$$OIL^*_{RW,t} = \int_0^{s^{EA}} OIL_t(o)\,do + \int_{s^{EA}}^1 OIL_t(o^*)\,do^* \qquad (56)$$

- Coal market

$$COAL^*_{RW,t} = \int_0^{s^{EA}} COAL_t(co)\,dco + \int_{s^{EA}}^1 COAL_t(co^*)\,dco^* \qquad (57)$$

- Gas market

$$GAS^*_{RW,t} = \int_0^{s^{EA}} GAS_t(ga)\,dga + \int_{s^{EA}}^1 GAS_t(ga^*)\,ga^* \qquad (58)$$

- Nuclear source market

$$NUC_{EA,t} = \int_0^{s^{EA}} NUC_t\left(n\right)dn \tag{59}$$

- Renewable sources market

$$RES_{EA,t} = \int_0^{s^{EA}} RES_t\left(r\right)dr \tag{60}$$

- Market of oil-based energy (similar conditions hold for other types of energy)

$$\int_0^{s^{EA}} EN_{oil,t}\left(o\right)do = \int_0^{s^{EA}} EN_{oilc,t}\left(x\right)dx + \int_0^{s^{EA}} EN_{oily,t}\left(h\right)dh \tag{61}$$

- Short-term sovereign bond

$$\int_0^{s^{EA}s^{ric}} B^G_{ric,t}\left(j\right)dj = B^G_t \tag{62}$$

- Long-term sovereign bond

$$\int_0^{s^{EA}s^{ric}} B^L_{ric,t}\left(j\right)dj = B^{G,long}_t \tag{63}$$

- Internationally traded bond

$$\int_0^{s^{EA}s^{ric}} B^P_t\left(j\right)dj + \int_{s^{EA}}^{s^{EA}+\left(1-s^{EA}\right)s^{ric}} B^P_t\left(j^*\right)dj^* = 0 \tag{64}$$

- Generic EA intermediate tradable h sold in EA

$$\int_0^{s^{EA}} Y_{EA,t}\left(h\right)dh = \int_0^{s^{EA}} C_{EA,t}\left(x\right)dx + \int_0^{s^{EA}} I_{EA,t}\left(i\right)di \tag{65}$$

- Generic EA intermediate tradable h sold in RW

$$\int_0^{s^{EA}} Y^*_{EA,t}\left(h\right)dh = \int_{s^{EA}}^{1} C_{EA,t}\left(x^*\right)dx^* + \int_{s^{EA}}^{1} I_{EA,t}\left(i^*\right)di^* \tag{66}$$

- Generic intermediate tradable h

$$\int_{0}^{s^{EA}} Y_{T,t}(h)\,dh = \int_{0}^{s^{EA}} Y_{EA,t}(h)\,dh + \int_{0}^{s^{EA}} Y_{EA,t}^{*}(h)\,dh \tag{67}$$

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2021

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AFFINITO M. and M. PIAZZA, *Always look on the bright side? Central counterparties and interbank markets during the financial crisis*, International Journal of Central Banking, v. 17, 1, pp. 231-283, **WP 1181 (July 2018).**

ALBANESE G., E. CIANI and G. DE BLASIO, *Anything new in town? The local effects of urban regeneration policies in Italy,* Regional Science and Urban Economics, v. 86, **WP 1214 (April 2019).**

ALBANESE G., G. DE BLASIO and A. LOCATELLI, *Does EU regional policy promote local TFP growth? Evidence from the Italian Mezzogiorno,* Papers in Regional Science, v. 100, 2, pp. 327-348, **WP 1253 (December 2019).**

ALBERTAZZI A., A. NOBILI and F. M. SIGNORETTI, *The bank lending channel of conventional and unconventional monetary policy,* Journal of Money, Credit and Banking, v. 53, 2-3, pp. 261-299, **WP 1094 (Jan 2017).**

ANZUINI A. and L. ROSSI, *Fiscal policy in the US: a new measure of uncertainty and its effects on the American economy*, Empirical Economics, v. 61, 6, pp. 2613-2634, **WP 1197 (November 2018).**

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AUER S., M. BERNARDINI and M. CECIONI, *Corporate leverage and monetary policy effectiveness in the euro area,* European Economic Review, v. 140, Article 103943, **WP 1258 (December 2019).**

BANERJEE R, L. GAMBACORTA and E. SETTE, *The real effects of relationship lending,* Journal of Financial Intermediation, v. 48, Article 100923, **WP 1133 (September 2017).**

BAMIEH O and A. CINTOLESI, *Intergenerational Transmission in regulated professions and the role of familism,* Journal of Economic Behavior & Organization, v. 192, pp. 857-879, **WP 1350 (October 2021).**

BARONE G., F. DAVID, G. DE BLASIO and S. MOCETTI, *How do house prices respond to mortgage supply?,* Journal of Economic Geography, v. 21, 1, pp.127-140, **WP 1282 (June 2020).**

BARONE G. and S. MOCETTI, *Intergenerational mobility in the very long run: Florence 1427-2011,* Review of Economic Studies, v. 88, 4, pp. 1863–1891, **WP 1060 (April 2016).**

BARTOCCI A., L. BURLON, A. NOTARPIETRO and M. PISANI, *Macroeconomic effects of non-standard monetary policy measures in the Euro Area: the role of corporate bond purchases,* The Manchester School, v. 89, S1, pp. 97-130, **WP 1241 (October 2019).**

BATINI N., A. CANTELMO, G. MELINA and S. VILLA, *How loose, how tight? A measure of monetary and fiscal stance for the euro area,* Oxford Economic Papers, v. 73, 4, pp. 1536-1556, **WP 1295 (September 2020).**

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BUSETTI F., M. CAIVANO, D. DELLE MONACHE and C. PACELLA, *The time-varying risk of Italian GDP,* Economic Modelling, v. 101, Article 105522, **WP 1288 (July 2020).**

BUSETTI F., S. NERI, A. NOTARPIETRO and M. PISANI, *Monetary Policy strategies in the new normal: a model-based analysis for the Euro Area,* Journal of Macroeconomics, v. 70, Article 103366, **WP 1308 (December 2020).**

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CORNELI F., *Financial integration without financial development,* Atlantic Economic Journal, v. 49, 2, pp. 201-220, **WP 1120 (June 2017).**

COVA P., P. PAGANO, A. NOTARPIETRO and M. PISANI, *Secular stagnation, R&D, public investment and monetary policy: a global-model perspective,* Macroeconomic Dynamics, v. 25, 5, pp. 1267-1287, **WP 1156 (December 2017).**

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DEL PRETE S. and M. L. STEFANI, *Women as "Gold Dust": gender diversity in top boards and the performanceof Italian banks,* Economic Notes, Monte dei Paschi di Siena, v. 50, 2, e12183, **WP 1014 (June 2015).**

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2022

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BARTOCCI A., A. NOTARPIETRO and M. PISANI, *Covid-19 shock and fiscal-monetary policy mix in a monetary union,* Economic challenges for Europe after the pandemic, Springer Proceedings in Business and Economics, Berlin-Heidelberg, Springer, **WP 1313 (December 2020).**

BOTTERO M., C. MINOIU, J. PEYDRÒ, A. POLO, A. PRESBITERO and E. SETTE, *Expansionary yet different: credit supply and real effects of negative interest rate policy,* Journal of Financial Economics, v. 146, 2, pp. 754-778, **WP 1269 (March 2020).**

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BARTOCCI A., A. NOTARPIETRO and M. PISANI, *Non-standard monetary policy measures in non-normal times,* International Finance, v. 26, 1, pp. 19-35, **WP 1251 (November 2019).**

DI ADDARIO S., P. KLINE, R. SAGGIO and M. SØLVSTEN, *It ain't where you're from, it's where you're at: hiring origins, firm heterogeneity, and Wages,* Journal of Econometrics,v. 233, 2, pp. 340-374, **WP 1374 (June 2022).**

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LOMBARDI M. J., M. RIGGI and E. VIVIANO, *Worker's bargaining power and the Phillips curve: a micro-macro analysis, and wages,* Journal of the European Economic Association, v. 21, 5, pp. 1905–1943, **WP 1302 (November 2020).**

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FORTHCOMING

BALTRUNAITE A., M. CANNELLA, S. MOCETTI and G. ROMA, *Board composition and performance of state-owned enterprises: quasi experimental evidence,* The Journal of Law, Economics, and Organization, **WP 1328 (April 2021).**

CIAPANNA E, S. MOCETTI and A. NOTARPIETRO, *The macroeconomic effects of structural reforms: an empirical and model-based approach,* Economic Policy, **WP 1303 (November 2022).**

FERRARI A. and V. NISPI LANDI, *Whatever it takes to save the planet? Central banks and unconventional green policy,* Macroeconomic Dynamics, **WP 1320 (February 2021).**

FERRARI A. and V. NISPI LANDI, *Toward a green economy: the role of central bank's asset purchases,* International Journal of Central Banking, **WP 1358 (February 2022).**

MICHELANGELI V. and E. VIVIANO, *Can internet banking affect households' participation in financial markets and financial awarness?,* Journal of Money, Credit and Banking, **WP 1329 (April 2021).**

MISTRETTA A., *Synchronization vs transmission: the effect of the German slowdown on the Italian business cycle,* International Journal of Central Banking, **WP 1346 (October 2021).**

RAINONE E., *Real-time identification and high frequency analysis of deposits outflows,* Journal of Financial Econometrics, **WP 1319 (February 2021).**