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In 2008 all ECB publications feature a motif taken from the €10 banknote.

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Abstract

This paper presents first the estimation of a two-country DSGE model for the euro area and the rest-of-the-world including relevant oil-price channels. We then investigate the optimal resolution of the policy tradeoffs emanating from oil-price disturbances. Our simulations show that the inflationary forces related to the use of oil as an intermediate good seem to require specific policy actions in the optimal allocation. However, the direct effects of oil prices should be allowed to exert their mechanical influence on CPI inflation and wage dynamics through the indexation schemes. We also illustrate that any fine-tuning strategy which tries to counteract the direct effects of oil-price changes in headline inflation would prove counterproductive both in terms to stabilization of underlying inflation and by causing unnecessary volatility in the macroeconomic landscape. Finally, it appears that perfect foresight on future oil price developments allows a more rapid absorption of the steady state decline in purchasing power and real national income in the optimal allocation. Through the various expectation channels, economic agents facilitate the necessary adjustments and optimal monetary policy can still tolerate the direct effects of oil price changes on CPI inflation as well as some degree of underlying inflationary pressures in the view of easing partly the burden of downward real wage shifts. Our monetary policy prescriptions have been derived in a modeling framework where oil-price fluctuations are essentially exogenous to policy actions and where expectations are formed under the rational expectations paradigm. Notably, the extension of such conclusions to imperfect knowledge and weak central bank credibility configurations remain challenging fields for further research.

Keywords: Oil prices, Optimal monetary policy, New open economy macroeconomics, Bayesian estimation.

JEL Classification: E4, E5, F4.

Non-Technical Summary

The main objective of this paper is to analyze the optimal stabilization plans for monetary policy in the face of exogenous oil-price shocks. This issue is treated first through the estimation of a two-country DSGE model for the euro area and the rest-of-the-world including relevant oil-price channels. Once the structural modeling framework is given satisfying data coherence, we then derive some concepts of optimal monetary policy setting and investigate the optimal resolution of the policy tradeoffs emanating from oil-price disturbances.

Four main oil-channels are introduced in the model: oil is serving final consumption; it is also used as an intermediate input in domestic firms' production; we allow for a mechanical real income effect of oil price changes through rule-of-thumb consumers that spend a fixed proportion of their current nominal income; finally, we account for the "recycling" of oil revenues into euro area and ROW exports through the introduction of a reduced-form oil-producing block. Obviously, the description of the oil-market functioning used in this paper is very stylized. However, the simplifying assumptions made here should not significantly affect the main results of the paper regarding the optimal design of monetary policy in the face of exogenous oil-supply shocks.

The original contributions of the paper cover several dimensions. First we provide some evidence on the macroeconomic transmission of oil price shocks to the euro area within an open-economy structural modeling framework featuring rational expectations. The estimated model points to implications of oil price shocks for economic activity which are on the lower bound of available estimates, mostly based on empirical agnostic models. We provide indications that the rational expectations and perfect central bank credibility assumptions may explain such more moderate propagation to real variables. In terms of structural inference, we estimate the share of rule-of-thumb consumers for the euro area to be around 20% whereas the elasticities of substitution of oil as an input in final consumption and aggregate production prove to be weakly identified given our macroeconomic dataset.

Second, we compare the stabilization properties of the estimated rules to the ones implied by optimal monetary policy conduct. It turns out that the optimal monetary policy would call for a more pronounced contraction of economic activity in order to mitigate significantly the indirect inflationary pressures at the producer level, notably through weaker wage responses. In addition, the optimal cooperation would activate a stronger exchange rate channel to ease the cost pressures generated by oil-price increases. Actually, the inflationary forces emanating from the intermediate consumption of oil require specific policy actions in the optimal allocation while the direct effects of oil prices should be allowed to exert their mechanical influence on CPI inflation and wage dynamics through the indexation schemes. We also illustrate that any fine-tuning strategy trying to counteract the direct effects of oil-price changes in headline inflation would prove counterproductive both in terms of stabilization of underlying inflation and by causing unnecessary volatility in the macroeconomic landscape.

1 Introduction

The main objective of this paper is to explore the monetary policy prescriptions emanating from optimal policy conduct in a DSGE framework which provides satisfying data coherence for the euro area.

An abundant literature has examined the macroeconomic implications of oil price fluctuations from both an empirical as well as structural perspective. Somewhat related to our work, Blanchard and Galí [2007] notably provided monetary policy considerations regarding the appropriate stabilization of oil price shocks. For the euro area, Jacquinot et al. [2009] developed a calibrated large scale DSGE model with a special focus on the energy sector while De Fiore and Lombardo [2008] explore the gains from international monetary policy cooperation in response to oil-price disturbances.

Recent advances in Bayesian estimation techniques make it possible to estimate relatively large structural Dynamic Stochastic General Equilibrium (DSGE) models. In this respect, the core foundations of the present model are inherited from Adjemian et al. [2008] who brought to data a two-country DSGE model for the US and the euro area. The model shares many features common in open-economy DSGE models. Notably, exchange rate pass-through is incomplete due to some partial nominal rigidity in the buyer's currency. We also introduce a number of nominal and real frictions such as sticky prices, sticky wages, variable capital utilization costs and habit persistence, following the seminal contribution from Smets and Wouters [2003]. Regarding the inclusion of oil, four main channels have been identified: oil is serving final consumption; it is also used as an intermediate input in domestic firms' production; we allow for a mechanical real income effect of oil price changes through rule-of-thumb consumers, which spend a fixed proportion of their real income each period; finally, we account for the "recycling" of oil revenues into euro area and ROW exports through the introduction of a reduced-form oil-producing block. Obviously, the description of the oil-market functioning used in this paper is very stylized. However, the simplifying assumptions should not significantly affect the main results of the paper regarding the optimal design of monetary policy in the face of exogenous oil-supply shocks.

Concerning optimal policy, the Ramsey approach to optimal monetary policy cooperation is computed by formulating an infinite-horizon Lagrangian problem of maximizing the conditional aggregate welfare of both countries subject to the full set of non-linear constraints forming the competitive equilibrium of the model. We solve the equilibrium conditions of the optimal allocation using second-order approximations to the policy function. We consider two concepts of optimal policy: one is the fully optimal monetary policy cooperation; the other consists in maximizing euro area welfare conditional on monetary policy in the ROW following the estimated Taylor rule. We thereby put into perspective the optimal international monetary policy cooperation with an optimal policy from an euro area perspective, treating the ROW block as a reduced-form one.

The original contributions of the paper cover several dimensions. First, we provide some evidence on the macroeconomic transmission of oil price shocks to the euro area within an open-economy structural modeling framework featuring rational expectations. The estimated model points to implications of oil price shocks for economic activity which are on the lower bound of available estimates, mostly based on empirical agnostic models. We provide evidence that the rational expectations and perfect central bank credibility assumptions may explain such more moderate propagation to real variables. In terms of structural inference, we estimate the share of rule-of-thumb consumers for the euro area to be around 20%. While estimated shares of oil absorption in the economy are reasonable, the elasticities of substitution of oil as input in final consumption and aggregate production prove to be weakly identified with the macroeconomic dataset used.

Second, we compare the stabilization properties of the estimated rules to the ones implied by optimal monetary policy conduct. Under both policy regimes, the direct effects of oil prices should be allowed to exert their mechanical influence on CPI inflation and wage dynamics through the indexation schemes. However, the optimal monetary policy would call for a more pronounced contraction of economic activity in order to mitigate significantly the indirect inflationary pressures at the producer level, notably through weaker wage responses. In addition, the optimal cooperation would activate a stronger exchange rate channel to ease the cost pressures generated by oil-price increases. We also illustrate that any fine-tuning strategy which attempts to counteract the direct effects of oil-price changes in headline inflation would prove counterproductive both in terms of stabilization of underlying inflation and by factoring unnecessary volatility in the macroeconomic landscape. Finally, we explore the optimal policy response to an *expected* oil-price surge. It appears that perfect foresight on future oil price developments leads to a more rapid absorption of the steady state decline in purchasing power and real national income. Through the various expectation channels, economic agents facilitate the necessary adjustments and optimal monetary policy can tolerate the direct effects of oil price changes on CPI inflation as well as some degree of underlying inflationary pressures in the view of easing partly the burden of downward real wage shift.

The rest of the paper is organized as follows. In section 2, the theoretical model is derived. Section 3 presents the estimation of the model and the inference made on the transmission of oil prices in the euro area. Section 4 deals with the derivation of optimal policy and the analysis of the optimal stabilization of oil-price shocks. Section 5 concludes.

2 The model

The world economy is composed of two symmetric countries, Home and Foreign, and a residual oil-producing block where we abstract from sound micro-economic foundations. In H and F, there is a continuum of "single-good-firms" producing differentiated goods that are imperfect substitutes. The number of households is proportional to the number of firms. Consumers receive utility from consumption and disutility from labor. In each country, the consumption baskets aggregating products from both countries have biased preferences towards locally produced goods. Concerning international frictions, we assume that financial markets are complete both domestically and internationally. We restrict the model to the perfect risk-sharing case in order to abstract from the interactions between the oil price effects on external accounts and the exchange rate risk premium (see Bodenstein et al. [2007] on this issue)[1]. Finally, export prices are sticky in the producer currency for a fraction of firms and in the buyer currency for the remaining firms.

Regarding the specification of oil-related channels, the oil price affects the economy through four different mechanisms. First, oil is, inter alia, a consumption good and thus the price of energy-related items directly affects the consumer price basket. Second, there is an indirect channel coming from the use of oil as an input in the domestic firms' production function. Oil is very much complementary to capital such that a rise in the oil price will increase the cost of production and lead to some substitution towards less capital intensive production. We also allow for rule-of-thumb consumers which mechanically spend a fixed proportion of their current nominal income. This feature helps capturing a mechanical real income effect of oil price changes on households' spending. Finally, there is a feedback effect at the international level coming from the "recycling" of higher revenues obtained by oil-exporting countries in the wake of an oil price increase. These higher revenues are partly redirected towards the euro area via higher import demand.

The oil-producing country is treated as an *ad hoc* reduced-form block: the oil-producing country has a fixed exchange rate with country F; the real price of oil in terms of country F consumer prices is exogenously determined while oil supply adjusts to clear the market (Bodenstein et al. [2007] made the same assumption); and oil revenues are gradually recycled into imports form country H and F. Such a description of the oil market is obviously very stylized and neglects important features of oil price dynamics. First, we do not account for the oil-producing industries in country H and F. Second, real oil prices can be expected to react to economic conditions beyond the narrow scope of oil-supply determinants. Third, the empirical literature on oil prices has emphasized the importance of non-linear patterns.

However, given that our estimation procedure only makes use of first-order model dynamics, we could not introduce such non-linear features. Moreover, up to a first order, our simulations suggests that a market-clearing condition determining oil prices, subject to exogenous oil-supply shocks, would only generate a limited contribution of non oil-related shocks to the real oil price dynamics. The amplitude of historical oil price fluctuations can hardly be reproduced by macroeconomic shocks through a linear-approximation of the model including endogenous oil price determination (which is consistent with the simulations reported by Jacquinot et al. [2009]). Finally, the primary focus of the paper deals with the optimal design of monetary policy in the face of "exogenous" oil price shocks and we prefer to pursue the discussion under the assumption that the monetary authorities do not have a control on oil price determination. We leave for further research the analysis of optimal monetary cooperation in the case of endogenous oil prices, and potentially non-linear supply constraints, which would create strong incentives for monetary policy to exploit its leverage on oil-price formation. Therefore, while acknowledging that there are limitations to our assumptions about the oil-market, they should not significantly affect the core results of the paper[2].

[1] We leave for further research the analysis of optimal monetary policy stabilization of oil price shock in presence of international financial frictions. Obviously, the implications regarding the optimal exchange rate adjustment could be significantly affected.

[2] We also re-estimated the benchmark model presented in the following sections assuming that a market-clearing condition determines real oil prices in the presence of exogenous oil-supply shocks. The parameter estimates remain very similar and the

Thereafter, we present the main decisions problems of economic agents, leaving the complete description of equilibrium conditions to the Appendix. Most of the derivation will be pursued for country H.

2.1 Households decision problem

We assume that in each country, there exists a continuum of infinitely-lived households. A fraction $1-\omega_r$ of households in each country H (resp. $1-\omega_r^*$ in country F) derives its consumption and investment plans from an optimizing program, those households being referred thereafter as $o-type$ households, while the remaining share of households, the $r-type$ households, follow a rule-of-thumb consumption behavior.

At time t, the utility function of a generic domestic consumer h belonging to country H is

$$\mathcal{W}_t(h) = \mathbb{E}_t \left\{ \sum_{j\geq 0} \beta^j \left[\frac{1}{1-\sigma_C} \left(C_{t+j}^h - hC_{t+j-1}^h \right)^{1-\sigma_C} - \frac{\tilde{L}}{1+\sigma_L} \left(L_{t+j}^h \right)^{1+\sigma_L} \right] \varepsilon_{t+j}^B \right\}$$

Households obtain utility from consumption, C_t^h, relative to an internal habit depending on past consumption, while receiving disutility from their labour services L_t^h. For $h \in [0, \omega_r]$, households are of $r-type$ with consumption and labor supply denoted C_t^r and L_t^r, while, for $h \in [0, \omega_r]$, households are of $o-type$ with the analogous notations C_t^o and L_t^o. The utility function also incorporates a consumption preference shock ε_t^B. $\tilde{L}$ is a positive scale parameter.

2.1.1 Optimizing households

$o-type$ households have access to financial markets which are assumed to be complete both domestically and internationally. They also own the productive capacities and make decisions on investment plans to build the capital stock which will be rented out to intermediate firms.

Each household h maximizes its utility function under the following budget constraint:

$$\begin{aligned} \sum_{h^{t+1}} \nu \left(h^{t+1} \mid h^t \right) \frac{B_{t+1}^h}{\underline{P}_t} + \frac{P_t}{\underline{P}_t} C_t^{o,h} + \frac{P_{N,t}}{\underline{P}_t} I_t^{o,h} \quad = \quad & \frac{(1-\tau_{W,t}) W_t^h L_t^{o,h} + A_t^{o,h} + D_t^{o,h} + TT_t^{o,h} + B_t^h}{\underline{P}_t} \\ & + \frac{P_{N,t}}{\underline{P}_t} \left[R_t^k u_t^h K_t^{o,h} - \Phi \left(u_t^h \right) K_t^{o,h} \right] \end{aligned}$$

where W_t^h is the wage rate, $\nu \left(h^{t+1} \mid h^t \right)$ is the period-t state contingent price of one nominal unit in state h^{t+1} in period $t+1$, $TT_t^{o,h}$ denote government lump-sum transfers (or taxes if negative), $D_t^{o,h}$ are dividends from ownership of firms, S_t is the nominal exchange rate, and

$$R_t^k u_t^h K_t^{o,h} - \Phi \left(u_t^h \right) K_t^{o,h}$$

share of oil-price variance explained by non-oil related shocks is well-below 10% (results not reported here).

represents the return on the real capital stock minus the cost associated with variations in the degree of capital utilization. The income from renting out capital services depends on the level of capital augmented for its utilization rate. The cost of capacity utilization is zero when capacity are fully used ($\Phi(1) = 0$). $A_t^{o,h}$ is a stream of income coming from state contingent securities which are traded among households to provide insurance against household-specific wage-income risk. This assumption implies that all $o - type$ households choose identical allocations in equilibrium.

We also introduce a consumption tax which affects the price of the distributed goods serving final consumption. Such a basket consists of non-oil distributed goods and oil quantities. The after-tax consumer price index (CPI) is denoted $P_t = (1 + \tau_{C,t}) \underline{P}_t$ where $\underline{P}_t$ is the price of the distribution good gross of consumption tax. Such a time-varying consumption tax could in principle rationalize the CPI inflation rate shocks that we introduce to estimate the model. We design the CPI shocks as $\frac{(1+\tau_{C,t})}{(1+\tau_{C,t-1})} = \varepsilon_t^{CPI}$. Investment is purchased out of non-oil distributed goods production with price $P_{N,t}$.

Separability of preferences and complete financial markets ensure that households have identical consumption plans.

2.1.2 Investment decisions of optimizing households

In each country, the capital is owned by optimizing households and rented out to the intermediate firms at a rental rate R_t^k. Households choose the capital stock, investment and the capacity utilisation rate in order to maximize their intertemporal utility function subject to the intertemporal budget constraint and the capital accumulation equation given by:

$$K_{t+1}^o = (1-\delta)K_t^o + E_t^I \left[1 - S\left(\frac{I_t^o}{I_{t-1}^o}\right)\right] I_t^o$$

where $\delta \in (0,1)$ is the depreciation rate, S is a non negative adjustment cost function such that $S(1) = 0$ and ε_t^I is an efficiency shock on the technology of capital accumulation.

The functional form used thereafter is $S(x) = \phi/2\ (x-1)^2$ for country H and $S(x) = \phi^*/2\ (x-1)^2$ for country F.

2.1.3 Rule-of-thumb households

$r - type$ households are assumed to consume their total current income. Such households do not smooth consumption and do not substitute intertemporally in the face of fluctuations in real interest rates. They do not have access to international bond trading and do not supply rental income from capital services.

Accordingly, the level of consumption will be equal to gross income net of taxes and transfers. In the country H, the rule-of-thumb household h will set consumption at:

$$C_t^{r,h} = \frac{(1-\tau_{W,t})\, W_t^h L_t^{r,h} + A_t^{r,h} + TT_t^{r,h}}{P_t}$$

where $A_t^{r,h}$ is a stream of income coming from state contingent securities which insures the consumers against the income risk of the wage distribution, while $TT_t^{r,h}$ denote government lump-sum transfers (or taxes if negative). Notice that the transfers to rule-of-thumb households can differ from those to the optimizing households. In practice, we assume active fiscal transfers which redistribute national income so that aggregate consumption of rule-of-thumb households is linked to real national income.

The point here is to specify hand-to-mouth behavior not restricted to labour income. Some fixed (negative) transfers are set to equalize the level of consumption for the two types of households in the steady state. The time-varying net transfers to rule-of-thumb consumers are financed through lump-sum taxes on $o - type$ consumers.

2.2 Labour supply and wage-setting by unions

Moreover, each household represents a differentiated labor service and we consider a continuum of unions, each of which representing workers of a certain type. Unions act as a monopoly supplier of the different labor types. For the sake of simplicity, we assume that they sell their services to a perfectly competitive firm which transforms it into an aggregate labor input using the following technology

$$L_t = \left[\int_0^1 L_t(h)^{\frac{1}{\mu_w}} \mathrm{d}h \right]^{\mu_w}$$

where $\mu_w = \frac{\theta_w}{\theta_w - 1}$ and $\theta_w > 1$ is the elasticity of substitution between differentiated labor services.

The unions face a labour demand curve with constant elasticity of substitution $L_t(h) = \left(\frac{W_t(h)}{W_t}\right)^{-\frac{\mu_w}{\mu_w - 1}} L_t$, where $W_t = \left(\int_0^1 W_t(h)^{\frac{1}{1-\mu_w}} \mathrm{d}h\right)^{1-\mu_w}$ is the aggregate wage rate.

We assume that the fraction of rule-of-thumb and optimizing consumers is uniformly distributed accross worker types. Taking into account this uniform allocation of labour demand implies that, in the aggregate, $L_t^o = L_t^r = L_t$.

In addition, unions set their wages on a staggered basis. Each period, every union faces a constant probability $1 - \alpha_W$ of changing its wage $\widetilde{W}_t(h)$, which will be the same for all suppliers of labor services. Otherwise, wages are indexed on past inflation and steady state inflation: $W_t(h) = [\Pi_{t-1}]^{\xi_w} \left[\overline{\Pi}\right]^{1-\xi_w} W_{t-1}(h)$ with $\Pi_t = \frac{P_t}{P_{t-1}}$. Unions might not be able to choose their nominal wage optimally in the near future. Thus, $\widetilde{W}_t(h)$ is chosen to maximize the weighted average of intertemporal utility across households types, given the budget constraint and the labor demand for wage setters which are unable to re-optimize after period t. We also introduce a time-varying income tax given by $1 - \tau_{w,t} = \left(1 - \overline{\overline{\tau}}_w\right) \varepsilon_t^W$.

2.3 Firms decision problems

2.3.1 Distribution goods

Various distribution sectors deliver two types of goods to the economy. First, some distribution firms produce a "non-oil goods" basket which aggregates final goods produced locally and imported. This output serves as an investment good and is also an input to another distribution sector which produces a consumption good aggregating non-oil goods with oil.

Regarding first non-oil goods, a continuum of companies operating under perfect competition mixes local production of final goods with imports. There is a home bias in the aggregation, which pins down the degree of openness at steady state. The distributor technology is given by

$$Y_N = \left[n_t^{\frac{1}{\xi}} Y_H^{\frac{\xi-1}{\xi}} + (1-n_t)^{\frac{1}{\xi}} Y_F^{\frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}}$$

$$Y_N^* = \left[(1-n_t^*)^{\frac{1}{\xi}} Y_H^{*\frac{\xi-1}{\xi}} + n_t^{*\frac{1}{\xi}} Y_F^{*\frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}}$$

ξ is the elasticity of substitution between bundles Y_H and Y_F. The degrees of home bias are subject to shocks $n_t = n\sqrt{\varepsilon_t^{\Delta n}}$ and $n_t^* = \frac{n}{\sqrt{\varepsilon_t^{\Delta n}}}$.

Before-tax distribution prices are defined by

$$\underline{P}_t = \left[n_t P_{H,t}^{1-\xi} + (1-n_t) P_{F,t}^{1-\xi} \right]^{\frac{1}{1-\xi}}$$

$$\underline{P}_t^* = \left[n_t^* P_{F,t}^{*1-\xi} + (1-n_t^*) P_{H,t}^{*1-\xi} \right]^{\frac{1}{1-\xi}}$$

$T = \frac{P_F}{P_H}$ and $T^* = \frac{P_F^*}{P_H^*}$ denote the interior terms of trade. We also make use of the relative prices $T_H = \frac{P_H}{\underline{P}}$ and $T_F^* = \frac{P_F^*}{\underline{P}^*}$.

Similarly, a continuum of companies operating under perfect competition mixes non-oil domestic goods and oil to serve final consumption with the following technology.

$$C_t = \left[\omega_C^{\frac{1}{\xi_o}} C_{N,t}^{\frac{\xi_o-1}{\xi_o}} + (1-\omega_C)^{\frac{1}{\xi_o}} C_{oil,t}^{\frac{\xi_o-1}{\xi_o}} \right]^{\frac{\xi_o}{\xi_o-1}}$$

The corresponding price indexes verify

$$\underline{P}_t = \left[\omega_C P_{N,t}^{1-\xi_o} + (1-\omega_C) P_{oil,t}^{1-\xi_o} \right]^{\frac{1}{1-\xi_o}}$$

where $T_{N,t} = \frac{P_{N,t}}{\underline{P}_t}$, and $T_{oil,t} = \frac{P_{OIL,t}}{\underline{P}_t}$.

2.3.2 Final goods

In country H, final producers for local sales and imports are in perfect competition and aggregate a continuum of differentiated intermediate products from home and foreign intermediate sector. Y_H and Y_F are sub-indexes of the continuum of differentiated goods produced respectively in country H and F. The elementary differentiated goods are imperfect substitutes with an elasticity of substitution denoted $\frac{\mu}{\mu-1}$. Final goods are produced with the following technology $Y_H = \left[\int_0^1 Y(h)^{\frac{1}{\mu}} \mathrm{d}h\right]^{\mu}$ and $Y_F = \left[\int_0^1 Y(f)^{\frac{1}{\mu}} \mathrm{d}f\right]^{\mu}$. In the country F, the corresponding indexes are given by $Y_F^* = \left[\int_0^1 Y^*(f)^{\frac{1}{\mu}} \mathrm{d}f\right]^{\mu}$ and $Y_H^* = \left[\int_0^1 Y^*(h)^{\frac{1}{\mu}} \mathrm{d}h\right]^{\mu}$. For a domestic product h, we denote $p(h)$ its price on local market and $p^*(h)$ its price on the foreign import market. The domestic-demand-based price indexes associated with imports and local markets in both countries are defined as $P_H = \left[\int_0^1 p(h)^{\frac{1}{1-\mu}} \mathrm{d}h\right]^{1-\mu}$, $P_H^* = \left[\int_0^1 p^*(h)^{\frac{1}{1-\mu}} \mathrm{d}h\right]^{1-\mu}$, $P_F^* = \left[\int_0^1 p^*(f)^{\frac{1}{1-\mu}} \mathrm{d}f\right]^{1-\mu}$ and $P_F = \left[\int_0^1 p(f)^{\frac{1}{1-\mu}} \mathrm{d}f\right]^{1-\mu}$. Domestic demand is allocated across the differentiated goods as follows

$$\begin{cases} \forall h \in [0,1] \quad Y(h) = \left(\frac{p(h)}{P_H}\right)^{-\frac{\mu}{\mu-1}} Y_H, \quad Y^*(h) = \left(\frac{p^*(h)}{P_H^*}\right)^{-\frac{\mu}{\mu-1}} Y_H^* \\ \forall f \in [0,1] \quad Y(f) = \left(\frac{p(f)}{P_F}\right)^{-\frac{\mu}{\mu-1}} Y_F, \quad Y^*(f) = \left(\frac{p^*(f)}{P_F^*}\right)^{-\frac{\mu}{\mu-1}} Y_F^* \end{cases}$$

2.4 Intermediate firms

Intermediate goods are produced with a Cobb-Douglas technology mixing labor and a CES composite of capital services $\widetilde{K}_t(\bullet) = u_t(\bullet)K_t(\bullet)$ and oil:

$$h \in [0,1], \quad Y_t(h) = E_t^A V_t(h)^\alpha L_t(h)^{1-\alpha} - \Omega$$

with

$$V_t(h) = \left[(1-\omega_Y)^{\frac{1}{\theta_o}} \ \widetilde{K}_t(h)^{\frac{\theta_o - 1}{\theta_o}} + \omega_Y^{\frac{1}{\theta_o}} \ V_{oil,t}(h)^{\frac{\theta_o-1}{\theta_o}}\right]^{\frac{\theta_o}{\theta_o - 1}}$$

where ε_t^A is an exogenous technology shock. Each firm sells its products both in the local and foreign market.

Firms are monopolistic competitors and produce differentiated products. For local sales, firms set prices on a staggered basis *à la* Calvo (1983). In each period, a firm h (resp. f) faces a constant probability $1-\alpha_H$ (resp. $1-\alpha_F^*$) of being able to re-optimize its nominal price. This probability is independent across firms and time in the same country. The average duration of a rigidity period is $\frac{1}{1-\alpha_H}$ (resp. $\frac{1}{1-\alpha_F^*}$). If a firm cannot re-optimize its price, the price evolves according to the following simple rule:

$$p_t(h) = \Pi_{H,t-1}^{\gamma_H} \overline{\Pi}^{1-\gamma_H} p_{t-1}(h)$$

The firm h chooses $\hat{p}_t(h)$ to maximize its intertemporal profit.

$$\mathbb{E}_t \left[\sum_{j=0}^{\infty} \alpha_H^j \Xi_{t,t+j} \left(\begin{array}{c} (1-\tau_{t+j})\hat{p}_t(h) Y_{t+j}(h) \left(\frac{P_{H,t-1+j}}{P_{H,t-1}}\right)^{\gamma_H} \left(\overline{\Pi}^j\right)^{1-\gamma_H} \\ -MC_{t+j} P_{H,t+j} \left(Y_{t+j}(h) + \Omega\right) \end{array} \right) \right]$$

where $Y_{t+j}(h) = \left(\frac{\tilde{p}_t(h)}{P_{H,t}}\right)^{-\frac{\mu}{\mu-1}} \left(\frac{P_{H,t}}{P_{H,t+j}} \left(\frac{P_{H,t-1+j}}{P_{H,t-1}}\right)^{\gamma_H} \left(\overline{\Pi}^j\right)^{1-\gamma_H} \right)^{-\frac{\mu}{\mu-1}} Y_{H,t+j}$.

$\Xi_{t,t+j} = \beta^j \frac{\Lambda_{t+j}^o P_t}{\Lambda_t^o P_{t+j}}$ is the marginal value of one unit of money to the $o-type$ households. MC_{t+j} is the real marginal cost deflated by the interior-producer-price and τ_t is a time-varying tax on firm's revenue. Due to our assumptions on the labor market and the rental rate of capital, the real marginal cost is identical across producers. We introduce a time varying tax on firms' revenue that is affected by an i.i.d shock defined by $1-\tau_t = \left(1-\overline{\overline{\tau}}\right)\varepsilon_t^P$.

Concerning exports, we assume that, in country H, a fraction η (respectively η^* in country F) of exporters exhibit producer-currency-pricing (PCP) while the remaining firms exhibit local-currency-pricing

(LCP). LCP exporters denominate their price in foreign currency and face nominal rigidities similar to the ones affecting local producers in the foreign country.

The aggregate LCP export price indexes are accordingly defined as

$$\tilde{P}_H^* = \left[\frac{1}{1-\eta}\int_\eta^1 p^*(h)^{\frac{1}{1-\mu}}dh\right]^{1-\mu}, \text{ and } \tilde{P}_F = \left[\frac{1}{1-\eta^*}\int_{\eta^*}^1 p(f)^{\frac{1}{1-\mu}}df\right]^{1-\mu}.$$

Aggregate export prices denominated in foreign currency are given by

$$P_H^* = \left[\eta\left(\frac{P_{H,t}}{S_t}\right)^{\frac{1}{1-\mu}} + (1-\eta)\tilde{P}_H^{*\frac{1}{1-\mu}}\right]^{1-\mu}, \text{ and } P_F = \left[\eta^*\left(S_t P_{F,t}^*\right)^{\frac{1}{1-\mu}} + (1-\eta^*)\tilde{P}_F^{\frac{1}{1-\mu}}\right]^{1-\mu}.$$

Let us define the following relative prices $R\tilde{E}R_H = \frac{S\tilde{P}_H^*}{P_H}$, $R\tilde{E}R_F = \frac{\tilde{P}_F}{SP_F^*}$ and $\tilde{T} = \frac{\tilde{P}_F}{P_H}$. Export margins relative to local sales are denoted $RER_H = \frac{SP_H^*}{P_H}$ and $RER_F = \frac{P_F}{SP_F^*}$. In the case of international price discrimination, those ratios represent the relative profitability of foreign sales compared with the local ones. $RER_{X,t} = \frac{S_t P_{N,t}^*}{P_{N,t}}$ is the real exchange rate measured with non-oil consumer price indices.

2.5 Oil producing country

The oil producing country has fixed exchange rate with country F. The budget constraint of the oil producer representative agent is given by

$$\frac{B_{F,t}^O}{R_t^*} + \frac{P_{H,t}}{S_t}O_{H,t} + P_{F,t}^* O_{F,t}^* = P_{oil,t}^*\left(Y_{oil,t} + Y_{oil,t}^*\right) + B_{F,t-1}^O$$

where $Y_{oil,t}$ and $Y_{oil,t}^*$ are aggregate demand quantities from country H and F, and where $O_{H,t}$ and $O_{F,t}^*$ are demands of non-oil goods demand produced in country H and F respectively.

The oil producer has a rule of thumb consumption behavior. The long term allocation of imports is consistent with a balanced budget ($B_F^O = 0$) and Cobb-Douglas preferences reflecting the relative country sizes. We assume that imports are adjusted only gradually towards the Cobb-Douglas allocation. The recycling of oil revenues into non-oil goods imports is therefore given by

$$O_{H,t} = (1-\alpha_{oil})O_{H,t-1} + \alpha_{oil}\frac{1}{2}\frac{T_{oil,t}}{T_{N,t}T_{H,t}}\left(Y_{oil,t} + Y_{oil,t}^*\right)$$

and

$$O_{F,t}^* = (1-\alpha_{oil})O_{F,t-1}^* + \alpha_{oil}\frac{1}{2}\frac{T_{oil,t}^*}{T_{N,t}^*T_{F,t}^*}\left(Y_{oil,t} + Y_{oil,t}^*\right)$$

The relative price of oil in terms of pre-tax consumer prices in country F, $T_{oil,t}^*$, is treated as exogenous in the model and subject to shocks. Supply of oil adjusts to price and demand conditions without costs.

2.6 Government

In country H, public expenditures $\overline{\overline{G}}$ are subject to random shocks ε_t^G. The government finances public spending with various taxes and lump-sum transfers.

The government also controls the short term interest rate R_t. Monetary policy is specified in terms of an interest rate rule: the monetary authority follows generalized Taylor rules which incorporate the level and first difference of inflation and output gap, defined as the deviation between actual and flexible-price output. Such reaction functions also incorporate a non-systematic component ε_t^R.

Written in deviation from the steady state, the interest feedback rule used in the estimation has the form:

$$r_t = \rho r_{t-1} + (1-\rho)\left[r_\pi \pi_{t-1} + r_y z_{t-1}\right] + r_{\Delta\pi}\Delta\pi_t + r_{\Delta y}\Delta z_t + \log\left(\varepsilon_t^R\right)$$

where small case variables denote log-deviation from their deterministic steady-state.

3 The transmission of oil-price shocks to the euro area in the estimated model

In this section, we describe the Bayesian estimation of the first order approximation of the model presented in the first section, on a euro area (EA) and rest-of-the-world (ROW) dataset. Thereafter, country H represents the euro area and country F, the rest-of-the-world. We make therefore the simplifying assumptions that oil prices are denominated in ROW's currency and that no domestic oil-production takes place in the EA and in the ROW.

For the euro area, we consider 8 key macroeconomic quarterly time series from 1975q1 to 2005q4 (series from 1970q1 to 1974q4 were used as a training sample): output, consumption, investment, employment, real wages, GDP deflator inflation rate, CPI inflation rate and 3 month short-term interest rate[3]. The euro area dataset is taken from Fagan et al (2001) and Eurostat. The exchange rate is the synthetic nominal effective exchange rate of the euro (see OECD source). Regarding the rest of the world variables, foreign output is given by the average of real GDP of euro area trade partners, weighted by the euro area export structure. The derivation of this aggregate can be found in Dees et al. [2007]. Foreign CPI is proxied by the average of CPI inflation rates aggregated with a double-weight structure consistent with the nominal effective exchange rate (see OECD source). Finally, the foreign interest rate is a weighted average of 3-month nominal interest rates for selected countries (given data limitations, we used series from US, Canada, UK, Switzerland and Japan). We account for oil as an intermediate input in the definition of the value added deflator and quantity through the measurement equations for GDP deflator inflation and real GDP, in a log-linear form[4].

[3] As in Smets and Wouters [2005], hours are linked to the number of people employed e_t^* with the following dynamics:

$$e_t = \beta \mathbb{E}_t e_{t+1} + \frac{(1-\beta\lambda_e)(1-\lambda_e)}{\lambda_e}(l_t - e_t)$$

[4] The technology structure specified in the model does not allow for a *value added* concept consistent with national accounts. Therefore, we linked real GDP and GDP deflator inflation to the state variables through the following log-linear relations:

$$gdp_t = z_t - \frac{\bar{V}_{oil}}{\bar{Z}} v_{oil,t}$$

,

$$\pi_t^{gdp} = \frac{\bar{Z}}{\bar{Y}}(n\pi_{H,t} - (1-n)(\pi_{H,t}^* + \Delta S_t)) + (1 - \frac{\bar{Z}}{\bar{Y}})(\Delta t_{oil,t} + \pi_t)$$

Given the dataset considered, we allow for as many shocks as variables. The exogenous disturbances introduced in the estimation can be divided into three categories:

- Efficient shocks: AR(1) shock on technology (ϵ_t^A), investment (ϵ_t^I), public expenditures (ϵ_t^G, ϵ_t^{G*}), consumption preference (ϵ_t^B).
- Inefficient shocks: i.i.d. shocks on PPI markups (ϵ_t^P, ϵ_t^{P*}), CPI markup (ϵ_t^{CPI}), labor market markup (ϵ_t^W), and AR(1) shock on international risk sharing ($\epsilon_t^{\Delta S}$, see section A.1 of in the Appendix for a definition of the shock).
- Policy shocks: shocks on interest rate policy rules (ϵ_t^R, ϵ_t^{R*}).
- Oil-price shock: AR(1) shock on the log-real oil price deflated by ROW CPI ($\epsilon_{oil,t}^*$).

To account for the ROW variables, we introduced a public expenditure shock, a markup shock and a monetary policy shock. An alternative set of shocks could have been envisaged but since we focus on the transmission of an oil-price shock and assume exogenous dynamics for it, our results are not crucially sensitive along this dimension of the model.

One specific aspect of the estimation regards the pre-filtering of variables. In previous papers for the euro area (see Smets and Wouters [2005], Adjemian et al. [2007], Adjemian et al. [2008] or Christoffel et al. [2007]), different approaches have been followed: quantities were assumed to feature either model-consistent deterministic trends or variable-specific observational trends; inflation and interest rate were either detrended prior to estimation or assumed to be stationary. In the later case, the sample mean for euro area inflation can be constrained by tight priors to be close to a steady state level of 2% annually which is consistent with the ECB's quantitative definition of price stability. Here, we propose to test for mean-breaks in the inflation rates, interest rates and growth rates of real variables and then remove those effects from the series prior to estimation. We implemented the multiple breaks test procedure of Altissimo and Corradi [2003], since it takes into account sample size when computing critical values. The only breaks present concern euro area inflation rates, and interest rates for both the euro area and the rest of the world (see in the appendix). All real data are then converted in log-level and detrended before estimation. The foreign inflation rate is also detrended.

Interestingly, the last period breaks for euro area inflation and nominal interest rate point to a steady state inflation rate of around 2% annually and a steady state nominal interest rate of around 4%. The pre-filtering applied to inflation and interest rate gives therefore sensible steady state values for the euro area. If the econometrician prefers to abstract from such adjustments, this would support the case for tight priors on the mean of those variables in order to capture better the properties of the data over the last decade (see Christoffel et al. [2007]). Concerning the estimation results presented in this section, we replicated the analysis with linear detrending for inflation and nominal interest rates and found very similar results (not reported here).

Regarding the parameter set, we impose a substantial degree of symmetry in the economic behavior of the euro area and the ROW: given the limited dataset used for the ROW, few parameters on this block will be estimated, constraining the others to be the same as in the euro area. The estimated parameters in the ROW block are related to the Euler equation, the nominal rigidity in the goods market and the Taylor rule. Such coefficients are the ones which are the most likely to be identified by data on output, inflation and interest rate. For the same reason, we did not introduce rule-of-thumb consumers in the ROW block. Moreover, we specified the CPI inflation rate as a target variable in the Taylor rule for the ROW but the GDP deflator inflation rate in the euro area interest rate rule. Given that the main focus of the paper concerns the transmission of oil prices, we preferred to specify the EA feedback rule in a form which does not feature any systematic response to *direct* inflationary effects of oil prices. However, in order to improve the identification of the Taylor rule coefficients for the ROW, we kept the CPI inflation rate since it is the only observed inflation rate in the estimation exercise.

Finally, we contrast the direct estimations of various model specifications with their corresponding DSGE-VAR inference. We closely follow the econometric approach used by Del Negro et al. [2007] which provide a detailed exposition of the method. Basically, the authors build the priors of a BVAR model from a DSGE model and evaluate the optimal weight of the DSGE priors. The posterior density is obtained from the likelihood function by augmenting the sample with artificial data generated by the DSGE model. The relative size of the artificial is denoted λ_{DSGE}. The perspective of the DSGE-VAR estimation is particularly useful in assessing the robustness of the structural inference, the identification of parameters and the possible misspecifications in the macroeconomic transmission of oil prices embodied in our model.

3.1 Calibrated parameters and prior distributions

Some parameters are fixed prior to estimation. This concerns generally parameters driving the steady state values of the state variables for which the econometric model including detrended data is quasi uninformative. Those parameters are assumed to be the same for the euro area and the rest of the world. The discount factor β is calibrated to 0.99, which implies annual steady state real interest rates of 4%. The depreciation rate δ is equal to 0.0025 per quarter. Markups are 1.3 in the goods market and 1.5 in the labor market. The steady state is consistent with a labor income share in total output of 60%. Actually, in order to impose zero after-tax profit share in the steady state, the fixed cost is set at $\Omega = \left(\frac{\mu}{1-\overline{\overline{\tau}}} - 1\right)\overline{\overline{Y}}$. Shares of consumption and investment in total steady state output are respectively 0.65 and 0.18. Finally, we sent the level of home bias n to 0.875 so that the steady state openness ratio for the euro area is close to the sample average.

The steady state oil import shares in final consumption and in the production of intermediate goods are determined by the parameters of the CES aggregators: ω_Y for the productive technology and ω_C for the final consumption basket. In the benchmark estimation, those parameters are calibrated. For the elasticity of substitutions, θ_o and ξ_o, we take the value used by Backus and Crucini [2000], setting them at 0.09. This implies a relative complementarity between on the one hand, oil consumption and the rest of household expenditures, and on the other hand, between the oil input and fixed capital. The other parameters are then chosen to map the very short-term elasticity of euro area HICP with respect to oil prices and the average share of nominal oil imports over nominal GDP over the last 15 years. We esti-

Tab. 1: **Benchmark model: parameter estimates for exogenous processes.**

Param	*A priori* beliefs			DSGE *A posteriori* beliefs				DSGE-VAR *A posteriori* beliefs			
	Distribution	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ϵ_t^A	Uni	5	2.89	0.78	0.85	0.59	1.11	0.57	0.62	0.41	0.82
ϵ_t^B	Uni	5	2.89	1.53	2.80	1.05	4.87	1.95	2.26	1.02	3.49
ϵ_t^G	Uni	5	2.89	1.73	1.76	1.56	1.96	1.26	1.27	1.08	1.44
ϵ_t^I	Uni	5	2.89	6.47	6.66	5.30	8.03	4.87	4.95	3.88	6.05
ϵ_t^W	Uni	5	2.89	0.19	0.20	0.15	0.25	0.15	0.16	0.12	0.19
ϵ_t^P	Uni	5	2.89	0.23	0.25	0.20	0.29	0.17	0.19	0.14	0.23
ϵ_t^{CPI}	Uni	5	2.89	0.27	0.28	0.25	0.31	0.19	0.19	0.16	0.22
ϵ_t^R	Uni	5	2.89	0.20	0.20	0.17	0.22	0.13	0.13	0.11	0.15
ϵ_t^{G*}	Uni	5	2.89	3.11	3.19	2.78	3.58	1.93	1.94	1.64	2.24
ϵ_t^{P*}	Uni	5	2.89	0.97	0.99	0.85	1.12	0.63	0.65	0.53	0.77
ϵ_t^{R*}	Uni	5	2.89	0.19	0.20	0.18	0.22	0.15	0.16	0.13	0.18
$\epsilon_t^{\Delta S}$	Uni	5	2.89	0.22	0.26	0.14	0.37	0.13	0.21	0.08	0.35
$\epsilon_{oil,t}^*$	Inv.Gam	10	Inf	12.64	12.80	11.38	14.16	9.64	9.76	8.48	11.18
ρ_A	Beta	0.5	0.2	0.88	0.87	0.82	0.91	0.77	0.72	0.61	0.84
ρ_B	Beta	0.5	0.2	0.09	0.13	0.03	0.24	0.12	0.15	0.02	0.27
ρ_G	Beta	0.5	0.2	0.91	0.91	0.85	0.96	0.81	0.78	0.65	0.92
ρ_I	Beta	0.5	0.2	0.12	0.15	0.05	0.26	0.08	0.10	0.02	0.18
ρ_w	Beta	0.5	0.2	0.36	0.35	0.17	0.53	0.26	0.26	0.08	0.41
ρ_{G^*}	Beta	0.5	0.2	0.99	0.99	0.99	1.00	0.88	0.86	0.78	0.95
$\rho_{\Delta S}$	Beta	0.5	0.2	0.92	0.91	0.87	0.95	0.93	0.89	0.82	0.96
ρ_{oil}	Beta	0.5	0.2	0.97	0.96	0.93	0.99	0.88	0.87	0.80	0.94

Tab. 2: **Benchmark model: behavioral parameter estimates.**

Param	A priori beliefs			DSGE A posteriori beliefs				DSGE-VAR A posteriori beliefs			
	Distribution	Mean	Std.	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mode	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ϕ	Norm	4	0.5	4.55	4.64	3.93	5.37	4.40	4.48	3.73	5.19
φ	Gam	0.2	0.1	0.23	0.27	0.10	0.42	0.21	0.27	0.08	0.45
σ_C	Norm	1	0.38	0.54	0.67	0.26	1.07	0.93	1.14	0.63	1.69
σ_C^*	Norm	1	0.38	1.18	1.27	0.77	1.81	1.17	1.24	0.68	1.76
h	Beta	0.7	0.1	0.83	0.82	0.73	0.91	0.82	0.80	0.69	0.92
h^*	Beta	0.7	0.1	0.87	0.86	0.81	0.91	0.83	0.81	0.72	0.89
σ_L	Gam	2	0.75	1.08	1.20	0.53	1.89	1.72	2.03	0.89	3.14
α_H	Beta	0.75	0.05	0.95	0.95	0.93	0.96	0.91	0.89	0.86	0.93
α_F^*	Beta	0.75	0.05	0.77	0.78	0.73	0.82	0.69	0.69	0.61	0.76
γ_H	Beta	0.5	0.15	0.37	0.37	0.21	0.53	0.35	0.35	0.15	0.53
γ_F^*	Beta	0.5	0.15	0.60	0.60	0.45	0.75	0.33	0.35	0.19	0.52
α_w	Beta	0.75	0.05	0.87	0.87	0.84	0.90	0.80	0.79	0.74	0.85
ξ_w	Beta	0.5	0.15	0.40	0.40	0.21	0.59	0.32	0.34	0.17	0.51
λ_e	Beta	0.75	0.05	0.81	0.81	0.78	0.85	0.78	0.78	0.74	0.82
ρ	Beta	0.75	0.1	0.86	0.86	0.82	0.90	0.80	0.79	0.73	0.84
ρ^*	Beta	0.75	0.1	0.91	0.91	0.88	0.93	0.88	0.87	0.84	0.90
r_π	Norm	1.5	0.1	1.48	1.48	1.32	1.63	1.46	1.46	1.30	1.63
r_π^*	Norm	1.5	0.1	1.37	1.38	1.21	1.54	1.46	1.46	1.28	1.63
$r_{\Delta\pi}$	Gam	0.3	0.1	0.22	0.21	0.15	0.28	0.25	0.25	0.18	0.33
$r_{\Delta\pi}^*$	Gam	0.3	0.1	0.09	0.10	0.06	0.13	0.14	0.14	0.10	0.19
r_Y	Gam	0.13	0.05	0.09	0.10	0.05	0.15	0.07	0.08	0.04	0.13
r_Y^*	Gam	0.13	0.05	0.20	0.22	0.13	0.30	0.12	0.13	0.06	0.21
$r_{\Delta Y}$	Gam	0.06	0.05	0.19	0.18	0.13	0.23	0.12	0.12	0.07	0.18
$r_{\Delta Y}^*$	Gam	0.06	0.05	0.29	0.30	0.24	0.36	0.28	0.29	0.20	0.37
ξ	Gam	2	0.75	0.22	0.23	0.15	0.31	0.24	0.27	0.15	0.40
η^*	Beta	0.5	0.28	0.28	0.29	0.14	0.43	0.19	0.19	0.00	0.34
η	Beta	0.5	0.28	0.69	0.68	0.53	0.82	0.54	0.56	0.37	0.76
α_{oil}	Beta	0.5	0.28	0.07	0.11	0.00	0.22	c	c	c	c
ω_r	Beta	0.5	0.28	0.80	0.79	0.70	0.88	0.83	0.84	0.74	0.94
λ_{DSGE}	Uni	5	2.89	-	-	-	-	1.91	1.87	1.60	2.14
$P_\lambda(\mathcal{Y})$					-1478.2				-1351.8		

mate that the elasticity of HICP energy to oil prices is slightly higher than 0.1 while the weight of HICP energy in total HICP is below 10%. We choose therefore to calibrate the steady state share of oil in final consumption to be 1% (adjusting accordingly ω_C). Regarding the oil intensity of domestic production, ω_Y is set so that steady state oil imports represent 1.5% of output. In doing so, approximately 60% of steady state oil absorption serves as an intermediate input and 40% as final consumption. Those figures are qualitatively in line with data coming from input/output tables.

As in Smets and Wouters [2005], the priors are assumed to be the same across countries. The standard errors of the innovations are assumed to follow uniform distributions. The prior distributions for most of the parameters are similar to the ones of Adjemian et al. [2008] (see Tables 1 and 2). In particular, we choose uniform priors for the open economy parameters, notably the intratemporal elasticity of substitution and the shares of PCP producers in both countries. Concerning the size of rule-of-thumb consumers in the euro area, ω_r, and the speed of oil-revenues recycling into foreign imports, α_{oil}, prior distributions are $Beta(0.5, 0.28)$. Finally, when the technology parameters related to oil absorption in final consumption and in the production of intermediate goods are estimated, we set $Beta(0.5, 0.28)$ priors for the weights ω_C and ω_Y, and $InverseGamma(0.09, 2)$ priors for the elasticities of substitution θ_o and ξ_o.

3.2 Posterior parameter estimates

The direct estimation results for the benchmark specification are presented in Tables 1 and 2. Regarding closed-economy parameters, our results are qualitatively similar to the ones of Smets and Wouters [2005] and Adjemian et al. [2008] for the euro area except for consumption preferences: the intertemporal elasticity of substitution is on the low side of available estimates while the habit persistence parameter is relatively high. This may be partly explained by the presence of non-Ricardian households which do not smooth their consumption intertemporally. In order to match the degree of autocorrelation for consumption expenditures present in the data, a higher habit persistence may be required while the intertemporal elasticity of substitution may control for the effect of the real interest rate. In terms of asymmetry with the ROW structural parameters, we note that the degree of nominal rigidity in price-setting is lower in the ROW while the interest rate rule is relatively more responsive to output.

The share of rule-of-thumb consumers in the euro area, $1 - \omega_r$, is estimated to be around 20%, using the benchmark specification which assumes that active government transfers link the disposable income of $r - type$ households to national income. By contrast, the posterior parameter estimate for this share is reduced to 6% when assuming that the $r - type$ household income fluctuates like labor compensation (see the *modified* $r - type$ columns in Table 3). Our results therefore suggest a lower size of rule-of-thumb consumers compared with what Coenen and Straub [2005] found for the euro area. A possible explanation for the different results may be related to the flat priors used in the present paper, while the authors set a $Beta(0.5, 0.1)$ prior distribution on the share of non-Ricardian households. Moreover, in Coenen and Straub [2005], the presence of rule-of-thumb consumers tends to deteriorate the marginal data density which suggests that a looser prior on the share may have implied a lower posterior estimate.

Turning to the parameters driving the open economy features of the model, we note first that the price elasticity of trade, ξ, is estimated around 0.22 in the benchmark model. This estimate is much lower than the one reported by Adjemian et al. [2008] in their model for the US and the euro area. This reflects the fact that the size of the expenditure switching effect estimated using ROW aggregate GDP and real effective exchange rate is presumably weaker than with US-related data. Moreover, we estimate the share of PCP and LCP firms (given by the parameters η and η^*). For the euro area, the share of PCP firms is around 70% while in the ROW, the share of PCP firms is lower and is centered around 30%. As explained by Adjemian et al. [2008], those parameter estimates are quite sensitive to the choice of price indices for the estimation. Indeed, with only CPI inflation observed in the ROW, the results for ROW producers may be tilted towards the LCP case. Finally, the amount of oil-recycling into foreign imports within a quarter, α_{oil}, is estimated with a posterior mode at 7% and a mean at 10%.

The DSGE-VAR estimation of the benchmark model delivers similar posterior distributions for most of the behavioral parameters. In general, posterior parameter distributions are slightly shifted towards the priors in comparison with the direct estimation case. Note that the oil-recycling parameter α_{oil} was not identified in the DSGE-VAR estimation so that we constrained it to 0.1. Table 3 also reports alternative estimation results based first on the modified rule-of-thumb behavior: here again, the posterior estimates are very close to the ones of the benchmark estimation except from the share of $r - type$ consumers (as already mentioned). Marginal data density comparison indicates that the benchmark specification for rule-of-thumb behavior is favored. The estimation of the benchmark specification over a shorter sample (1985Q1 to 2005Q1) also present posterior distributions similar to the ones obtained with the long sample, for most of the structural parameters. A noticeable difference regards the posterior distribution of the intertemporal elasticity of substitution, σ_C, which is significantly higher and centered around 1.3.

Finally, we investigated the estimation of the oil technology. The results for the direct and DSGE-VAR estimation are shown in Table 4, for both the long and short sample. In all cases, the elasticities of substitution, θ_o and ξ_o, are not well-identified, the posterior distributions being similar, and almost identical in the DSGE-VAR estimations, to the prior ones. By contrast, the weight of oil in final consumption, ω_C, is precisely pinned down in all models at around 1%, which is also the value we used in our benchmark calibration. This result is obtained with relatively uninformative priors, as explained earlier. The estimates of the oil share as an intermediate input in production, ω_Y, obtained through direct estimations, point to levels closer to our baseline calibration. However, the DSGE-VARs deliver negligible values for ω_Y. Finally, when we compare the direct estimations for the long and short samples, we do not find evidence of lower oil intensity in production over the more recent periods. In order to improve the identification of those parameters, more data would be needed notably on intermediate consumption of oil. This explains why we preferred to rely on informed calibration for those parameters in the benchmark estimation.

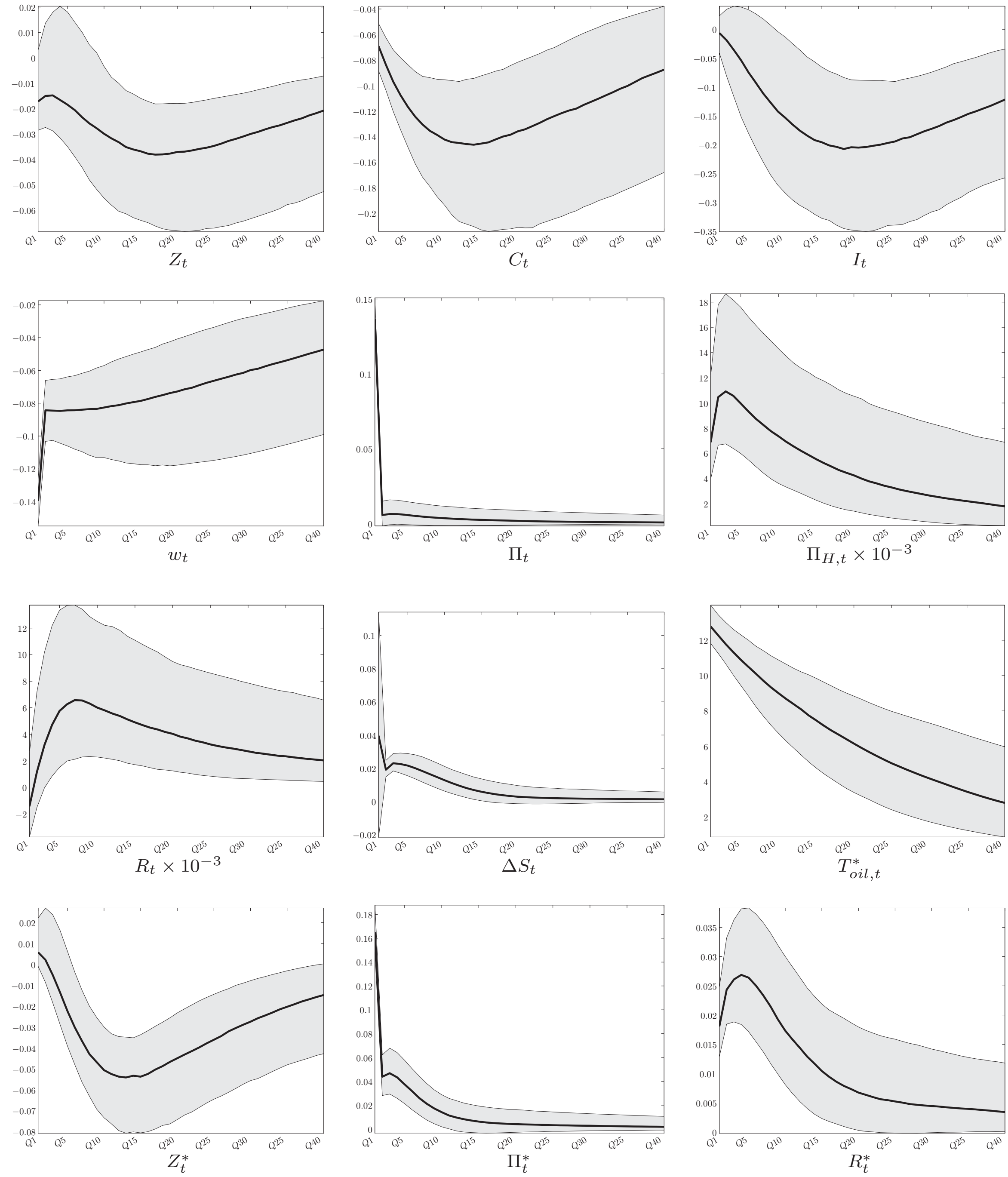


Fig. 1: Impulse Response Functions associated to a shock on $\epsilon^*_{oil,t}$. **Benchmark model**: *direct estimation*.

3.3 Assessing the oil-price macroeconomic transmission and dynamics

We turn now to the transmission of oil price shocks in the benchmark model. Figure 1 shows that a more than 10% temporary increase in oil prices leads to 0.1 pp direct effect on euro area CPI inflation. PPI inflation increases persistently by 0.01 pp, at a quarterly frequency. Those inflationary pressures erode real wages which remain approximately at 0.1 pp below baseline over the short to medium term. Euro area interest rate increases by a couple of basis points (at an annual rate). Regarding activity, the maximum decline in euro area consumption and investment reaches 0.15 and 0.2 pp respectively after 3 to 5 years. The decrease in output is more limited, due notably to the recycling of oil revenues, with a peack at more than 0.04 pp. The absorption from the oil-producing block acts as a symmetric foreign demand shock on the euro area and the ROW, supporting output and crowding out domestic demand. In the ROW, given more flexible prices, the inflationary pressures induced by the oil price hike are more pronounced leading to tighter monetary policy and stronger contraction in economic activity. The nominal exchange rate of the euro appreciates marginally.

Figure 7 in the Appendix illustrates the main implications of alternative parameter estimates for the transmission of oil-supply shocks. Starting from the benchmark case, we replace first the intertemporal elasticity of substitution and the habit persistence with the values obtained in the short-sample estimation. This leads to a more limited impact on consumption and output but amplifies the contraction in investment. The response of PPI inflation is more muted and the exchange rate appreciation is slightly stronger. Second, we change the specification of the rule-of-thumb consumer behavior, linking their spending expenditures to labor income. Compared with the benchmark case, aggregate consumption is less negatively affected since the substitution between oil input and labor exerts a compensating effect on rule-of-thumb household income. But overall, the impulse response functions to oil-supply shocks are quite robust to the various model estimations presented in this paper.

An extensive strand of literature has studied the macroeconomic propagation of oil price shocks and we do not pretend here to provide a seriously competing model from an empirical perspective. Instead, we introduced simple but plausible structural features describing the transmission mechanism of oil price shocks to the euro area economy under rational expectations and tried to provide satisfying data coherence through full-information bayesian inference. We therefore limit our comparison to selected contributions based on DSGE models. In particular, Jacquinot et al. [2009] use empirical benchmarks to assess their modeled transmission mechanism for oil, based on a more sophisticated description of oil-related industry sectors than in our DGSE framework. Evidence reported in their study for the impulse responses on euro area inflation is relatively similar to ours. However, the effects of oil price shocks on economic activity obtained in the present paper lie on the low range of available estimates: they are nonetheless close to the ones obtained with the Area-Wide-Model (see Fagan et al. [2005]) and some SVAR results.

The DSGE-VAR approach implemented here also provides a natural framework to compare the model-based transmission of oil prices to more "agnostic" benchmarks. In this respect, the comparison of the DSGE and the DSGE-VAR impulse response functions presented in Figures 8 confirms that the structural model may underestimate the contractionary effects of oil prices on the euro area, notably for aggregate output. However, such a result may also come from the rational expectations assumption which makes monetary policy, specified as an interest rate feedback rule, very effective in stabilizing inflation expectations and muting the second round effects of oil price shocks. To illustrate this point, we re-estimated the DSGE-VAR allowing the central bank inflation target perceived by wage and price setters to be correlated with oil price shocks in the euro area, while the true inflation target is left unchanged. More precisely, we specify the deviations of the perceived inflation target from steady state as follows:

$$\overline{\pi}_t = \rho_{\overline{\pi}}\overline{\pi}_{t-1} + \rho_{\overline{\pi},oil}\epsilon^*_{oil,t}$$

The autoregressive parameter is calibrated at 0.8 while $\rho_{\overline{\pi},oil}$ is estimated. This configuration is meant to approximate a configuration of weak central bank credibility, whereby sizeable markup shocks are likely to shift private agent perceptions about the inflation comfort zone for the monetary authority. The DSGE-VAR estimation delivers a posterior mode of 0.01 for $\rho_{\overline{\pi},oil}$ and the marginal data density of the model is almost the same as in the benchmark DSGE-VAR. The transmission of oil-price shock in this case is presented in Figure 9. The response of euro area PPI inflation in the DSGE is now much stronger than in the benchmark case which leads to a more pronounced monetary policy tightening together with a larger and more protracted decline of economic activity. Compared with the DSGE-VAR impulse responses, the propagation mechanisms derived from the DSGE now appear much more similar. This simple exercise emphasizes the role of expectational instability in the transmission of cost-push shocks in general and oil prices in particular. In the present paper, we restrain our analysis to a full information and rational expectations environment and leave such extensions for further research.

4 Monetary policy response to oil-prices

4.1 Defining optimal policy and accounting for the zero lower bound

The Ramsey approach to optimal monetary policy cooperation is computed by formulating an infinite-horizon Lagrangian problem of maximizing the conditional expected social welfare subject to the full set of non-linear constraints forming the competitive equilibrium of the model.

We are mainly interested in comparing the macroeconomic stabilization performances of different monetary policy regimes within a medium scale open economy framework including a wide set of shocks and frictions. Thus we introduce a fiscal intervention in the form of subsidies on labor and goods markets, in order to offset the first order distortions caused by the presence of monopolistic competition in the markets.

As in Adjemian et al. [2008], in order to avoid high probabilities of hitting the zero bound under the Ramsey allocation, we introduce in households' welfare for each country a quadratic term penalizing the variance of the nominal interest rate:

$$\mathcal{W}_{H,t}^{R} = \mathcal{W}_{H,t} + \lambda_R \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(R_{t+j} - R^\star\right)^2$$
$$\mathcal{W}_{F,t}^{R} = \mathcal{W}_{F,t} + \lambda_R^* \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(R_{t+j}^* - R^\star\right)^2$$

where λ_R and λ_R^* are the weights attached to the cost of nominal interest rate fluctuations. The calibration of those parameters aims at bringing the unconditional variance of the nominal interest rates under optimal monetary policy cooperation close to the ones obtained with the estimated rules.

Compared with Adjemian et al. [2008], the specific features of the oil price transmission and the modeling framework of the present paper relate to the introduction of rule-of-thumb consumers and the asymmetry in the currency denomination of oil prices. Indeed, while Adjemian et al. [2008] could already assess the optimal stabilization of a common markup shock at the CPI or PPI level, we account here more precisely for the direct versus the cost channel of the shock as well as the role of exchange rate adjustment. In addition, the eventual trade-offs between heterogenous responses of households' types and price stability can be explored.

We also derive some concept of optimal policy from the euro area perspective which consists in maximizing euro area welfare conditional on monetary policy in the ROW following the estimated Taylor rule. Given that the structural microfoundations of the ROW block have been estimated on aggregate data covering heterogenous economic configurations, we put into perspective the optimal international monetary policy cooperation with optimal policy for the euro area treating the ROW block as reduced-form. For comparison purposes, the coefficient λ_R for the euro area optimal policy is set to be the same as for the optimal cooperation case.

We abstract here from the analysis of non-cooperative optimal monetary policy arrangements as in Coenen et al. [2008] or De Fiore and Lombardo [2008]. The comparison with the euro area optimal policy is only meant to illustrate the additional degrees of freedom that monetary policy could acquire with respect to the optimal cooperation, notably through stronger exchange rate adjustments.

4.2 Optimal response to oil-price shocks

Figure 2 compares the transmission of a positive oil-price shock under the estimated Taylor rules, the optimal monetary policy cooperation and the euro area optimal policy. The structural parameters are drawn from the posterior distribution of the benchmark direct estimation. In comparison with the estimated rules, the optimal cooperation implies a more pronounced contraction in consumption, investment and output for the euro area. After a positive oil price shock, labor demand suffers from the decline in economic activity but benefits from a favorable substitution effect due to a higher cost of capital (including energy prices). With the estimated rules, the substitution effects are dominant and hours rise while the optimal cooperation generates a much weaker increase in the short term and a slight decline in the medium term. Similarly, the decrease in real wages below baseline is larger and more persistent in the optimal allocation. Overall, the optimal cooperation is substantially reducing the deviations from the flexible price allocation. We report in Figures 2, X_t^{gap} variables which are the percentage deviations from the the flexible price and wage equilibrium with no $r - type$ consumers. The optimal policy achieves a better stabilization of euro area output, consumption and investment gaps, and to a lesser extent, the real wage gap.

Regarding prices, the direct effects of oil price increases on CPI inflation are the same under both policy regimes. However, after a few quarters, the response of headline inflation appears significantly more muted in the optimal allocation. At the producer level, inflation increases only marginally under optimal policy, with the response of producer prices amounting to half of that observed under the estimated rules. Such marked differences in the stabilization outcomes are obtained with limited asymmetries in the interest rate path: the optimal policy is slightly less restrictive than the estimated rules for the posterior mode of the IRFs, and the distribution of short-term responses of the policy rate shows likely occurrences of interest rate cuts in the short run for the optimal allocation. Such a similarity may partly be due to the welfare penalty on interest rate fluctuations introduced in the optimal policy program: as shown in Adjemian et al. [2008], this constraint is very effective in controlling the optimal interest rate volatility while marginally affecting the main stabilization properties of the optimal allocation, with the exception of the exchange rate.

On the ROW, while the estimated rule implies a moderate increase in the policy rate, the optimal cooperation is accommodative in the short run, therefore leading to a more pronounced appreciation of the euro on impact. In this case, the stronger adjustment of international relative prices provides some support to ROW output in the few quarters after the shock. Like in the euro area, the optimal policy also achieves a better stabilization of CPI inflation over the medium term compared with the estimated rule, albeit tolerating a higher inflation rate than in the euro area due to more flexible price-setting.

Overall, the optimal monetary policy cooperation would call for a more pronounced contraction of economic activity in the euro area in order to mitigate significantly the inflation pressures at the producer level, notably through weaker wage responses. In addition, higher interest rate differentials in the optimal cooperation would activate a stronger exchange rate channel to ease the underlying inflationary pressures affecting the euro area. This asymmetric pattern is hardly present under the estimated rules and results notably from the ability of the optimal monetary policy to exploit the oil-price denomination in the ROW currency.

We now turn to the main features of the euro area optimal policy , taking as given the estimated rule for the ROW in the maximization program of the monetary authority. Broadly speaking, euro area optimal policy delivers macroeconomic responses which are close to the estimated rule case for the ROW and similar to the optimal monetary policy cooperation for the euro area. Consequently, the real exchange rate change on impact is in between the muted response under the estimated rules and the sharp appreciation generated by the optimal allocation. At the margin, euro area optimal policy generates a slightly higher responses of PPI inflation rates than the optimal cooperation.

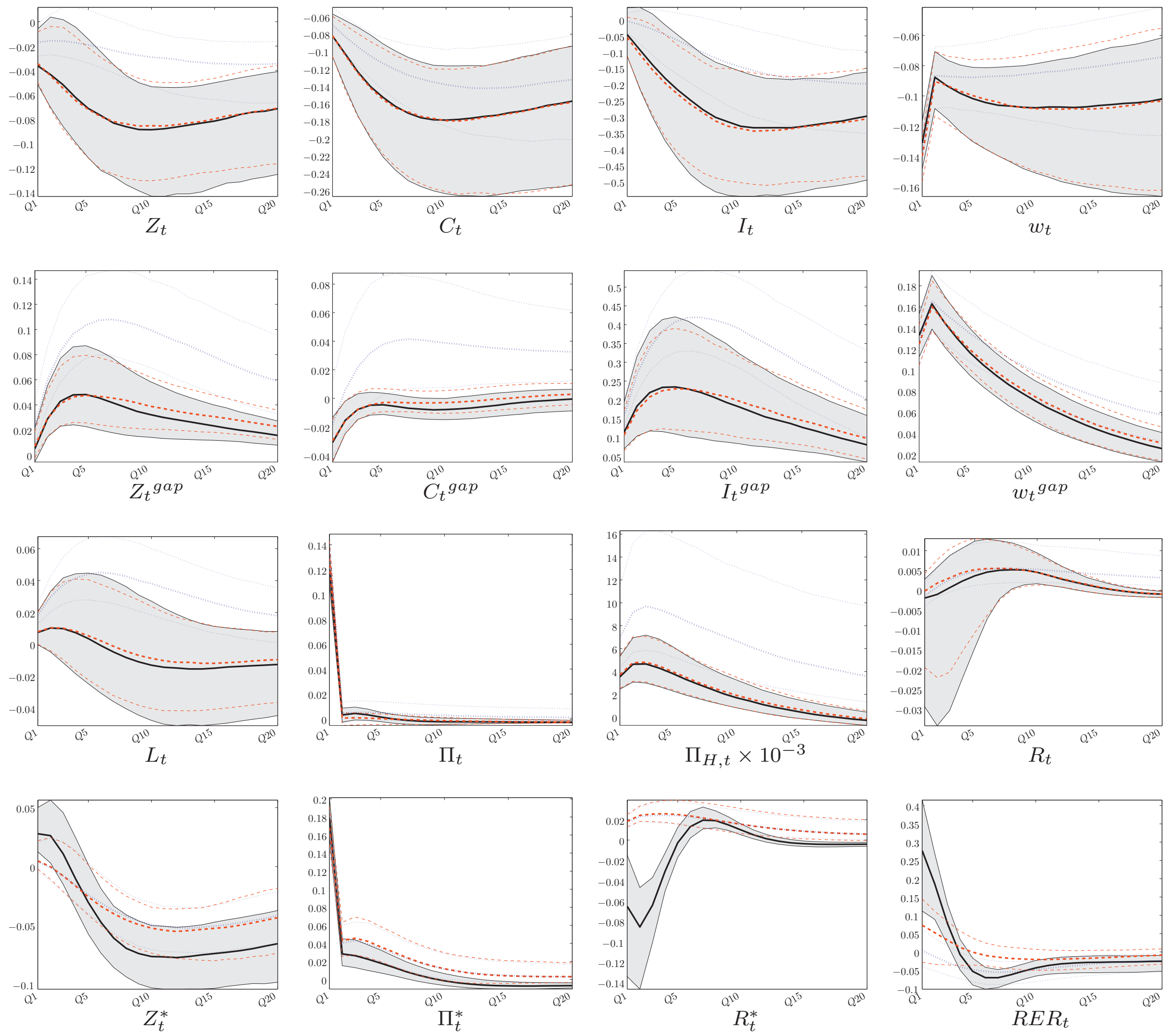


Fig. 2: Impulse Response Functions associated to a shock on $\epsilon^*_{oil,t}$. *Optimal cooperation (plain lines and shaded areas), Optimal euro area (dotted lines), Estimated (dashed lines).*

4.3 Optimal stabilization and rule-of-thumb consumers

In order to investigate further the role of household heterogeneity and the currency denomination of oil prices for the optimal interest rate path, Figures 3 compare the impulse response functions to an oil price shock, under optimal monetary policy cooperation and optimal policy for the euro area, with or without $r - type$ households. In doing so, we remove the welfare penalty on interest rate fluctuations. The constraints imposed on the optimal volatility of the policy instruments are indeed likely to mask the implications that the presence of rule-of-thumb consumers can have on the interest rate response and on the amplitude of exchange rate adjustments.

A first observation is that, the interest rate penalty affects significantly the short-term response of interest rates and the real exchange rate under optimal cooperation. Compared with the benchmark transmission of Figure 2, the optimal allocation calls for a substantial cut in the euro area interest rate and an even more pronounced one in the ROW, leading to a sharp appreciation of the euro. The decline of the euro area interest rate under the optimal policy is due to the presence of rule-of-thumb consumers since removing them would lead to an increase of the policy rate in the very short term. Actually, the oil price shock creates a significant asymmetry in the consumption responses of the various households' types and therefore entails substantial welfare costs related to imperfect risk sharing among consumers. A way for monetary policy to address those deficiencies is to lean against the abrupt fall in consumption of rule-of-thumb consumers stemming from the immediate income effect. But in doing so, monetary policy could deteriorate the stabilization of inflation both domestically and abroad. This trade-off between limiting the imperfect risk sharing across households and delivering price stability is apparent in the comparison of the impulse responses with or without $r - type$ households under optimal monetary policy cooperation: the decline in euro area interest rate implies that the ROW interest rate would have to decline more than without $r - type$ households, but the extent of policy accommodation in the ROW faces constraints in terms of inflation volatility which limits the size of the interest rate differential across countries and moderate the exchange rate channel that can be activated. On balance, PPI inflation in the euro area is slightly more muted in the absence of rule-of-thumb consumers. In addition, the stronger exchange rate adjustment mitigates the direct effects of the oil-price hike on euro area CPI inflation.

In the case of the optimal monetary policy from the euro area perspective, the ROW interest rate follows the estimated rule and cannot serve the purpose of optimal stabilization. When rule-of-thumb consumers are present, the euro area interest rate cannot decline significantly: given the muted response of the ROW interest rate, a desired policy accommodation to address the heterogenous household responses in the euro area would generate demand-driven inflationary pressures which could not be counterbalanced by exchange rate appreciation. Therefore both the euro area and the ROW interest rate move marginally and the nominal exchange rate of the euro features a residual appreciation. Without $r - type$ households, the optimal policy for the euro area regains some room for manoeuvre to increase rates in the short term and thereby to activate sizeable interest rate differentials across countries leading to ample exchange rate adjustments. However, compared with the optimal cooperation under the same configuration, the feedback rule followed by the ROW limits the ability of the euro area monetary authority to exploit the exchange rate channel.

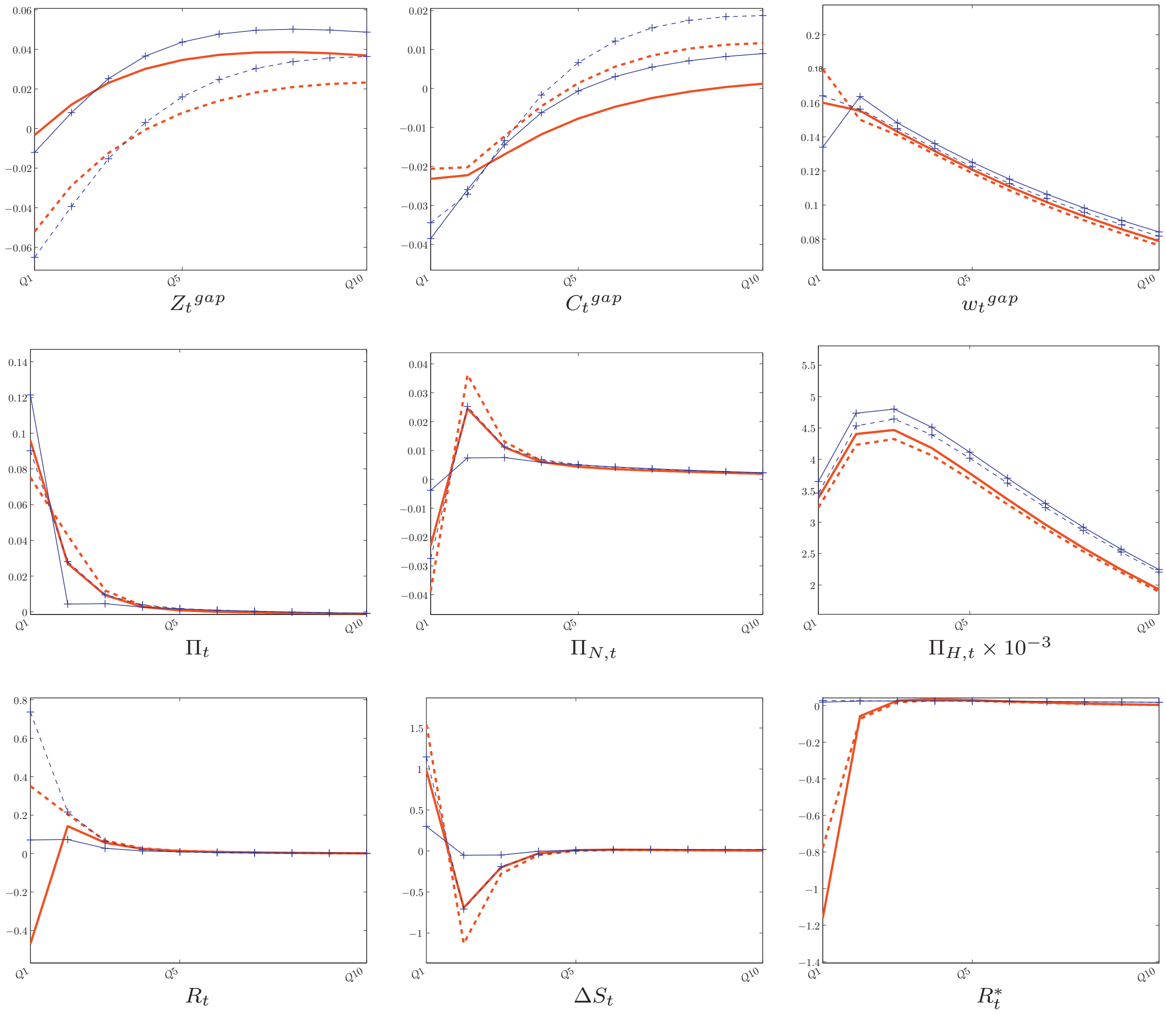


Fig. 3: Impulse Response Functions associated to a shock on $\epsilon^*_{oil,t}$. **No interest rate penalty.** *Optimal cooperation (plain lines: benchmark, dotted lines: no rule-of-thumb consumers), Optimal euro area (plain and cross lines: benchmark, dotted and cross lines: no rule-of-thumb consumers).*

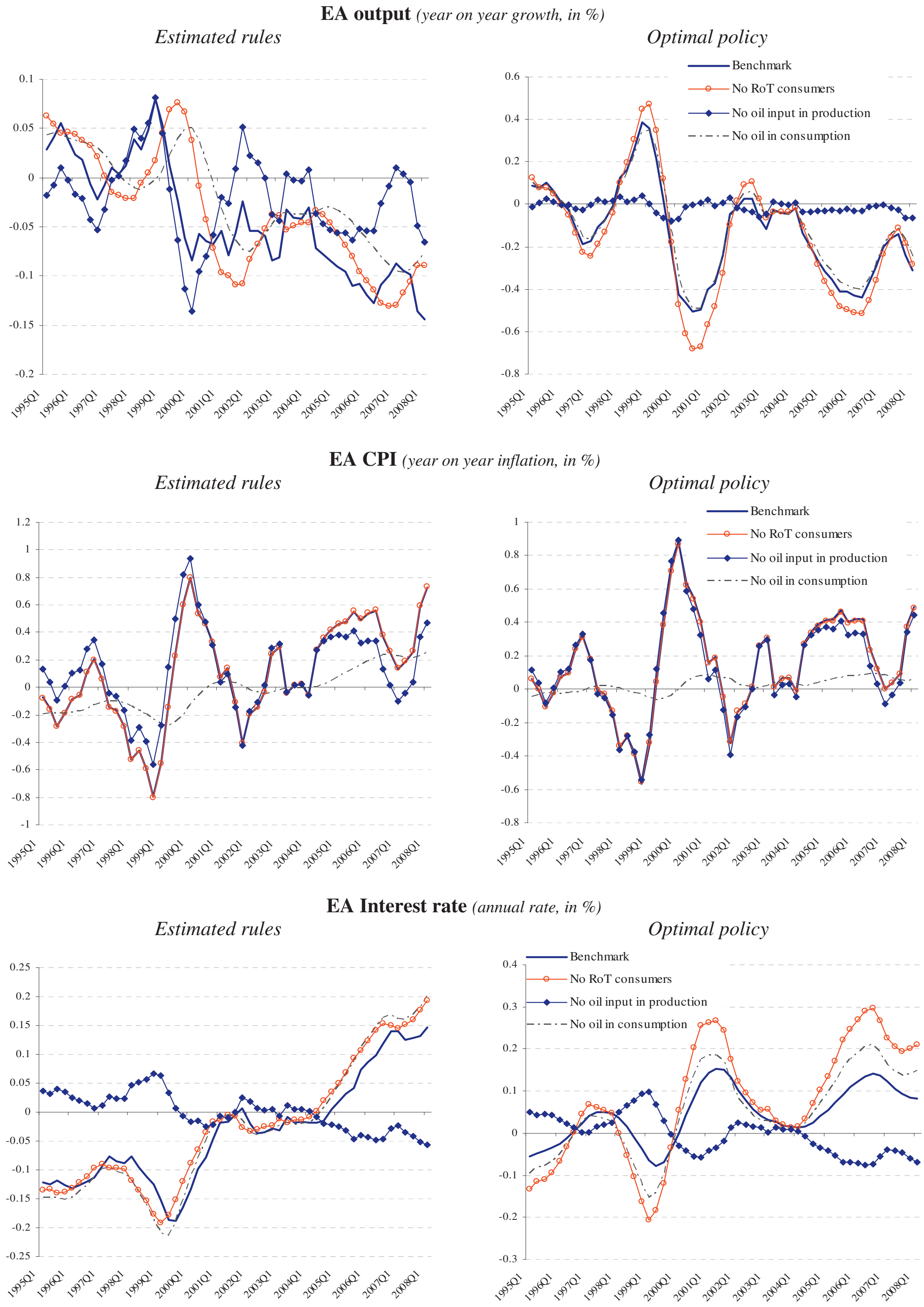
4.4 Disentangling oil-price channels

In the following, we identify several channels of oil price macroeconomic transmission and try to illustrate their quantitative significance through various simulations. First, we consider the case where oil is not used as a final consumption good and thus the price of oil has no direct impact on CPI inflation. Second, we shut down the indirect channel associated with the use of oil as an intermediate input. Finally, by getting rid of the rule-of-thumb consumers, we mute somewhat the mechanical real income effect of oil price changes.

We focus in this section on the historical contribution of oil price shocks to the main euro area variables and present some sensitivity analysis with respect to the various channels through which oil prices affect the economy. Here again, one should keep in mind that in our modeling framework, real oil prices are treated as exogenous so that any fluctuations could be seen as supply-driven. Acknowledging this caveat, the purpose of the counterfactual analysis is to illustrate the difference in the stabilization properties between the estimated rules and the optimal policy cooperation using meaningful amplitudes of oil-price fluctuations. We will concentrate on the period 2004 to 2008 during which repeated oil price surges have been recorded.

The contribution of oil price shocks to euro area CPI inflation, output and interest rate, under each of these configurations, is documented in Figures 4 for both the estimated rules and the optimal monetary policy cooperation (contribution analysis for additional variables are exposed in Figures 10 to 12 in the Appendix). The plain lines show the transmission of oil price shocks when the structural parameters are set to their estimated values in the benchmark estimation. Focusing on the repeated surges in oil prices from 2004 to 2008, the model with the estimated rules evaluates the negative contribution of the commodity price shocks on annual GDP growth for the euro area to reach 0.1 pp per year on average over the period. The optimal monetary policy cooperation would imply a more pronounced slowdown in economic activity, subtracting 0.3 pp of average annual GDP growth. In particular, the amplitude of capital expenditures retrenchment would be much larger and more synchronized with consumption in the optimal allocation. Regarding prices, the contribution of oil price shocks to inflationary pressures at the producer level for the euro area has gradually reached around 0.25 pp of year-on-year PPI inflation from 2005 onwards with the estimated rules. On CPI inflation, the direct effects of oil price increases added another 0.3 pp on average from 2004 to 2008 to those underlying inflationary pressures. The euro area wage increases consistent with such inflation dynamics under the estimated rules would amount to 0.25 pp of year-on-year changes on average over the period. Under optimal monetary policy, however, the wage response is much more subdued and the building-up of producer price pressures are three times smaller. The muted underlying inflationary pressures are then reflected in lower CPI inflation outcomes for the optimal allocation. Finally, the increase in euro area interest rate is slightly larger and more persistent with the estimated rules, reaching 15 bp in 2008, but the optimal policy still generates stronger interest rate differentials and therefore higher short term appreciation of nominal exchange rate. Under both monetary policy regimes, the oil price surges recorded over the last 5 years would have led to very moderate fluctuations on interest rate and exchange rate.

Fig. 4: Contributions of historical oil price shocks to euro area output, inflation and interest rate.

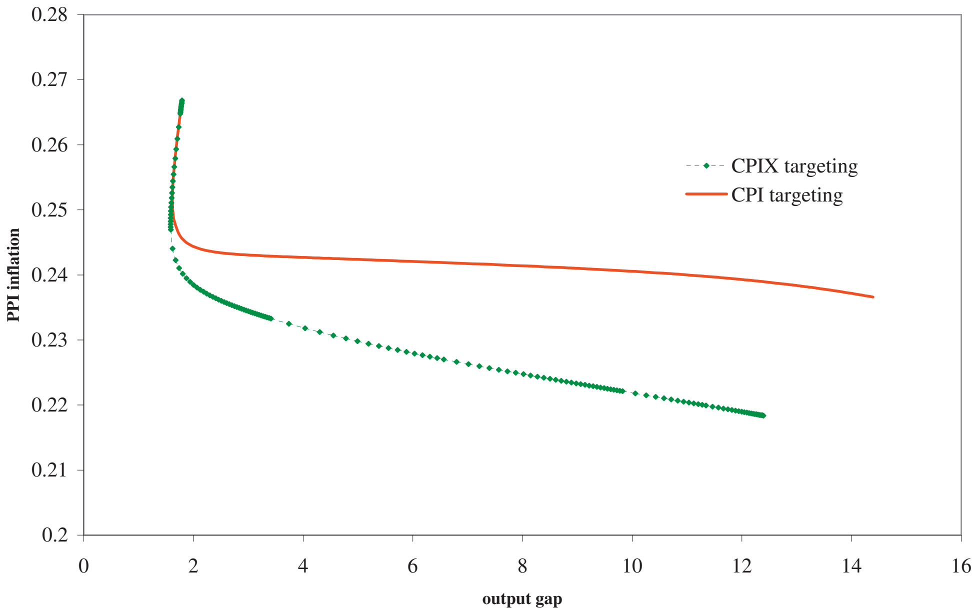


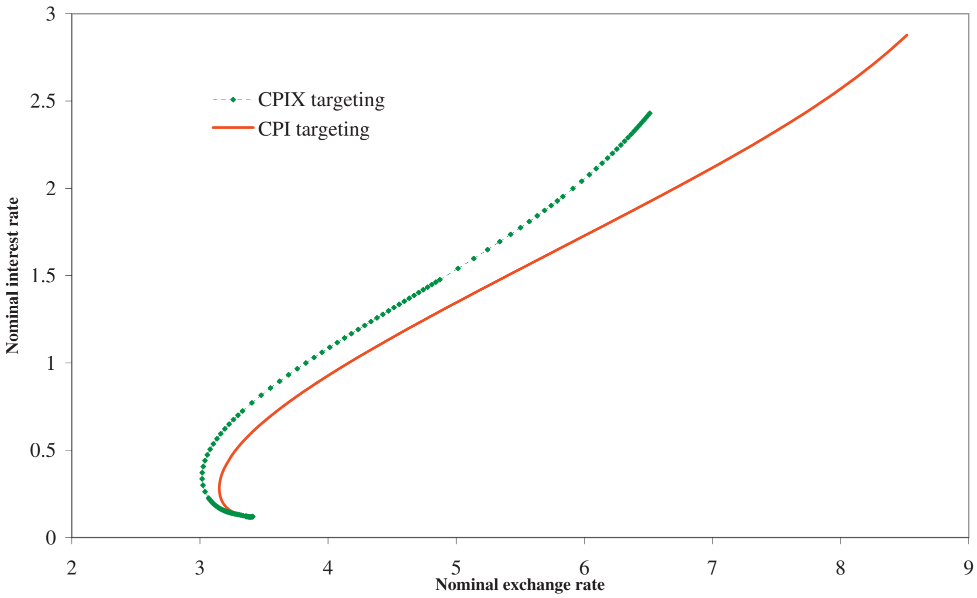
We now try to disentangle the role of the various oil price channels in explaining such different stabilization properties. First we consider the configuration in which oil is not used as an intermediate input, $\omega_Y = 0$. In this case, the contributions of oil price shocks to euro area macroeconomic aggregates turn out to be strongly similar under the estimated rules and the optimal cooperation: around half of the direct effects of oil prices on CPI inflation are allowed to be passed onto nominal wages through the partial indexation scheme, which leads to some increases in PPI inflation. The decline of GDP growth is then significantly reduced to less than 0.05 pp per year from 2004 to 2008. Given the negative real income effects and the marginal increases in non-energy prices, interest rate are even decreased by few basis points over the period. Overall, the estimated euro area interest rate rule targeting GDP inflation and detrended output seems to implement an economic allocation very close to the optimal one when oil is only used as a final consumption good. The optimal policy tells us that there is no need to counteract the direct inflationary effects of oil price shocks as well as their impact on wage due to backward indexation provided that those inflationary pressures do not get entrenched in PPI inflation.

If the differences in the oil price transmission between the estimated rules and the optimal cooperation are not driven by the final-consumption oil channel, the intermediate input channel is instead explaining most of the divergences. When removing oil prices from final consumption, setting $\omega_C = 0$, we observe asymmetric wage responses under both policies: from 2004 to 2008, wages would have increased by 0.2 pp annually under the estimated rules while the optimal monetary policy cooperation would have induced a decrease in nominal wages by less than 0.1 pp. This leads to much more limited price pressures at the producer and consumer levels in the optimal allocation. The gap in the size of the economic contraction induced by the different monetary policy settings is also widenning. Note that, by muting the direct effects of oil price on CPI, we mitigated the real income channel from the rule-of-thumb consumer behavior. This explains why in this case, the output decline is more driven by investment than consumption compared with the benchmark configuration. Overall, the inflationary forces emanating from the intermediate consumption of oil are strongly counteracted by optimal policy, which induces dampening pressures on wages in order to mitigate the cost channel of oil prices. This feature contrasts with the tolerance for a positive wage response under the estimated rules.

A final dimension of oil price transmission explored in this section regards the size of $r - type$ consumer and the mechanical real income effect. When setting $\omega_r = 0$, we observe limited modifications on the nominal side of the euro area economy, under both policy regimes. At the margin, the optimal allocation achieves a slightly lower contribution of oil price hikes from 2004 to 2008 on PPI and wage inflation. However, on economic activity, the absence of rule-of-thumb consumers allows optimal policy to be more restrictive and to amplify the adjustment on investment and then GDP while the contributions to consumption are similar to the benchmark case. Under the estimated rules, the implications on the real effects of oil price shocks mainly concern the timing of the consumption response which is delayed compared with the benchmark transmission.

Fig. 5: Loss function simulations: comparison of CPI versus CPI excluding energy inflation targeting.
Standard deviations of euro area variables, in %.





4.5 The costs of fine-tuning policies

The experiments conducted in the previous section are illustrative of the magnitude of the effects that one could expect from oil price developments, should monetary policy benefit from a high level of credibility and manage to optimally steer expectations. Broadly speaking, monetary policy prevents the emergence of entrenched inflationary effects, while looking through the short-term impacts on headline inflation. The medium-term orientation of monetary policy strategy in the central banking community clearly advises against excessive fine-tuning of macroeconomic variables, including inflation. Such fine-tuning would be costly for a central bank. Thereafter we intend to illustrate this point.

Let us consider the following monetary policy settings for the euro area which minimize an intertemporal loss function, given the structural equilibrium conditions describing the world economy and subject to the constraint that ROW monetary policy follows the estimated interest rate rule.
The loss function considered can be written as follows:

$$\mathcal{L}_{H,t} = \lambda_\pi \pi_t^2 + \lambda_{\pi_N} \pi_{N,t}^2 + \lambda_y \left[\Delta y_t^{gap}\right]^2 + \lambda_r r_t^2 + \beta \mathbb{E}_t \mathcal{L}_{H,t+1}$$

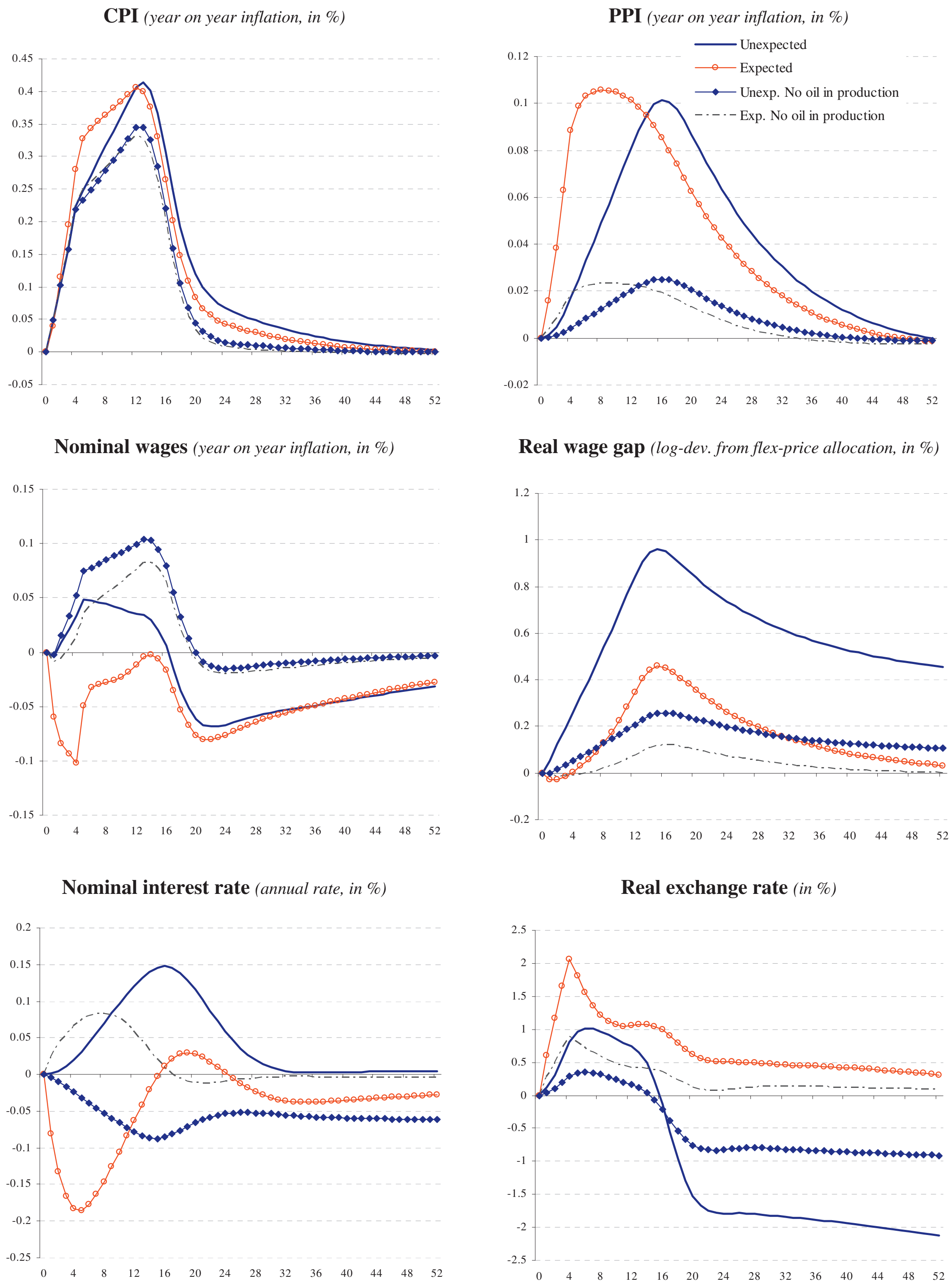
where λ_π, λ_{π_N}, λ_y and λ_r are the coefficients weighting the respective costs of volatility in CPI inflation, CPI excluding energy inflation, changes in the model-based output gap and nominal interest rate. We set $\lambda_y = \lambda_r = 0.5$ and then vary each weight on a nominal inflation indicator from 0 to ∞, setting the other term to zero. For any loss function, we derive the stochastic allocation and compare the standard deviations of selected euro area variables.

Figure 5 shows the trade-off curves implied by the two sets of monetary policy: one targeting CPI inflation and output gap, the other targeting CPI inflation excluding energy and output gap. The first chart plots the volatility of PPI inflation against the volatility of the output gap for both classes of policy. It appears that the strict headline inflation targeting would imply higher PPI inflation variance and stronger fluctuations in the output gap. The same would be true for the nominal interest rate and nominal exchange rate as shown in the second chart of Figures 5. Unambiguously, the fine-tuning strategy which consists in trying to counteract mechanically the direct effects of oil-price changes in headline inflation proves counterproductive. The direct effects of sectoral price changes (measured by the difference between the headline inflation and inflation excluding the sectoral item) can only be counteracted at the cost of excessive fluctuations in real quantities and a stronger response in underlying inflation.

4.6 Optimal monetary policy response to a permanent expected change in the relative price of oil

A final exercise conducted in this paper deals with the implications of the expected versus the unexpected nature of oil-price fluctuations. The repeated surges in energy costs recorded since the beginning of the century have been to a large extent unexpected by the vast majority of market participants. This is notably attested by the progressive upward shift in oil futures following the series of hikes in spot

Fig. 6: Deterministic simulations: Expected versus Unexpected 100% increase in steady state real oil prices, spread over a 5-year period. Comparison with the no oil in production case. *EA variables, deviation from steady state, in %. Time unit = quarter.*



prices. We consider here a counterfactual experiment exploring the appropriate monetary policy conduct should economic agents have foreseen a dramatic increase in oil prices over an extended period of time. Under optimal monetary policy cooperation, we compare the economic consequences of a stylized 100% permanent increase in oil prices spread over five years, depending on whether the future oil price path has been fully anticipated or results from a succession of unanticipated oil-supply shocks.

Figure 5 presents the impulse responses for selected variables for the euro area, under the benchmark parameter set, and in the no-oil-in-production case. In the benchmark configuration, a first observation is that the correct anticipation of future oil price changes leads to a dramatically different wage path: nominal wage declines by 0.05 pp on average during the first three years while in the unexpected case, monetary policy allows upside surprises in CPI inflation to be passed on labor costs through backward indexation. Moreover, perfect foresight on future oil price increases generates a front loading of inflationary pressures at the producer level, which materializes only later in the unexpected scenario. The combination of lower wage response and faster pick-up in PPI inflation strongly reduces the real wage gap when oil price increases are fully anticipated. Nominal interest rate declines below baseline by less than 20 bp in the fully anticipated case while the interest rate move is on the upside and more gradual when the oil price fluctuations are not expected. The exchange rate appreciates by more in the expected case. Overall, the perfect foresight on the oil price path leads to a more rapid absorption of the steady state decline in purchasing power and real national income. Through the various expectation channels, economic agents facilitate the necessary adjustments in real income and aggregate demand. Optimal monetary policy can tolerate the direct effects of oil price changes on CPI inflation as well as some degree of underlying inflationary pressures in the view of easing partly the burden of downward real wage shifts. Under rational expectations, the optimal policy transmission suggests that the anticipation of future oil price surges does not create a case to curb the direct inflationary effects of oil price shocks.

We now conduct some sensitivity analysis around the previous deterministic simulations by considering a configuration where oil is not used as intermediate input. In this case, the differences in economic transmission of expected versus unexpected oil price shocks are less pronounced than in the benchmark exercise. In particular, wage inflation rises in the expected case, albeit to a lower extent than in the unexpected case. A key difference with the benchmark transmission is that the real wage gap to close is much narrower: when oil is used in production, oil prices exert pressures on the overall cost of capital which would lead to an opposite move for real labor costs along the factor price frontier, if prices and wages were flexible. Consequently, some nominal wage growth can be tolerated. And, as previously noticed, some PPI inflation materializes which contributes to limit the opening of a real wage gap. Under perfect foresight, the inflation pressures are front loaded compared with the unexpected case. Turning to interest rates, monetary policy is more restrictive when the oil price increases are anticipated. The reverse was true in the benchmark simulations. Overall, those simulations illustrate that the assumptions made on the technology structure related to oil are crucial dimensions for monetary policy analysis, which can lead to significantly different prescriptions depending on the expected *versus* unexpected nature of commodity price changes.

5 Conclusion

All in all, this paper presents an extension to existing medium-scale open-economy DSGE models, which have been successfully brought to euro area data, by including some relevant features of the macroeconomic transmission of oil-price shocks. But the ultimate goal of this contribution has been to explore the monetary policy prescriptions coming from a welfare-maximizing policy setting, within a modeling framework providing appropriate data coherence.

It turns out that the optimal policy conduct, while being undoubtedly geared towards delivering price stability over the medium term after oil-price shocks, is tolerating their direct inflationary effects on headline inflation and do not advocate fine-tuning actions to stabilize short-term volatility in CPI inflation. At the same time, the optimal allocation clearly suggests that wages should feature a muted response after oil-price shocks. This will facilitate the necessary downward adjustment in real labor costs and counterbalance the cost pressures stemming from the intermediate use of oil in production.

Our monetary policy prescriptions have been derived in a modeling framework where oil-price fluctuations are essentially exogenous to policy actions and where private sector expectations are formed under the rational expectations paradigm. Notably, the extent to which such conclusions could be extended to imperfect knowledge as well as weak central bank credibility configurations remain challenging fields for further research.

References

S. Adjemian, M. Darracq Pariès, and S. Moyen. Optimal monetary policy in an estimated dsge for the euro area. Working Paper 803, European Central Bank, 2007.

S. Adjemian, M. Darracq Pariès, and S. Smets. A quantitative perspective on optimal monetary policy cooperation between the us and the euro area. Working Paper 884, European Central Bank, 2008.

F. Altissimo and V. Corradi. Strong rules for detecting the number of breaks ina time series. *Journal of Econometrics*, 117:207–244, 2003.

D. K. Backus and M. J. Crucini. Oil prices and the terms of trade. *Journal of International Economics*, 50: 185–213, 2000.

O. Blanchard and J. Galí. The macroeconomic effects of oil price shocks: Why are the 2000s so different from the 1970s? Economics Working Papers 1045, Universitat Pompeu Fabra, 2007.

M. Bodenstein, C. Erceg, and L. Guerrieri. Oil shocks and external adjustment. International Finance Discussion Papers 897, Board of Governors of the Federal Reserve System, June 2007.

K. Christoffel, G. Coenen, and A. Warne. The new area wide model for the euro area: Specification, estimation, preperties. Manuscript, European Central Bank, 2007.

G. Coenen and R. Straub. Does government spending crowd in private consumption? theory and empirical evidence for the euro area. Working Paper 513, European Central Bank, August 2005.

G. Coenen, G. Lombardo, F. Smets, and R. Straub. International transmission and monetary policy cooperation. Working Paper 858, European Central Bank, January 2008.

F. De Fiore and G. Lombardo. The gains from monetary policy cooperation in a large dsge model with oil. mimeo, European Central Bank, 2008.

S. Dees, F. di Mauro, H. Pesaran, and V. Smith. Exploring the international linkages of the euro area: A global var analysis. *Journal of Applied Econometrics*, 22(1):1–38, 2007.

M. Del Negro, F. Schorfheide, F. Smets, and R. Wouters. On the fit of new-keynesian models. *Journal of Business and Economic Statistics*, 25(2):123–143, 2007.

G. Fagan, J. Henry, and R. Mestre. An area-wide model for the euro area. *Economic Modelling*, 22, 2005.

P. Jacquinot, M. Kuismanen, R. Mestre, and M. Spitzer. An assessment of the inflationary impact of oil shocks in the euro area. *The Energy Journal*, 30(1), 2009.

S. Schmitt-Grohe and S. Uribe. Optimal inflation stabilization in a medium-scale macroeconomic model. Working Paper 11854, NBER, December 2005.

F. Smets and R. Wouters. An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of the European Economic Association*, 1(5):1123–1175, 2003.

F. Smets and R. Wouters. Comparing shocks and frictions in us and euro area business cycles: a bayesian dsge approach. *Journal of Applied Econometrics*, 20(1), 2005.

M. Woodford. *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton University Press, 2003.

A Model description

This section presents first order conditions associated with the decision problems of section 2.

A.1 $o - type$ households

The first order condition related to consumption expenditures is given by

$$\Lambda_t^o = \varepsilon_t^B \left(C_t^o - hC_{t-1}^o\right)^{-\sigma_C} - \beta h \mathbb{E}_t \left[\varepsilon_{t+1}^B \left(C_{t+1}^o - hC_t^o\right)^{-\sigma_C}\right] \tag{1}$$

where $\frac{\Lambda_t^o}{(1+\tau_{C,t})}$ is the Lagrange multiplier associated with the budget constraint.
The first order conditions associated with contingent bond holdings, combined with the ones of country F lead to the following risk sharing condition:

$$\frac{\Lambda_t^{o,*}}{\Lambda_t^o} = \varepsilon_t^{\Delta S} \kappa RER_t \tag{2}$$

where $RER_t = \frac{S_t P_t^*}{P_t}$, $\kappa = \frac{\Lambda_0^{o,*}}{RER_0 \Lambda_0^o}$ (normalized to 1 given our steady state assumptions). The previous equation is derived from the set of optimality conditions that characterize the optimal allocation of wealth among state-contingent securities. $\varepsilon_t^{\Delta S}$ is a unitary-mean disturbance affecting the optimal risk sharing condition. The introduction of such a shock is obviously arbitrary but is meant to help matching exchange rate fluctuations in the estimation. Taking the one-period ahead expectation of the log-difference of this equation results in a first order approximation of the uncovered-interest-rate parity condition in which $\mathbb{E}_t \left[\Delta \log(\varepsilon_{t+1}^{\Delta S})\right]$ appears as a residual term.
In addition, those conditions for country H imply the following Euler equation for $o - type$ households:

$$\Lambda_t^o = R_t \beta \mathbb{E}_t \left[\Lambda_{t+1}^o \frac{P_t}{P_{t+1}}\right] \tag{3}$$

where R_t is the one-period-ahead nominal interest rates for country H.
The choices for investment, capacity utilization and capital stock result in the following first order conditions:

$$Q_t = \mathbb{E}_t \left[\beta \frac{\Lambda_{t+1}^o T_{N,t+1}}{\Lambda_t^o T_{N,t}} \frac{1+\tau_{C,t}}{1+\tau_{C,t+1}} \left(Q_{t+1}(1-\delta) + R_{t+1}^k u_{t+1} - \Phi\left(u_{t+1}\right)\right)\right] \varepsilon_t^Q \tag{4}$$

$$\begin{aligned} 1 &= Q_t \left[1 - S\left(\frac{I_t^o}{I_{t-1}^o}\right) - \frac{I_t^o}{I_{t-1}^o} S'\left(\frac{I_t^o}{I_{t-1}^o}\right)\right] \varepsilon_t^I \\ &\quad + \beta \mathbb{E}_t \left[Q_{t+1} \frac{\Lambda_{t+1}^o T_{N,t+1}}{\Lambda_t^o T_{N,t}} \frac{1+\tau_{C,t}}{1+\tau_{C,t+1}} \left(\frac{I_{t+1}^o}{I_t^o}\right)^2 S'\left(\frac{I_{t+1}^o}{I_t^o}\right) \varepsilon_{t+1}^I\right] \end{aligned} \tag{5}$$

$$R_t^k = \Phi'\left(u_t\right) \tag{6}$$

where $\frac{\Lambda_t^o T_{N,t}}{(1+\tau_{C,t})} Q_t$ is the lagrange multiplier associated with the capital accumulation equation

$$K_{t+1}^o = (1-\delta) K_t^o + \varepsilon_t^I \left[1 - S\left(\frac{I_t^o}{I_{t-1}^o}\right)\right] I_t^o \tag{7}$$

A.2 $r - type$ households

In the country H, with an active government policy to redistribute national income, the rule-of-thumb households will set consumption at:

$$C_t^r = (1 - \tau_{W,t})\, w_t L_t + \widetilde{TT}_t^r \tag{8}$$

where $\widetilde{TT}_t^r$ can be an active government transfer scheme which provides the $r - type$ consumers with disposable income homogenous to national income minus a fixed payment which ensures that consumption is equalized between households' types in the steady state.

A.3 Labour supply and wage-setting by unions

The first order condition of the wage-setting program can be written recursively as follows:

$$\frac{\widetilde{W}_t(h)}{P_t} = \left(\mu_w \frac{\mathcal{H}_{1,t}^w}{\mathcal{H}_{2,t}^w}\right)^{\frac{\mu_w - 1}{\mu_w(1+\sigma_L)-1}}$$

$$\mathcal{H}_{1,t}^w = \varepsilon_t^B \widetilde{L} L_t^{1+\sigma_L} \left[\frac{w_t}{1+\tau_{C,t}}\right]^{\frac{(1+\sigma_L)\mu_w}{\mu_w - 1}} + \alpha_w \beta \mathbb{E}_t \left[\left(\frac{\Pi_{t+1}}{\Pi_t^{\xi_w} \left[\overline{\Pi}\right]^{1-\xi_w}}\right)^{\frac{(1+\sigma_L)\mu_w}{\mu_w - 1}} \mathcal{H}_{1,t+1}^w\right] \tag{9}$$

$$\begin{aligned} \mathcal{H}_{2,t}^w &= (1 - \tau_{w,t}) \left(\omega_r \Lambda_t^r + (1 - \omega_r) \Lambda_t^o\right) L_t \left[\frac{w_t}{1+\tau_{C,t}}\right]^{\frac{\mu_w}{\mu_w - 1}} \\ &\quad + \alpha_w \beta \mathbb{E}_t \left[\left(\frac{\Pi_{t+1}}{\Pi_t^{\xi_w} \left[\overline{\Pi}\right]^{1-\xi_w}}\right)^{\frac{1}{\mu_w - 1}} \mathcal{H}_{2,t+1}^w\right] \end{aligned} \tag{10}$$

where w_t denotes the aggregate real wage (measured with the before-tax CPI), and Λ_t^r is the marginal utility of consumption for $r - type$ households.

$$\Lambda_t^r = \varepsilon_t^B \left(C_t^r - hC_{t-1}^r\right)^{-\sigma_C} - \beta h \mathbb{E}_t \left[\varepsilon_{t+1}^B \left(C_{t+1}^r - hC_t^r\right)^{-\sigma_C}\right] \tag{11}$$

Finally, the aggregate wage dynamics is given by.

$$\left[\frac{w_t}{1+\tau_{C,t}}\right]^{\frac{1}{1-\mu_w}} = (1 - \alpha_w) \left(\mu_w \frac{\mathcal{H}_{1,t}^w}{\mathcal{H}_{2,t}^w}\right)^{-\frac{1}{\mu_w(1+\sigma_l)-1}} + \alpha_w \left[\frac{w_{t-1}}{1+\tau_{C,t-1}}\right]^{\frac{1}{1-\mu_w}} \left(\frac{\Pi_t}{\Pi_{t-1}^{\xi_w} \overline{\Pi}^{1-\xi_w}}\right)^{\frac{-1}{1-\mu_w}} \tag{12}$$

When wages are perfectly flexible (*ie* $\alpha_W = 0$), the wage setting scheme collapses to:

$$\frac{(1+\tau_{C,t})\,\mu_w}{(1\text{-}\tau_{w,t})} \varepsilon_t^B \tilde{L} L_t^{\sigma_l} = \left(\omega_r \Lambda_t^r + (1 - \omega_r) \Lambda_t^o\right) w_t$$

The real wage is equal to a markup $\frac{(1+\tau_{C,t})\mu_w}{(1\text{-}\tau_{w,t})}$ over the marginal rate of substitution between consumption and labor.

A.4 Firms

Cost minimization in the non-oil distribution sector gives:.

$$Y_{H,t} = n_t \left(T_{H,t}\right)^{-\xi} Y_t \tag{13}$$

$$Y_{F,t} = (1-n_t)\left(T_t\, T_{H,t}\right)^{-\xi} Y_t \tag{14}$$

$$Y^*_{F,t} = n^*_t \left(T^*_{F,t}\right)^{-\xi} Y^*_t \tag{15}$$

$$Y^*_{H,t} = (1-n^*_t)\left(\frac{T^*_{F,t}}{T^*_t}\right)^{-\xi} Y^*_t \tag{16}$$

Similarly, costs minimization implies the following allocation of aggregate consumption among the two goods as follows

$$C_{oil,t} = \omega_C \left(T_{oil,t}\right)^{-\xi_o} C_t \tag{17}$$

$$C_{N,t} = (1-\omega_C)\left(T_{N,t}\right)^{-\xi_o} C_t \tag{18}$$

$$C^*_{oil,t} = \omega_C \left(T^*_{oil,t}\right)^{-\xi_o} C^*_t \tag{19}$$

$$C^*_{N,t} = (1-\omega_C)\left(T^*_{N,t}\right)^{-\xi_o} C^*_t \tag{20}$$

The real marginal cost is identical across intermediate producers within each country:

$$MC_t = \frac{w_t^{(1-\alpha)} {R^k_{o,t}}^{\alpha}}{\varepsilon^A_t \alpha^\alpha (1-\alpha)^{(1-\alpha)} T_{H,t} T_{N,t}} \tag{21}$$

with

$$R^k_{o,t} = \left[(1-\omega_Y)\ \left(R^k_t T_{N,t}\right)^{1-\theta_o} + \omega_Y\ {T_{oil,t}}^{1-\theta_o}\right]^{\frac{1}{1-\theta_o}} \tag{22}$$

and the real marginal cost for country F is given by,

$$MC^*_t = \frac{w_t^{*(1-\alpha)} {R^{k*}_{o,t}}^{\alpha}}{\varepsilon^{A*}_t \alpha^\alpha (1-\alpha)^{(1-\alpha)} T^*_{F,t} T^*_{N,t}} \tag{23}$$

with

$$R^{k*}_{o,t} = \left[(1-\omega_Y)\ \left(R^{k*}_t T^*_{N,t}\right)^{1-\theta_o} + \omega_Y\ {T^*_{N,t}}^{1-\theta_o}\right]^{\frac{1}{1-\theta_o}} \tag{24}$$

The first order condition associated with the firm's choice of $\hat{p}_t(h)$ can be written in the following recursive form $\frac{\hat{p}_t(h)}{P_{H,t}} = \mu \frac{\mathcal{Z}_{H1,t}}{\mathcal{Z}_{H2,t}}$ where

$$\mathcal{Z}_{H1,t} = \Lambda^o_t MC_t Y_{H,t} \frac{T_{H,t}T_{N,t}}{1+\tau_{C,t}} + \alpha_H \beta \mathbb{E}_t \left[\left(\frac{\Pi_{H,t+1}}{\Pi^{\gamma_H}_{H,t}\overline{\Pi}^{1-\gamma_H}}\right)^{\frac{\mu}{\mu-1}} \mathcal{Z}_{H1,t+1}\right] \tag{25}$$

and

$$\mathcal{Z}_{H2,t} = (1-\tau_t)\Lambda_t Y_{H,t} \frac{T_{H,t}T_{N,t}}{1+\tau_{C,t}} + \alpha_H \beta \mathbb{E}_t \left[\left(\frac{\Pi_{H,t+1}}{\Pi^{\gamma_H}_{H,t}\overline{\Pi}^{1-\gamma_H}}\right)^{\frac{1}{\mu-1}} \mathcal{Z}_{H2,t+1}\right] \tag{26}$$

Accordingly, the aggregate price dynamics leads to the following relation.

$$1 = \alpha_H \left(\frac{\Pi_{H,t}}{\Pi^{\gamma_H}_{H,t-1}\overline{\Pi}^{1-\gamma_H}}\right)^{\frac{1}{\mu-1}} + (1-\alpha_H)\left(\mu \frac{\mathcal{Z}_{H1,t}}{\mathcal{Z}_{H2,t}}\right)^{\frac{1}{1-\mu}} \tag{27}$$

Equations analogous hold for foreign producers and governs the dynamics of $\Pi^*_{F,t}$ as follows

$$\mathcal{Z}^*_{F1,t} = \Lambda^*_t MC^*_t Y^*_{F,t} \frac{T^*_{F,t}}{1+\tau^*_{C,t}} + \alpha^*_F \beta \mathbb{E}_t \left[\left(\frac{\Pi^*_{F,t+1}}{\Pi^{*\gamma^*_F}_{F,t} \overline{\Pi}^{*1-\gamma^*_F}} \right)^{\frac{\mu}{\mu-1}} \mathcal{Z}^*_{F1,t+1} \right] \tag{28}$$

$$\mathcal{Z}^*_{F2,t} = (1-\tau^*_t) \Lambda^*_t Y^*_{F,t} \frac{T^*_{F,t}}{1+\tau^*_{C,t}} + \alpha^*_F \beta \mathbb{E}_t \left[\left(\frac{\Pi^*_{F,t+1}}{\Pi^{*\gamma^*_F}_{F,t} \overline{\Pi}^{*1-\gamma^*_F}} \right)^{\frac{1}{\mu-1}} \mathcal{Z}^*_{F2,t+1} \right] \tag{29}$$

and

$$1 = \alpha^*_F \left(\frac{\Pi^*_{F,t}}{\Pi^{*\gamma^*_F}_{F,t-1} \overline{\Pi}^{*1-\gamma^*_F}} \right)^{\frac{1}{\mu-1}} + (1-\alpha^*_F) \left(\mu \frac{\mathcal{Z}^*_{F1,t}}{\mathcal{Z}^*_{F2,t}} \right)^{\frac{1}{1-\mu}} \tag{30}$$

Similarly, the inflation dynamics of LCP export prices for the country H, $\tilde{\Pi}^*_{H,t}$, is described by the following three equations

$$\tilde{\mathcal{Z}}^*_{H1,t} = \Lambda_t MC_t Y^*_{H,t} \frac{T_{H,t} T_{N,t}}{1+\tau_{C,t}} + \alpha^*_F \beta \mathbb{E}_t \left[\left(\frac{\tilde{\Pi}^*_{H,t+1}}{\tilde{\Pi}^{*\gamma^*_F}_{H,t} \overline{\Pi}^{1-\gamma^*_F}} \right)^{\frac{\mu}{\mu-1}} \tilde{\mathcal{Z}}^*_{H1,t+1} \right] \tag{31}$$

$$\tilde{\mathcal{Z}}^*_{H2,t} = (1-\tau_t) \Lambda_t Y^*_{H,t} \frac{T_{H,t} T_{N,t}}{1+\tau_{C,t}} R\tilde{E}R_{H,t} + \alpha^*_F \beta \mathbb{E}_t \left[\left(\frac{\tilde{\Pi}^*_{H,t+1}}{\tilde{\Pi}^{*\gamma^*_F}_{H,t} \overline{\Pi}^{1-\gamma^*_F}} \right)^{\frac{1}{\mu-1}} \tilde{\mathcal{Z}}^*_{H2,t+1} \right] \tag{32}$$

$$1 = \alpha^*_F \left(\frac{\tilde{\Pi}^*_{H,t}}{\tilde{\Pi}^{*\gamma^*_F}_{H,t-1} \overline{\Pi}^{1-\gamma^*_F}} \right)^{\frac{1}{\mu-1}} + (1-\alpha^*_F) \left(\mu \frac{\tilde{\mathcal{Z}}^*_{H1,t}}{\tilde{\mathcal{Z}}^*_{H2,t}} \right)^{\frac{1}{1-\mu}} \tag{33}$$

LCP export price inflation for country F, $\tilde{\Pi}_{F,t}$, is given by the equivalent formulation

$$\tilde{\mathcal{Z}}_{F1,t} = \Lambda^*_t MC^*_t Y_{F,t} \frac{T^*_{F,t} T^*_{N,t}}{1+\tau^*_{C,t}} + \alpha_H \beta \mathbb{E}_t \left[\left(\frac{\tilde{\Pi}_{F,t+1}}{\tilde{\Pi}^{\gamma_H}_{F,t} \overline{\Pi}^{*1-\gamma_H}} \right)^{\frac{\mu}{\mu-1}} \tilde{\mathcal{Z}}_{F1,t+1} \right] \tag{34}$$

$$\tilde{\mathcal{Z}}_{F2,t} = (1-\tau^*_t) \Lambda^*_t Y_{F,t} \frac{T^*_{F,t} T^*_{N,t}}{1+\tau^*_{C,t}} R\tilde{E}R_{F,t} + \alpha_H \beta \mathbb{E}_t \left[\left(\frac{\tilde{\Pi}_{F,t+1}}{\tilde{\Pi}^{\gamma_H}_{F,t} \overline{\Pi}^{*1-\gamma_H}} \right)^{\frac{1}{\mu-1}} \tilde{\mathcal{Z}}_{F2,t+1} \right] \tag{35}$$

$$1 = \alpha_H \left(\frac{\tilde{\Pi}_{F,t}}{\tilde{\Pi}^{\gamma_H}_{F,t-1} \overline{\Pi}^{*1-\gamma_H}} \right)^{\frac{1}{\mu-1}} + (1-\alpha_H) \left(\mu \frac{\tilde{\mathcal{Z}}_{F1,t}}{\tilde{\mathcal{Z}}_{F2,t}} \right)^{\frac{1}{1-\mu}} \tag{36}$$

Moreover, cost minimization implies that input ratios are equalized across firms in each country. Aggregate capital-labour and capital-energy ratios are therefore given by

$$\frac{w_t L_t}{R^k_{o,t} V_t} = \frac{1-\alpha}{\alpha} \tag{37}$$

and

$$\frac{V_{oil,t}}{u_t K_{t-1}} = \frac{\omega_Y}{\omega_Y - 1} \left(\frac{R^k_t T_{N,t}}{T_{oil,t}} \right)^{\theta_o} \tag{38}$$

The relations hold for country F:

$$\frac{w_t^* L_t^*}{R_{o,t}^{k*} V_t^*} = \frac{1-\alpha}{\alpha} \tag{39}$$

and

$$\frac{V_{oil,t}^*}{u_t^* K_{t-1}^*} = \frac{\omega_Y}{\omega_Y - 1} \left(\frac{R_{o,t}^{k*} T_{N,t}^*}{T_{oil,t}^*} \right)^{\theta_o} \tag{40}$$

A.5 Market clearing conditions

Aggregate supply of consumption goods is equal to the weighted average of the corresponding variables for each consumer type

$$C_t = \omega_r C_t^r + (1-\omega_r) C_t^o \tag{41}$$
$$C_t^* = \omega_r^* C_t^{r*} + (1-\omega_r^*) C_t^{o*} \tag{42}$$

Aggregate investment and capital stocks are given by

$$I_t = (1-\omega_r) I_t^o \tag{43}$$
$$K_t = (1-\omega_r) K_t^o \tag{44}$$
$$I_t^* = (1-\omega_r^*) I_t^{o*} \tag{45}$$
$$K_t^* = (1-\omega_r^*) K_t^{o*} \tag{46}$$

Overall demand for oil is

$$Y_{oil,t} = C_{oil,t} + V_{oil,t} \tag{47}$$
$$Y_{oil,t}^* = C_{oil,t}^* + V_{oil,t}^* \tag{48}$$

Aggregate domestic demands for non-oil goods are given by

$$Y_{N,t} = C_{N,t} + I_t + \overline{\overline{G}} \varepsilon_t^G + \Phi(u_t) K_{t-1} \tag{49}$$
$$Y_{N,t}^* = C_{N,t}^* + I_t^* + \overline{\overline{G}} \varepsilon_t^{G*} + \Phi(u_t^*) K_{t-1}^* \tag{50}$$

Aggregate productions of intermediate goods verify

$$Z_t = \varepsilon_t^A (V_t)^\alpha (L_t)^{1-\alpha} - \Omega \tag{51}$$
$$Z_t^* = \varepsilon_t^{A*} (V_t^*)^\alpha (L_t^*)^{1-\alpha} - \Omega \tag{52}$$

with

$$V_t = \left[(1-\omega_Y)^{\frac{1}{\theta_o}} (u_t K_{t-1})^{\frac{\theta_o - 1}{\theta_o}} + \omega_Y^{\frac{1}{\theta_o}} V_{oil,t}^{\frac{\theta_o - 1}{\theta_o}} \right]^{\frac{\theta_o}{\theta_o - 1}} \tag{53}$$
$$V_t^* = \left[(1-\omega_Y)^{\frac{1}{\theta_o}} (u_t^* K_{t-1}^*)^{\frac{\theta_o - 1}{\theta_o}} + \omega_Y^{\frac{1}{\theta_o}} V_{oil,t}^{*\frac{\theta_o - 1}{\theta_o}} \right]^{\frac{\theta_o}{\theta_o - 1}} \tag{54}$$

Given the oil-recycling demand addressed to country H and F

$$O_{H,t} = (1-\alpha_{oil}) O_{H,t-1} + \alpha_{oil} \frac{1}{2} \frac{T_{oil,t}}{T_{N,t} T_{H,t}} \left(Y_{oil,t} + Y_{oil,t}^* \right) \tag{55}$$

and

$$O^*_{F,t} = (1-\alpha_{oil})\,O^*_{F,t-1} + \alpha_{oil}\frac{1}{2}\frac{T^*_{oil,t}}{T^*_{N,t}T^*_{F,t}}\left(Y_{oil,t}+Y^*_{oil,t}\right) \tag{56}$$

market clearing conditions in the intermediate-goods markets lead to the following relations

$$Z_t = \Delta_{H,t}Y_{H,t} + \Delta^*_{H,t}Y^*_{H,t} + O_{H,t} \tag{57}$$

$$Z^*_t = \Delta^*_{F,t}Y^*_{F,t} + \Delta_{F,t}Y_{F,t} + O^*_{F,t} \tag{58}$$

where $\Delta_{H,t} = \int_0^1 \left(\frac{p_t(h)}{P_{H,t}}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}h$, $\Delta^*_{H,t} = \int_0^1 \left(\frac{p^*_t(h)}{P^*_{H,t}}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}h$, $\Delta^*_{F,t} = \int_0^1 \left(\frac{p^*_t(f)}{P^*_{F,t}}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}f$ and $\Delta_{F,t} = \int_0^1 \left(\frac{p_t(f)}{P_{F,t}}\right)^{-\frac{\mu}{\mu-1}} \mathrm{d}f$ measure price dispersions among products of country H and F, sold locally or exported.

Those indexes have the following dynamics

$$\Delta_{H,t} = (1-\alpha_H)\left(\mu\frac{\mathcal{Z}_{H1,t}}{\mathcal{Z}_{H2,t}}\right)^{-\frac{\mu}{\mu-1}} + \alpha_H\Delta_{H,t-1}\left(\frac{\Pi_{H,t}}{\Pi^{\gamma_H}_{H,t-1}\overline{\Pi}^{1-\gamma_H}}\right)^{\frac{\mu}{\mu-1}} \tag{59}$$

$$\Delta^*_{F,t} = (1-\alpha^*_F)\left(\mu\frac{\mathcal{Z}^*_{F1,t}}{\mathcal{Z}^*_{F2,t}}\right)^{-\frac{\mu}{\mu-1}} + \alpha^*_F\Delta^*_{F,t-1}\left(\frac{\Pi^*_{F,t}}{\Pi^{*\gamma^*_F}_{F,t-1}\overline{\Pi}^{*1-\gamma^*_F}}\right)^{\frac{\mu}{\mu-1}} \tag{60}$$

$$\Delta^*_{H,t} = \eta\Delta_{H,t} + (1-\eta)\,\tilde{\Delta}^*_{H,t} \tag{61}$$

$$\tilde{\Delta}^*_{H,t} = (1-\alpha^*_F)\left(\mu\frac{\tilde{\mathcal{Z}}_{H1,t}}{\tilde{\mathcal{Z}}_{H2,t}}\right)^{-\frac{\mu}{\mu-1}} + \alpha^*_F\tilde{\Delta}^*_{H,t-1}\left(\frac{\tilde{\Pi}^*_{H,t}}{\tilde{\Pi}^{*\gamma^*_F}_{H,t-1}\overline{\Pi}^{1-\gamma^*_F}}\right)^{\frac{\mu}{\mu-1}} \tag{62}$$

$$\Delta_{F,t} = \eta^*\Delta^*_{F,t} + (1-\eta^*)\,\Delta_{F,t} \tag{63}$$

$$\tilde{\Delta}_{F,t} = (1-\alpha_H)\left(\mu\frac{\tilde{\mathcal{Z}}_{H1,t}}{\tilde{\mathcal{Z}}_{H2,t}}\right)^{-\frac{\mu}{\mu-1}} + \alpha_H\tilde{\Delta}_{F,t}\left(\frac{\tilde{\Pi}_{F,t}}{\tilde{\Pi}^{\gamma_H}_{F,t-1}\overline{\Pi}^{*1-\gamma_H}}\right)^{\frac{\mu}{\mu-1}} \tag{64}$$

Finally, some relative prices have finally to be defined as a function of stationary variables. First, the 4 inflation rates for export prices and local sales prices determine 3 relative prices: 2 relative export margins for LCP producers and interior terms of trade for country H.

$$R\tilde{E}R_{H,t} = R\tilde{E}R_{H,t-1}\frac{\tilde{\Pi}^*_{H,t}\,(1+\Delta S_t)}{\Pi_{H,t}} \tag{65}$$

$$R\tilde{E}R_{F,t} = R\tilde{E}R_{H,t-1}\frac{\tilde{\Pi}_{F,t}}{\Pi^*_{F,t}\,(1+\Delta S_t)} \tag{66}$$

$$T_t = T_{t-1}\frac{\Pi_{F,t}}{\Pi_{H,t}} \tag{67}$$

The following variables are deduced from the previous three relative prices.

$$RER_{H,t} = \left[\eta + (1-\eta)\, R\tilde{E}R_{H,t}^{\frac{1}{1-\mu}}\right]^{1-\mu} \quad (68)$$

$$RER_{F,t} = \left[\eta + (1-\eta)\, R\tilde{E}R_{F,t}^{\frac{1}{1-\mu}}\right]^{1-\mu} \quad (69)$$

$$T_t^* = \frac{T_t}{RER_{H,t}RER_{F,t}} \quad (70)$$

$$T_{H,t} = \left[n_t + (1-n_t)T_t^{1-\xi}\right]^{\frac{1}{\xi-1}} \quad (71)$$

$$T_{F,t}^* = \left[n_t^* + (1-n_t^*)T_t^{*\xi-1}\right]^{\frac{1}{\xi-1}} \quad (72)$$

$$RER_{X,t} = RER_{H,t}T_{H,t}\frac{T_t^*}{T_{F,t}^*} \quad (73)$$

Aggregate export price inflation rates and non-oil goods inflation rates are given by

$$\Pi_{H,t}^* = \frac{RER_{H,t}}{RER_{H,t-1}}\frac{\Pi_{H,t}}{(1+\Delta S_t)} \quad (74)$$

$$\Pi_{F,t} = \frac{RER_{F,t}}{RER_{F,t-1}}\Pi_{F,t}^*\,(1+\Delta S_t) \quad (75)$$

$$\Pi_{N,t} = \frac{T_{H,t}}{T_{H,t-1}}\Pi_{H,t} \quad (76)$$

$$\Pi_{N,t}^* = \frac{T_{F,t}^*}{T_{F,t-1}^*}\Pi_{F,t}^* \quad (77)$$

Given the exogenous relative price of oil in country F, $T_{oil,t}^*$, we can then solve the following system

$$T_{N,t} = \left[\frac{1-\omega_C T_{oil,t}^{1-\xi_o}}{1-\omega_C}\right]^{\frac{1}{1-\xi_o}} \quad (78)$$

$$T_{N,t}^* = \left[\frac{1-\omega_C T_{oil,t}^{*1-\xi_o}}{1-\omega_C}\right]^{\frac{1}{1-\xi_o}} \quad (79)$$

$$RER_t = RER_{X,t}\frac{T_{N,t}}{T_{N,t}^*} \quad (80)$$

$$T_{oil,t} = RER_t T_{oil,t}^* \quad (81)$$

$$\Pi_t = \frac{T_{N,t-1}}{T_{N,t}}\Pi_{N,t}\varepsilon_t^{CPI} \quad (82)$$

$$\Pi_t^* = \frac{T_{N,t-1}^*}{T_{N,t}^*}\Pi_{N,t}^*\varepsilon_t^{CPI*} \quad (83)$$

A.6 Welfare

The aggregate conditional welfare for each country are defined by $\mathcal{W}_{H,t} = \int_0^1 \mathcal{W}_t(h)\mathrm{d}h$ and $\mathcal{W}_{F,t} = \int_0^1 \mathcal{W}_t(f)\mathrm{d}f$.

We already mentioned that all households have the same consumption plans. Consequently, making use of the labor demand curve faced by each household we obtain

$$\mathcal{W}_{H,t} = \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left[\begin{array}{c} \frac{\omega_r}{1-\sigma_C} \left(C^r_{t+j} - hC^r_{t-1+j}\right)^{1-\sigma_C} + \frac{1-\omega_r}{1-\sigma_C} \left(C^o_{t+j} - hC^o_{t-1+j}\right)^{1-\sigma_C} \\ - \frac{\tilde{L}}{1+\sigma_L} L^{1+\sigma_l}_{t+j} \Delta_{w,t+j} \end{array} \right] \varepsilon^B_{t+j}$$

where we defined

$$\Delta_{w,t} = \int_0^1 \left(\frac{W_t(h)}{W_t} \right)^{-\frac{(1+\sigma_l)\mu_w}{\mu_w - 1}} \mathrm{d}h$$

As for the price dispersion index, we can show that

$$\begin{aligned} \Delta_{w,t} &= \alpha_w \Delta_{w,t-1} \left(\frac{w_t}{w_{t-1}} \frac{\Pi_t}{\Pi^{\xi_w}_{t-1} \bar{\Pi}^{1-\xi_w}} \right)^{\frac{(1+\sigma_l)\mu_w}{\mu_w - 1}} \\ &\quad + (1-\alpha_w)\, w_t^{\frac{(1+\sigma_l)\mu_w}{\mu_w - 1}} \left(\mu_w \frac{\mathcal{H}^w_{1,t}}{\mathcal{H}^w_{2,t}} \right)^{-\frac{\mu_w(1+\sigma_l)}{\mu_w(1+\sigma_l)-1}} \end{aligned} \qquad (84)$$

The welfare for country F is determined by the analogous relations.

A.7 Competitive equilibrium and Ramsey formulation of optimal monetary policy

The competitive equilibrium is a set of stationary 41 processes for country H, Λ^o_t, C^o_t, u_t, Q_t, I^o_t, R^k_t, K^o_t, I_t, K_t, Λ^r_t, C^r_t, Z_t, C_t, L_t, w_t, $\mathcal{H}^w_{1,t}$, $\mathcal{H}^w_{2,t}$, $\Delta_{w,t}$, V_t, $V_{oil,t}$, $C_{oil,t}$, $C_{N,t}$, $Y_{oil,t}$, $Y_{N,t}$, $Y_{H,t}$, $Y^*_{H,t}$, $O_{H,t}$, MC_t, $R^k_{o,t}$, $\Pi_{H,t}$, $\Delta_{H,t}$, $\mathcal{Z}_{H1,t}$, $\mathcal{Z}_{H2,t}$, $\tilde{\Pi}^*_{H,t}$, $\tilde{\Delta}^*_{H,t}$, $\tilde{\mathcal{Z}}^*_{H1,t}$, $\tilde{\mathcal{Z}}^*_{H2,t}$, $\Pi^*_{H,t}$, $\Delta^*_{H,t}$, $\Pi_{N,t}$, Π_t as well as the analogous 28 processes for country F, 13 relative prices $R\tilde{E}R_{H,t}$, $R\tilde{E}R_{F,t}$, $RER_{H,t}$, $RER_{F,t}$, T_t, T^*_t, $T_{H,t}$, $T^*_{F,t}$, $RER_{X,t}$, $T_{N,t}$, $T^*_{N,t}$, RER_t, $T_{oil,t}$ and the depreciation rate ΔS_t. The 96 stationary processes satisfy the relations (1)-(84) and the analogous of equations (1), (2)-(12), (84) for country F, given the policy rates R_t, R^*_t, traditional closed-economy exogenous stochastic processes for country H, ε^A_t, ε^B_t, ε^I_t, ε^G_t,ε^W_t, ε^P_t, ε^R_t, with the analogous shocks for country F, the additional open-economy exogenous stochastic processes ε^{CPI*}_t, ε^{CPI}_t, $\varepsilon^{\Delta S}_t$, $\varepsilon^{\Delta n}_t$, the relative oil price in country F, $T^*_{oil,t}$ and initial conditions for country H, C^o_{-1}, I^o_{-1}, K^o_{-1}, $\Delta_{H,-1}$, $\tilde{\Delta}^*_{H,-1}$, $\Pi_{H,-1}$, $\tilde{\Pi}^*_{H,-1}$, $\Delta_{w,-1}$, w_{-1}, analogous initial conditions for country F, and $R\tilde{E}R_{H,-1}$, $R\tilde{E}R_{F,-1}$, T_{-1}.

As in Schmitt-Grohe and Uribe [2005], we assume that the monetary authorities have been operating for an infinite number of periods and will honor commitments made in the past when choosing their optimal policies. This form of policy commitment is similar to the notion of optimality from a *timeless perspective* in the sense of Woodford [2003]

We define the Ramsey policy as the monetary policies under commitment which maximize the joint sum of intertemporal households' welfare for country H and country F. Formally, the Ramsey equilibrium is a set of 96 processes defined in the competitive equilibrium for $t \geq 0$ that maximize

$$\mathcal{W}_{World,0} = \mathcal{W}_{H,0} + \mathcal{W}_{F,0}$$

subject to the competitive equilibrium conditions (1)-(84) and the analogous of equations (1), (2)-(12), (84) for country F, $\forall t \succ -\infty$, given exogenous stochastic processes and the initial values of the variables listed above dated $t \prec 0$, as well as the values of the Lagrange multipliers associated with the constraints listed above dated $t \prec 0$.

	Number of breaks	Dates		
Euro area variables				
Output growth	0*			
Consumption expenditure growth	0*			
Investment growth	0*			
Producer price inflation	3*	1972Q4*	1984Q1*	1993Q2*
Consumer price inflation	3	1972Q4	1985Q1*	1994Q1
Real wage growth	0*			
Nominal short-term interest rate	1*			1995Q4*
ROW variables				
Output growth	0*			
Consumer price inflation	0*			
Relative oil price	0*			
Nominal short-term interest rate	1*			1991Q3*

Note: * indicates robustness to a different parametrisation of the bandwidth used for the computation HAC variance.

The test does not allow for the break to be in the first or last 7 quarters and imposes at least 7 quarters between two breaks.

Tab. 3: **Alternative models 1: behavioral parameter estimates.**

Param.	*modified $r-type$* DSGE			*modified $r-type$* DSGE-VAR			*Bench. short sample* DSGE			*Bench. short sample* DSGE-VAR		
	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ϕ	4.76	4.01	5.44	4.40	3.66	5.24	4.27	3.56	5.02	4.16	3.40	4.88
φ	0.27	0.11	0.42	0.29	0.11	0.50	0.23	0.09	0.37	0.23	0.05	0.40
σ_C	0.49	0.22	0.78	1.07	0.45	1.62	1.29	0.73	1.80	1.31	0.77	1.85
σ_C^*	1.30	0.72	1.78	1.19	0.67	1.63	1.23	0.73	1.73	1.13	0.60	1.65
h	0.85	0.80	0.91	0.79	0.68	0.89	0.81	0.73	0.90	0.77	0.68	0.87
h^*	0.82	0.73	0.91	0.81	0.71	0.92	0.79	0.68	0.91	0.75	0.61	0.90
σ_L	1.28	0.59	1.99	2.01	0.79	3.12	1.37	0.60	2.07	1.83	0.67	2.92
α_H	0.94	0.93	0.96	0.90	0.87	0.93	0.94	0.93	0.96	0.88	0.85	0.92
α_F^*	0.77	0.73	0.82	0.68	0.61	0.76	0.74	0.68	0.79	0.72	0.63	0.80
γ_H	0.36	0.20	0.53	0.37	0.19	0.55	0.49	0.30	0.68	0.37	0.18	0.57
γ_F^*	0.60	0.45	0.75	0.37	0.17	0.54	0.56	0.39	0.74	0.33	0.16	0.49
α_w	0.88	0.84	0.91	0.80	0.75	0.85	0.84	0.81	0.88	0.77	0.71	0.83
ξ_w	0.40	0.21	0.59	0.33	0.16	0.49	0.34	0.16	0.50	0.29	0.12	0.45
λ_e	0.81	0.78	0.85	0.78	0.75	0.82	0.78	0.74	0.82	0.76	0.71	0.80
ρ	0.86	0.82	0.89	0.79	0.74	0.85	0.83	0.79	0.88	0.77	0.71	0.85
ρ^*	0.91	0.88	0.93	0.88	0.85	0.90	0.92	0.92	0.92	0.87	0.84	0.91
r_π	1.47	1.33	1.63	1.44	1.32	1.60	1.48	1.31	1.65	1.47	1.31	1.62
r_π^*	1.38	1.21	1.55	1.47	1.31	1.64	1.41	1.26	1.56	1.49	1.32	1.65
$r_{\Delta\pi}$	0.22	0.16	0.30	0.26	0.17	0.33	0.23	0.14	0.33	0.23	0.14	0.32
$r_{\Delta\pi}^*$	0.10	0.07	0.13	0.13	0.10	0.16	0.09	0.06	0.12	0.14	0.10	0.19
r_Y	0.09	0.04	0.13	0.08	0.04	0.13	0.09	0.03	0.14	0.09	0.04	0.14
r_Y^*	0.21	0.13	0.29	0.14	0.07	0.21	0.16	0.08	0.24	0.12	0.05	0.19
$r_{\Delta Y}$	0.19	0.13	0.24	0.15	0.09	0.21	0.18	0.12	0.24	0.13	0.06	0.19
$r_{\Delta Y}^*$	0.30	0.24	0.36	0.29	0.22	0.36	0.31	0.23	0.39	0.26	0.15	0.36
ξ	0.23	0.14	0.31	0.30	0.16	0.43	0.26	0.16	0.36	0.29	0.17	0.43
η^*	0.27	0.13	0.41	0.21	0.06	0.38	0.20	0.07	0.33	0.16	0.00	0.29
η	0.67	0.52	0.82	0.51	0.33	0.72	0.79	0.67	0.91	0.78	0.63	0.96
α_{oil}	0.09	0.01	0.18	c	c	c	0.09	0.00	0.17	c	c	c
ω_r	0.94	0.89	1.00	0.97	0.93	1.00	0.83	0.71	0.95	0.83	0.72	0.95
λ_{DSGE}	-	-	-	1.87	1.60	2.13	-	-	-	2.38	2.04	2.75
$P_\lambda(\mathcal{Y})$	-1483			-1357.2			-932.8			-840.1		

Tab. 4: **Alternative models 2: estimated oil-input technology, behavioral parameter estimates.**

Param.	*Full sample.* DSGE			*Full sample.* DSGE-VAR			*Short sample* DSGE			*Short sample* DSGE-VAR		
	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$	Mean	$\mathcal{I}_1$	$\mathcal{I}_2$
ϕ	4.63	3.90	5.33	4.37	3.64	5.11	4.24	3.50	4.97	4.17	3.39	4.97
φ	0.27	0.10	0.43	0.25	0.07	0.42	0.28	0.10	0.45	0.23	0.06	0.39
σ_C	0.67	0.24	1.12	1.17	0.64	1.71	1.26	0.74	1.76	1.32	0.81	1.83
σ_C^*	1.27	0.74	1.77	1.25	0.69	1.81	1.23	0.69	1.72	1.13	0.59	1.66
h	0.86	0.82	0.91	0.81	0.74	0.90	0.82	0.75	0.89	0.77	0.67	0.87
h^*	0.83	0.74	0.91	0.79	0.67	0.92	0.79	0.68	0.89	0.75	0.60	0.91
σ_L	1.18	0.52	1.82	2.04	0.88	3.16	1.24	0.56	1.91	1.88	0.65	2.97
α_H	0.94	0.93	0.96	0.89	0.85	0.93	0.94	0.93	0.96	0.88	0.84	0.92
α_F^*	0.78	0.73	0.82	0.67	0.60	0.75	0.74	0.68	0.80	0.70	0.61	0.79
γ_H	0.37	0.21	0.54	0.35	0.15	0.55	0.49	0.31	0.68	0.36	0.17	0.55
γ_F^*	0.60	0.44	0.75	0.35	0.18	0.51	0.56	0.38	0.74	0.31	0.14	0.47
α_w	0.87	0.84	0.90	0.79	0.74	0.84	0.84	0.81	0.88	0.77	0.71	0.83
ξ_w	0.39	0.21	0.58	0.35	0.18	0.53	0.34	0.16	0.51	0.30	0.13	0.46
λ_e	0.81	0.78	0.85	0.78	0.74	0.82	0.79	0.74	0.83	0.76	0.71	0.81
ρ	1.47	1.31	1.64	1.46	1.29	1.63	1.48	1.32	1.65	1.48	1.32	1.65
ρ^*	1.37	1.21	1.54	1.46	1.30	1.61	1.40	1.22	1.56	1.48	1.31	1.63
r_π	0.21	0.15	0.28	0.26	0.18	0.33	0.23	0.14	0.32	0.23	0.14	0.33
r_π^*	0.10	0.07	0.13	0.15	0.10	0.19	0.09	0.05	0.12	0.14	0.09	0.18
$r_{\Delta\pi}$	0.86	0.82	0.90	0.79	0.73	0.85	0.83	0.78	0.88	0.78	0.71	0.85
$r_{\Delta\pi}^*$	0.91	0.88	0.93	0.87	0.84	0.90	0.91	0.89	0.94	0.88	0.84	0.91
r_Y	0.10	0.05	0.16	0.08	0.03	0.13	0.08	0.03	0.13	0.09	0.04	0.15
r_Y^*	0.21	0.13	0.30	0.14	0.06	0.21	0.16	0.08	0.24	0.13	0.05	0.20
$r_{\Delta Y}$	0.18	0.12	0.24	0.12	0.06	0.19	0.17	0.11	0.24	0.12	0.05	0.19
$r_{\Delta Y}^*$	0.30	0.23	0.36	0.29	0.20	0.37	0.31	0.23	0.39	0.26	0.15	0.35
ξ	0.23	0.14	0.32	0.27	0.16	0.38	0.27	0.16	0.36	0.29	0.16	0.41
η^*	0.28	0.13	0.43	0.20	0.02	0.36	0.21	0.08	0.34	0.18	0.00	0.32
η	0.68	0.55	0.83	0.55	0.35	0.75	0.78	0.65	0.91	0.77	0.59	0.96
α_{oil}	0.15	0.00	0.31	-	-	-	0.06	0.01	0.11	-	-	-
ω_r	0.81	0.72	0.90	0.85	0.75	0.95	0.84	0.73	0.95	0.84	0.73	0.96
θ_o	0.18	0.02	0.46	0.10	0.02	0.19	0.08	0.02	0.14	0.47	0.02	1.26
ξ_o	0.09	0.02	0.19	0.56	0.02	1.15	0.09	0.02	0.17	0.23	0.02	0.56
ω_C	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ω_Y	2E-03	0E+00	5E-03	5E-04	0E+00	1E-03	3E-03	1E-03	5E-03	2E-03	0E+00	5E-03
λ_{DSGE}	-	-	-	1.87	1.59	2.14	-	-	-	2.37	2.01	2.74
$P_\lambda(\mathcal{Y})$	-1488.3			-1356.3			-940.6			-851.3		

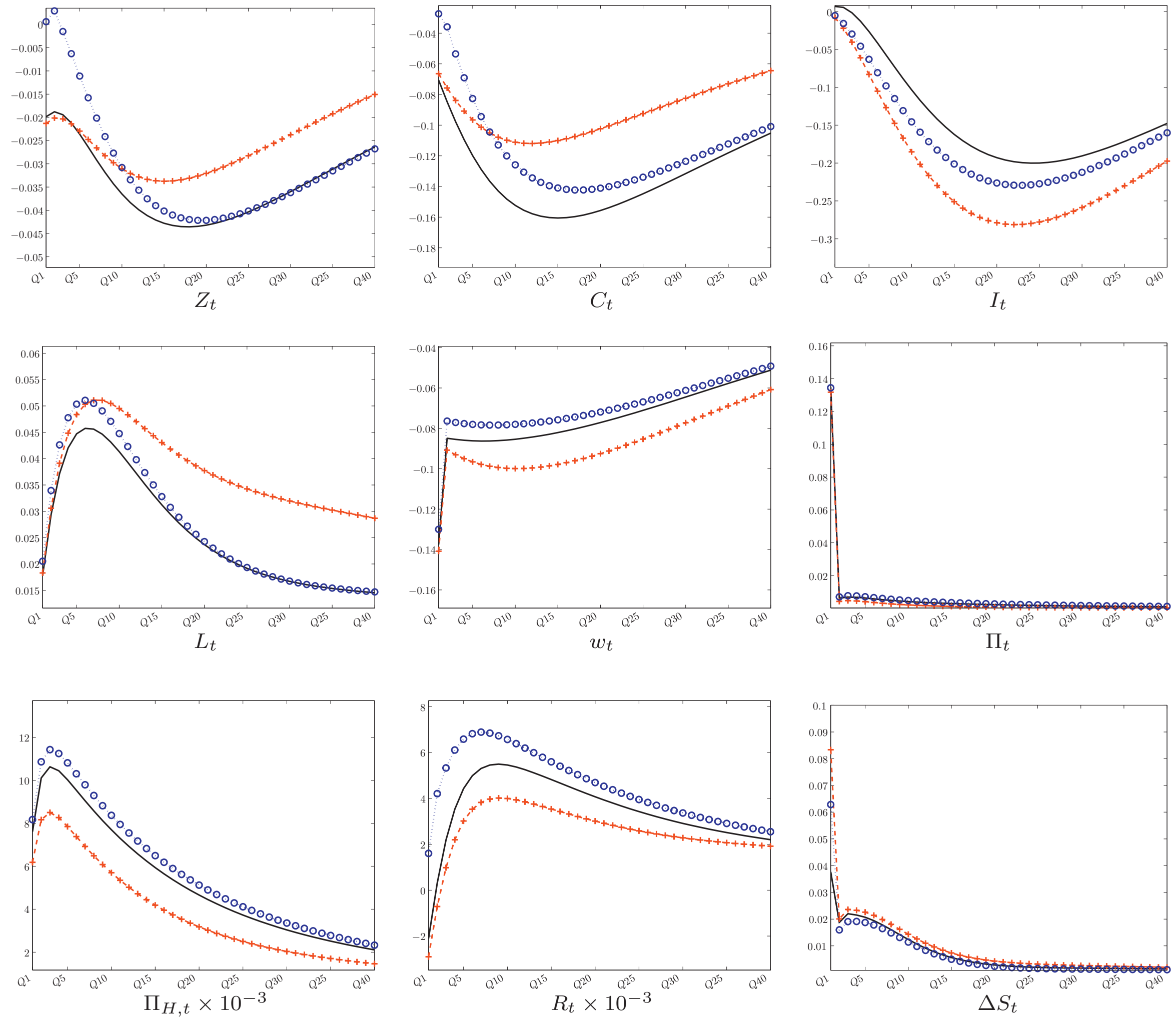


Fig. 7: Impulse Response Functions associated to a shock on $\epsilon^*_{oil,t}$. *Benchmark (plain lines), σ_C and h at their short-sample estimation values (dotted and cross lines), modified $r-type$ specification (dashed and circle lines).*

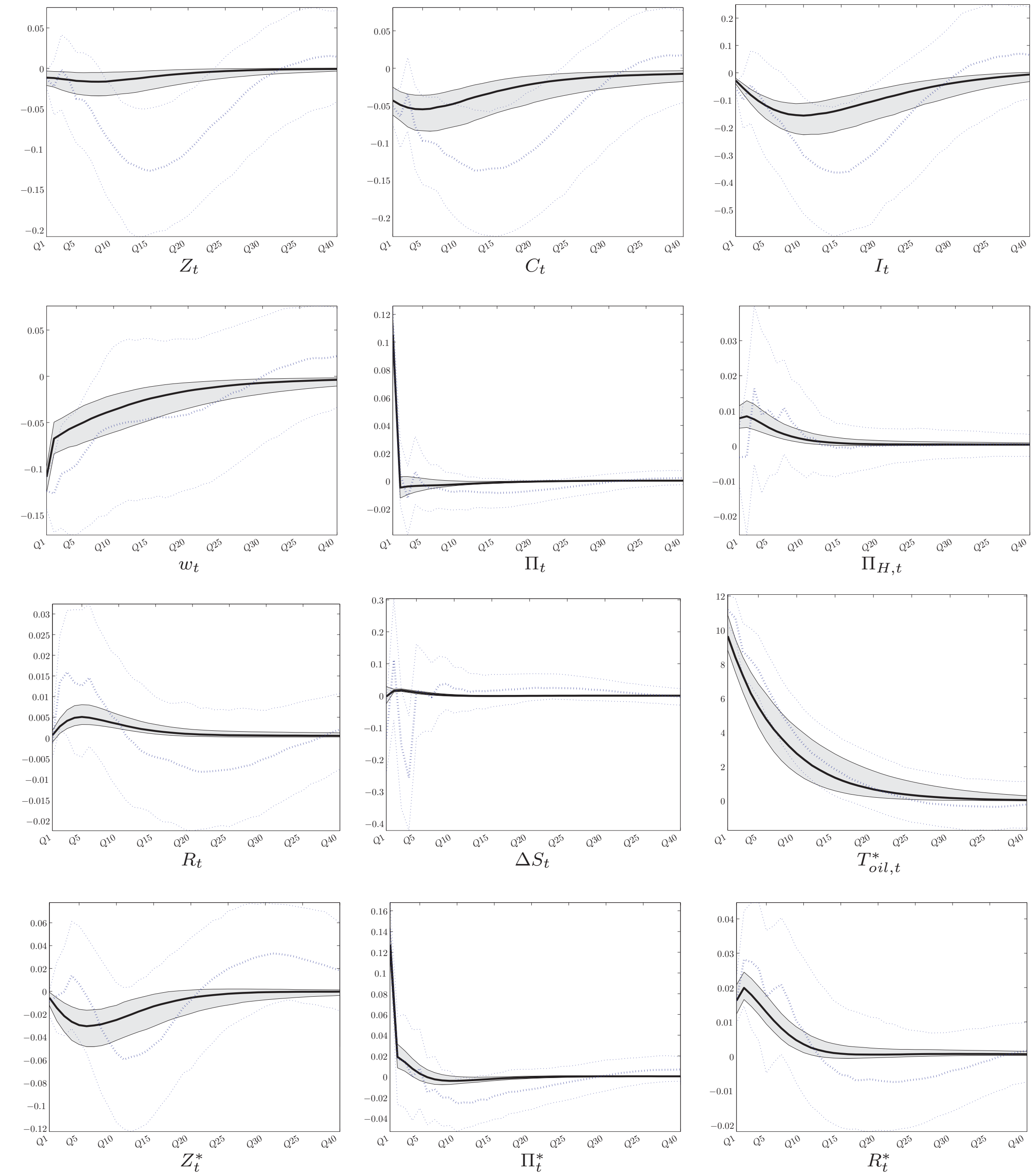


Fig. 8: Impulse Response Functions associated to a shock on $\epsilon^*_{oil,t}$. **Benchmark model**: *DSGE-VAR estimation*. *DSGE (plain lines and shaded areas), DSGE-VAR (dotted lines).*

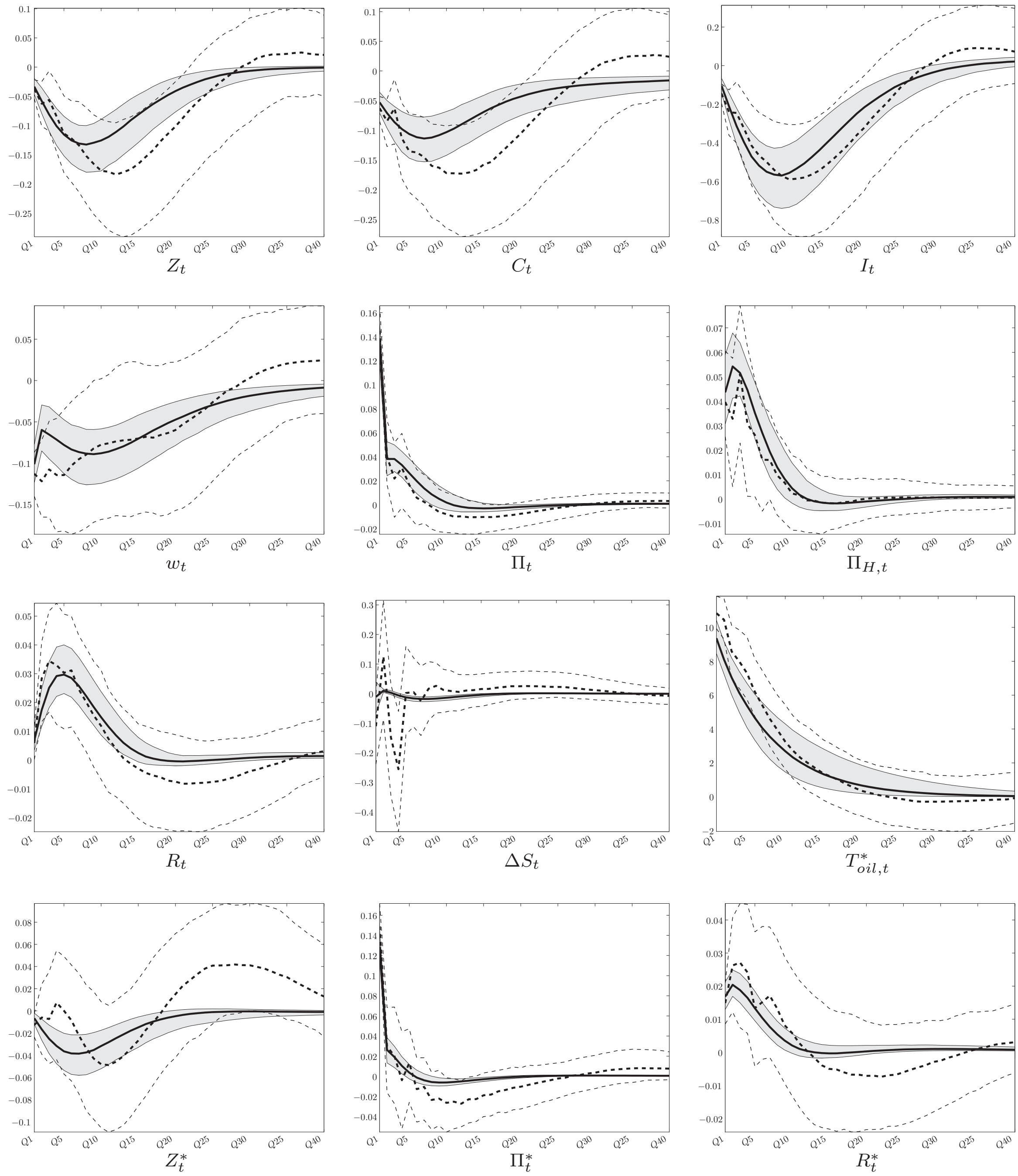


Fig. 9: Impulse Response Functions associated to a shock on $\epsilon^*_{oil,t}$. *DSGE (plain lines and shaded areas), DSGE-VAR (dotted lines): weak anchoring of private long term inflation expectations .*

Fig. 10: Contributions of historical oil price shocks to euro area macroeconomic aggregates 1.

EA output *(year on year growth, in %)*

Estimated rules *Optimal policy*

EA Consumption *(year on year growth, in %)*

Estimated rules *Optimal policy*

EA Investment *(year on year growth, in %)*

Estimated rules *Optimal policy*

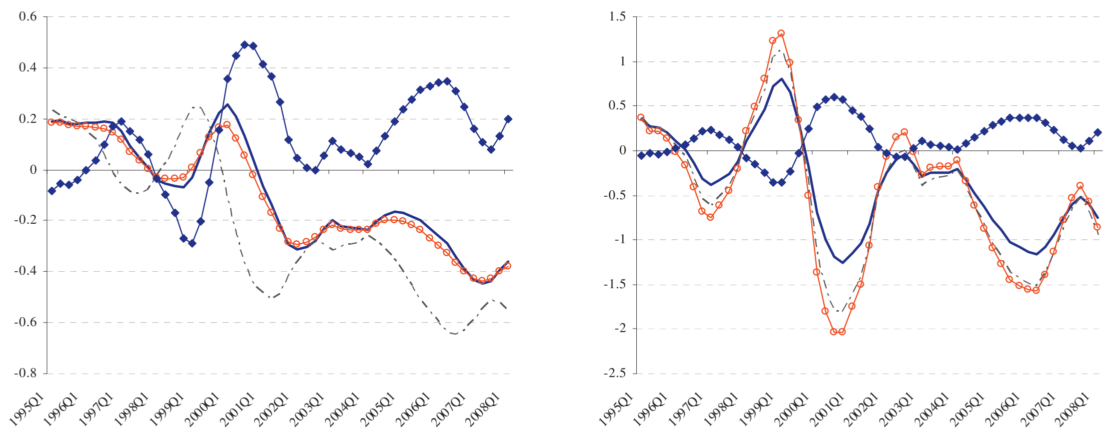
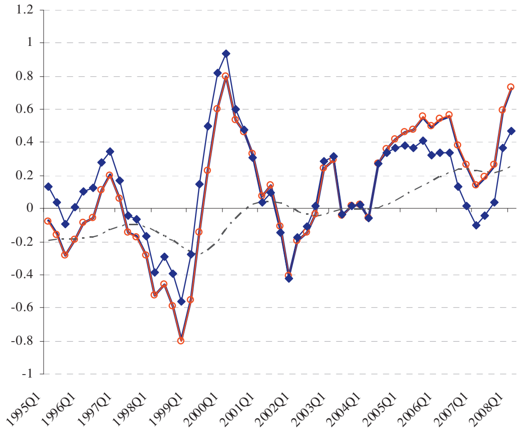


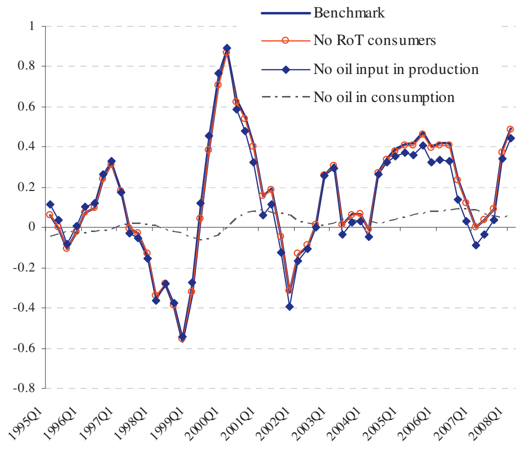
Fig. 11: Contributions of historical oil price shocks to euro area macroeconomic aggregates 2.

EA CPI *(year on year inflation, in %)*

Estimated rules

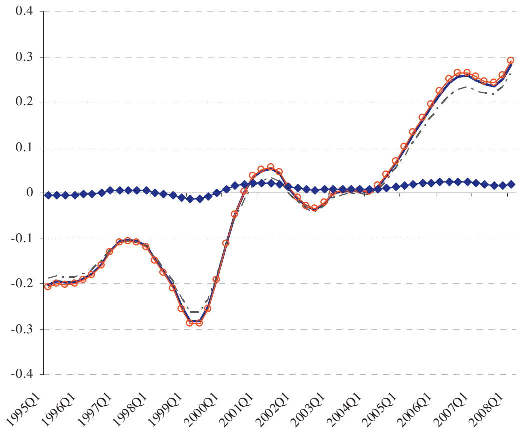


Optimal policy

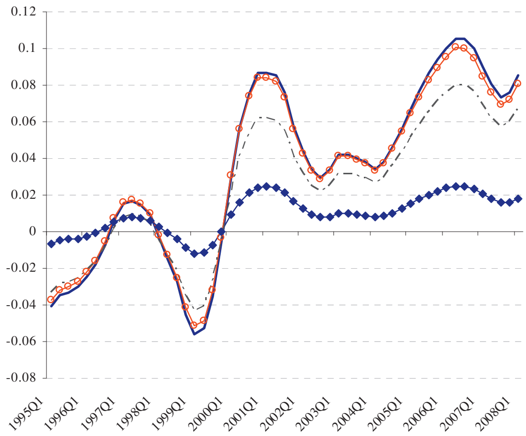


EA PPI *(year on year inflation, in %)*

Estimated rules

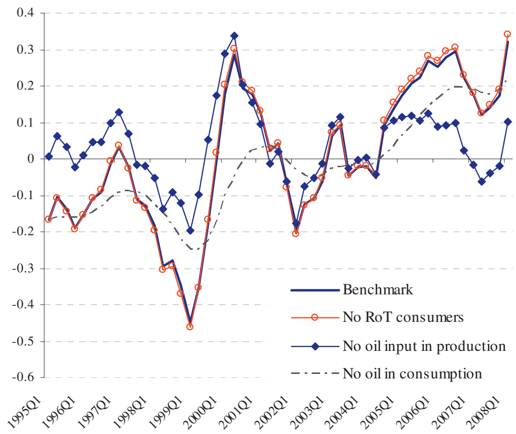


Optimal policy



EA Nominal Wages *(year on year inflation, in %)*

Estimated rules



Optimal policy

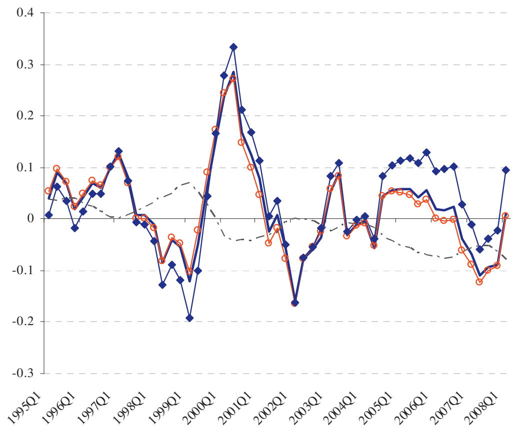
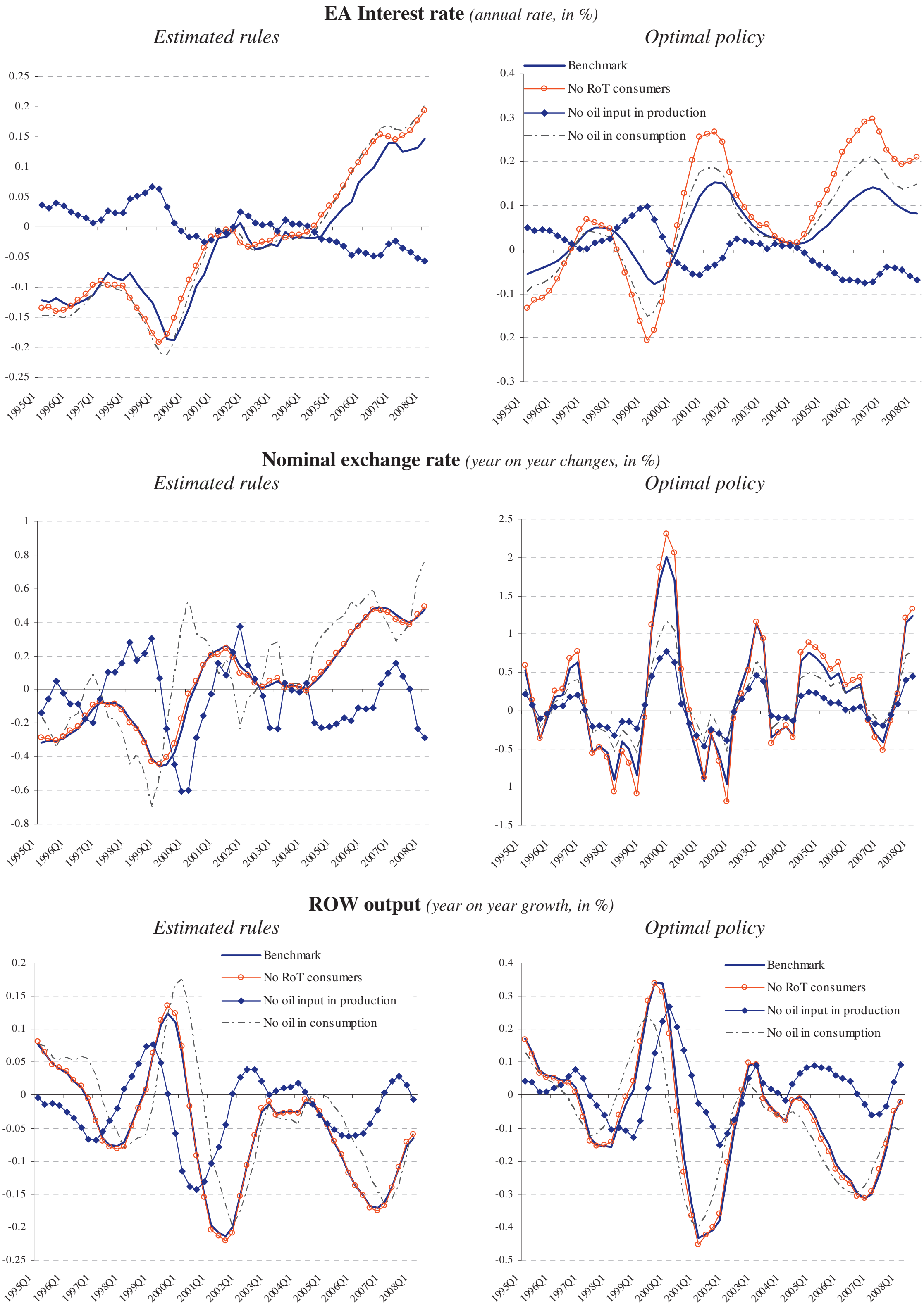


Fig. 12: Contributions of historical oil price shocks to euro area macroeconomic aggregates 3.



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