A Quantitative Perspective on Optimal Monetary Policy Cooperation between the US and the euro area*

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Comments welcome

Abstract

The objective of this paper is to examine the main features of optimal monetary policy cooperation within a micro-founded macroeconometric framework. First, using Bayesian techniques, we estimate a two-country dynamic stochastic general equilibrium (DSGE) model for the United States (US) and the euro area (EA). The main features of the new open economy macroeconomics (NOEM) are embodied in our framework: in particular, imperfect exchange rate pass-through and incomplete financial markets internationally. Each country model incorporates the wide range of nominal and real frictions found in the closed-economy literature: staggered price and wage settings, variable capital utilization and fixed costs in production. Then, using the estimated parameters and disturbances, we study the properties of the optimal monetary policy cooperation through welfare analysis, impulse responses and variance decompositions.

Keywords: DSGE models, Optimal monetary policy, New open economy macroeconomics, Bayesian estimation.

JEL classification: E4, E5, F4.

1 Introduction

The main objective of this paper is to analyze the design of optimal monetary cooperation between the US and the euro area, using an estimated two-country DSGE framework. In doing so, we intend to bring together the literature on optimal policy in estimated closed-economy models (like Levin et al. [2005] for the US or Adjémian et al. [2007] for the euro area) and papers estimating two-country models (like De Walque et al. [2005], Rabanal and Tuesta [2006], Bergin [2006] or Adolfson et al. [2005]). The focus of our study will then be on the implications of optimal policy for international business cycle properties.

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Recent advances in Bayesian estimation techniques make it possible to estimate relatively large structural Dynamic Stochastic General Equilibrium (DSGE) models. This paper first contributes to the empirical literature which makes advances in this direction by estimating a two-country DSGE model. Following the closed-economy work of Smets and Wouters [2003] the model embodies a larger range of frictions and shocks that improve the model's ability to capture the time series properties of the main macro-economic data. In addition, we use an explicit two-county US-euro area framework that allows for estimating and testing structural differences across the two areas. In contrast to the small open economy specification of Adolfson et al. [2005], it also allows for two-way economic and financial interaction between the two areas.

The model shares many features common in open-economy DSGE models. Exchange rate pass-through is incomplete due to some nominal rigidity in the buyer's currency. The specification is flexible enough to let the data discriminate between the polar cases of local-currency-pricing (LCP) and producer-currency-pricing (PCP). Financial markets are incomplete internationally and a risk premium on external borrowing is related to the net foreign asset position. Finally, even under flexible prices and wages, purchasing power parity does not hold due to a home bias in aggregate domestic demand. As in Christiano et al. [2005] we introduce a number of nominal and real frictions such as sticky prices, sticky wages, variable capital utilization costs and habit persistence. In addition, following Smets and Wouters [2003] a large set of structural shocks enters the model. The open economy dimension also requires additional disturbances. We add a shock to the uncovered interest rate parity condition (UIP) as it is usually done in the open economy literature, a preference shock on the relative home bias and two shocks to the distribution sector markups (affecting the CPI equations).

Obviously, the use of a two-country framework implies that the rest of the world is ignored. An alternative approach, pursued for example by De Walque et al. [2005], is to include a rest-of-the-word block which is designed to explicitly capture the role of third-market effects in the interaction between the euro area and the US. Such a rest-of-the-word block can also be used as a source of common shocks such as oil price shocks. Second, for comparison purposes, we tried to stick as closely as possible to the modelling framework of Smets and Wouters [2003], while at the same time introducing the most important New Open Economics Macroeconomics (NOEM) features. Of course, a number of important open economy features were not included such as the slow adjustment of import and export shares following expenditure switching shocks or the fact that import shares of different aggregate demand components may differ. As a result, given the relatively simple trade structure underlying our model, we did not explicitly include bilateral export and import quantities and prices in our set of macro variables to be used in the estimation. Empirically, the transmission channels of the various shocks that work through trade quantities and prices will be captured in a reduced form by their effects on relative aggregate demand, consumer versus producer prices and the current account. But a clear advantage of such a parsimonious specification of international frictions will be gained in the analysis of optimal monetary policy cooperation as it will become easier to understand the role of the few key parameters driving those international features on the design of optimal policy.

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. The numerical strategy is based on perturbation methods and is well-suited for our modeling framework, given the large number of state variables. This general method to derive the second-order approximation of the Ramsey solution allows us to depart from some widespread restrictions used in the literature to rely on undistorted non-stochastic steady state. In addition, contrary to the linear-quadratic approach of Benigno and Woodford [2006] which approximates the Ramsey problem by a linear quadratic one, the second-order approximation of the optimal allocation performed in this paper enables us in principle to depart from the certainty equivalence and analyze the effect of policies on the first moment of the state variables. In the paper, since we intend to focus on the macroeconomic stabilization properties of the optimal policy within a relatively sophisticated modeling framework, the constraint of efficient steady state is imposed to *ex ante* avoid creating additional policy tradeoffs due to the inefficient steady state and concentrate on the implications of the already rich structure of frictions and shocks on optimal monetary policy cooperation.

The original contributions of the paper, which to our knowledge constitutes the first analysis of optimal policy in an estimated two-country DSGE, cover several dimensions.

First, as in Adjémian et al. [2007], we incorporate the zero lower bound constraint into the analysis. In this respect, the optimal monetary policy cooperation is not operational given that it generated a high probability to tilt the zero bound. This result is of course related to the fact that we use an estimated two-country DSGE incorporating a full set of structural shocks. However, it turns out that, accounting for the zero lower bound has a marginal impact on welfare cost and on the stabilization properties of the optimal policy. In particular, when constraining the volatility of the policy instrument in the optimal allocation, the only second-order moment affected is the nominal exchange rate.

Second, we make a special effort to illustrate the empirical properties of the optimal allocation for the US and the euro area, focusing in particular on the driving factors of the Ramsey allocation dynamics compared with the one derived from using the estimated interest rate rules. We first compare some selected moments under the different policy regimes. Then we explore the structural decomposition of those moments and complement the analysis by looking at impulse response functions. This allows us to study the stabilization properties of the optimal policy across the different type of shocks.

Our conclusions on the business cycle properties of the optimal monetary policy cooperation are twofold. First of all, we confirm most of the results obtained in the closed-economy literature based on estimated medium-scale DGSE. The volatility in the optimal allocation is higher for real aggregates but lower for nominal variables than in the estimated model. The optimal policy is increasing the impact of supply shocks on activity while limiting the role of demand disturbances. On inflation, optimal stabilization only allows the markup shocks to generate fluctuations. Compared with the estimated Taylor rules, the optimal monetary policy cooperation features strong differences as regards the reaction to labor market shocks.

Moreover, concerning international business cycle dynamics, we show that the optimal policy significantly reduces the size of international spillovers on economic activity. More specifically, cross-country output correlation as well as the contribution of foreign shocks to domestic output fluctuations are much lower in the optimal allocation than in the estimated model: notably, the positive transmission on output of demand shocks is more limited or short-lived with the optimal policy whereas the negative transmission of labor market shocks is much stronger at short horizons.

In addition, while under the estimated rules, the conditional correlation between relative consumption and the real exchange rate is negative at all horizons (therefore accounting for the *consumption-real exchange rate anomaly*), the covariance is first positive and turns negative beyond the 5-year horizon in the optimal allocation. This is partly due to a less negative contribution of the home bias shock and more positive contributions of labor market shocks at horizons below three years under the optimal monetary policy cooperation.

Regarding exchange rate dynamics, volatility is higher in the optimal allocation despite the constraints introduced to limit the standard deviations of policy instruments. This reflects notably a more pronounced overshooting pattern of nominal exchange after labor market and preference shocks.

A final dimension of the paper also investigates whether some properties of optimal monetary policy cooperation found in some theoretical contributions (see for example Darracq Pariès [2007] or Benigno and Benigno [2006]) can be extended to more general modeling framework.

The rest of the paper is organized as follows. In section 2, the theoretical model is derived. Section 3 presents the simple cases for which the Ramsey problem associated with the optimal monetary cooperation can be formulated in a way illustrative of the implications of international price setting and international financial frictions in particular. Section 4 contains a short description of the data used, a discussion of parameter calibration and prior distributions, and then reports our estimation results. Section 5 explores the dynamic properties of the optimal monetary cooperation using the estimated model, focusing on propagation of shocks, variance decomposition and cross-country correlations. Finally, section 6 presents some sensitivity analysis along the dimension of the key open-economy parameters.

2 Theoretical model

The world economy is composed of two symmetric countries: Home and Foreign. In each country, there is a continuum of "single-good-firms" indexed on $[0, 1]$, 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.

Regarding domestic frictions, the model is mainly based on Christiano et al. [2005] and Smets and Wouters [2003]. The sophistication of modelling framework is first guided by the need to match a certain level data coherence, and in this respect, available studies point to an appropriate set of necessary frictions. However, we prefer to restrain this degree of sophistication in order to better understand the normative dimensions of the model, and in particular, we do not include non-tradables in this set-up. Therefore, we introduce in the model some relevant frictions to induce intrinsic persistence in the propagation of shocks, including adjustment costs on investment and capacity utilization, habit persistence and staggered nominal wage and price contracts with partial indexation.

Concerning international frictions, we assume that financial markets are complete domestically but incomplete internationally. Moreover export prices are sticky in the producer currency for a fraction of firms and in the buyer currency for the rest.

Finally, we specify a sufficient number of structural shocks in order to account for the stochastic properties of the observed data. Compared with the closed-economy models, we introduce a risk premium shock on the uncovered interest-rate parity, a preference shock on the degree of home bias in consumption and markup shocks affecting specifically the CPI inflation rates.

Concerning policy evaluation, the needed second-order numerical approximation implies that the exact nonlinear recursive formulation of the complete set of equilibrium conditions should be derived. This is specifically relevant for the equilibrium Phillips curves for prices and wages as well as the micro-foundations of the associated markup shocks. Similarly, two additional variables which are constant at a first-order approximation, now appear in the nonlinear setting, related to the measure of price and wage dispersion.

For the sake of clarity, most of the derivation will be pursued for country H. Analogous relations hold for country F.

2.1 Consumer's program

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

$$\mathcal{W}_t(h) = \mathbb{E}_t \left\{ \sum_{j \geq 0} \beta^j \left[\frac{1}{1-\sigma_C} \left(C^h_{t+j} - hC^h_{t+j-1} \right)^{1-\sigma_C} - \frac{\varepsilon^L_{t+j}\tilde{L}}{1+\sigma_L} \left(L^h_{t+j} \right)^{1+\sigma_L} \right] \varepsilon^B_{t+j} \right\}$$

Households obtain utility from consumption of a distribution good C^h_t (which also serves as an investment good), relative to an internal habit depending on past consumption, while receiving disutility from its labour services L^h_t. Utility also incorporates a consumption preference shock ε^B_t and a labor supply shock ε^L_t. $\tilde{L}$ is a positive scale parameter.

Financial markets are incomplete internationally. As assumed generally in the literature, Home households can trade two nominal risk-less bonds denominated in the domestic and foreign currency. A risk premium as a function of real holdings of the foreign assets in the entire economy, is introduced on international financing of Home consumption expenditures.

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

$$\frac{B^h_{H,t}}{\underline{P}_t R_t} + \frac{S_t B^h_{F,t}}{P_t R^*_t \varepsilon^{\Delta S}_t \Psi \left(\frac{\mathbb{E}_t S_{t+1}}{S_{t-1}} - 1, \frac{S_t \left(B_{F,t} - \overline{\overline{B}}_F \right)}{\underline{P}_t} \right)} + \frac{P_t}{\underline{P}_t} C^h_t + I^h_t = \frac{B^h_{H,t-1}}{\underline{P}_t} + \frac{S_t B^h_{F,t-1}}{\underline{P}_t}$$
$$+ \frac{(1-\tau_{W,t}) W^h_t L^h_t + A^h_t + TT^h_t}{\underline{P}_t} + R^k_t u^h_t K^h_t - \Phi\left(u^h_t\right) K^h_t + \frac{\Pi^h_t}{\underline{P}_t}$$

where W^h_t is the wage, A^h_t is a stream of income coming from state contingent securities, S_t is the nominal exchange rate, TT^h_t and $\tau_{W,t}$ are government transfers and time-varying labor tax respectively, and

$$R^k_t u^h_t K^h_t - \Phi\left(u^h_t\right) K^h_t$$

represents the real 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 and the cost of capacity utilization is zero when capacity are fully used ($\Phi(1) = 0$). Π^h_t are the dividends emanating from monopolistically competitive intermediate firms. Finally, $B^h_{H,t}$ and $B^h_{F,t}$ are the individuals holding of domestic and foreign bonds denominated in local currency. The risk premium function $\Psi(\bullet, \bullet)$ is differentiable, decreasing in both arguments and verifies $\Psi(0,0) = 1$. Here, like Adolfson et al. [2007], we expanded the usual specification of the risk premium found in the open economy literature by introducing a term depending on the expected change in the exchange rate. As shown for example in the empirical work of Duarte and Stockman [2005], the forward risk premium on exchange rate is strongly negatively correlated with the expected depreciation.

We also introduced a specific consumption tax which affect the price of the distributed goods serving final consumption (and not investment). 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 time-varying consumption tax could in principle rationalize the CPI inflation rate shocks that we will introduced to estimate the model but we will come back to this point later.

Finally, separability of preferences and complete financial markets domestically ensure that households have identical consumption plans.

The first order condition related to consumption expenditures is given by

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

where $\frac{\Lambda_t}{(1+\tau_{C,t})}$ is the lagrange multiplier associated with the budget constraint.

First order conditions corresponding to the quantity of contingent bonds imply that

$$\Lambda_t = R_t \beta \mathbb{E}_t \left[\Lambda_{t+1} \frac{P_t}{P_{t+1}}\right] \tag{2}$$

$$\Lambda_t = R_t^* \varepsilon_t^{\Delta S} \Psi\left(\frac{\mathbb{E}_t S_{t+1}}{S_{t-1}} - 1, \frac{S_t\left(B_{F,t} - \overline{\overline{B}}_F\right)}{\underline{P}_t}\right) \beta \mathbb{E}_t \left[\Lambda_{t+1} \frac{S_{t+1} P_t}{S_t P_{t+1}}\right]$$

where R_t and R_t^* are one-period-ahead nominal interest rates for country H and F respectively.

The previous equations imply an arbitrage condition on bond prices which corresponds to a modified uncovered interest rate parity (UIP):

$$\frac{R_t}{R_t^* \varepsilon_t^{\Delta S} \Psi\left(\frac{\mathbb{E}_t S_{t+1}}{S_{t-1}} - 1, \frac{S_t\left(B_{F,t} - \overline{\overline{B}}_F\right)}{\underline{P}_t}\right)} = \frac{\mathbb{E}_t \left[\Lambda_{t+1} \frac{S_{t+1} P_t}{S_t P_{t+1}}\right]}{\mathbb{E}_t \left[\Lambda_{t+1} \frac{P_t}{P_{t+1}}\right]} \tag{3}$$

where $\varepsilon_t^{\Delta S}$ is a unitary-mean disturbance affecting the risk premium.

Note that the equivalent arbitrage condition for country F is

$$\frac{\varepsilon_t^{\Delta S} R_t^*}{R_t \Psi\left(1 - \frac{\mathbb{E}_t S_{t+1}}{S_{t-1}}, \frac{\left(B_{H,t}^* - \overline{\overline{B}}_H\right)}{S_t \underline{P}_t^*}\right)} = \frac{\mathbb{E}_t \left[\Lambda_{t+1}^* \frac{S_t P_t^*}{S_{t+1} P_{t+1}^*}\right]}{\mathbb{E}_t \left[\Lambda_{t+1}^* \frac{P_t^*}{P_{t+1}^*}\right]}$$

Thereafter, the functional forms used for the risk premium and for the adjustment costs on capacity utilization are given by

$$\Psi(X,Y) = \exp\left(-\chi_{\Delta S} X - 2\chi Y\right) \text{ and } \Phi(X) = \frac{\overline{\overline{R^k}}}{\varphi}\left(\exp\left[\varphi\left(X-1\right)\right] - 1\right).$$

2.2 Labor supply and wage setting

In country H, each household is a monopoly supplier of a differentiated labor service. For the sake of simplicity, we assume that he sells his services to a perfectly competitive firm which transforms it into an aggregate labor input using a CES 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 household faces a labor 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.

Households set their wage on a staggered basis. Each period, any household faces a constant probability $1 - \alpha_w$ of optimally adjusting its nominal wage, say $\widetilde{W}_t(h)$, 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 $\Pi_t = \frac{P_t}{P_{t-1}}$. Taking into account that they might not be able to choose their nominal wage optimally in a near future, $\widetilde{W}_t(h)$ is chosen to maximize the intertemporal utility under the budget constraint and the labor demand for wage setters unable to re-optimize after period t:

$$L_{t+j}(h) = \left(\frac{\widetilde{W}_t(h)}{P_t}\right)^{-\frac{\mu_w}{\mu_w-1}} \left(\frac{P_t}{P_{t+j}} \left[\frac{P_{t-1+j}}{P_{t-1}}\right]^{\xi_w} \left[\overline{\Pi}\right]^{j(1-\xi_w)}\right)^{-\frac{\mu_w}{\mu_w-1}} \left(\frac{W_{t+j}}{P_{t+j}}\right)^{\frac{\mu_w}{\mu_w-1}} L_{t+j}$$

The first order condition of this program can be written recursively as follows:

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

$$\mathcal{H}^w_{1,t} = \varepsilon^B_t \varepsilon^L_t \widetilde{L} L_t^{1+\sigma_L} \left[\frac{w_t}{1+\tau_{C,t}}\right]^{\frac{(1+\sigma_L)\mu_w}{\mu_w-1}} + \alpha_w \beta \mathbb{E}_t \left[\left(\frac{\Pi_{t+1}}{\Pi_t^{\xi_w} \left[\overline{\Pi}\right]^{1-\xi_w}}\right)^{\frac{(1+\sigma_L)\mu_w}{\mu_w-1}} \mathcal{H}^w_{1,t+1}\right] \tag{4}$$

$$\mathcal{H}^w_{2,t} = (1 - \tau_{w,t}) \Lambda_t L_t \left[\frac{w_t}{1+\tau_{C,t}}\right]^{\frac{\mu_w}{\mu_w-1}} + \alpha_w \beta \mathbb{E}_t \left[\left(\frac{\Pi_{t+1}}{\Pi_t^{\xi_w} \left[\overline{\Pi}\right]^{1-\xi_w}}\right)^{\frac{1}{\mu_w-1}} \mathcal{H}^w_{2,t+1}\right] \tag{5}$$

where w_t denotes the aggregate real wage (measured with the before-tax CPI), and the time-varying income tax is given by $1 - \tau_{w,t} = \left(1 - \overline{\overline{\tau}}_w\right) \varepsilon^W_t$.

Finally, the aggregate wage dynamics is given by.

$$\left[\frac{w_t}{1+\tau_{C,t}}\right]^{\frac{1}{1-\mu_w}} = (1 - \alpha_w) \left(\mu_w \frac{\mathcal{H}^w_{1,t}}{\mathcal{H}^w_{2,t}}\right)^{-\frac{1}{\mu_w(1+\sigma_l)-1}} + \alpha_w \left[\frac{w_{t-1}}{1+\tau_{C,t-1}}\right]^{\frac{1}{1-\mu_w}} \left(\frac{\Pi_t}{\Pi_{t-1}^{\xi_w} \overline{\Pi}^{1-\xi_w}}\right)^{\frac{-1}{1-\mu_w}} \tag{6}$$

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

$$\frac{(1+\tau_{C,t})\, \mu_w}{(1\text{-}\tau_{w,t})} \varepsilon^B_t \varepsilon^L_t \tilde{L} L_t^{\sigma_l} = \Lambda_t w_t$$

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

2.3 Investment decisions

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

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

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.

This results in the following first order conditions, where $\frac{\Lambda_t}{(1+\tau_{C,t})}Q_t$ is the lagrange multiplier associated with the capital accumulation equation:

$$Q_t = \mathbb{E}_t \left[\beta \frac{\Lambda_{t+1}}{\Lambda_t} \frac{1+\tau_{C,t}}{1+\tau_{C,t+1}} \left(Q_{t+1}(1-\delta) + R_{t+1}^k u_{t+1} - \Phi(u_{t+1})\right)\right] \varepsilon_t^Q \tag{8}$$

$$\begin{aligned} & Q_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right) - \frac{I_t}{I_{t-1}} S'\left(\frac{I_t}{I_{t-1}}\right)\right] \varepsilon_t^I \\ +\beta \mathbb{E}_t & \left[Q_{t+1} \frac{\Lambda_{t+1}}{\Lambda_t} \frac{1+\tau_{C,t}}{1+\tau_{C,t+1}} \left(\frac{I_{t+1}}{I_t}\right)^2 S'\left(\frac{I_{t+1}}{I_t}\right) \varepsilon_{t+1}^I\right] = 1 \end{aligned} \tag{9}$$

$$R_t^k = \Phi'(u_t) \tag{10}$$

We follow Smets and Wouters [2003] by introducing an *ad hoc* shock ε_t^Q accounting for fluctuations of the external finance risk premium. 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.

2.4 Optimal risk sharing

It is worth examining the case of complete asset market structure because our definition of the flexible price equilibrium will assume that financial markets are also complete internationally. In that case, households in both countries are allowed to trade in the contingent one-period nominal bonds denominated in the home currency. This leads to the following risk sharing condition:

$$\frac{\Lambda_t^*}{\Lambda_t} = \kappa RER_t$$

where $RER_t = \frac{S_t P_t^*}{P_t}$ is the real exchange rate and $\kappa = \frac{\Lambda_0^*}{RER_0 \Lambda_0}$ (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.

When markets are complete, it is no use evaluating the current account path in order to determine the relative consumption dynamics. Consumption levels in both countries differ only to the extent that the real exchange rate deviates from purchasing power parity (PPP). In our model, those deviations are allowed for by two assumptions. The first one is the preference bias for locally produced goods, implying that the real exchange rate depends on the terms of trade. The second one is the possibility that prices might not be denominated in the producer currency, which generates failures of the law of one price.

2.5 Distribution sector

A continuum of companies operating under perfect competition mixes local production with imports. There is a home bias in the aggregation, which pins down the degree of openness at steady state. The distributor technology, $\forall i \in [0,1]$, is given by

$$Y_i = \left[n_t^{\frac{1}{\xi}} Y_{i,H}^{\frac{\xi-1}{\xi}} + (1-n_t)^{\frac{1}{\xi}} Y_{i,F}^{\frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}}$$

$$Y_i^* = \left[(1-n_t^*)^{\frac{1}{\xi}} \, Y_{i,H}^{*\,\frac{\xi-1}{\xi}} + n_t^{*\frac{1}{\xi}} Y_{i,F}^{*\,\frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}}$$

ξ is the elasticity of substitution between bundles Y_H and Y_F. The degrees of home bias are subject to shocks. But as only the difference of openness rates enters the linearized aggregate equations in absence of adjustment costs on imports, home bias shocks are given by $n_t = n\sqrt{\varepsilon_t^{\Delta n}}$ and $n_t^* = \frac{n}{\sqrt{\varepsilon_t^{\Delta n}}}$.

Cost minimization determines import demands.

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

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

where 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 $T_F^* = \frac{P_F^*}{\underline{P}^*}$.

2.6 Final goods sector

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 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 $P_F = \left[\int_0^1 p(f)^{\frac{1}{1-\mu}} \mathrm{d}f\right]^{1-\mu}$. And domestic demand is allocated across the differentiated goods as follows

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

2.7 Intermediate firms

On the supply side, goods are produced with a Cobb-Douglas technology as follows:

$$\begin{cases} \forall h \in [0,1], \quad Y_t(h) = \varepsilon_t^A \left(u_t K_{t-1}(h)\right)^{\alpha} L_t(h)^{1-\alpha} - \Omega \\ \forall f \in [0,1], \quad Y_t^*(f) = \varepsilon_t^{A*} \left(u_t^* K_{t-1}^*(f)\right)^{\alpha} L_t^*(f)^{1-\alpha} - \Omega \end{cases}$$

where ε_t^A and ε_t^{A*} are exogenous technology parameters. Each firm sells its products in the local market and in the foreign market. We denote $Y_H(h)$ and $Y_H^*(h)$ (respectively $Y_F^*(f)$ and $Y_F(f)$) the local and foreign sales of domestic producer h (respectively foreign producer f) and we define $L_H(h)$ and $L_H^*(h)$ (respectively $L_F^*(f)$ and $L_F(f)$) the corresponding labor demand.

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 a 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:

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

As the distribution of prices among the share α_H of producers unable to re-optimize at t is similar to the one at $t-1$, the aggregate price index has the following dynamics:

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

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

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

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

$\Xi_{t,t+j} = \beta^j \frac{\Lambda_{t+j} P_t}{\Lambda_t P_{t+j}}$ is the marginal value of one unit of money to the household. 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.

$$MC_t = \frac{w_t^{(1-\alpha)} R_t^{k\alpha}}{\varepsilon_t^A \alpha^\alpha (1-\alpha)^{(1-\alpha)} T_{H,t}} \tag{11}$$

In our model, all firms that can re-optimize their price at time t choose the same level.

The first order condition associated with the firm's choice of $\hat{p}_t(h)$ is

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

This price setting scheme can be written in the following recursive form $\frac{\hat{p}_t(h)}{P_{H,t}} = \mu \frac{Z_{H1,t}}{Z_{H2,t}}$ where

$$\mathcal{Z}_{H1,t} = \Lambda_t MC_t Y_{H,t} \frac{T_{H,t}}{1+\tau_{C,t}} + \alpha_H \beta \mathbb{E}_t \left[\left(\frac{\Pi_{H,t+1}}{\Pi_{H,t}^{\gamma_H} \overline{\Pi}^{1-\gamma_H}} \right)^{\frac{\mu}{\mu-1}} \mathcal{Z}_{H1,t+1} \right] \tag{12}$$

and

$$\mathcal{Z}_{H2,t} = (1-\tau_t) \Lambda_t Y_{H,t} \frac{T_{H,t}}{1+\tau_{C,t}} + \alpha_H \beta \mathbb{E}_t \left[\left(\frac{\Pi_{H,t+1}}{\Pi_{H,t}^{\gamma_H} \overline{\Pi}^{1-\gamma_H}} \right)^{\frac{1}{\mu-1}} \mathcal{Z}_{H2,t+1} \right] \tag{13}$$

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

$$1 = \alpha_H \left(\frac{\Pi_{H,t}}{\Pi_{H,t-1}^{\gamma_H} \overline{\Pi}^{1-\gamma_H}} \right)^{\frac{1}{\mu-1}} + (1-\alpha_H) \left(\mu \frac{\mathcal{Z}_{H1,t}}{\mathcal{Z}_{H2,t}} \right)^{\frac{1}{1-\mu}} \tag{14}$$

When the probability of being able to change prices tends towards unity, this implies that the firm sets its price equal to a markup $\frac{\mu}{(1-\tau_t)}$ over marginal cost. The time varying tax on firms' revenue is affected by an i.i.d shock defined by $1-\tau_t = \left(1-\overline{\overline{\tau}}\right) \varepsilon_t^P$.

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

$$\mathcal{Z}^*_{F1,t} = \Lambda^*_t MC^*_t Y^*_{F,t} \frac{T^*_{F,t}}{1+\tau^*_{C,t}} + \alpha^*_F \beta \mathbb{E}_t \left[\left(\frac{\Pi^*_{F,t+1}}{\Pi^{*\gamma^*_F}_{F,t} \overline{\Pi}^{*1-\gamma^*_F}} \right)^{\frac{\mu}{\mu-1}} \mathcal{Z}^*_{F1,t+1} \right] \tag{15}$$

$$\mathcal{Z}^*_{F2,t} = (1-\tau^*_t) \Lambda^*_t Y^*_{F,t} \frac{T^*_{F,t}}{1+\tau^*_{C,t}} + \alpha^*_F \beta \mathbb{E}_t \left[\left(\frac{\Pi^*_{F,t+1}}{\Pi^{*\gamma^*_F}_{F,t} \overline{\Pi}^{*1-\gamma^*_F}} \right)^{\frac{1}{\mu-1}} \mathcal{Z}^*_{F2,t+1} \right] \tag{16}$$

and

$$1 = \alpha^*_F \left(\frac{\Pi^*_{F,t}}{\Pi^{*\gamma^*_F}_{F,t-1} \overline{\Pi}^{*1-\gamma^*_F}} \right)^{\frac{1}{\mu-1}} + (1-\alpha^*_F) \left(\mu \frac{\mathcal{Z}^*_{F1,t}}{\mathcal{Z}^*_{F2,t}} \right)^{\frac{1}{1-\mu}} \tag{17}$$

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

$$MC^*_t = \frac{W^{*(1-\alpha)}_t R^{k*\alpha}_t}{\varepsilon^{A*}_t \alpha^\alpha (1-\alpha)^{(1-\alpha)} T^*_F} \tag{18}$$

Similarly, the time varying tax on firms' revenue is affected by an i.i.d shock defined by $1 - \tau^*_t = \left(1 - \overline{\overline{\tau}}\right) \varepsilon^{P*}_t$.

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). Consequently, aggregate export prices denominated in foreign currency are given by

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

The aggregate LCP export price indexes are accordingly defined as

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

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 $RER_F = \frac{P_F}{SP^*_F}$. If there is some form of international price discrimination, those ratios figure the relative profitability of foreign sales compared with the local ones.

LCP exporters also set their prices on a staggered basis and features of nominal rigidities are the same as for the local producers.

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

$$\tilde{\mathcal{Z}}^*_{H1,t} = \Lambda_t MC_t Y^*_{H,t} \frac{T_{H,t}}{1+\tau_{C,t}} + \alpha^*_F \beta \mathbb{E}_t \left[\left(\frac{\tilde{\Pi}^*_{H,t+1}}{\tilde{\Pi}^{*\gamma^*_F}_{H,t} \overline{\Pi}^{1-\gamma^*_F}} \right)^{\frac{\mu}{\mu-1}} \tilde{\mathcal{Z}}^*_{H1,t+1} \right] \tag{19}$$

$$\tilde{\mathcal{Z}}^*_{H2,t} = (1-\tau_t) \Lambda_t Y^*_{H,t} \frac{T_{H,t}}{1+\tau_{C,t}} R\tilde{E}R_{H,t} + \alpha^*_F \beta \mathbb{E}_t \left[\left(\frac{\tilde{\Pi}^*_{H,t+1}}{\tilde{\Pi}^{*\gamma^*_F}_{H,t} \overline{\Pi}^{1-\gamma^*_F}} \right)^{\frac{1}{\mu-1}} \tilde{\mathcal{Z}}^*_{H2,t+1} \right] \tag{20}$$

$$1 = \alpha^*_F \left(\frac{\tilde{\Pi}^*_{H,t}}{\tilde{\Pi}^{*\gamma^*_F}_{H,t-1} \overline{\Pi}^{1-\gamma^*_F}} \right)^{\frac{1}{\mu-1}} + (1-\alpha^*_F) \left(\mu \frac{\tilde{\mathcal{Z}}^*_{H1,t}}{\tilde{\mathcal{Z}}^*_{H2,t}} \right)^{\frac{1}{1-\mu}} \tag{21}$$

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

$$\tilde{\mathcal{Z}}_{F1,t} = \Lambda^*_t MC^*_t Y_{F,t} \frac{T^*_{F,t}}{1+\tau^*_{C,t}} + \alpha_H \beta \mathbb{E}_t \left[\left(\frac{\tilde{\Pi}_{F,t+1}}{\tilde{\Pi}^{\gamma_H}_{F,t} \overline{\Pi}^{*1-\gamma_H}} \right)^{\frac{\mu}{\mu-1}} \tilde{Z}_{F1,t+1} \right] \tag{22}$$

$$\tilde{\mathcal{Z}}_{F2,t} = (1-\tau^*_t) \Lambda^*_t Y_{F,t} \frac{T^*_{F,t}}{1+\tau^*_{C,t}} R\tilde{E}R_{F,t} + \alpha_H \beta \mathbb{E}_t \left[\left(\frac{\tilde{\Pi}_{F,t+1}}{\tilde{\Pi}^{\gamma_H}_{F,t} \overline{\Pi}^{*1-\gamma_H}} \right)^{\frac{1}{\mu-1}} \tilde{Z}_{F2,t+1} \right] \tag{23}$$

$$1 = \alpha_H \left(\frac{\tilde{\Pi}_{F,t}}{\tilde{\Pi}^{\gamma_H}_{F,t-1} \overline{\Pi}^{*1-\gamma_H}} \right)^{\frac{1}{\mu-1}} + (1-\alpha_H) \left(\mu \frac{\tilde{\mathcal{Z}}_{F1,t}}{\tilde{\mathcal{Z}}_{F2,t}} \right)^{\frac{1}{1-\mu}} \tag{24}$$

Moreover, cost minimization implies that capital labor ratio are equalized across firms in each country. Aggregate capital labor ratios are therefore given by

$$\frac{w_t L_t}{R^k_t u_t K_{t-1}} = \frac{1-\alpha}{\alpha} \tag{25}$$

and

$$\frac{w^*_t L^*_t}{R^{k*}_t u^*_t K^*_{t-1}} = \frac{1-\alpha}{\alpha} \tag{26}$$

2.8 Government

In country H, public expenditures $\overline{\overline{G}}$ are subject to random shocks ε^G_t. The government finances public spending with the 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 deviations of lagged inflation and the lagged output gap defined as the difference between actual and flexible-price output. Such reaction functions also incorporate a non-systematic component ε_t^R.In an open economy framework, the choice of the price deflator in the reaction function remains an issue. In the benchmark model, we assumed that monetary authorities target domestic objectives: the domestic detrended output and CPI inflation rate.

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

$$r_t = \rho r_{t-1} + (1-\rho)\left[r_\pi \pi_{t-1} + r_y z_{t-1}\right] + r_{\Delta\pi}\Delta\pi_t + r_{\Delta y}\Delta z_t + \log\left(\varepsilon_t^R\right) \tag{27}$$

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

2.9 Market clearing conditions

Aggregate domestic demands are given by

$$Y_t = C_t + I_t + \overline{\overline{G}}\varepsilon_t^G + \Phi(u_t) K_{t-1} \tag{28}$$

$$Y_t^* = C_t^* + I_t^* + \overline{\overline{G}}\varepsilon_t^{G*} + \Phi(u_t^*) K_{t-1}^* \tag{29}$$

where K_t and K_t^* are the aggregate capital stocks.

Aggregate productions verify

$$Z_t = \varepsilon_t^A (u_t K_{t-1})^\alpha (L_t)^{1-\alpha} - \Omega \tag{30}$$

$$Z_t^* = \varepsilon_t^{A*} \left(u_t^* K_{t-1}^*\right)^\alpha (L_t^*)^{1-\alpha} - \Omega \tag{31}$$

where L_t and L_t^* are the labour input.

Market clearing conditions in goods markets lead to the following relations

$$Z_t = n_t \Delta_{H,t} (T_{H,t})^{-\xi} Y_t + (1-n_t^*)\Delta_{H,t}^* \left(\frac{T_{F,t}^*}{T_t^*}\right)^{-\xi} Y_t^* \tag{32}$$

$$Z_t^* = n_t^* \Delta_{F,t}^* \left(T_{F,t}^*\right)^{-\xi} Y_t^* + (1-n_t)\Delta_{F,t} (T_t T_{H,t})^{-\xi} Y_t \tag{33}$$

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

$$\Delta_{H,t} = (1-\alpha_H)\left(\mu\frac{\mathcal{Z}_{H1,t}}{\mathcal{Z}_{H2,t}}\right)^{-\frac{\mu}{\mu-1}} + \alpha_H \Delta_{H,t-1}\left(\frac{\Pi_{H,t}}{\Pi_{H,t-1}^{\gamma_H}\overline{\Pi}^{1-\gamma_H}}\right)^{\frac{\mu}{\mu-1}} \tag{34}$$

$$\Delta_{F,t}^* = (1-\alpha_F^*)\left(\mu\frac{\mathcal{Z}_{F1,t}^*}{\mathcal{Z}_{F2,t}^*}\right)^{-\frac{\mu}{\mu-1}} + \alpha_F^* \Delta_{F,t-1}^*\left(\frac{\Pi_{F,t}^*}{\Pi_{F,t-1}^{*\gamma_F^*}\overline{\Pi}^{*1-\gamma_F^*}}\right)^{\frac{\mu}{\mu-1}} \tag{35}$$

$$\Delta^*_{H,t} = \eta \Delta_{H,t} + (1-\eta)\,\tilde{\Delta}^*_{H,t} \tag{36}$$

$$\tilde{\Delta}^*_{H,t} = (1-\alpha^*_F)\left(\mu \frac{\tilde{\mathcal{Z}}_{H1,t}}{\tilde{\mathcal{Z}}_{H2,t}}\right)^{-\frac{\mu}{\mu-1}} + \alpha^*_F \tilde{\Delta}^*_{H,t-1}\left(\frac{\tilde{\Pi}^*_{H,t}}{\tilde{\Pi}^{*\gamma^*_F}_{H,t-1}\overline{\Pi}^{1-\gamma^*_F}}\right)^{\frac{\mu}{\mu-1}} \tag{37}$$

$$\Delta_{F,t} = \eta^* \Delta^*_{F,t} + (1-\eta^*)\,\Delta_{F,t} \tag{38}$$

$$\tilde{\Delta}_{F,t} = (1-\alpha_H)\left(\mu \frac{\tilde{\mathcal{Z}}_{H1,t}}{\tilde{\mathcal{Z}}_{H2,t}}\right)^{-\frac{\mu}{\mu-1}} + \alpha_H \tilde{\Delta}_{F,t}\left(\frac{\tilde{\Pi}_{F,t}}{\tilde{\Pi}^{\gamma_H}_{F,t-1}\overline{\Pi}^{*1-\gamma_H}}\right)^{\frac{\mu}{\mu-1}} \tag{39}$$

Equilibrium in the bond markets implies that $B_{F,t}+B^*_{F,t}=0$ and $B_{H,t}+B^*_{H,t}=0$. Moreover, demand for bonds denominated in currency F emanating from agents in country H is given by

$$\begin{aligned}\frac{S_t B_{F,t}}{\underline{P}_t R^*_t} - \frac{B^*_{H,t}}{\underline{P}_t R_t} &= \frac{S_t B_{F,t-1}}{\underline{P}_t} - \frac{B^*_{H,t-1}}{\underline{P}_t} \\ &\quad + T_{H,t}Y_{H,t} + \underline{RER}_t \frac{T^*_{F,t}}{T^*_t} Y^*_{H,t} - Y_t\end{aligned} \tag{40}$$

where $\underline{RER}_t$ is the real exchange rate measured with distribution prices gross of consumption taxes.

We abstracted here from the risk premium in the accummulation equation for the net foreign assets. Up to a first order approximation, this modifiation is neutral but at a second order, it brings some symmetry in the effect of financial market imperfections on the stochastic steady state for each country.

Let us define the current account of country H as $CA_t = \frac{S_t\left(B_{F,t}-B_{F,t-1}\right)}{\underline{P}_t R^*_t} - \frac{\left(B^*_{H,t}-B^*_{H,t-1}\right)}{\underline{P}_t R_t}$.

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.

$$R\tilde{E}R_{H,t} = R\tilde{E}R_{H,t-1}\frac{\tilde{\Pi}^*_{H,t}\,(1+\Delta S_t)}{\Pi_{H,t}} \tag{41}$$

$$R\tilde{E}R_{F,t} = R\tilde{E}R_{H,t-1}\frac{\tilde{\Pi}_{F,t}}{\Pi^*_{F,t}\,(1+\Delta S_t)} \tag{42}$$

$$T_t = T_{t-1}\frac{\Pi_{F,t}}{\Pi_{H,t}} \tag{43}$$

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

$$RER_{H,t} = \left[\eta + (1-\eta)\,R\tilde{E}R_{H,t}^{\frac{1}{1-\mu}}\right]^{1-\mu} \tag{44}$$

$$RER_{F,t} = \left[\eta + (1-\eta)\,R\tilde{E}R_{F,t}^{\frac{1}{1-\mu}}\right]^{1-\mu} \tag{45}$$

$$T_t^* = \frac{T_t}{RER_{H,t}RER_{F,t}} \tag{46}$$

$$T_{H,t} = \left[n_t + (1-n_t)T_t^{1-\xi}\right]^{\frac{1}{\xi-1}} \tag{47}$$

$$T_{F,t}^* = \left[n_t^* + (1-n_t^*)T_t^{*\xi-1}\right]^{\frac{1}{\xi-1}} \tag{48}$$

$$\underline{RER}_t = RER_{H,t}T_{H,t}\frac{T_t^*}{T_{F,t}^*} \tag{49}$$

Finally, aggregate export price inflation rates and after-tax CPI inflation rates are given by

$$\Pi_{H,t}^* = \frac{RER_{H,t}}{RER_{H,t-1}}\frac{\Pi_{H,t}}{(1+\Delta S_t)} \tag{50}$$

$$\Pi_{F,t} = \frac{RER_{F,t}}{RER_{F,t-1}}\Pi_{F,t}^*\,(1+\Delta S_t) \tag{51}$$

$$\Pi_t = \frac{T_{H,t}}{T_{H,t-1}}\Pi_{H,t}\varepsilon_t^{CPI} \tag{52}$$

$$\Pi_t^* = \frac{T_{F,t}^*}{T_{F,t-1}^*}\Pi_{F,t}^*\varepsilon_t^{CPI*} \tag{53}$$

The shock we have introduced on CPI inflation can be related to the timy-varying consumption tax by $\frac{(1+\tau_{C,t})}{(1+\tau_{C,t-1})} = \varepsilon_t^{CPI}$. However, given the empirical and normative analysis at the core this paper, the plausible nature of CPI inflation volatility that could be explained by those shocks (like oil and non-oil commodity prices shocks for example) may not be associated with the distortionary impact associated with the consumption tax described in this model. Consequently, in the rest of the paper, we assume that the shocks ε_t^{CPI} and ε_t^{CPI*} have no supply side interactions through the wage and price settings. Technically, this corresponds to assuming constant consumption tax rates and allowing those shocks to enter the model only through the previous two equations.

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

$$\mathcal{W}_{H,t} = \mathbb{E}_t\sum_{j=0}^{\infty}\beta^j\left[\begin{array}{c}\frac{1}{1-\sigma_C}\left(C_{t+j}-\gamma C_{t-1+j}\right)^{1-\sigma_C} \\ -\frac{\varepsilon_{t+j}^L\tilde{L}}{1+\sigma_L}L_{t+j}^{1+\sigma_l}\Delta_{w,t+j}\end{array}\right]\varepsilon_{t+j}^B$$

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

$$\begin{aligned} \Delta_{w,t} &= \alpha_w \Delta_{w,t-1} \left(\frac{w_t}{w_{t-1}} \frac{\Pi_t}{\Pi_{t-1}^{\xi_w} \bar{\Pi}^{1-\xi_w}}\right)^{\frac{(1+\sigma_l)\mu_w}{\mu_w-1}} \\ &+ (1-\alpha_w)\, w_t \left(\mu_w \frac{\mathcal{H}_{1,t}^w}{\mathcal{H}_{2,t}^w}\right)^{-\frac{\mu_w(1+\sigma_l)}{\mu_w(1+\sigma_l)-1}} \end{aligned} \quad (54)$$

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

2.10 Competitive equilibrium

The competitive equilibrium is a set of stationary 28 processes for country H, u_t, Q_t, I_t, K_t, R_t^k, Y_t, Z_t, C_t, Λ_t, L_t, MC_t, Π_t, $\Pi_{H,t}$, $\Delta_{H,t}$, $\mathcal{Z}_{H1,t}$, $\mathcal{Z}_{H2,t}$, $\Pi_{H,t}^*$, $\tilde{\Pi}_{H,t}^*$, $\tilde{\Delta}_{H,t}^*$, $\tilde{\mathcal{Z}}_{H1,t}^*$, $\tilde{\mathcal{Z}}_{H2,t}^*$, w_t, $\mathcal{H}_{1,t}^w$, $\mathcal{H}_{2,t}^w$, $\Delta_{H,t}^*$, $B_{F,t}$, $\Delta_{w,t}$, R_t, as well as the analogous 29 processes for country F, 9 relative prices $R\tilde{E}R_{H,t}$, $R\tilde{E}R_{F,t}$, $RER_{H,t}$, $RER_{F,t}$, $\underline{RER}_t$, T_t, T_t^*, $T_{H,t}$, $T_{F,t}^*$ and the depreciation rate ΔS_t. The 66 stationary processes satisfy the relations (1)-(10) and their analogous for country F, the relations (11)-(54) and the analogous of (27) and (54) for country F, given traditional closed-economy exogenous stochastic processes for country H, ε_t^A, ε_t^B, ε_t^I, ε_t^G, ε_t^L, ε_t^W, ε_t^P, ε_t^Q, ε_t^R, with the analogous shocks for country F, the additional open-economy exogenous stochastic processes ε_t^{CPI*}, ε_t^{CPI}, $\varepsilon_t^{\Delta S}$, $\varepsilon_t^{\Delta n}$, the common factors F_t^A, F_t^I, F_t^{CPI}, F_t^R, and initial conditions for country H, C_{-1}, I_{-1}, K_{-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}.

2.11 The Ramsey formulation of optimal monetary policy cooperation

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 commitment 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 64 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)-(10) and their analogous for country F, and the conditions (11)-(28), (30)-(52) and the analogous of (52) 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 $t \prec 0$.

3 Bayesian estimation of the US-Euro Area Model

In this section, we describe the Bayesian estimation on a US and euro area (EA) dataset of the first order approximation of the model described in the previous section. We follow in particular the econometric approach used by Smets and Wouters [2005] who estimated closed-economy models similar to ours on both the euro area and the US. Regarding the open economy literature, various studies have attempted to bring multi-country models on data over the recent years. More specifically, we could refer to the results of De Walque et al. [2005], Rabanal and Tuesta [2006], Bergin [2006] or Adolfson et al. [2005]. In terms of empirical contribution, the paper extends the successful estimation studies conducted within closed-economy framework by adding the necessary international frictions to account for interdependence between the US and the euro area while limiting to the maximum the sophistication of the international linkages. Indeed, since our main objective is to explore the normative implications of optimal monetary cooperation in a modelling framework with satisfying data coherence, we kept the open economy specifications relatively simple which allows us to build more easily on the intuitions provided by the theoretical literature.

Thereafter, country H represents the US and country F, the euro area. Concerning the structural shocks introduced in the estimation, we chose to keep a large set of domestic shocks as in Smets and Wouters [2005]. While recognizing that the specification of a large number of shocks could pause identification problems, it is worth enriching our structure of disturbance when analyzing the optimal policy.

The exogenous can be divided in three categories:

- Efficient shocks: AR(1) shocks on technology (ϵ_t^A, ϵ_t^{A*}), investment (ϵ_t^I, ϵ_t^{I*}), labor supply(ϵ_t^L, ϵ_t^{L*}), public expenditures (ϵ_t^G, ϵ_t^{G*}), consumption preferences (ϵ_t^B, ϵ_t^{B*}) and relative home bias $\epsilon_t^{\Delta n}$.
- Inefficient shocks: i.i.d. shocks on PPI markups (ϵ_t^P, ϵ_t^{P*}), CPI markups (ϵ_t^{CPI}, ϵ_t^{CPI*}), labor market markups (ϵ_t^W, ϵ_t^{W*}), Tobin's Q (ϵ_t^Q, ϵ_t^{Q*}) and UIP ($\epsilon_t^{\Delta S}$).
- Policy shocks: shocks on short term interest rates (ϵ_t^R, ϵ_t^{R*}).

Since the two-country framework is supposed to encompass the macroeconomic interactions between the US and the euro area in the world economy, correlations in the structural shocks stemming from rest of the world shocks or uncaptured spillovers cannot be ruled out *ex ante*. Consequently, we allow in particular for possible common AR(1) factors for efficient shocks and CPI markups. For the benchmark model described thereafter, we only retained common factors on productivity shocks (f_t^A), investment shocks (f_t^I), CPI markup shocks (f_t^{CPI}) and monetary policy shocks (f_t^R), which were selected on the basis of their significance in explaining economic fluctuations and the implied marginal data density.

3.1 Data

Compared with the closed-economy version of the model that has been estimated in the US and the euro area separately by Smets and Wouters [2005], the two-country framework embodies four additional variables in the estimation and four additional shocks closely related to the new variables: the exchange rate together with the UIP shock, the current account with the relative home bias shock, CPI inflation rates with CPI markup shocks. Introducing two price deflators per country is necessary in order to describe the imperfect exchange pass-through. The current account has been incorporated in the estimation to improve the inference on the financial frictions.

For each country, we potentially consider 8 key macro-economic quarterly time series from 1972q1 to 2005q4: output, consumption, investment, hours worked, real wages, GDP deflator inflation rate, CPI inflation rate and 3 month short-term interest rate. US series come from BEA and BLS. Euro area data are taken from Fagan et al (2001) and Eurostat. Concerning the euro area, employment numbers replace hours. Consequently, as in Smets and Wouters [2005], hours are linked to the number of people employed e_t^* with the following dynamics:

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

The exchange rate is the euro/dollar exchange rate. Due to statistical problems in computing long series of bilateral current account and current account for the euro area, we used the US current account as a share of US GDP. Aggregate real variables are expressed per capita by dividing with working age population. All the data are detrended before the estimation.

Our structural description of the US and euro area interactions assumes no rest of world and therefore remains, from a global point of view, a reduced-form representation. As already mentioned, in order to take into account sources of economic fluctuations emanating from other countries, we allow first for common structural shocks. But we also introduce correlation between the home bias preference shock and the euro area public expenditure shock. Since we used the US total net trade instead of the bilateral net trade, we intend to capture through this variable, rest-of-the-world shocks that affect the US current account with moderate immediate impact on euro area output. The correlation between home bias shock and euro area public expenditures shock ($\rho_{\Delta n,G}$), which acts as a GDP residual shock, is meant to control for this drawback. Notice however that using total US trade instead of bilateral trade broadens the data information on the rest of the world. Finally, given that, in the first order approximation of the model, the UIP shock has weak structural interpretation, examining the links with other shocks seems justified. Consequently, correlations between the UIP shock and other efficient shocks are incorporated in the estimation and may account for the impact of fundamental shocks on time-varying risk premium. In practice, the benchmark model exposed in this section features a correlation between the UIP shocks and the US productivity shocks ($\rho_{A,\Delta S}$) as well as the government expenditure shocks ($\rho_{G,\Delta S}$, $\rho_{G^*,\Delta S}$) from both countries. Those correlations were also selected according to their significance and the improvement brought to the marginal data density [1].

3.1.1 Calibrated parameters

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 US and the euro area. 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 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 output in steady state are respectively 0.65 and 0.18.

3.1.2 Prior distribution of parameters

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, except for the common factors where we choose inverse-gamma priors (see Table 1). Initially, the priors for the common factors were not uniform since the estimation could easily bring the standard deviation of those shocks to zero which leads to singular configurations. However for the common shocks retained here we could have applied less informative priors. In DSGE models, data are often very informative about the variance of structural disturbances and we keep loose priors to avoid helping artificially the identification of our shock structure by our assumptions on priors. The distribution of the persistence parameters in the efficient and policy shocks is assumed to follow a beta distribution with mean 0.85 and standard error 0.1. The additional correlations between structural shocks have uniform priors too (see Table 2). Concerning the parameters of the Taylor rules, we follow Smets and Wouters [2005]: the long run coefficient on inflation and

[1] The correlation between the home bias shock and EA government expenditures is introduced by adding a term $\rho_{\Delta n,G}\epsilon_t^{\Delta n}$ in the AR(1) of the EA government spending exogenous. The correlations with the UIP shock are introduced by adding terms like $(\varepsilon_t^A)^{\rho_{A,\Delta S}}$ in the risk premium exogenous $\varepsilon_t^{\Delta S}$

output gap are described by a Normal distribution with mean 1.5 and 0.125, and standard errors 0.1 and 0.05 respectively (see Table 3). The persistence parameter follows a normal around 0.75 with a standard error of 0.1. The prior on the short run reaction coefficients to inflation and output gap changes reflect the assumptions of a gradual adjustment towards the long run. Concerning preference parameters, the intertemporal elasticity of substitution is set at 1 with standard error of 0.375. The habit parameter is centered on 0.7 with standard deviation of 0.1 and the elasticity of labor supply has mean 2 and standard error of 0.75. Adjustment cost parameter for investment follows a $\mathcal{N}(4, 0.5)$ and the capacity utilization elasticity is set at 0.2 with a standard error of 0.1. Concerning the Calvo probabilities of price and wage settings, we assume a beta distribution around 0.75. The degree of indexation to past inflation is centered on 0.5.

Regarding the open economy parameters, we intend to remain fully agnostic on such parameters and choose uniform priors for the intratemporal elasticity of substitution, the parameters guiding the share of PCP producers, the degree of home bias in consumption and the elasticity of foreign exchange risk premium with respect to the net foreign assets.

Note therefore that the steady state value of the openness ratio is estimated. As a structural description a the rest of the world is not included in our framework, we try to "let the data speak" about the effective openness ratio in this reduced form model of the international linkages between the US and the euro area. One interesting point is to see if the estimated openness ratio is closer to the bilateral openness, around 2%, rather than to the overall openness, above 13%.

3.2 Posterior parameter estimates

Posterior parameter estimates (see Table 1 to 3) commonly found in the closed-economy literature are relatively similar in the US and the euro area which is line with previous work done by Smets and Wouters [2005]. However, marginally, nominal rigidities in price-setting seem to be larger in the euro area than in the US. This feature is also consistent with the results of the Inflation Persistence Network see Altissimo et al. [2006] for a comprehensive summary of results). At the same time, the indexation coefficients on past inflation are larger in the US. The estimated preferences parameters also differ between the US and the euro area. The intertemporal elasticity of substitution is higher in the euro area but the habit persistence is more limited. Differences are much smaller for the labor supply elasticity but those parameters are very badly identified (see Figure 3). Finally the adjustment costs on investment and capacity utilization seem to be higher in the euro area than in the US. Concerning monetary policy rules, there is not much evidence of strong differences in reaction functions. Of course, some asymmetries could be highlighted. For example, the estimation tends to suggest that interest rate smoothing is slightly higher in the euro area than in the US. Note that the level terms on inflation in the policy rules are poorly identified (see Figure 3). But overall, the degree of asymmetry between the US and the euro area due to differences in parameters is relatively limited. The main source of asymmetries comes from differences in shock structure with the productivity shock having a stronger role in the EA while the labor supply and public expenditure shocks are more important in the US.

We now focus on the parameters driving the open economy features which are critical in NOEM models: the price elasticity of trade (ξ), the share of PCP producers (η and η^*), the degree of home bias (n) and the UIP risk premium elasticity with respect to net foreign assets (χ).

The intratemporal elasticity of substitution is estimated around 2.5 in the benchmark model with the highest probability density interval going approximately from 1.5 to 3.3 (see Figure 3). This parameter is crucial for a wide range of international economics issues. The NOEM literature frequently uses unitary assumptions in order to improve the tractability of the theoretical analysis. However, empirical studies on international trade, generally obtained with disaggregated data, find much higher estimates (see Harrigan [1993] for example). With time series analysis, estimates can be found from 0.1 to 2 (see Hooper et al. [2002]). Within structural models, Bergin [2006] reports estimates close to unity, whereas Rabanal and Tuesta [2006] find much lower values and Adolfson et al. [2005] much higher. Corsetti et al. [2005] illustrate the role of the price elasticity of tradables under incomplete markets on the sign of the international transmission: there is some cutoff value of ξ around which the sign of the international transmission switches and the volatility of the exchange rate increases strongly. This critical value is very much related to the the degree of home bias. De Walque et al. [2005], within a more sophisticated framework, show that their estimation algorithm could find a solution for ξ in regions on both sides of this value, without being able to cross it. In our set-up, we deliberately used a uninformative priors and made sure that the initialization of the MCMC algorithm covers all the prior support. It seems that the posterior density does not present such strong bi-modal pattern. Note that, for a given value of n, a too low value of ξ can generate an unstable equilibrium and the critical value could possibly be within this domain of instability. Moreover, the higher the home bias, the larger this instability area. For example, when we fix all the parameters at the mode of the benchmark model and allow ξ to vary from 2.5 to 0, the variance of the exchange rate keeps on increasing till we reach some point where the equilibrium becomes unstable. Of course, this does not prove that there cannot be some parameter configurations with high likelihood for which the critical point pattern could exist but it nonetheless gives some support to our intuition.

The extent to which nominal exchange rate fluctuations pass-through into core prices and the way to incorporate such features in theoretical models are topical issues in international economics. In this paper, imperfect pass-through is achieved through a combination of nominal rigidities and/or currency denomination of exports. Should all prices be flexible, firms would have no incentive to discriminate in international markets and the law of one price would hold. In our benchmark setting, we estimate the share of PCP and LCP firms (given by the parameters η and η^*). For the US, the share of PCP firms is centered on 90% with a mode at 99% and a distribution between 79% to 100%. In the euro area, the share of PCP firms is lower and is centered on 79% with a distribution between 62% and 100% (see Figure 4). Therefore, the estimated immediate euro-dollar pass-through on inflation is relatively high in the estimated model (as in the preferred model of Rabanal and Tuesta [2006]) and the US exporting firms seem to be relatively more "price makers" than the European firms. Note that the parameter posteriors related to exchange rate pass-through depend crucially on the price deflators introduced in the estimation procedure. If GDP inflation rates are removed, the LCP shares increase significantly in both countries (estimation not reported here). Conversely, if CPI inflation rates are removed, the estimation favors strongly the PCP case. This result put into perspective the finding of Bergin [2006] who, using only CPI inflation, concluded that LCP was the appropriate specification.

The model also gives some information about the risk premium of the UIP linked to net foreign assets. The posterior distribution for this parameter range from 0.001 to 0.024 with a mode at 0.017 (see Figure 4). Our estimate implies that net foreign assets amounting to 20% of GDP would increase the risk premium by 34 basis points (the distribution ranging from 2 bp to 48 bp). Bergin [2006] finds a result of 0.00384 and Rabanal and Tuesta [2006] report values between 0.005 and 0.013, estimates which are all in our posterior distribution. In addition, the parameter driving the negative correlation between the risk premium and the expected change in the exchange rate ($\chi_{\Delta S}$) is estimated around 0.15 and seems to be well-identified. This value is much lower than the one reported by Adolfson et al. [2007] in their small open economy model of the Swedish economy.

Our model tries to estimate a reduced form of the US and euro area interactions in the world economy. A rest of the world sector is not introduced. Consequently, the relevant value of the steady state openness ratio can be higher than the bilateral openness ratio in order to take into account third markets effects. In the benchmark version, the openness ratio is estimated and the result points to values quite close to the bilateral openness ratio (see Figure 3). Chari et al. [2002] developed a two-country model with sticky prices and local-currency-pricing calibrated for the US and the euro area and also used a value of $n = 0.984$ in their simulation analysis. Rabanal and Tuesta [2006] estimated a lower home bias which corresponds to an openness ratio around 6%. Alternatively, we estimated a model keeping the steady state openness ratio fixed at 10%. Overall, this restriction deteriorates considerably the performance of the model as the likelihood function decreases strongly (estimation not reported here). The intratemporal elasticity of substitution is then much lower at 0.6. The exchange rate pass-through is also estimated to be lower and asymmetries between the US and the euro area are more pronounced as only 26% of EA firms are PCP against 88% in the US.

Finally, the correlations we allowed between the structural shocks and the UIP shock were retained for US productivity shocks and for both US and EA government spending shocks. In each case, the correlation amplifies the reaction of the exchange rate: the exchange depreciates more after the productivity shock while the appreciation induced by the government expenditure shock is larger. Regarding the correlation between the home bias shock and the EA government spending shock which we introduced to control for the introduction of the total US current account instead of the bilateral one, the posterior estimate comes out relatively high and well-identified (see Figure 2). This will partially break the asymmetry of the propagation of the home bias shock which pushes the output in opposite directions in the two countries.

We now turn to the analysis of the optimal monetary policy cooperation using the estimated parameters and disturbances.

4 Optimal monetary policy cooperation between the US and the euro area

4.1 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. The first order conditions to this problem are obtained using symbolic Matlab procedures.

As it is common in the optimal monetary policy literature of closed-economy models (see for example Khan et al. [2003] and Schmitt-Grohe and Uribe [2005]), we assume a particular recursive formulation of the policy commitment labelled by Woodford [2003] as optimality *from a timeless perspective*. This imposes that the policy rule which is optimal in the latter periods is also optimal in the initial period and avoids the problem of finding initial conditions for the lagrange multipliers, which are now endogenous and given by their steady state values. The Ramsey approach to optimal monetary policy in an open economy context has also been studied for example by Faia and Monacelli [2004].

Since 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, we assume a fiscal intervention, namely subsidies on labor and goods markets, to offset the first order distortions caused by the presence of monopolistic competition in the markets. This ensure that the steady state is efficient, and that the flexible price equilibrium is Pareto optimal. Note that those constraints can easily be relaxed with our methodology but are imposed in order to better understand the stabilization properties of the optimal policy.

From an operational perspective, we have to face the issue that the zero lower bound is an occasionally binding constraint. To avoid high probabilities of hitting the zero bound under the

Ramsey allocation, we thus follow Woodford [2003] by introducing in the households welfare for each country a quadratic term penalizing the variance of the nominal interest rate:

$$\mathcal{W}^R_{H,t} = \mathcal{W}_{H,t} + \lambda_R \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(R_{t+j} - R^\star\right)^2 \tag{55}$$

$$\mathcal{W}^R_{F,t} = \mathcal{W}_{F,t} + \lambda^*_R \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left(R^*_{t+j} - R^\star\right)^2 \tag{56}$$

where λ_R and λ^*_R are the weights attached to the cost on nominal interest rate fluctuations. Instead of fixing this parameter to match a particular value of the probability to hit the zero bound, we pragmatically choose calibration of those parameters so that, under the operational optimal monetary policy coordination, the unconditional variance of the nominal interest rates are close to the ones obtained with the estimated rules. The penalty needed to achieve those standard deviations is substantially higher in the US than in the euro area. Under this assumption, the probability to hit the zero bound is reasonably low, even for a zero steady state inflation which implies that the steady state real rate is more than three times the standard deviation of the interest rate. Note that with the indexation schemes introduced in the price and wage settings, the Ramsey steady state is consistent with any level of inflation rate.

In the following we constrain accordingly the volatility of the policy instruments so as to make the optimal monetary policy cooperation operational. Table 4 shows that beyond reducing the fluctuations of the policy instruments, the penalization for interest rate volatility in the welfare function is not affecting strongly the variance of output components and inflation in the optimal allocation. The same conclusion would hold by analyzing the respective impulse responses and variance decompositions under both policy regimes. Consequently, the operational feature that we implemented in the Ramsey allocation is sufficient to maintain the fluctuations of the policy rates within reasonable range but does not seem to deteriorate significantly the domestic stabilization properties of the optimal policy. However, the standard deviation of the nominal exchange is significantly reduced in the constrained optimal monetary policy cooperation.

4.2 Welfare calculations

In each country, we compute the fraction of consumption stream from alternative monetary policy regime to be added (or subtracted) to achieve the reference level corresponding to the steady state allocation. That is, for example in country H, we measure the welfare cost in percentage points, $welfarecost = \psi \times 100$, by solving for ψ the following equation,

$$\overline{\overline{\mathcal{W}}} = \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left[\frac{1}{1-\sigma_C} \left(C^a_{t+j} - \gamma C^a_{t-1+j}\right)^{1-\sigma_c} (1+\psi)^{1-\sigma_c} - \frac{\tilde{L}\varepsilon^L_{t+j}}{1+\sigma_L} L^{a(1+\sigma_l)}_{t+j} \Delta^a_{W,t+j} \right] \varepsilon^B_{t+j}$$

which gives

$$\psi = \left[\frac{\overline{\overline{\mathcal{W}}} + \mathcal{W}^a_{t,L}}{\mathcal{W}^a_t + \mathcal{W}^a_{t,L}} \right]^{\frac{1}{1-\sigma_C}} - 1$$

where $\overline{\overline{\mathcal{W}}}$ is the steady state welfare, X^a_t denotes the variable X_t under the alternative policy regime and $\mathcal{W}^a_{t,L} = \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \frac{\tilde{L}\varepsilon^L_{t+j}}{1+\sigma_L} L^{a(1+\sigma_L)}_{t+j} \Delta^a_{W,t+j}$.

Table 4 reports conditional welfare measures relative to the steady state allocation. First, we can observe that the total welfare is only slightly reduced when imposing the operational constraints. In terms of country-specific welfare costs, they are similar with constrained and unconstrained policies for both countries but the deterioration in welfare is more pronounced in the US than in the euro area. This is due to the relative size of the weights which have been introduced. The penalty for the US has indeed to be twice as large as for the euro area to bring down the volatility of the policy rate. Overall, even if the volatility of the instruments is highly constrained, monetary policy is still effective in improving the welfare of agents.

In Table 4, we investigate the implications of the shock structure for the optimal allocation. With all the shocks present, the welfare costs of business cycles under the optimal policy represent respectively 2.5% and 2.7% of euro area and US steady state consumption. The corresponding costs under the estimated rules increase by 0.5 percentage point for the US and by 2 percentage points for the euro area. When only efficient shocks are allowed, the welfare cost of fluctuations are less important, around 0.2% for the US and 0.5% for the euro area. In this case, note that the policy instrument penalties have a negligible impact on welfare and variances, except for interest rates and exchange rate.

This clearly points to the need of strongly motivating the inefficient structural shocks introduced in the model. Most of the empirical literature relied on markup shocks which in practice act as residuals of the first order approximation of the supply curves. But the normative implications of those estimated sources of inefficient fluctuations are dramatic. In our study, we observe that the operational constraints on the policy instruments are powerful to bring back macroeconomic volatility relatively in line with the optimal allocation obtained by imposing steady state subsidies. Analysis of impulse responses supports this claim.

In the following sections, the optimal policy will refer to the modified Ramsey allocation and will be compared with the estimated rules across several dimensions.

5 International business cycles under estimated and optimal monetary policy

This section analyzes the business cycle properties and its fundamental sources under the estimated policies and the optimal monetary policy cooperation within the benchmark model estimated in section 3.

5.1 Comparison of second-order moments

First, we compare selected moments implied by our estimation with those from the actual data and from the optimal allocation (see Table 5). In doing so, we use both detrended and HP-filtered data. With a detrending procedure, the estimated model delivers higher volatility of real variables than in the data. In this respect, applying an HP-filter helps the estimated model to match those standard deviations. In the optimal allocation, the volatility of real variables is higher than in the estimated model with both filtering methods. Regarding prices, the estimated model generates slightly higher inflation volatility than in the data. Compared with the estimated rules, the optimal policy implies much smaller variances of PPI inflation rates and to a lesser extent, CPI inflation rates. Those features of the optimal allocation are similar to the results of Adjémian et al. [2007] which studied the optimal monetary policy in an estimated closed-economy model of the euro area.

Turning to the nominal exchange rate, the standard deviation in the estimated model is very close to the one observed in the data. Even if the constrained imposed on the fluctuations of the policy instruments for the optimal policy are set to ensure that the standard deviations of interest rates are similar to the ones obtained with the estimated rules, exchange rate volatility turns out to be significantly higher in the optimal allocation.

Cross-country correlations of output and consumption in the estimated model are positive but lower than in the data (with HP-filtering increasing significantly the correlation of output across countries in the estimated model). In contrast, the optimal allocation implies negligible co-movements between output of both countries. This is true for both detrended and HP-filtered data. On consumption, the optimal monetary cooperation implements degrees of correlation which are closer to the ones generated by the estimated model. While stylized NOEM models find it difficult to match the observed negative correlation between the real exchange rate and relative consumption across countries, our more general setting with various shocks accounts appropriately for this feature. The correlation between relative consumption and the real exchange rate is less negative in the optimal allocation than in the estimated model when using detrending procedures. With conventional HP-filtering, this correlation even turns positive showing that the optimal policy tries more than the estimated rules to counteract the imperfect risk sharing. We will come back to this point later.

Finally, regarding the asymmetries between the US and the euro area, we observe that the differences between the optimal cooperation and the estimated rules are much more pronounced for the euro area.

In order to explain those results, we will first try to illustrate how the sources of economic fluctuations under both monetary regimes affect the variances and covariances described previously.

5.2 Shock decomposition of moments

Table 6 presents the shock decomposition of unconditional variances under the estimated rules and the optimal policy. For comparison purposes, the specific and common shocks on policy rules have been subtracted from the estimated model. Table 7 to 13 also report selected conditional moments at various time horizons.

Regarding activity, the contribution of labor market shocks to the variance of forecast errors on output is much higher under the optimal policy, especially over the short to medium term. In particular, in the optimal allocation, the combination of the labor supply and wage markup shocks accounts for around 80% of the forecast errors at a two years horizon for the euro area and 70% for the US, compared with 7% and 10% respectively under the estimated rule. Conversely, the relative contributions of demand shocks, price markup shocks and equity premium shocks are higher with the estimated rules up to a two-year horizon. The productivity shock is more important under the optimal policy at a below-two-year horizon but less beyond.

As far as international spillovers are concerned, note first that the estimated model implies a relatively low transmission of domestic shocks from one country to the other. In terms of shock decomposition of theoretical variance (see Table 6), foreign shocks contribute only to 1% of aggregate fluctuations for both countries in the long term[2]. De Walque et al. [2005] also report very moderate spill-overs in their estimated models for the US and the euro area. At a below-two-year horizon, the contribution of foreign shocks in the estimated model is higher: the contribution of non-domestic shocks in the short-term (1 to 2 years) is close to 13% for both countries, of which one fourth comes from the spill-overs of domestic shocks of the foreign country. The relative contribution of the shocks form the foreign country to domestic fluctuations is significantly lower at a 1-to-3-year horizon under the optimal policy. The optimal policy is substantially muting the short-term spill-overs from open economy shocks and common factors. Overall, at all horizons, non-domestic shocks represent less than 5% in the optimal allocation.

Regarding prices, the optimal monetary cooperation is significantly limiting the impact of efficient shocks on inflation forecast errors. While efficient supply shocks account for 60% and 45% of US and euro area inflation variances in the long run under the estimated rules, this share is reduced to less than 10% for both countries under the optimal policy. Price markup shocks (PPI and CPI) are the main source of forecast errors in the very short-term with the estimated rules but its contribution rapidly decreases at longer horizon. Under the optimal policy, price markup shocks explain more than 80% of forecast errors at all horizons. Turning to non-domestic shocks, the relative contribution of the UIP shock to the CPI inflation rates is similar under both policy regimes while the role of the home bias shocks is higher in the optimal allocation. Regarding the international spill-overs, the optimal policy increases the

[2]Note in addition that the role of foreign shocks in domestic fluctuations would even be lower without the estimated correlations with the UIP shocks.

contribution of foreign shocks in particular through a stronger transmission of the common CPI markup shock and to a lesser extent, of labor market shocks.

Concerning the nominal exchange rate, the UIP shock and the home bias shock explain around 70% of the fluctuations at all horizons under the estimated rules, compared with less than 60% in the optimal allocation. The home bias shock plays indeed a key role in exchange rate fluctuations through its strong impact on the current account dynamics and subsequently, on the UIP risk premium[3]. Moreover, the optimal monetary cooperation is increasing the contribution of labor market shocks, preference shocks and to a lesser extent, price markup shocks whereas the role government expenditure shocks is reduced. We will come back on this point when analyzing the impulse responses.

We now turn to the shock decomposition of selected covariances at different time horizons. Regarding the cross-country covariance of output, the conditional covariance under the estimated rules is positive at all horizons and increases continuously. Under the optimal policy the covariance is negative below two years but turns positive and increases afterwards while remaining much lower than under the estimated rules. The optimal monetary cooperation reinforces the negative spill-overs of labor market shocks, generates a negative transmission of euro area preference shock, and limits the positive transmission of public expenditure shocks. At the same time, the contribution of UIP and home bias shocks as well as of the common productivity shock is higher in the optimal allocation. The shock decomposition of conditional covariance of consumption across countries is relatively similar under both policies. In particular, the only shocks inducing negative covariance are the preference shocks, the UIP and the home bias shocks.

Turning to the conditional correlation between relative consumption and the real exchange rate, those shocks are also the main negative contributors and can help explaining the *consumption-real exchange rate anomaly* (see Chari et al. [2002]). Under the estimated rules, the covariance is negative at all horizons while under the optimal policy, the covariance is first positive and turns negative beyond the 5-year horizon. This difference is partly explained by the less negative contribution of the home bias shock and more positive contributions of labor market shocks at horizons below three years under the optimal monetary policy cooperation.

5.3 Selected impulse responses

Figures 6 to 28 show the median impulse response functions and the density intervals covering 80% of the posterior distribution. The comparison of impulse responses between the estimated rules and the optimal policy complement the analysis of the previous section and gives a better

[3]We also estimated a version of the model dropping the current account from the set of observed variables and eliminating the home bias shock. Doing so, the share of exchange rate volatility explained by the open economy shock is reduced to less than 40% and around two thirds when removing the correlations of structural shocks with the UIP residual.

interpretation of the resulting changes to international spillovers and exchange rate adjustment.

Positive efficient supply shocks raise the natural output of the domestic economy, creating a slack in resource use, and call for real depreciation in order for demand to absorb the excess supply. Both monetary regimes accommodate those shocks in the source country by decreasing interest rates. Exchange rate overshoots, depreciating on impact and then gradually appreciating. Current account increases as the relative price effect overcomes the income effect. Spill-overs to the foreign economy of those shocks is a priori ambiguous with conflicting relative price and income effects. Note that, due to a high degree of home bias, the ”Marshall-Lerner” condition holds even if the intratemporal elasticity of substitution is close to one. However, as trade volumes react immediately to relative prices, the current account does not exhibit J-curve profile after a relative price shock. Adding adjustment costs on trade flows would circumvent this drawback. However, as our model is not estimated on trade data, not incorporating this additional friction should not alter significantly the performance of the model.

Regarding positive productivity shocks first, the optimal allocation generates, in the source country, a stronger and faster response of real variables and real wage while the downward pressures on prices are much more limited. The associated interest rate path is more accommodative in the short term but reverts very rapidly to its initial level. Notice that over longer horizons, the response of real variables becomes significantly closer in both monetary regimes. The difference in transmission between the optimal and the estimated polices is much less pronounced for the US. The nominal exchange rate depreciate more strongly on impact in the optimal allocation but appreciate more sharply afterwards. In the US case, the estimated correlation of the productivity shock with the exchange rate risk premium is reinforcing the initial depreciation. Spill-overs on activity and hours are negative and stronger but more short-lived in the optimal case. On consumption, investment and interest rate, the spill-overs are positive.

Another efficient supply shock in the model is the labor supply shock for which the differences highlighted above turn out to be much more pronounced. The timely and hump-shaped decrease in interest rate in the source country under the optimal policy stimulates output, consumption and investment while leaving quasi unchanged inflation and real wages. By contrast, the estimated rule is not supportive enough to prevent a decrease in real wage and inflation in the source country. The two monetary regimes are therefore quite different in terms of exchange rate and international spill-over, with a much sharper depreciation in the optimal case, a stronger increase in the current account and a higher negative transmission in the short-term.

Positive efficient demand shocks like preference and public spending shocks increase the output gap and require a real appreciation so that lower external demand counterbalances excess domestic demand. Monetary policy in both regimes appear to lean against these shocks by increasing interest rate in the source country. Exchange rate overshoots, appreciating on impact and then gradually depreciating. Current account records a deficit given that both relative output and relative price effects worsen the external position.

After a positive preference shock, the increase in consumption in the source country is more limited under the optimal policy and the contraction in investment is stronger. The appreciation on impact of the nominal exchange rate is more pronounced in the optimal policy but more short-lived. Similarly, the current account decreases more in the optimal policy on impact but then rebounds more rapidly. Overall, GDP remains below the baseline in the short term for the euro area under the optimal policy whereas it increases first in the US. PPI Inflation rates and real wages are almost fully stabilized in the optimal policy and the short-run volatility in CPI inflation rates is mainly due to exchange fluctuations. Under the estimated rule, the preference shock is expansionary on GDP and upward pressures emerge on real wages and inflation. In terms of spill-overs, the preference shocks induce a negative transmission to foreign consumption in the short term and an appreciation of the real exchange rate under both policy regimes. Such shocks are therefore helpful in explaining the *consumption-real exchange rate anomaly* and would still contribute to do so with perfect risk sharing.

Differences between the two policy regimes are less pronounced for the other efficient shocks affecting demand components. The responses in the source country of GDP, consumption, investment and real wages to an investment shock or a government spending shock are relatively similar under the optimal policy and the estimated rule, deviations from baseline being somewhat more pronounced with the estimated rule. The exchange appreciation and the deterioration of the external accounts are also very close. However the endogenous price pressures in the source country are much more muted in the optimal allocation. While after a preference shock, the international transmission on foreign activity is positive with the estimate rule but could be either sign with the optimal, the spill-overs after the other efficient shocks on demand are clearly positive with both monetary regimes and both countries but significantly more short-lived with the optimal policy. *Ex post* demand multipliers on economic activity between the US and the euro area are close to 0.1 with the investment specific technology shocks and 0.2 to 0.4 with the government expenditure shocks.

Considering inefficient shocks, the transmission of price markup shocks to activity and prices in the source economy is not strongly different under both monetary regimes, suggesting similar inflation (prices and wage)/output tradeoff for this type of shock. The optimal policy is nonetheless achieving a slightly smaller contraction of real variables and a significantly lower path of the policy rate in the source country. With the estimated rule, the nominal exchange rate depreciates slowly for two years and the current account decreases slightly as the impact of the cost-push shock on competitiveness dominates in the short run. Under the optimal policy, the depreciation is stronger so that the fluctuations of the real exchange rate and the current account are marginal. In terms of spill-overs, the transmission of the price-markup shock is negative on real variables and positive on inflation under the estimated rule while the international transmission is quasi-neutral in the optimal allocation.

In the case of wage markup shocks, the optimal policy implies a very different stabilization pattern compared with the estimated rules. The optimal policy is much more restrictive in the source country, delivering much lower activity variables and more stable PPI inflation rate. Contrary to the price-markup case, the nominal exchange rate is strongly appreciating under the optimal policy and the current account decreases in the short-term. The international transmission of the shock is significantly negative on activity in the short-run under the optimal policy while it is negligible under the estimated rules. Note that the dynamic response to this shock presents some similarities with the labor supply shock expect for the real wage path. The efficient labor market shock does not require an adjustment of the real wage and such strong stabilization has no welfare cost. With the wage markup shock however, the distortive nature of the fluctuations implies that the optimal policy allows some significant pass-through on the wage dynamics.

The UIP shock leads to a strong appreciation of the nominal exchange rate on impact and a sharp deterioration of the current account. Under both policy regimes, the appreciation is accompanied by a decrease in home interest rate and an increase of a similar magnitude in the foreign country. Over the first quarters, home output contracts and foreign output expands while home domestic demand increases and foreign domestic demand drops by a similar amount. This strong asymmetry is present with both the optimal and the estimated policies. However, the response of output is more short-lived in the optimal allocation and the inflation rates are better stabilized. The home bias shock is equivalent to a fully asymmetric world demand shock, when we abstract from the correlation with the euro area government spending shock that we introduced for the estimation. In that case, as for the UIP shock, in one country the current account increases, output expands, interest rate rises and domestic demand contracts while macro variables in the other country mirror these developments on the negative side. However, compared with the UIP shock, the exchange rate appreciates for the country experiencing the net-trade expansion. Those properties are true for the two policy regimes but the optimal cooperation stabilizes more rapidly the real variables and the inflation rates. Note therefore that the UIP and the home bias shocks have both a strong impact on the exchange rate and the current account but imply a correlation between those two variables of opposite sign. Mixing UIP and home bias shocks can generate ”exchange rate disconnect” as they have similar impact on exchange rate but opposite impact on current account. The differences between the two policy regimes in the transmission of the home bias shock are amplified when accounting for the correlation of the euro area government expenditure shock. In the estimated model, the international transmission on output for example is still negative but muted while the optimal policy generates a positive correlation of activity across countries.

6 Sensitivity analysis

In this section, we perform a sensitivity analysis concerning some of the previous results and explore in particular the effects on welfare and second-order moments of the incomplete markets and international price setting. As illustrated by Darracq Pariès [2007] within in a much simpler modeling framework in which explicit solutions for the optimal policy can be obtained, the typology of the structural disturbances is also a key factor affecting the optimal allocation.

First, comparing the perfect risk sharing and the imperfect risk sharing cases of Table 14, we see that the welfare loss of incomplete financial markets, as specified in the estimated model, is around 1 percentage point of welfare costs for both countries when all the shocks are introduced (except the UIP shock which would be less consistent with the perfect risk sharing specification). In that case, compared with the benchmark parametrization (which is close to the PCP case), imposing the LCP for exporters reduces the welfare losses associated with the imperfect risk sharing. Regarding the welfare effect of the LCP assumptions, it reduces only marginally the aggregate welfare and can be beneficial to one country. For example, under perfect risk sharing, the US welfare cost is 1.9% in the benchmark model and 1.8% in the LCP case. All those welfare properties extend qualitatively to the case where only efficient shocks are introduced but the welfare levels and differences are negligible.

Turning to second-order moments, the imperfect risk sharing and LCP have a marginal impact on inflation volatility. With both set of shocks, perfect risk sharing slightly reduces the standard deviation of inflation rates by 0.01 and the LCP assumption decreases by the same amount the volatility of CPI inflation rates leaving the standard deviation of PPI inflation almost unchanged. Regarding real variables, one common feature is the slight increase in output volatility under perfect risk sharing compared with the imperfect risk sharing case. Finally, the volatility of the nominal exchange rate is higher under LCP. Under our benchmark parametrization with a very high home bias, higher exchange rate fluctuations are needed to promote efficient adjustments in the real exchange rate despite the welfare costs associated with the failure of the law-of-one-price. The introduction of perfect risk sharing reduces the volatility of the nominal exchange rate when all shocks are present but it increases when only efficient shocks are allowed.

Actually, in order to explore further the role of key international parameters on the optimal allocation, we conducted a simple sensitivity analysis on the second order moments of inflation rates, output gaps, consumption gaps (defined as the log-difference of a real variable with its flexible price and wages equivalent) and the nominal exchange according to different values of the home bias (n), the price elasticity of trade (ξ), the share of PCP producers (η and η^*). The ranges of values considered are meant to cover the potentially plausible outcomes of an estimation exercise. Table 15 present the results in the benchmark specification and Table 16 produces the same analysis under perfect risk sharing [4].

Let us consider first the results under perfect risk sharing. Regarding the intratemporal elasticity of substitution ξ, the volatility of the nominal exchange rate is a decreasing function of ξ in all configurations. PPI and CPI inflation standard deviations are also decreasing with ξ while the standard deviations of consumption gaps are increasing. With respect to the home bias, in most cases, the exchange rate standard deviation is increasing with n. Even if the relation is not monotonic with our sensitivity ranges, the inflation volatilities are in general decreasing with the degree of home bias except under LCP for the euro area. The standard deviations of consumption gaps are decreasing with n. For the output gap volatility, the only monotonic relation for the range of values of Table 16 concerns the negative impact of higher degree of home bias. Finally, given values for ξ and n, the exchange rate volatility is not monotonic in the degree of pass-through η and η^*: for low values of ξ and n, the volatility is higher under PCP than under LCP while for higher values of ξ and n, the reverse is true. Concerning the inflation rates, the PCP assumption delivers higher CPI inflation volatility than under LCP. The standard deviations of consumption gaps are increasing with the share of PCP exporters and in relative terms, a lower share of PCP producers decreases the consumption gap volatility compared with the output gap volatility. Those features are related to the results of Darracq Pariès [2007] which shows in particular that under LCP the optimal policy stabilizes CPI inflation rates and consumption gaps while under PCP, the optimal policy targets PPI inflation and output gaps. Overall, note that the parameter space used has a very limited impact on PPI inflation volatilities.

When analyzing the analogous results under incomplete markets (see Table 15), most of the monotonic properties do not hold anymore. The sensitivity of variances to the open economy parameters is affected by the cutoff point for ξ around which volatilities increase strongly. Darracq Pariès [2007] illustrates the implications of financial autarky for optimal monetary policy cooperation under PCP and highlights the role of such cut-off point on the optimal allocation. Actually, within the parameter space of our sensitivity analysis, this corresponds to an hyperplan which should be investigated numerically. Presumably, the properties identified under perfect risk sharing seem to extend to the imperfect risk sharing case with values of ξ large enough compared with n. To illustrate this point, Figure 5 shows that the cutoff point seems to be between 0.3 and 0.5 for the range considered on the degree of home bias and it is an increasing function of n. Such singularity in open economy models with imperfect international financial markets constitutes an empirical challenge, in particular if one intends to bring Ramsey-type monetary policy to the data. Moreover, it urges us to carefully think about the relevance of departing from perfect risk sharing, to the extent that enough shocks and frictions

[4]In the perfect risk sharing model, we allowed for an exchange rate shock affecting the perfect risk sharing condition so that when differentiating this relation and taking one lead, we obtain the same residual shock as in the UIP relation of the benchmark model.

could be added. In our estimation work, we indeed noticed that a model with perfect risk sharing but including an exchange rate shock as a time-varying wedge on the optimal risk sharing condition could perform as well as the imperfect risk sharing specification, at least in terms of marginal data density (estimation not reported here).

7 Concluding remarks

In this paper, we have built on the literature estimating open economy DSGEs in order to explore within a more operational framework, the normative prescriptions of such structural models regarding the optimal monetary policy cooperation between the US and the euro area.

Most of the results highlighted by the literature using estimated closed-economy models (see Adjémian et al. [2007]), extend to our framework. Beyond this, we explore the international business cycle properties of the optimal policy and show in particular that international spillovers are reduced when comparing the optimal monetary policy cooperation with the estimated rules while that nominal exchange rate volatility is increased.

In addition, we explore the sensitivity of some results to the key open economy parameters. While the international price-setting assumptions do not seem to lead to strong modifications in the stabilization properties of the optimal policy, financial market imperfections could have more dramatic consequences and we emphasize the need to carefully think about the relevance of departing from perfect risk sharing.

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Tab. 1: PARAMETER ESTIMATES 1

Shock names	*A priori* beliefs			*A posteriori* beliefs				
	Distribution	Mean	Std.	Mode	Mean	Std.	$\mathcal{I}_1$	$\mathcal{I}_2$
ϵ_t^A	Uniform	1.000	0.577	0.418	0.414	0.041	0.348	0.481
ϵ_t^B	Uniform	2.500	1.443	1.864	2.278	0.535	1.444	3.108
ϵ_t^G	Uniform	3.000	1.155	3.312	3.314	0.208	2.970	3.651
ϵ_t^L	Uniform	0.100	0.058	0.009	0.015	0.009	0.004	0.026
ϵ_t^I	Uniform	3.500	2.021	2.842	3.166	1.041	1.458	4.870
ϵ_t^R	Uniform	0.250	0.144	0.225	0.226	0.017	0.197	0.254
ϵ_t^Q	Uniform	6.000	3.464	5.405	5.222	1.769	2.345	8.206
ϵ_t^P	Uniform	0.500	0.289	0.271	0.278	0.024	0.240	0.317
ϵ_t^W	Uniform	0.500	0.289	0.381	0.386	0.029	0.339	0.434
ϵ_t^{CPI}	Uniform	0.500	0.289	0.152	0.152	0.019	0.121	0.183
ϵ_t^{A*}	Uniform	1.000	0.577	0.648	0.705	0.082	0.572	0.837
ϵ_t^{B*}	Uniform	2.500	1.443	2.292	2.328	0.383	1.714	2.941
ϵ_t^{G*}	Uniform	3.000	1.155	2.381	2.348	0.168	2.072	2.621
ϵ_t^{L*}	Uniform	0.100	0.058	0.024	0.029	0.007	0.017	0.039
ϵ_t^{I*}	Uniform	3.500	2.021	0.784	0.862	0.277	0.421	1.319
ϵ_t^{R*}	Uniform	0.250	0.144	0.115	0.110	0.017	0.083	0.138
ϵ_t^{Q*}	Uniform	6.000	3.464	7.066	7.202	0.817	5.855	8.542
ϵ_t^{P*}	Uniform	0.500	0.289	0.325	0.329	0.023	0.292	0.367
ϵ_t^{W*}	Uniform	0.500	0.289	0.228	0.225	0.023	0.187	0.262
ϵ_t^{CPI*}	Uniform	0.500	0.289	0.255	0.259	0.019	0.227	0.290
$\epsilon_t^{\Delta S}$	Uniform	0.500	0.289	0.082	0.152	0.042	0.083	0.217
$\epsilon_t^{\Delta n}$	Uniform	0.500	0.289	0.505	0.484	0.050	0.403	0.562
f_t^A	Inverse Gamma	0.500	Inf	0.187	0.212	0.052	0.128	0.294
f_t^I	Inverse Gamma	0.500	Inf	0.373	0.508	0.256	0.144	0.875
f_t^R	Inverse Gamma	0.500	Inf	0.111	0.114	0.014	0.091	0.136
f_t^{CPI}	Inverse Gamma	0.500	Inf	0.148	0.151	0.018	0.121	0.180

Tab. 2: PARAMETER ESTIMATES 2

Parameters	*A priori* beliefs			*A posteriori* beliefs				
	Distribution	Mean	Std.	Mode	Mean	Std.	$\mathcal{I}_1$	$\mathcal{I}_2$
ρ_A	Beta	0.850	0.100	0.932	0.919	0.032	0.873	0.968
ρ_B	Beta	0.850	0.100	0.432	0.473	0.089	0.325	0.617
ρ_G	Beta	0.850	0.100	0.979	0.941	0.032	0.892	0.990
ρ_L	Beta	0.850	0.100	0.969	0.945	0.045	0.893	0.996
ρ_I	Beta	0.850	0.100	0.677	0.683	0.092	0.531	0.833
ρ_{A^*}	Beta	0.850	0.100	0.987	0.962	0.018	0.936	0.992
ρ_{B^*}	Beta	0.850	0.100	0.938	0.865	0.061	0.779	0.961
ρ_{G^*}	Beta	0.850	0.100	0.963	0.948	0.017	0.922	0.974
ρ_{L^*}	Beta	0.850	0.100	0.949	0.930	0.022	0.895	0.965
ρ_{I^*}	Beta	0.850	0.100	0.956	0.906	0.062	0.828	0.988
ρ_{F^A}	Beta	0.850	0.100	0.937	0.910	0.052	0.839	0.984
ρ_{F^I}	Beta	0.850	0.100	0.944	0.868	0.092	0.743	0.985
ρ_{F^R}	Beta	0.850	0.100	0.513	0.523	0.084	0.384	0.661
$\rho_{F^{CPI}}$	Beta	0.850	0.100	0.571	0.574	0.091	0.424	0.722
$\rho_{A,\Delta S}$	Uniform	0.000	0.577	-0.144	-0.225	0.147	-0.390	-0.040
$\rho_{G,\Delta S}$	Uniform	0.000	0.577	0.011	0.027	0.011	0.011	0.043
$\rho_{\Delta n,G^*}$	Uniform	4.000	2.309	2.749	3.141	0.651	2.035	4.185
$\rho_{G^*,\Delta S}$	Uniform	0.000	0.577	-0.037	-0.060	0.015	-0.083	-0.035
$\rho_{\Delta S}$	Beta	0.850	0.100	0.976	0.968	0.019	0.941	0.997
$\rho_{\Delta n}$	Beta	0.850	0.100	0.998	0.992	0.005	0.985	0.999

Tab. 3: PARAMETER ESTIMATES 3

Parameters	*A priori* beliefs			*A posteriori* beliefs				
	Distribution	Mean	Std.	Mode	Mean	Std.	$\mathcal{I}_1$	$\mathcal{I}_2$
σ_C	Normal	1.000	0.375	0.824	0.884	0.235	0.500	1.258
σ_C^*	Normal	1.000	0.375	1.907	1.736	0.298	1.233	2.211
h	Beta	0.700	0.100	0.745	0.755	0.051	0.673	0.839
h^*	Beta	0.700	0.100	0.412	0.479	0.078	0.349	0.600
σ_L	Gamma	2.000	0.750	1.666	1.890	0.734	0.744	3.025
σ_L^*	Gamma	2.000	0.750	1.488	1.776	0.686	0.718	2.823
ϕ	Normal	4.000	0.500	4.410	4.524	0.452	3.777	5.264
ϕ^*	Normal	4.000	0.500	4.765	4.867	0.437	4.163	5.601
φ	Gamma	0.200	0.100	0.373	0.427	0.128	0.216	0.629
φ^*	Gamma	0.200	0.100	0.765	0.807	0.201	0.479	1.133
α_w	Beta	0.750	0.050	0.806	0.794	0.038	0.731	0.856
α_w^*	Beta	0.750	0.050	0.816	0.821	0.032	0.769	0.873
ξ_w	Beta	0.500	0.150	0.360	0.371	0.123	0.170	0.572
ξ_w^*	Beta	0.500	0.150	0.238	0.251	0.092	0.100	0.397
λ_e	Beta	0.750	0.050	0.833	0.834	0.014	0.811	0.858
α_H	Beta	0.750	0.050	0.879	0.873	0.016	0.847	0.900
α_F^*	Beta	0.750	0.050	0.928	0.929	0.008	0.916	0.943
γ_H	Beta	0.500	0.150	0.677	0.671	0.099	0.512	0.831
γ_F^*	Beta	0.500	0.150	0.349	0.354	0.074	0.230	0.474
η	Beta	0.500	0.280	0.987	0.905	0.075	0.800	1.000
η^*	Uniform	0.500	0.289	0.786	0.776	0.121	0.604	0.989
ξ	Uniform	3.000	1.732	2.592	2.359	0.564	1.466	3.226
n	Uniform	0.850	0.087	0.979	0.977	0.005	0.970	0.985
χ	Uniform	0.100	0.058	0.017	0.013	0.007	0.001	0.024
$\chi_{\Delta S}$	Uniform	0.500	0.289	0.134	0.147	0.034	0.089	0.202
ρ	Beta	0.750	0.100	0.781	0.783	0.024	0.744	0.824
ρ^*	Beta	0.750	0.100	0.840	0.847	0.024	0.809	0.886
r_π	Normal	1.500	0.100	1.566	1.577	0.089	1.432	1.723
r_π^*	Normal	1.500	0.100	1.515	1.497	0.097	1.339	1.658
$r_{\Delta\pi}$	Gamma	0.300	0.100	0.257	0.256	0.051	0.172	0.340
$r_{\Delta\pi}^*$	Gamma	0.300	0.100	0.226	0.207	0.036	0.146	0.266
r_Y	Gamma	0.125	0.050	0.068	0.082	0.024	0.043	0.119
r_Y^*	Gamma	0.125	0.050	0.077	0.124	0.046	0.050	0.197
$r_{\Delta Y}$	Gamma	0.063	0.050	0.191	0.178	0.026	0.136	0.221
$r_{\Delta Y}^*$	Gamma	0.063	0.050	0.220	0.206	0.028	0.160	0.252

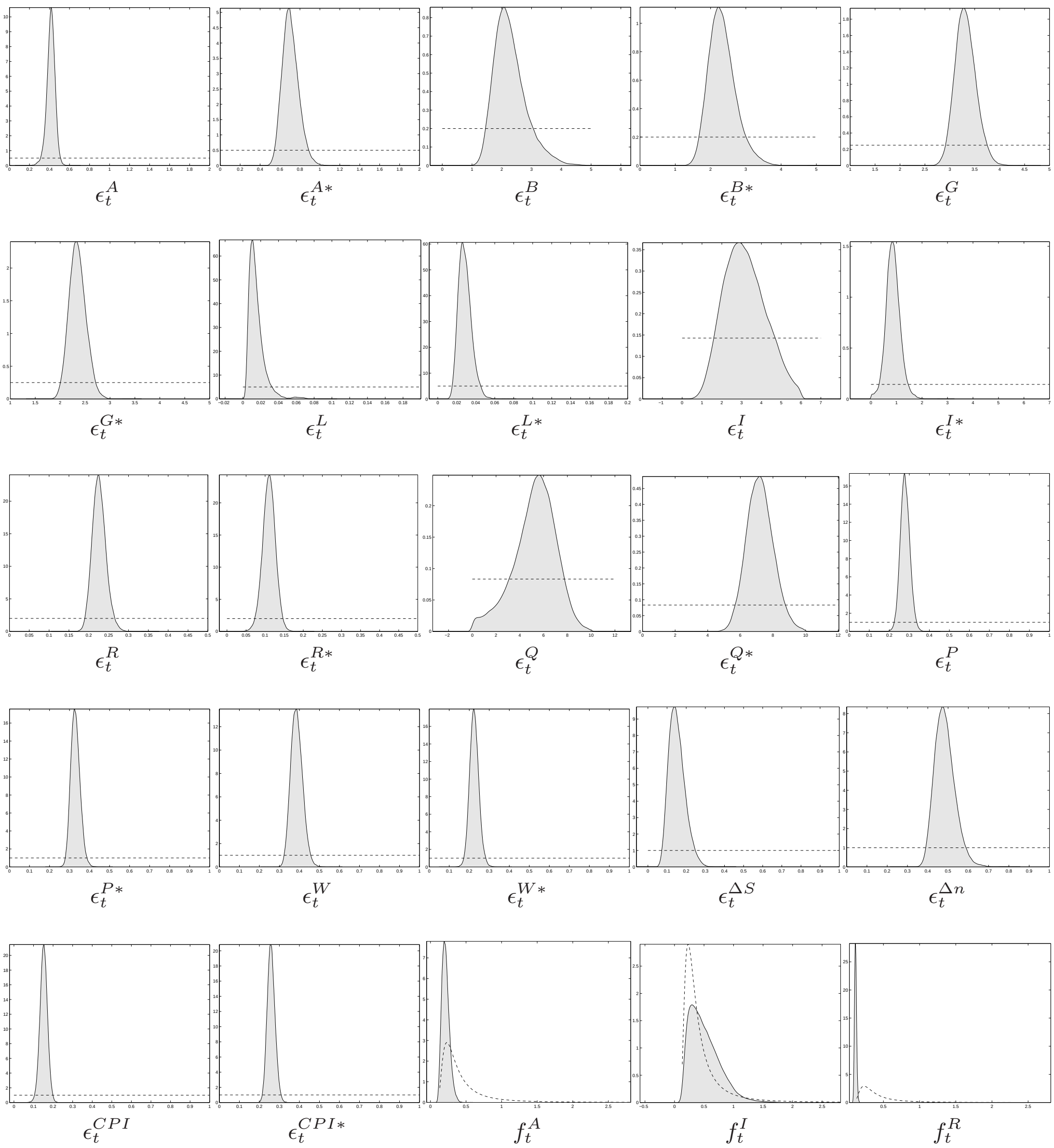

Fig. 1: Posterior densities.

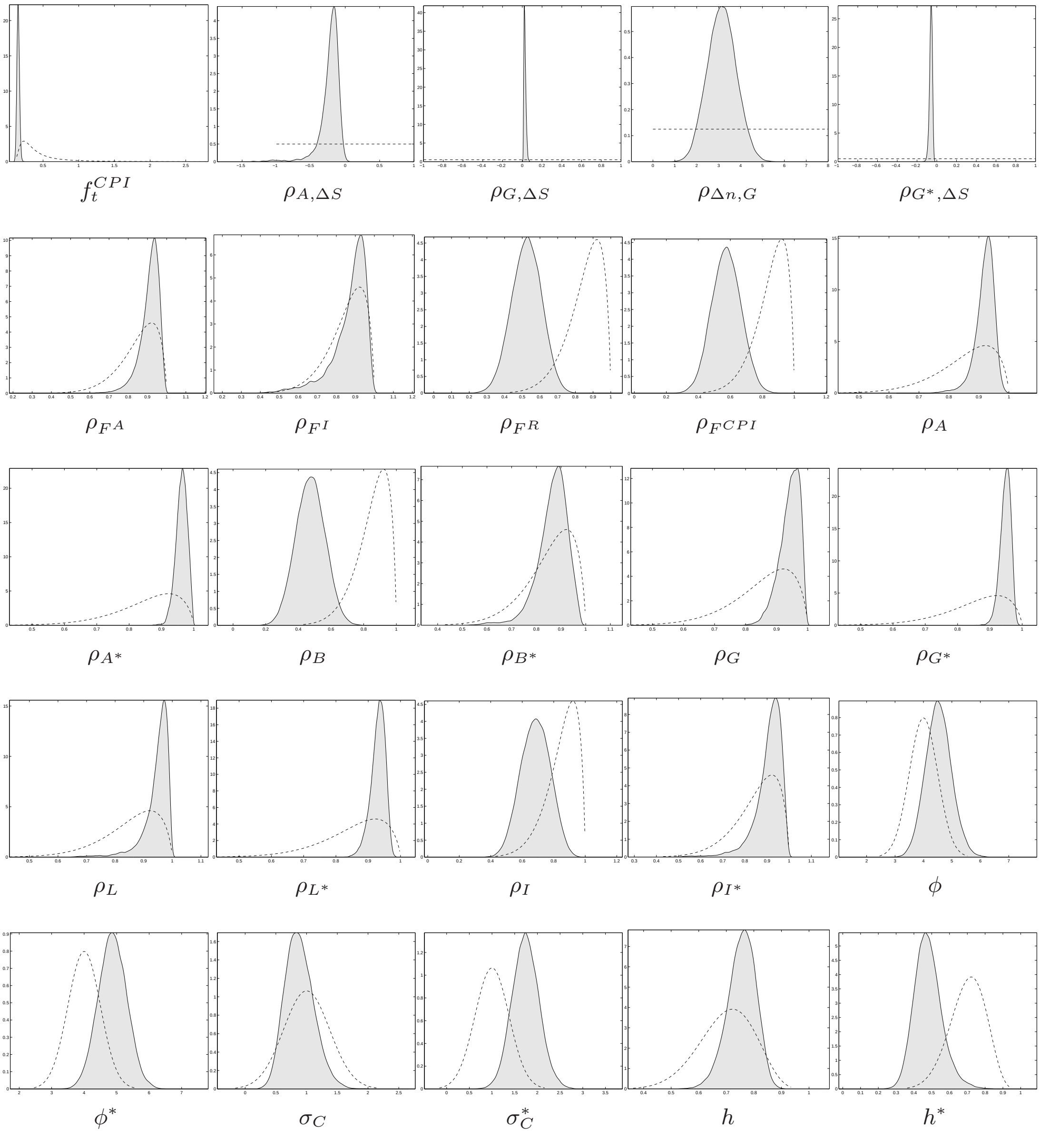

Fig. 2: Posterior densities.

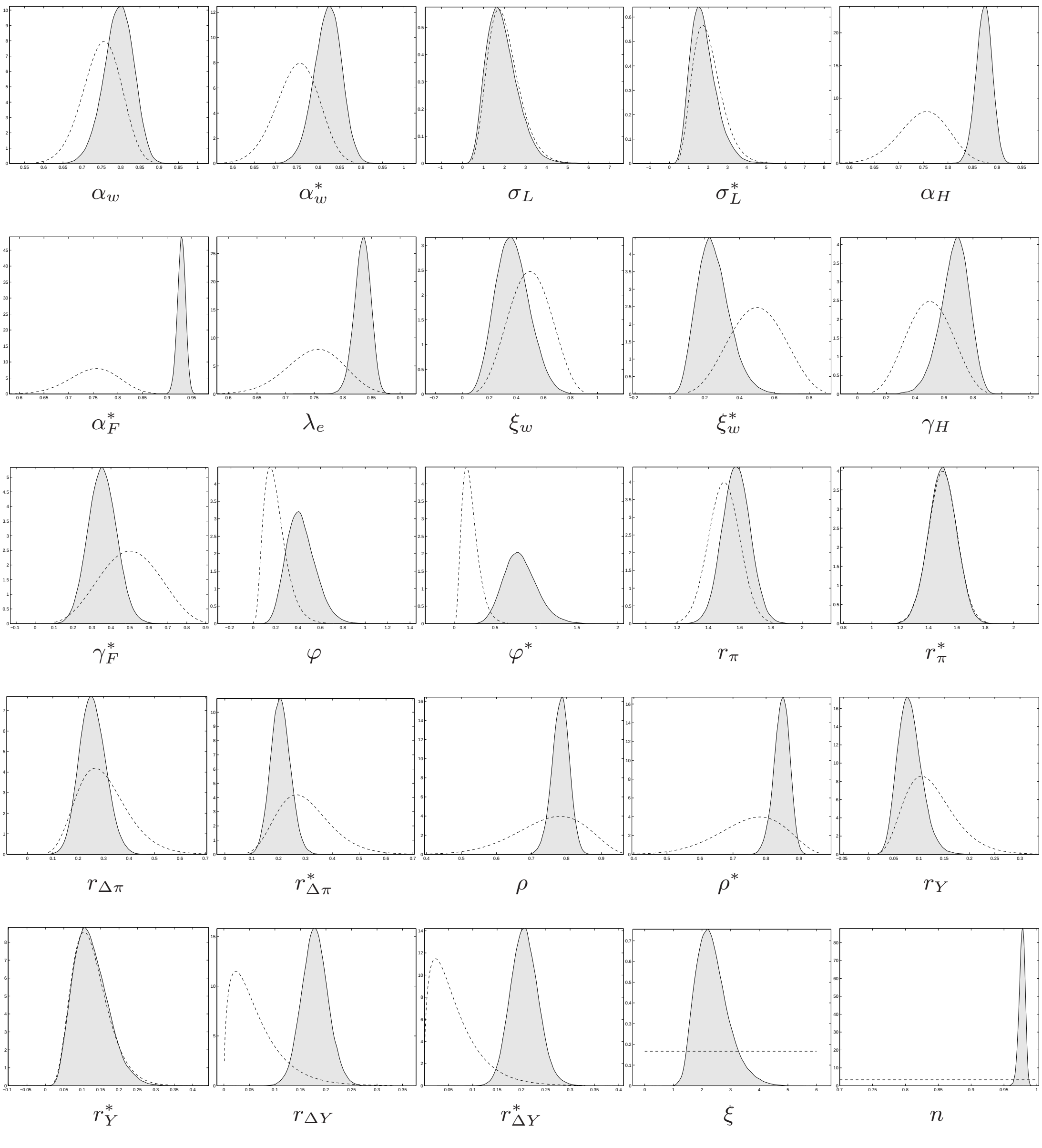

Fig. 3: Posterior densities.

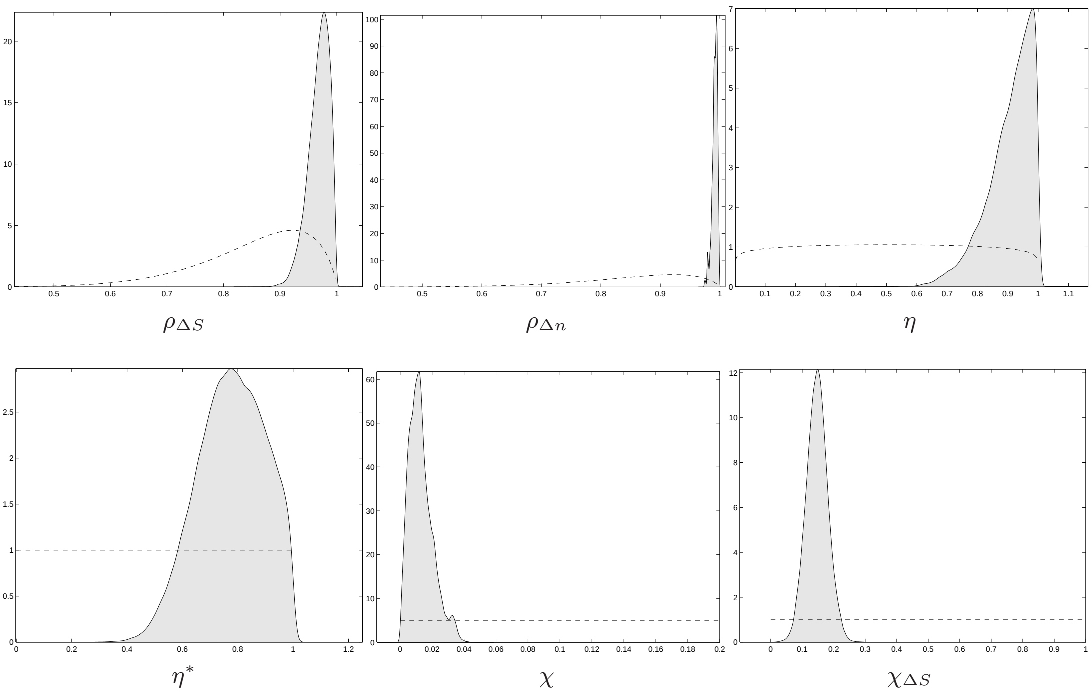

Fig. 4: Posterior densities.

Tab. 4: WELFARE CALCULATIONS: THE ROLE OF SHOCK STRUCTURE AND INTEREST RATE SMOOTHING

	All shocks			Efficient shocks	
	$\lambda_R = 0$ subs.	λ_R subs.	Estimated	$\lambda_R = 0$ subs.	λ_R subs.
Standard deviation					
US variables					
Z_t	4.40	4.27	3.82	3.64	3.68
C_t	4.42	4.37	4.23	3.90	3.92
I_t	11.40	11.45	10.82	9.77	9.84
w_t	1.74	1.76	1.96	1.24	1.25
Π_t	0.44	0.42	0.54	0.17	0.16
$\Pi_{H,t}$	0.37	0.36	0.51	0.16	0.15
R_t	6.11	0.52	0.49	1.28	0.27
euro area variables					
Z_t^*	6.67	6.62	4.73	6.49	6.48
C_t^*	5.88	5.81	5.13	5.64	5.62
I_t^*	16.60	16.65	11.24	16.03	16.07
w_t^*	5.37	5.37	5.02	5.20	5.20
Π_t^*	0.48	0.47	0.76	0.15	0.14
$\Pi_{F,t}^*$	0.35	0.35	0.71	0.12	0.12
R_t^*	4.03	0.59	0.61	1.08	0.44
ΔS_t	8.21	5.30	4.65	4.13	3.06
Welf. Cond.					
$\mathcal{W}_{US,0}$	-2.24	-2.30	-2.65	-0.18	-0.18
$\mathcal{W}_{EA,0}$	-2.15	-2.16	-3.97	-0.47	-0.48
$\mathcal{W}_{World,0}$	-4.39	-4.46	-6.62	-0.65	-0.66
$welfarecost_{US}$	-2.62	-2.69	-3.10	-0.21	-0.21
$welfarecost_{EA}$	-2.46	-2.48	-4.55	-0.54	-0.55

Tab. 5: COMPARISON OF SECOND-ORDER MOMENTS

	detrended			HP		
	data	Estimated	Optimal	data	Estimated	Optimal
Standard deviation						
US variables						
Z_t	2.78	3.82	4.27	1.55	1.58	1.84
C_t	2.86	4.23	4.38	1.25	1.18	1.27
I_t	7.44	10.82	11.47	4.26	4.15	4.48
w_t	2.34	1.96	1.76	0.83	1.03	0.90
Π_t	0.47	0.54	0.42	0.34	0.40	0.37
$\Pi_{H,t}$	0.44	0.51	0.36	0.30	0.34	0.30
R_t	0.67	0.49	0.52	0.40	0.33	0.36
euro area variables						
Z_t^*	2.23	4.73	6.62	1.02	1.16	2.10
C_t^*	2.32	5.13	5.80	0.88	1.20	1.48
I_t^*	6.21	11.24	16.64	2.83	3.23	5.01
w_t^*	3.62	5.02	5.36	0.72	1.05	0.79
Π_t^*	0.50	0.76	0.47	0.33	0.47	0.44
$\Pi_{F,t}^*$	0.46	0.71	0.35	0.33	0.38	0.32
R_t^*	0.61	0.61	0.59	0.29	0.23	0.41
ΔS_t	4.62	4.65	5.30	4.27	4.38	5.08
CA_t	1.15	1.46	1.35	0.51	0.49	0.52
Correlations						
Z_t, Z_t^*	0.43	0.11	0.00	0.46	0.29	0.01
C_t, C_t^*	0.16	0.11	0.07	0.31	0.14	0.12
C_t^{rel}, RER_t	-0.31	-0.35	-0.22	-0.25	-0.12	0.14

Tab. 6: COMPARISON OF THE SHOCK DECOMPOSITION OF UNCONDITIONAL VARIANCES

	Estimated rules							Optimal policy						
	Z_t	Π_t	R_t	ΔS_t	Z_t^*	Π_t^*	R_t^*	Z_t	Π_t	R_t	ΔS_t	Z_t^*	Π_t^*	R_t^*
US shocks	91.7	86.5	85.8	11.2	0.7	0.6	1.9	95.5	74.5	89.3	14.8	0.2	1.0	1.8
ε^A	11.0	9.6	5.5	2.8	0.2	0.1	0.4	10.6	6.6	5.2	2.9	0.0	0.2	0.2
ε^L	50.3	37.3	40.3	0.8	0.0	0.1	0.2	58.6	0.6	4.5	1.3	0.0	0.1	0.1
ε^I	8.4	0.7	14.9	0.8	0.1	0.0	0.1	1.7	0.3	3.9	0.4	0.0	0.0	0.0
ε^B	4.0	0.5	8.4	0.4	0.0	0.0	0.0	0.6	0.1	10.1	1.1	0.0	0.1	0.5
ε^G	8.2	1.0	5.5	6.2	0.4	0.4	1.1	5.8	1.0	0.8	4.1	0.1	0.3	0.4
ε^Q	1.4	0.1	2.6	0.1	0.0	0.0	0.0	0.3	0.0	2.2	0.2	0.0	0.0	0.0
ε^P	4.8	25.5	4.7	0.1	0.0	0.0	0.0	0.9	51.3	2.2	0.4	0.0	0.0	0.0
ε^{CPI}	0.2	7.0	0.7	0.1	0.0	0.0	0.0	0.0	13.4	0.1	0.0	0.0	0.0	0.0
ε^W	3.3	4.9	3.3	0.1	0.0	0.0	0.0	17.1	1.2	60.3	4.3	0.0	0.3	0.4
EA shocks	1.0	1.3	4.8	20.6	95.0	92.7	92.8	0.7	2.9	3.4	30.7	98.8	83.1	94.6
ε^{A^*}	0.1	0.2	0.6	1.7	43.3	31.7	39.0	0.0	0.1	0.1	0.7	20.9	4.0	4.6
ε^{L^*}	0.0	0.1	0.4	1.2	34.0	28.8	31.2	0.3	0.8	0.5	12.4	69.5	1.4	38.0
ε^{I^*}	0.0	0.1	0.2	0.6	5.4	0.1	3.4	0.0	0.0	0.0	0.2	0.9	0.1	1.6
ε^{B^*}	0.1	0.1	0.5	1.9	3.6	3.9	14.5	0.1	0.3	0.2	4.4	3.5	0.4	14.7
ε^{G^*}	0.7	0.8	3.1	14.8	2.2	0.6	0.7	0.2	1.4	2.1	8.9	1.0	0.6	0.1
ε^{Q^*}	0.0	0.0	0.0	0.2	1.9	0.0	2.3	0.0	0.0	0.1	0.5	0.1	0.0	4.6
ε^{P^*}	0.0	0.0	0.1	0.1	3.6	17.2	1.0	0.0	0.0	0.0	0.3	0.8	47.8	0.9
ε^{CPI^*}	0.0	0.0	0.0	0.1	0.9	10.2	0.4	0.0	0.0	0.0	0.0	0.0	28.7	0.1
ε^{W^*}	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.1	0.2	0.4	3.2	2.1	0.2	30.1
Open economy shocks														
$\varepsilon^{\Delta S}$	0.6	0.9	3.2	13.8	0.8	0.9	2.8	0.2	3.1	3.6	9.0	0.1	0.7	1.8
$\varepsilon^{\Delta n}$	2.0	1.2	0.7	54.5	0.6	1.1	0.5	0.6	3.4	1.5	45.5	0.2	3.0	0.8
Common shocks														
F^A	2.4	2.5	2.0	0.0	0.3	0.4	0.5	2.3	1.5	1.6	0.0	0.5	0.2	0.6
F^I	1.4	0.1	2.0	0.0	1.2	0.0	1.1	0.5	0.1	0.3	0.0	0.2	0.0	0.4
F^{CPI}	0.9	7.5	1.4	0.0	1.4	4.2	0.4	0.1	14.6	0.3	0.0	0.0	12.1	0.1

Tab. 7: COMPARISON OF THE SHOCK DECOMPOSITION OF CONDITIONAL VARIANCES: EA GDP

	Estimated						Ramsey					
quarters	1	4	8	12	20	40	1	4	8	12	20	40
US shocks	5.8	4.0	2.8	2.0	1.0	0.5	1.9	0.5	0.2	0.2	0.1	0.1
ε^A	1.2	0.9	0.7	0.5	0.3	0.1	0.3	0.1	0.0	0.0	0.0	0.0
ε^L	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0
ε^I	0.5	0.5	0.4	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
ε^B	0.4	0.3	0.2	0.1	0.1	0.0	0.4	0.1	0.0	0.0	0.0	0.0
ε^G	3.4	2.0	1.3	0.9	0.5	0.2	0.4	0.1	0.0	0.0	0.0	0.0
ε^Q	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^P	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{CPI}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^W	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.1	0.0	0.0	0.0
EA shocks	87.3	86.8	86.3	88.0	92.1	95.4	97.1	98.5	98.7	98.8	98.8	98.9
ε^{A^*}	1.1	0.8	5.7	13.5	25.0	36.9	2.7	5.2	6.7	8.2	11.4	17.9
ε^{L^*}	0.3	1.4	7.0	16.3	30.9	37.7	75.3	80.0	80.7	80.2	78.0	72.5
ε^{I^*}	0.0	0.9	4.1	6.9	8.2	6.4	0.1	0.4	0.7	0.8	0.9	0.9
ε^{B^*}	21.6	30.2	23.7	16.2	8.2	4.2	0.8	2.3	3.5	3.9	3.9	3.4
ε^{G^*}	18.7	9.1	6.7	5.3	3.5	2.5	6.3	2.0	1.3	1.1	1.1	1.1
ε^{Q^*}	28.4	17.4	12.4	8.8	4.6	2.2	2.2	0.3	0.2	0.1	0.1	0.1
ε^{P^*}	10.8	20.5	20.9	16.5	9.1	4.3	0.9	1.0	1.0	1.0	0.9	0.8
ε^{CPI^*}	5.6	6.2	5.6	4.3	2.3	1.1	0.2	0.1	0.0	0.0	0.0	0.0
ε^{W^*}	0.9	0.3	0.2	0.2	0.2	0.2	8.7	7.1	4.5	3.4	2.6	2.1
Open economy shocks												
$\varepsilon^{\Delta S}$	4.6	3.2	2.3	1.6	0.8	0.4	0.3	0.1	0.0	0.0	0.0	0.0
$\varepsilon^{\Delta n}$	0.4	0.3	0.3	0.2	0.1	0.3	0.6	0.5	0.3	0.3	0.3	0.3
Common shocks												
F^A	0.4	0.1	0.1	0.3	0.4	0.4	0.1	0.4	0.5	0.5	0.5	0.5
F^I	0.0	0.5	1.4	2.0	2.1	1.4	0.0	0.1	0.2	0.2	0.2	0.2
F^{CPI}	1.5	5.0	6.7	5.8	3.4	1.6	0.0	0.1	0.1	0.1	0.0	0.0

Tab. 8: COMPARISON OF THE SHOCK DECOMPOSITION OF CONDITIONAL VARIANCES: US GDP

	Estimated						Ramsey					
quarters	1	4	8	12	20	40	1	4	8	12	20	40
US shocks	81.1	85.3	87.1	88.3	89.9	91.7	86.7	95.0	95.7	95.6	95.6	95.8
ε^A	0.0	1.5	7.3	12.1	14.0	11.6	1.4	6.2	9.8	11.4	11.8	10.8
ε^L	0.0	1.0	7.5	17.8	34.6	49.0	16.3	31.8	41.3	47.3	53.6	58.9
ε^I	8.5	20.1	21.7	18.0	12.3	8.6	5.1	5.2	3.3	2.5	2.0	1.6
ε^B	20.4	20.8	13.3	9.2	5.9	4.1	6.7	2.1	1.2	0.9	0.7	0.6
ε^G	34.7	19.9	14.3	11.5	9.1	8.4	33.9	11.6	6.7	5.8	5.5	5.8
ε^Q	10.1	6.4	4.4	3.2	2.1	1.4	5.2	1.1	0.5	0.4	0.3	0.3
ε^P	5.0	13.9	14.5	10.9	7.0	4.9	0.5	1.4	1.5	1.3	1.1	0.9
ε^{CPI}	1.0	1.0	0.7	0.5	0.3	0.2	0.2	0.1	0.0	0.0	0.0	0.0
ε^W	1.3	0.7	3.3	5.0	4.7	3.4	17.3	35.6	31.4	25.9	20.5	16.9
EA shocks	5.1	3.5	2.2	1.5	1.0	0.7	7.8	2.4	1.2	0.9	0.7	0.6
ε^{A^*}	0.1	0.1	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0
ε^{L^*}	0.0	0.0	0.0	0.0	0.0	0.0	3.2	1.1	0.5	0.4	0.3	0.3
ε^{I^*}	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{B^*}	0.6	0.4	0.3	0.2	0.1	0.1	1.3	0.5	0.2	0.2	0.1	0.1
ε^{G^*}	4.0	2.7	1.7	1.2	0.7	0.5	2.0	0.5	0.3	0.2	0.2	0.2
ε^{Q^*}	0.1	0.1	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
ε^{P^*}	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{CPI^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{W^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.1	0.1	0.1	0.1
Open economy shocks												
$\varepsilon^{\Delta S}$	3.0	2.0	1.3	0.9	0.6	0.4	1.6	0.4	0.2	0.1	0.1	0.1
$\varepsilon^{\Delta n}$	9.3	5.6	4.5	3.7	2.8	2.2	3.8	0.8	0.4	0.4	0.4	0.5
Common shocks												
F^A	0.2	0.2	1.3	2.3	2.9	2.5	0.0	1.0	2.0	2.4	2.6	2.4
F^I	0.1	0.3	0.8	1.2	1.5	1.5	0.1	0.3	0.4	0.5	0.6	0.5
F^{CPI}	1.3	3.0	2.8	2.1	1.3	0.9	0.1	0.1	0.1	0.1	0.1	0.1

Tab. 9: COMPARISON OF THE SHOCK DECOMPOSITION OF CONDITIONAL VARIANCES: EA CPI INFLATION

	Estimated						Ramsey					
quarters	1	4	8	12	20	40	1	4	8	12	20	40
US shocks	0.7	0.5	0.4	0.4	0.4	0.5	1.0	0.9	1.0	0.9	0.9	0.9
ε^A	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
ε^L	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
ε^I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^B	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
ε^G	0.4	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
ε^Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{CPI}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^W	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3
EA shocks	86.3	88.3	90.8	91.9	92.8	93.0	84.6	82.5	82.8	83.0	83.1	83.2
ε^{A^*}	2.7	13.8	20.3	23.2	26.5	31.0	0.2	2.2	3.4	3.7	3.8	3.8
ε^{L^*}	2.9	15.4	24.3	28.3	30.8	30.1	1.2	1.2	1.2	1.2	1.3	1.4
ε^{I^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
ε^{B^*}	0.2	2.0	3.4	3.9	4.2	4.0	0.3	0.3	0.3	0.3	0.3	0.4
ε^{G^*}	1.0	0.8	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
ε^{Q^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{P^*}	48.2	34.9	26.2	22.4	19.1	17.0	48.8	47.7	47.6	47.8	48.0	47.9
ε^{CPI^*}	31.2	21.0	15.7	13.3	11.3	10.1	33.3	30.4	29.6	29.2	29.0	28.8
ε^{W^*}	0.1	0.3	0.3	0.3	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2
Open economy shocks												
$\varepsilon^{\Delta S}$	0.9	0.8	0.6	0.6	0.6	0.8	0.7	0.6	0.6	0.6	0.6	0.6
$\varepsilon^{\Delta n}$	2.1	1.5	1.2	1.1	1.0	1.1	3.3	3.1	3.1	3.0	3.0	3.0
Common shocks												
F^A	0.1	0.4	0.5	0.5	0.5	0.4	0.0	0.1	0.1	0.1	0.1	0.1
F^I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F^{CPI}	9.8	8.5	6.4	5.5	4.7	4.2	10.4	12.7	12.4	12.3	12.2	12.1

Tab. 10: COMPARISON OF THE SHOCK DECOMPOSITION OF CONDITIONAL VARIANCES: US CPI INFLATION

	Estimated						Ramsey					
quarters	1	4	8	12	20	40	1	4	8	12	20	40
US shocks	76.6	81.3	84.1	85.4	86.4	86.8	74.8	76.1	76.4	76.8	77.0	76.5
ε^A	0.9	8.7	11.6	11.2	10.3	9.7	0.2	4.0	5.7	5.5	5.9	6.6
ε^L	1.3	11.8	23.4	29.7	34.9	38.3	0.2	0.4	0.5	0.5	0.5	0.6
ε^I	0.0	0.3	0.6	0.7	0.7	0.7	0.1	0.1	0.2	0.3	0.3	0.3
ε^B	0.0	0.4	0.5	0.5	0.5	0.5	0.1	0.1	0.1	0.1	0.1	0.1
ε^G	0.5	0.4	0.5	0.6	0.8	1.0	0.3	0.2	0.2	0.2	0.2	0.3
ε^Q	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
ε^P	52.7	41.8	32.0	29.0	26.7	25.0	53.6	54.7	53.8	54.7	54.6	53.4
ε^{CPI}	20.1	12.1	9.1	8.0	7.3	6.8	20.3	15.9	15.1	14.6	14.3	13.9
ε^W	1.2	5.7	6.2	5.6	5.1	4.8	0.0	0.8	0.8	0.9	1.1	1.3
EA shocks	1.6	1.2	1.1	1.1	1.1	1.2	2.7	2.2	2.1	2.0	2.0	2.2
ε^{A^*}	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ε^{L^*}	0.1	0.1	0.1	0.1	0.1	0.1	1.1	0.8	0.8	0.8	0.7	0.7
ε^{I^*}	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{B^*}	0.2	0.1	0.1	0.1	0.1	0.1	0.4	0.3	0.3	0.3	0.3	0.3
ε^{G^*}	1.2	0.9	0.8	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.9
ε^{Q^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{P^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{CPI^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ε^{W^*}	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Open economy shocks												
$\varepsilon^{\Delta S}$	1.1	0.8	0.8	0.7	0.8	0.9	0.9	0.7	0.8	0.8	0.9	1.4
$\varepsilon^{\Delta n}$	3.2	2.0	1.5	1.3	1.2	1.1	4.1	3.4	3.3	3.2	3.1	3.1
Common shocks												
F^A	0.4	2.3	3.0	2.9	2.7	2.6	0.2	1.0	1.4	1.4	1.4	1.5
F^I	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1
F^{CPI}	17.1	12.3	9.5	8.6	7.8	7.3	17.4	16.6	16.1	15.9	15.6	15.2

Tab. 11: COMPARISON OF THE SHOCK DECOMPOSITION OF CONDITIONAL COVARIANCE: US-EA GDP. The contributions of shocks sum to the conditional covariance.

	Estimated						Ramsey					
quarters	1	4	8	12	20	40	1	4	8	12	20	40
Cov. Cond.	0.10	0.29	0.40	0.46	0.58	0.78	-0.15	-0.66	-0.34	-0.06	0.08	0.17
US shocks	0.06	0.16	0.17	0.15	0.13	0.14	0.01	-0.08	-0.01	0.03	0.03	0.02
ε^A	0.00	-0.01	-0.05	-0.08	-0.10	-0.10	-0.01	-0.03	-0.03	-0.02	-0.01	0.00
ε^L	0.00	0.00	-0.01	-0.02	-0.04	-0.03	-0.02	-0.08	-0.08	-0.07	-0.08	-0.08
ε^I	0.01	0.05	0.08	0.10	0.10	0.10	0.01	0.02	0.03	0.02	0.02	0.02
ε^B	0.01	0.04	0.04	0.04	0.04	0.04	0.02	0.03	0.04	0.04	0.04	0.04
ε^G	0.04	0.10	0.13	0.14	0.15	0.15	0.04	0.08	0.08	0.09	0.10	0.08
ε^Q	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01
ε^P	0.00	-0.02	-0.04	-0.04	-0.04	-0.04	0.00	0.00	0.00	0.00	0.00	0.00
ε^{CPI}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ε^W	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.03	-0.10	-0.05	-0.04	-0.04	-0.04
EA shocks	0.05	0.13	0.15	0.16	0.17	0.24	-0.17	-0.67	-0.58	-0.47	-0.47	-0.46
ε^{A^*}	0.00	0.00	-0.01	-0.01	-0.01	0.03	-0.01	-0.04	-0.05	-0.04	-0.05	-0.06
ε^{L^*}	0.00	0.00	-0.01	-0.01	0.00	0.06	-0.16	-0.58	-0.51	-0.41	-0.39	-0.35
ε^{I^*}	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01
ε^{B^*}	0.01	0.06	0.07	0.07	0.07	0.08	-0.01	-0.06	-0.05	-0.04	-0.03	-0.02
ε^{G^*}	0.03	0.08	0.09	0.10	0.10	0.08	0.04	0.07	0.06	0.05	0.04	0.01
ε^{Q^*}	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
ε^{P^*}	0.00	-0.02	-0.03	-0.03	-0.03	-0.03	0.00	0.00	0.00	0.00	0.00	0.00
ε^{CPI^*}	0.00	0.00	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00
ε^{W^*}	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	-0.06	-0.04	-0.04	-0.04	-0.04
Open economy shocks												
$\varepsilon^{\Delta S}$	-0.01	-0.04	-0.05	-0.05	-0.05	-0.05	-0.01	-0.01	-0.01	-0.01	-0.01	-0.02
$\varepsilon^{\Delta n}$	-0.01	-0.02	-0.03	-0.04	-0.03	0.00	0.02	0.03	0.05	0.06	0.08	0.12
Common shocks												
F^A	0.00	0.00	0.01	0.03	0.08	0.12	0.00	0.05	0.16	0.25	0.34	0.39
F^I	0.00	0.01	0.03	0.07	0.14	0.20	0.00	0.01	0.04	0.07	0.09	0.10
F^{CPI}	0.01	0.06	0.13	0.14	0.14	0.14	0.00	0.01	0.01	0.01	0.01	0.01

Tab. 12: COMPARISON OF THE SHOCK DECOMPOSITION OF CONDITIONAL COVARIANCE: US-EA CONSUMPTION. The contributions of shocks sum to the conditional covariance.

	Estimated						Ramsey					
quarters	1	4	8	12	20	40	1	4	8	12	20	40
Cov. Cond.	0.00	0.08	0.26	0.44	0.71	1.08	0.04	0.42	0.87	1.09	1.40	1.98
US shocks	0.01	0.07	0.17	0.27	0.42	0.66	0.02	0.17	0.34	0.43	0.57	0.81
ε^{A}	0.00	0.01	0.02	0.03	0.04	0.04	0.00	0.03	0.06	0.07	0.08	0.09
ε^{L}	0.00	0.01	0.04	0.08	0.14	0.23	0.00	0.02	0.05	0.07	0.09	0.15
ε^{I}	0.00	0.00	0.00	0.00	0.02	0.05	0.00	0.01	0.01	0.01	0.02	0.02
ε^{B}	0.00	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01
ε^{G}	0.01	0.05	0.11	0.16	0.23	0.34	0.01	0.07	0.16	0.22	0.33	0.49
ε^{Q}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ε^{P}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ε^{CPI}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ε^{W}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.07	0.06	0.06	0.06
EA shocks	0.00	0.04	0.17	0.33	0.62	1.17	0.03	0.25	0.53	0.71	0.98	1.61
ε^{A^*}	0.00	0.04	0.12	0.22	0.39	0.71	0.00	0.03	0.08	0.11	0.18	0.34
ε^{L^*}	0.00	0.03	0.09	0.16	0.27	0.43	0.02	0.21	0.44	0.57	0.76	1.12
ε^{I^*}	0.00	0.00	0.01	0.01	0.01	0.04	0.00	0.00	0.01	0.02	0.02	0.03
ε^{B^*}	-0.01	-0.06	-0.13	-0.17	-0.21	-0.22	-0.01	-0.06	-0.13	-0.17	-0.19	-0.16
ε^{G^*}	0.00	0.03	0.07	0.10	0.15	0.20	0.00	0.03	0.08	0.12	0.17	0.23
ε^{Q^*}	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.01	0.01
ε^{P^*}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ε^{CPI^*}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ε^{W^*}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.04	0.04	0.04
Open economy shocks												
$\varepsilon^{\Delta S}$	0.00	-0.03	-0.06	-0.08	-0.12	-0.14	-0.01	-0.05	-0.10	-0.14	-0.18	-0.22
$\varepsilon^{\Delta n}$	0.00	-0.03	-0.10	-0.18	-0.35	-0.87	0.00	0.00	-0.02	-0.06	-0.16	-0.54
Common shocks												
F^{A}	0.00	0.01	0.02	0.04	0.07	0.10	0.00	0.03	0.08	0.10	0.14	0.21
F^{I}	0.00	0.02	0.04	0.04	0.04	0.14	0.00	0.01	0.04	0.05	0.05	0.11
F^{CPI}	0.00	0.01	0.02	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00

Tab. 13: COMPARISON OF THE SHOCK DECOMPOSITION OF CONDITIONAL COVARIANCE: RELATIVE CONSUMPTION AND REAL EXCHANGE RATE COVARIANCE. The contributions of shocks sum to the conditional covariance.

	Estimated						Ramsey					
quarters	1	4	8	12	20	40	1	4	8	12	20	40
Cov. Cond.	-0.72	-3.76	-6.78	-9.37	-15.76	-41.65	1.14	5.66	6.97	5.64	1.06	-18.24
US shocks	0.00	0.84	2.87	4.88	7.86	10.59	0.22	2.45	5.19	6.88	9.18	11.65
ε^A	0.00	0.11	0.51	0.88	1.23	1.18	0.04	0.38	0.89	1.17	1.38	1.30
ε^L	0.01	0.13	0.63	1.33	2.54	3.91	0.12	0.80	1.52	1.93	2.57	3.76
ε^I	0.02	0.09	0.11	0.12	0.27	0.63	0.02	0.17	0.28	0.29	0.36	0.60
ε^B	-0.13	-0.39	-0.42	-0.42	-0.42	-0.43	-0.25	-0.82	-0.90	-0.89	-0.90	-0.91
ε^G	0.10	0.76	1.79	2.68	3.94	4.94	0.07	0.71	1.87	2.90	4.34	5.48
ε^Q	0.00	0.01	0.01	0.01	0.02	0.03	0.01	0.05	0.06	0.06	0.06	0.07
ε^P	0.01	0.11	0.15	0.14	0.14	0.14	0.00	0.00	-0.01	-0.01	-0.01	-0.01
ε^{CPI}	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
ε^W	0.00	0.02	0.09	0.13	0.14	0.15	0.21	1.16	1.47	1.43	1.38	1.36
EA shocks	-0.07	-0.22	0.51	1.77	4.37	8.27	1.30	6.08	9.07	10.86	13.96	19.76
ε^{A^*}	0.05	0.44	1.26	2.15	3.70	6.07	0.13	0.77	1.36	1.79	2.57	4.52
ε^{L^*}	0.03	0.31	1.01	1.78	2.97	4.06	1.22	6.10	9.50	11.25	13.67	17.10
ε^{I^*}	0.02	0.14	0.26	0.30	0.31	0.70	0.01	0.08	0.18	0.24	0.25	0.50
ε^{B^*}	-0.29	-1.62	-2.80	-3.43	-3.90	-3.98	-0.31	-1.68	-2.83	-3.36	-3.69	-3.59
ε^{G^*}	0.10	0.42	0.66	0.84	1.13	1.23	0.00	-0.06	-0.09	-0.01	0.20	0.26
ε^{Q^*}	0.01	0.01	0.01	0.02	0.04	0.06	0.03	0.11	0.12	0.13	0.13	0.14
ε^{P^*}	0.01	0.05	0.07	0.07	0.08	0.08	0.00	0.00	0.00	-0.01	0.00	0.02
ε^{CPI^*}	0.01	0.03	0.03	0.03	0.03	0.04	0.00	0.00	0.00	0.00	0.00	0.00
ε^{W^*}	0.00	0.00	0.01	0.01	0.01	0.01	0.21	0.76	0.83	0.83	0.82	0.81
Open economy shocks												
$\varepsilon^{\Delta S}$	-0.18	-1.16	-2.35	-3.21	-4.21	-4.71	-0.25	-1.54	-3.06	-4.10	-5.29	-5.90
$\varepsilon^{\Delta n}$	-0.46	-3.24	-7.81	-12.83	-23.82	-55.84	-0.14	-1.34	-4.23	-7.99	-16.78	-43.73
Common shocks												
F^A	0.00	0.00	0.01	0.02	0.02	0.03	0.00	0.00	0.00	-0.01	-0.01	-0.02
F^I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F^{CPI}	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00

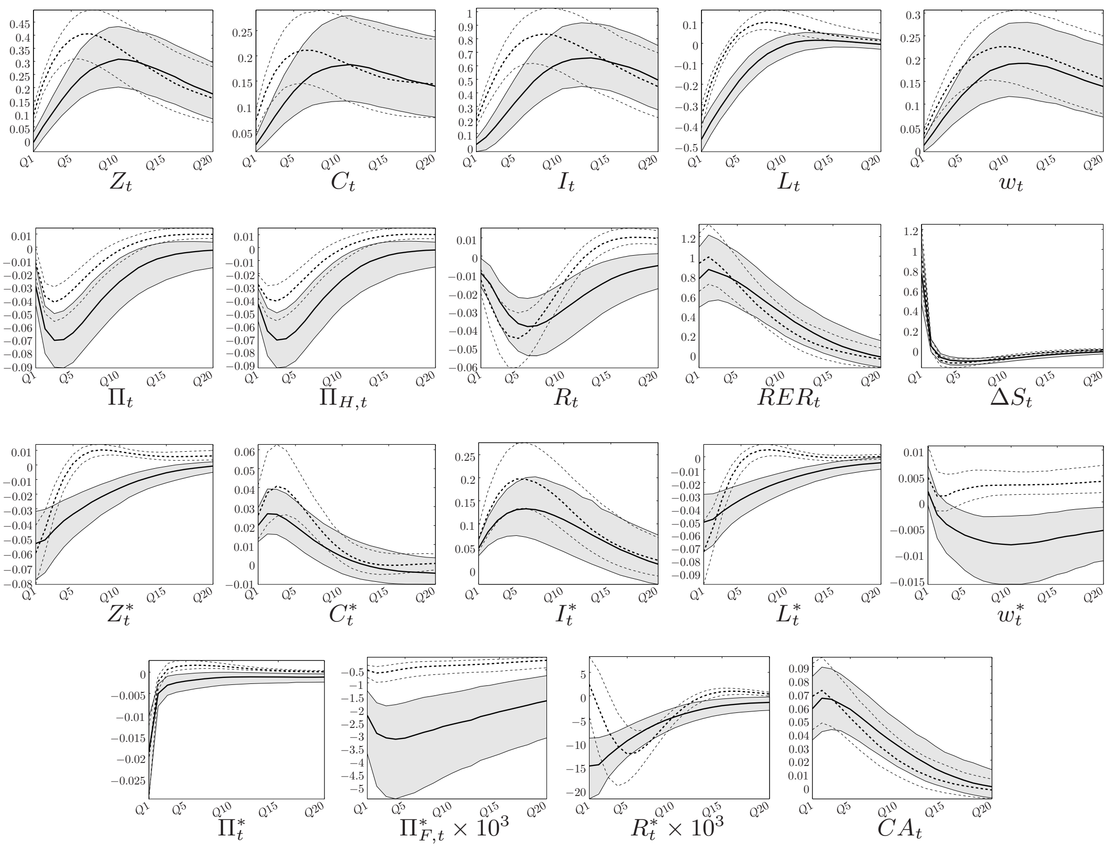

Fig. 5: Impulse Response Functions associated to a shock on ϵ_t^A. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

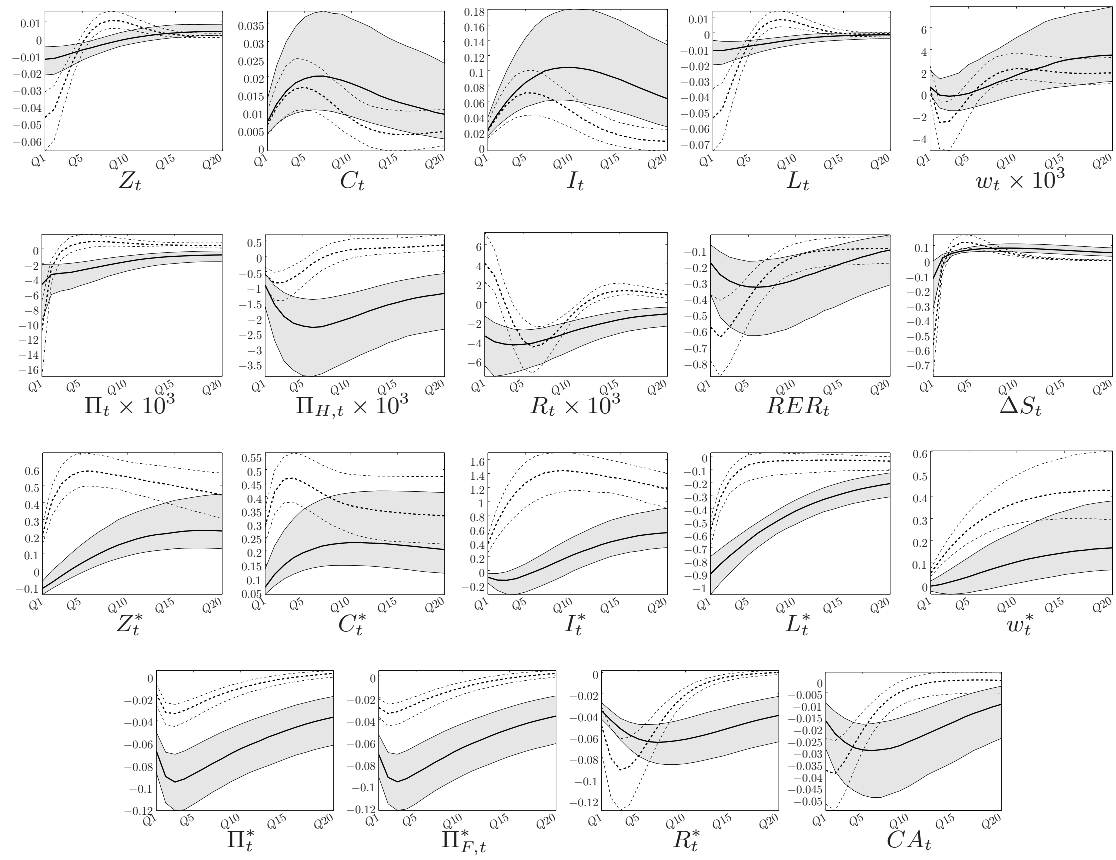

Fig. 6: Impulse Response Functions associated to a shock on ϵ_t^{A*}. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

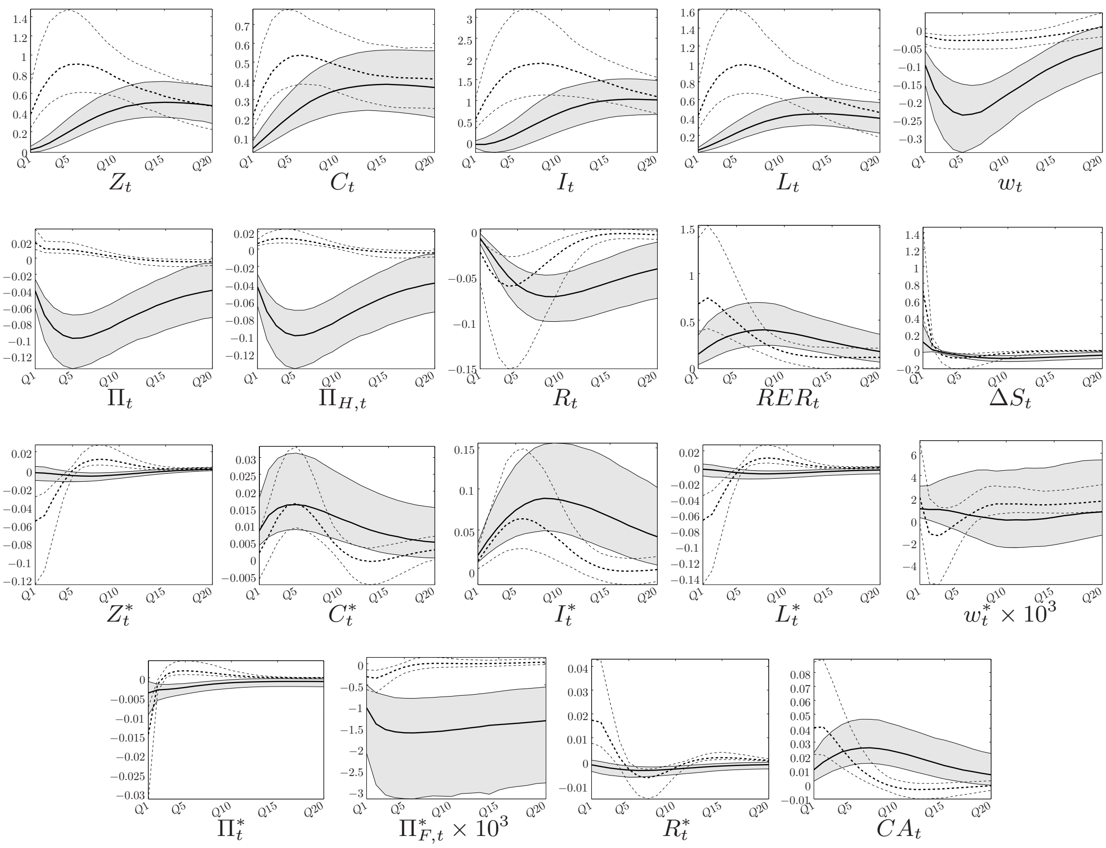

Fig. 7: Impulse Response Functions associated to a shock on ϵ_t^L. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

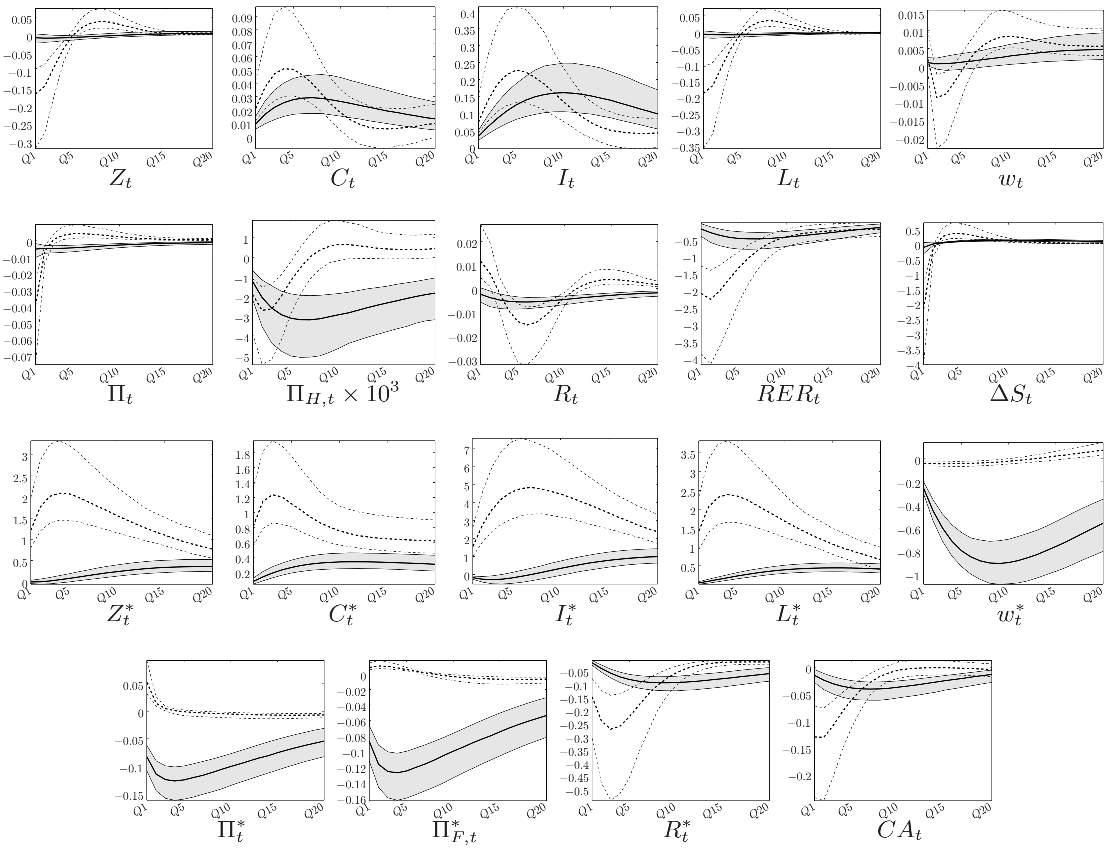

Fig. 8: Impulse Response Functions associated to a shock on ϵ_t^{L*}. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

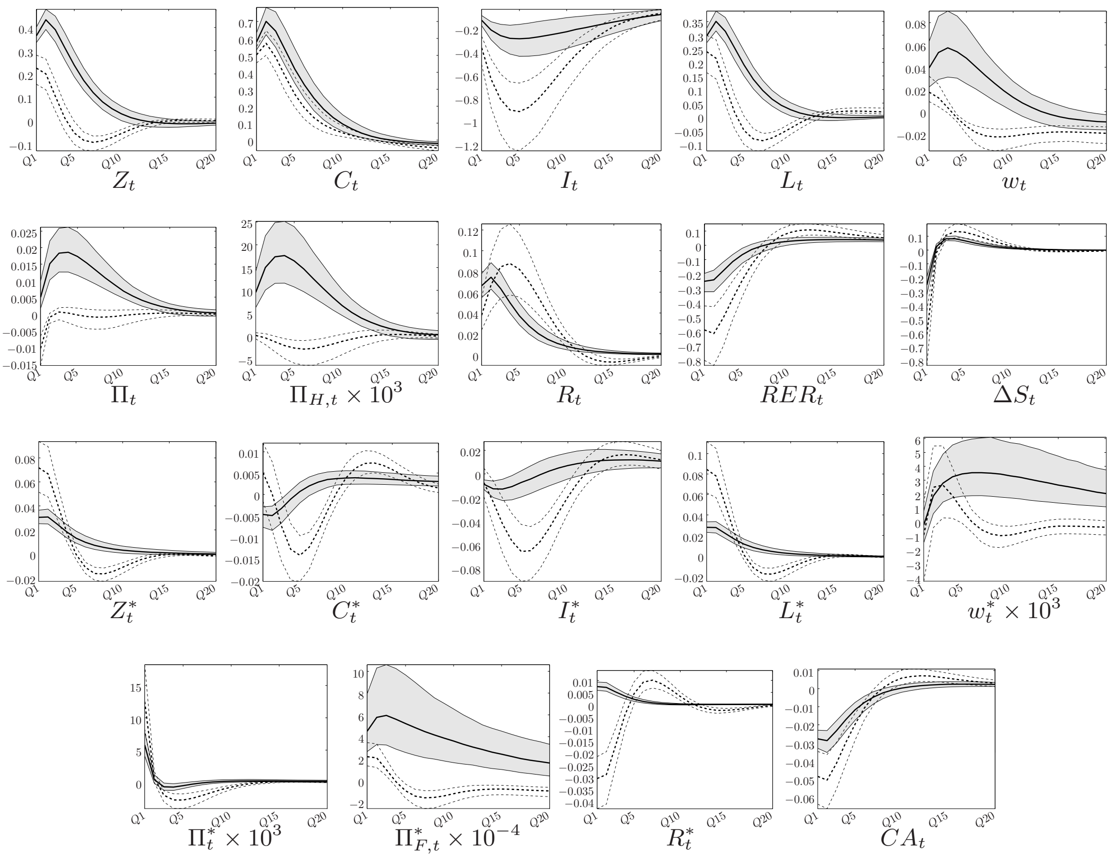

Fig. 9: Impulse Response Functions associated to a shock on ϵ_t^B. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

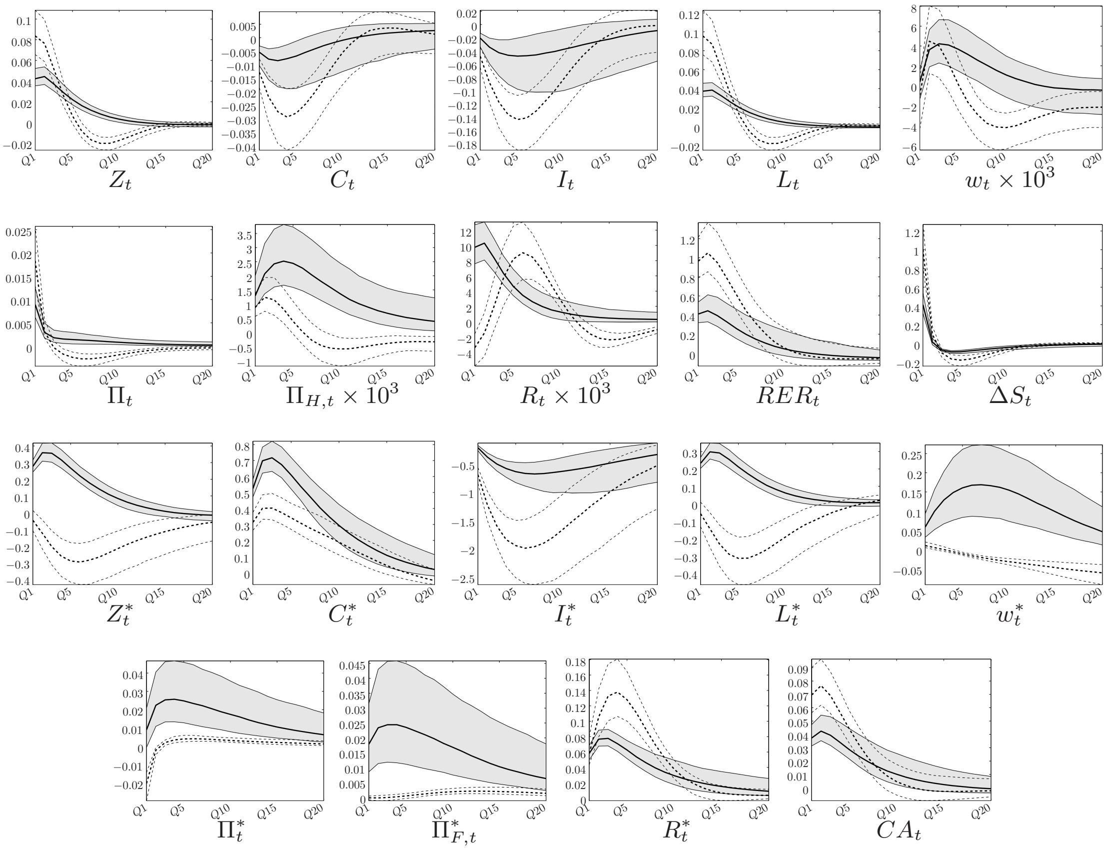

Fig. 10: Impulse Response Functions associated to a shock on ϵ_t^{B*}. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

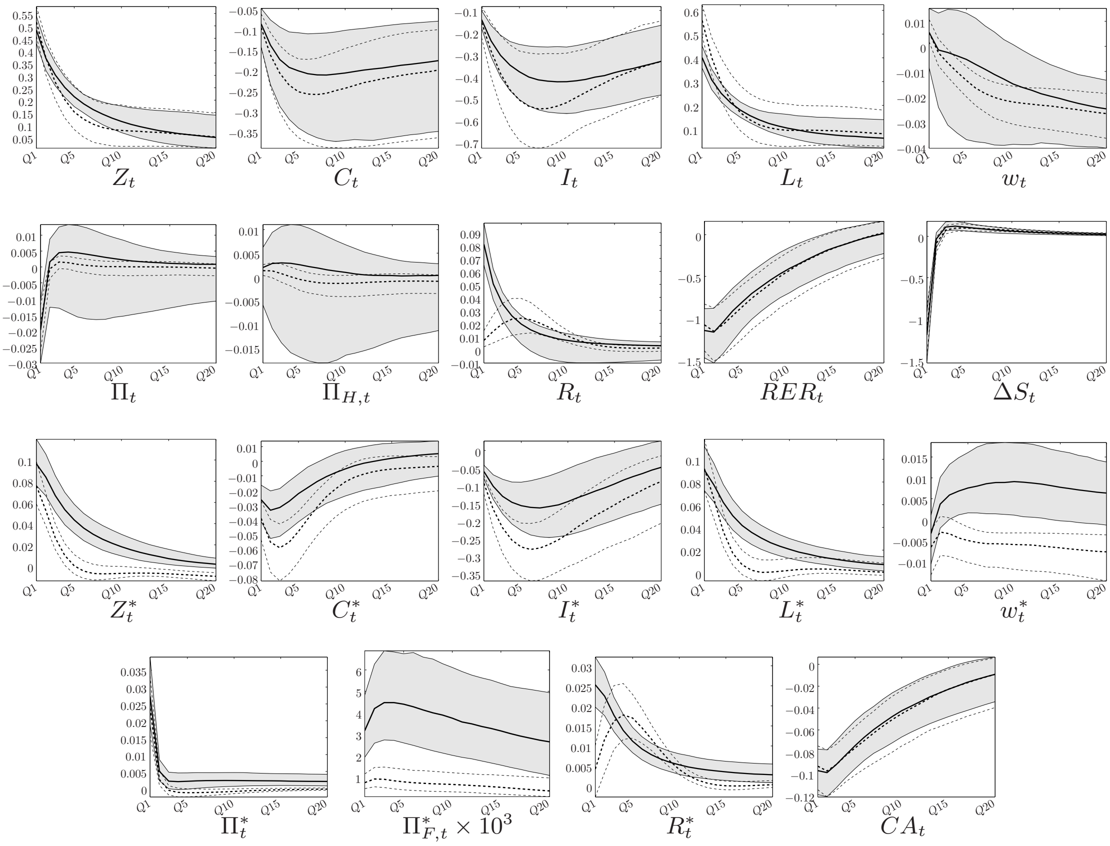

Fig. 11: Impulse Response Functions associated to a shock on ϵ_t^G. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

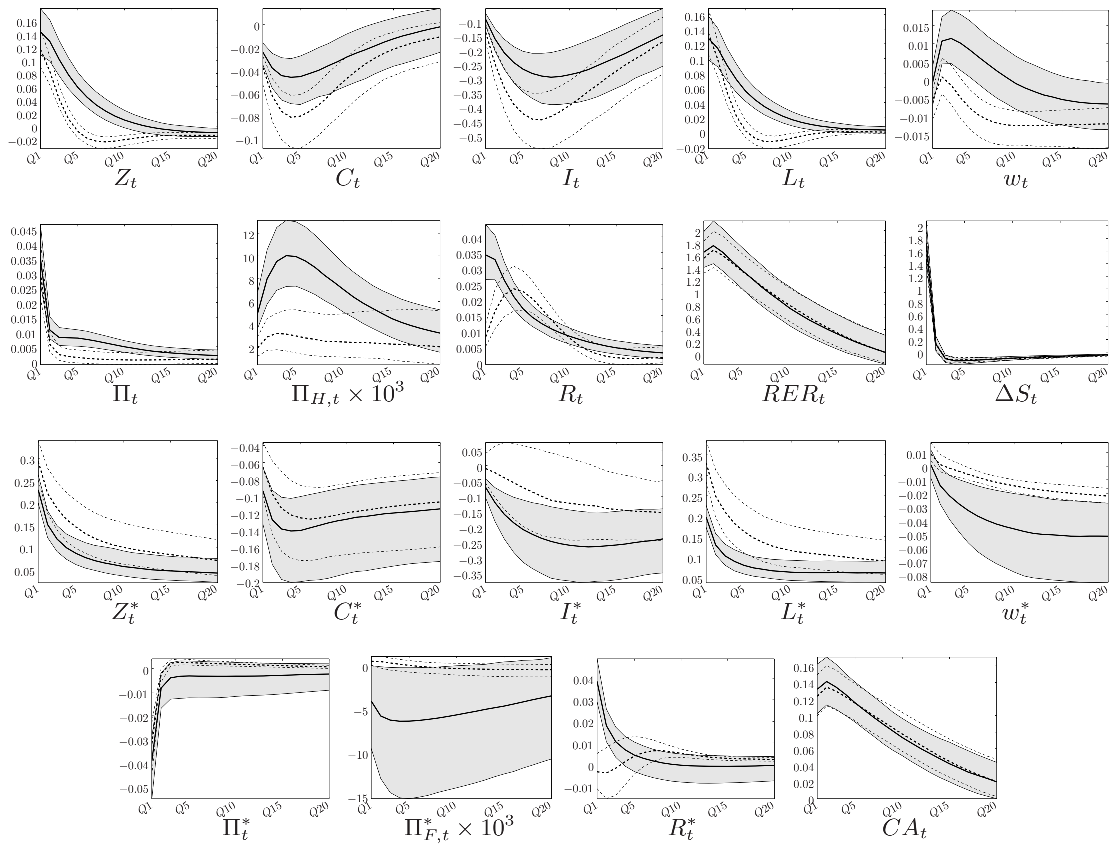

Fig. 12: Impulse Response Functions associated to a shock on ϵ_t^{G*}. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

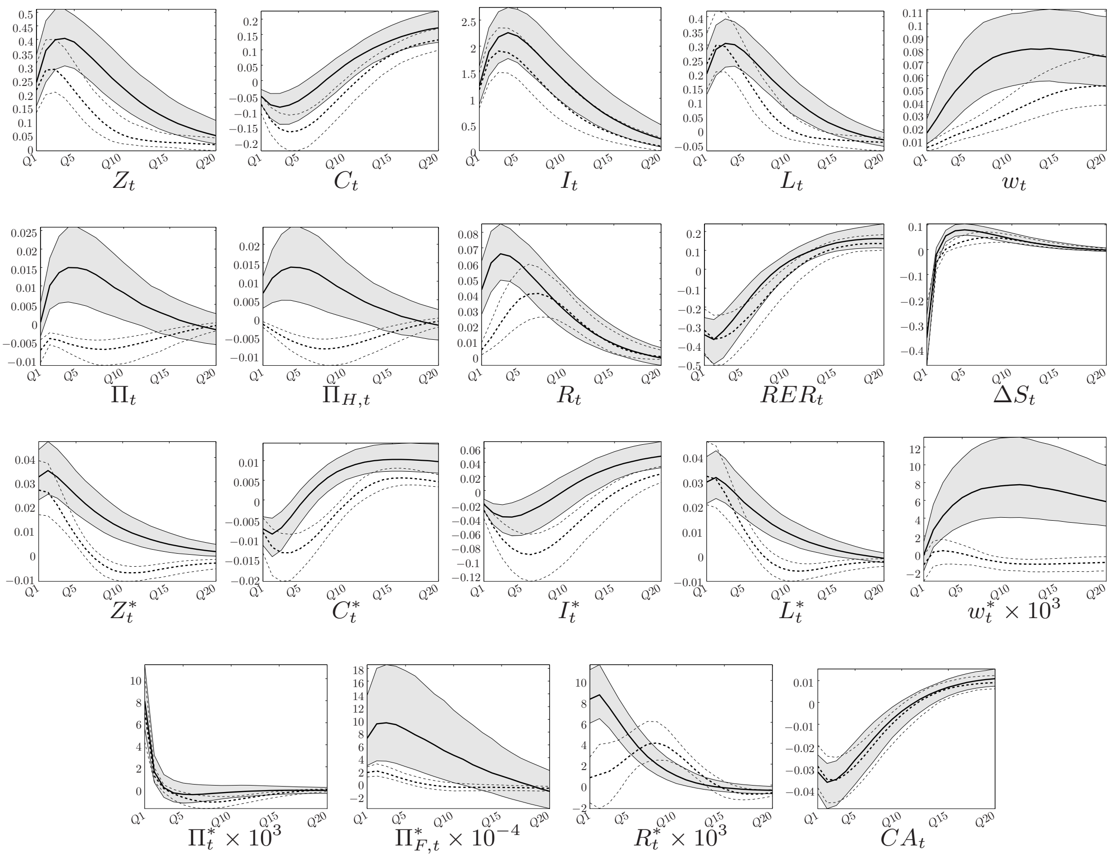

Fig. 13: Impulse Response Functions associated to a shock on ϵ_t^I. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

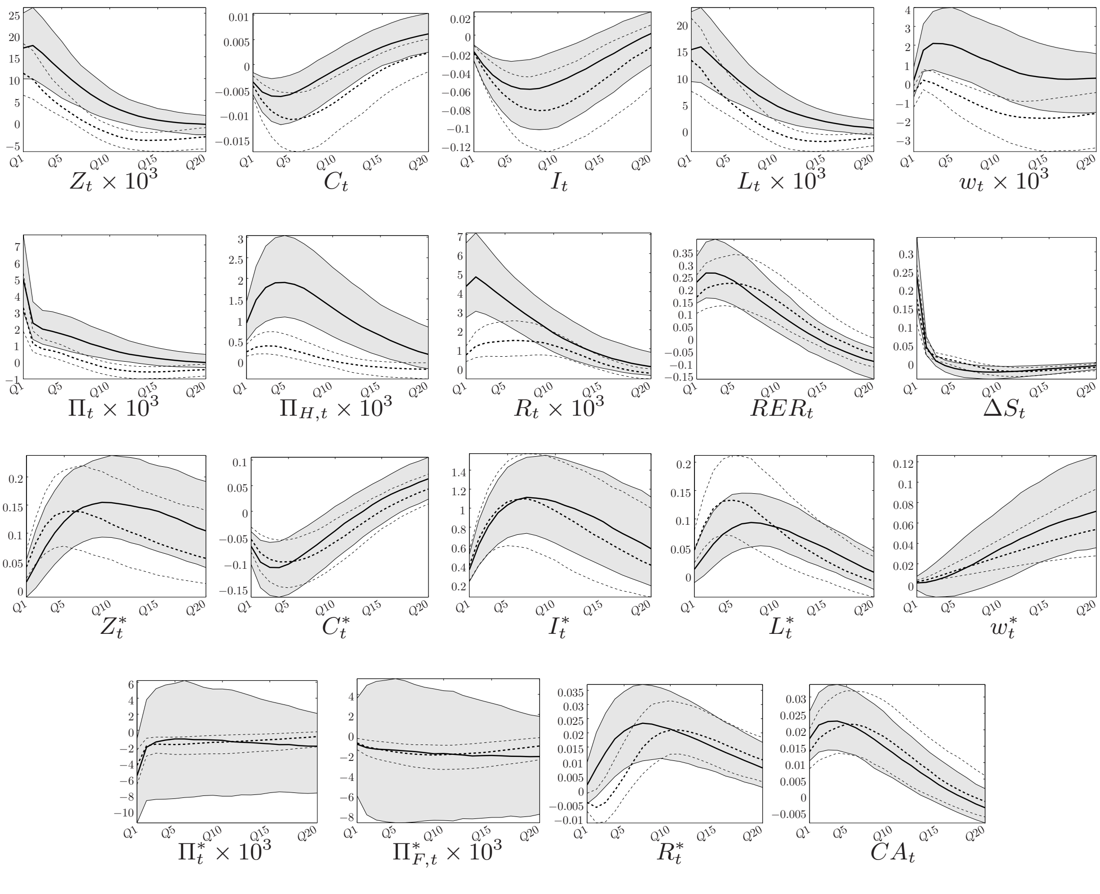

Fig. 14: Impulse Response Functions associated to a shock on ϵ_t^{I*}. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

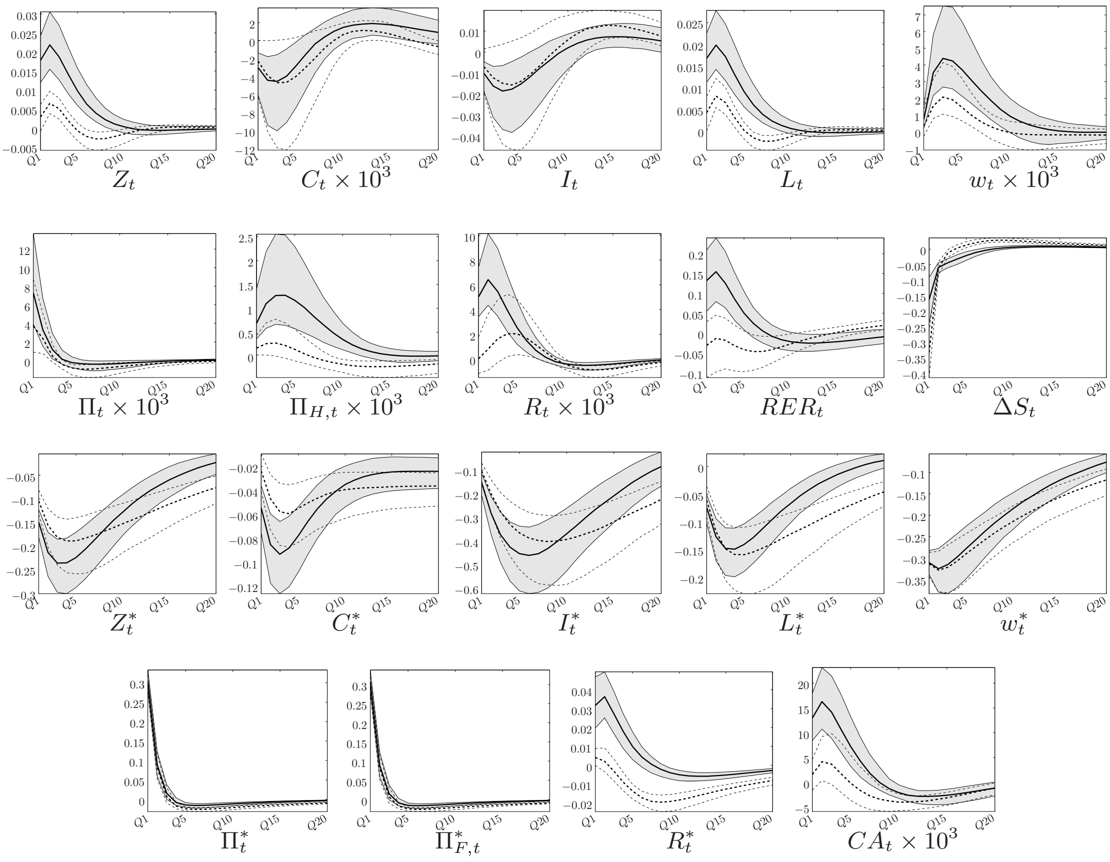

Fig. 15: Impulse Response Functions associated to a shock on ϵ_t^{P*}. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

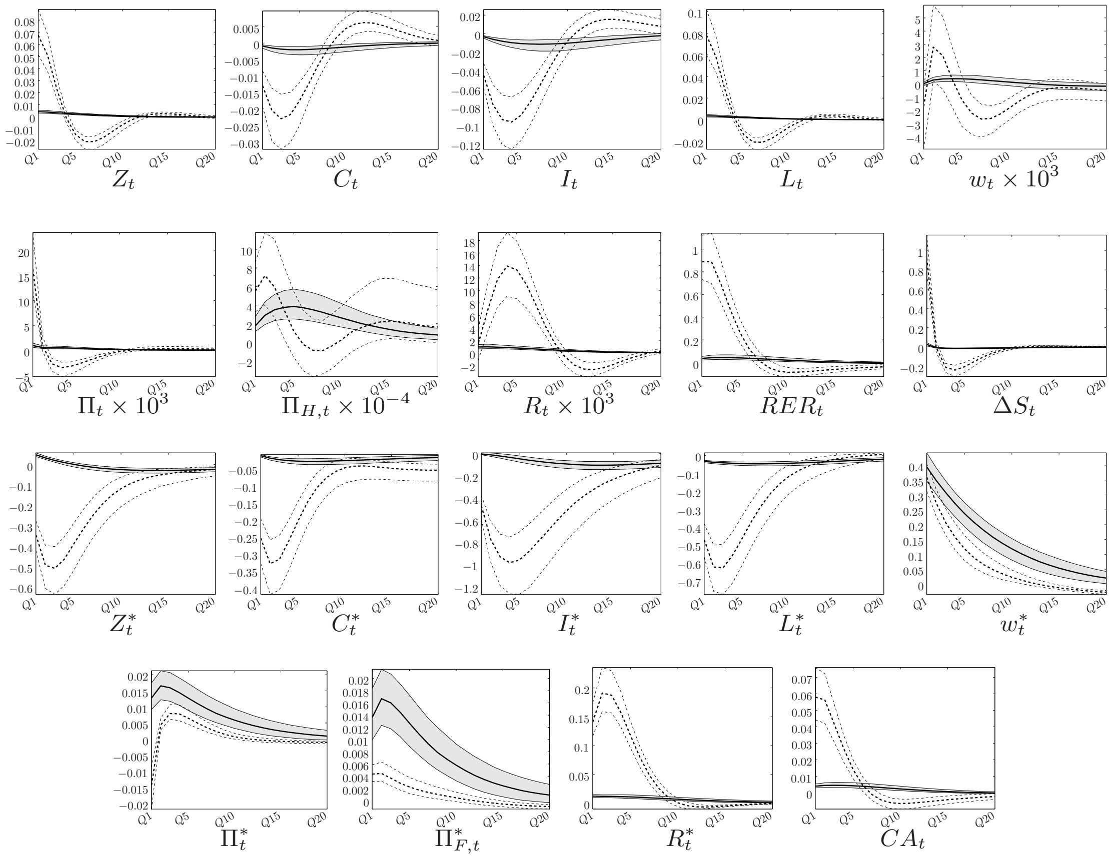

Fig. 16: Impulse Response Functions associated to a shock on ϵ_t^{W*}. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

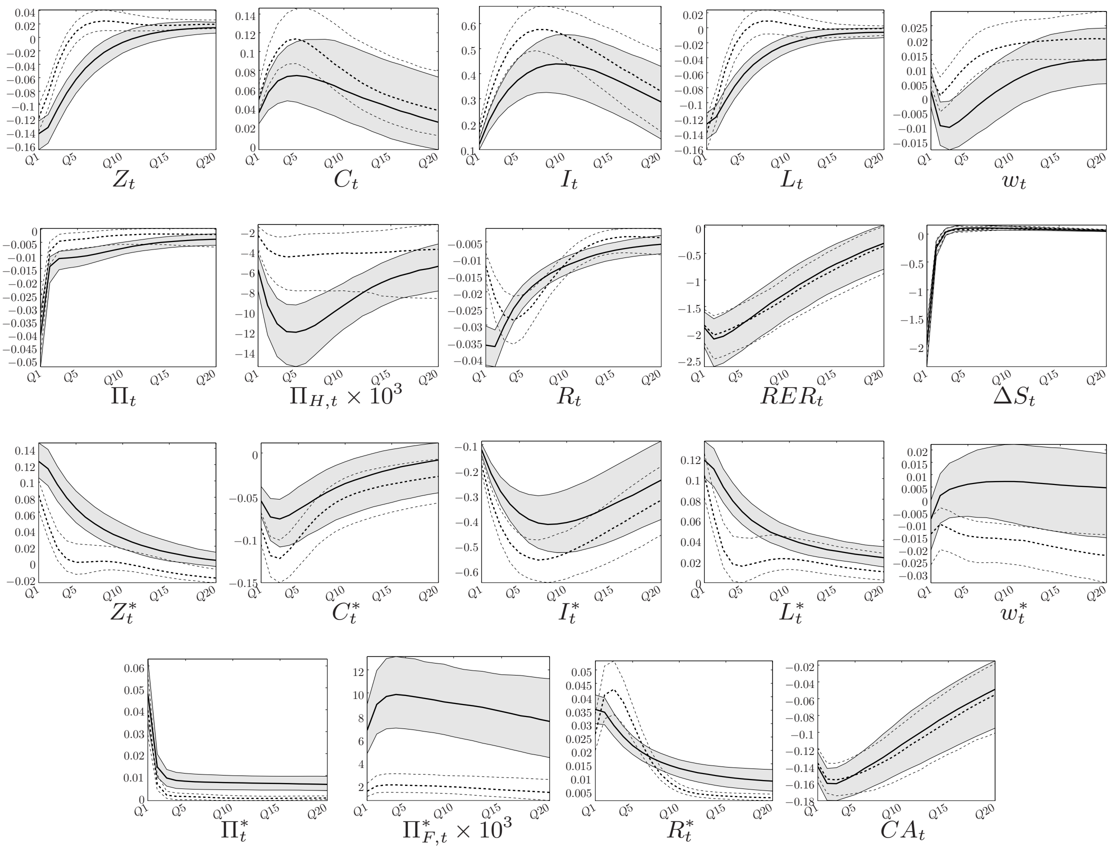

Fig. 17: Impulse Response Functions associated to a shock on $\epsilon_t^{\Delta S}$. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

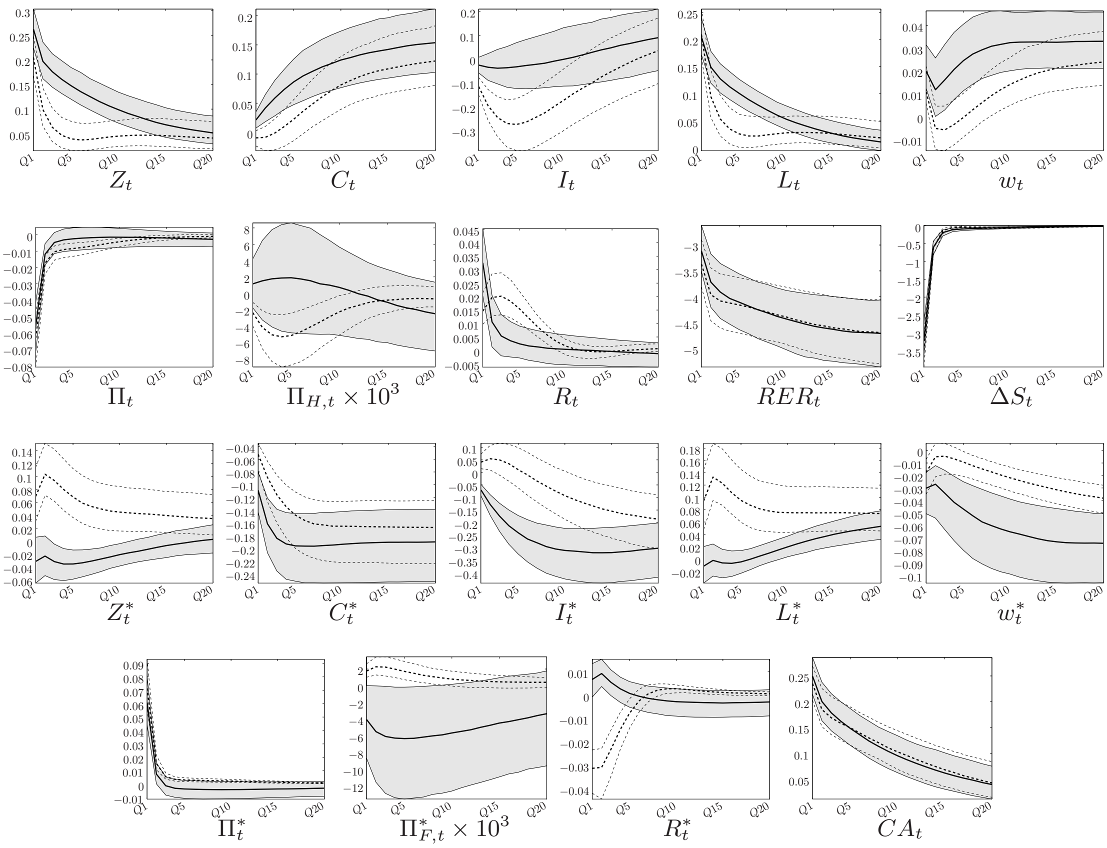

Fig. 18: Impulse Response Functions associated to a shock on $\epsilon_t^{\Delta n}$. *Optimal (dotted lines), Estimated (plain lines and shaded areas).*

Tab. 14: SENSITIVITY ANALYSIS: WELFARE AND MOMENTS

	no UIP shock				Efficient shocks			
price-setting	Bench	Bench	LCP	LCP	Bench	Bench	LCP	LCP
risk sharing	Bench	Perfect	Bench	Perfect	Bench	Perfect	Bench	Perfect
Standard deviation								
US variables								
Z_t	4.26	4.49	4.29	4.49	3.68	3.69	3.70	3.70
C_t	4.29	5.03	4.37	5.06	3.92	3.70	3.92	3.74
I_t	11.14	11.13	11.45	11.29	9.84	9.82	9.87	9.95
w_t	1.75	1.74	1.79	1.76	1.25	1.24	1.26	1.25
Π_t	0.41	0.40	0.40	0.39	0.16	0.15	0.15	0.14
$\Pi_{H,t}$	0.35	0.34	0.35	0.34	0.15	0.14	0.15	0.14
R_t	0.51	0.51	0.53	0.52	0.27	0.27	0.27	0.27
euro area variables								
Z_t^*	6.62	7.05	6.58	7.01	6.48	6.70	6.44	6.65
C_t^*	5.77	5.59	5.80	5.64	5.62	5.23	5.64	5.28
I_t^*	16.45	16.84	16.80	17.24	16.07	16.40	16.36	16.79
w_t^*	5.36	5.31	5.37	5.33	5.20	5.15	5.20	5.16
Π_t^*	0.46	0.46	0.45	0.45	0.14	0.14	0.12	0.12
$\Pi_{F,t}^*$	0.35	0.35	0.35	0.35	0.12	0.12	0.12	0.12
R_t^*	0.59	0.60	0.64	0.65	0.44	0.45	0.46	0.47
ΔS_t	5.03	4.26	5.94	4.75	3.06	3.92	3.60	4.38
Welf. Cond.								
$\mathcal{W}_{US,0}$	-2.27	-1.63	-2.31	-1.52	-0.18	-0.18	-0.19	-0.17
$\mathcal{W}_{EA,0}$	-2.14	-1.18	-2.19	-1.32	-0.48	-0.45	-0.48	-0.47
$\mathcal{W}_{World,0}$	-4.41	-2.81	-4.50	-2.83	-0.66	-0.63	-0.67	-0.65
$welfarecost_{US}$	-2.66	-1.91	-2.70	-1.77	-0.21	-0.22	-0.23	-0.20
$welfarecost_{EA}$	-2.45	-1.36	-2.51	-1.51	-0.55	-0.52	-0.55	-0.54

Tab. 15: SENSITIVITY ANALYSIS: KEY OPEN ECONOMY PARAMETERS AND MOMENTS 1

			Optimal Policy								
η, η^*	n	ξ	π_t	$\pi_{H,t}$	$\widehat{z}_t$	$\widehat{c}_t$	Δs_t	π_t^*	$\pi_{F,t}^*$	$\widehat{z}_t^*$	$\widehat{c}_t^*$
			standard deviations, *in percent*								
$0, 0$	0.825	0.3	3.73	3.58	11.55	24.03	26.64	1.21	1.10	7.66	16.46
		0.5	0.79	0.66	3.73	15.42	12.01	0.48	0.41	2.28	10.70
		1.5	0.43	0.38	2.46	5.00	3.76	0.42	0.35	2.66	3.47
		2.5	0.42	0.37	2.72	4.65	3.61	0.42	0.35	2.94	3.26
	0.9	0.3	2.25	2.03	5.23	11.12	7.76	0.85	0.65	3.95	7.76
		0.5	1.25	1.17	6.82	23.90	28.56	0.59	0.52	3.28	16.55
		1.5	0.42	0.37	2.42	4.97	4.41	0.43	0.35	2.56	3.44
		2.5	0.41	0.37	2.63	4.34	3.94	0.43	0.35	2.73	3.03
	0.975	0.3	1.28	1.04	4.71	9.49	40.58	0.62	0.43	2.60	6.68
		0.5	4.34	4.52	19.58	49.32	181.28	1.36	1.45	12.83	34.36
		1.5	0.41	0.36	2.35	5.16	8.82	0.45	0.35	2.55	3.60
		2.5	0.40	0.36	2.49	4.16	5.92	0.45	0.35	2.56	2.90
$1, 1$	0.825	0.3	4.55	2.23	11.14	11.52	23.24	4.23	1.01	9.74	8.25
		0.5	0.99	0.65	5.04	18.07	4.73	0.90	0.43	3.28	13.05
		1.5	0.58	0.38	2.37	5.08	2.33	0.60	0.35	2.45	3.60
		2.5	0.50	0.38	2.52	4.71	1.64	0.52	0.35	2.67	3.35
	0.9	0.3	2.31	1.13	6.71	11.58	19.24	2.09	0.58	4.78	7.97
		0.5	1.26	1.32	13.27	30.96	9.12	0.93	0.76	9.56	22.74
		1.5	0.52	0.38	2.37	5.07	3.11	0.54	0.35	2.44	3.58
		2.5	0.47	0.38	2.49	4.42	2.22	0.50	0.35	2.56	3.13
	0.975	0.3	1.33	0.66	5.03	8.82	41.27	1.21	0.42	2.94	6.07
		0.5	12.45	13.54	121.41	109.98	93.21	6.06	7.14	105.48	87.85
		1.5	0.45	0.36	2.35	5.24	7.62	0.49	0.35	2.49	3.71
		2.5	0.43	0.36	2.45	4.18	4.70	0.47	0.35	2.47	2.95

Tab. 16: SENSITIVITY ANALYSIS: KEY OPEN ECONOMY PARAMETERS AND MOMENTS 2

Optimal Policy with Perfect Risk Sharing												
η, η^*	n	ξ	π_t	$\pi_{H,t}$	$\widehat{z}_t$	$\widehat{c}_t$	Δs_t	π_t^*	$\pi_{F,t}^*$	$\widehat{z}_t^*$	$\widehat{c}_t^*$
			standard deviations, *in percent*								
$0, 0$	0.825	0.3	0.51	0.36	2.39	3.47	5.37	0.43	0.35	1.47	2.44
		0.5	0.49	0.36	2.25	3.85	5.20	0.43	0.35	1.47	2.75
		1.5	0.45	0.35	2.31	5.07	4.67	0.42	0.35	2.08	3.73
		2.5	0.43	0.34	2.57	5.70	4.41	0.42	0.35	2.55	4.24
	0.9	0.3	0.43	0.35	2.25	2.26	5.73	0.43	0.35	1.45	1.55
		0.5	0.42	0.35	2.20	2.55	5.60	0.43	0.35	1.45	1.78
		1.5	0.41	0.34	2.28	3.71	5.13	0.43	0.35	1.83	2.69
		2.5	0.40	0.34	2.47	4.45	4.84	0.43	0.35	2.21	3.28
	0.975	0.3	0.39	0.34	2.17	1.46	5.99	0.45	0.35	1.44	0.98
		0.5	0.39	0.34	2.17	1.50	5.95	0.45	0.35	1.45	1.00
		1.5	0.39	0.34	2.21	1.77	5.77	0.45	0.35	1.53	1.22
		2.5	0.39	0.34	2.27	2.11	5.61	0.45	0.35	1.65	1.49
$1, 1$	0.825	0.3	1.14	0.39	2.46	3.78	5.96	1.12	0.35	1.50	2.80
		0.5	0.98	0.37	2.33	4.27	5.04	0.98	0.35	1.41	3.22
		1.5	0.64	0.35	2.27	5.59	2.85	0.66	0.34	1.68	4.35
		2.5	0.52	0.34	2.37	6.18	2.01	0.56	0.34	1.95	4.84
	0.9	0.3	0.74	0.36	2.29	2.40	6.10	0.75	0.35	1.47	1.72
		0.5	0.68	0.35	2.24	2.78	5.51	0.70	0.35	1.43	2.04
		1.5	0.54	0.34	2.26	4.16	3.68	0.57	0.35	1.59	3.20
		2.5	0.48	0.34	2.34	4.94	2.76	0.52	0.35	1.81	3.85
	0.975	0.3	0.42	0.34	2.17	1.47	6.08	0.47	0.35	1.44	0.99
		0.5	0.42	0.34	2.18	1.52	5.92	0.47	0.35	1.44	1.03
		1.5	0.41	0.34	2.20	1.90	5.25	0.47	0.35	1.47	1.37
		2.5	0.41	0.34	2.24	2.33	4.69	0.46	0.35	1.54	1.74

Fig. 19: Sensitivity Analysis 3, Modified Optimal Monetary Policy Cooperation.