Nominal Rigidities in an Estimated Two Country DSGE model

Riccardo Cristadoro, Andrea Gerali, Stefano Neri and Massimiliano Pisani*
Bank of Italy, Research Department

Version: February 10 2006
PRELIMINARY

Abstract

This paper uses bayesian techniques to estimate a small-scale two country model based on the Euro Area and the U.S. data. The model, based on the New Open Economy Macroeconomics framework, is microfounded and characterized by nominal price rigidities, a non-tradable sector, home bias in consumption and incomplete financial markets at international level. Two versions of the model are estimated: in one the international law of one price for tradable goods holds, in the other there is international price discrimination. Several results emerge. First, nominal rigidities are quite symmetric across countries. Second, Euro Area and U.S. monetary policies are different; in particular, U.S policy makers seems to be relatively more aggressive against inflation. Third, international spillovers are low.

*Email Address: riccardo.cristadoro@bancaditalia.it; andrea.gerali@bancaditalia.it; stefano.neri@bancaditalia.it; massimiliano.pisani@bancaditalia.it

1 Introduction

The main international policy institutions and the central banks have recently started to build up medium-to-large scale open economy models based on the so called New Open Economy Macroeconomics (NOEM) framework, whose main features are microfoundations of the households and firms optimization problems and nominal rigidities.[1] However, researchers have started to estimate NOEM models only recently; in comparison to the theory, relatively little work has been done.[2] Taking the model to the data is an important step in the research agenda because a framework can be trusted for policy analysis only if it accurately reflects international cross-correlations and basic features of the international economy, such as cross-country differences in preferences, technology and degree of nominal rigidities.[3]

We contribute to the ongoing debate by focusing on nominal rigidities (a crucial aspect of NOEM models) and by estimating a small-scale two country NOEM model on Euro Area and U.S. data. In particular, we try to understand if the Euro Area and the U.S. are symmetric in terms of nominal price rigidities and monetary policy reaction functions and if international spillovers are relevant for determining the behavior of domestic variables, in particular inflation rates.

We include a tradable and a nontradable sector in each country.

The nontradable sector has a nonneglible weight in both the Euro Area and the U.S.; hence, by not including it, the model would be mis-specified along a very important dimension for overall nominal rigidity.[4]

Firms in the tradable sector, through their pricing decisions, affect international relative prices and hence the transmission of spillovers. Two versions of the model are estimated, which differ only for the pricing decisions of firms in the tradable sector. In the first version we assume that the producer of a tradable good sets prices in the currency of the country it belongs to and moreover that it sets only one price, which is converted in the other currency using the exchange rate; hence the international law of one price holds and the pass-through of nominal exchange

[1] Probably the best example of a large scale NOEM model is the IMF Global Economy Model. See Laxton and Pesenti [2003].

[2] For recent contributions that estimate small open economies, see Adolfson et al. [2004], Ambler et al. [2004], Dib[2003], Justiniano and Preston [2004]. For bayesian estimates of two-country models, see Batini et al. [2005] and Adjémian et al. [2005].

[3] Note that in recent years a dramatic increase in theoretical work in the NOEM literature has characterized the international macroeconomics field. Hence, results from estimating model could be useful in guiding theoretical work, contributing to give indications on the solutions of various controversies existing in the theoretical literature. For a survey of the NOEM literature, see Lane [2001].

[4] Recent thereotical developments have re-emphasized the important role of nontradable sector for the international spillovers, giving rise to a wide debate. See Corsetti, Dedola and Leduc [2004]. For an earlier contribution, see Tesar [1993].

rate movements into import prices is complete. In the second version, there is international pricing discrimination, because exporting firms adopt a local currency pricing strategy and set a price which is country-specific; hence, the international law of one price does not hold.

The nominal exchange rate is the other variable affecting international relative prices. In the model it is determined according to the so called "modified" uncovered interest parity (UIP). Thanks to the assumption of incomplete markets at international level, we can study to what extent a two country model with nominal rigidities is able to explain the exchange rate variability.[5] We estimate a financial friction affecting international financial markets. One it's the so called risk premium term, which existing literature has found to be useful to properly account for the empirical failure of the UIP.[6] The other is the risk premium shock: the eventual predominance of its capability of explaining real exchange rate variability over that of other nominal and real shocks should be thought of as a symptom of low cross-country spillovers. To help the model to capture the extreme volatility of nominal exchange rate, we assume home bias in consumption preferences, based on the presumption that foreign trade is a small portion of total economic activity.[7]

Finally, we estimate monetary policy rules for the U.S. and the Euro Area and study the propagation of monetary policy shocks. Unanticipated changes in monetary policy appear as innovations in the interest rate feedback rule.[8]

The main results of our estimation exercises are the as follows.

First, nominal rigidities are rather symmetric across countries: nominal rigidities in the nontradable sector are higher than those in the tradable sector; in the local currency pricing version of the model, the price of a tradable good in its domestic market is stickier than the price in the exporting market; the size of the price stickiness in the tradable sector is similar across countries; the only source of asymmetry in nominal rigidities is the non tradable sector, whose prices in the US are stickier than those in the Euro Area. Second, there exist some differences in the monetary policies: the reaction of U.S. monetary policy to deviations of inflation from the target is stronger that that of the Euro Area monetary policy; the latter seems to react

[5] Chari et al. [2002] try to explain the real exchange rate volatility by calibrating a two country model with sticky prices. See also Clarida and Gali [1994].

[6] Note that the assumption of incomplete markets implies that in our model there is a current account. However, given the lack of data on this variable, we prefer to focus on the other main source of spillovers: the real exchange rate.

[7] On the relationship between home bias and exchange rate volatility see Dornbush [1976] and Warnock [2003].

[8] Our model is close to those estimated by Bergin [2004] and Lubik and Schorfheide [2005]. Differently from Bergin, we allow for the presence of nontradable sector and we do not introduce physical capital accumulation, mainly to keep the model as simple as possible, in line with the focus of the paper, which is on nominal rigidities and prices rather than on quantities. Differently from us, Bergin estimates the model using maximum likelihood techniques. Lubik and Schorfheide, like us, use bayesian techniques; however, they do not have a nontradable sector nor pricing-to-market. See also Bergin [2003] for a first attempt to estimate a NOEM model.

also the nominal exchange rate movements; the persistence parameter and that of reaction to output growth are rather similar across countries. Third, international spillovers are low: the risk premium shock is the main determinant of the real exchange rate fluctuations, while other shocks have a rather limited effect; domestic shocks are the main determinants of the fluctuations of inflations and of the main macroeconomic variables (other the real exchange rate); finally, the model does a relatively good job in matching the correlation between domestic sectorial inflation rates, between domestic inflation rates and domestic interest rate, while it is not able to replicate cross-country correlations, with the exception of those between consumptions and between consumptions and real exchange rates.

The paper is organized as follows. Section 2 illustrates the problems solved by the households and firms and the monetary policy setting. Section 3 describes the log-linearized model. Section 4 reports the results of the estimation. Section 5 concludes.

2 Structure of the model

The world economy consists of two countries of equal size, H and F. Each country is specialized in the production of one type of tradable good, produced in a number of varieties over a continuum of unit mass. Varieties of tradable goods are indexed by $h \in [0,1]$ in the Home country and $f \in [0,1]$ in the Foreign country. Each country also produces an array of differentiated nontradable goods, indexed by $n \in [0,1]$. All goods are used for consumption purposes only.

Firms are monopolistic suppliers of one variety of goods only. These firms employ homogenous labor inputs, supplied in a perfect competition regime by domestic households. Households are indexed by $j \in [0,1]$ in the Home country and $j^* \in [0,1]$ in the Foreign country. Nominal rigidities are introduced by assuming that each firm faces a quadratic price-adjustment cost.

In what follows, the setup is described focusing on the Home country. Similar expressions characterize the Foreign economy, with the convention that variable referring to foreign firms and households are marked with an asterisk.

2.1 Households

In what follows we illustrate the problem solved by households; hence we report preferences, budget constraint and first order conditions.

2.1.1 Preferences

Home agent j's lifetime expected utility $\mathcal{U}$ is defined as:

$$\mathcal{U}\left(j\right)\equiv E_0\sum_{t=0}^{\infty}\beta^t\left[\frac{C_t\left(j\right)^{1-\sigma_c}}{1-\sigma_c}-\frac{\kappa}{\tau}L_t(j)^{\tau}\right]Z_{U,t} \tag{1}$$

where $\beta < 1$, is the discount rate, $(1/\sigma_c)$ is the elasticity of intertemporal substitution, $\tau - 1$ is the the inverse of the Frisch elasticity of labor supply. The instantaneous utility is a function of a consumption index $C\left(j\right)$, to be defined below, and labor effort $L(j)$. Instantaneous utility is state-dependent, as we allow for utility shocks Z_U. We do not introduce money explicitly, but we interpret this model as a cash-less limiting economy, in the spirit of Woodford [1998], in which the role of money balances in facilitating transactions is negligible.[9]

Household consume all types of domestically-produced nontraded goods, and both types of traded goods. So $C_t\left(n,j\right)$ is consumption of variety n of home nontraded good by agent j at time t; $C_t(h,j)$ and $C_t(f,j)$ are the same agent's consumption of Home variety h and Foreign variety f. For each type of good, it is assumed that one variety is an imperfect substitute for all other varieties, with constant elasticity of substitution $\theta > 1$. The consumption of Home and Foreign goods by Home agent j is defined as:

$$C_{N,t} \equiv \left[\int_0^1 C_t\left(n,j\right)^{\frac{\theta-1}{\theta}}dn\right]^{\frac{\theta}{\theta-1}}, \qquad \theta > 1 \tag{2}$$

$$C_{H,t} \equiv \left[\int_0^1 C_t\left(h,j\right)^{\frac{\theta-1}{\theta}}dh\right]^{\frac{\theta}{\theta-1}} \tag{3}$$

$$C_{F,t} \equiv \left[\int_0^1 C_{F,t}(f,j)^{\frac{\theta-1}{\theta}}df\right]^{\frac{\theta}{\theta-1}} \tag{4}$$

The consumption aggregator of tradeable goods of individual j is:

$$C_{T,t}\left(j\right)=\left[a_H^{\frac{1}{\rho}}C_{H,t}\left(j\right)^{\frac{\rho-1}{\rho}}+\left(1-a_H\right)^{\frac{1}{\rho}}C_{F,t}\left(j\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}, \qquad \rho > 0 \tag{5}$$

a_H measures the home bias in consumption. If $a_H = \frac{1}{2}$, there is no home bias in consumption; that is, for any relative price, domestic and foreign consumers will demand the same quantities of the domestic good. For $a_H > \frac{1}{2}$, domestic consumers will always demand relatively more domestic goods than other country's consumers. ρ denotes the intratemporal elasticity of substitution between C_H and C_F.

The full consumption basket is:

$$C_t\left(j\right)=\left[a_T^{\frac{1}{\phi}}C_{T,t}\left(j\right)^{\frac{\phi-1}{\phi}}+\left(1-a_T\right)^{\frac{1}{\phi}}C_{N,t}\left(j\right)^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}}, \quad \phi > 0 \tag{6}$$

[9] Techinically, the model can then be interpreted as a limiting case in which the relative importance of the service flow from real money balances in the utility function goes to zero.

ϕ is the intratemporal elasticity of substitution between C_T and C_N. a_T measures the relative weight that individuals put on traded goods. Parameters describing preferences are the same in the Home and Foreign country, the only exception being home-bias in consumption. Hence, the aggregator of tradable goods in the Foreign country is:

$$C_{T,t}\left(j^*\right)=\left[\left(1-a_H\right)^{\frac{1}{\rho}} C_{H,t}\left(j^*\right)^{\frac{\rho-1}{\rho}}+a_H^{\frac{1}{\rho}} C_{F,t}\left(j^*\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}, \qquad \rho>0 \tag{7}$$

2.1.2 Price indexes and Relative Prices

Let $p_t(h)$ and $p_t(f)$ denote the price of varieties h and f expressed in the Home currency, respectively. The utility-based price indexes of Home-produced tradables are:

$$P_{H,t} = \left[\int_0^1 p_t(h)^{1-\theta}\, dh\right]^{\frac{1}{1-\theta}} \tag{8}$$

$$P_{F,t} = \left[\int_0^1 p_t(f)^{1-\theta}\, df\right]^{\frac{1}{1-\theta}} \tag{9}$$

$$P_{N,t} = \left[\int_0^1 p_t(n)^{1-\theta}\, dn\right]^{\frac{1}{1-\theta}} \tag{10}$$

The price indexes $P_{H,t}^*$, $P_{F,t}^*$, $P_{N,t}^*$ are analogously defined. The utility-based price indexes of tradable goods in the Home and Foreign countries are respectively:

$$P_{T,t} = \left[a_H {P_{H,t}}^{1-\rho}+\left(1-a_H\right) P_{F,t}^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{11}$$

$$P_{T,t}^* = \left[(1-a_H){P_{H,t}^*}^{1-\rho}+a_H P_{F,t}^{*1-\rho}\right]^{\frac{1}{1-\rho}} \tag{12}$$

The utility-based consumer price indexes are:

$$P_t=\left[a_T {P_{T,t}}^{1-\phi}+\left(1-a_T\right) P_{N,t}^{1-\phi}\right]^{\frac{1}{1-\phi}} \tag{13}$$

$$P_t^*=\left[a_T {P_{T,t}^*}^{1-\phi}+\left(1-a_T\right) P_{N,t}^{*1-\phi}\right]^{\frac{1}{1-\phi}} \tag{14}$$

Here some relative prices indexes are defined:

$$T_t \equiv \frac{P_{F,t}}{P_{H,t}}, \qquad T_t^* \equiv \frac{P_{F,t}^*}{P_{H,t}^*} \tag{15}$$

$$X_t \equiv \frac{P_{N,t}}{P_{T,t}}, \qquad X_t^* \equiv \frac{P_{N,t}^*}{P_{T,t}^*} \tag{16}$$

$$RS_t \equiv \frac{S_t P_t^*}{P_t} \tag{17}$$

T and T^* represent the price of the foreign tradable composite good in terms of the home tradable composite good in the Home and in the Foreign country, respectively.X and X^* represent the price of nontradable good in terms of tradable good in the home and foreign country, respectively. RS is the Home country real exchange rate; S is the nominal exchange rate, expressed as number of Home currency units per unit of Foreign one.[10]

2.1.3 Demand Functions

Given the structure of preferences, the home household j demand functions for varieties h, f, n are given by:

$$c(h,j) = a_H a_T \left(\frac{p_t(h)}{P_{H,t}}\right)^{-\theta} \left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\rho} \left(\frac{P_{T,t}}{P_t}\right)^{-\phi} C(j) \tag{18}$$

$$c(f,j) = (1 - a_H a_T) \left(\frac{p_t(f)}{P_{H,t}}\right)^{-\theta} \left(\frac{P_{F,t}}{P_{T,t}}\right)^{-\rho} \left(\frac{P_{T,t}}{P_t}\right)^{-\phi} C(j) \tag{19}$$

$$c(n,j) = (1 - a_T) \left(\frac{p_t(n)}{P_{N,t}}\right)^{-\theta} \left(\frac{P_{N,t}}{P_t}\right)^{-\phi} C(j) \tag{20}$$

Similar demand functions hold in the Foreign Country.

2.1.4 Household budget constraint

Following Benigno [2001], it is assumed that Home households allocate their wealth among two risk-free bonds having one-period maturity. One is denominated in domestic currency and the other in foreign currency. In contrast, households that belong to Foreign country can allocate their wealth only in a risk-free nominal bond denominated in the foreign currency. Thus, the budget constraint of household j in country H (expressed in real terms with respect to the consumption-based price index) is:

[10] In the producer currency pricing case the international law of one price holds ($p_t(f) = S_t p_t^*(f)$ and $p_t^*(h) = p_t(h)/S_t$); hence the Home and Foreign country terms of trade are equal to T and $1/T^*$, respectively. In the local currency pricing case the law of one price does not hold ($p_t(f) \neq S_t p_t^*(f)$ and $p_t^*(h) \neq p_t(h)/S_t$) and the Home and Foreign country terms of trade, equal to P_F/SP_H^* and $P_H^*/(P_F/S)$, are different from T and $1/T^*$, respectively.

$$\frac{B_{H,t}(j)}{P_t R_t}+\frac{S_t B_{F,t}(j)}{P_t R_t^* \Phi\left(\frac{S_t B_{F,t}}{P_t}\right) Z_{RP,t}} \leq WE_{t-1}(j)+\frac{1}{P_t}\int_0^1 \Pi_t(h)dh+\frac{1}{P_t}\int_0^1 \Pi_t(n)dn+\frac{W_t}{P_t}L_t(j)-C_t(j) \tag{21}$$

at each date t, with

$$WE_{t-1}(j) \equiv \frac{B_{H,t-1}(j)+S_t B_{F,t-1}(j)}{P_t} \tag{22}$$

$B_{H,t}(j)$ is household j's holding of the risk-free one-period nominal bond denominated in units of currency H. The gross nominal interest rate on this bond is R_t. $B_{F,t}(j)$ is household j's holding of the risk-free one-period nominal bond, denominated in units of currency F. The price of this bond is inversely proportional to its gross nominal interest rate R_t^*. The factor of proportionality is the function $\Phi(.)\, Z_{RP,t}$, which depends on the real holdings of the foreign assets in the entire economy. This implies that Home agents take the function $\Phi(.)\, Z_{RP,t}$ as given when deciding on optimal holding of foreign bond. $Z_{RP,t}$ can be interpreted as a risk-premium shock. $\Phi(.)$ satisfies the following restrictions: $\Phi(0) = 1$ and $\Phi(.)$ assumes the value 1 only if $B_{F,t} = 0$; $\Phi'(.) < 0$ in a neighborhood of zero. The function $\Phi(.)$ captures the costs, for households belonging to country H, of undertaking positions in the international asset market. As borrowers, they will be charged a premium on the foreign interest rate; as lenders, they will receive a remuneration lower than the foreign interest rate. Revenues from the premium are rebated lump-sum to the foreign agents:

$$Q_t = \frac{S_t B_{F,t}}{P_t}\frac{1}{R_t^*}\left[\frac{1}{\Phi\left(\frac{S_t B_{F,t}}{P_t}\right) Z_{RP,t}} - 1\right] > 0 \tag{23}$$

The revenues are positive, given the shape of the function $\Phi(.)$. This additional cost $\Phi(.)$ is introduced to pin down a well-defined steady-state for consumption and assets in the context of international incomplete markets.[11] In defining the budget constraint, it is also assumed that all households belonging to a country share the profits $\Pi(.)$ from firms in equal proportion and that each household supplies her labor services $L(j)$ to each firm in the economy at the nominal wage W . Labor services are assumed to be homogenous across households and firms, and thus there is perfectly competitive labor market.

Households of the Foreign country can allocate their wealth only in the risk-free nominal bond denominated in units of their own currency. However, they do not face any cost of intermediation and they can lend and borrow at the risk-free nominal interest rate R_t^*. Their budget constraint

[11] See for more details Schmitt-Grohe, Stephanie and Martin Uribe [2003].

is:

$$\frac{B_{F,t}\left(j^{*}\right)}{P_{t}^{*}R_{t}^{*}} \leq WE_{t-1}\left(j^{*}\right)+\frac{1}{P_{t}^{*}}\int_{0}^{1}\Pi_{t}(f)df+\frac{1}{P_{t}^{*}}\int_{0}^{1}\Pi_{t}(n^{*})dn^{*}+Q_{t}+\frac{W_{t}^{*}}{P}L_{t}(j)-C_{t}\left(j^{*}\right) \quad (24)$$

with

$$WE_{t-1}\left(j^{*}\right)=\frac{B_{F,t}\left(j^{*}\right)}{P_{t}^{*}} \quad (25)$$

Note that the profits from the risk premium are added up to the resources available to foreign agents.

It is further assumed that the initial level of wealth ($WE_{-1}\left(j\right)$ and $WE_{-1}\left(j^{*}\right)$) is the same across all the households belonging to the same country. This assumption, combined with the fact that all the households within a country work for all the firms earning the same wage and that share the profits in equal proportion, implies that within a country all the households face no idiosyncratic risk and thus share the same budget constraint. In their consumption and labor decisions, they will choose the same path of consumption and labor. The index j can thus be dropped and consider a representative agent for each country.

2.1.5 First order conditions

First order conditions (FOCs) of the Home representative agent are:

$$C_{t}^{-\sigma_{c}}Z_{U,t}=\beta R_{t}E_{t}\left[Z_{U,t+1}C_{t+1}^{-\sigma_{c}}\left(\frac{P_{t}}{P_{t+1}}\right)^{-1}\right] \quad (26)$$

$$C_{t}^{-\sigma_{c}}Z_{PR,t}=\beta R_{t}^{*}\Phi\left(\frac{S_{t}B_{F,t}}{P_{t}}\right)Z_{RP,t}E_{t}\left[C_{t+1}^{-\sigma_{c}}Z_{PR,t+1}\frac{S_{t+1}}{S_{t}}\left(\frac{P_{t}}{P_{t+1}}\right)^{-1}\right] \quad (27)$$

$$\frac{W_{t}}{P_{t}}=\frac{\kappa}{\tau}L_{t}^{\tau}C^{\sigma_{c}} \quad (28)$$

plus the appropriate no-Ponzi games and transversality conditions. The first FOC represents the Euler equation derived by maximizing holdings of nominal bond denominated in Home currency. The second FOC follows from the optimal choice of holdings of nominal bond denominated in Foreign currency. The third FOC equates the marginal rate of substitution between consumption and labor to the real wage.

The FOCs of the Foreign agent are similar:

$$C_{t}^{*-\sigma_{c}}Z_{U,t}^{*}=\beta\left(1+i_{t}^{*}\right)E_{t}\left[C_{t+1}^{*-\sigma_{c}}Z_{U,t+1}^{*}\left(\frac{P_{t}^{*}}{P_{t+1}^{*}}\right)^{-1}\right] \quad (29)$$

$$\frac{W_{t}^{*}}{P_{t}^{*}}=\frac{\kappa}{\tau}L_{t}^{*\tau}C^{*\sigma_{c}} \quad (30)$$

2.2 Firms

Each firm in the two-country economy solves the following two-step problem: a static cost minimization problem and an intertemporal profit maximization problem.

2.2.1 Cost Minimization

Let $Y_t(h) + Y_t^*(h)$ denote total output of a differentianted tradable good h, and $L(h)$ the demand for labor input by the producer h. By the same token, $Y(n)$ denotes total production of a differentiated nontradable good n, and $L(n)$ the corresponding demand for labor input. The production function of the Home tradable and nontradable goods are, respectively:

$$Y_t(h) + Y_t^*(h) = Z_{H,t} L_t(h) \qquad\qquad Y_t(n) = Z_{N,t} L_t(n) \tag{31}$$

Z denotes stochastic productivity parameters, which are sector-specific. Similar expressions hold for firms in the Foreign country. From now on, let's focus on the problem solved by each firm in the Home country tradable sector; other firms, in all the remaining sectors of the two-country economy, solve a similar problem.

In each period, the firm chooses the optimal quantity of labor to employ so to minimize the following expression:

$$p_t(h) Y_t(h) + S_t p_t^*(h) Y_t^*(h) - W_t L_t(h) \tag{32}$$

subject to technology constraint in equation (31) .

The solution is given by the nominal marginal cost MC, which is equal to:

$$MC_t(h) = \frac{W_t}{Z_{H,t}} \tag{33}$$

2.2.2 Profit Maximization

Firms are monopolistic suppliers of their products. They can affect the quantity demanded through their pricing decisions. However, because they are small with respect to the overall market, they take as given the price indexes P, P_H, P_F, P_N, P_T, and their respective foreign counterparts as well as C and C^*.

It is assumed that firms face a price-quadratic adjustment cost.[12] When the firm decides to change the price it sets in the Home (Foreign) country, it must purchase an amount $\mu(h)$ ($\mu^*(h)$), of the composite good produced in its sector and sell it in the Home (Foreign) market.

[12] Here it is illustrated only the problem solved by firms on the Home country tradable sector. The problems of firms belonging to the nontradable sector of the Home country and of firms in the Foreign country can be similarly derived. Note however that the size of adjustment costs can be different across sectors and countries.

Following Hairault and Portier [1993], Rotemberg [1996], Ireland [1997], Dedola and Leduc [2001], the adjustment costs are given by the following quadratic function:

$$\mu(h) = \frac{\kappa_H}{2}\left(\frac{p_{H,t}(h)}{p_{H,t-1}(h)} - \pi_H\right)^2 Y_{H,t} \tag{34}$$

$$\mu^*(h) = \frac{\kappa_H^*}{2}\left(\frac{p_{H,t}^*(h)}{p_{H,t-1}^*(h)} - \pi_H^*\right)^2 Y_{H,t}^* \tag{35}$$

κ_H and κ_H^* measure the size of good h price stickiness in the Home and in the Foreign country, respectively. The value of κ_H can be different from the value of κ_H^*. Note also that there are no costs to adjusting prices when the Home tradable good steady state inflation rate prevails.

Given the marginal cost, each firm chooses its price to maximize its profits. In what follows, two alternative pricing strategies are illustrated: the producer currency (LCP) case and the local currency pricing (LCP) case. In the first case, each firm sets only one price, taking into account the world demand for its good: when measured in the same currency, the produced good has the same price in both the Home and Foreign markets. In the second case, it is assumed that there is international price discrimination; hence, when expressed in the same currency, the price of the produced good in the Home market is different from the price in the Foreign market.

The LCP case Each firm in the Home tradable sector chooses $p_t(h)$ and $p_t^*(h)$ so to maximize the expected discounted value of profits:[13]

$$\sum_{t=0}^{\infty}\beta^t\frac{C_t^{-\sigma_C}}{P_t}\frac{P_0}{C_0^{-\sigma_C}}\left\{\begin{array}{c} p_t(h)\,y_t(h) + S_t p_t^*(h)\,y_t^*(h) - \frac{W_t}{Z_{H,t}}\times[y_t(h)+y_t^*(h)] \\ -P_{H,t}\frac{k_H}{2}\left(\frac{p_t(h)}{p_{t-1}(h)} - \pi_H\right)^2 \times Y_{H,t} \\ -P_{H,t}^*\frac{k_H^*}{2}\left(\frac{p_t^*(h)}{p_{t-1}^*(h)} - \pi_H^*\right)^2 \times Y_{H,t}^* \end{array}\right\} \tag{36}$$

where $\beta^t\frac{C_t^{-\sigma_C}}{P_t}\frac{P_0}{C_0^{-\sigma_C}}$ is the Home country representative agent intertemporal rate of substitution, $y_t(h)y$ and $y_t^*(h)$ are the total demand from the Home and Foreign country, respectively:

$$y_t(h) = a_H a_T\left(\frac{p_t(h)}{P_{H,t}}\right)^{-\theta}\left(\frac{P_{H,t}}{P_{T,t}}\right)^{-\rho}\left(\frac{P_{T,t}}{P_t}\right)^{-\phi} C_t \tag{37}$$

$$y_t^*(h) = (1-a_H)a_T\left(\frac{p_t^*(h)}{P_{H,t}^*}\right)^{-\theta}\left(\frac{P_{H,t}^*}{P_{T,t}^*}\right)^{-\rho}\left(\frac{P_{T,t}^*}{P_t^*}\right)^{-\phi} C_t^* \tag{38}$$

The optimal $p_t(h)$ satisfies the following FOC:

[13] See Benigno [2004] for a similar problem solved using Calvo price adjustment.

$$
\begin{aligned}
& \frac{C_t^{-\sigma}}{P_t}(1-\theta)\, p_t(h)^{-\theta}\left[\frac{1}{P_{H,t}}\right]^{-\theta} \times Y_{H,t} \\
& +\frac{C_t^{-\sigma}}{P_t}\theta p_t(h)^{-\theta-1}\left[\frac{1}{P_{H,t}}\right]^{-\theta} \kappa \frac{W_t}{Z_{H,t}} \times Y_{H,t} \\
& -\frac{C_t^{-\sigma_c}}{P_t} k_H P_{H,t} \frac{1}{p_{t-1}(h)}\left(\frac{p_t(h)}{p_{t-1}(h)}-\pi_H\right) \times Y_{H,t} \\
& +\frac{C_{t+1}^{-\sigma_c}}{P_{t+1}} \beta k_H P_{H,t+1} \frac{p_{t+1}(h)}{p_t^2(h)}\left(\frac{p_{t+1}(h)}{p_t(h)}-\pi_H\right) \times Y_{H,t+1} \\
= \; & 0
\end{aligned} \tag{39}
$$

FOC from maximization with respect to $p_t^*(h)$ is:

$$
\begin{aligned}
& (1-\theta)\, p_t^*(h)^{-\theta} \frac{C_t^{-\sigma}}{P_t}\left[\frac{1}{P_{H,t}^*}\right]^{-\theta} \times Y_{H,t}^* \\
& +\theta p_t^*(h)^{-\theta-1} \frac{C_t^{-\sigma}}{P_t}\left[\frac{1}{P_{H,t}^*}\right]^{-\theta} \kappa^* \frac{W_t}{Z_{H,t}} \times Y_{H,t}^* \\
& -\frac{C_t^{-\sigma_c}}{P_t} k_H^* P_{H,t}^* \frac{1}{p_{t-1}^*(h)}\left(\frac{p_t^*(h)}{p_{t-1}^*(h)}-\pi_H^*\right) \times Y_{H,t}^* \\
& +\beta \frac{C_{t+1}^{-\sigma_c}}{P_{t+1}} k_H^* P_{H,t+1}^* \frac{p_{t+1}^*(h)}{p_t^{*2}(h)}\left(\frac{p_{t+1}^*(h)}{p_t^*(h)}-\pi_H^*\right) \times Y_{H,t}^* \\
= \; & 0
\end{aligned} \tag{40}
$$

where equations .... have been used.

The PCP case In the case of producer currency pricing, the international law of one price holds for (tradable) goods. Hence $p_t^*(h) = p_t(h)/S_t$, revenues $p_t(h)Y_t(h) + S_t p_t^*(h) Y_t^*(h)$ can be rewritten as $p_t(h)[Y_t(h) + Y_t^*(h)]$ and only $p_t(h)$ is optimally chosen to maximize profits given the world demand $Y_t(h) + Y_t^*(h)$ for good h:

$$
\sum_{t=0}^{\infty} \beta^t \frac{C_t^{-\sigma_C}}{P_t} \frac{P_0}{C_0^{-\sigma_C}}
\left\{
\begin{array}{c}
p_t(h)\left[y_t(h)+y_t^*(h)\right] - \frac{W_t}{Z_{H,t}} \times \left[y_t(h)+y_t^*(h)\right] \\
-P_{H,t}\frac{k_H}{2}\left(\frac{p_t(h)}{p_{t-1}(h)}-\pi_H\right)^2 \times \left(Y_{H,t}+Y_{H,t}^*\right) \\
-P_{H,t}\frac{k_H}{2}\left(\frac{p_t(h)}{p_{t-1}(h)}-\pi_H\right)^2 \times \left(Y_{H,t}+Y_{H,t}^*\right)
\end{array}
\right\} \tag{41}
$$

Differently from the LCP case, there is just one first order condition, which is:

$$
\begin{aligned}
& \frac{C_t^{-\sigma}}{P_t}(1-\theta)\, p_t(h)^{-\theta}\left[\frac{1}{P_{H,t}}\right]^{-\theta} \times \left[Y_{H,t}+Y_{H,t}^*\right] \\
& +\frac{C_t^{-\sigma}}{P_t}\theta p_t(h)^{-\theta-1}\left[\frac{1}{P_{H,t}}\right]^{-\theta} \kappa \frac{W_t}{Z_{H,t}} \times \left[Y_{H,t}+Y_{H,t}^*\right] \\
& -\frac{C_t^{-\sigma_c}}{P_t} k_H P_{H,t} \frac{1}{p_{t-1}(h)}\left(\frac{p_t(h)}{p_{t-1}(h)}-\pi_H\right) \times \left[Y_{H,t}+Y_{H,t}^*\right] \\
& +\frac{C_{t+1}^{-\sigma_c}}{P_{t+1}} \beta k_H E_t\left\{P_{H,t+1} \frac{p_{t+1}(h)}{p_t^2(h)}\left(\frac{p_{t+1}(h)}{p_t(h)}-\pi_H\right) \times \left[Y_{H,t+1}+Y_{H,t+1}^*\right]\right\} \\
= \; & 0
\end{aligned} \tag{42}
$$

2.3 Monetary Policy

Monetary policy is endogenous: it reacts to the economic conditions and it is modeled through interest-rate feed-back rules. The Central bank's instrument is the one-period nominal interest rate. It is assumed that the policymakers credibly commit at period 0 to a specified rule:

$$
R_t = R_{t-1}^{\rho_R}\left(\frac{Y_t}{Y_{t-1}}\right)^{(1-\rho_R)\rho_Y} \pi_t^{(1-\rho_R)\rho_\pi}\left(\frac{S_t}{S_{t-1}}\right)^{(1-\rho_R)\rho_S} \exp(\varepsilon_{R,t}) \tag{43}
$$

$$
R_t^* = R_{t-1}^{*\rho_R^*}\left(\frac{Y_t^*}{Y_{t-1}^*}\right)^{(1-\rho_R)^*\rho_Y^*} \pi_t^{*(1-\rho_R^*)\rho_\pi^*}\left(\frac{S_t}{S_{t-1}}\right)^{-\left(1-\rho_R^*\right)\rho_S^*} \exp(\varepsilon_{R,t}^*) \tag{44}
$$

where $\varepsilon_{R,t}$ and $\varepsilon_{R,t}^*$ are monetary policy innovations.

3 The log-linearized model

The model is not solvable in closed form. The behavior of the economy in the two cases, PCP and LCP, is then analyzed in the neighborhood of a deterministic steady state in which inflation and exchange rate depreciation are zero using a log-linear approximation to the model equations. In this steady state the shocks are set to their mean value. Nominal interest rates are equal to the preferences' discount rate. Given that in steady state each firm in the tradable sector charges the same price in the domestic and foreign markets (i.e. the law of one price holds) and that the marginal cost and the markup is the same for all firms in the economy, all relative prices are equal to one. Moreover, in the steady state consumption is equalized across countries and the net foreign asset position is equal to zero.

The deviation of the logarithm of a variable from its steady state is denoted with $z_t = \ln z_t - \ln \bar{z}$. In what follows, firstly the log-linearized versions of the relative price equations are reported; then the supply block of the log-linearized model is illustrated, distinguishing the two pricing strategies of the firms producing tradable goods (PCP versus LCP); finally, the demand, monetary policy and exogenous law of motion blocks are reported.

I. Relative Prices and Inflation Rates.

$$\widehat{TOT}_t = \widehat{TOT}_t + \Delta S_t + \pi^*_{F,t} - \pi_{H,t} \tag{45}$$

$$\hat{T}_t = \hat{T}_{t-1} + \pi_{F,t} - \pi_{H,t} \tag{46}$$

$$\hat{T}^*_t = \hat{T}^*_{t-1} + \pi^*_{F,t} - \pi^*_{H,t} \tag{47}$$

$$\hat{X}_t = \hat{X}_{t-1} + \pi_{N,t} - \pi_{T,t} \tag{48}$$

$$\hat{X}^*_t = \hat{X}^*_{t-1} + \pi^*_{N,t} - \pi^*_{T,t} \tag{49}$$

$$\widehat{RS}_t = \widehat{RS_{t-1}} + \Delta S_t + \pi^*_t - \pi_t \tag{50}$$

Note that $\pi_{.,t} \equiv \ln(1 + \pi_{.,t}) \equiv \ln(P_{.,t}/P_{.,t-1})$ and that $\Delta S_t \equiv \ln(S_t/S_{t-1})$.

The first equation represents the Home country terms of trade law of motion. The second and third equations, present only in the local currency pricing case (in the producer currency case, they both coincide to $\widehat{TOT}$), are the laws of motion of relative prices of tradable goods in the Home and Foreign country. The fourth and fifth equations describe the law of motions of the nontradable-to-tradable price ratio in the Home and in Foreign country. The last equation is the law of motion of Home country real exchange rate.

Equations describing inflation rates are reported.

$$\pi_{T,t} = a_H \pi_{H,t} + (1 - a_H)\pi_{F,t} \tag{51}$$

$$\pi^*_{T,t} = (1 - a_H)\pi^*_{H,t} + a_H \pi^*_{F,t} \tag{52}$$

$$\pi_t = a_T \pi_{T,t} + (1 - a_T)\pi_{N,t} \tag{53}$$

$$\pi^*_t = a_T \pi^*_{T,t} + (1 - a_T)\pi^*_{N,t} \tag{54}$$

The first two equations describe tradable good inflation rates in the Home and Foreign country. The last two equation the CPI inflations rates.

II. Supply Block.

The supply side of the economy depends on the production functions and on the pricing assumptions. The production functions of the Home tradable good, Home nontradable good, Foreign tradable good and Foreign nontradable good are respectively:

$$a_H a_T \hat{Y}_{H,t} + (1 - a_H) a_T \hat{Y}^*_{H,t} = \hat{z}_{H,t} + \hat{L}_{H,t} \tag{55}$$

$$(1 - a_T) \hat{Y}_{N,t} = \hat{z}_{N,t} + \hat{L}_{N,t} \tag{56}$$

$$a_H a_T \hat{Y}^*_{F,t} + (1 - a_H) a_T \hat{Y}_{F,t} = \hat{z}^*_{F,t} + \hat{L}_{F,t} \tag{57}$$

$$(1 - a_T) \hat{Y}^*_{N,t} = \hat{z}^*_{N,t} + \hat{L}^*_{N,t} \tag{58}$$

The supply schedules of goods produced in the nontradable sectors are:

$$\pi_{N,t} = \beta \pi_{N,t+1} + \frac{\theta - 1}{k_N} [(\tau - 1)\hat{L}_t - \hat{z}_{N,t} + \sigma_c \hat{C}_t - a_T \hat{X}_t] \tag{59}$$

$$\pi^*_{N,t} = \beta \pi^*_{N,t+1} + \frac{\theta - 1}{k^*_N} [(\tau - 1)\hat{L}^*_t - \hat{z}^*_{N,t} + \sigma_c \hat{C}^*_t - a_T \hat{X}^*_t] \tag{60}$$

where $\hat{L}_t$ and $\hat{L}^*_t$ are the amount of employed labor by the whole economy in the Home and Foreign country, respectively:

$$\hat{L}_t = a_T \hat{L}_{H,t} + (1 - a_T)\hat{L}_{N,t} \tag{61}$$

$$\hat{L}^*_t = a_T \hat{L}^*_{F,t} + (1 - a_T)\hat{L}^*_{N,t} \tag{62}$$

Regarding the supply schedules of tradable curves, we make the distinction in PCP and LCP case.

II.a. The LCP Case

In this case there is international price discrimination; hence each tradable good has different prices in the two countries. The supply schedules are:

$$\pi_{H,t} = \beta \pi_{H,t+1} + \frac{\theta - 1}{k_H} [(\tau - 1)\hat{L}_t - \hat{z}_{H,t} + \sigma_c \hat{C}_t + (1 - a_H)\hat{T}_t + (1 - a_T)\hat{X}_t] \tag{63}$$

$$\pi^*_{H,t} = \beta \pi^*_{H,t+1} + \frac{\theta - 1}{k^*_H} \left[(\tau - 1)\hat{L}_t - \hat{z}_{H,t} + \sigma_c \hat{C}_t - \widehat{RS}_t + a_H \hat{T}^*_t + (1 - a_T)\hat{X}^*_t\right] \tag{64}$$

$$\pi_{F,t} = \beta\pi_{F,t+1} + \frac{\theta - 1}{k_F}[(\tau - 1)\hat{L}_t^* - \hat{z}_{F,t}^* + \sigma_c\hat{C}_t^* + \widehat{RS}_t - a_H\hat{T}_t + (1 - a_T)\hat{X}_t] \tag{65}$$

$$\pi_{F,t}^* = \beta\pi_{F,t+1}^* + \frac{\theta - 1}{k_F^*}[(\tau - 1)\hat{L}_t^* - \hat{z}_{F,t} + \sigma_c\hat{C}_t^* - (1 - a_H)\hat{T}_t^* + (1 - a_T)\hat{X}_t^*] \tag{66}$$

The first two equations are the Home and Foreign country supply schedules of the home produced good; the last two are analogue equation for the foreign produced good

II.b. The PCP Case

In this case, there is no international price discrimination. For each tradable good there is only one pricing equation, that holds worldwide.

The supply schedules are:

$$\pi_{H,t} = \beta\pi_{H,t+1} + \frac{\theta - 1}{k_H}[(\tau - 1)\hat{L}_t - \hat{z}_{H,t} + \sigma_c\hat{C}_t + (1 - a_H)\widehat{TOT}_t + (1 - a_T)\hat{X}_t] \tag{67}$$

$$\pi_{H,t}^* = \pi_{H,t} - \Delta S_t \tag{68}$$

$$\pi_{F,t}^* = \beta\pi_{F,t+1}^* + \frac{\theta - 1}{k_F^*}[(\tau - 1)\hat{L}_t^* - \hat{z}_{F,t} + \sigma_c\hat{C}_t^* - (1 - a_H)\widehat{TOT}_t + (1 - a_T)\hat{X}_t^*] \tag{69}$$

$$\pi_{F,t} = \pi_{F,t}^* + \Delta S_t \tag{70}$$

The first and the third equations are the worldwide supply schedules of the home and foreign produced goods, respectively; the second equation, which exploits the international law of one price, is price inflation rate of home produced good in the Foreign country; similarly, the fourth equation describes the price inflation rate of the foreign produced good in the Home country.

III. Aggregate Demand Block.

The aggregate demand block is composed by the log-linearized Home and Foreign Euler equations

$$-\sigma_c\hat{C}_t + \hat{z}_{U,t} = -\sigma_c\hat{C}_{t+1} + \hat{R}_t - \pi_{t+1,C} + \hat{z}_{U,t+1} \tag{71}$$

$$-\sigma_c\hat{C}_t^* + \hat{z}_{U,t}^* = -\sigma_c\hat{C}_{t+1}^* + \hat{R}_t^* - \pi_{t+1,C}^* + +\hat{z}_{U,t+1}^* \tag{72}$$

From equations (26) and (27) the following modified uncovered interest parity (UIP) is obtained:

$$\hat{R}_t = \hat{R}_t^* + \Delta S_{t+1} - k_0 b_{F,t} + \hat{z}_{RP,t+1} \tag{73}$$

with $b_{F,t} \equiv \left(S_t B_{F,t}/P_t\right)/Y$.

The Home country net foreign asset equation

$$\begin{aligned}\beta b_{F,t} - b_{F,t-1} &= a_H a_T (a_H - 1)\hat{T}_t + (a_T - 1)a_H a_T \hat{X}_t + a_H a_T \hat{Y}_{H,t} \\ &+ a_H a_T (a_H - 1)\hat{T}_t^* + (a_T - 1)(1 - a_H)a_T \hat{X}_t^* + (1 - a_H)a_T \widehat{RS}_t + (1 - a_H)a_T \hat{Y}_{H,t}^* \\ &+ (1 - a_T)a_T \hat{X}_t + (1 - a_T)\hat{Y}_{N,t} - \hat{C}_t\end{aligned} \tag{74}$$

In the PCP case, the above equation can be written as:

$$\begin{aligned}\beta b_{F,t} - b_{F,t-1} &= a_H a_T (a_H - 1)\widehat{TOT}_t + (a_T - 1)a_H a_T \hat{X}_t + a_H a_T \hat{Y}_{H,t} \\ &+ a_H a_T (a_H - 1)\widehat{TOT}_t + (a_T - 1)(1 - a_H)a_T \hat{X}_t^* \\ &+ (1 - a_H)a_T \widehat{RS}_t + (1 - a_H)a_T Y_{H,t}^* \\ &+ (1 - a_T)a_T \hat{X}_t + (1 - a_T)\hat{Y}_{N,t} - \hat{C}_t\end{aligned} \tag{75}$$

Finally, the resource constraints of the Home and Foreign economies are respectively:

$$Y_t = a_H a_T \hat{Y}_{H,t} + (1 - a_H)a_T \hat{Y}_{H,t}^* + (1 - a_T)\hat{Y}_{N,t} \tag{76}$$

$$Y_t^* = a_H a_T \hat{Y}_{F,t}^* + a_H a_T \hat{Y}_{F,t} + (1 - a_T)\hat{Y}_{N,t}^* \tag{77}$$

IV. Monetary Policy Rules.

Monetary policy is modelled through interest-rate feedback rules. The nominal interest rate is designed to react to its previous period value (capturing the tendency of the monetary authorities to smooth changes in interest rates) to the deviations of inflation, output growth, nominal exchange rate changes from their respective targets:

$$\hat{R}_t = (1 - \rho_R)\hat{R}_{t-1} + (1 - \rho_R)\rho_\pi \pi_t + (1 - \rho_R)\rho_y \left(\hat{Y}_t - \hat{Y}_{t-1}\right) + (1 - \rho_R)\rho_{\Delta S}\Delta S_t + \varepsilon_{R,t} \tag{78}$$

$$\hat{R}_t^* = (1 - \rho_R^*)\hat{R}_{t-1}^* + (1 - \rho_R^*)\rho_\pi^* \pi_t^* + (1 - \rho_R^*)\rho_y^* \left(\hat{Y}_t^* - \hat{Y}_{t-1}^*\right) - (1 - \rho_R^*)\rho_{\Delta S}^*\Delta S_t + \varepsilon_{R,t}^* \tag{79}$$

The coefficients ρ_π, ρ_y, $\rho_{\Delta S}$, and ρ_π^*, ρ_y^*, $\rho_{\Delta S}^*$ reflect the weight given to deviations of domestic targets, i.e. the consumption inflation rates, the output growth and nominal exchange rate changes. $\varepsilon_{R,t}$ and $\varepsilon_{R,t}^*$ are two i.i.d. shocks that capture the unexpected component of monetary policy.

V. The exogenous law of motions
Technology shocks follow the process:

$$\begin{pmatrix} \hat{z}_{H,t} \\ \hat{z}^*_{F,t} \\ \hat{z}_{N,t} \\ \hat{z}^*_{N,t} \end{pmatrix} = \begin{pmatrix} \rho_H & \rho_{H,F} & 0 & 0 \\ \rho_{F,H} & \rho_F & 0 & 0 \\ 0 & 0 & \rho_N & \rho_{N,N^*} \\ 0 & 0 & \rho_{N^*,N} & \rho^*_N \end{pmatrix} \begin{pmatrix} \hat{z}_{H,t-1} \\ \hat{z}^*_{F,t-1} \\ \hat{z}_{N,t-1} \\ \hat{z}^*_{N,t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{H,t} \\ \varepsilon^*_{F,t} \\ \varepsilon_{N,t} \\ \varepsilon^*_{N,t} \end{pmatrix} \tag{80}$$

Hence the stochastic productivity parameters are correlated cross-country but not cross-sectors. Disturbances are assumed to be orthogonal across countries:

$$\begin{pmatrix} \varepsilon_{H,t} \\ \varepsilon_{N,t} \end{pmatrix} \sim N \begin{pmatrix} 0 \\ 0 \end{pmatrix} ; \begin{pmatrix} \sigma_{H,H} & \sigma_{H,N} \\ \sigma_{N,H} & \sigma_{N,N} \end{pmatrix} \tag{81}$$

$$\begin{pmatrix} \varepsilon^*_{F,t} \\ \varepsilon_{N,t} \end{pmatrix} \sim N \begin{pmatrix} 0 \\ 0 \end{pmatrix} ; \begin{pmatrix} \sigma_{F^*,F^*} & \sigma_{F^*,N^*} \\ \sigma_{N^*,F^*} & \sigma_{N^*,N^*} \end{pmatrix} \tag{82}$$

Shocks to preferences have the following law of motion:

$$\hat{z}_{U,t} = \rho_U \hat{z}_{U,t-1} + \varepsilon_{U,t} \qquad \varepsilon_{U,t} \sim N(0;\ \sigma_U) \tag{83}$$

$$\hat{z}^*_{U,t} = \rho^*_U \hat{z}^*_{U,t-1} + \varepsilon^*_{U,t} \qquad \varepsilon^*_{U,t} \sim N(0;\ \sigma^*_U) \tag{84}$$

Shocks to UIP follow the process:

$$\hat{z}_{RP,t} = \rho_{RP} \hat{z}_{RP,t} + \varepsilon_{RP,t} \qquad \varepsilon_{RP,t} \sim N(0;\ \sigma_{RP}) \tag{85}$$

Finally, there are innovations in monetary policy in each country denoted by $\varepsilon_{R,t}$ and $\varepsilon^*_{R,t}$:

$$\varepsilon_{R,t} \sim N(0;\ \sigma_R) \qquad \varepsilon^*_{R,t} \sim N(0;\ \sigma^*_R) \tag{86}$$

4 The Estimation Procedure

In this section we illustrate the data used for estimation; then we review the choice of prior distributions, the estimation methodology and the obtained results.

4.1 Data

To estimate the parameters, data over the period 1983.1-2003.4 are used on 9 key macroeconomic variables: real consumption, tradable and nontradable inflation rates, nominal short term interest rates for both the Euro Area and the U.S. and the euro-dollar real exchange rate. The model has implications for the log deviations from steady state of all these variables, and thus we pre-processed the data before the estimation stage. In particular, data on the real exchange rate are logged and demeaned; data on consumption are logged and then linearly detrended; data on nominal interest rates and on inflation rates are demeaned.[14] The Euro Area is the Home country.

4.2 Prior Distributions

A number of parameters were kept fixed from the start of the exercise. This can be seen as a very strict prior. The discount factor β is calibrated at 0.99, implying an annual steady-state real interest of 4%; the elasticity of substitution between varieties, θ, is set equal to 6, implying a steady state markup of 1.2; the parameter that summarizes the disutility from labor supply, τ, is set equal to 1.57.

Prior distributions for the parameters are summarized in Tables 1 and 2. We assume all parameters to be *a priori* independent.

The mean of intratemporal elasticity of substitution between home and foreign tradable goods, ρ, is set equal to 1.1, while the mean of intratemporal elasticity of substitution between tradable and non tradable goods is equal to 1.2. The standard deviation is both cases is set equal to 0.2^2.

The mean of the home bias, a_H, is set equal to 0.75 (standard deviation equal to 0.2^2), that of the weight of tradable goods in the consumption basket is 0.5 (standard deviation 0.2^2). [15]

The parameter of the premium paid by home agents for their net foreign asset position has a mean equal to 0.005 and a standard deviation of 0.005^2.

The elasticity of marginal utility with respect to consumption has a mean value equal to 2 (standard deviation 0.25^2), so that its inverse, which corresponds to the elasticity of intertemporal substitution, is 0.5.

The priors on the coefficients in the monetary policy reaction functions are standard: a relatively high prior mean on the inflation coefficient (1.5, with standard deviation equal to 0.25^2) helps to guarantee a unique solution path when solving the model, the persistence coefficient

[14] See Lubik and Schorfheide [2005], Smets and Wouters [2003, 2004] for estimation of DSGE model using Euro Area and U.S. data.

[15] Stockman and Tesar [1995] suggest that the share of nontradables in the consumption basket of the seven largest OECD countries is roughly 50 percent.

mean is set to 0.75 (standard deviation equal to 0.1^2), the output growth and nominal exchange rate variation coefficients means are both set to zero (with standard deviation equal to 0.1^2 and 0.25^2, respectively).

Parameters measuring the degree of stickiness are assumed to have the same mean value, equal to 50 (as in Ireland [1997]), with standard deviation equal to 25^2.

All the shock variances and technology cross-correlation coefficient are assumed to have a sparse distribution. The autoregressive parameters of the shocks are assumed to follow a beta distribution with mean 0.9 and standard error 0.05^2.

4.3 Parameter Estimates

The computation of the posterior distribution of the estimated parameters proceeds in the following steps.[16] First, we search for a maximum of the kernel of the posterior distribution (using a numerical optimization routine) in order to find the posterior mode.[17] Next we use a Random Walk Metropolis-Hastings algorithm to explore the parameter space in a neighborhood of that point The algorithm constructs a Gaussian approximation around the posterior mode and uses a scaled version of the asymptotic covariance matrix as the covariance matrix for its jump distribution. This allows for an efficient exploration of the posterior distribution at least in the neighborhood of the mode. The algorithm generates a sequence of dependent draws from the posterior distribution that can be used to approximate the posterior distribution of any quantity of interest.[18] Geweke [1999] reviews regularity conditions that guarantee the convergence of Markov chains generated by Metropolis Hastings algorithms to the posterior distribution of interest.

Tables 1 and 2 report two sets of parameter estimates, coming from the LCP and the PCP models respectively. The tables report some key information about the prior distribution of each parameter while the rest of the columns report some key percentiles from the posterior (2.5^{th}, 50^{th} and 97.5^{th} percentiles), the posterior means and posterior standard deviations of all the estimated parameters as delivered by a $500,000$ run of Metropolis-Hastings algorithm.

Several interesting results emerge.

[16] See An and Schorfheide (2005) for a review of Bayesian methods for estimation of DSGE models.

[17] The number of structural shock is equal to that of the observable variables; hence the singularity problem, typical of DSGE models, is avoided without sny recourse to stochastic measurement errors. The likelihood function associated with the linear state-space form of the model solution is captured using the Kalman filter. If the parameter vector implies multiple or unstable solutions, then the likelihood is set to zero.

[18] For more details on the application of baysian techniquies to DSGE models, see An and Schorfheide [2005], Del Negro et al [2004], Schorfheide [2000]. See also DeJong et al. [2000]. For an applicaton of maximum likelihood methods, see See Ireland [2004] and Kim [2000]

First, results are not much different between the LCP and the PCP versions; hence in the following we discuss the results of the LCP version.

Second, the data seem to be particularly informative about the home bias coefficient a_H: its mean and median values are approximately 0.98, a value much higher than the prior mean. Such a high value, probably due to the attempt of the model to fit the real exchange rate volatility, limits, as we will be clear below, the size of international spillovers and it is crucial for the results reported in the rest of the paper. Note that a similar value using data on the Euro Area and U.S. has already been found by other authors.[19]

Third, the sample is partially informative about the degree of domestic nominal rigidities: the posterior distributions for parameters that regulate the rigidity of export prices, k_H^* and k_F match quite perfectly with the prior, indicating that our sample is quite uninformative about them. Note also that nontradable goods are stickier than tradable goods and that the degree of stickiness of tradable good prices is higher in the respective domestic market than in the importing country; the possible reason is that prices denominated in the currency of importing country (incomplete exchange rate pass-through) react at least partially to real exchange rate fluctuations (see equations (65) and (64)). Finally, the estimates seem to be rather similar for the tradable sectors, while the U.S. nontradable prices seem to be stickier than the Euro Area counterparts.

Fourth, the sample is uninformative about the weight of tradable goods in the consumption basket, a_T, the elasticity of intratemporal substitution between home and foreign tradable goods, ρ, the elasticity of substitution between tradable and nontradable goods, ϕ. The estimate of the intertemporal elasticity of substitution $(1/\sigma_c)$ is around 0.8, close to the value used in much of the Real Businnes Cycle literature, which assumes an elasticity of substitution between 0.5 and 1.

The premium paid by home agents for taking a position in the international financial markets is estimated to be 0.0009.[20] This implies that a reduction of 10 percentage points in the net foreign asset position of the Home country translates in an increase in the premium paid of 0.009%.

Finally, the estimated monetary policy reaction functions show that U.S. policy makers react to inflation more strongly than the Euro Area policy-makers do. The latter seem to react to variations in nominal exchange rate. The persistence parameters and those of reaction to output growth are rather similar across countries. The similarity in the estimates of the nominal rigidities across the two countries contribute to explain the almost symmetric responses of the two economies to the same qualitative shock, as we will see in the next section.

[19] Posterior mode for home bias in Adjémian et al. [2005] is around 0.97.

[20] Bergin (2004) finds a result of 0.00384.

4.4 Impulse Response Analysis

Figures 1 to 4 plot the impulse responses to the various structural shocks. The impulse responses to each of 9 structural shocks are calculated for a selection of 500 draws from the posterior distribution of the parameters. The graphs plot the mean response together with the 5^{th} and 95^{th} percentiles.

The interesting results are several.

First, the impulse of the two versions of the model, PCP and LCP, are very similar: the relatively high size of home bias limits the effects of the nominal exchange rate. Second, the responses are specular across countries: the symmetry of the estimates implies that the reaction to a given shock is similar. Because of these results, we only show responses to Euro Area shocks for the LCP version of the model. Third, responses to domestic shocks are in the majority of the cases significant; to the contrary, responses to foreign shocks are almost always small and not significant: the high degree of home bias limits the effect of exchange rate variations on the U.S. inflation rates and relative prices.

Figure 1 plots the impulse response to a monetary shock in the Euro Area. Following the increase in the nominal interest rate, the CPI, its two components (tradable and nontradable) and domestic consumption decrease; the nominal exchange rate appreciates. International spillovers have a relatively small size and almost always not significant.

Figure 2 plots the responses to a home tradable technology shock in the Euro Area. On impact, the increase in the home tradable good supply induces a decrease in tradable inflation; nontradable inflation increases because of the higher overall demand (due to the positive income and wealth effects, which dominate the substitution effect); in the aggregate, the tradable component dominates and CPI inflation decreases; lower CPI inflation and higher output induce a reaction in the policy rule and the nominal interest rate increases. In this case international spillovers are significant, although relatively small. This is due to the fact that we allow technology shocks to be internationally correlated, although with a lag.

Figure 3 plots the responses to a preference shock in the Euro Area. Home consumption increases, causing an increase in Home inflation. Given the higher CPI inflation rate and higher output, the home monetary authority increase the nominal interest rate. As a consequence, the nominal exchange rate appreciates. Also in this case, international spillovers are relatively small and hardly significant.

Figure 4 plots the responses to a positive risk-premium shock. The higher interest rate differential implies that consumption in the Home country decreases with respect to the Foreign country. Because of lower labor effort, supply decreases (more than demand) and consequently inflation increases. The UIP equation implies that in period $t+1$ an exchange rate appreciation has to be expected; hence in period t the nominal exchange rate depreciates. The opposite mechanism applies in the Foreign country: consumption and labor effort increase, CPI and sectorial inflation rates decrease as well as the nominal interest rate.

4.5 Unconditional Correlations

Table 3 reports the unconditional correlations obtained from the data and from the model. The internal propagation mechanisms in the model, i.e. mainly the interest rate smoothing and the price stickiness, do a relatively good job in matching the correlation between tradable and nontradable inflation rates in each country, between inflation rates and interest rates domestically, between consumption cross-country and between consumptions and real exchange rate. Other correlations, in particular cross-country correlations, generated by the model are lower than those found in the data. This failure clearly points to the fact that some other mechanisms of international propagation of the shocks are missing from the model.

4.6 Variance Decomposition

The contribution of each of the structural shocks to the unconditional forecast error variance of the endogenous variables is shown in Table 4. This exercise reinforces the message coming from the impulse responses and the correlation analyses just performed: the dynamics of the two countries are rather uncoupled and specular. In fact, not only the domestic shocks are the main determinants explaining tradable and nontradable inflation rates as well as consumptions, but also the part of explained variability is similar across countries. Home preference shocks explain around 75 percent of the Home tradable and nontradable inflation rate variability, Foreign preference shocks explain a similar percentage of the foreign tradable and nontradable inflation rate variability (around 80 percent). In the Home (Foreign) country, home tradable technology shock explains 16 (14) percent of the Home (Foreign) tradable inflation rate, while Home (Foreign) nontradable technology shock explains 15 (13) percent of Home (Foreign) nontradable inflation rate. Note also that in both countries monetary shocks have a rather limited role in explaining price variability.

In both countries consumption is mainly explained by the domestic technology shocks: in the Home country, technology shock in the Home tradable and nontradable sectors explain respectively 59 and 28 percent of Home consumption; in the Foreign country, these numbers are 51 and 33 percent.

Variations in real exchange rate are mainly explained by the shock to the UIP (83 percent), followed by shocks to home and foreign preferences (respectively 8.5 and 7.7 percent). Also this result confirm the low degree of international spillovers

4.7 Historical Decomposition

Figures 5 to 9 summarize the historical contribution of the various estimated structural shocks to the dynamics of each observable variable. The decomposition is based on the best estimates of the shocks and helps understanding how the model interprets specific movements in the observed data series.

Results are not much different from those previously illustrated. They confirm the strong insularity of the two economies.

The real exchange rate is mostly accounted for by the risk-premium shock, followed by the preference shocks. Home (i.e. Euro Area) and Foreign (i.e. U.S.) tradable good inflation rates are mainly explained by the Home and Foreign preference shocks, respectively. Home consumption is explained by home shocks, in particular preference and technology shocks, while Foreign consumption is explained by foreign preference and technology shocks.

5 Conclusions

In this paper we have estimated a new open economy model using Euro Area and U.S. data. Two versions of the model are estimated, which differ in the pricing strategy of the exporting firms: in one version the PCP assumption holds, so exporting firms sell their product at the same price at home and abroad; in the second, the LCP assumption holds, so exporting firms are able to make price discrimination across the domestic and foreign markets. The model is characterized by the presence of nontradable sector, the absence of capital accumulation, home bias in consumption and international incomplete markets. Nontradable sector allows to get a more complete picture of the degrees of nominal rigidities in each of the two economies. International incomplete markets and home bias in preferences are exploited to increase the capability of the model to explain movement of the exchange rate.

The overall picture we get from the estimates and from the performed exercises is that two economies are rather symmetric in terms of nominal rigidities and that international spillovers are relatively small.

A possible development of the present work consists in building up a more articulated supply side of the economy, by formalizing more articulated wholesale and retail sectors and introducing distribution costs. The estimation of a vertical structure of this type could probably shed new light on the mechanisms of interaction across economies. Also, other mechanisms to improve the international correlations should be considered, like for example the inclusion of global shocks, to increase the capability of the estimated model to match the cross-country empirical correlations.

References

[1] An, Sungbae, and Frank Schorfeide [2005]. "Bayesian Analysis of DSGE Models," University of Pennsylvania, unpublished.

[2] Adjémian, Stéphane, Matthieu Darracq Pariès, and Frank Smets [2005]. "Structural Analysis of US and EA Businness Cycle", unpublished.

[3] Adolfson, Malin, Stefan Laseen, Jesper Linde, and Mattias Villani [2004]. "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through," Manuscript, Sveriges Riksbank.

[4] Ambler, Steve, Ali Dib and N. Rebei [2004]. "Optimal Taylor Rules in an Estimated Model of a Small Open Economy," Manuscript, Bank of Canada.

[5] Batini, Nicoletta, Alejandro Justiniano, Paul Levine, and Joseph Pearlman [2005]. "Model Uncertainty and the Gains from Coordinating Monetary Rules", unpublished.

[6] Benigno Gianluca [2004]. "Real Exchange Rate Persistence and Monetary Policy Rules," Journal of Monetary Economics, 51, 473-502.

[7] Benigno, Pierpaolo [2001]. "Price Stability with Imperfect Financial Integration," New York University, unpublished.

[8] Bergin, Paul R. [2003]. "Putting the 'New Open Economy Macroeconomics' to a Test," Journal of International Economics, 60, 3-34.

[9] Bergin, Paul R. [2004]. "How Well Can the New Open Economy Macroeconomics Explain the Exchange Rate and the Current Account?," Journal of International Money and Finance.

[10] Clarida, Richard, and Jordi Gali [1994]. "Sources of Real Exchange Rate Fluctuations: How Important Are Nominal Shocks?," Carnegie-Rochester Series in Public Policy 41, 1-56.

[11] Chari, V.V., Patrick Kehoe, Ellen McGrattan [2002]. "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rate," Review of Economic Studies, 69, 533-563.

[12] Corsetti, Giancarlo, Luca Dedola and Sylvain Leduc [2004]. "International Risk-Sharing and The Transmission of Productivity Shocks", Manuscript, European University Institute.

[13] Dedola, Luca, and Sylvain Leduc [2001]. "Why Is the Business-Cycle Behavior of Fundamentals Alike across Exchange-Rate Regimes?," International Journal of Finance & Economics, 6(4), 401-19.

[14] DeJong, David N., Beth F. Ingram, and Charles H. Whiteman [2000]. "A Bayesian Approach to Dynamic Macroeconomics," Journal of Econometrics 98, 203-223.

[15] Del Negro, Marco, Frank Schorfheide, Frank Smets, and Raf Wouters [2004]. "On the Fit and Forecasting Performance of New-Keynesian Models," Federal Reserve Bank of Atlanta, manuscript.

[16] Dib, Ali [2003]. "Monetary Policy in Estimated Models of Small Open and Closed Economies," Bank of Canada Working Paper, 2003-27.

[17] Dornbusch, Rudi [1976]. "Expectations and exchange rate dynamics," Journal of Political Economy 84, 1161–1176.

[18] Geweke, John [1999]. "Using Simulation Methods for Bayesian Econometric Models: Inference, Development and Communication," Econometric Reviews, 18, 1-126.

[19] Hairault, Jean-Olivier and Franck Portier [1993]. "Money, New-Keynesian macroeconomics and the business cycle," European Economic Review, 37(8), 1533-1568.

[20] Ireland, Peter [1997]. "A small, structural, quarterly model for monetary policy evaluation," Carnegie-Rochester Conference Series on Public Policy, 47, 83-108.

[21] Ireland, Peter [2004]. "A Method for Taking Models to the Data," Journal of Economic Dynamics and Control 28(6), 1205-1226.

[22] Justiniano, Alejandro and Bruce Preston [2004]. "Small Open Economy DSGE Models - Specification, Estimation, and Model Fit," Manuscript, International Monetary Fund and Department of Economics,Columbia University.

[23] Lane, Philip [2001]. "The New Open Economy Macroeconomics: A Survey," Journal of International Economics 54, 235-266.

[24] Kim, Jinill, [2000]. "Constructing and estimating a realistic optimizing model of monetary policy," Journal of Monetary Economics 45, 329-359.

[25] Laxton, Doug and Paolo Pesenti [2003]. "Monetary Policy Rules for Small, Open, Emerging Economies," Journal of Monetary Economics, 50, 1109-1146.

[26] Lubik, Thomas, and Frank Schorfheide [2005]. "A Bayesian Look at New Open Economy Macroeconomics," NBER Macroeconomics Annual.

[27] Rotemberg, Julio [1996]. "Prices, output and hours: An empirical analysis based on a sticky price model," Journal of Monetary Economics 37 (1996), 505-33.

[28] Schmitt-Grohe, Stephanie and Martin Uribe [2003]. "Closing small open economy models," Journal of International Economics, 61, 163-185.

[29] Schorfheide, Frank [2000]. "Loss Function-Based Evaluation of DSGE Models," Journal of Applied Econometrics, 15, 645-670.

[30] Smets, Frank and Raf Wouters [2003] "An Estimated Stochastic Dynamic General Equilibrium Model for the Euro Area," Journal of the European Economic Association, 1, 1123-1175.

[31] Smets, Frank and Raf Wouters [2004]. "Comparing Shocks and Frictions in U.S. and Euro Area Business Cycles: A Bayesian DSGE Approach," National Bank of Belgium Working Paper, 61.

[32] Smets, Frank, and Raf Wouters [2004]. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," manuscript, April.

[33] Stockman, Alan C., and Linda Tesar [1995]. "Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements," American Economic Review, 83, 473-86.

[34] Tesar, Linda [1993]. "International Risk Sharing and Non-Traded Goods," Journal of International Economics, 35 (1-2), 69-89.

[35] Warnock, Francis [2003]. "Exchange rate dynamics and the welfare effects of monetary policy in a two-country model with home-product bias," Journal of International Money and Finance, 22, 343-363.

[36] Woodford, Michael [1998]. "Doing without Money: Controlling Inflation in a Post-monetary World," Review of Economic Dynamics, 1, 173-219.

Table 1a. Posterior Estimation: Main Parameters (LCP model)

parameter	prior mean	2.5	50	97.5	mean	st. dev.
a_H	0.75	0.9766	0.9834	0.9890	0.9832	0.0032
a_T	0.5	0.4307	0.5569	0.6898	0.5578	0.0665
ϕ	1.2	0.9494	1.2816	1.6693	1.2888	0.1847
ρ	1.1	0.8176	1.0925	1.4336	1.1013	0.1573
κ_0	0.005	0.0003	0.0009	0.0013	0.0009	0.0003
σ_C	2.0	1.0291	1.2142	1.4261	1.2179	0.1010
κ_H	50	164.0301	219.8616	283.6741	220.7895	30.5985
κ_H^*	50	21.7180	55.8679	116.1764	59.3074	24.5788
κ_F	50	18.5695	49.1129	108.2545	53.0308	23.3144
κ_F^*	50	129.6705	195.7899	279.2403	198.0826	38.2517
κ_N	50	152.4116	202.5672	258.4874	203.2850	27.0101
κ_N^*	50	187.9933	257.3546	329.4185	257.4742	36.8709
ρ_R	0.75	0.5527	0.6417	0.7169	0.6399	0.0421
ρ_π	1.5	1.2657	1.3764	1.5139	1.3800	0.0634
ρ_Y	0.0	0.2213	0.3749	0.5190	0.3739	0.0759
$\rho_{\Delta S}$	0.0	0.0010	0.0228	0.0480	0.0233	0.0120
ρ_R^*	0.75	0.4954	0.5815	0.6579	0.5801	0.0417
ρ_π^*	1.5	1.4541	1.5793	1.7254	1.5824	0.0690
ρ_Y^*	0.0	0.2150	0.3498	0.4834	0.3498	0.0682
$\rho_{\Delta S}^*$	0.0	-0.0176	0.0012	0.0211	0.0013	0.0098

Table 1b. Posterior Estimation: Shocks Parameters (LCP model)

parameter	prior mean	2.5	50	97.5	mean	st. dev.
σ_{ε_R}		0.0019	0.0022	0.0026	0.0022	0.0002
$\sigma_{\varepsilon_{R^*}}$		0.0016	0.0019	0.0023	0.0019	0.0002
ρ_{Z_H}	0.9	0.9605	0.9735	0.9850	0.9733	0.0063
ρ_{Z_F}	0.9	0.9501	0.9599	0.9683	0.9597	0.0047
ρ_{Z_N}	0.9	0.9625	0.9721	0.9801	0.9719	0.0045
$\rho^*_{Z_N}$	0.9	0.9547	0.9647	0.9726	0.9644	0.0046
ρ_{PR}	0.9	0.9674	0.9773	0.9854	0.9771	0.0047
ρ^*_{PR}	0.9	0.9584	0.9693	0.9771	0.9689	0.0048
ρ_{RP}	0.9	0.9545	0.9663	0.9764	0.9661	0.0056
σ_{Z_H}		0.0078	0.0095	0.0115	0.0095	0.0009
σ_{Z_F}		0.0075	0.0092	0.0114	0.0092	0.0010
σ_{Z_N}		0.0069	0.0083	0.0100	0.0084	0.0008
$\sigma_{Z^*_N}$		0.0072	0.0087	0.0105	0.0087	0.0008
$\sigma_{Z_{PR}}$		0.0122	0.0165	0.0226	0.0167	0.0027
$\sigma_{Z^*_{PR}}$		0.0146	0.0192	0.0242	0.0192	0.0025
$\sigma_{Z_{RP}}$		0.0016	0.0022	0.0029	0.0022	0.0003
$\rho_{Z_{HF}}$		-0.0021	0.0071	0.0120	0.0064	0.0036
$\rho_{Z_{FH}}$		-0.0088	-0.0055	-0.0017	-0.0054	0.0018
$\rho_{Z_{NN^*}}$		0.0029	0.0084	0.0135	0.0083	0.0027
$\rho_{Z_{N^*N}}$		-0.0022	-0.0002	0.0017	-0.0002	0.0010
$\sigma_{Z_{HF}}$		-0.0015	0.0001	0.0020	0.0001	0.0009
$\sigma_{Z_{FH}}$		-0.0033	-0.0013	0.0003	-0.0014	0.0010
$\sigma_{Z_{NN^*}}$		-0.0018	0.0005	0.0021	0.0004	0.0010
$\sigma_{Z_{N^*N}}$		-0.0020	-0.0004	0.0020	-0.0003	0.0010

Table 2a. Posterior Estimation: Main Parameters(PCP model)

parameter	prior mean	2.5	50	97.5	mean	st. dev.
a_H	0.75	0.9954	0.9969	0.9980	0.9968	0.0007
a_T	0.5	0.4062	0.5244	0.6479	0.5253	0.0620
ϕ	1.2	0.8393	1.1844	1.6189	1.1966	0.1986
ρ	1.1	0.8776	1.2008	1.6302	1.2145	0.1933
κ_0	0.005	0.0010	0.0017	0.0022	0.0017	0.0003
σ_C	2.0	1.0358	1.2286	1.4395	1.2312	0.1034
κ_H	50	142.4133	213.0679	307.8791	216.2498	42.4322
κ_F^*	50	178.5008	224.3518	272.9234	224.8940	24.3545
κ_N	50	162.1078	232.4799	321.9850	234.6386	40.6900
κ_N^*	50	162.0592	241.0139	338.9179	243.5820	45.2443
ρ_R	0.75	0.5574	0.6512	0.7270	0.6492	0.0428
ρ_π	1.5	1.2284	1.3368	1.4724	1.3404	0.0623
ρ_Y	0.0	0.1948	0.3481	0.4960	0.3475	0.0766
$\rho_{\Delta S}$	0.0	-0.0014	0.0179	0.0413	0.0185	0.0108
ρ_{R_*}	0.75	0.4755	0.5747	0.6599	0.5727	0.0471
ρ_{π_*}	1.5	1.4492	1.5862	1.7444	1.5894	0.0756
ρ_{Y_*}	0.0	0.2219	0.3593	0.4988	0.3598	0.0709
$\rho_{\Delta S}^*$	0.0	-0.0169	0.0024	0.0226	0.0025	0.0100

Table 2b. Posterior Estimation: Shocks Parameters(PCP model)

parameter	prior mean	2.5	50	97.5	mean	st. dev.
σ_{ε_R}		0.0017	0.0020	0.0025	0.0020	0.0002
$\sigma_{\varepsilon_{R^*}}$		0.0017	0.0020	0.0024	0.0020	0.0002
ρ_{Z_H}	0.9	0.9721	0.9825	0.9898	0.9821	0.0046
ρ_{Z_F}	0.9	0.9484	0.9536	0.9588	0.9536	0.0026
ρ_{Z_N}	0.9	0.9705	0.9782	0.9842	0.9780	0.0035
$\rho_{Z_N^*}$	0.9	0.9532	0.9630	0.9710	0.9627	0.0046
$\rho_{Z_{PR}}$	0.9	0.9739	0.9812	0.9868	0.9810	0.0033
ρ_{PR^*}	0.9	0.9603	0.9661	0.9710	0.9660	0.0027
ρ_{RP}	0.9	0.9308	0.9587	0.9808	0.9580	0.0128
σ_{Z_H}		0.0053	0.0078	0.0102	0.0078	0.0012
σ_{Z_F}		0.0056	0.0080	0.0100	0.0080	0.0011
σ_{Z_N}		0.0070	0.0084	0.0102	0.0085	0.0008
$\sigma_{Z_N^*}$		0.0070	0.0085	0.0105	0.0086	0.0009
$\sigma_{Z_{PR}}$		0.0125	0.0168	0.0226	0.0170	0.0026
$\sigma_{Z_{PR}^*}$		0.0145	0.0180	0.0223	0.0181	0.0020
$\sigma_{Z_{RP}}$		0.0014	0.0025	0.0041	0.0026	0.0007
$\rho_{Z_{HF}}$		-0.0250	-0.0150	-0.0028	-0.0147	0.0057
$\rho_{Z_{FH}}$		-0.0181	-0.0114	-0.0023	-0.0110	0.0041
$\rho_{Z_{NN^*}}$		0.0066	0.0133	0.0180	0.0130	0.0029
$\rho_{Z_{N^*N}}$		-0.0048	-0.0027	-0.0000	-0.0026	0.0013
$\sigma_{Z_{HF}}$		-0.0077	-0.0053	-0.0034	-0.0054	0.0011
$\sigma_{Z_{HF}}$		0.0031	0.0055	0.0082	0.0055	0.0013
$\sigma_{Z_{NN^*}}$		-0.0006	0.0007	0.0022	0.0007	0.0007
$\sigma_{Z_{N^*N}}$		-0.0023	-0.0008	0.0006	-0.0008	0.0007

Table 3. Unconditional Correlations(LCP model)

	$C^{(EU)}$	$\pi_T^{(EU)}$	$\pi_N^{(EU)}$	RS	$R^{(EU)}$	$C^{(US)}$	$\pi_T^{(US)}$	$\pi_N^{(US)}$	$R^{(US)}$
$C^{(EU)}$	1.00	-0.09	-0.01	-0.44	0.31	-0.03	0.32	0.10	0.02
$\pi_T^{(EU)}$	-0.10	1.00	0.97	0.60	0.85	-0.22	0.79	0.91	0.79
$\pi_N^{(EU)}$	-0.05	0.77	1.00	0.51	0.88	-0.30	0.80	0.90	0.74
RS	-0.17	-0.01	-0.01	1.00	0.31	0.23	0.33	0.53	0.51
$R^{(EU)}$	-0.19	0.79	0.78	-0.01	1.00	-0.20	0.83	0.82	0.76
$C^{(US)}$	-0.08	0.04	0.03	0.22	0.04	1.00	-0.09	-0.15	-0.02
$\pi_T^{(US)}$	-0.01	0.07	0.07	0.06	0.06	-0.03	1.00	0.92	0.84
$\pi_N^{(US)}$	-0.04	0.08	0.07	0.07	0.06	0.01	0.78	1.00	0.86
$R^{(US)}$	-0.03	0.08	0.07	0.06	0.07	-0.07	0.84	0.85	1.00

Table 4. Forecast Error Variance Decomposition(LCP model)

	$z_T^{(EU)}$	$z_T^{(US)}$	$\varepsilon_R^{(EU)}$	$\varepsilon_R^{(US)}$	$z_N^{(EU)}$	$z_N^{(US)}$	$z_U^{(EU)}$	$z_U^{(US)}$	z_{RP}	TOTAL
$C^{(EU)}$	55.5	1.4	5.4	0.0	28.1	1.6	3.6	0.3	4.0	100.0
$\pi_T^{(EU)}$	16.0	0.1	2.7	0.0	2.8	0.2	75.5	0.6	2.1	100.0
$\pi_N^{(EU)}$	5.4	0.1	2.8	0.0	14.0	0.1	74.9	0.6	2.0	100.0
RS	0.3	0.1	0.0	0.0	0.1	0.1	8.5	7.7	83.1	100.0
$R^{(EU)}$	4.9	0.1	11.1	0.0	2.6	0.1	78.2	0.5	2.6	100.0
$C^{(US)}$	3.2	49.4	0.0	3.8	0.0	31.7	0.5	6.1	5.2	100.0
$\pi_T^{(US)}$	0.2	15.2	0.0	1.3	0.0	2.9	0.0	79.9	0.5	100.0
$\pi_N^{(US)}$	0.2	4.6	0.0	1.0	0.0	12.8	0.0	81.0	0.4	100.0
$R^{(US)}$	0.1	4.7	0.0	7.9	0.0	2.2	0.0	84.8	0.4	100.0

Figure 1: Impulses Responses from a Monetary Policy Shock in the Euro Area

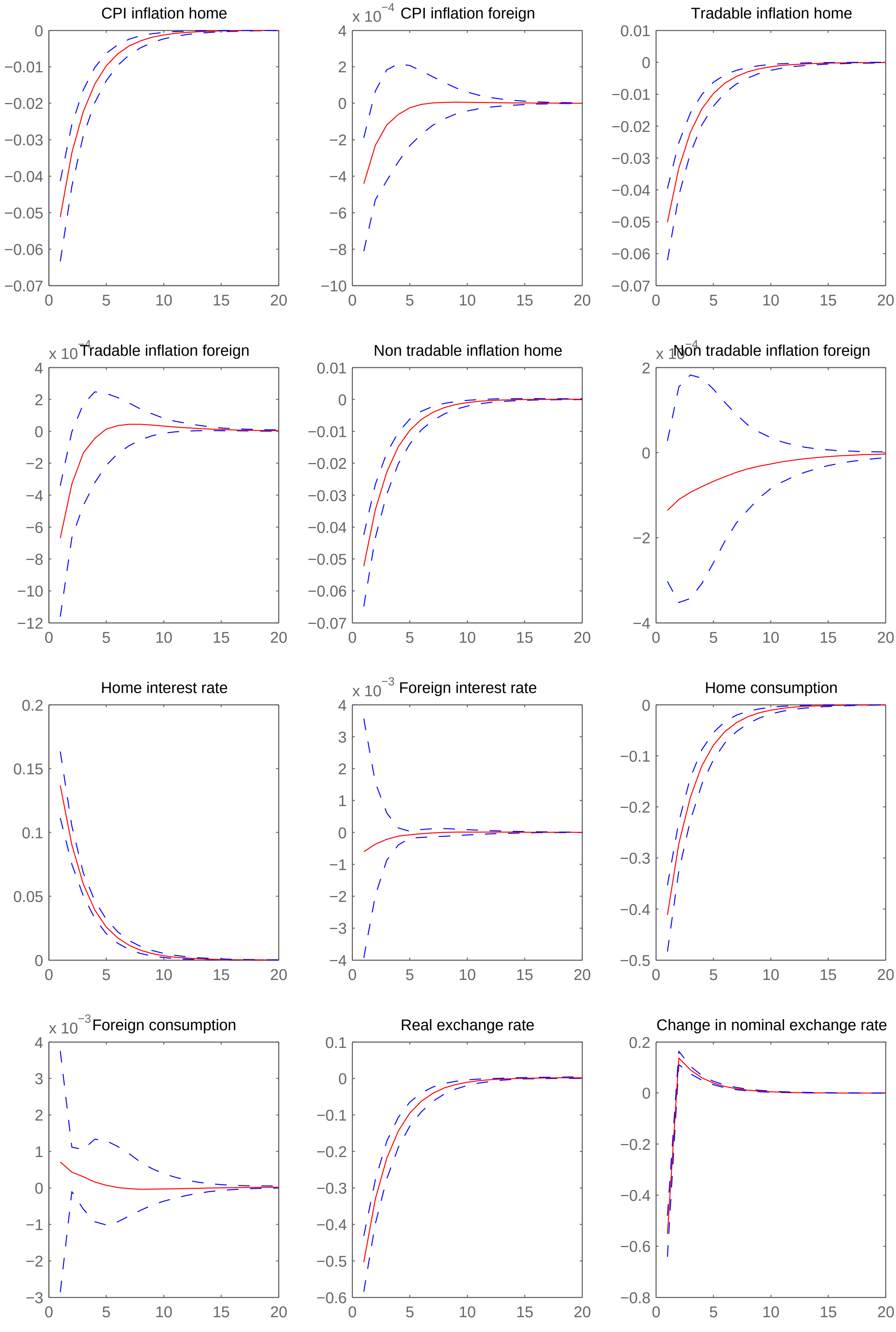

Figure 2: Impulses Responses from a Tradable Technology Shock in the Euro Area

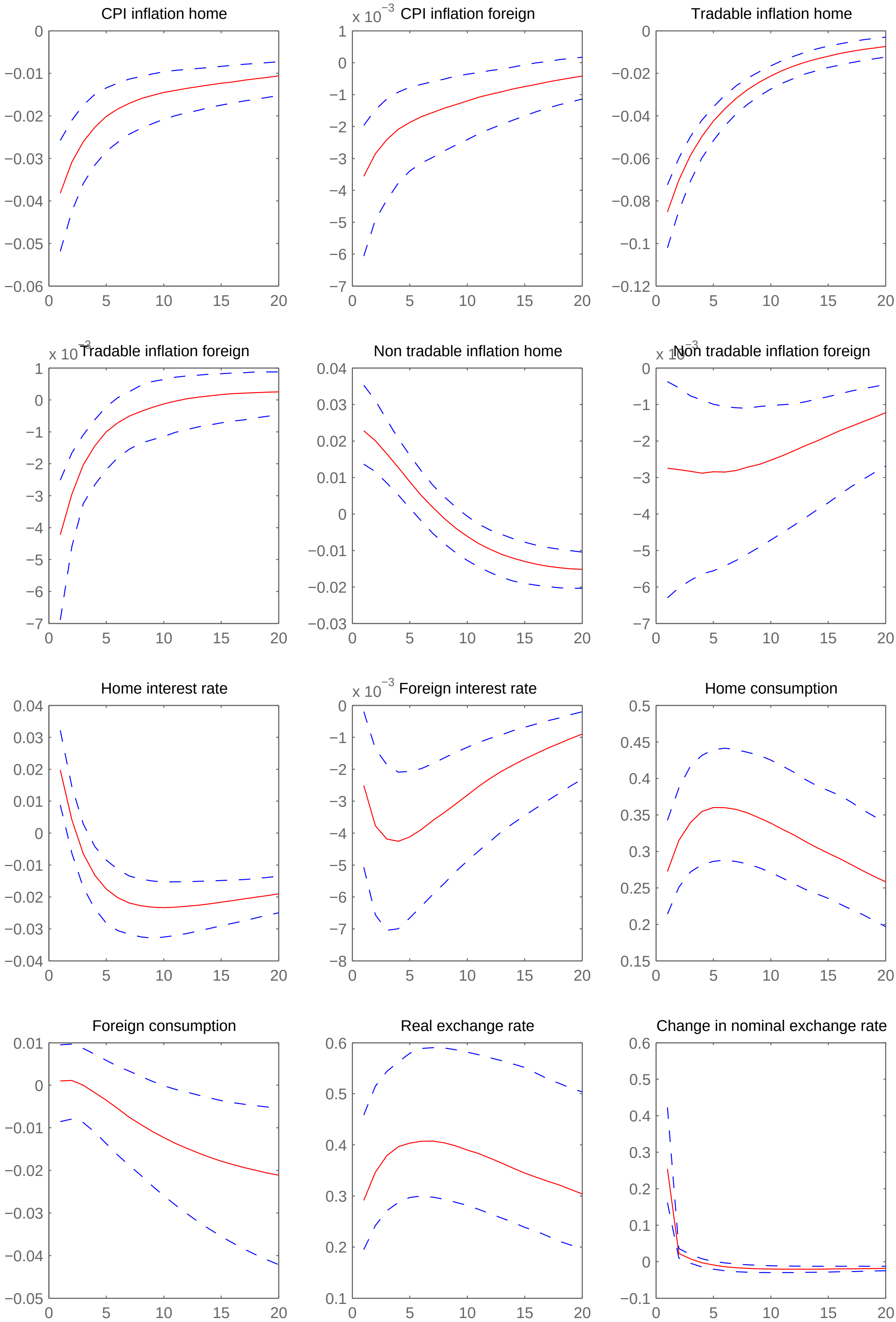

Figure 3: Impulses Responses from a Preference Shock in the Euro Area

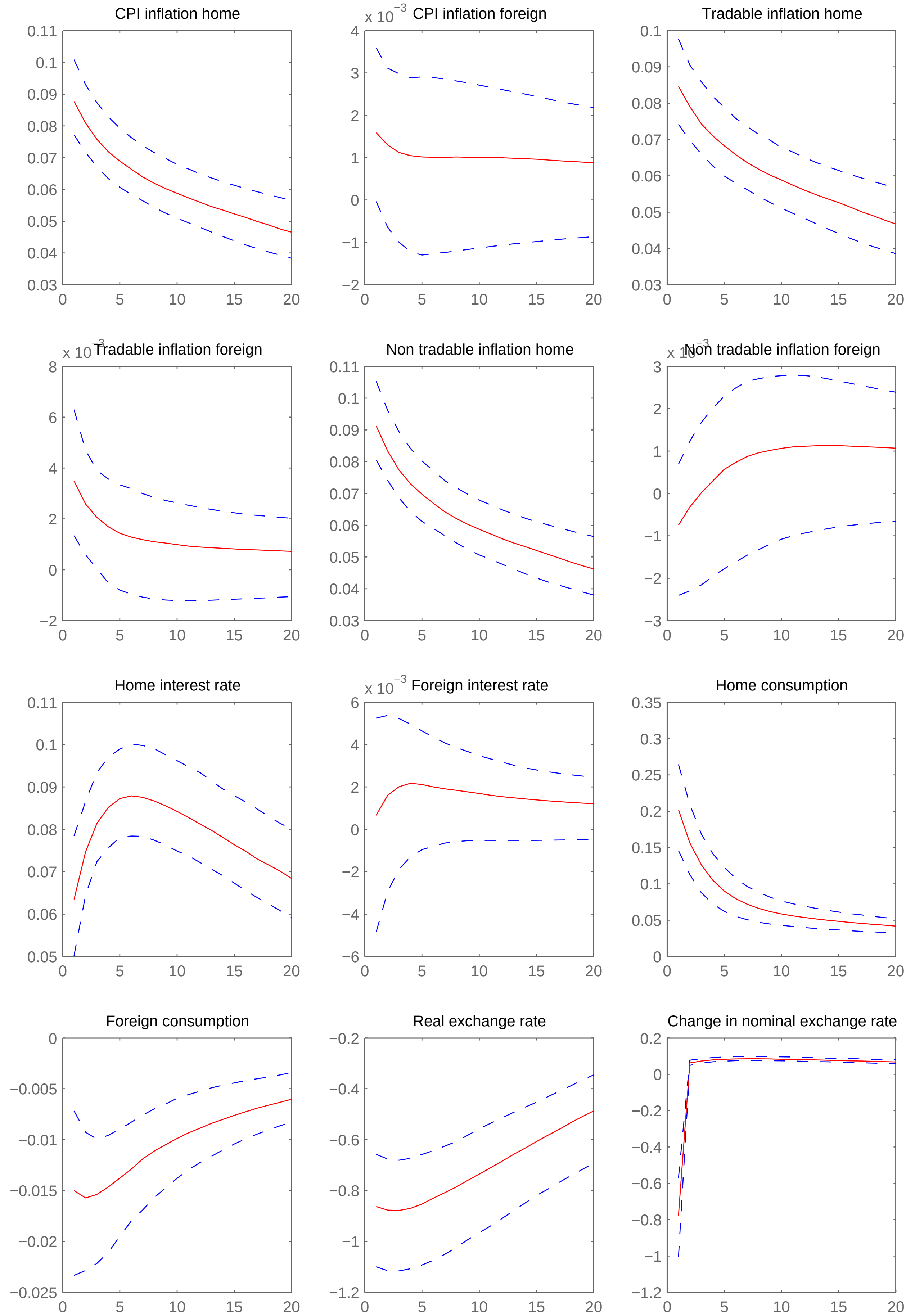

Figure 4: Impulses Responses from a UIP Shock

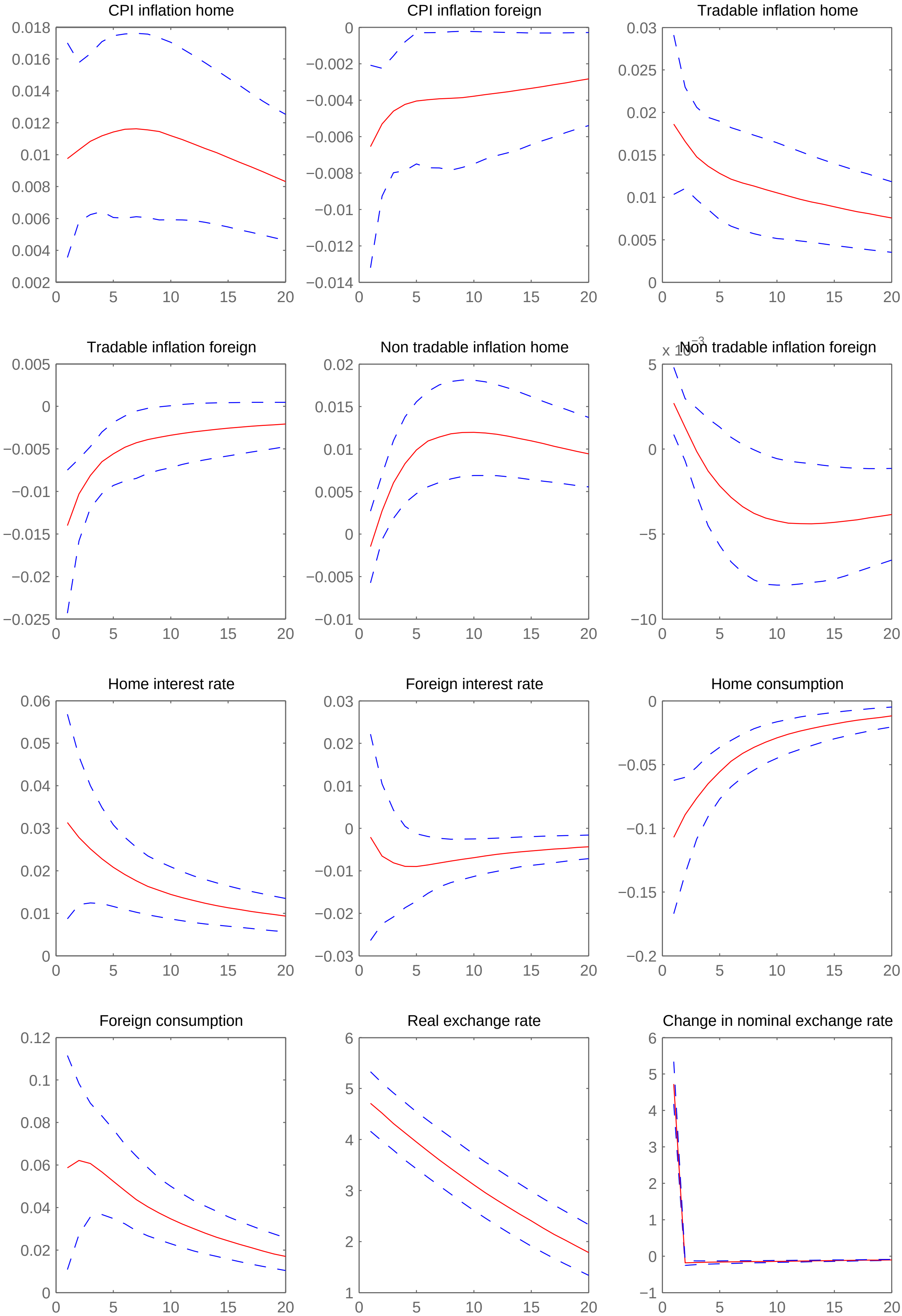

Figure 5: Historical Decomposition of Real Exchange Rate

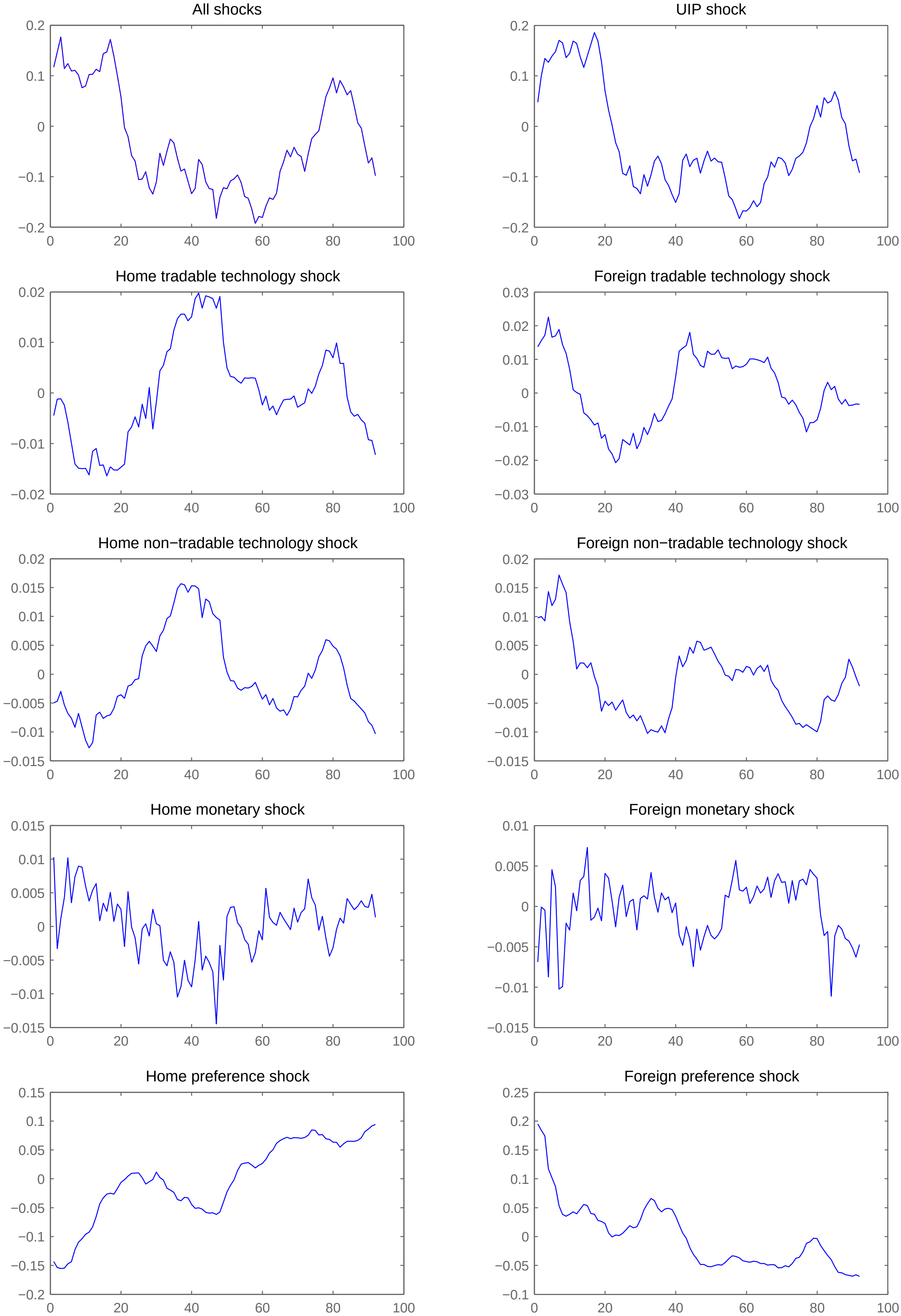

Figure 6: Historical Decomposition of Euro Area Tradable Inflation

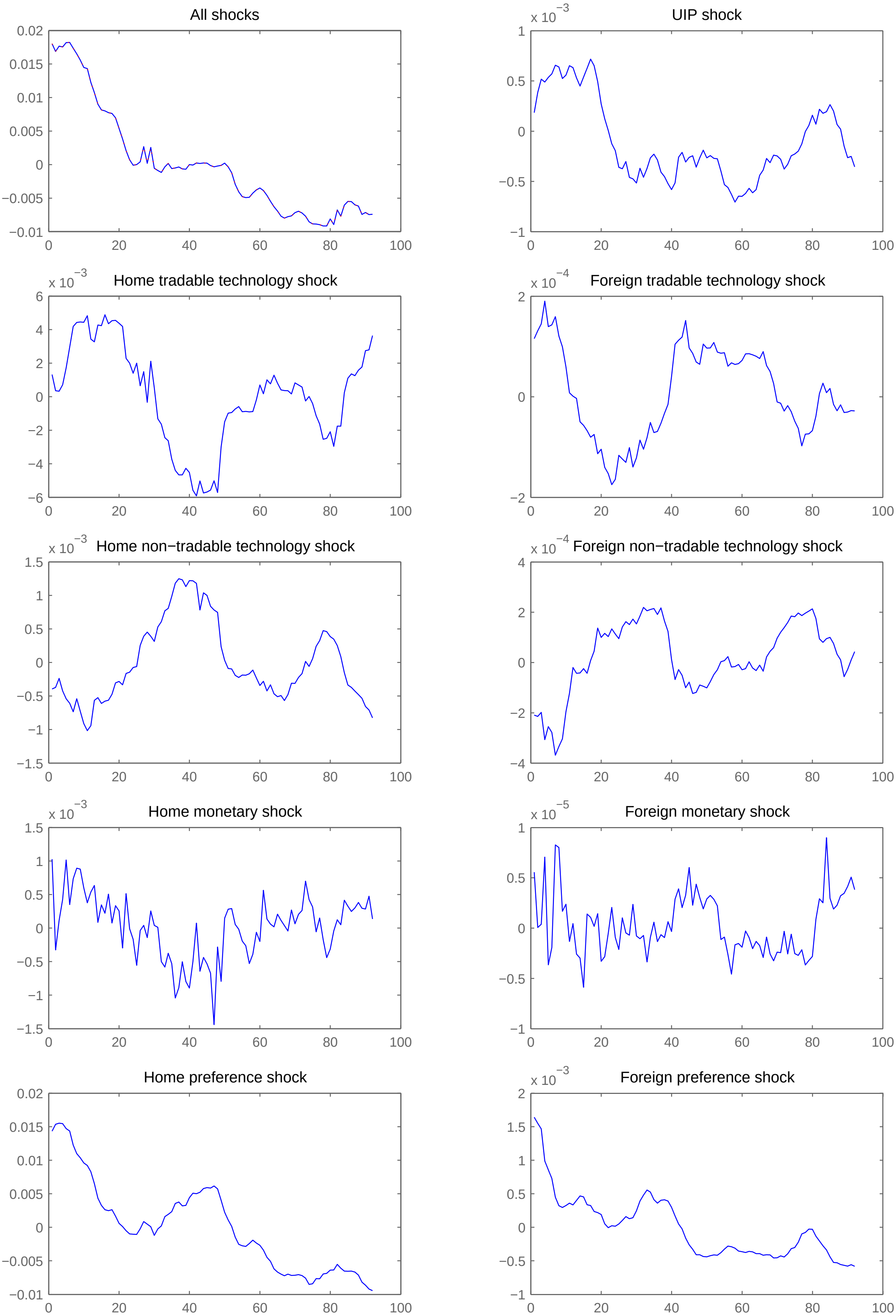

Figure 7: Historical Decomposition of US Tradable Inflation

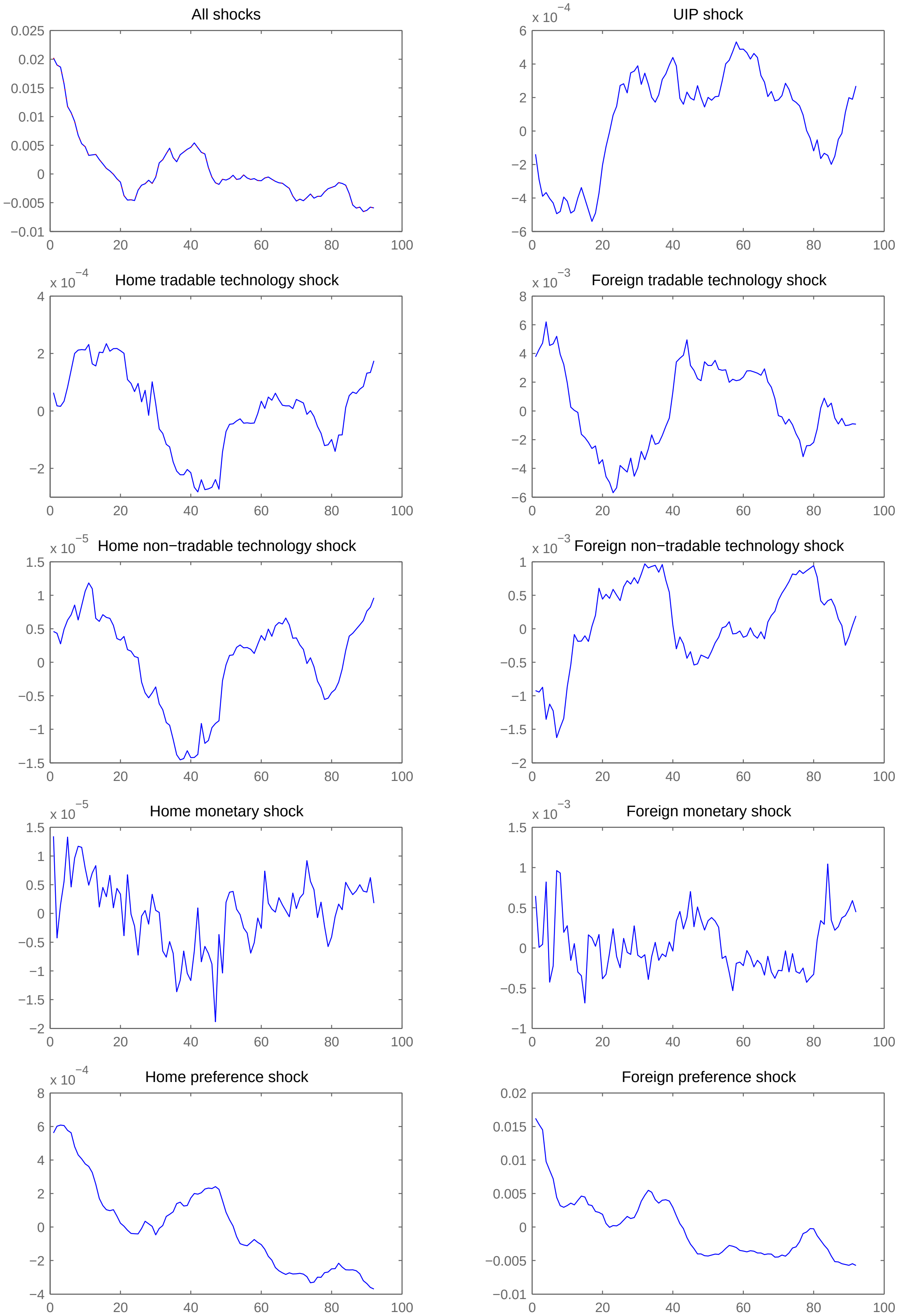

Figure 8: Historical Decomposition of Euro Area Consumption

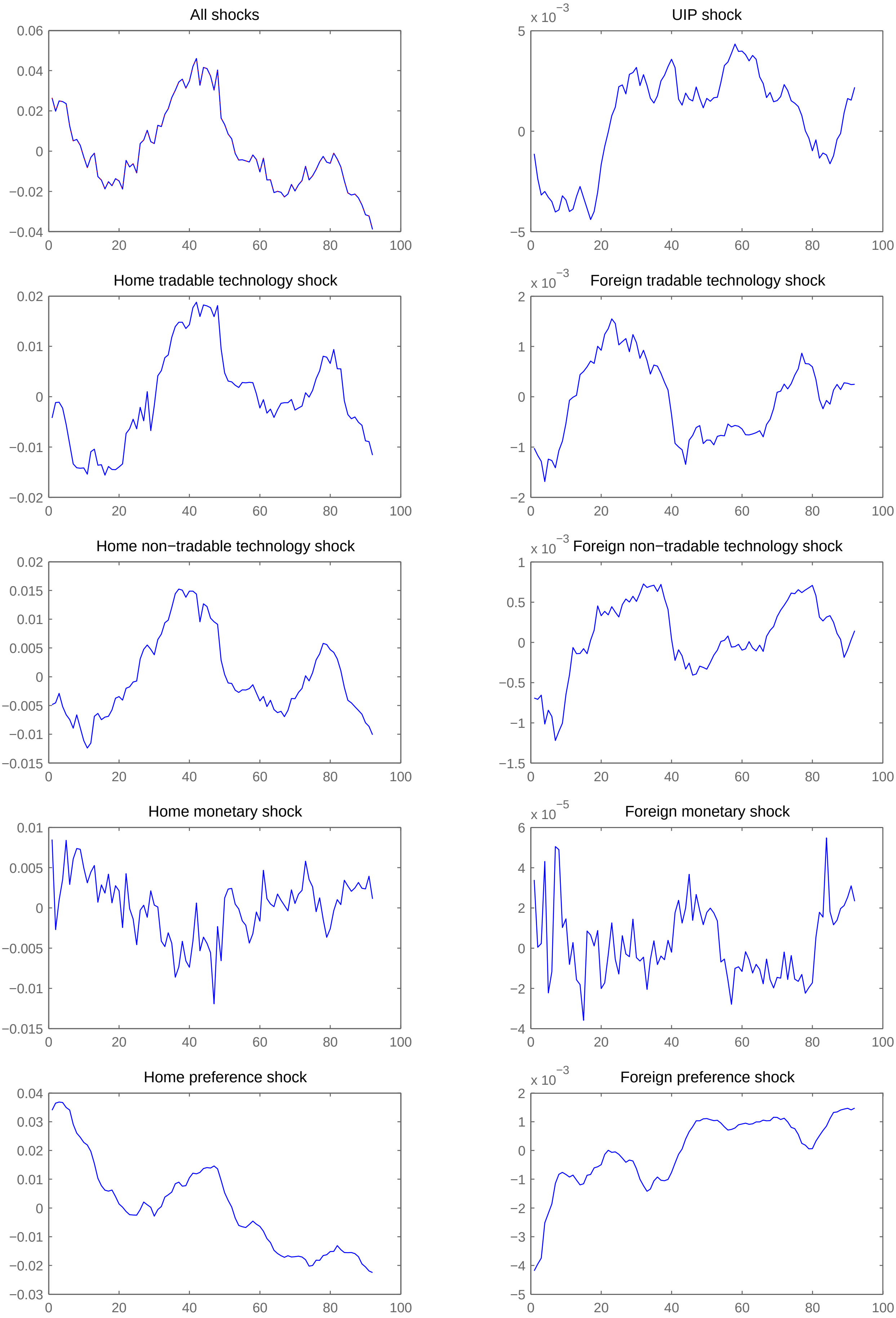

Figure 9: Historical Decomposition of US Consumption