The euro area periphery and the rest-of-the-world: a DSGE approach.

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Abstract

This research builds upon recent work undertaken for other small open economies to construct a DSGE model for an euro area peripheral economy. The model takes into account of euro area membership and departs from the literature by considering two different sectors: a goods and other services sector and a tourism sector. The tourism sector focuses on exports, is more labour intensive, and has a significant share of its market located outside the euro zone. Some parameters of the model are calibrated and others estimated using Bayesian techniques to match the case of Cyprus, but can also be applied to other countries. The model properties are validated through statistical tests, impulse-response analysis, and variance decompositions.

Keywords: DSGE models, small open economy, bayesian methods
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1 Introduction

DSGE models have become the workhorse of modern policy analysis in recent years. They combine the rigorous optimization analysis and rational expectations of real business cycle models with nominal rigidities, giving a non-trivial role to monetary policy. Due to the fact that they are constructed from optimizing conditions for all agents in the economy, their reduced form can be linked to the structural parameters of the model, making them less vulnerable to the Lucas critique, and therefore more suitable for analyzing the relative importance of shocks, simulating the effects of different policies, and undertaking forecasting exercises.

Following the seminal work of Smets and Wouters (2003), who developed a new Keynesian dynamic stochastic general equilibrium (DSGE) model for the euro area, similar work has been undertaken for several European countries, including Austria, Belgium, Luxembourg, Sweden, and Spain, with promising results (see Breuss and Rabitsh, 2009; Jenfils and Burggrave, 2007; Deak et al., 2011; Adolfson et al., 2008; and Burriel et al., 2010).

Among country models, two groups can be identified: (i) small open economy models, which treat the country as a small-open economy taking developments in the rest of the euro area as exogenous; and (ii) two-country models which model the country's economy alongside the euro area. Two-country models have been used even in the analysis of small countries like Austria (Breuss and Rabitsh, 2009), the reason being that such countries are part of the euro area and want to be able to make their own projections to contribute to the euro area monetary policy debate.

The broad set up of a DSGE models tends to consider four main blocks: households, firms, fiscal policy, and monetary policy. In addition, a range of shocks are also scattered in the model to confer it its stochastic nature and enable to address specific policy questions. Labour and product markets are often assumed to operate under monopolistic competition, resulting in price and wage markups often assumed to be subject to shocks. Smets and Wouters (2003) show that markup shocks when included explain a significant percentage of the variation in inflation. In the household block, the shocks typically considered include a consumption preference shock, and a labor supply shock (shock to the preferences for leisure). But so far small open economy models for euro area countries have largely ignored the rest-of-the-world and shocks emanating from it.

This project aims at developing a DSGE model in the style of new-Keynesian/New Open Economy Macroeconomics for a peripheral small euro area economy exposed to euro exchange rate shocks, and other shocks emanating from outside the euro area. The research builds upon other small open economy models, in particular Cuche-Curti et al. (2008), Adolfson et al (2007), and Cristofell at al. (2008); extended with a tourism sector, which exports to the rest-of-the world and is also more labour intensive. This sector will be exposed to a range of shocks originated in the rest of the world, and will also be exposed to euro nominal exchange rate fluctuations caused by euro area monetary policy. We show that this sector can be an important channel for the transmission of shocks, a results which is in line with the findings of Canova and Dallari (2013), who show using data for a set of Mediterranean economies that tourism can be an important channel for the transmission of business cycle fluctiations across countries, even though it has been largely disregarded in policy analysis.

The model is partially calibrated and partially estimated to match the behavior of the Cypriot economy, and euro area peryphery with a significant share of exports to non-Eurozone countries. The parameter estimation uses Bayesian techniques, which are found to provide a robust and efficient way of matching the models to actual data. The model is intended for undertaking simulations of different policies and exogenous shocks, and can be applied to other periphery countries.

Bayesian estimation basically boils down to treating the parameters of the model as random variables, allowing the adoption of a "prior" probability distribution for each parameter which summarizes any available information (see Carlin and Louis, 2009). Apart from simplifying the use of priors in estimation, and therefore allowing for prior information to be used in models with a relatively large number of parameters, Bayesian estimation also has the advantage that the posterior inference does not depend on the model being correctly specified.[1] Estimating a set of model parameters using Baeysian techniques also allows us to take into account of parameter uncertainty when analysing, for instance, impulse response functions.

Overall we find that the model has economically plausible properties, especially with regard to the propagation of key economic shocks, and that the euro exchange rate can be an important channel for the propagation of shocks in this type of economies.

2 The model

2.1 Households

Households are assumed to maximize utility over an infinite life horizon. Their utility is assumed to depend positively on consumption and leisure, with habit formation in consumption. In terms of their budget constraints, we allow for households to be grouped into two categories: saving and rule-of-thumb households. Rule-of- thumb households do not owe any assets and just consume their current income flow, facing a period-by-period budget constraint. This assumption, which can be justified by myopia or credit constrains, for instance, breaks down the Ricardian equivalence, allowing a fiscal expansion to have a positive effect on private consumption, as suggested by empirical evidence (see Gali et al., 2007). Saving households, on the other hand can owe capital and assets, and receive dividends and transfers. These households decide how much to save and invest so as to maximize their lifetime consumption and leisure. The share of rule of thumb consumers in the economy is s_R, while the share of optimizing consumers is $(1 - s_R)$.

[1] Despite these advantages and the increasing popularity of Bayesian estimation of DSGE models, there are still challenges in this area, relating in particular to the identification of structural parameters (see Canova, 2007).

2.1.1 Optimizing Consumers

Optimizing consumers on the other hand maximize the present value of their expected life-time utility subject to an intertemporal budget constraint.

The present value of the expected life-time utility of optimizing household j is given by:

$$U_{C,t} \equiv E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left(\varepsilon_{C,\tau} \ln \left(C_{\tau}^{O}(j) - H_{\tau}^{O} \right) - \varepsilon_{l,\tau} \frac{l_{\tau}^{O}(j)^{1+\nu}}{1+\nu} \right) \tag{1}$$

where C^O is the real consumption of optimizing households, and l^O is the labour supplied by optimizing households, ε_C and are ε_l are preference shocks to consumption and labour respectively, and β is the time discount factor such that $0 < \beta < 1$. $H_t^O(j)$ is the stock of external habits given by $H_t^O = hC_{t-1}^O$, where the parameter h $(0 < h < 1)$ determines the importance of external habit formation.[2] The presence of habit formation in consumption means that an increase in consumption today will increase the marginal utility of consumption in the following period (intuitively, as described in Schmitt-Grohe and Uribe, 2008, "the more the consumer eats today, the hungrier he wakes up tomorrow"). As h tends to unity, households act to smooth changes in consumption rather than the level of consumption. This assumption improves in general the empirical fit of the model, as it can generate the "hump-shaped" impulse responses of output and consumption to demand and supply shocks, typically observed in VAR models, since they provide an additional incentive for consumption smoothness on top of that stemming from the concavity of the utility function (see Bergin and Tchakarov, 2003, and references therein).

Optimizing households are assumed to supply differentiated units of labour to labour unions. Each union is a monopolistic supplier of a type labour and has some market power over wages subject to Calvo-type restrictions (see Calvo, 1983), which imply that the optimal wage in period t, $W_t^*(j)$ can only be negotiated with a probability $(1 - \xi_w)$. Each period, wages that are not reset are updated by a wage indexation rate $\Omega_{Wt,t-t_0}$, where t_0 is the last period when wages could be re-set. Hence $W_t = \Omega_{Wt,t-t_0} W_{t_0}$ with $\Omega_{Wt,t-t_0} = 1$ for $t = t_0$.[3] Households are insured against labour income uncertainty through state-contingent securities, which pay a net cash inflow of $P_t A_t^O(j)$, such that $(1-\tau_t^l)W_t(j)l_t^O(j)+P_tA_t^O(j)$ is equal for households (where τ^l is the tax rate on labour), making the optimizing households maximization problem symmetric. State contingent securities sum up to zero across optimizing households, that is $\int_{j=0}^{S_O} A_t^O(j)dj = 0$.

[2] Notice that for the model to be consistent with a balanced-growth path it is necessary to assume either non-separable preferences in consumption and leisure or logarithmic preferences over consumption (see Ireland, 2004).

[3] Although the empirical relevance of wage rigidity has been questioned in the literature (since there is scope for the stickiness in formal wages to be privately neutralized), a number of contributions have found that wage rigidity helps DSGE models explain many features of the data, such as the persistence in the effects of monetary shocks (see Christiano et al., 2005, as well as Canzoneri et al., 2007, and references therein).

Optimizing households can also invest in capital stock and rent it in the subsequent period to domestic firms at the nominal rental price Z_t^K. Investment is subject to adjustment costs, hence the standard capital accumulation law of motion is modified as follows:

$$K_t^O(j) = \varepsilon_{I,t}\left(1-\Gamma^I\left(\frac{I_t^O(j)}{I_{t-1}^O(j)}\right)\right)I_t^O(j)+(1-\delta)\,K_{t-1}^O(j) \tag{2}$$

$$\Gamma^I \equiv \frac{\gamma^I}{2}\left(\frac{I_t^O(j)}{I_{t-1}^O(j)}-\overline{\zeta}\right)^2 \tag{3}$$

where $I_t^O(j)$ is the investment of household j in period t, $\varepsilon_{I,t}$ is an investment shock, δ is the depreciation rate, $\gamma^I > 0$ determines the costs of adjusting investment, and $\overline{\zeta}$ is the steady-state growth rate of the economy. The inclusion of investment adjustment costs allows to map the fall in real interest rates (liquidity effect) and the hump-shaped response of investment to a monetary expansion, typically found in empirical VAR studies (see Christiano et al., 2010). Investment adjustment costs are also said to generate other desirable dynamics to the models, including more desirable responses of output, hours worked, and real wages to fiscal shocks (see Burnside et al., 2004).[4]

Households can also invest in both domestic government bonds and Eurozone (excluding the domestic economy) bonds. It is assumed that households cannot borrow from the government, hence the stock of domestic government bonds is non-negative. The stock of Eurozone bonds can be positive (with the domestic economy being a net lender) or negative (with the domestic economy being a net debtor). Domestic bonds yield the domestic nominal interest rate R, while Eurozone bonds yield the foreign interest rate R^{EZ}, adjusted by a risk premium $\Theta\left(b_t^{EZ},\varepsilon_{\Theta,t}\right) = \varepsilon_{\Theta,t}\exp\left(-\varpi_\Theta\left(b_t^{EZ}-\overline{b}^{EZ}\right)\right)$, where $b_t^{EZ}$are the economy's total real stationary holdings of Eurozone bonds, such that $b_t^{EZ} = \frac{B_t^{EZ}}{\Gamma_t P_t}$, $\overline{b}^{EZ}$ is the steady-state equilibrium real stationary holdings of Eurozone bonds, ϖ_Θ is a parameter measuring the degree of capital mobility, and $\varepsilon_{\Theta,t}$ is a risk premium shock. This risk premium implies that the household has to pay a remuneration higher than R^{EZ} when the economy's net debt position is above it's steady state level or $\varepsilon_{\Theta,t}$ is positive. This assumption is crucial to pin-down a well-defined steady-state for consumption and assets (see Schmitt-Grohe and Uribe, 2003, for a discussion of the non-stationarity problem). In steady-state $\varepsilon_{\Theta,t} = 1$ and $\Theta\left(\overline{b}^{EZ},1\right) = 1$, hence $\overline{R} = \overline{R}^{EZ}$. Finally, optimizing households also receive dividends from firms. It is assumed that all firms' profits are distributed equally among households in the form of dividends.

Given household's resources and their uses described above, the optimizing household j intertemporal budget constraint can be written as:

[4] Empirical evidence on the magnitude of investment adjustment costs is limited, with aggregate studies typically finding costs more significant than studies using disaggregate sectoral data (see Groth and Khan, 2010).

$$
\begin{aligned}
& (1+\tau_t^C)P_{C,t}C_t^O(j)+P_{I,t}I_t^O(j)+B_t^O(j)+B_t^{EZ,O}(j) && (4)\\
\leq\ & R_{t-1}B_{t-1}^O(j)++R_{t-1}^{EZ}\Theta\left(b_{t-1}^{EZ},\varepsilon_{\Theta,t-1}\right)B_{t-1}^{EZ,O}(j)+(1-\tau_t^l)W_t(j)l_t^O(j)+P_tA_t^O+ && (5)\\
& +(1-\tau_t^K)Z_t^KK_{t-1}^O(j)+DIV_t^O+TR_t^O && (6)
\end{aligned}
$$

where τ^C, τ^l, and τ^K, are the economy-wide tax rates on consumption, labour, and capital, and $P_{C,t}$ and $P_{I,t}$ are the price deflators for consumption and investment, respectively, and $TR_t^O(j)$ are net lum-sum transfers paid to optimizing households. $P_{C,t}$ is assumed to be the numeraire. In this set up, the no-Ponzi game condition for debt accumulation is given by:

$$
\lim_{s\longrightarrow\infty}E_t\left\{\rho_{t+s}\left(B_{t+s}+B_{t+s}^{EZ}\right)\right\}=0 \tag{7}
$$

where $\rho_{t+s}=\prod_{k=0}^{s}\frac{1}{R_{t+k-1}}$ for s>0, and $\rho_{t+s}=1$, for $s=0$.

The optimizing household j maximizes its welfare (1) with respect to consumption (C_t^O), domestic and Eurozone bond holdings ($B_t^O, B_\tau^{EZ,O}$), investment (I_t^O), and capital (K_t^O), subject to the constraints imposed by (2) (4),and (7).Maximization with respect to consumption requires:

$$
\begin{aligned}
U_{C,t} &\equiv \varepsilon_{C,t}\left(C_t^O(j)-hC_{t-1}^O\right)^{-1}=\lambda_t^O(j)(1+\tau_t^C)P_{C,t}\\
\lambda_t^O(j) &= \frac{\varepsilon_{C,t}\left(C_t^O(j)-hC_{t-1}^O\right)^{-1}}{(1+\tau_t^C)P_{C,t}}
\end{aligned}
$$

Maximization with respect to domestic bonds requires:

$$
\beta E_t\left[\lambda_{t+1}^O(j)\right]R_t=\lambda_t^O(j)
$$

where $U_{C,t}$ is the life-time marginal utility of consumption in period t. Maximization with respect to foreign bonds requires:

$$
\beta E_t\left[\lambda_{t+1}^O(j)\right]R_t^{EZ}\Theta\left(b_t^{EZ},\varepsilon_{\Theta,t}\right)=\lambda_t^O(j)
$$

Maximization with respect to investment requires:

$$
\begin{aligned}
P_{I,t} &= P_{C,t}Q_t(j)\varepsilon_{I,t}\left(1-\Gamma^I\left(\frac{I_t^O(j)}{I_{t-1}^O(j)}\right)-\Gamma^{I\prime}\left(\frac{I_t^O(j)}{I_{t-1}^O(j)}\right)\frac{I_t^O(j)}{I_{t-1}^O(j)}\right)+\\
&\quad +\beta E_t\left[\frac{\lambda_{t+1}^O(j)}{\lambda_t^O(j)}P_{C,t+1}Q_{t+1}\varepsilon_{I,t+1}\Gamma^{I\prime}\left(\frac{I_{t+1}^O(j)}{I_t^O(j)}\right)\left(\frac{I_{t+1}^O(j)}{I_t^O(j)}\right)^2\right]
\end{aligned}
$$

where

$$
\begin{aligned}
\Gamma^{I\prime}\left(\frac{I_t^O(j)}{I_{t-1}^O(j)}\right) &= \gamma^I\left(\frac{I_t^O(j)}{I_{t-1}^O(j)}-\overline{\zeta}\right)\\
\Gamma^{I\prime}\left(\frac{I_{t+1}^O(j)}{I_t^O(j)}\right) &= \gamma^I\left(\frac{I_{t+1}^O(j)}{I_t^O(j)}-\overline{\zeta}\right)
\end{aligned}
$$

and Q_t is the "Tobin's Q": $Q_t \equiv \dfrac{\varsigma_t}{P_{C,t}\lambda_t^O}$. Maximization with respect to capital (K_t) requires:

$$P_{C,t}Q_t(j) = \beta E_t \left[\frac{\lambda_{t+1}^O(j)}{\lambda_t^O(j)} \left((1-\tau_{t+1}^K)Z_{t+1}^K + P_{C,t+1}Q_{t+1}(1-\delta)\right) \right]$$

2.1.2 Rule-of-Thumb or Liquidity Constrained Consumers

It is assumed that ROT consumers have an utility function of a similar form as (1),but face a period-by-period budget constraint of the form:

$$(1+\tau_t^C)P_{C,t}C_t^R = (1-\tau_t^l)W_t l_t^R + TR_t^R \tag{8}$$

where W_t is the average nominal wage rate negotiated by labour unions, l^R is the amount of labour supplied by rule of thumb consumers, and T_t^R are net lum-sum tranfers received by this type of households. These transfers are useful because with and appropriate distribution of steady-state transfers between optimizing and rule of thumb consumers it is possible to ensure that $\overline{C}^R = \overline{C}^O = C$ in steady-state and this simplifies the solution of the model. These consumers will use all of their disposable income in consumption.

Total real consumption (C) is the weighted average of consumption of these two consumer categories:

$$C_t = s_R C_t^R + (1-s_R)C_t^O \tag{9}$$

$$l_t = s_R l_t^R + (1-s_R)l_t^O \tag{10}$$

$$TR_t = s_R TR_t^R + (1-s_R)TR_t^O \tag{11}$$

2.1.3 Wage-setting

Wages are set by a continuum of labour unions, each representing a specific type of labour j. Rule-of-thumb and optimizing consumers are assumed to be uniformily distributed across labour types. Hence, for each labour type j, its union chooses a wage that maximizes the weighted average of the utility of optimizing and rule of thumb consumers subject to their budget constraints and the labour demand function, which is equivalent to maximizing:

$$E_t \sum_{\tau=t}^{\infty} (\beta\xi_w)^{\tau-t} \left\{ \begin{array}{c} s_R \left[\lambda_t^R(1-\tau_t^l)W_t l_t^R(j) - \varepsilon_{H,\tau}\frac{l_t^R(j)^{1+\nu}}{1+\nu}\right] + \\ +(1-s_R)\left[\lambda_t^O(1-\tau_t^l)W_t l_t^O(j) - \varepsilon_{H,\tau}\frac{l_t^O(j)^{1+\nu}}{1+\nu}\right] \end{array} \right\}$$

subject to the labour demand function, which under monopolistic competition will take the form:

$$l_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\phi_l} l_t$$

where ϕ_l is the elasticity of substitution between varieties of labour. Households take total labour demand as given and there is perfect labour mobility across sectors, hence the same wage prevails across sectors. It is also assumed that the union takes into account the fact that firms allocate labor demand uniformly across different worker, independently of their household type. It follows that, in the aggregate, we will have $l_t^R = l_t^O = l_t$.

With probability $(\xi_w)^{\tau-t}$ the wage $\Omega_{W\tau,\tau-t}W(j)_t^*$ will be in effect in period τ, hence the FOC for the union's maximization problem with respect to $W_t^*(j)$ is given by:

$$W_t^*(j)^{1+\phi_l\nu} E_t \sum_{\tau=t}^{\infty} (\beta\xi_w)^{\tau-t} \left\{ \lambda_\tau(j)(1-\tau_\tau^l)\Omega_{W\tau,\tau-t} \left(W_\tau/\Omega_{W\tau,\tau-t}\right)^{\phi_l} l_\tau \right\}$$

$$= \frac{\phi_l}{(\phi_l-1)} E_t \sum_{\tau=t}^{\infty} (\beta\xi_w)^{\tau-t} \left\{ \varepsilon_{l,\tau} \left(W_\tau/\Omega_{W\tau,\tau-t}\right)^{\phi_l(1+\nu)} l_\tau^{(1+\nu)} \right\}$$

Defining $\mu^W \equiv \frac{\phi_l}{(\phi_l-1)}$ and rearranging yields:

$$W_t^*(j)^{1+\phi_l\nu} = \mu^W \frac{E_t \sum_{\tau=t}^{\infty} (\beta\xi_w)^{\tau-t} \left\{ \varepsilon_{l,\tau} \left(W_\tau/\Omega_{W\tau,\tau-t}\right)^{\phi_l(1+\nu)} l_\tau^{(1+\nu)} \right\}}{E_t \sum_{\tau=t}^{\infty} (\beta\xi_w)^{\tau-t} \left\{ \lambda_\tau(j)(1-\tau_\tau^l)\Omega_{W\tau,\tau-t} \left(W_\tau/\Omega_{W\tau,\tau-t}\right)^{\phi_l} l_\tau \right\}}$$

which will be equal for all optimizing households, hence $W_t^*(j) = W_t^*$, for all j.

$$W_t^{*1+\phi_l\nu} = \mu^W \frac{\Psi_t^W}{\Phi_t^W}$$

where

$$\begin{aligned} \Psi_t^W &= \beta\xi_w E_t \left(1/\Omega_{Wt+1,1}\right)^{\phi_l(1+\nu)} \Psi_{t+1}^W + \varepsilon_{l,t} \left(W_t\right)^{\phi_l(1+\nu)} l_t^{O(1+\nu)} \\ \Phi_t^W &= \beta\xi_w E_t \Omega_{Wt+1,1} \left(1/\Omega_{Wt+1,1}\right)^{\phi_l} \Phi_{t+1}^W + \lambda_t(1-\tau_t^l) \left(W_t\right)^{\phi_l} l_t^O \end{aligned}$$

The optimal wage results therefore in a markup over the expected marginal rate of substitution between consumption and labour. We do not consider wage markup shocks because these cannot be distinguished from the preference shock to the disutility of labour considered above [5] Notice that the aggregate wage in the economy can be written as:

$$W_t = \left[(1-\xi_w) W_t^{*1-\phi_l} + \xi_w \left(\Omega_{Wt,1} W_{t-1}\right)^{1-\phi_l} \right]^{\frac{1}{1-\phi_l}}$$

2.2 Firms

2.2.1 Retail Sector (Final Goods: Private Consumption, Public Consumption, Investment)

In the retail sector firms produce three types of final goods under perfect competition: a private consumption good (C), a public consumption good (G), and an investment good (I). For the production of each one of the three final goods, the following inputs are used: domestic

[5] It is only possible to distinguish between these two shocks if the labour market is modeled explicitly to account for unemployment (see Gali et al., 2011).

intermediate goods (X^{gd}), imported foreign intermediate goods (X^{gm}) and energy (E). The final goods are produced using CES production function. Moreover, final goods are non-tradable (i.e. cannot be exported). The final good destined for sector S, $S = C, G, I$, is given by:

$$S_t = \left[(1-\omega_E)^{1-\rho_E}(S_t^g)^{\rho_E} + \omega_E^{1-\rho_E}(E_t^S)^{\rho_E}\right]^{1/\rho_E} \tag{12}$$

where,

$$S_t^g = \left[(1-\omega_{M,S})^{1-\rho_{M,S}}(X_t^{gd,S})^{\rho_{M,S}} + \omega_{M,S}^{1-\rho_{M,S}}(X_t^{gm,S})^{\rho_{M,S}}\right]^{1/\rho_{M,S}} \tag{13}$$

The parameters ρ_E and $\rho_{M,S}$ determine the elasticities of substitution between intermediate goods and energy and between domestic goods and imported goods, which are given by $\frac{1}{1-\rho_E}$ and $\frac{1}{1-\rho_{M,S}}$, respectively, with $\rho_E < 1$ and $\rho_{M,S} < 1$. The nested structure assumed in the aggregation allows for different elasticities of substitution between domestic and imported intermediate goods and energy. This can be important for matching CPI dynamics (see Cuche-Curtis et al., 2009), and allows to compute a model consistent measure of core inflation.

The demand of retail firms for intermediate goods and energy is determined by the minimization of the expenditure needed to produce a given amount of final good:

$$\min P_t^{gd} X_t^{gd,s} + P_t^{gm} X_t^{gm,s} + P_t^E E_t^s \tag{14}$$

s.t. (12) and (13) for $S = C, G, I$. This assumes that the price charged by intermediate goods firms and the price of energy inputs is invariant to its final use. Note that $P_{S,t} = MC_{S,t} =$ *lagrange multiplier* since the retailer is a competitive producer:

$$\begin{aligned}\mathcal{L} &= \left[P_t^g X^{gd,S} + P_t^m X^{gm,S} + P_t^E E^S\right] + \\ &+ P_{S,t}\left[S_t - \left[(1-\omega_E)^{1-\rho_E}(S_t^g)^{\rho_E} + \omega_E^{1-\rho_E}(E_t^S)^{\rho_E}\right]^{1/\rho_E}\right]\end{aligned}$$

FOCs with respect to $X_t^{gd,S}$ yield:

$$X_t^{gd,S} = \left(\frac{P_t^g}{P_{S,t}}\right)^{-\frac{1}{1-\rho_{M,S}}} \left[(1-\omega_E)S_t\right]^{\frac{1-\rho_E}{1-\rho_{M,S}}} (1-\omega_{M,S}) \left(S_t^g\right)^{\frac{\rho_E-\rho_{M,S}}{1-\rho_{M,S}}}$$

and analogously for imports:

$$X_t^{gm,S} = \left(\frac{P_t^m}{P_{S,t}}\right)^{-\frac{1}{1-\rho_{M,S}}} \left[(1-\omega_E)S_t\right]^{\frac{1-\rho_E}{1-\rho_{M,S}}} \omega_{M,S} \left(S_t^g\right)^{\frac{\rho_E-\rho_{M,S}}{1-\rho_{M,S}}}$$

The FOCs with respect to E_t^S yield:

$$E_t^S = \left(\frac{P_t^E}{P_{S,t}}\right)^{-\frac{1}{1-\rho_E}} \omega_E S_t$$

The price of the final good produced for sector s, $S = C, G, I$, can be obtained by substituting the input demands into the bundleling function (12):

$$P_{S,t} = \left[(1-\omega_E) \left[(1-\omega_{M,S}) \left(P_t^g\right)^{\frac{\rho_{M,S}}{\rho_{M,S}-1}} + \omega_{M,S} \left(P_t^m\right)^{\frac{\rho_{M,S}}{\rho_{M,S}-1}} \right]^{\frac{\left(1-\rho_{M,S}\right)\rho_E}{(1-\rho_E)\rho_{M,S}}} + \omega_E \left(P_t^E\right)^{\frac{\rho_E}{\rho_E-1}} \right]^{\frac{\rho_E-1}{\rho_E}}$$

The bundle of intermediate domestic goods $X_t^{gd,S}$ is a budle of varieties produced by each individual intermediate domestic goods firm f, such that:

$$X_t^{gd,S} = \left[\int_0^1 X_t^{gd,S}(f)^{\theta_g} df \right]^{\frac{1}{\theta_g}}$$

The parameter θ_{gd} determine the elasticity of substitution between varieties of domestic intermediate goods, which is given by $\frac{1}{1-\theta_{gd}}$, with $\theta_{gd} < 1$. Given this bundle, the demand for individual varieties which minimizes expenditures for a given amount of domestic intermediate good is given by:

$$X_t^{gd,S}(f) = \left(\frac{P_t^g(f)}{P_t^g} \right)^{-\frac{\theta_g}{1-\theta_g}} X_t^{gd,S}$$

with the corresponding price indexes being:

$$P_t^g = \left[\int_0^1 P_t^g(f)^{\frac{\theta_g}{\theta_g-1}} df \right]^{\frac{\theta_g-1}{\theta_g}}$$

2.2.2 Imports

It is assumed that all of domestic imports come from the Eurozone and that the domestic demand for Eurozone imports does not affect the price of imports, hence P_t^m (expressed in euros) is taken as given.

2.2.3 Intermediate Sectors

It is assumed that there are two intermediate sub-sectors in the economy. One sub-sector produces intermediates goods and services that can be either used domestically (X^{gd}) or exported (X^{gf}) to the Eurozone. The other sub-sector produces intermediate tourism services (X^s) that can only exported, either to the Eurozone ($X^{s,EZ}$) or to the rest of the world ($X^{s,RoW}$). Both types of goods are produced combining three inputs: Capital (K), Labour (l) and Oil (E), but the technology can differ across sectors.

The total output of firm f will be $X^d(f) = X^{gd}(i) + X^{gf}(i) + X^s(i)$.

The goods production function is given by:

$$X_t^g(f) = A_t^g \left(\Gamma_t l_t^g(f)\right)^{\alpha_{Lg}} \left(K_t^g(f)\right)^{\alpha_{Kg}} \left(E_t^g(f)\right)^{1-\alpha_{Lg}-\alpha_{Kg}} - \cancel{c}_g \Gamma_t \tag{15}$$

where A_t^g is a good specific stationary shock, ϕ_g is a fixed cost parameter. Γ_t is a unit root technology level, which grows at rate $\zeta_t = \dfrac{\Gamma_t}{\Gamma_{t-1}}$, and ϕ_g is a fixed cost parameter. Fixed costs grow at the same rate as technology to ensure zero profits in steady-state.

The production function for tourism services is given, in an analogous way, by:

$$X_t^s(f) = A_t^s\left(\Gamma_t l_t^s(f)\right)^{\alpha_{Ls}}\left(K_t^s(f)\right)^{\alpha_{Ks}}\left(E_t^s(f)\right)^{1-\alpha_{Ls}-\alpha_{Ks}} - \phi_s\Gamma_t \tag{16}$$

Factor Demands Each period firm f in sector j solves the cost minimization problem to choose the optimal amount of each input given the respective prices.

$$\min TC_t(f) = W_t l_t^j(f) + Z_t^K K_t^j(f) + P_t^E E_t^j(f) \tag{17}$$

s.t producing given amounts of goods and services using technology (15) for $j = g$, and () for $j = s$.

$$\begin{aligned}\mathcal{L} &= W_t l_t^j(f) + Z_t^K K_t^j(f) + P_t^E E_t^j(f) + \\ &\quad + P_t^j\left[X_t^j(f) - A_t^j\left(\Gamma_t l_t^j(f)\right)^{\alpha_{lj}}\left(K_t^j(f)\right)^{\alpha_{Kj}}\left(E_t^j(f)\right)^{1-\alpha_{lj}-\alpha_{Kj}} + \phi_j\Gamma_t\right]\end{aligned}$$

The FOCs for good j imply that:

$$\begin{aligned}l_t^j(f) &= \frac{\alpha_{lj}}{\alpha_{Kj}}\frac{Z_t^K}{W_t}K_t^j(f) \\ E_t^j(f) &= \frac{1-\alpha_{lj}-\alpha_{Kj}}{\alpha_{Kj}}\frac{Z_t^K}{P_t^E}K_t^j(f)\end{aligned}$$

Given the optimality conditions and the production functions, maginal costs for sector j can be written as:

$$MC_t^j = \frac{\partial TC_t^j(f)}{\partial X_t^j(f)} = \left[\frac{W_t}{\alpha_{lj}\Gamma_t}\right]^{\alpha_{lj}}\left[\frac{Z_t^K}{\alpha_{Kj}}\right]^{\alpha_{Kj}}\left[\frac{P_t^E}{1-\alpha_{lj}-\alpha_{Kj}}\right]^{\left(1-\alpha_{lj}-\alpha_{Kj}\right)}\frac{1}{A_t^j} \tag{18}$$

Price Setting Intermediate goods firms in each sector also have to decide on the profit maximizing prices they will charge for their output. It is assumed that firm f in sector j is able to set new prices with probability $(1-\xi_j)$. The fraction of firms with contracts set τ periods ago is $(1-\xi_j)\xi_j^\tau$. Intermediate goods prices are set considering the total demand for intermediate goods defined in terms of consumption units, regardless of their final use (this simplifies the model considerably). Firms, therefore, set an optimal price in period t that maximizes the present value of all future expected real profits to which this price may apply. The price of intermediate tourism services is set in a similar way, so as to maximize the present value of expected tourism profits.When setting prices, intermediate firms in sector j, choose a price $P_t^j(f)$ which maximize the market value of the firm:

$$MV_t^j(f) = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \lambda_\tau \mathcal{F}_\tau^j(f)$$

where

$$\mathcal{F}_t^j(f) = P_t^j(f) X_t^j(f) - TC_\tau^j(X_\tau^j(f))$$

s.t to the goods demand:

$$X_t^j(f) = \left(\frac{P_t^j(f)}{P_t^j}\right)^{-\frac{1}{1-\theta_{j,t}}} X_t^j$$

Prices that cannot be re-set in period t are indexed by the indexation rate $\Omega_{P,t-t_0}$, where t_0 is the last period when prices could be re-set, hence:

$$P_t^j(f) = \Omega_{P,t-t_0}^j P_{t_0}^j(f)$$

where $\Omega_{P,t-t_0}^j = 1$ fot $t = t_0$, with probability ξ_j. Therefore, with probability $(\xi_j)^{\tau-t}$ the price $\Omega_{P\tau,\tau-t}^j P_t^{j*}(f)$ will be in effect in period τ. Maximizing the value of the firm under this assumption yields an optimal re-setting price $P_t^{j*}(f)$, given by:

$$P_t^{j*} = \frac{\Psi_t^j}{\Phi_t^j}$$

for, $j = g, s$, where

$$\begin{aligned}
\Psi_t^j &= \xi_j \beta E_t \Psi_{t+1}^j \left(1/\Omega_{Pt+1,1}^j\right)^{\frac{1}{1-\theta_j}} + \lambda_t \left(P_t^{j*}(f)\right)^{-\frac{\theta_{j,t}}{1-\theta_{j,t}}} \left(\frac{1}{1-\theta_{j,t}}\right) MC_t^j \left(P_t^j\right)^{\frac{1}{1-\theta_j}} X_t^j \\
\Phi_t^j &= \xi_j \beta E_t \left(1/\Omega_{Pt+1,1}^j\right)^{\frac{1}{1-\theta_j}-1} \Phi_{t+1}^j + \lambda_t \left(P_t^{j*}(f)\right)^{-\frac{\theta_{j,t}}{1-\theta_{j,t}}} \left(\frac{\theta_{j,t}}{1-\theta_{j,t}}\right) \left(P_t^j\right)^{\frac{1}{1-\theta_j}} X_t^j
\end{aligned}$$

Notice that the ggregate price P_t^j can be written as:

$$P_t^j = \left[\left(1-\xi_j\right) P_t^{j*1-\theta_{j,t}} + \xi_j \left(\Omega_{Pt,1}^j P_{t-1}^j\right)^{1-\theta_{j,t}}\right]^{\frac{1}{1-\theta_{j,t}}}$$

2.3 Energy Inputs

Energy input prices (oil and gas) affect Cypriot inflation both directly through its direct impact on the CPI (final goods production), and indirectly via changes in the price of domestic intermediate goods which are a function of the marginal cost (18). It is assumed that an energy importing firm, imports all the quantities of energy inputs (oil and gas) demanded by firms at the international market price (P_t^E), expessed in euros, and sells these quantities to firms at marginal cost (P_t^E), independently of their use.

$$E_t = E_t^C + E_t^G + E_t^I + \int_0^1 E_t^g(f)\mathrm{d}f + \int_0^1 E_t^s(f)\mathrm{d}f$$

2.4 Foreign Demand

Foreign aggregate demand consists of demand for Cypriot goods by the Eurozone (X^{gf}), and of demand for tourism services by both the Eurozone ($X^{s,EZ}$) and the rest-of-the-world ($X^{s,RoW}$). For consistency with the model it is assumed that these foreign demands are exogenously given by:

$$X_t^{gf} = \left(\varpi^{EZ,g}\right)\left(\frac{P_t^g}{P_t^{Y,EZ}}\right)^{-\frac{1}{1-\rho_g^{EZ}}} \frac{N_t^{EZ}}{N_t} Y_t^{EZ}$$

where X_t^{gf} is expressed in per head of Cypriot population. The parameter $\varpi^{EZ,g}$ gives the quasi-share of Cypriot goods in the production of Eurozone final goods; $\frac{1}{1-\rho_g^{EZ}}$ is the elasticity of substitution of Cypriot goods in the Eurozone; $P_t^{Y,EZ}$ is the Eurozone GDP deflator; and Y_t^{EZ} is Eurozone per-capita output (excluding the domestic economy). The definitions are analogous for tourism services:

$$X^{s,EZ} = \left(\varpi^{EZ,s}\right)\left(\frac{P_t^s}{P_t^{Y,EZ}}\right)^{-\frac{1}{1-\rho_s^{EZ}}} \frac{N_t^{EZ}}{N_t} Y_t^{EZ}$$

$$X^{s,RoW} = \left(\varpi^{ROW,s}\right)\left(\frac{P_t^s/NER_t^{€/\text{ROW}}}{P_t^{Y,ROW}}\right)^{-\frac{1}{1-\rho_s^{ROW}}} \frac{N_t^{ROW}}{N_t} Y_t^{ROW}$$

where $NER_t^{€/\text{ROW}}$ is the nominal exchange rate measured as euros per ROW currency and $X^{s,j}$, $j = EZ, ROW$ are expressed in per head of local population, and and Y_t^{ROW} is the rest-of-the-world per-capita output .

2.5 Indexation

It is assumed that economic agents take as an indexation factor the average of last periods gross CPI inflation rate and the economy's steady-state gross CPI inflation rate:

$$\Omega_{Pt,t-t_0}^g = \Omega_{Pt,t-t_0}^s = \Omega_{t,t-t_0} = \left(\prod_{\tau=t_0}^{t-1} \Pi_\tau\right)^\gamma \left(\overline{\Pi}^{t-t_0}\right)^{1-\gamma}$$

Nominal wages are assumed to be indexed also to steady-state labour productivity growth.

$$\Omega_{Wt,t-t_0} = \left[\left(\prod_{\tau=t_0}^{t-1} \Pi_\tau\right)^\gamma \left(\overline{\Pi}^{t-t_0}\right)^{1-\gamma}\right]\left(\prod_{\tau=t_{0+1}}^{t} \zeta_\tau\right)$$

$$\Omega_{Pt,0}^g = \Omega_{Wt,0} = 1$$

This is equivalent to assuming that a fraction g of non-adjusting firms index their prices acording to last period's gross inflation rate, while the other fraction uses the steady-state gross inflation rate (see also Del Negro, 2007).

2.6 Fiscal Authority

The government finances government consumption, debt payments, and net transfers with revenues obtained from taxation and new debt issuance, hence the government budget constraint is given by:

$$P_{G,t}G_t + R_{t-1}\frac{B_{t-1}}{\zeta_t^N} + TR_t = \tau_t^C P_t^C C_t + \tau_t^L W_t L_t + \tau_t^K Z_t^K \frac{K_{t-1}}{\zeta_t^N} + B_t$$

where ζ_t^N is the growth rate of the population, since variables are defined in per-capita terms. Defining current government expenditures and revenues:

$$\begin{aligned} Exp_{G,t} &\equiv P_{G,t}G_t + (R_{t-1} - 1)\frac{B_{t-1}}{\zeta_t^N} + TR_t \\ \operatorname{Re} v_{G,t} &\equiv \tau_t^C P_t^C C_t + \tau_t^L W_t L_t + \tau_t^K Z_t^K \frac{K_{t-1}}{\zeta_t^N} \end{aligned}$$

Defining the government budget deficit BD_t as:

$$BD_t \equiv Exp_{G,t} - \operatorname{Re} v_{G,t} = P_{G,t}G_t + (R_{t-1} - 1)\frac{B_{t-1}}{\zeta_t^N} + TR_t - \tau_t^C P_t^C C_t - \tau_t^L W_t L_t - \tau_t^K Z_t^K \frac{K_{t-1}}{\zeta_t^N}$$

$$B_t = \frac{B_{t-1}}{\zeta_t^N} + BD_t$$

Defining primary expenditures and the primary budget deficit, that is the government expenditures and deficit net of interest payments:

$$\begin{aligned} Exp_{G,t}^{prim} &\equiv P_{G,t}G_t + TR_t \\ BD_t^{prim} &\equiv Exp_{G,t}^{prim} - \operatorname{Re} v_{G,t} = P_{G,t}G_t + TR_t - \tau_t^C P_t^C C_t - \tau_t^L W_t L_t - \tau_t^K Z_t^K \frac{K_{t-1}}{\zeta_t^N} \\ BD_t &= BD_t^{prim} + (R_{t-1} - 1)\frac{B_{t-1}}{\zeta_t^N} \end{aligned}$$

To prevent an explosive debt path a fiscal rule is imposed on the primary deficit, and net transfers adjust automatically to fulfill this rule, defined in terms of the log-linearized variables.

2.7 Monetary Authority

In DSGE models it is typical to assume that the central bank sets the nominal interest rate according to a Taylor type rule. In its simplest form the Taylor rule indicates that interest rates should react to inflation and output gaps, but various generalizations have been proposed in the literature. Two additional elements for instance are often considered (see Orphanides, 2007). The first of this elements is the lagged interest rate, capturing interest rate smoothing, which Woodford (2003) shows to be particularly important in models with strong expectations channels. The other element are deviations of output growth (rather than level) from potential output growth. A Taylor rule model including all four elements (inflation gap, output gap, lagged interest rate, and output growth gaps) has the empirical advantage that it can be shown to nest a variety of monetary policy strategies, including money growth targeting, reformulated in terms of an interest rate instrument (see Orphanides, 2007). This can be particularly useful if there are breaks in monetary policy regimes. For some small open economies an exchange rate objective can also be embedded in the Taylor rule (see, for instance, Adolfson et al., 2007). For countries that belong to a monetary union monetary policy is decided by the central bank of the union. When the union as a whole is modeled alongside the individual country, a Taylor rule for the union is considered. When the country is small and modeled on its own as a small open economy and the country is too small to influence the common central bank's decisions, interest rates may be assumed exogenous (see Almeida, 2009), but in most cases some weight for the country in the common central bank utility function is allowed for and this improves the convergence properties of the mode (see Burriel at al., 2010). In the case of this model we use a simple interest rate rule for the ECB of the form:

$$\frac{R_t^{EZ}}{\overline{R}^{EZ}} = \left[\frac{R_{t-1}^{EZ}}{\overline{R}^{EZ}}\right]^{\rho_R} \left[\left(\frac{\Pi_t^{EZ}}{\overline{\Pi}^{EZ}}\right)^{\psi_\pi} \left(\frac{Y_t^{EZ}}{\overline{Y}^{EZ}}\right)^{\psi_y}\right]^{(1-\rho_R)} \varepsilon_{REZ,t} \tag{19}$$

where barred variables indicate steady-state values. We allow for some weight for the local economy in this monetary policy function. The ECB's monetary policy will also have an impact on the the euro's exchange rate which is relevant for trade with the rest of the world. For determining this effect it will be exogenously assumed that UIP holds between the euro and ROW currencies:

$$\frac{R_t^{EZ}}{R_t^{ROW}} = E_t\left[\frac{NER_{t+1}^{€/\mathrm{ROW}}}{NER_t^{€/\mathrm{ROW}}}\right]$$

2.8 Market Clearing Conditions

In this economy the market clearing conditions for labour capital and energy are given by the following equations:

$$E_t = E_t^C + E_t^G + E_t^I + E_t^g + E_t^s \tag{20}$$

$$E_t^g = \int_0^1 E_t^g(f)df \tag{21}$$

$$E_t^s = \int_0^1 E_t^s(f)df \tag{22}$$

$$K_{t-1} = K_t^g + K_t^s \tag{23}$$

$$K_t^g = \int_0^1 K_t^g(f)df \tag{24}$$

$$K_t^s = \int_0^1 K_t^s(f)df \tag{25}$$

$$l_t = l_t^g + l_t^s \tag{26}$$

$$l_t^g = \int_0^1 l_t^g(f)df \tag{27}$$

$$l_t^s = \int_0^1 l_t^s(f)df \tag{28}$$

In domestic intermediate market the market clearing condition guarantees that the supply of domestic intermediate goods for domestic use must be equal to the total demand for them, from final good producers:

$$X_t^{gd} = X_t^{gd,C} + X_t^{gd,G} + X_t^{gd,I} \tag{29}$$

Equivalently for the supply of imported intermediate goods:

$$X_t^{gm} = X_t^{gm,C} + X_t^{gm,G} + X_t^{gm,I} \tag{30}$$

Considering also exports, the market clearing conditions for total domestic production is given by:

$$X_t^g = X_t^{gd} + X_t^{gf}$$

$$X_t^s = X_t^{s,EZ} + X_t^{s,ROW}$$

Notice that X_t^{gf} and $X_t^{s,EZ}$, and $X_t^{s,ROW}$ are expressed in domestic per capita terms.

2.8.1 GDP and Balance of Payments

Aggregating across households, yields the aggregate resource constraint for the economy:

$$GDP_t \equiv P_t^Y Y_t = P_{C,t}C_t + P_{G,t}G_t + P_{I,t}I_t + B_t^{EZ} - R_{t-1}^{EZ}\Theta\left(\widetilde{b}_{t-1}^{EZ}, \varepsilon_{\Theta,t-1}\right)\frac{1}{\zeta_t^N}B_{t-1}^{EZ}$$

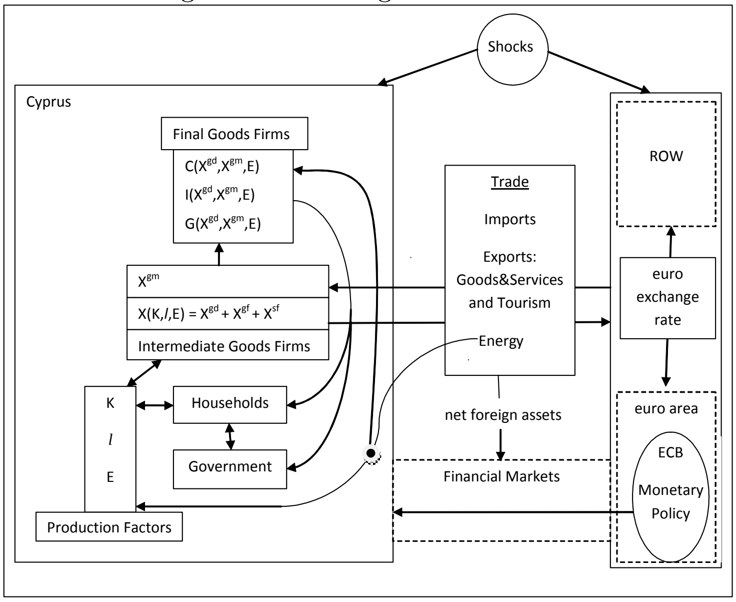
where $\zeta_t^N = \frac{N_t}{N_{t-1}}$ is the gross rate of growth of the population, and:

$$\begin{aligned} Y_t &\equiv X_t^g + X_t^s - E_t^g - E_t^s \\ P_t^Y &= \frac{X_t^g}{Y_t}P_t^g + \frac{X_t^s}{Y_t}P_t^s - \frac{E_t^g + E_t^s}{Y_t}P_t^E \end{aligned}$$

The aggregare resource constraint equation uses the balance of payments equilibrium condition:

$$P_t^g X_t^{gf} + P_t^s X_t^s - P_t^m X_t^{gm} - P_t^E E_t = B_t^{EZ} - R_{t-1}^{EZ}\Theta\left(\widetilde{b}_{t-1}^{EZ}, \varepsilon_{\Theta,t-1}\right)\frac{1}{\zeta_t^N}B_{t-1}^{EZ}$$

Figure 1: Main Agents and Flows



2.9 Shocks

The stochastic behaviour of the model is given by a series of shocks that can be represented as follows:

$$\begin{aligned} \widehat{\varepsilon}_t &= \gamma_\varepsilon \widehat{\varepsilon}_{t-1} + \sigma_\varepsilon \eta_{\varepsilon,t} \\ \eta_{\varepsilon,t} &\sim i.i.d \;\; N(0,1) \end{aligned}$$

where $\varepsilon = \left\{ \varepsilon_C, \varepsilon_l, \varepsilon_I, \varepsilon_{\Theta,t}, \;\mu^g, \mu^s, A^g, \; A^s, p^m, p^E, \; g, y^{ROW}, \pi^{ROW}, R^{ROW}, y^{EZ}, \pi^{EZ}, \varepsilon_{R^{EZ}} \right\}$, and hats represent deviations from steady state. Figure 1 gives a summary of the model relations.

3 Steady-State Calibration

The solution strategy used to find the steady-state of the model follows closely the solution strategy described in Christoffel et al. (2008). The steady-state of the model has been solved and the steady-state parameters have been calculated to match the long-term properties (long-term average shares relative to output) observed in the available data for Cyprus. The steady-state parameters chosen to match the properties of aggregate available data are listed in Table 1.

For some of the parameters, the calibration has followed the literature. The long-run growth rate of the economy and the steady-state inflation rate have been both set at annualized rate of 2%, in line with the euro area potential output growth and with the ECB's target for inflation. The parameter β has been calibrated to yield an annualized long-term nominal interest rate of

Table 1: Calibration of steady-state parameters.

Calibrated steady-state parameters		
Decription	Parameter	Value
utility discount factor	β	0.999
rate of capital depreciation	δ	0.02
share of imports in final consumption basket	$\omega_{M,C}$	0.45
share of imports in final investment basket	$\omega_{M,I}$	0.45
share of imports in final government consumption basket	$\omega_{M,G}$	0.45
share of energy in final baskets	ω_E	0.02
labour share in the domestic goods sector	α_{lg}	0.59
capital share in the domestic goods sector	α_{Kg}	0.38
labour share in the tourism sector	α_{ls}	0.69
capital share in the tourism sector	α_{Ks}	0.28
inverse of the price markup for the goods sector (OECD)	$\overline{\theta}_g$	0.74
steady-state growth rate of productivity	$\overline{\zeta}$	1.005
steady-state population growth rate	$\overline{\zeta}^N$	1.002
steady-state capital tax rate	$\overline{\tau}^K$	0.48
steady-state consumption tax rate	$\overline{\tau}^C$	0.17
steady-state labour tax rate	$\overline{\tau}^l$	0.25

4.5%, in line with that of the euro area (see Christoffel et al., 2008). In line with the literature, we set the capital depreciation rate at 2%, while the tax rate on capital has been calibrated to yield a capital-to-output ratio of about 7.5. The import shares were calibrated so that the imports to GDP ratio can match closely the data, and the shares of energy in both the retail and the intermediate goods sector have been set so that the energy to output ratio is close to it's empirical counterpart of 5%. The labour and capital shares across sectors have calibrated to approximate the labour ratios that could be observed in the data. The consumption and labour tax rates were calibrated so that the government revenue to GDP ratios approximate the ratios observed in the data. The inverse of the steady-state price markup in the goods and other services sector has been calibrated yield a price markup of about 1.35, in line with OECD estimates (see Martins et al., 1996). The inverse of the steady-state price markup in the tourism sector and the steady-state TFP in the tourism sector are jointly calibrate so that the steady-state ratio of tourism to consumer prices is one (this calibration considerably simplifies the solution). In Table 2 we show the steady-state solution that these parameters generate and compare them with the available aggregate data.

Table 2: Steady-State Output Shares – Model and Data.

Steady-state output shares			
Variable description	Name	Model	Data
capital-output ratio	K/Y	7.578	-
investment-output ratio	I/Y	0.188	0.19
home demand for domestic goods	X^{gd}/Y	0.539	-
foreign demand for domestic goods	X^{gf}/Y	0.344	0.33
total demand domestic goods	X^{g}/Y	0.883	-
home demand domestic goods, consumption	$X^{gd,C}/Y$	0.340	-
home demand domestic goods, investment	$X^{gd,I}/Y$	0.102	-
home demand domestic goods, government	$X^{gd,G}/Y$	0.097	-
demand for goods and services imports, consumption	$X^{gm,C}/Y$	0.278	-
demand for goods and services imports, investment	$X^{gm,I}/Y$	0.083	-
demand for goods and services imports, government	$X^{gm,G}/Y$	0.079	-
euro-area demand for domestic tourism services	$X^{s,EZ}/Y$	0.074	0.07
rest-of-the world demand for domestic tourism services	$X^{s,ROW}/Y$	0.074	0.07
total demand for domestic tourism services	X^{s}/Y	0.148	0.14
energy use, final consumption good	E^{C}/Y	0.013	-
energy use, final investment good	E^{I}/Y	0.004	-
energy use, final government consumption good	E^{G}/Y	0.004	-
energy use, goods and other services sector	E^{g}/Y	0.004	-
energy use, tourism sector	E^{s}/Y	0.031	-
energy use, total	E/Y	0.051	0.05
capital-output ratio, goods and other services sector	K_g/Y	6.713	-
capital-output ratio, tourism sector	K_s/Y	0.826	-
labour-output ratio, goods and other services sector	l_g/Y	0.476	-
labour-output ratio, tourism sector	l_s/Y	0.093	-
labour-output ratio	l/Y	0.569	-
government debt	B/Y	0.600	-
government consumption	G/Y	0.180	-
government transfers	TR/Y	0.264	-
government expenditures	Exp/Y	0.451	0.47
government primary expenditures	Exp^{prim}/Y	0.444	-
consumption taxes	Tax^{C}/Y	0.107	-
labour taxes	Tax^{l}/Y	0.156	-
capital taxes	Tax^{K}/Y	0.182	-
government revenue	Rev/Y	0.445	0.44
government deficit	BD/Y	0.006	-
government primary deficit	BD^{prim}/Y	-0.001	-
private consumption	C/Y	0.632	0.64
imports of goods and services	X^{gm}/Y	0.492	0.51
total exports of goods and services	$(X^{gf}+X^{s})/Y$	0.492	0.48

Table 3 provides additional information on labour ratios, by comparing the sectoral labour shares generated by the model with those available in the data. In the model the labour share of the tourism sector appears slightly overstated.

4 Bayesian Estimation

Using the steady state calibration described earlier, we used the log-linearized model equations to estimate the dynamics of the model to match a sub-set of macroeconomic series.[6] The variables were selected based on data quality and convergence of the optimization algorithm. In the final specification we have retained seven variables: output (y); consumption (c); government consumption as a share of GDP (gy); investment (inv); consumer price inflation Pi; hours

[6] The estimation and analysis of the model uses Dynare (see Adjemian et al., 2011).

Table 3: Sectoral Labour Shares

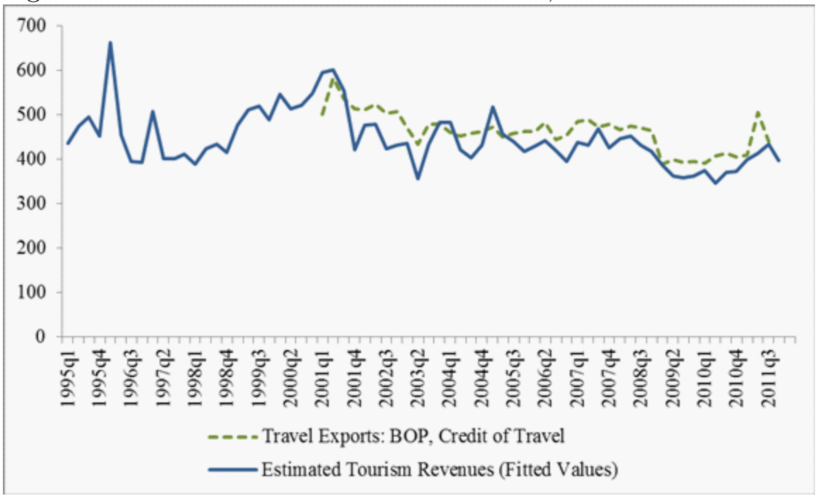
Labour Supply:		Share of total	
Description	Variable	model	data
labour-output ratio, goods and other services sector	l_g/Y	0.84	0.86
labour-output ratio, tourism sector	l_s/Y	0.16	0.14
labour-output ratio	l/Y	1	1

worked (l); the euro area interest rate (REZ) and tourism output proxied by estimated tourism revenues (xs).

The data is quarterly and covers the period 1995Q1 to 2012Q2. The series were collected from several sources, including Eurostat, the Statistical Service of Cyprus, the Central Bank of Cyprus and the Euro Area Wide Model Database (for euro area variables). All the series are adjusted for seasonality. Data on tourism revenues is limited, and in this case regression analysis was used to obtain a longer time series. Series on tourism revenues for Cyprus are available from the Statistical Service of Cyprus (CyStat); however the data starts from 2001. To estimate our series we made use of three monthly series, namely the tourism arrivals, tourism revenues and the real effective exchange rate for Cyprus. The exchange rate series were taken from Eurostat while the rest were taken from CyStat. The tourism arrivals and the real exchange rate series both start in 1995M1, but the tourism revenues were available only since 2001M1. To estimate the tourism revenues for the period 1995M1 to 2000M12, we regressed the available real tourism revenues (deflated using the CPI deflator), on tourism arrivals and the real effective exchange rate of Cyprus, all in logarithms. The Adjusted-R2 turned out to be 0.99 (or 0.67 when we include a constant in the model). All the time series were seasonally adjusted. The sample of the regression spanned the period from 2001M1 to 2011M12. Given the availability of tourism arrivals and the real exchange rate, we were then able to compute the fitted values of tourism revenues for the whole period including the missing period, i.e. 1995M1 to 2000M12. Since the regression was estimated in logs, we took the exponential of the fitted values as an estimate of real tourism revenues for Cyprus. Finally, the estimated monthly tourism revenues were converted into quarterly. The resulted estimated quarterly series for tourism revenues can be seen in Figure 2. For comparison reasons, in the graph below we also have included the travel credit series from the balance of payments, representing the exported travel products of Cyprus. This series can be found in the Central Bank of Cyprus database and like the rest related series, it is also short in terms of period covered, starting from 2001Q1.

Using these variables we were able to estimate the parameters determining the exogenous shocks hitting the Cypriot economy as well as the parameters determining habit formation (h), wage rigidity (ξ_W), price rigidity (ξ_g and ξ_s), and indexation (γ). Coefficients which were not estimated have been calibrated from the literature. Table 4 shows reports the calibration choices for non-estimated parameters that affect only the dynamics of the model (are not used to define the steady-state of the model). In this version of the model the share of rule-of-thumb consumers has been set to zero, since the performance of the model was worse for positive shares. The risk parameter is a parameter that is typically difficult to identify and hence it is typically

Figure 2: Tourism Revenues in Real Terms, Data and Estimates



calibrated in the literature. Our calibration follows (Christoffel et al., 2008) and the parameter is set at 0.01 so that the evolution of the current account has a relatively small impact on the risk premium in the short-run, while the net foreign asset position is stabilized at zero over a reasonable period of time. Another parameter that is difficult to identify according to the literature is the inverse of the Frisch elasticity of labour supply. This has been set equal to 2 in line with available estimates reported in the literature. Elasticities of substitution have also been calibrated in this study. The elasticity of substitution between labour varieties has been fixed so as to yield a wage markup of markup of 1.3, which is consistent with OECD estimates (see Jean and Nicoletti, 2002). The parameters determining the elasticities of substitution between imports and domestic goods and services and between goods and services and energy were taken from the calibrations of Cuche-Curtis et al. (2009) for Switzerland. The elasticities of substitutions for exports were calibrated in line with that for imports. Finally, we also chose to calibrate policy parameters. Monetary policy parameters were taken from Adolfson et al (2007), while the fiscal rule parameters calibration follows Gali at al. (2007), and ensures that government debt converges close to the long-term target within simulation periods.

For the parameter estimation we had to use priors which we initially obtained from previous literature (Christoffel et al., 2008) but subsequently adjusted to improve the estimation results. The retained priors are summarized in Tables 5 to 7, along with the posterior estimates. The posterior distributions reported in the table are based on a Markov chain with 150,000 draws from which 75% have been discarded, and 5 parallel chains.[7] The parameter estimates obtained are broadly consistent with the literature. For instance, wages are found to be stickier than prices, a result which is commonly found in the literature. The relatively high stickiness of wages is a fairly intuitive result for Cyprus where wage negotiations remain highly centralized.

[7] According to Griffoli (2011) this improves the computation of between group variance of the parameter means, one of the key criteria to evaluate the e ciency of the Metropolis-Hastings to evaluate the posterior distribution.

Table 4: Calibration of Remaining Parameter Values.

Calibrated Dynamic Parameters		
Description	Parameter	Value
Risk premium sensitivity to CA position	ω_{Θ}	0.01
Elasticity of substitution varieties of labour	ϕ_l	4.35
Parameter determining the elasticity of substitution between imports and domestic goods.	ρ_M	0.01
Parameter determining the elasticity of substitution between energy and intermediate goods	ρ_E	-10.0
Parameter determining the Eurozone elasticity of substitution for domestic goods	$\rho_{g,EZ}$	0.01
Parameter determining the Eurozone elasticity of substitution for tourism services	$\rho_{s,EZ}$	0.01
Parameter determining the Rest-of-the-world elasticity of substitution for tourism services	$\rho_{s,ROW}$	0.01
Inverse of the Frisch elasticity of labour supply	ν	2.00
Eurozone Taylor Rule interest rate smoothing parameter	ρ_R	0.88
Eurozone Taylor Rule inflation gap weighting parameter	ψ_{Π}	2.50
Eurozone Taylor Rule output gap weighting parameter	ψ_{Ψ}	0.15
Fiscal rule parameter - debt	χ_b	0.20
Fiscal rule parameter - deficit	χ_d	0.10
Investment adjutsment costs parameter	γ_{Inv}	5.00

Additionally, the persistence of investment-specific shocks is estimated to be relatively low, while the standard deviation of investment-specific shocks is estimated to be relatively large as would be expected from investment data. Also consistent with the literature is the fact that the persistence of tax rate shocks is estimated to be higher than the persistence of government spending shocks. Plots of the data used in estimation, together with plots of prior and posterior distribution and smoothed innovations are reported in the Appendix. The estimated innovations appear stationary but may exhibit some autocorrelation in a few cases which could be resolved with the inclusion of more autoregressive terms in the shock equations, at the cost of an increase in the number of parameters.

Table 5: Prior and Posterior Distributions of Estimated Parameters.

Parameter	Prior			Posterior			
	Shape	Mean	St. Dev.	Mode	Mean	5%	95%
Habits							
h	beta	0.70	0.20	0.7167	0.7551	0.6660	0.8469
Wage and Price Setting							
ξ_w	beta	0.70	0.10	0.7411	0.7034	0.5866	0.8227
ξ_g	beta	0.70	0.10	0.5874	0.5682	0.3987	0.7383
ξ_s	beta	0.70	0.10	0.6098	0.5647	0.3817	0.7453
γ	beta	0.70	0.10	0.4286	0.4441	0.2749	0.6152

5 Diagnosis

Using both the calibrations and the estimated parameters, we analyze the impulse responses of the model to a range of shocks to evaluate the properties of the model. The simulation horizon corresponds to 20 quarters. Figure 4 (displayed at the end) shows impulse-response functions to a set of selected structural shocks: (i) a consumption preference shock; (ii) an investment specific shock; (iii) a transitory technology shock in the goods and other services sector; (iv) a transitory technology shock in the tourism sector; (v) a euro area inflation shock; and (vi) a rest-of-the-world output shock. All impulse responses are reported as percentage deviations from the non-stochastic steady state, except for the impulse responses of the inflation and

Table 6: Prior and Posterior Distributions of Estimated Parameters - Autoregressive parameters for Shocks.

Parameter	Prior			Posterior			
	Shape	Mean	St. Dev.	Mode	Mean	5%	95%
Autoregressive parameters - shock persistence							
γ_{ζ}	beta	0.70	0.10	0.5048	0.4951	0.3413	0.6469
γ_{C}	beta	0.60	0.10	0.5591	0.5003	0.3021	0.6893
γ_{I}	beta	0.60	0.10	0.6090	0.5992	0.4400	0.7591
γ_{Inv}	beta	0.20	0.10	0.0644	0.0972	0.0169	0.1726
γ_{G}	beta	0.50	0.10	0.3988	0.4031	0.2803	0.5273
γ_{Θ}	beta	0.80	0.10	0.7287	0.7058	0.5686	0.8418
$\gamma_{\mu g}$	beta	0.20	0.10	0.0625	0.0937	0.0144	0.1720
$\gamma_{\mu s}$	beta	0.50	0.10	0.4889	0.4821	0.3243	0.6420
γ_{pm}	beta	0.70	0.10	0.6072	0.6018	0.4438	0.7635
γ_{pE}	beta	0.70	0.10	0.7215	0.7026	0.5463	0.8653
γ_{pyEZ}	beta	0.50	0.10	0.6645	0.6507	0.5029	0.7969
γ_{pyROW}	beta	0.50	0.10	0.7206	0.6824	0.5132	0.8507
γ_{RROW}	beta	0.70	0.10	0.6703	0.6671	0.5244	0.8262
γ_{yEZ}	beta	0.50	0.10	0.4887	0.4915	0.3362	0.6449
γ_{yROW}	beta	0.50	0.10	0.4981	0.4903	0.3309	0.6593
$\gamma_{\tau C}$	beta	0.70	0.10	0.7202	0.7013	0.5461	0.8650
$\gamma_{\tau l}$	beta	0.70	0.10	0.7221	0.7011	0.5399	0.8683
$\gamma_{\tau K}$	beta	0.70	0.10	0.7212	0.6982	0.5473	0.8629
$\gamma_{\Pi EZ}$	beta	0.50	0.10	0.4562	0.4647	0.3062	0.6149
$\gamma_{\Pi ROW}$	beta	0.50	0.10	0.5021	0.5066	0.3511	0.6675
γ_{Ag}	beta	0.70	0.10	0.7131	0.6984	0.5680	0.8294
γ_{As}	beta	0.70	0.10	0.7345	0.7121	0.5642	0.8637
γ_{REZ}	beta	0.70	0.10	0.4088	0.4159	0.2936	0.5370

interest rates which are reported as percentage-point deviations.

A consumption preference shock increases consumption. The highest impact of the shock is felt with a delay due to the consumption habits inbuilt in the model. Investment falls and only starts to recover after 5 quarters. Goods and services production and GDP increase together with the increase in consumption demand, and so does import demand. Wages and employment increase together with inflation. Higher imports deteriorate the current account and put upward pressure on interest rates. Pressure on marginal costs induces a contraction of the tourism sector.

An investment shock increases investment on impact and lowers consumption temporarily. Output increases to face the higher investment demand. There is a short-lived fall in tourism output as resources are diverted to the goods and services sector, but in the long-run the sector benefits from lower marginal costs. As production progressively shifts towards capital, employment falls after the first quarter and so does wage inflation. This shock puts also downward pressure on inflation.

A transitory technology shock in the goods and other services sector triggers a decline in real marginal cost. This decline in marginal cost causes prices to fall, as the prices of intermediate goods are set as a markup on marginal cost. With domestic demand adjusting only sluggishly to the shift in supply, both employment and wages go down. The supply shock also causes a temporary increase in investment. In the tourism sector the real depreciation of the domestic currency leads to expenditure switching away from foreign towards domestic goods, thereby boosting exports in the long-run although there is a short-term diversion of resources away from the tourism sector.

The transmission of a transitory productivity shock in the tourism sector is similar to that

Table 7: Prior and Posterior Distributions of Estimated Parameters - Standard Deviations of Shocks.

Parameter	Prior			Posterior			
	Shape	Mean	St. Dev.	Mode	Mean	5%	95%
Standard deviations of shocks							
σ_{ζ}	inv.gamma	0.05	inf	0.0100	0.0105	0.0078	0.0130
σ_{C}	inv.gamma	0.05	inf	0.0222	0.0447	0.0109	0.0867
σ_{l}	inv.gamma	0.05	inf	0.0230	0.0454	0.0116	0.0884
σ_{Inv}	inv.gamma	0.05	inf	0.1826	0.1742	0.1349	0.2191
σ_{G}	inv.gamma	0.05	inf	0.0261	0.0267	0.0229	0.0304
σ_{Θ}	inv.gamma	0.05	inf	0.0288	0.0318	0.0149	0.0479
$\sigma_{\mu g}$	inv.gamma	0.05	inf	0.0244	0.0260	0.0165	0.0350
$\sigma_{\mu s}$	inv.gamma	0.05	inf	0.0219	0.0380	0.0113	0.0683
σ_{pm}	inv.gamma	0.05	inf	0.0130	0.0136	0.0104	0.0167
σ_{pE}	inv.gamma	0.05	inf	0.0226	0.0356	0.0119	0.0595
σ_{pyEZ}	inv.gamma	0.05	inf	0.0188	0.0206	0.0125	0.0286
σ_{pyROW}	inv.gamma	0.05	inf	0.0231	0.0673	0.0118	0.1578
σ_{RROW}	inv.gamma	0.05	inf	0.0693	0.0482	0.0147	0.0815
σ_{yEZ}	inv.gamma	0.05	inf	0.0256	0.0249	0.0156	0.0338
σ_{yROW}	inv.gamma	0.05	inf	0.0234	0.0592	0.0111	0.1361
$\sigma_{\tau C}$	inv.gamma	0.05	inf	0.0229	0.0412	0.0123	0.0793
$\sigma_{\tau l}$	inv.gamma	0.05	inf	0.0230	0.0397	0.0127	0.0707
$\sigma_{\tau K}$	inv.gamma	0.05	inf	0.0230	0.0360	0.0124	0.0623
$\sigma_{\Pi EZ}$	inv.gamma	0.05	inf	0.0146	0.0161	0.0110	0.0211
$\sigma_{\Pi ROW}$	inv.gamma	0.05	inf	0.0234	0.0609	0.0116	0.1254
σ_{Ag}	inv.gamma	0.05	inf	0.0097	0.0099	0.0080	0.0117
σ_{As}	inv.gamma	0.05	inf	0.0210	0.0250	0.0132	0.0366
σ_{REZ}	inv.gamma	0.05	inf	0.0063	0.0066	0.0059	0.0073

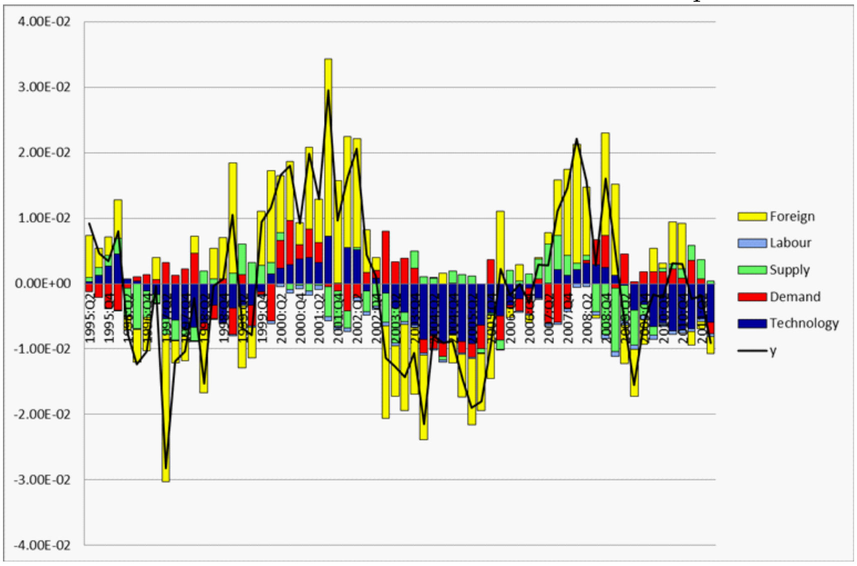
of a shock to the goods and other services sector. Since this sector is more labour intensive, the decline in employment and the increase in investment are less pronounced. Improvement in the country's current account position leads to a reduction of interest rate risk premium and a small reduction of the domestic interest rate.

An euro area inflation shock prompts the European central bank to increase euro area interest rates. Domestic demand is negatively affected with investment falling relatively more that consumption. The increase in euro area interest rates prompts a nominal appreciation of the euro which translates into a real appreciation for Cyprus, given also the expected inflation. This real appreciation has a significant negative impact on the tourism sector, and output is this sector is falls relatively more than in the remaining sectors. Following the fall in demand, firms reduce their demand for labour and employment falls along with nominal wages.

An output shock in the rest-of-the -world increases demand for tourism services significant, and has also a positive effect on employment and output. The effect on the goods and other services sector, as well as the effect on comsumption and investment is positive but more difficult to quantify.There is a positive but small effect on inflation, and a real appreciation, consistent with the revenue inflow from an increase in tourism receipts.

In the DSGE-CY model the contribution of the various shocks to the fluctuation of endogenous variables can be analyzed through variance-decompositions. Table 8 shows the variance decompositions of selected variable to shocks. To facilitate the analysis the shocks have been grouped into technology shocks (productivity and investment shocks); demand shocks (consumption preference, consumption tax rate, and government consumption shocks); supply shocks (price markup and capital tax rate shocks); labour market shocks (labour preference and labour tax rate shocks); foreign shocks (foreign output, foreign inflation, risk premium,

Figure 3: Sources of Fluctuations in GDP - Historical Decompositions of Shocks



and foreign interest rates shocks). The results show that foreign shocks explain the largest percentage of Cyprus macroeconomic fluctuations.

Table 8: Variance decompositions, in percent.

Variables	Shocks					
	Technology	Demand	Supply	Labour	Foreign	Total
Output	0.6	2.3	2.3	0.0	94.8	100
Consumption	0.9	13.8	1.3	0.0	83.9	100
inv	37.3	0.1	1.8	0.0	60.8	100
xg	1.0	4.7	0.8	0.0	93.6	100
xs	0.5	0.0	7.8	0.0	91.7	100
l	14.0	0.1	47.5	0.1	38.3	100

The relative weight of foreign shocks in the model can also be observed with the historical decomposition of observed variables used in the estimation into the contributions of its structural shocks (see Figure 3). Here we have focused on the decompositions of GDP cycles (the decomposition of consumption and investment in shown in the Appendix). Shocks have been once more grouped into the five categories mentioned above. As it can be observed, foreign shocks tend to drag GDP in most of the cycles. Domestic demand shocks have some weight in explaining fluctuations in consumption, but are less significant for determining GDP cycles, where technology shocks have more weight (technology shocks appear to have had a significant weight in the 2004 downturn). It is important to notice that the 2010-2011 downturn cannot be fully captured within the model as this would require extending the model with a banking sector and credit supply shocks, but the dominance of negative technology shocks in this period (which include investment specific shocks) is consistent with the negative shock to investment felt during this period.

6 Conclusions and Further Research

In this study, a New-Keynesian DSGE model for a small open economy integrated in a monetary union has been developed and estimated for the Cypriot economy using a Bayesian approach. In addition, the study has also provided a survey of the literature associated with DSGE models, and a description of a set of small open economy models recently produced by other studies.

This is the first effort to build a DSGE model for Cyprus which can be used for policy analysis. The modeling strategy is ambitious in the sense that it deviates from the literature by incorporating two external blocks instead of one (the euro area and the rest of the world), and because it considers two intermediate sectors. A subset of model parameters has been estimated to allow the model to better match the moments observed in macroeconomic data for Cyprus, while the remaining sub-set of parameters was calibrated with values obtained from the literature.

We have presented the estimation results obtained by employing Bayesian methods. The obtained estimates for the parameters of interest are generally in line with the DSGE literature. Among them, some are particularly noteworthy. Wages stickiness is found to be higher than price stickiness, a result commonly found in the literature. The relatively high stickiness of wages is a fairly intuitive result for Cyprus where wage negotiations remain highly centralized. In addition, wages and prices exhibit a considerable degree of indexation to past inflation, a result that is in line with the formal link of wages to inflation still in place. Also, the persistence of investment-specific shocks is estimated to be relatively low, while the standard deviation of investment-specific shocks is estimated to be relatively large as would be expected from investment data. Equally consistent with the literature is the fact that the persistence of tax rate shocks is estimated to be higher than the persistence of government spending shocks.

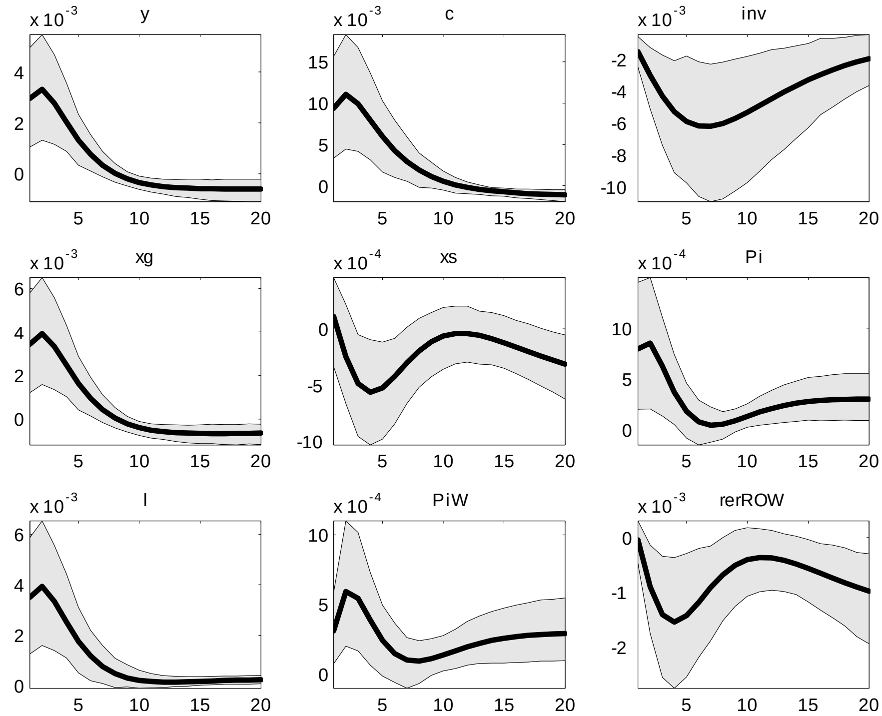
We have further examined the empirical properties of the model by studying its impulse-response functions and variance decompositions. Overall, the results indicate that the estimated DSGE-CY has economically plausible properties, especially with regard to the propagation of key economic shocks.

Some problems were however encountered, which should be mentioned. In particular, the treatment of the data was a complex task, and we opted for the use of hp-filtered data, which is recognized to be subject to a number of caveats. Also, some identification problems may exist, as this is a common problem in the estimation of medium-large scale DSGE models. Although the data was informative in the majority of the cases, in some cases the prior and posterior distributions overlap, and some estimates seem to be significantly influenced by the chosen priors, an influence that ideally should have been minimal. It also appears that some of the estimated innovations may exhibit autocorrelation. In addition, this version of the model does not incorporate many of the adjustment costs, typically found in the literature, needed to produce smoother and well-shaped impulse responses. This simplification compensates the more structural complexity of the model, limiting the number of parameters, and therefore increasing the probability of convergence of the optimization algorithms.

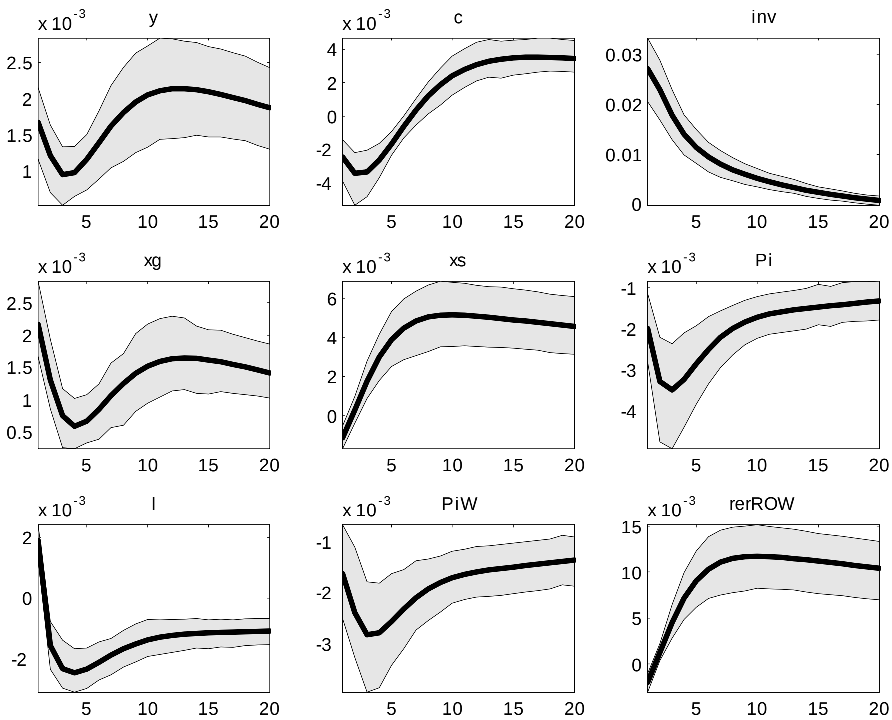
The existence of these caveats indicates that this work can be improved in some dimensions. The estimated version of the DSGE-CY can be subject to further refinements in the light of the practical experience gained with this exercise. As mentioned the model contains a number of simplifying assumptions which can be relaxed. For instance, the number of autocorrelation terms in some of the shock equations could be increased to deal with autocorrelation. In addition, some of the building blocks of the model can be modeled in further detail, like energy markets. The interactions among foreign variables can also be improved with the use of VARs (e.g. in the current version import prices are unrelated to energy prices). The fiscal and foreign variables of the model can also be modeled outside the model, following Adolfson et al. (2007). This strategy would allow for a more realistic treatment of these variables and a considerably reduction of the "estimation burden" currently imposed.

Finally, a better description of the 2010-2011 downturn which is still unfolding in Cyprus as a consequence of the Greek debt crisis would require extending the model with a banking sector, and exercise which we leave to further research.

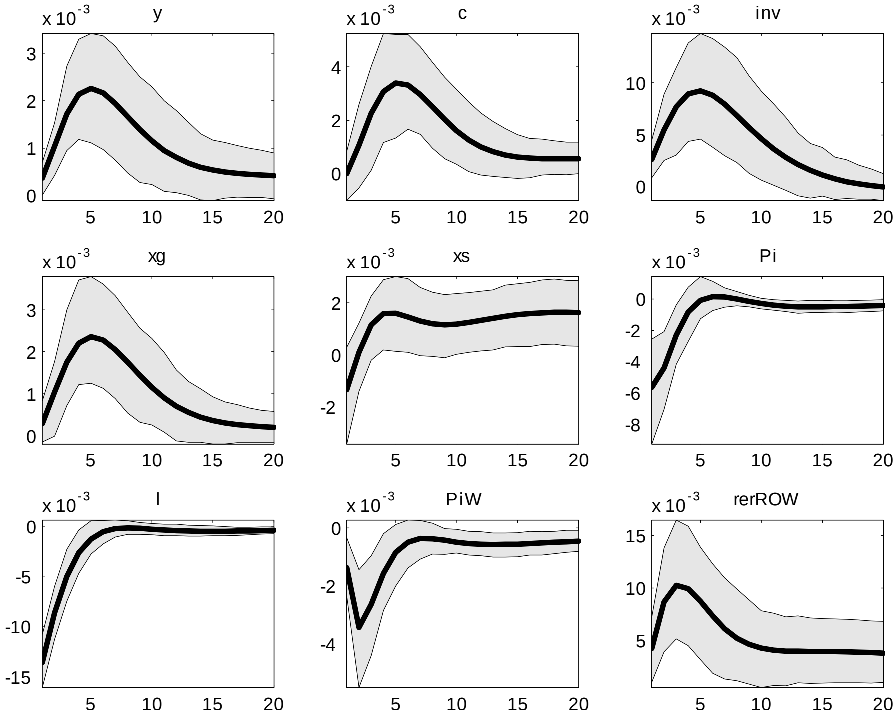
Figure 4: Impulse Responses



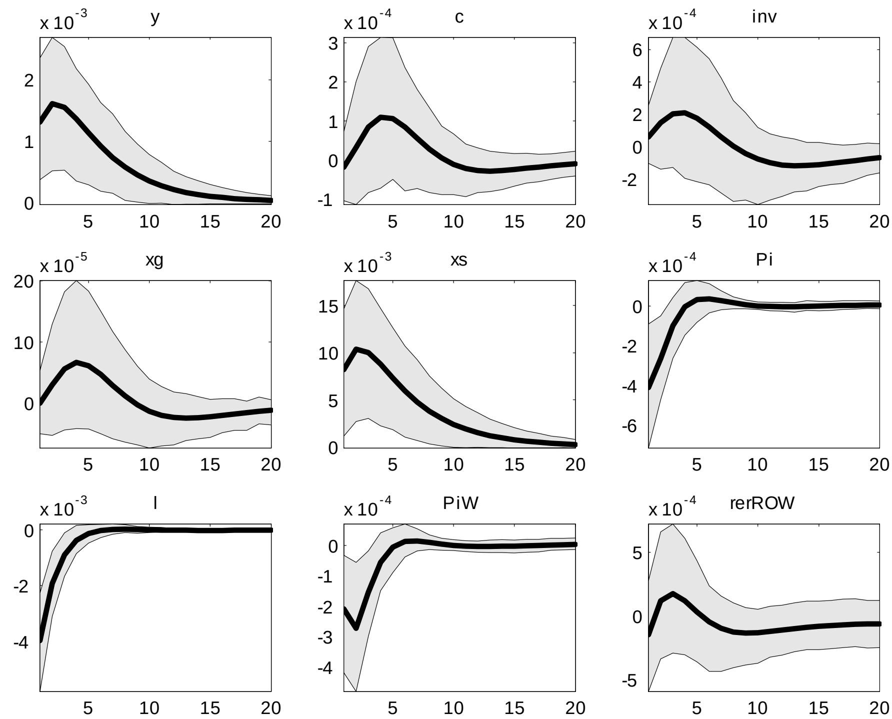
IRFs to a consumption preference shock



IRFs to an investment specific shock



IRFs to a transitory productivity shock - goods and services sector



IRFs to a transitory technology shock - tourism sector

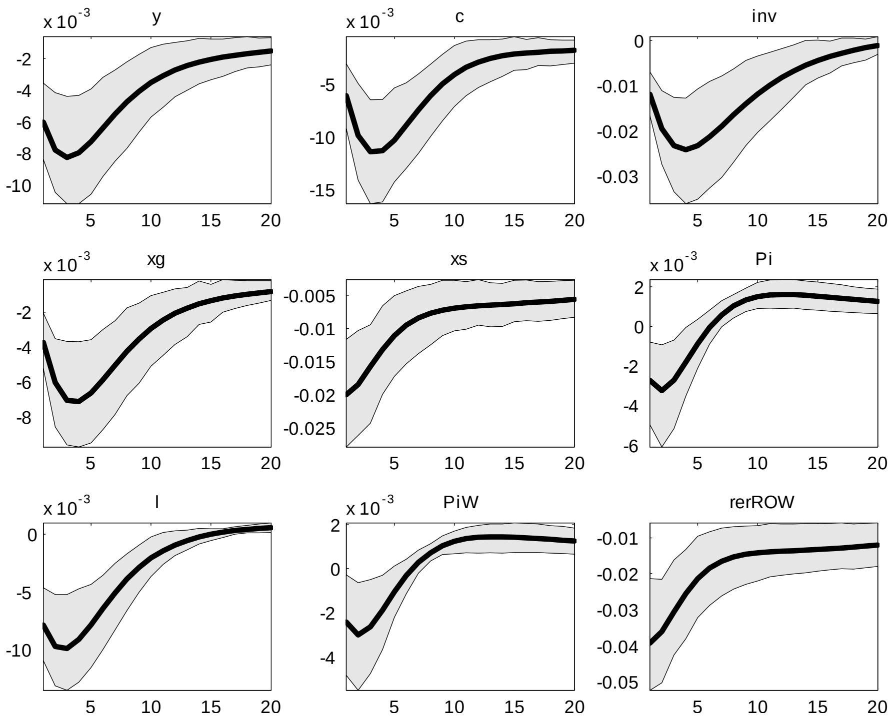


Figure 4: IRFs to an euro area inflation shock

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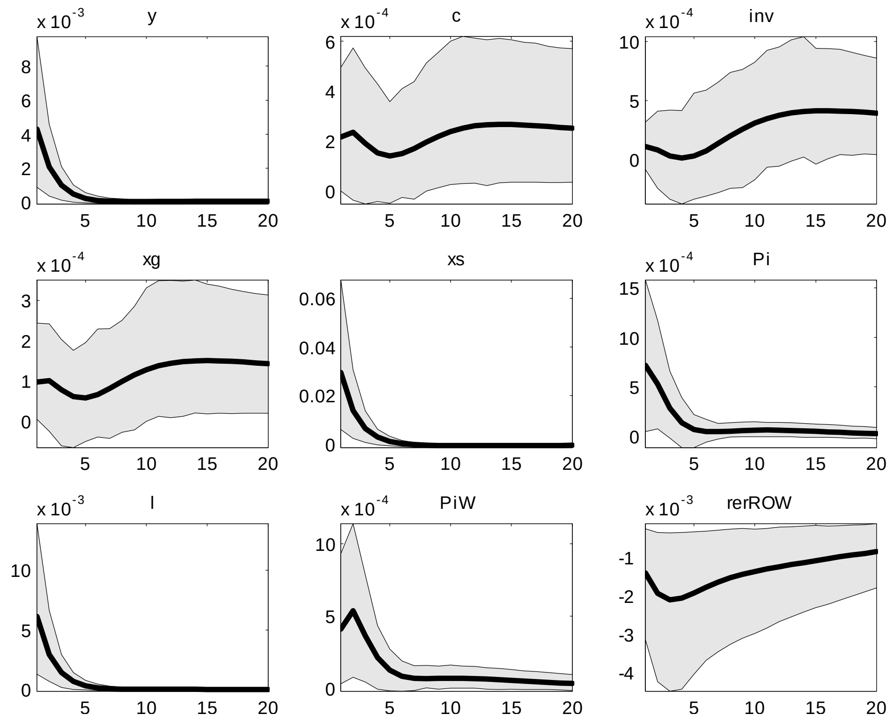

Figure 5: IRFs to a ROW output shock

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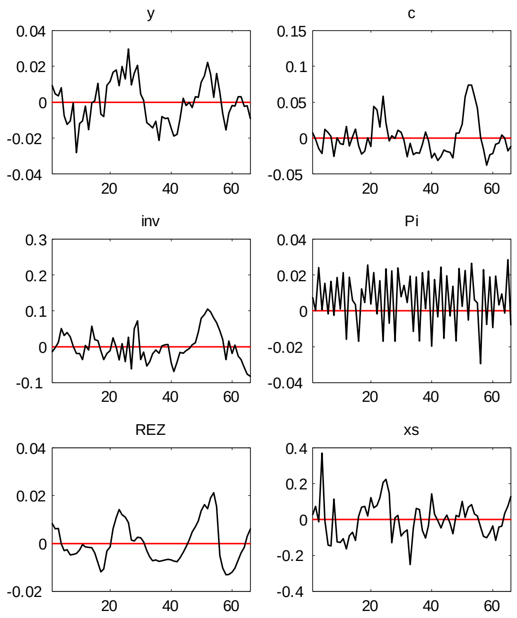
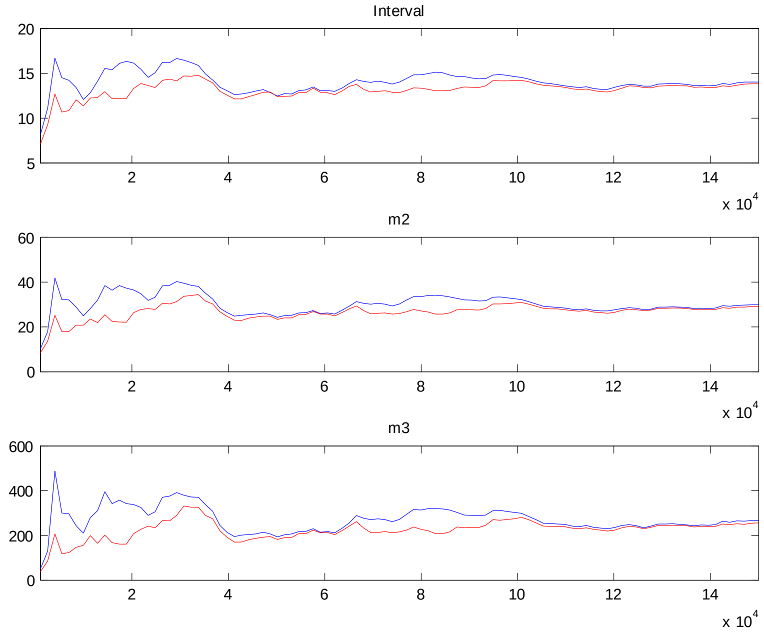
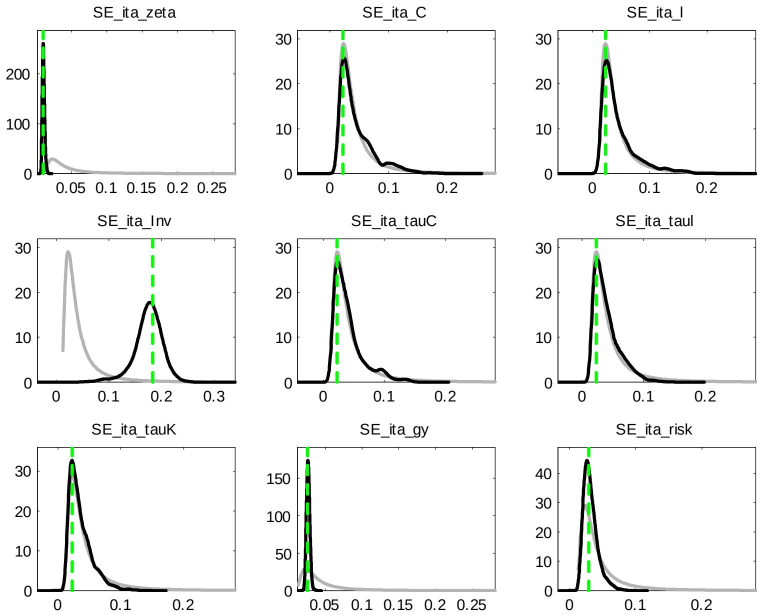
Appendix: Data and Estimation Results



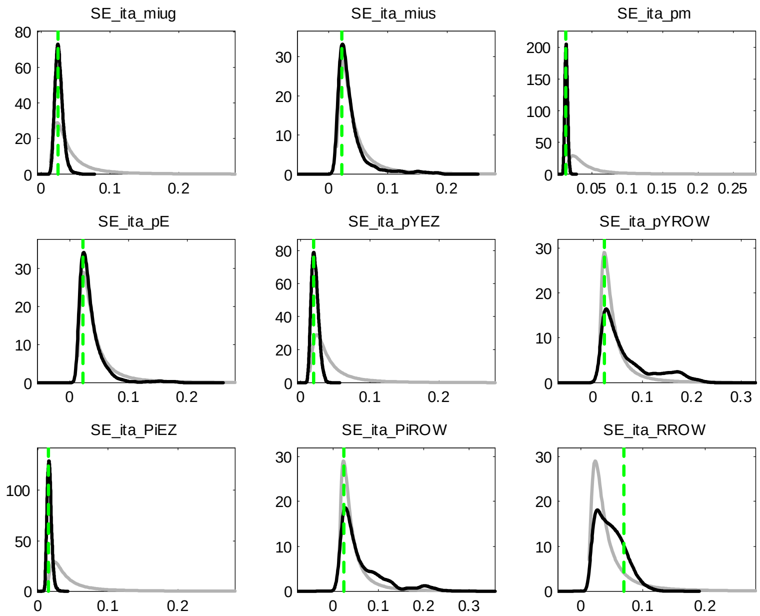
Observed Variables



Multivariate MH Convergence Diagnosis



Prior and Posterior Distributions



Prior and Posterior Distributions (cont.)

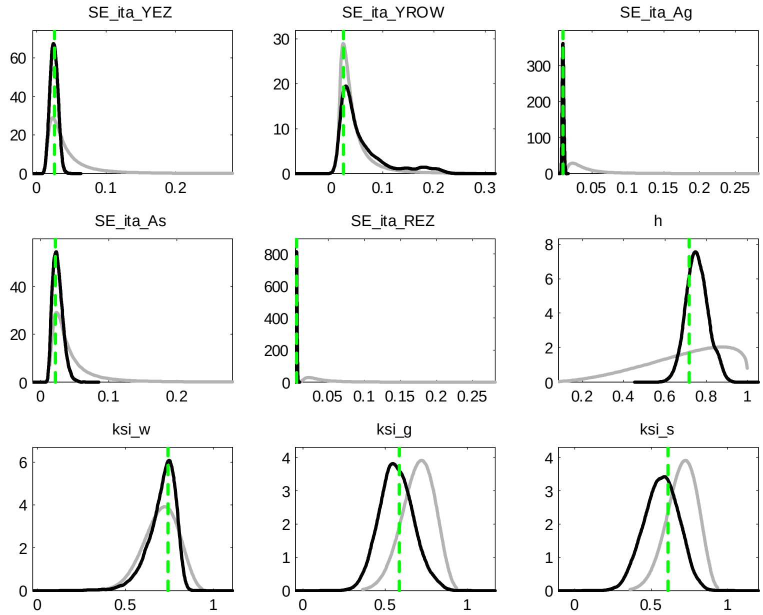
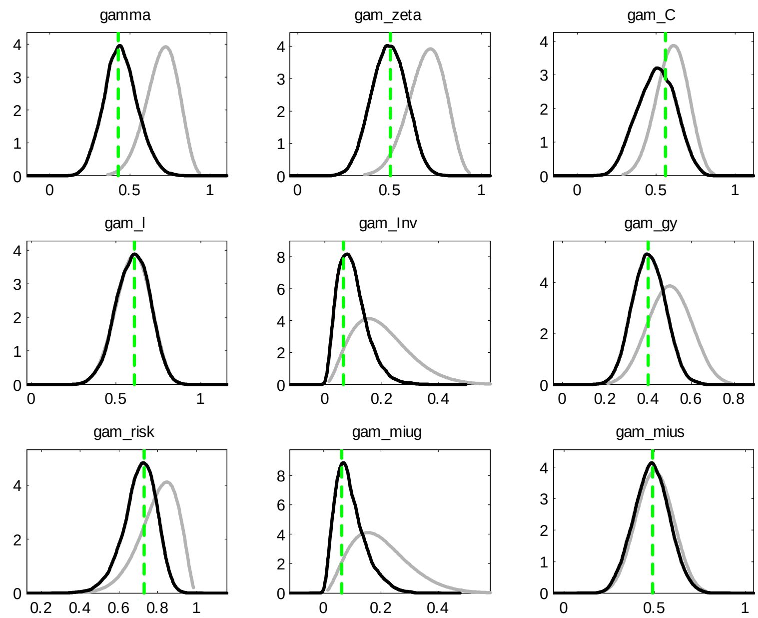
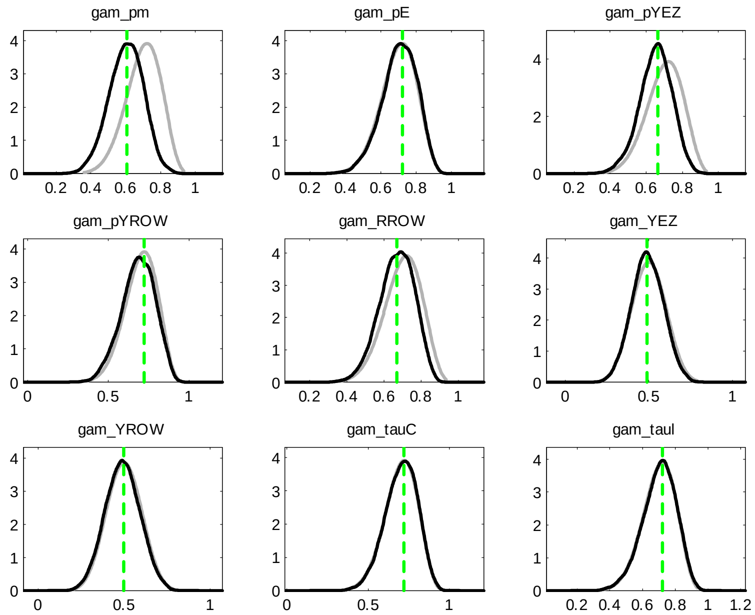


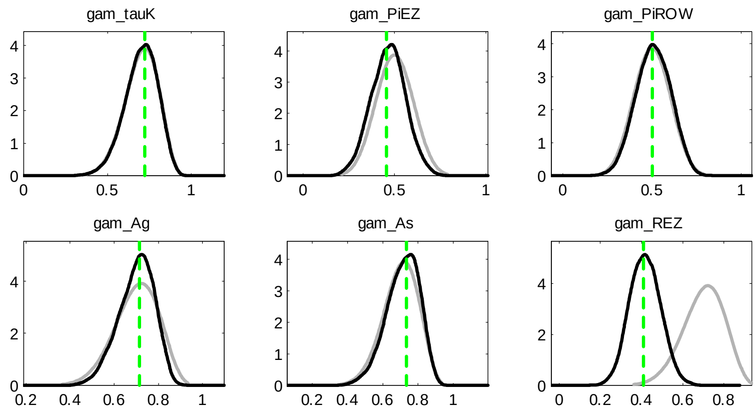
Figure 6: Prior and Posterior Distributions (cont.)



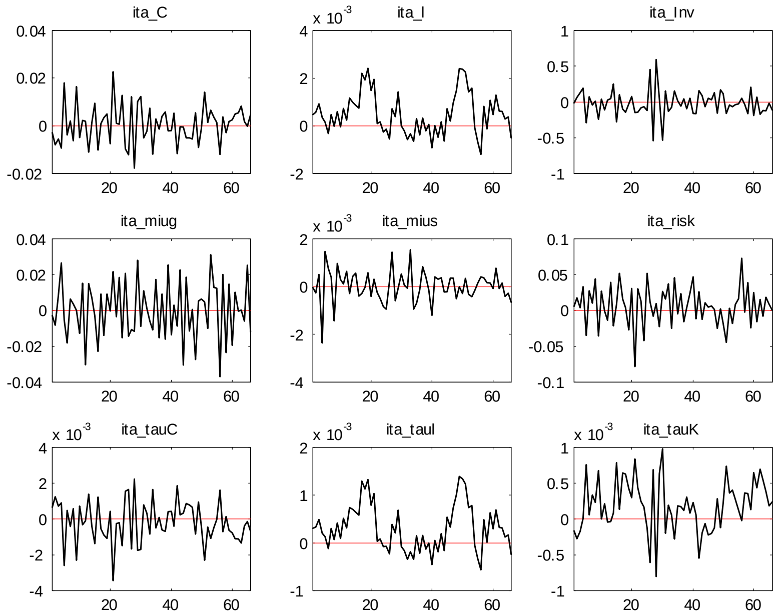
Prior and Posterior Distributions (cont.)



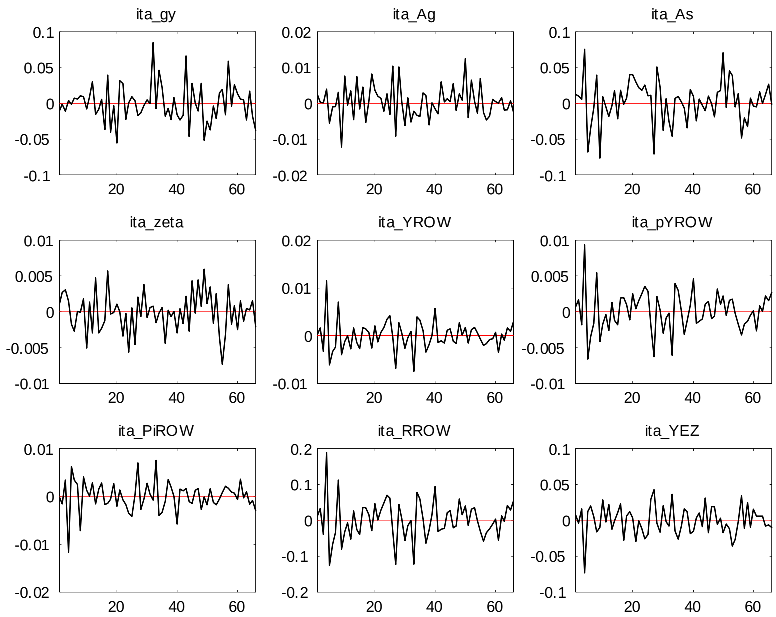
Prior and Posterior Distributions (cont.)



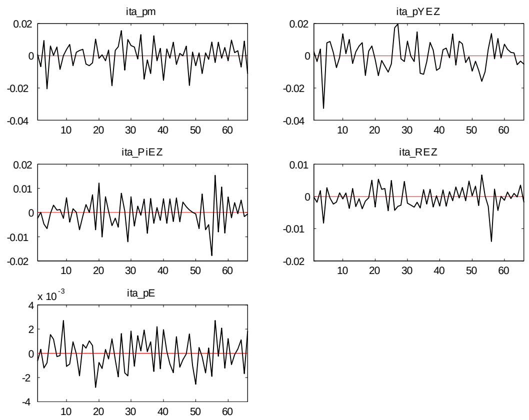
Prior and Posterior Distributions (cont.)



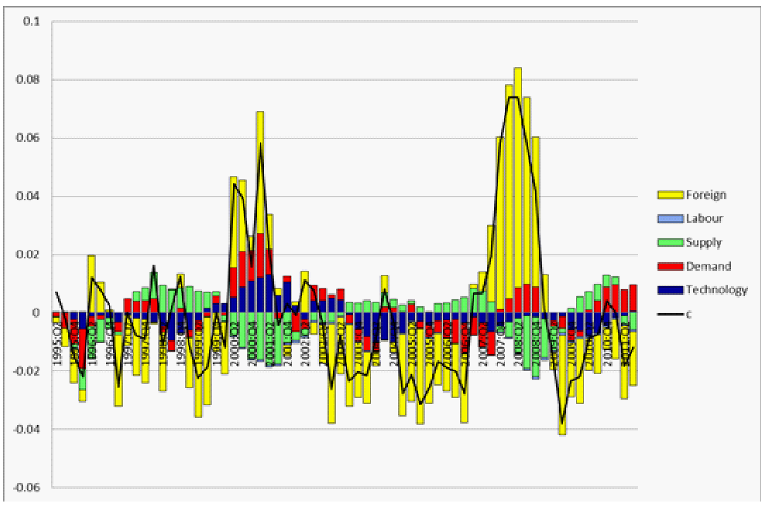
Estimated Innovations



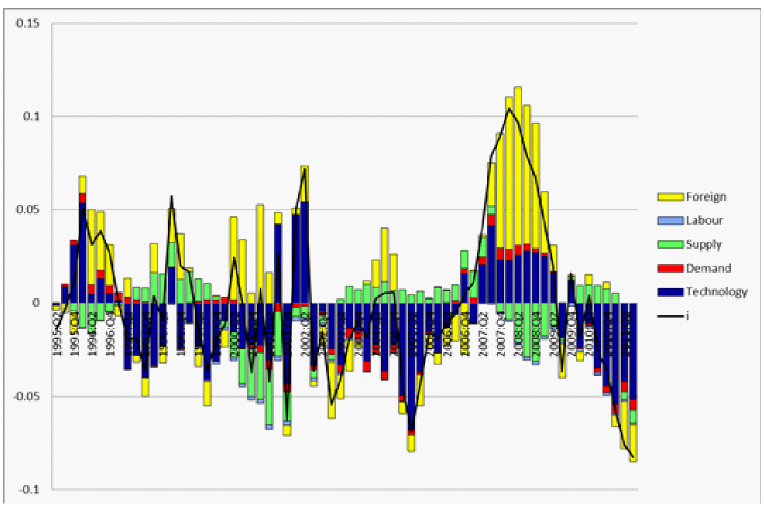
Estimated Innovations (cont.)



Estimated Innovations (cont.)



Sources of Fluctuations in Private Consumption - Historical Decompositions of Shocks



Sources of Fluctuations in Investment - Historical Decompositions of Shocks