Bayesian Estimation of a Small Open Economy DSGE Model for Azerbaijan

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Abstract

This paper develops and estimates a Dynamic Stochastic General Equilibrium (DSGE) model for the Azerbaijan economy. The model incorporates with open economy features such as habit formation and cost of adjustment in capital accumlation. The model features five types of economic agents, namely households, firms, aggregators, the rest of the world and the government and includes a number of shocks and frictions. It is estimated with Bayesian techniques using thirteen macro economic variables: GDP inflation, private consumption good inflation, investment good inflation, real wages, real private consumption, real investment, real GDP, employment, real exports, real imports, nominal interest rate, foreign real GDP and foreign nominal interest rate. The main aim of the paper is to estimate various specifications of a small open economy model in order to determine the model which provides a better fit of Azerbaijan economy.

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Introduction

Nowadays one of the main research areas for central banks is to analyse the effect of their monetary policy - how it works, ho it affects key economic variables and to which magnitude. Central banks have tended mainly to calibrate the parameters of their structural models using a combination of economic theory and stylized macroeconomic facts, rather than estimating them directly. They do it mainly due to the shortage of data. But recently there has been a growing interest from central banks and academia in using dynamic stochastic general equilibrium (DSGE) models for analyzing macroeconomic fluctuations and to use these models for quantitative policy analysis.

This paper makes a first attempt to estimate Small Open Economy Dynamic Stochastic General Equilibrium (DSGE) model for the Azerbaijan economy. To the best of my knowledge, there no papers has been written in this are related to Azerbaijan. The main aim of the paper is to estimate various specifications of a small open economy model in order to determine the model which provides a better fit of Azerbaijan economy. Unstable volatile changes in economic variables caused by structural changes of the economy may raise some weaknesses regarding the model estimate. The fact that Azerbaijan is a developing country makes it an interesting case to investigate the behaviour of the economy in a DSGE framework.

The model was estimated using Bayesian estimation techniques. The paper is mainly based on the works of Smets and Wouters (2003), Adolfson et al. (2007) and Almeida et al. (2009). There are five types of economic agents in the model namely households, firms, aggregators, the rest of the world and the government. As in Christiano, Eichenbaum and Evans (2005), the model includes a number of nominal and real frictions such as sticky prices, sticky wages, capital adjustment costs and habit persistence that enable a closer matching of the short-run properties of the data and a more realistic short-term adjustment to shocks.

The interesting results related to the model are the following. The results of the estimation shows a low share of import goods in the production of final goods sector which is less than 1% for Azerbaijan. This is less than the results found in Almeida et al. (2009) and was explained by the type of the final goods produced in Azerbaijan. Azerbaijan is a developing country and the final goods produced in the country mainly raw materials, agricultural products and low technology products but the imported goods mainly consist of high technology products which is mainly directed to consumption and not to production.

The Calvo stickiness of the parameters found in the model is low compared with the findings of the Smets and Wouters (2003). Under the traditional assumption that the households own the capital stock and assuming that the markup shocks in each sector are white noise, the implied average duration of the price contracts are rather short, of about 2 quarters which is differ from the results found in Smets and Wouters (2003) and Almeida et al. (2009). This again comes from the nature of the economy. Azerbaijan economy suffered from two digit inflation rate during the long time. Therefore households and firms are obliged to change the wages and prices periodically every 1.4 and 2 quarters respectively.

Moreover, the model yields a low elasticity of substitution between domestic and imported goods. The typical estimates for the substitution elasticity between home and foreign goods are around 5 to 20 using micro data (see the references in Obstfeld and Rogoff, 2000). However, using macro data the estimates are usually a lot lower, in the range of 1.5 to 2[1]. The elasticity of substitution between domestic and imported goods was found around 1.3 which is less than the one found in the common literature[2].

[1] See Collard and Dellas (2002)

[2] I used $\vartheta^h + 1$ form in the model compare with the form ϑ^h generally used in literature. Therefore to compare the

The paper is organized as follows. Chapter 2 motivates the study and provide with some reference of background literature. In Chapter 3 the theoretical model is derived and described. In Chapter 4, the model is estimated for the Azerbaijan economy, presenting some data and methodological considerations, and the estimation results and evaluation. The importance of nominal and real frictions in the model, impulse responses from different shocks is also discussed in Chapter 4. Lastly, in Chapter 5 I review my main findings and make suggestions for further work in developing the model.

result I must add one to the result.

Chapter 1 - Background and motivation

There were several important changes in the macroeconomic modelling over the last thirty years. The traditional large-scale macroeconometric models used in the 60s and 70s was criticized. The main critique was on the theoretical side and came from Lucas (1976) when he developed an argument that became known as the "Lucas critique". Therefore the need for a new paradigm emerged and became the main concern of macroeconomists

As a response to the critiques, in 80s economists moved to a new type of macroeconomic models, whose genesis can be found in Kydland and Prescott (1982). In this article, decisions of economic agents were modelled based on their expectations on all future developments.

Although RBC models provided a fundamental methodological contribution, they soon became insufficient, especially for policy analysis in central banks and other policy institutions, giving rise to a new debate in the field of macroeconomics. Therefore in 90s a new school of thought emerged so-called New-Keynesian Macroeconomics (NKM). They shared the RBC approach belief that macroeconomics needed rigorous micro foundations, using DSGE models as their main instrument, but they enriched it by introducing various types of nominal and real rigidities, monopolistic competition and broader set of random disturbances into DSGE models. The introduction of: sticky prices based on previous studies like Calvo (1983), which allowed for price inertia, changing the strong RBC assumption of money neutrality; the introduction of consumption habits in the utility function, based on Abel (1990), which helped in capturing consumption persistency; capital adjustment costs based on King (1991), which allowed models to capture the liquidity effect; demand shocks was defined as in Rotemberg and Woodford (1995); nominal stickiness to wages, following Erceg, Henderson and Levin (2000), which played an important role in explaining inflation and output dynamics; price and wage indexation and the inclusion of investment adjustment costs, based on Christiano, Eichenbaum and Evans (2005), which have improved the ability of the models to capture the inflation persistence present in the data and enhanced the ability of models to capture investment dynamics.

These new assumptions became very successful in generating a meaningful role for monetary and other economic policies and captured some of the salient features of macroeconomic time series that RBC models previously missed. They began to be used not only by academics but also by applied researchers and central bankers. Parallel with developments on the theoretical ground, major advances were also accomplished with respect to the econometric apparatus associated with DSGE models. Lots of econometric procedures have been proposed to parameterise and evaluate DSGE models which can be categorised according to a "weak" or "strong" econometric interpretation of DSGE models as suggested in Geweke (2006).

In the "weak" interpretation, a DSGE model mimics the world only along a carefully specified set of dimensions. Parameters are chosen such that selected features given by the model match as closely as possible those observed in the data. This approach -- calibration is originally proposed by Kydland and Prescott (1982), which simply attributes values to the parameters, based on information from previous studies and common knowledge. There is given another approach - the Generalised Method of Moments (GMM), in Christiano and Eichenbaum (1990) where parameters are chosen in a way that selected equilibrium equations are verified, as precisely as possible.

In contrast to "weak" interpretation, the whole set of implications of the model was taken into account in the "strong" econometric interpretation of DSGE models, attempting to obtain estimates that are able to provide a full characterisation of the observed data series. Two methods - Classical and Bayesian Maximum Likelihood Estimation (MLE) methods fit the "strong" interpretation category. Both methods based on a probabilistic structure for the model, which enables the construction of a function, the likelihood function, which expresses the probability of observing a given dataset as a function of the parameters of the underlying model. In Classical MLE, parameter estimates are simply the values found to produce the maximum value of the likelihood, which is directly obtained from the process. Kim (2000) and Ireland (2001) applied this method in their estimations. In Bayesian MLE the researcher based on previous studies or on his personal beliefs attributes to different possible values of the parameters. The information from the prior is then combined with the information from the likelihood and the resulting function can then be maximised, with respect to the parameters, in the same way as described before. Bayesian estimation is clearly the one that has got more supporters. Classical MLE has proven to be feasible only for systems of relatively small size and not for the large-scale models that have been used recently. First DeJong et al. (2000) used Bayesian MLE method for estimation of DSGE model. Several researchers such as Smets and Wouters (2003), Adolfson et al. (2005), Rabanal and Rubio-Ramirez (2005), Adolfson et al.(2007), and Christoffel, Coenen and Warne (2008) also used this method in their estimations.

The development of a deeper econometric framework surrounding DSGE models has made them attractive not only because of their theoretical consistency but also because of their data explanatory power. Many studies have documented the empirical possibilities and usefulness of these models, even when compared with more traditional econometric tools like Vector Autoregressions (VAR), Vector Error Correction Models (VECM), Bayesian Vector Autoregressions (BVAR), among others. Some reference examples are Smets and Wouters (2003), Fernandez-Villaverde and Rubio-Ramirez (2004), Del Negro, Schorfheide, Smets andWouters (2005), Adolfson et al. (2005), Juillard, Kamenik, Kumhof and Laxton (2006) and Adolfson et al. (2007).

One of the main points in this evolution was the development of Dynare, a pre-processor and a collection of publically available Matlab routines, specifically developed for the simulation, solution and estimation of DSGE models. It has enabled an easier access to quantitative DSGE modelling. The combination of a strong theoretical framework with a good empirical fit has turned New-Keynesian DSGE models into one of the most attractive tools for modern macroeconomic modelling and has led to their widespread use. They became vehicle for economists to structure their thinking and understand the functioning of the economy, being used for a number of purposes, from policy analysis to welfare measurement, identification of shocks, scenario analysis and forecasting exercises. They are the object of attention not only in the academia but also in a number of policy-making institutions as central banks and international organisations such as IMF whose model, presented in Kumhof and Laxton (2007), has been used for e.g. to analyse the effects of fiscal policy on the US economy; the Bank of Sweden given in Adolfson et al.(2007) that has used its model, both for policy analysis and forecasting; the Bank of Finland that can be seen in Kilponen and Ripatti (2006), which besides being applied to the study of many relevant issues of the Finnish economy, like ageing and demographics.

New-Keynesian DSGE models and their estimation is certainly one of the most interesting and promising fields in modern macroeconometric research, from which no country should be left out. In the case of Azerbaijan to my knowledge, no attempt has yet been made to estimate a New-Keynesian DSGE model. Therefore I consider this to be not only a legitimate but also necessary task, which has led to the conduct of the present study.

Chapter 2 - A Small Open Economy Model

In this section we derive and present a New-Keynesian DSGE model for a small open economy with five types of agents namely households, firms, aggregators, the rest of the world (RW) and the government. The derivations of the key structural equations implied by the model proposed by Almeida et al. (2009).

Households maximize their utility with goods and labor. They consume, invest in capital stock, save in both domestic and foreign bonds and supply differentiated labour services.

There are two types of firms: intermediate and final good firms. The former are divided into three category: domestic good firms, who produce a differentiated domestic good using capital and labour; import good firms, who transform an homogeneous foreign good into a differentiated import good, by brand naming; and composite good firms who combine the domestic and import goods to produce a composite good. The later consist of four types: private consumption, investment, government consumption and export good firms. Each firm buys the composite good and produce a differentiated final good by brand naming.

Aggregators take the economy's differentiated products and bundle them to produce homogeneous products. Their mission is to act as a "bridge", solving the mismatch between those who demand homogeneous products and those who supply differentiated products. There is one aggregator for each differentiated product in the economy, namely: labour services, domestic and import goods and the four types of final good.

The RW interact with the home economy by buying the final export good, selling an homogeneous foreign good and bonds.

The government has no productive activity in the economy, just taking the role consumption of final government consumption good, tax collection, transfers and debt issuance. To ensure a non-explosive path of public debt, a fiscal rule is imposed.

There are several shocks in the model which enable a closer matching of the short-run properties of the data, and a number of real and nominal frictions, which allow for a more realistic short-term adjustment to shocks.

2.1 Households

The economy is inhabited by a representative household who seeks to maximize his or her utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \varepsilon_t^c \ln\left[C_t(i) - hC_{t-1}(i) \right] - \frac{\varepsilon_t^l}{1+\sigma_l} L_t(i)^{1+\sigma_l} \right\} \tag{1}$$

where $U_t(i)$ is the instantaneous utility function, representing the utility obtained by the household, β time discount factor, σ_l is the inverse of the elasticity of work effort with respect to (w.r.t.) the marginal disutility of labour and ε_t^c and ε_t^l are preference shocks to consumption and labour. $L_t(i)$ is denotes the amount of labour supplied by the household and $C_t(i)$ is private consumption. $H_t(i)$ consumption habit defined as a proportion of the household's consumption:

$$H_t(i) = hC_{t-1}(i) \tag{2}$$

where $0 \leq h \leq 1$ determines the degree of habit persistence.

Based on Erceg (2000) , labour is differentiated over households with each one being a monopoly supplier of a particular variety of labour. Households sell these varieties to a labour aggregator who bundles them to produce an homogeneous labour input, which is then supplied to domestic good firms. Being a monopoly supplier of a particular variety of labour, each household has some decision power over the wage it charges, $W_t(i)$. But, households cannot define their wages optimally in every period. They do i t if they receives a "wage-change signal" which occurs randomly at a constant (exogenous) probability, $1-\xi_w$. In this case households sets a new,optimal, wage, $\widetilde{W}_t^{0}(i)$. Thus only $1-\xi_w$ proportion of households that get to reoptimise their price in each period. ξ_w proportion of households that not receive the "signal" update their previous period wage by indexating it to the current inflation rate target, $\overline{\pi}_t = \overline{\left(\frac{P_t}{P_{t-1}}\right)}$, entered as a shock, the previous period inflation rate, $\overline{\pi}_{t-1} = \overline{\left(\frac{P_{t-1}}{P_{t-2}}\right)}$ and the current period growth rate of the permanent technology shock, $\varsigma_t = \frac{z_t}{z_{t-1}}$. More formally, a household who does not get to reoptimise in period t will set its wage according to:

$$W_t(i) = \pi_{t-1}^{\kappa_w}\pi_t^{1-\kappa_w}\varsigma_t W_{t-1}(i) \tag{3}$$

where $0 \leq \kappa_w \leq 1$ is the degree of wage indexation to the previous period inflation rate.

The capital stock that households own, rent to domestic good firms at the rental rate R_t^k. The Capital accumulated during period t is determined by the investment made during that period, $I_t(i)$. As modelled in Christiano et al. (2005) investment is subject to adjustment costs which represented by the function $S\left(\frac{I_t(i)}{I_{t-1}(i)}\right)$ with the properties $S(\varsigma) = 0, S(\varsigma)' = 0$ and $S(\varsigma)'' > 0$ and subject to a shock, ε_t^i. So, the household's capital accumulation equation is given as:

$$K_{t+1}(i) = (1-\delta)K_t(i) + \varepsilon_t^i\left[1 - S\left(\frac{I_t(i)}{I_{t-1}(i)}\right)\right]I_t(i) \tag{4}$$

where $0 \leq \delta \leq 1$ is the depreciation rate.

Each household saves both in domestic and foreign bonds. Domestic bonds, $B_t(i)$, are bought from the government and yield the domestic nominal interest rate at the time $t-1$, R_{t-1}. The stock of bonds is assumed to be non-negative, meaning that households are not allowed to borrow from the government. Foreign bonds, $B_t^*(i)$, are bought from the RW.The household is a net borrower when $B_t^*(i)<0$ and a net lender when $B_t^*(i)>0$. The foreign bonds yield the foreign nominal interest rate, R_{t-1}^*, adjusted by a risk-premium, $\ddot{b}_t^* = \frac{B_t^*}{z_{t+1}P_{t+1}}$. The function assumed to be a decreasing function of the real stationary holdings of foreign assets of the entire domestic economy, $\ddot{b}_t^* = \dfrac{B_t^*}{z_{t+1}P_{t+1}}$ and an increasing function of a risk-premium shock, ε_t^{ϕ}[3] It was assume that $\Phi\left(\ddot{b}_t^*, \varepsilon_{t-1}^{\phi}\right) = \exp\left(-\ddot{b}_t^* + \varepsilon_{t-1}^{\phi}\right)$.

The government provides households with lump-sum transfers TR_t and households by the way pay a consumption tax, τ_t^c and a labour-income tax, τ_t^l

As the households are unsure about their labor income because they do not know which wage they will be able to charge in each period each household participates in a market of state-contingent securities, with the net cash inflow being given by $P_tA_t(i)$. By this way households insure themselves against the uncertainty. So $W_t(i)L_t(i)+P_tA_t(i)$ is equal for all households, eliminating the labour-income uncertainty. The aggregate value of the state-contingent assets is assumed to be zero, $P_t\int_0^1 A_t(i)\,di = 0$

Households own all the firms in the economy. They earn dividends $DIV_t(i)$ as a profit receiving their profits in the form of dividends and dividends are distributed equally among

[3] See Schmitt-Grohe and Uribe (2003) and Benigo (2001)

households, $DIV_t(i) = DIV_t$.

So in each period, households get their disposal income from the domestic and foreign bonds they accumulated from the previous period and the interest they earned on them, $R_{t-1}B_t(i) + R_{t-1}^* \; \Phi\left(\tilde{b}_t^*, \varepsilon_{t-1}^{\phi}\right) B_t^*(i)$. So the household's budget constraint will be:

$$R_{t-1}B_t(i) + R_{t-1}^*\Phi\left(\tilde{b}^*, \varepsilon_{t-1}^{\phi}\right) B_t^*(i) + \left(1-\tau_t^l\right) W_t(i) L_t(i) + P_t A_t(i) + R_t^k K_t(i) + TR_t + DIV_t$$

$$= B_{t+1}(i) + B_{t+1}^*(i) - \left(1-\tau_t^c\right) P_t^c C_t(i) - P_t^i I_t(i) \tag{5}$$

where $P_t A_t(i)$ is the net income from their state-contingent securities, $R_t^k K_t(i)$ is the income received from renting the capital stock and TR_t the lump-sum transfers they receive from the government. The representative household's optimisation problem is to choose the levels of consumption, domestic and foreign bonds, investment and capital stock that maximise (1) subject to the constraints imposed by (2), (4) and (5).

Households will maximise their utility (1) subject to (3) and (5) and the demand from the labour aggregator given in (34). Solving the optimisation problem, I get six first order conditions (FOC), which were summarised in the following five equations. The consumption Euler equation:

$$\frac{U_{t+1}^{c,life}(i)}{U_t^{c,life}(i)} = \frac{\pi_{t+1}}{\beta R_t} \tag{6}$$

where $U_t^{c,life}(i) = \dfrac{\varepsilon_t^c}{C_t(i) - hC_{t-1}(i)} - \beta h \dfrac{\varepsilon_{t+1}^c}{C_{t+1}(i) - hC_t(i)}$. is the additional utility a household gets from increasing consumption by one unit in period t. As it is visible from the equation household's consumption in a given period is dependent on its past and expected future consumption, the real interest rate, current and future consumption shocks. If there is no habits in households, consumption would not depend on its past and future value.

The modified uncovered interest rate parity (UIP) condition is given by:

$$R_t = R_t^* \Phi\left(\tilde{b}_{t+1}^*, \varepsilon_t^{\phi}\right) \tag{7}$$

which means that the domestic bonds yield is equal to the foreign bonds yield, adjusted by the risk premium.

From the FOC w.r.t. $I_t(i)$ we get:

$$Q_t(i)\varepsilon_t^i \begin{bmatrix} -S'\left(\frac{I_t(i)}{I_{t-1}(i)}\right)\frac{I_t(i)}{I_{t-1}(i)} \\ +1-S\left(\frac{I_t(i)}{I_{t-1}(i)}\right) \end{bmatrix} + \beta Q_{t+1}(i)\frac{\pi_{t+1}}{\beta R_t}\varepsilon_{t+1}^i(i) S'\left(\frac{I_{t+1}(i)}{I_t(i)}\right)\left(\frac{I_{t+1}(i)}{I_t(i)}\right)^2 = \frac{P_t^i}{P_t} \tag{8}$$

where $Q_t(i)$ is the marginal utility of a unit of capital in terms of the marginal utility of a unit of consumption. As we see the household's investment in each period depends on its the value of the capital stock, the price of investment goods, past and expected future investment and investment shocks. If there were no adjustment costs, current investment would only depend on current investment.

From the FOC w.r.t. $\tilde{W}_t^o(i)$ we obtain:

$$E_t \sum_{s=0}^{\infty} (\beta\xi_w)^s \tilde{L}_{t+s}(i)\left\{\tilde{U}^l_{t+s}(i)\mu_w + \frac{\tilde{W}_t^0(i)}{P_t z_t} z_{t+s} U_t^{c,life}(i)\left(1-\tau^l_{t+s}\right)\frac{X^w_{t+s}}{\pi_{t+s}\ldots\pi_{t+1}}\right\} = 0 \tag{9}$$

where

$$\tilde{W}_{t+s}(i) = X^w_{t+s}\frac{z_{t+s}}{z_t}\tilde{W}_t^0(i) \tag{10}$$

$$X^w_{t+s} = \begin{cases} 1 & \text{if } s = 0 \\ \left(\pi_{t+s-1}\ldots\pi_t\right)^{\kappa_w}\left(\bar{\pi}_{t+s}\ldots\bar{\pi}_{t+1}\right)^{1-\kappa_w} & \text{if } s > 0 \end{cases} \tag{11}$$

and $\tilde{U}^{l}_{t+s}(i)$ is the marginal (dis)utility of wage optimising households from extra unit of labour. The households reoptimise their nominal wage at time t so that the discounted value of all its future after-tax marginal return to working (i.e. the utility of consuming) is a mark-up over the discounted value of the corresponding marginal cost (i.e. the disutility of working). I also have to mention that $U_t^{c,life}(i)$ is independent of the wage optimisation decision, so doen't need the : subscript.

From the FOC w.r.t. $K_{t+1}(i)$:

$$Q_t(i) = \frac{\pi_{t+1}}{R_t}\left(r^k_{t+1} + Q_{t+1}(i)(1-\delta)\right) \tag{12}$$

which says that the current value of the capital stock is a function of its expected rental rate, its expected future value, taking into account its depreciation and the ex-ante real interest rate.

All optimising households behave symmetrically and face the same conditions. Therefore $C_t(i) = C_t$, $U_t^{c,life}(i) = U_t^{c,life}$, $B_t(i) = B_t$, $B_t^*(i) = B_t^*$, $K_t(i) = K_t$, $I_t(i) = I_t$, $Q_t(i) = Q_t$, $\tilde{L}_t(i) = \tilde{L}_t$, $\tilde{U}_{t+s}(i) = \tilde{U}_{t+s}$ and $\tilde{W}^0_t(i) = \tilde{W}^0_t$. Here it is not the case for $W_t(i)$ and $L_t(i)$, as these can be relative to households who are not optimising their wages, who can have distinct wages and consequently distinct labour supplies.

2.2 Firms

There are two types of firms operating in the economy: intermediate and final good firms.

Intermediate good firms

Intermediate good firms are of three types: domestic, import and composite good firms.

Domestic good firms

There is a continuum of domestic good firms, indexed by $j \in (0,1)$. The domestic firms produce a specific variety of domestic good, $Y_t^d(j)$, by using the following Cobb-Douglas production function:

$$Y_t^d(j) = z_t^{1-\alpha_d} \varepsilon_t^a K_t(j)^{\alpha_d} L_t(j)^{1-\alpha_d} + z_t \phi_d \tag{13}$$

where ϕ_d is a fixed cost of production, $0 \le \alpha_d \le 1$ is the capital income share, ε_t^a is a domestic, stationary, technology shock. $K_t(j)$ is capital and $L_t(j)$ is labour. The domestic firms sell their products to the domestic good aggregator. The fixed cost is added to ensure zero profits in the steady-state and is assumed to grow with z_t. Otherwise it would become irrelevant and profits would systematically be positive.

All firms rents capital by rental rate R_t^k and hires labour from households with wage rate W_t in perfectly competitive markets. But firms work in a monopolistically competitive environment, using their power over the price they charge, P_t^d *as* they produce differentiated products.

The price setting decision is modelled as an indexation variant of the mechanism spelled out in Calvo (1983). Firms, like in the wages case, will only update their prices when they get a "price-change signal", that occurs with a constant probability, $1-\xi_d$. In this case firms sets a new, optimal, price, $\tilde{P}_t^d(j)$. The rest of the firms that do not get the "signal" update their previous period price by partially indexating it to the current inflation rate target, $\overline{\pi}_t$ and to the previous period domestic good inflation rate, π_{t-1}^d. Generally a domestic good firm that does not get to reoptimise its price in period t, will set it according to:

$$P_t^d(j) = \left(\pi_{t-1}^d\right)^{\kappa_d} \overline{\pi}_t^{1-\kappa_d} P_{t-1}^d(j) \tag{14}$$

where $0 \le \kappa_d \le 1$ is the degree of domestic good price indexation to its previous period inflation rate.

All firms choose labour and capital to minimise the cost of the production, subject to (13), which produces two FOCs that can be summarised as:

$$\frac{K_t(j)}{L_t(j)} = \frac{\alpha_d}{1-\alpha_d}\frac{W_t}{R_t^k} \tag{15}$$

where we see that for a given installed capital stock, the labour demand depends on rental rate of capital and the wage. The capital labour ratio is the same for all firms.

The firm's marginal cost is equal to:

$$MC_t^d(j) = \frac{1}{z_t^{1-\alpha_d}\varepsilon_t^a}\left(\frac{1}{\alpha_d}\right)^{\alpha_d}\left(\frac{1}{1-\alpha_d}\right)^{1-\alpha_d} W_t^{1-\alpha_d}\left(R_t^k\right)^{\alpha_d} \tag{16}$$

which is dependent on technology shocks and factor costs and the same for all firms.

The firms paralel with cost minimization also have to decide on the profit maximising price to charge for their output. A firm who receives the "Calvo signal" and reoptimise, will set a price that maximises its expected profits in all future possible states of nature, taking into account that the entire flow of profits will possibly depend on the price set in t. A firm that does not reoptimise, just will set its price according to (14). As firms are owned by households, they will maximise expected profits using the rate applied by households to discount their future income streams which contemplates the time discount factor and the marginal utility of an extra unit of wealth, $\lambda_{t+s}^{u} = U_{t+s}^{c,life}$. Solving the problem,we get the following FOC:

$$E_t \sum_{s=0}^{\infty} (\beta \xi_d)^s \frac{\lambda_{t+s}^{u}}{\mu_{t+s}^{d} - 1} \tilde{Y}_{t+s}^{d}(j) \frac{P_{t+s}^{d}}{P_{t+s}} \left\{ \frac{X_{t+s}^{d}}{\pi_{t+s}^{d} \dots \pi_{t+1}^{d}} \frac{\tilde{P}_t^{0,d}(j)}{P_t^{d}} - \frac{MC_{t+s}^{d}}{P_{t+s}^{d}} \mu_{t+s}^{d} \right\} = 0 \tag{17}$$

where

$$P_{t+s}^{d}(j) = X_{t+s}^{d} \tilde{P}_t^{0,d}(j) \tag{18}$$

and

$$X_{t+s}^{d} = \{\} 1 \text{if} s = 0 \left(\pi_{t+s-1}^{d} \dots \pi_t^{d}\right)^{\kappa_d} \left(\bar{\pi}_{t+s} \dots \bar{\pi}_{t+1}\right)^{1-\kappa_d} \text{ if} s > 0 \tag{19}$$

The domestic good firm that reoptimises set the price at time t so that the discounted value of all future revenues obtained from production is a markup over the discounted value of all the corresponding marginal costs. All domestic good firms which optimise their prices face the same conditions, behaving symmetrically. So $\tilde{Y}_{t+s}^{d}(j) = \tilde{Y}_{t+s}^{d}$ and $\tilde{P}_t^{0,d}(j) = \tilde{P}_t^{0,d}$.

Import good firms

There is a continuum of import good firms in the economy, indexed by $m \in (0,1)$.Each import good firm buys a certain amount of homogeneous foreign good, M_t, and changes it by brand naming to a differentiated import good, $Y_t^{m}(m)$, and sells it to the import good aggregator. As domestic good firms, import good firms are also subject to fixed production costs, $z_t \phi_m$.

Taking the price of the foreign good, P_t^{*} as given, that is equal for all firms, import good firms operate in perfect competition in their input market. However, the firms act as in monopolistic competition in their output markets, charging P_t^m for their product which is also subject to an indexation variant of the Calvo mechanism. As described above with $1-\xi_m$ probability the firms set a new reoptimised price, $\tilde{P}_t^m(m)$ by receiving a "price-change signal". Firms that do not reoptimise simply set their price as an update of the previous period price, according to:

$$P_t^m(m) = \left(\pi_{t-1}^m\right)^{\kappa_m} \bar{\pi}_t^{1-\kappa_m} P_{t-1}^m(m) \tag{20}$$

where $0 \leq \kappa_m \leq 1$ is the degree of import good price indexation to its previous period inflation rate.

The main problem of each of these firms is to decide which price to charge for their product. It is modelledsimiliar to the price optimisation problem of domestic good firms, producing the following FOC w.r.t. the price of import good:

$$E_t \sum_{s=0}^{\infty} \left(\beta\xi_m\right)^s \frac{\lambda_{t+s}^u}{\mu_{t+s}^m - 1} \tilde{Y}_{t+s}^m(m) \frac{P_{t+s}^m}{P_{t+s}} \left\{ \frac{X_{t+s}^m}{\pi_{t+s}^m \ldots \pi_{t+1}^m} \frac{\tilde{P}_t^{0,m}(m)}{P_t^m} - \frac{MC_{t+s}^m}{P_{t+s}^m} \mu_{t+s}^m \right\} = 0 \tag{21}$$

which is similiar to the price FOC of domestic good firms, and where:

$$P_{t+s}^m(m) = X_{t+s}^m \tilde{P}_t^{0,m}(m) \tag{22}$$

$$X_{t+s}^m = \{\} 1 \text{if} s = 0 \left(\pi_{t+s-1}^m \ldots \pi_t^m\right)^{\kappa_m} \left(\bar{\pi}_{t+s} \ldots \bar{\pi}_{t+1}\right)^{1-\kappa_m} \text{if} s > 0 \tag{23}$$

and

$$MC_{t+s}^m = P_{t+s}^* \tag{24}$$

All importing good firms which optimise their prices face the same conditions, behaving symmetrically. So $\tilde{Y}_{t+s}^m(m) = \tilde{Y}_{t+s}^m$ and $\tilde{P}_t^{0,m}(m) = \tilde{P}_t^{0,m}$.

Composite good firm

There is only one composite good firm in the economy that buys the homogeneous import good, Y_t^m *and* the homogeneous domestic good, Y_t^d from the aggregators and combines them to produce a homogeneous composite good, Y_t^h,which is then sold to final good firms. The composite good firm produce using the following CES technology:

$$Y_t^h = \left[\left(1-\omega_h\right)^{\frac{1}{\vartheta_h+1}} \left(Y_t^d\right)^{\frac{\vartheta_h}{\vartheta_h+1}} + \omega_h^{\frac{1}{\vartheta_h+1}} \left(Y_t^m\right)^{\frac{\vartheta_h}{\vartheta_h+1}} \right]^{\frac{\vartheta_h+1}{\vartheta_h}} \tag{25}$$

where $0 \le \omega_h \le 1$ determines the share of import good in the production of composite good and $0 \le \vartheta_h \le \infty$ is the elasticity of substitution between domestic and import goods

The firm operates in a perfectly competitive market, taking the prices of the domestic and import goods, P_t^d and P_t^m and the price of its output, P_t^h, as given.

The main problem of the firm to minimise the cost of the production copmosite goods by the combination of domestic and import good subject to (25), where we get the FOC w.r.t. domestic good:

$$Y_t^d = \left(1-\omega_h\right)\left(\frac{P_t^h}{P_t^d}\right)^{\vartheta_h+1} Y_t^h \tag{26}$$

and the FOC w.r.t. import good:

$$Y_t^m = \omega_h \left(\frac{P_t^h}{P_t^m}\right)^{\vartheta_h+1} Y_t^h \tag{27}$$

Final good firms

There are four types of final good firms in the economy namely private consumption, investment, government consumption and export, being indexed by $f \in \{C, I, G, X\}$. For each type there is a continuum of firms, indexed by $n \in (0,1)$, who buy a certain amount of composite good, Y_t^f, differentiate it, by brand naming and producing different final good, $Y_t^f(n)$, which are then sold to their respective aggregator. Like in the domestic and import good firms cases, each type of final good firms is subject to fixed production costs, $z_t \phi_f$.

Final good firms operate in perfect competition in their input markets, taking the price of the composite good, P_t^h, as given. However, they charge a price $P_t^f(n)$ for their differentiated products working in monopolistic competition markets.

The firms define their prices by the same mechanism as described in the wages, domestic good and import good prices cases. They reoptimise their prices if a "price-change signal" is received, which occurs with probability $1-\xi_f$, setting a new price $\tilde{P}_t^{0,f}(n)$ is also the proportion of firms that get to reoptimise in each period. They also define the duration of final good price contracts, given by $\frac{1}{1-\xi_f}$. Otherwise, they just simply update their prices by the following rule:

$$P_t^f(n) = \left(\pi_{t-1}^f\right)^{\kappa_f} \bar{\pi}_t^{1-\kappa_f} P_{t-1}^f(n) \tag{28}$$

where $0 \leq \kappa_f \leq 1$ is the degree of type f final good price indexation to its previous period inflation rate.

All final good firms in the economy have to decide which price they will charge for their product. Writing the modelled similiar to the price optimisation problem of domestic and import good firms we get the following FOC w.r.t. the price of type f final good:

$$E_t \sum_{s=0}^{\infty} \left(\beta \xi_f\right)^s \frac{\lambda_{t+s}^u}{\mu_{t+s}^f - 1} \tilde{Y}_{t+s}^f(n) \frac{P_{t+s}^f}{P_{t+s}} \left\{ \frac{X_{t+s}^f}{\pi_{t+s}^f \ldots \pi_{t+1}^f} \frac{\tilde{P}_t^{0,f}(n)}{P_t^f} - \frac{MC_{t+s}^f}{P_{t+s}^f} \mu_{t+s}^f \right\} = 0 \tag{29}$$

where

$$P_{t+s}^f(n) = X_{t+s}^f \tilde{P}_t^{0,f}(n) \tag{30}$$

and

$$X_{t+s}^f = \left\{ \begin{matrix} 1 \text{ if } s = 0 \\ \left(\pi_{t+s-1}^f \ldots \pi_t^f\right)^{\kappa_f} \left(\overline{\pi}_{t+s} \ldots \overline{\pi}_{t+1}\right)^{1-\kappa_f} \text{ if } s > 0 \end{matrix} \right\} \tag{31}$$

The interpretation of equation (29) is perfectly equivalent to the domestic and import goods Phillips curves and where:

$$MC_{t+s}^f = P_{t+s}^h \tag{32}$$

All final good firms which optimise their prices face the same conditions, behaving symmetrically. So $\tilde{Y}_{t+s}^f(n) = \tilde{Y}_{t+s}^f$ and $\tilde{P}_t^{0,f}(n) = \tilde{P}_t^{0,f}$

2.3 Aggregators

There exist aggregators in the economy which solve the mismatch between the supply of differentiated products and the demand for homogeneous products. All the aggregators operate in a perfectly competitive environment both in their input and output markets, and therefore take the price of both their inputs and output as given. For each type of supplied differentiated product, there exist an aggregator that buys the different products and combines them to produce an homogeneous product that can satisfy the economy's demand, using a CES technology.

The labour aggregator buys the different labour varieties, $L_t(i)$, from households and combines them and produce a homogeneous labour input, L_t, which then sells to the domestic good firms. The homogeneous labour input is given by:

$$L_t = \left({}_0^1 L_t \left(i \right)^{\frac{1}{\mu_w}} di \right)^{\mu_w} \tag{33}$$

where $1 \leq \mu_w < \infty$ is wage markup, which is dependent on the elasticity of substitution between varieties of labour, $0 \leq \vartheta^w < \infty$, such that $\mu_w = \frac{\vartheta^w + 1}{\vartheta^w}$

Solving the problem of the labour aggregator - to decide on the combination of different labour varieties that minimises the cost of producing L_t, subject to (33) we get the following FOC w.r.t. each variety of labour:

$$L_t \left(i \right) = \left(\frac{W_t}{W_t \left(i \right)} \right)^{\frac{\mu_w}{\mu_w - 1}} L_t \tag{34}$$

The domestic good aggregator produce an homogeneous domestic good, Y_t^d using the different varieties of domestic good, $Y_t^d \left(j \right)$, from the domestic good firms. Then domestic good aggregators sell to the composite good firm. The homogeneous domestic good is given by:

$$Y_t^d \left(\int_0^1 Y_t^d \left(j \right)^{\frac{1}{\mu_t^d}} dj \right)^{\mu_t^d} \tag{35}$$

where $1 \leq \mu_t^d < \infty$ is the domestic good price markup, modelled as a shock, dependent on the elasticity of substitution between varieties of domestic good, $0 \leq \vartheta_t^d < \infty$, such that $\mu_t^d = \frac{\vartheta_t^d + 1}{\vartheta_t^d}$.

The domestic good aggregator alsos solve the problem similiar to the one solved by the labour aggregator, where we get the following FOC w.r.t. each variety of domestic good:

$$Y_t^d \left(j \right) = \left(\frac{P_t^d}{P_t^d \left(j \right)} \right)^{\frac{\mu_t^d}{\mu_t^d - 1}} Y_t^d \tag{36}$$

The import good aggregator as domestic good aggregators takes the different varieties of

[4] Based on Adolfson et al. (2005) it is considered that the wage markup is time-invariant, contrary to the other markups, to prevent identification problems generated by the coexistence of two shocks, the labour supply shock and the wage markup shock in the log-linearized wage equation.

import good, $Y_t^m(m)$, from the import good firms and use them to produce an homogeneous import good, Y_t^m, which is later sold to the composite good firm. The homogeneous import good is given by:

$$Y_t^m \left(\int_0^1 Y_t^m(m)^{\frac{1}{\mu_t^m}} dm \right)^{\mu_t^m} \tag{37}$$

where $1 \leq \mu_t^m < \infty$ is the import good price markup, modelled as a shock, dependent on the elasticity of substitution between varieties of import good, $0 \leq \vartheta_t^m < \infty$, such that $\mu_t^m = \dfrac{\vartheta_t^m + 1}{\vartheta_t^m}$.

From the import good aggregatorproblem we get the following FOC w.r.t. each variety of import good:

$$Y_t^m(m) = \left(\frac{P_t^m}{P_t^m(m)} \right)^{\frac{\mu_t^m}{\mu_t^m - 1}} Y_t^m \tag{38}$$

The final good aggregator buys takes the different varieties of type f final good, $Y_t^f(n)$, combines them and produce an homogeneous type f final good, Y_t^f, The produced good is later sold to households, the government and the RW for private consumption, investment, government consumption and export purposes. The homogeneous type f final good is given by:

$$Y_t^f \left(\int_0^1 Y_t^f(n)^{\frac{1}{\mu_t^f}} dn \right)^{\mu_t^f} \tag{39}$$

where $1 \leq \mu_t^f < \infty$ is the type f final good price markup, modelled as a shock, dependent on the elasticity of substitution between varieties of type f final goos, $0 \leq \vartheta_t^f < \infty$, such that $\mu_t^f = \dfrac{\vartheta_t^f + 1}{\vartheta_t^f}$.

Solving the similiar to the above mentioned aggregators problem for final good aggregator, we get the following FOC w.r.t. each variety of type f final good:

$$Y_t^f(n) = \left(\frac{P_t^f}{P_t^f(n)} \right)^{\frac{\mu_t^f}{\mu_t^f - 1}} Y_t^f \tag{40}$$

2.4 Rest of the World

The RW's demand for the export good, $X_{t,}$ corresponds to the home economy's exports. RW agents combine their own domestic homogeneous good with domestic economy's homogeneous export good and produce Y_t^*. The RW's demand for the export good is defined as:

$$X_t = \left(\frac{P_t^*}{P_t} \right)^{\vartheta_* + 1} Y_t^* \tag{41}$$

where $0 \le \vartheta_* < \infty$ is the foreign economy's elasticity of substitution between the domestic export good and the RW's good.

It was assumed that there is a stationary foreign technology shock, $\zeta_t^* = \frac{z_t^*}{z_t}$, where z_t^* is the permanent technology level abroad, to allow for temporary differences between domestic and foreign permanent technological progresses. It is also assumned that foreign economy variables (inflation, output and interest rate) are exogenously given as shocks.

2.5 Government

The government expenditure consist of government consumption of good, $P_t^g G_t$, transfers to households, TR_t and payment of debt services, $(R_{t-1} - 1) B_t$. To meet her expenditures government issue debt, B_t and obtains resources from taxes, $\tau_t^c P_t^c C_t + \tau_t^l \int_0^1 W_t(i) L_t(i) di$.

The difference between the government's current spending and revenue was defined as the government's primary deficit, where debt related resources and expenditures were excluded. The government's primary deficit is equal to:

$$SG_t^{prim} = P_t^g G_t + TR_t - \tau_t^c P_t^c C_t - \tau_t^l \int_0^1 W_t(i) L_t(i) di \tag{42}$$

The government's total deficit also includes interest outlays and equal to:

$$SG_t^{tot} = SG_t^{prim} + (R_{t-1} - 1) B_t \tag{43}$$

Then the government's budget constraint canbe defined as:

$$B_{t+1} + \tau_t^c P_t^c C_t + \tau_t^l \int_0^1 W_t(i) L_t(i) d = R_{t-1} B_t + P_t^g G_t + TR_t$$

$$B_{t+1} = B_t + SG_t^{tot} \tag{44}$$

A fiscal rule is defined by the government to prevent an explosive debt path, acting as a restriction over SG_t^{prim} such that TR_t adjusts endogenously to ensure that the debt to Gross Domestic Product (GDP) ratio converges to a long-term, pre-specified value. The rule is given already in its stationary form by:

$$\frac{\ddot{sg}_t^{prim}}{\ddot{gdp}} = -d_g \left(\frac{\ddot{b}_{t+1}}{\ddot{gdp}} - \left(\frac{\ddot{b}}{\ddot{gdp}} \right)^{tar} \right) \tag{45}$$

where $\left(\frac{\ddot{b}}{\ddot{gdp}} \right)^{tar}$ is the target value for the stationary debt to GDP ratio. The fiscal policy variables such as taxes and expenditures are exogenously given as shocks.

2.6 Aggregation

At this moment some aggregation procedures are needed that allow to obtain the behaviour of the economy as whole. The indices i can be dropped from the households' expenditure decisions and therefore the aggregate demand for consumption good, government bonds, foreign bonds, investment good and the aggregate supply of capital services can easily define as:

$$\int_0^1 C_t(i)\,di = \int_0^1 C_t di = C_t \tag{46}$$

$$\int_0^1 B_t(i)\,di = \int_0^1 B_t di = B_t \tag{47}$$

$$\int_0^1 B_t^*(i)\,di = \int_0^1 B_t^* di = B_t^* \tag{48}$$

$$\int_0^1 I_t(i)\,di = \int_0^1 I_t di = I_t \tag{49}$$

$$\int_0^1 K_t(i)\,di = \int_0^1 K_t di = K_t \tag{50}$$

I have to mention that aggregators and the composite good firm have to comply with a zero profit condition, as they work in perfect competition. Therefore we get the following equations:

$$W_t L_t = \int_0^1 W_t(i) L_t(i)\,di \tag{51}$$

$$P_t^d Y_t^d = \int_0^1 P_t^d(j) Y_t^d(j)\,dj \tag{52}$$

$$P_t^m Y_t^m = \int_0^1 P_t^m(m) Y_t^m(m)\,dm \tag{53}$$

$$P_t^f Y_t^f = \int_0^1 P_t^f(n) Y_t^f(n)\,df \tag{54}$$

$$P_t^h Y_t^h = P_t^d Y_t^d - P_t^m Y_t^m \tag{55}$$

Next, we get the aggregate supply of domestic good,from equations (13), (38), (63) and (64):

$$Y_t^d = \left(\frac{ \left(\int_0^1 P_t^d\left(j\right)^{-\frac{\mu_t^d}{\mu_t^d - 1}} dj \right)^{-\frac{\mu_t^d - 1}{\mu_t^d}} }{ P_t^d } \right)^{\frac{\mu_t^d}{\mu_t^d - 1}} \int_0^1 Y_t^d\left(j\right) dj \tag{56}$$

$$= \left(\frac{ \left(\int_0^1 P_t^d\left(j\right)^{-\frac{\mu_t^d}{\mu_t^d - 1}} dj \right)^{-\frac{\mu_t^d - 1}{\mu_t^d}} }{ P_t^d } \right)^{\frac{\mu_t^d}{\mu_t^d - 1}} z_t^{1-\alpha_d} \varepsilon_t^a K_t^{\alpha_d} L_t^{1-\alpha_d} - z_t \phi_d \tag{57}$$

As we see the supply of domestic good by the domestic good aggregator, Y_t^d, is not only a function of what could be produced using the available technology and inputs. There is an efficiency distortion which comes from the monopoly power of the domestic good firms.

The aggragate wage equation is obtained using the (3), (33) and (34):

$$W_t = \left[\left(1-\xi_w\right)\left(\tilde{W}_t\right)^{-\frac{1}{\mu_w - 1}} + \xi_w \left(\pi_{t-1}^{\kappa_w} \bar{\pi}^{1-\kappa_w} \zeta_t W_{t-1} \right)^{-\frac{1}{\mu_w - 1}} \right]^{-\left(\mu_w - 1\right)} \tag{58}$$

The same operations was done for domestic, import and final goods, and get their prices:

$$P_t^d = \left[\left(1-\xi_d\right)\left(\tilde{P}_t^d\right)^{-\frac{1}{\mu_t^d - 1}} + \xi_d \left(\left(\pi_{t-1}^d\right)^{\kappa_d} \bar{\pi}^{1-\kappa_d} P_{t-1}^d \right)^{-\frac{1}{\mu_t^d - 1}} \right]^{-\left(\mu_t^d - 1\right)} \tag{59}$$

$$P_t^m = \left[\left(1-\xi_m\right)\left(\tilde{P}_t^m\right)^{-\frac{1}{\mu_t^m - 1}} + \xi_m \left(\left(\pi_{t-1}^m\right)^{\kappa_m} \bar{\pi}^{1-\kappa_m} P_t^m \right)^{-\frac{1}{\mu_t^m - 1}} \right]^{-\left(\mu_t^m - 1\right)} \tag{60}$$

$$P_t^f = \left[\left(1-\xi_f\right)\left(\tilde{P}_t^f\right)^{-\frac{1}{\mu_t^f - 1}} + \xi_f \left(\left(\pi_{t-1}^f\right)^{\kappa_f} \bar{\pi}^{1-\kappa_f} P_t^f \right)^{-\frac{1}{\mu_t^f - 1}} \right]^{-\left(\mu_t^f - 1\right)} \tag{61}$$

Combining the equations (26) and (27) in (25) we get the aggragate price of composite good:

$$P_t^h = \left[\left(1-\omega_h\right)\left(P_t^d\right)^{-\vartheta_h} + \omega_h \left(P_t^m\right)^{-\vartheta_h} \right]^{-\frac{1}{\vartheta_h}} \tag{62}$$

2.7 Market clearing condition

Finally to complete the model we define the market clearing conditions. Labor market:

$$L_t = \int_0^1 L_t\left(j\right) dj \tag{63}$$

Capital market:

$$K_t = \int_0^1 K_t\left(j\right) dj \tag{64}$$

In the domestic and import good markets, supply by the aggregators have to equal demand by the composite good firm:

$$Y_t^d = \left(1-\omega_h\right)\left(\frac{P_t^h}{P_t^d}\right)^{\vartheta_h+1} Y_t^h \tag{65}$$

$$Y_t^m = \omega_h \left(\frac{P_t^h}{P_t^m}\right)^{\vartheta_h+1} Y_t^h = M_t \tag{66}$$

In the final good market, supply by the private consumption, investment, government consumption and export good aggregators must equal demand by households, the government and the RW:

$$Y_t^c = C_t \tag{67}$$

$$Y_t^i = I_t \tag{68}$$

$$Y_t^g = G_t \tag{69}$$

$$Y_t^x = \left(\frac{P_t^*}{P_t} \right)^{\vartheta_* + 1} Y_t^* = X_t \tag{70}$$

Foreign bond market:

$$B_{t+1}^* - R_{t-1}^* \Phi\left(\ddot{b}_t^*; \varepsilon_{t-1}^{\phi} \right) B_t^* = P_t^x X_t - P_t^* M_t \tag{71}$$

Composite good market:

$$Y_t^h = Y_t^c + Y_t^i + Y_t^g + Y_t^x = C_t + I_t + G_t + X_t \tag{72}$$

Some useful identities

$$GDP = P_t C_t + P_t^i I_t + P_t^g G_t + P_t^x X_t - P_t^* M_t \tag{73}$$

2.8 Shocks

There were used twenty structural shocks in the model with the following univariate representation:

$$\xi_t^i = \left(1 - \rho_{\xi^i}\right) \bar{\xi}^i + \rho_{\xi^i} \xi_{t-1}^i + \eta_{\xi^i, t} \tag{74}$$

where $\eta_{\xi^i,t} : \ N\left(0, \sigma_{\xi^i}^2\right)$, $i = \left\{ \varepsilon^a, \varepsilon^l, \varepsilon^i, \varepsilon^c, \varepsilon^{\phi}, \bar{\pi}, \mu^d, \mu^c, \mu^i, \mu^g, \mu^m, \mu^x, \zeta, \zeta^*, \pi^*, r^*, y^*, \tau^c, \tau^l, G \right\}$

and $E\left(\xi_t^i\right) = .\bar{\xi}^i$. For $\left\{ \varepsilon^a, \varepsilon^l, \varepsilon^i, \varepsilon^c \right\}$ it is assumed that $\bar{\xi}^i = 1$

Chapter 3 - Empirical analysis

This chapter provides the empirical aspects related with the procedure used to obtain the posterior distribution of the structural parameters underlying model described in Chapter 2. Then the main estimation results will be presented. The model will be estimated using Bayesian methods.

3.1 Bayesian approach

In recent years, substantial improvements in computational technology has seen the use of Bayesian methods throughout the economics literature, especially in open economy DSGE modelling. Bayesian modellers recognize that " all models are false" , rather than assuming they are working with the correct model. This perspective contrasts with classical methods that search for the single model with the highest posterior probability given the evidence. Bayesian inference is in terms of probabilistic statements about unknown parameters rather than classical hypothesis testing procedures associated with notional repeated samples.

In the Bayesian context, all information about the parameter vector θ is contained in the posterior distribution. All information about μ from the data is conveyed through the likelihood: the likelihood principle always holds. For a particular model i, the posterior density of the model parameter θ can be written as:

$$p\left(\theta \setminus Y^{T}, i\right)=\frac{L\left(Y^{T} \setminus \theta, i\right) p(\theta \setminus i)}{\int L\left(Y^{T} \setminus \theta, i\right) p(\theta \setminus i) m\theta} \tag{75}$$

where $p(\theta \setminus i)$ is the prior density and $L\left(Y^{T} \setminus \theta, i\right)$ is the likelihood conditional on the observed data Y_t.[5] The likelihood function can be computed via the state-space representation of the model together with the measurement equation linking the observed data and the state vector. The model state-space representation will be:

$$S_{t+1} = \Gamma_1 S_t + \Gamma_2 w_{t+1} \tag{76}$$

$$Y_t = \Lambda S_t + \mu_t \tag{77}$$

where $S_t = \{x_t, y_t\}$ x_t and y_t is the equilibriums described by the matrices of the deep parameters, $Y_t is$ the vector of observed variables, μ_t is the measurement error, matrices Γ_1 and Γ_2 are functions of the model's deep parameters and Λ defines the relationship between the observed and state variables.

The likelihood function is computed under the assumption of normally distributed disturbances by combining the state-space representation implied by the solution of the linear rational expectations model and the Kalman filter. Posterior draws are obtained using Markov Chain Monte Carlo methods. After obtaining an approximation to the mode of the posterior, I rely on a Random Walk Metropolis algorithm to generate posterior draws, as discussed in Schorfheide (2000). Point estimates of θ can be obtained from the generated values by using various location measures, such as the mean or median. Similarly, measures of uncertainty follow from computing the percentiles of the draws.

3.2 Data

Data from 1995 Q1 to 2009 Q4 for Azerbaijan is used to compute the key steady state ratios of Azerbaijan economy taken from International Monetory Fond[6], International Labor

[5] For detailed information see Lui (2006)
[6]http://www.imfstatistics.org/imf/

Organization[7], The State Statistical Cometee of the Republic of Azerbaijan[8] and Central Bank of Azerbaijan[9] . To perform the estimation, I used quarterly data, over the same years.The choice of the period was conditioned by the fact that Azerbaijan macroeconomic series are unavailable and the series that are available for the estimation process have an extremely erroneous behaviour until 1995, which motivated me to take a sample starting from 1995. I chose to match the following set of thirteen variables: GDP infation, investment good infation, private consumption good inflation (including taxes), real GDP, real private consumption, real investment, employment, real exports, real imports, real wages, nominal interest rate, foreign real GDP and foreign nominal interest rate. All infation rates were obtained as the fourth order difference of the log of their respective deflator. Real wages were obtained by scaling nominal wages by the private consumption good deflator.

To render the data stationary, I applied an HP-filter with $\lambda = 1600$ as for usual quarterly data and used the detrended series instead of the original ones.The HP filter provided a reasonable treatment of the data. The correspondent time series of variables are shown in Figure 1.

3.3 Calibration

As commonly done in the DSGE literature, a number of parameters were calibrated from the outset, not being included in the estimation process. This procedure helps to deal with the problem of identification from which DSGE models commonly suffer, arising from the fact that the variables used in the estimation may contain little information about some of the parameters of interest. In small scale models this problem may be solved by carefully looking at each

[7]http://laborsta.ilo.org/
[8]http://www.azstat.org/index.php
[9]www.cbar.az

equation, but in medium or large-scale models (like in this case) this task is almost impossible. Furthermore, incorporating fixed parameters in the estimation process can be viewed as imposing a very strict prior, being therefore consistent with the Bayesian approach to estimation.

The parameters that were chosen to calibrate pertain mostly to three aspects: those crucial to determine the steady-state; those for which reliable estimates are available from other sources; and those whose values are crucial to replicate the main steady-state key ratios of the Azerbaijan economy.

Azerbaijan is a small open economy. Until now there has not been written any paper in this area. Therefore I had difficulties in choosing priors for estimation. As the starting point the priors for Azerbaijan was taken from the Almeida et al. (2009) according to the similarities in the macroeconomic indicators of the countries. Based on the prior means in Almeida et al. (2009) the private consumption good price stickiness parameter, ξ^{c}, was set at 0.6 and the inverse of the elasticity of labour supply, σ^{l}, at 2. The long-run annual inflation rate, $\bar{\pi}$ for Azerbaijan was set to 1.005 equal to euro area long-run annual inlation rate 2% which is the target of the Central Bank of the Azerbaijan[10]. The steady-state tax rates were set according to Almeida et al. (2009), where $\tau^{c} = 0.304$ and $\tau^{l} = 0.287.$ To match the sample mean of the empirical long-run annual investment to capital ratio of 8%, the depreciation rate δ is set to 0.015. The steady-state real GDP growth and inflation rate for Azerbaijan were assumed to be equal to the euro area average. So ζ was defined to be equal to $1.005.$ To produce a steady-state long-run nominal interest rate of 4.5%, in accordance with Christoffel et al. (2008) the discount rate β was set to 0.999. The habit persistence parameter, h, was calibrated at 0.65 and the import good price stickiness , ξ_{m}, at 0.5, as a parameters which used in Adolfson et al. (2007) . The steady-state government to

[10]Central Bank of Azerbaijan, 2010

domestic output ratio is $g_y = 0.14$ and the target debt to GDP ratio, $\left(\frac{\bar{b}}{gdp}\right)^{tar}$, was set at 60%, as in Almeida et al. (2009).

3.4 Priors

Bayesian inference starts out from a prior distribution of the model's non-calibrated parameters. Priors' density functions reflect our beliefs about parameter values. The Bayesian estimation technique allows us to use this prior information from earlier studies at both the macro and micro level. When the evidence is weak or nonexistent, I impose more diffuse priors. Table 1 depicts the prior distribution for each parameter, which mainly taken from Almeida et al. (2009) and Adolfson et al (2007).

The inverse gamma distribution was used for parameters that assumed to be positive, such as the standard deviations of shocks, the steady-state markups and the elasticities of substitution. The mean was set at 0.15 for most of the shocks, which is standard value in the macro literature. To ensure the success of the numerical optimisation of the posterior kernel the prior mean had to be set at a considerably low level, 0.02, for the remaining shocks. Based on Almeida et al. (2009) the standard deviations were all set equal to the means, which produced rather uninformative priors. The elasticitiy of substitution for Azerbaijan and RW were assumed prior means of 0.515 and standard deviations of 0.1 which are common values in the literature. The prior means for the steady-state markup values were set at 5% for the final goods, 25% for wages and 15% for domestic goods what were based on the calibration made in Almeida et al. (2009). Markup for import prices was considered 20%, which used in Adolfson et al (2007). The standard deviations for all of these priors were set at 0.1, what is usually used in the literature.

The beta distribution was defined for the parameters bounded between zero and one which include the shocks autoregressive parameters, stickiness and indexation parameters underlying the wage and price-setting decisions and the share of import goods in the production of the composite good. There was no a-priori strong information related with the autoregressive parameters. Therefore the priors were completely harmonised, with their mean set at 0.6. The wage and price Calvo probability prior means were set at 0.7, so that the average contract duration is 3 quarters and one month, which is a simple average of the values implied in the calibration made in Almeida et al. (2009). All prior means for the indexation parameters were set at 0.5, in line with Adolfson et al (2007), and standard errors at 0.1. The prior mean for the share of import good in the composite good's production was set at 0.4, as in Almeida et al.(2009). The standard deviation of all these parameters was set at 0.1, which is in line with what is usually assumed in the DSGE literature.

Finally, a normal distribution was defined for the investment adjustment cost parameter, which is not upper bounded. The prior's mean and standard deviation were set at 7.6 and 1.5, respectively, based on Adolfson et al (2007).

3.5 Estimation Results

In addition to the prior distribution, Table 1 reports two sets of results regarding the parameter estimates. The estimated posterior mode of the parameters, which is obtained by directly maximising the log of the posterior distribution with respect to the parameters, and an approximate standard error based on the corresponding Hessian were defined in the first set. The second set reports the mean and 5 and 95 percentile of the posterior distribution of the parameters obtained through the Metropolis-Hastings sampling algorithm. The latter is based on 500000 draws with 5 distinct chains. Figures 2-8 summarises this information by plotting the prior distribution and the posterior distribution. As it is visible for the majority of the parameters, the prior and posterior distributions are reasonably distinct which indicates that the observed data does provide additional information for most parameters. Therefore, the obtained results are not solely "prior driven". This is particularly true for the parameters governing the persistence and volatility of shocks, which is usual in DSGE models. There are some exceptions such as the private consumption, investment, government consumption, import and export goods markups, together with the wages and domestic goods indexation parameter, whose posterior distributions are essentially equal to their respective priors. Related with the shape of the posteriors, it is visible that except the wage markup all they are approximately normal which is in line with the asymptotic properties of Bayesian estimation. Such distribution of wage markup can be explained by the fact that the most of the firms in Azerbaijan report loer wages than the real.

Overall, most parameters are estimated significantly different from zero. I start the analysis with the markups' steady-state values. As in Almeida et al (2009) the prior conviction of low markups in the final goods sector seems to be confirmed by the data not only for investment, μ^i, government consumption, μ^g and export goods, μ^x, but also for private consumption good, μ^c, and import goods sector, μ^m. The posterior mean for these parameters is close to one, indicating a high degree of competition in these markets. However, the markups for the wages and domestic goods are estimated to be 397% and 384%, respectively, which seem unreasonable values. Note however that the Azerbaijan labour market is suffer from a deep lack of competition and therefore these results, although implausibly high, seem to go in the right direction. As in Almeida et al. (2009) I also get the elasticity of substitution between domestic and import goods is close to 0.3 and the "quasi-share" of import goods is 18%which can be explained with relatively low share of import goods in final goods' production, but results for these parameters Azerbaijan are better. The elasticity of substitution between foreign products and the domestic ones is equal to 0.33. Although the parameter is below the assumed one for the prior distribution, the model matches the prior distribution for Azerbaijan better than for the Portugal.

The investment adjustment cost parameter is estimated to be equal to 2.8, which less than the value commonly found in the literature. If we look at the Calvo stickiness parameters, it is visible that prices in the government consumption and domestic goods markets are less sticky, with average durations of price contracts close to 2 and 1.5 quarters respectively. In spite of the Almeida et al (2009) wage contracts are more flexible than the domestic good prices, being renegotiated every 1.4 quarters. The greater stickiness in wages relative to prices is counterintuitive as in Smets and Wouters (2002).

According to the estimation, the results suggest that inflation persistence is the highest for consumption good prices, around 57%, and the lowest for import prices, around 38%. The wage indexation is 51%. The indexation parameters found in this model are less than in Smets and Wouters (2002) but more than the results obtained in Almeida et al. (2009).

Finally, I consider the persistency and volatility parameters of structural shocks. As in Almeida et al. (2009) the lowest and highest autoregressive parameters are estimated for the import goods price markup,0.49 and foreign output shock, 0.82, but the interval for this model is 0.33 compare with the one in Almeida et al. (2009), 0.53 which is 1.6 times less and indicates more exact estimation. As the posterior distribution's 95 percentile does not exceed 0.90 for any of the shocks none of the shocks is excessively persistent, which mean there are no unit roots in these processes. Compared to the closed economy model of Smets and Wouters (2003), my estimates are considerably lower, while when compared to the open economy model of Adolfson et al (2007) estimates are higher for process and the same for wages. This can be explained by the extra possibility of propagation of shocks hitting the economy in the open economy. If we look at the estimated standard deviations, we see that as in Almeida et al (2009) the markups shocks in the final goods markets in the model are more volatile than those concerning to foreign output and interest rate markets. And I have to note that the appropriate shocks are more volatile for the

Azerbaijan than for the Portuguese economy. This parameter uncertainty can be explained as more uncertainties in the developing Azerbaijan economy compare with the developed the Portuguese economy.

If we look at the diagnosis concerning the numerical maximisation of the posterior kernel in Figures 12 -22, we see that overall they indicate that the optimisation procedure was able to precisely obtain a robust maximum for the posterior kernel. Analysing the results for each parameter individually, we observe that most of the parameters do not in fact exhibit convergence problems, notwithstanding the fact that for some of them this evidence is stronger than for others. All the information can be summarised in three graphs in Figure 9: the parameter mean (designated interval), the parameter variance (designated m2) and the parameter third moment (designated m3). For results to be sensible, both lines, for each of the three measures, must become relatively constant and converge to each other. It is visible that for all the three moments, both within and between chains overall convergence was achieved.

3.6 Sensitivity Analysis

In this section I will make a sensitivity analysis to assess the importance of the different frictions, shocks and priors in the model. The relative model comparison is carried out using the marginal likelihood. Table 2 shows sensitivity analysis with respect to frictions when some of the nominal and real frictions in the model are turned off. The columns show the results of the estimated parameter when: 1) there is no wage stickiness, 2) there is no price stickiness, 3) there is no habit formation, 4) there is no investment adjustment cost. As it is visible form Table 2 all frictions play an important role in the model, especially price stickiness and investment adjustment costs are important. Therefore it is not surprising that most of the parameters governing the role of nominal and real frictions are far from zero.

The role of various shocks in the model was examined in Table 3. The shocks were shut down systematically and the impact on the estimated parameters (posterior mode) and the marginal likelihood were given in the table. What is clear from this analysis is that when considering the relatively large set of observable variables all shocks appear to matter, but in particular I find that technology shocks, the markup shocks for final, import and export goods and consumption goods shocks are the most important. It is also visible from Table 3 that the fiscal policy and risk premium shocks are not very important for the empirical performance of the model, suggesting that more work is needed to incorporate fiscal policy and risk premium shocks in a more realistic way than what was done in this paper. This might be an interesting avenue for future research.

In Table 4 to assess the sensitivity of the results of the assumed priors I changed the priors in two ways and re-estimated the model. In the table Model I was given as a benchmark. In Model II, I increased all prior means and standard deviations by 10%. Comparing the obtained results with those of the benchmark model, it is visible that the majority of the estimates did not changed substantially as in Almeida(2009). In Model III, I kept the prior means unchanged and increased substantially the prior standard deviations, with increases ranging from 20%. Although results changed more compare with the results in Model II, the overall conclusions remained the same for most of the parameters as in the benchmark model. Therefore it can be concluded that for reasonable changes in the values of the priors mean and standard deviation, quantitative results are somewhat sensible but the overall qualitative results are quite robust.

3.7 Impulse Response Analysis

Based on the impulse functions of estimated shock in the baseline model we can say that all the model's variables return to their steady-state value, maintaining the conclusion given by the Blanchard-Kahn and rank conditions that the model is indeed stable. However due to lack of the space not all IRF were given in the paper. Generally, results seem to make sense from an economic point of view but my objective is not analyse the economy's IRF's to each of the shocks. So following the results from previous section I took the shocks which are important and analysed the results for the stationary technology shock and consumption good which are described in Figures 10 and 11.

Figure 10 shows that the positive technology shock has an expansionary effect in the economy, GDP, consumption, investment, wages and export rise, while employment, real interest rates and import falls. Due to the rise in productivity, the production cost falls on impact which leads to decrease of inflation. The employment is also decreasing due to positive technology shock. Experienced decline in employment increases the wages which increases the private consumption. Additional demand and the cost pressure created by the wages increase the inflation. As the nominal interest rate is fixed, growth in inflation leads the real interest rate decrease which by the leads increase in the investment. Decrease in the inflation at the beginning of the positive technology shock decreases the prices of the domestic goods relative to the foreign goods what is the reason of the growth in the export and decline in the import. But later the inflation increases, become positive and export starts to decrease and import starts to increase.

The consumption shock accounts for a substantial amount of the cyclical behaviour of consumption as can be seen from Figure 11. Quite naturally, investment drops while households increase their labour effort in order to finance the desired increase in consumption. The habit persistence generates the hump-shaped consumption response. Increase in labor supply increase the output and decrease the wage rate. Decreased wage and investment leads to decrease in inflation rate. As a result of a decrease in investments the real interest rate increases. Increasing consumption decreases the export and increases the import which changes to opposite direction after the consumption starts to decrease. When households start to consume less parallel they work less than before due to substitution effect. Therefore, wages and investment decrease approximately until 4th period after which it starts to increase increasing the inflation. Due to increasing investment the real interest rate also gradually decreases.

Conclusions and directions for further work

In this paper, the New-Keynesian DSGE model was developed and estimated for the Azerbaijan economy, using Bayesian techniques. Generally the results are suffivient and come from the nature of the economy.

DSGE models are currently a central piece of macroeconometric modelling being used in most policy making and academic institutions. Among the several techniques used to estimate these models, the Bayesian approach has emerged as the most fruitful one and has been widely adopted in the most recent years. Despite the importance assumed by these topics in modern macroeconometrics, no attempt had yet been made (to the best of my knowledge) to explore them for the Azerbaijan economy, which was certainly a major flaw in the modelling of the country's macroeconomic fluctuations. I consider my work to be a first step in filling out this gap and hope that it can contribute to a new strategy in modelling Azerbaijan's business cycle, in line with the one already in use in many countries.

The estimation results of the model are generally satisfactory. The diagnostic measures seem to indicate that the estimation is robust in the majority of its fields, in particular in what concerns the quality of the numerical posterior kernel maximisation and the convergence of the MH algorithm. The data seems to be reasonably informative about most of the parameters and the model fit the observed data quite good. The obtained estimates for the parameters of interest are generally in line with the available literature and, in most cases, seem to make sense from an economic point of view. Among them some are particularly noteworthy. Firstly, the finding of low markups in the final goods sector indicates a high degree of competition in these markets, while the opposite seems to occur in the labour and intermediate goods sectors, which is in line with Almeida et al. (2009). Secondly, wage and price stickiness are low with average contract durations of 1.4 and 1.5 quarters, respectively, which comes from nature of the economy. Thirdly, the share of import goods in the production of final goods sector is less than 1% which explained by the type of the final goods produced in Azerbaijan as it consist mainly from raw materials, agricultural products and low technology products. But mainly high technology products were imported to the country which is mainly directed to the consumption not to production. Fourthly, all prices exhibit a considerable degree of indexation to past inflation, especially consumption goods and wages, which seem to be considerably backward looking. Comparably high wage indexation seems logical for the labour market, since wage negotiations usually take into account on past inflation developments. Finally, fiscal policy and risk premium shocks are not very important for the model, suggesting that more work is needed in this direction to get a more realistic results.

I also conduct an extensive test for the role of various shocks included in the model. According to the estimated model, many shocks matter for the fluctuations in the endogenous variables. Consumption, import and export markup shocks are important for output fluctuations shocks. For inflation, I find that markup shocks and inflation target shocks are most prominent, but there is a clear role of consumption tax shocks as well. The real interest rate in the model is mostly driven by import and export markup shocks.

However, there were several problems in the estimation. First, difficulties in the treatment of the data obliged me to use filtered data, which is recognised to be subject to caveats. Based on the diagnostic measures I can say that some parameters appearing to be estimated in a poorer than others, especially, in the case of the wages, domestic good price markups and investment adjustment cost. The results for the first two parameters are implausibly high and for investment adjustment cost too low. Furthermore, although the data was informative in the majority of the cases, some estimates seemed to be reasonably influenced by the chosen priors, an influence that ideally should be as small as possible. Finally, it was not possible to estimate all major model parameters robustly, which indicates some deficiencies of the model calibration.

The existence of these caveats indicates that the analysis needs to be further improved in a number of dimensions. Their importance is, however, as in any estimation procedure, difficult to assess. I believe that the balance is certainly positive and consider that my work has shown that the estimation of a New-Keynesian DSGE model for Azerbaijan, using Bayesian techniques, can provide useful insights into the characteristics of the Azerbaijan economy and an empirically valid tool for the modelling of Azerbaijan macroeconomic fluctuations.

In the future, I would like to consider some additional aspects not covered in this study, to further enhance the possibilities surrounding the estimation of a New-Keynesian DSGE model for the Azerbaijan economy and hopefully overcome some of the caveats I encountered in this work. In particular, I would like to re-estimate the model using unfiltered data to check the robustness of my results and possibly obtain reliable estimates for the parameters that I have not been able to estimate.

In fact, strong and sustained rise in oil prices observed in recent years poses a challenge to monetary policy and its ability to simultaneously to achieve low inflation and stable output. Therefore I consider that it would be interesting to model the oil-price endogenously within a DSGE framework which plays an important role in Azerbaijan economy and look at the effects of an oil price shock to the economy.

Finally, I would like the consider the DSGE-VAR approach explored in Del Negro and Schorfheide (2004) and Del Negro et al. (2005), which seems to be one of the most promising ways of bringing stylised macroeconomic models to the data.

References

(2010). Main direction of the Monetary Policy of Central Bank of Azerbaijan, Central Bank of Azerbaijan.

Abel, A. (1990). "Asset prices under habit formation and catching up with the joneses." The American Economic Review.

Adolfson, M., Laseen, S., Linde, J. and Villani, M. (2005). "Bayesian estimation of an open economy DSGE model with incomplete pass-through." Sveriges Riksbank - working papers series.

Adolfson, M., Laseen, S., Linde, J. and Villani, M. (2007). "Evaluating an estimated new keynesian small open economy model." Sveriges Riksbank - working papers series.

Alejandro Justiniano, B. P. (2004). "Small Open Economy DSGE Models: Specifcation, Estimation and Model Fit."

Buncic, D. a. M., Martin (2007). "An estimated New Keynesian policy model for Australia." Munich Personal RePEc Archive.

Calvo, G. (1983). "Staggered prices in a utility-maximising framework." Journal of Monetary Economics.

Christiaan Heji, P. d. B., Philip Hans Franses, Teun Kloek, Herman K. van Dijk (2004). Econometric Methods with Applications in Business Economics. Rotterdam, Oxford University Press Inc. , New York.

Christiano, L., Eichenbaum, M. and Evans, C. (2005). "Nominal rigiditis and the dynamic effects of a shock to monetary policy." Journal of Political Economy.

Christoffel, K., Coenen, G. and Warne, A. (2008). "The new area-wide model of the euro area: a micro-founded open-economy model for forecasting and policy analysis." European Central Bank - working papers series.

DeJong, D., Ingram, B. and Whiteman, C. (2000). "A bayesian approach to dynamic macroeconomics."

Eldar Ismailov, M. E., Jannatkhan Eyvazov, Abbas Maleki, Ainura Elebaeva, Ariel Cohen, Vitaly Naumkin (2007). Central Eurasia. Sweden, CA&CC Press.

Əliyev, Ü. (2008). Keçid dovünün milli iqtisadi problmləri. Baki, İqtisad Universiteti nəşriyyatı.

Erceg, C., Henderson, D. and Levin, A. (2000). "Optimal monetary policy with staggered wage and price contracts." Journal of Monetary Economics.

Feizi, M. (2008). "A new Keynesian Small Open Economy DSGE Model in Islamic Economic Framework: The Case of Iran." Journal of Economic Literature.

Frank Smets, R. W. (2002) An Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area.

Fritz Breuss, K. R. (2008). "An estimated two-country DSGE model of Austria and the Euro area."

Gary Koop, D. J. P., Justin L. Tobias (2007). Bayesian Econometric Methods. New York, Cambridge University press.

Giancarlo Corsetti, L. D., Sylvain Leduc (2005). "DSGE Models of High Exchange-Rate Volatility and Low Pass-Through."

Giles, D. E. A. (2003). Computer_Aided Econometrics. New York, Marcel Dekker Inc.

Haider, A. a. K., Safdar Ullah (2008). "A Small Open Economy DSGE Model for Pakistan."

Ida Wolden Bache, L. B., Junior Maih (2008). "Estimating a DSGE model for Norway with optimal monetary policy."

Kai Philipp Christoffel, G. C., Anders Warne (2008). The New Area-Wide Model of the Euro Area: A Micro-Founded Open-Economy Model for Forecasting and Policy Analysis European Central Bank - working paper series.

Kilponen, J. a. R., A. (2006). "Labour and product market competition in a small open economy: simulation results using a DGE model of the Finnish economy." Bank of Finland - Discussion papers series.

King, R. (1991). "Money and business cycles." Federal Reserve Bank of San Francisco - Proceedings.

Kydland, F. a. P., E. (1982). "Time to build and aggregate fluctuations." Econometrica.

Lancaster, T. (2004). An introduction to modern Bayesian Econometrics. Padstow, Blackwell Publishing.

Liu, P. (2006). "A Small New Keynesian Model of the New Zealand Economy."

Malin Adolfson, S. L., Jesper Lind and Mattias Villani (2005). "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through."

Mehdiyev, R. (2008). Defining the strategy of tomorrow:cporse towards modernization. Baku, "Şərq-Qərb" mətbəəsi.

Olekah, J. K. A. (2007). "Estimating a DSGE Model of Nigerian Economy."

Rabanal, P. a. R.-R., J. (2005). "Comparing new keynesian models of the business cycle: a bayesian approach." Journal of Monetary Economics.

Robert G. King, M. B. (1995) Measuring Business Cycles Approximate Band-Pass Filters for Economic Time Series.

Rotemberg, J. a. W., M. (1995). "Dynamic general equilibrium models with imperfectly competitive product markets." National Bureau of Economic Research - working papers series.

Sungbae An, F. S. (2007). "Bayesian Analysis of DSGE Model." Econometric Reviews.

Thomas Lubik, F. S. (2005). "A Bayesian Look at New Open Economy Macroeconomics."

Appendices

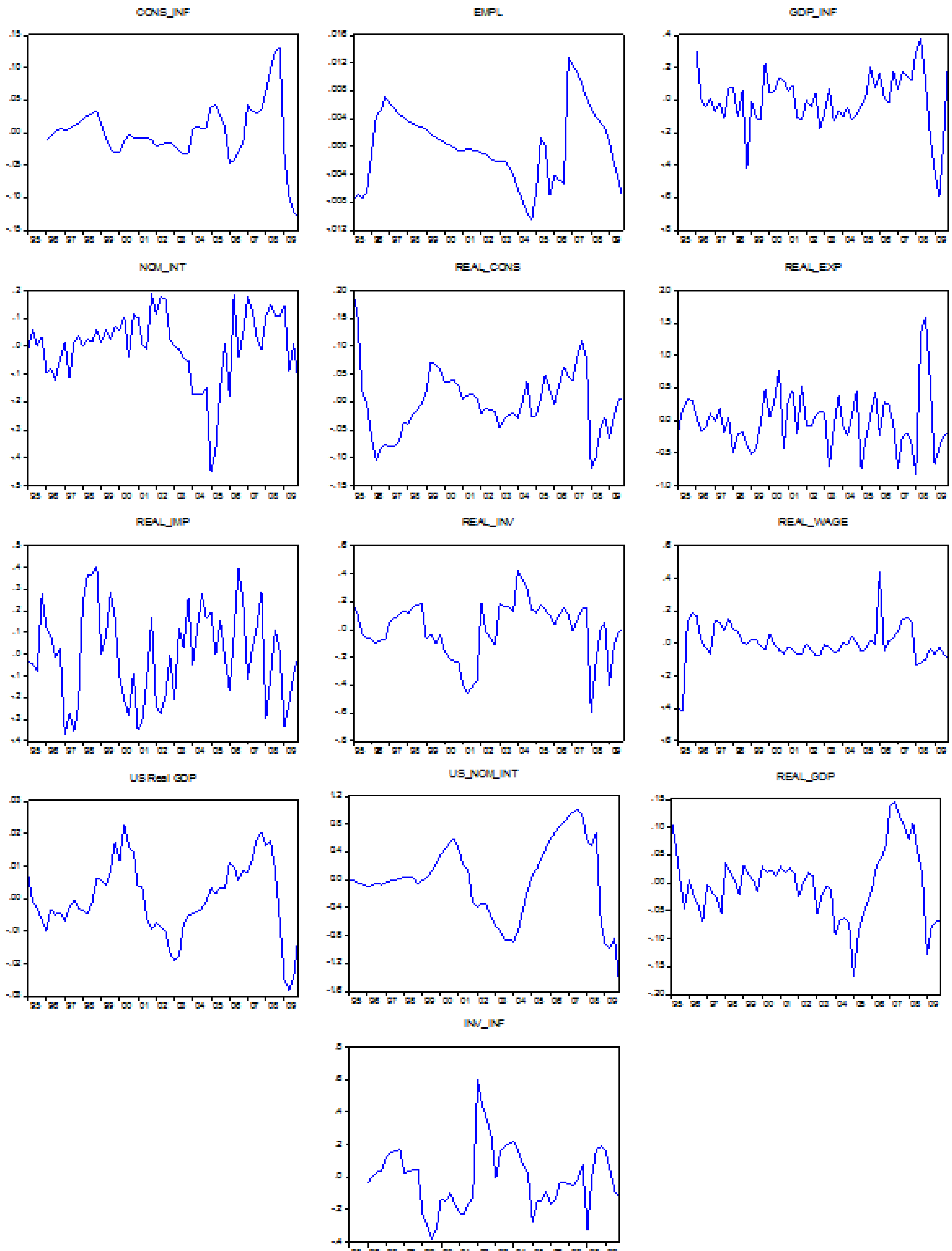


Figure 1: Data

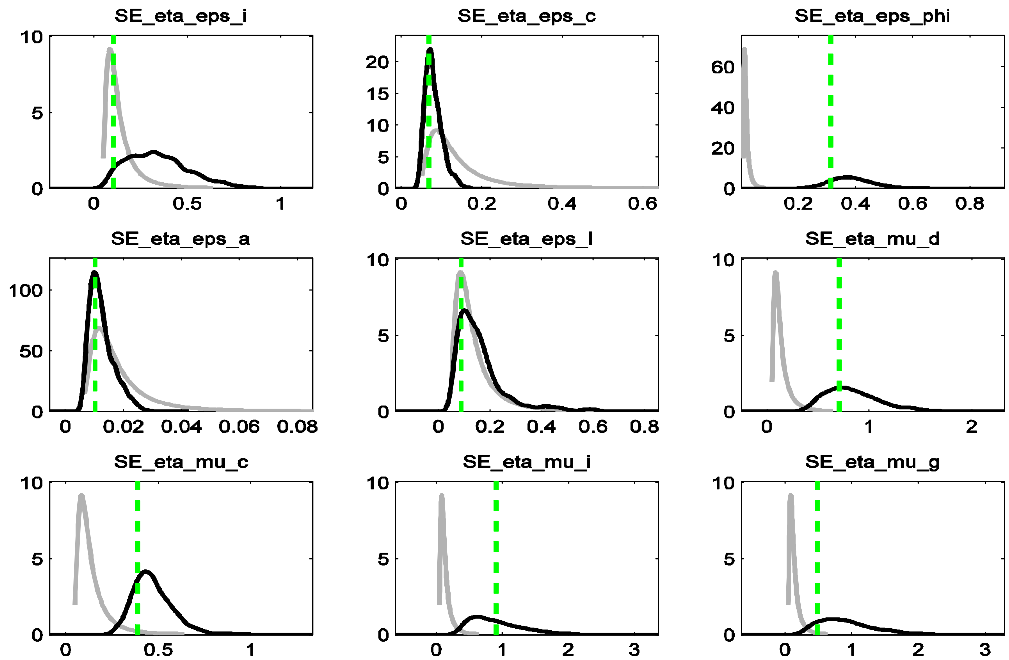


Figure 2: Priors and posteriors of estimated parameters

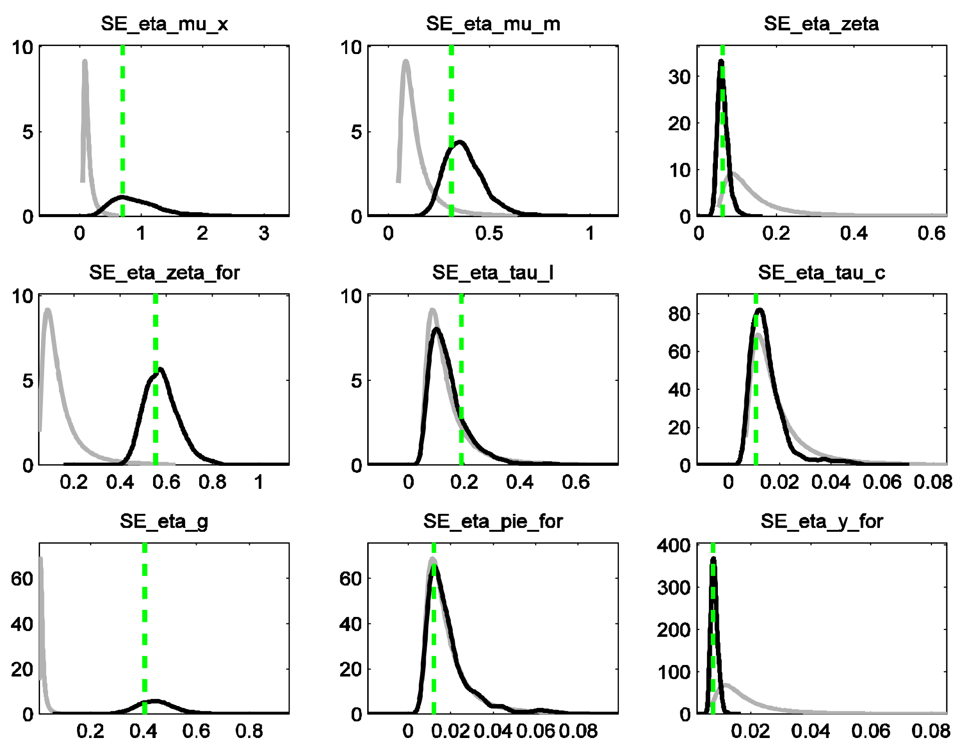


Figure 3: Priors and posteriors of estimated parameters

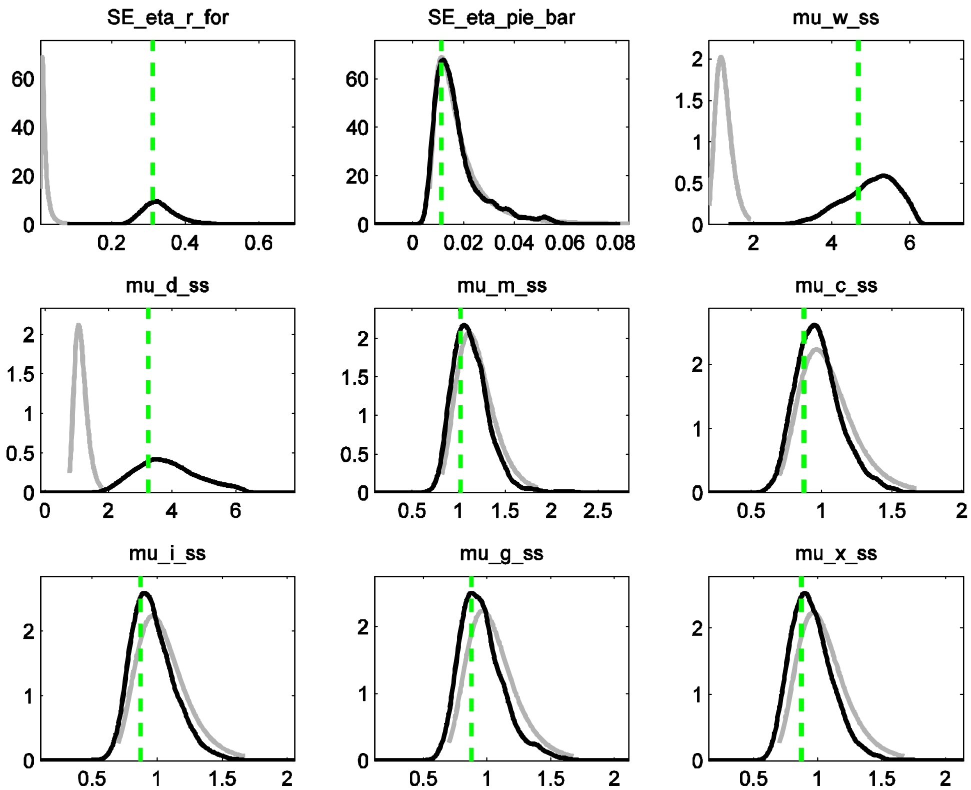


Figure 4: Priors and posteriors of estimated parameters

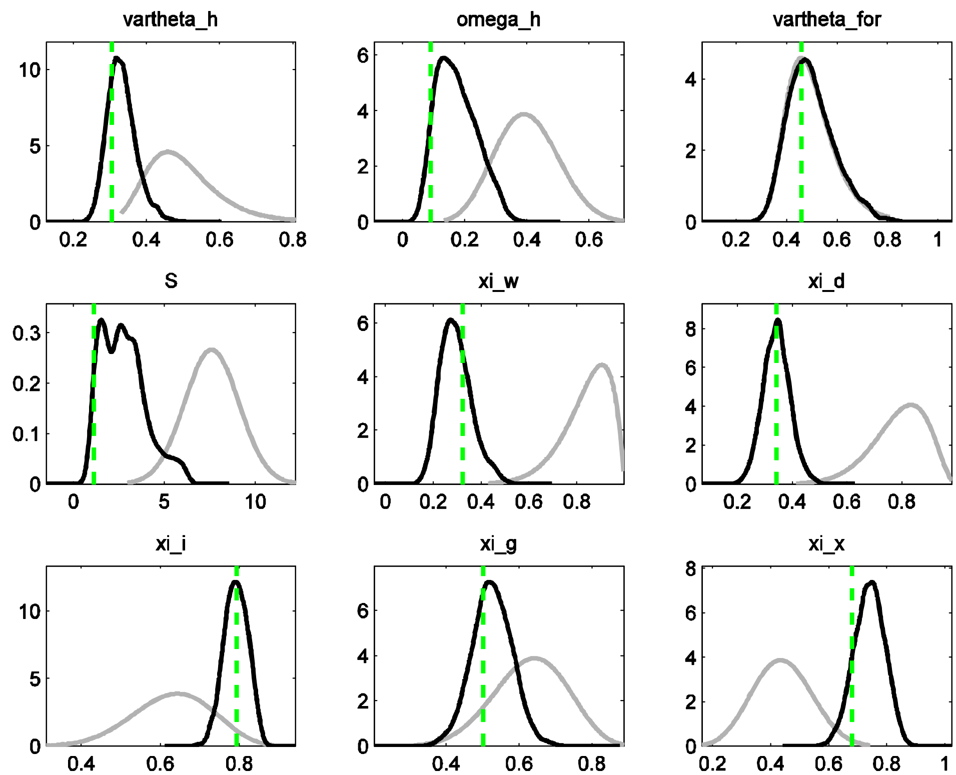


Figure 5: Priors and posteriors of estimated parameters

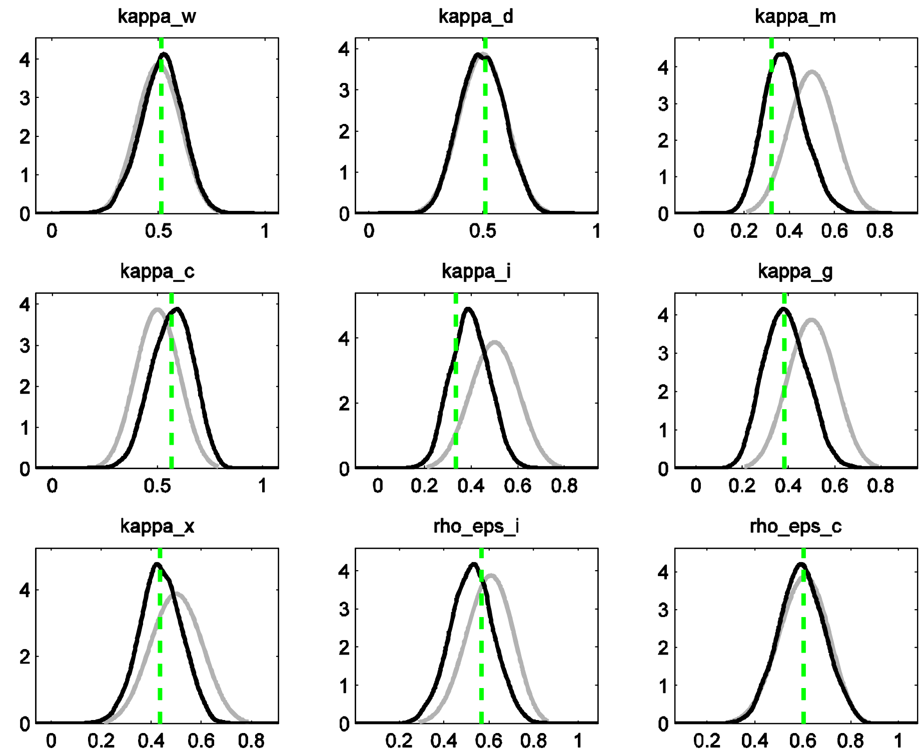


Figure 6: Priors and posteriors of estimated parameters

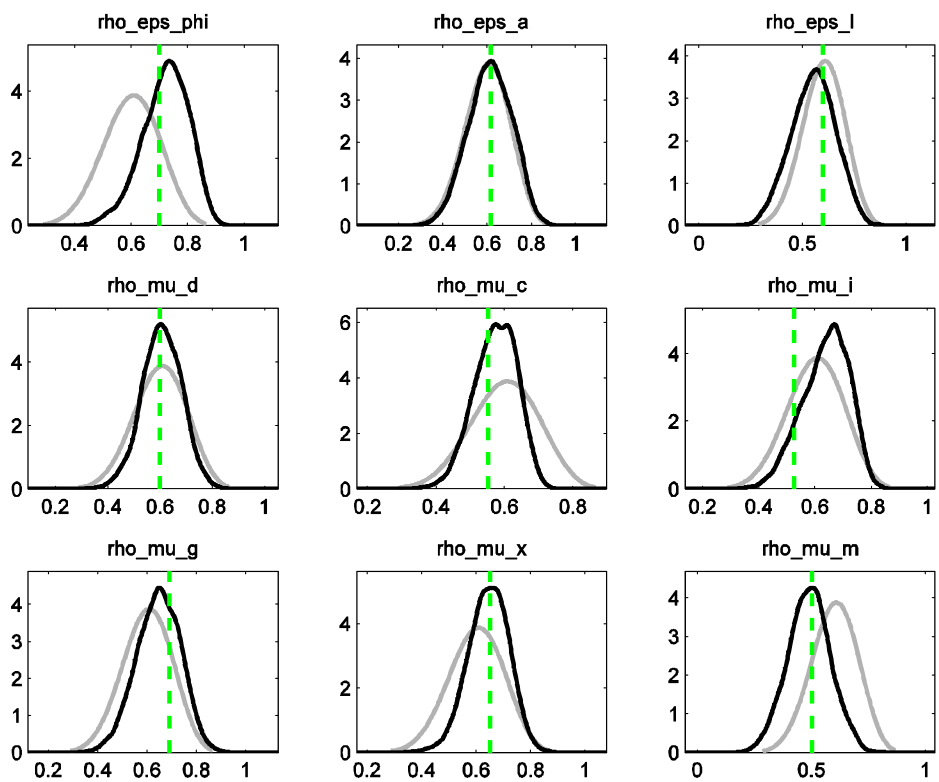


Figure 7: Priors and posteriors of estimated parameters

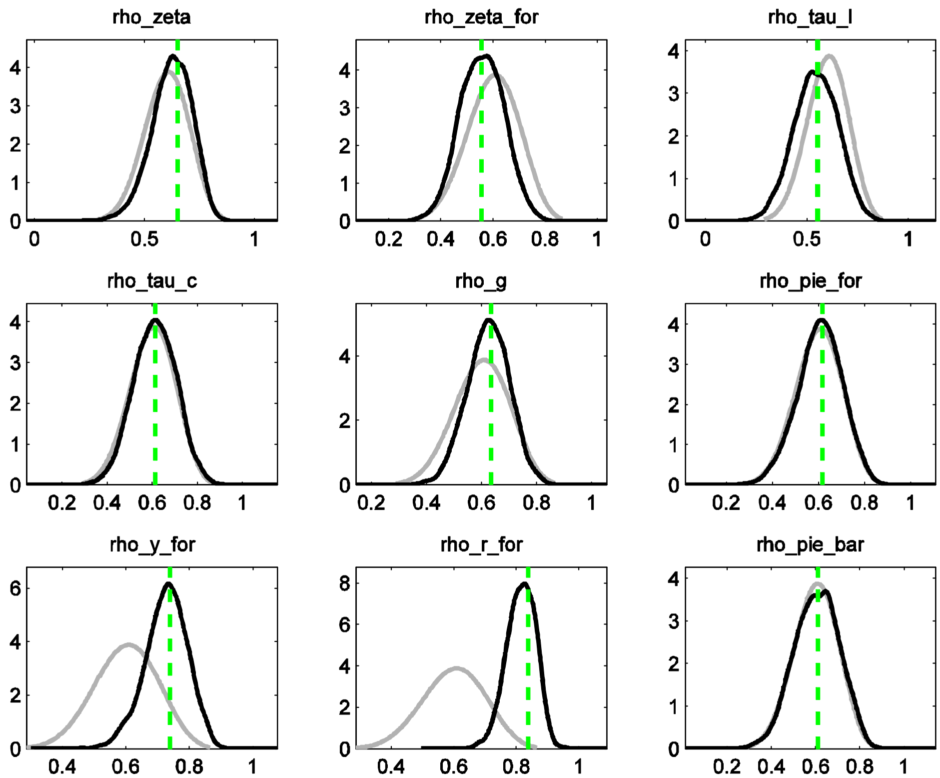


Figure 8: Priors and posteriors of estimated parameters

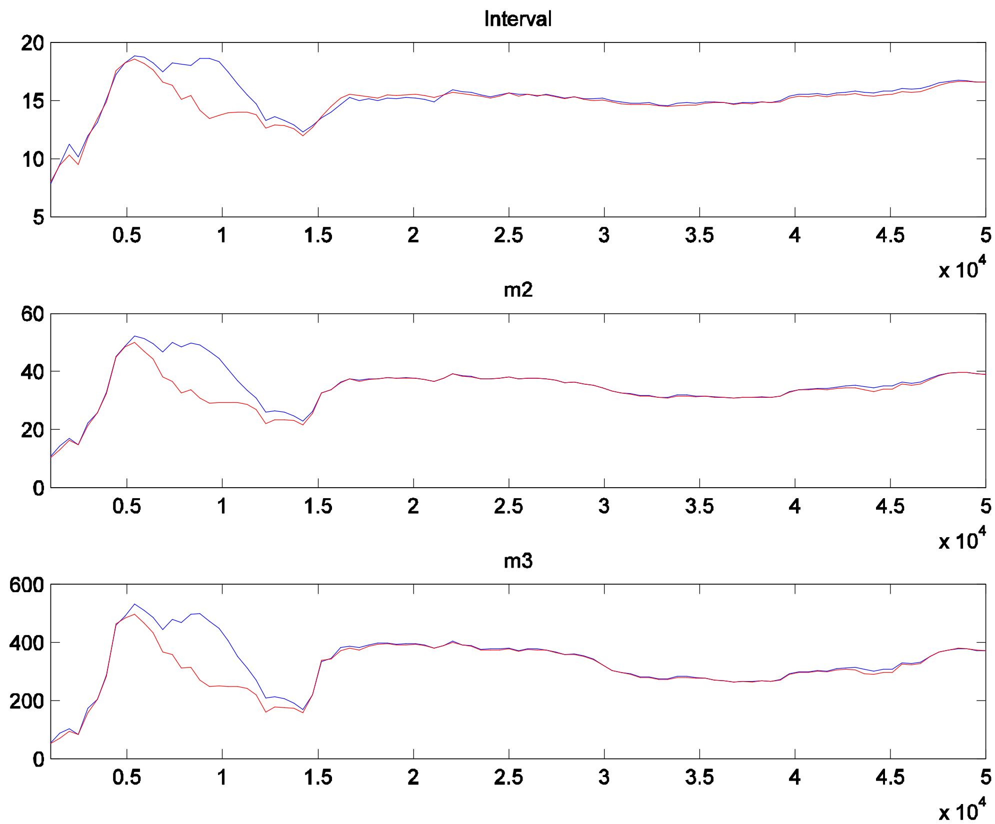


Figure 9: Multivariate MH convergence diagnosis

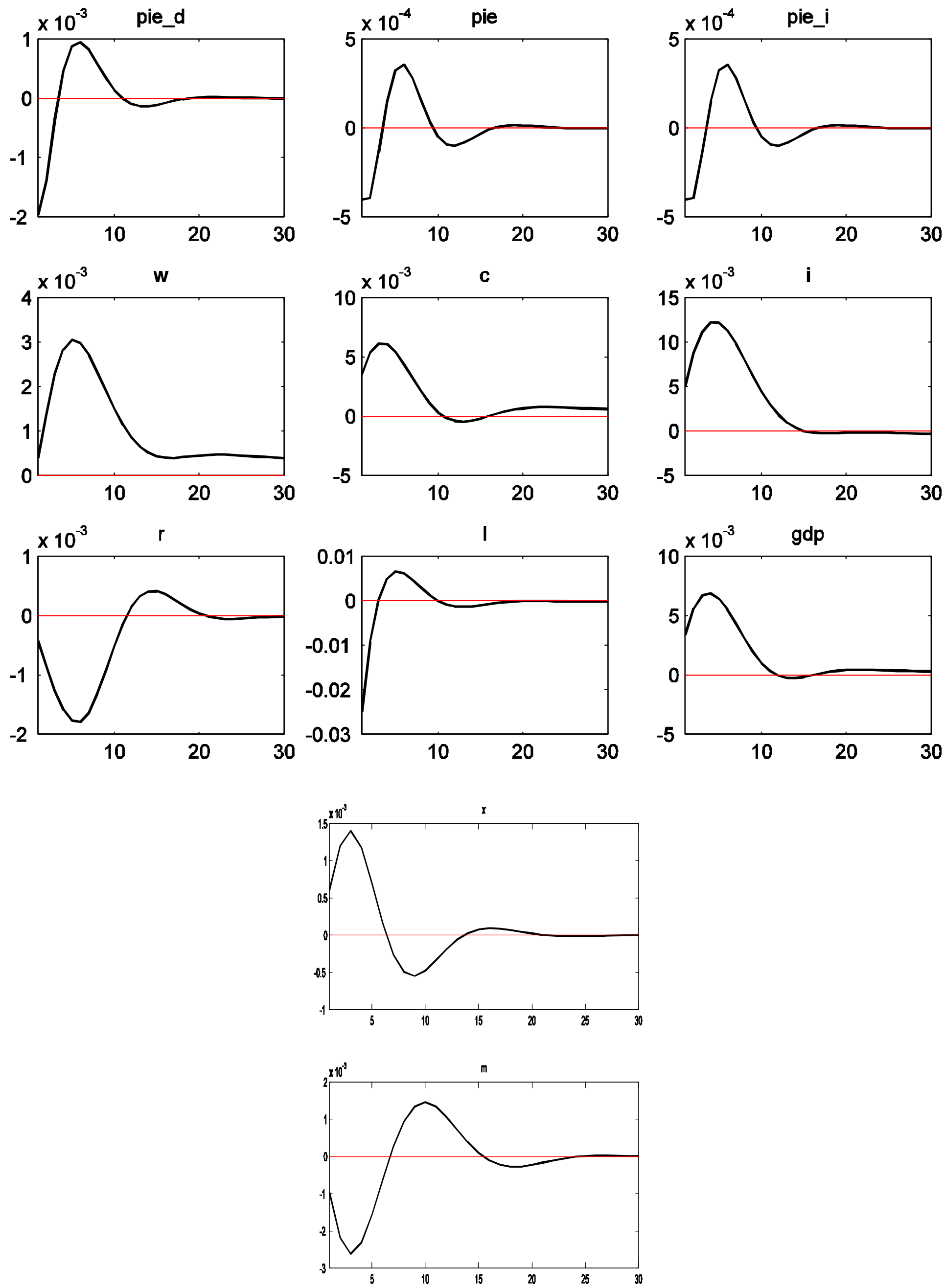


Figure 10: Impulse response to technology shock

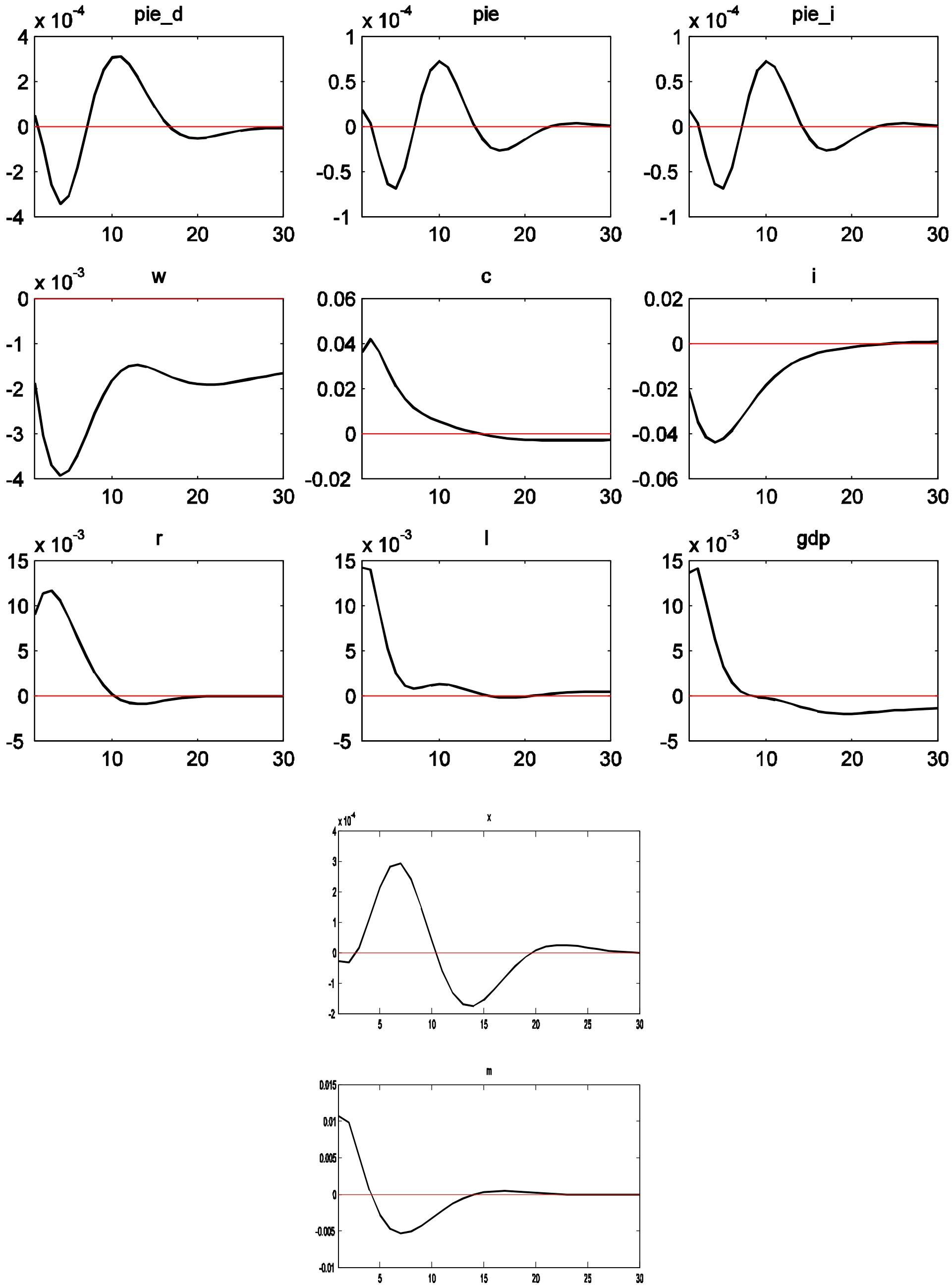


Figure 11: Impulse response to consumption shock

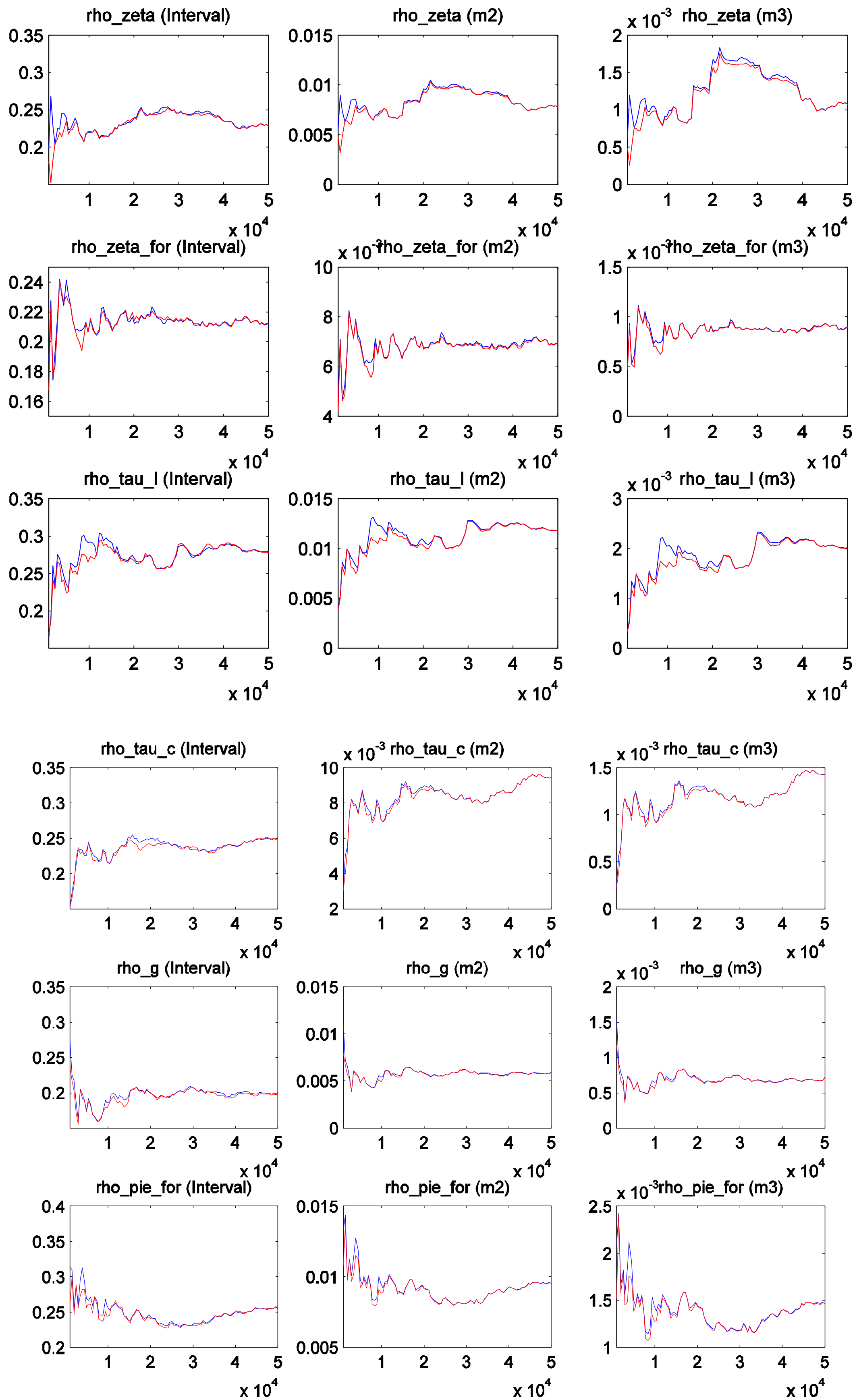


Figure 12: Univariate MH convergence diagnosis

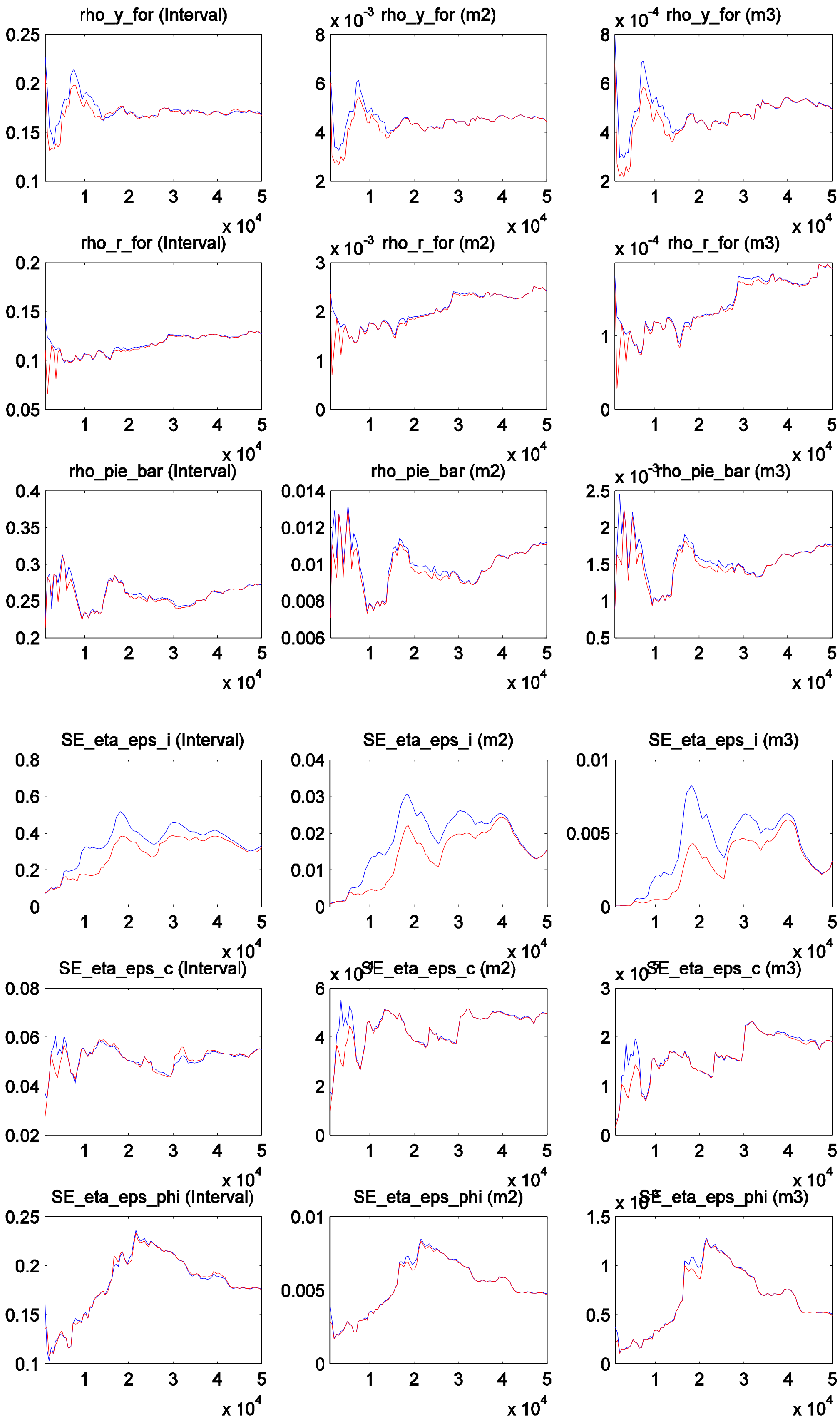


Figure 13: Univariate MH convergence diagnosis (cont.)

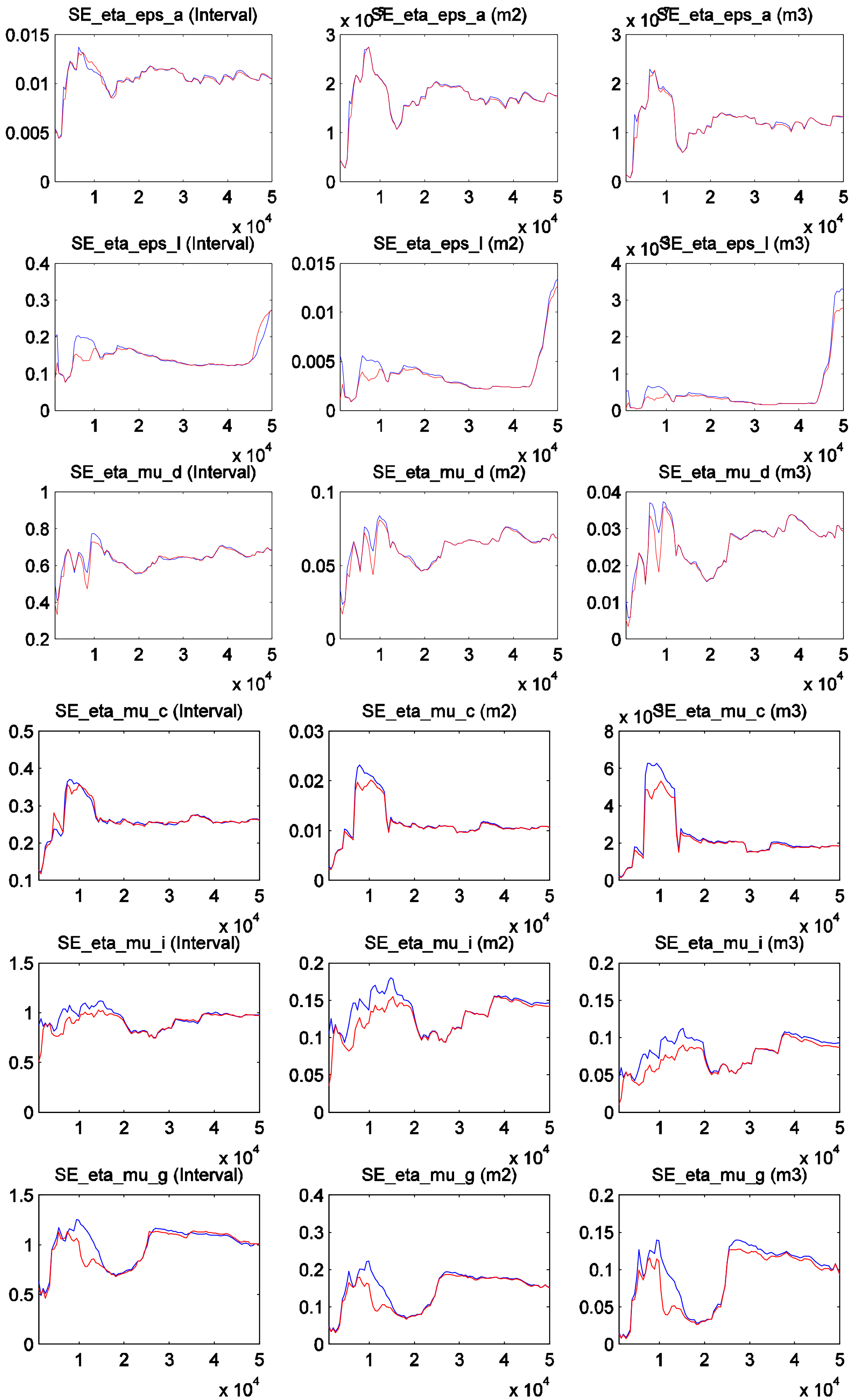
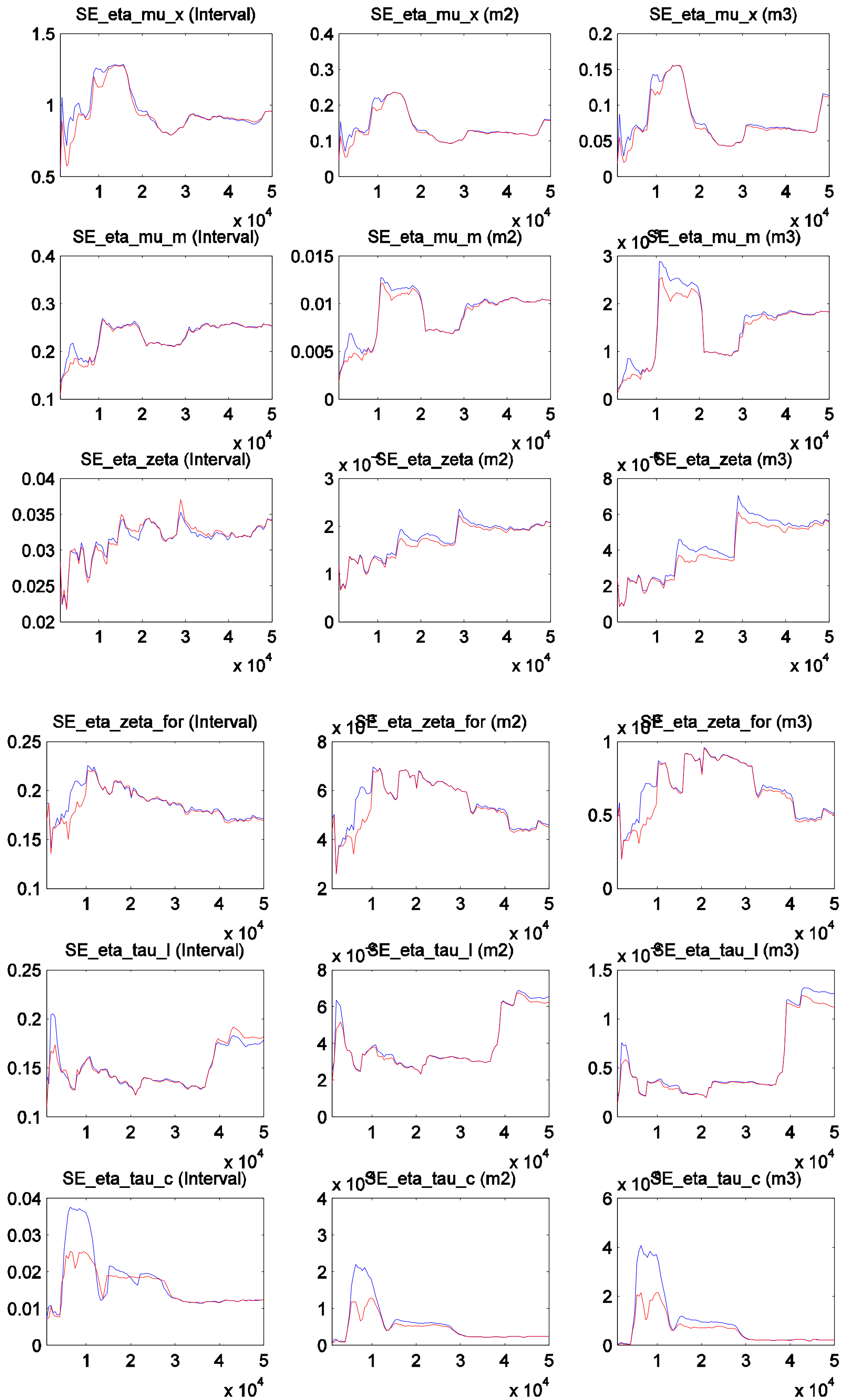


Figure 14:Univariate MH convergence diagnosis (cont.)



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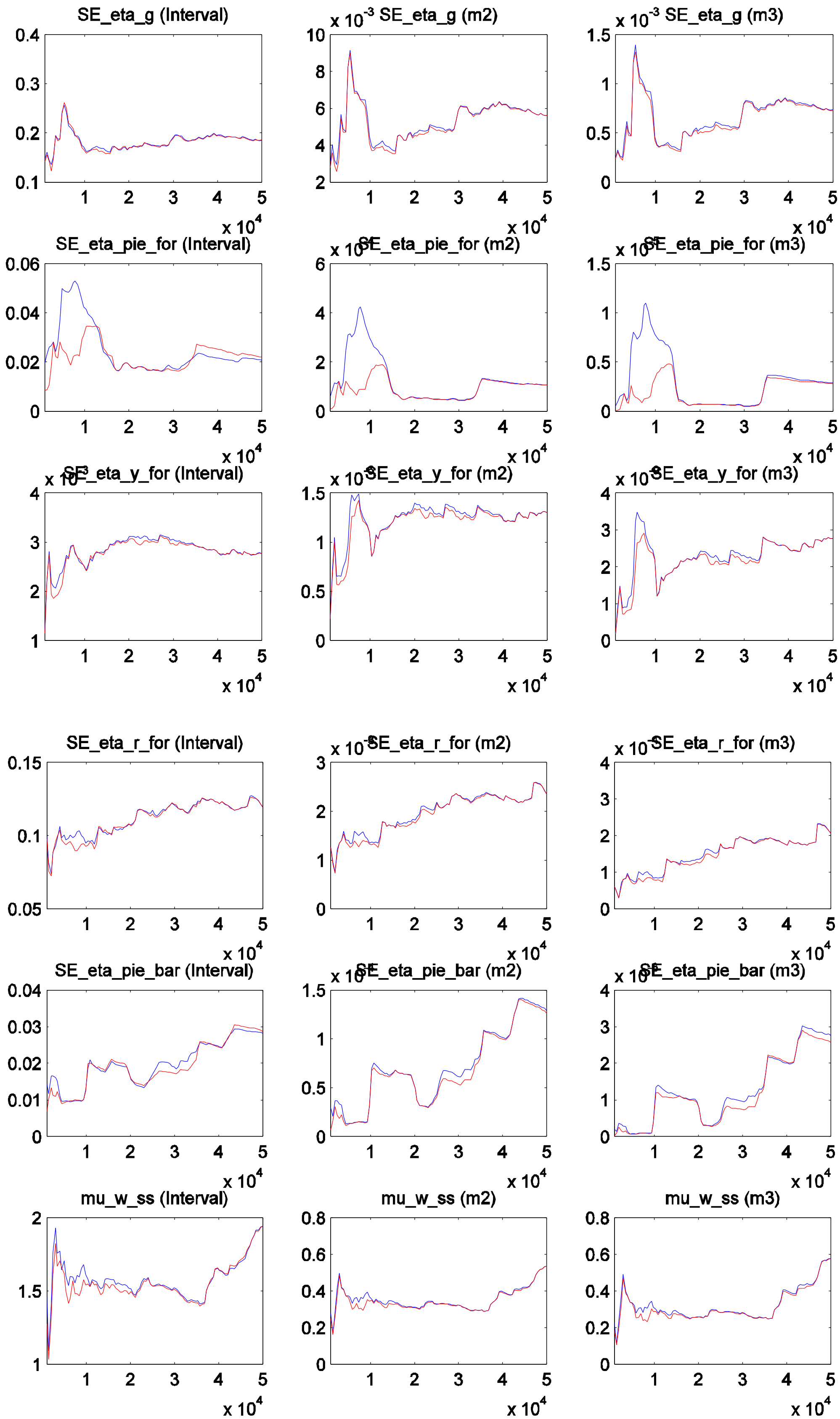

Figure 16:Univariate MH convergence diagnosis (cont.)

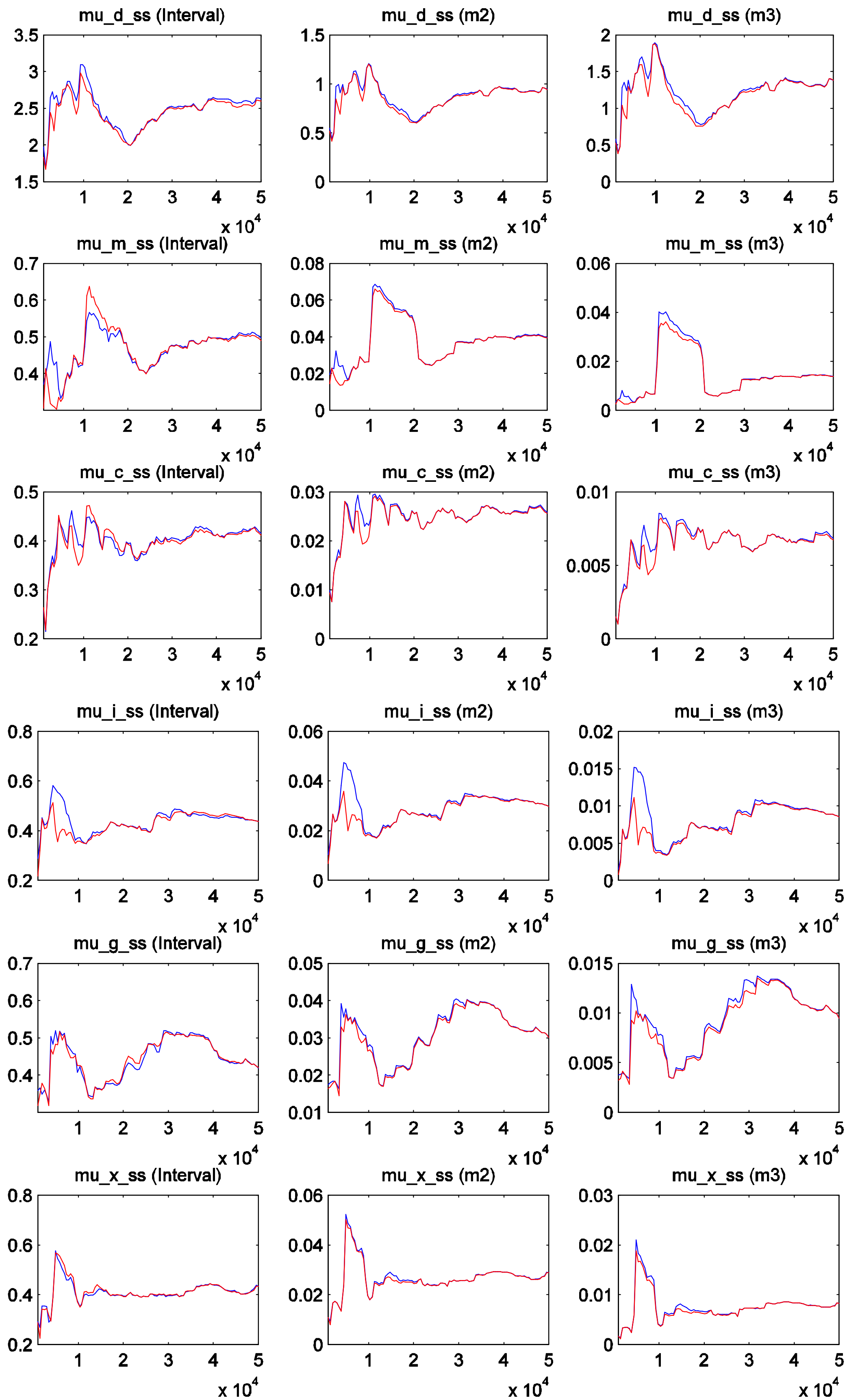

Figure 17: Univariate MH convergence diagnosis (cont.)

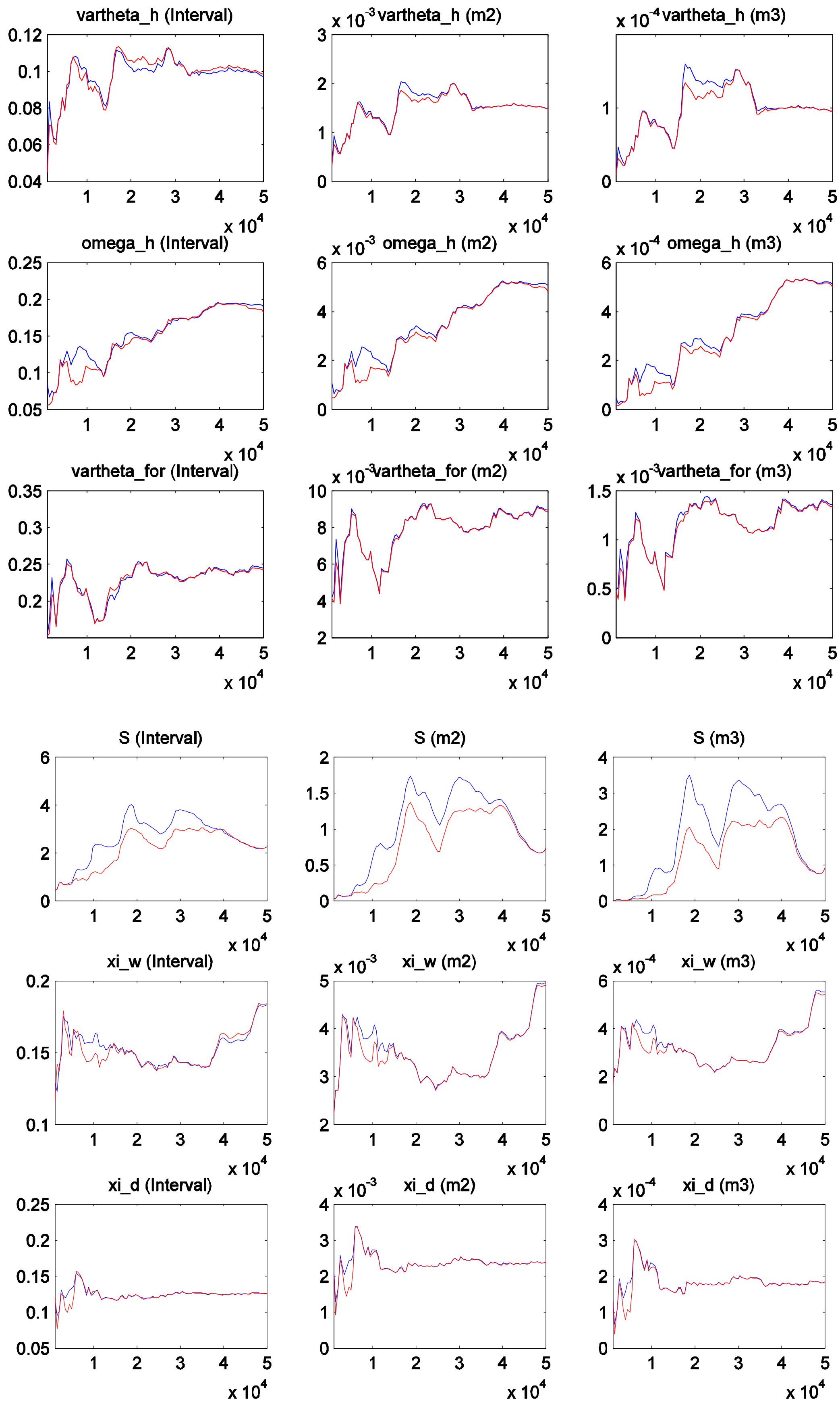

Figure 18: Univariate MH convergence diagnosis (cont.)

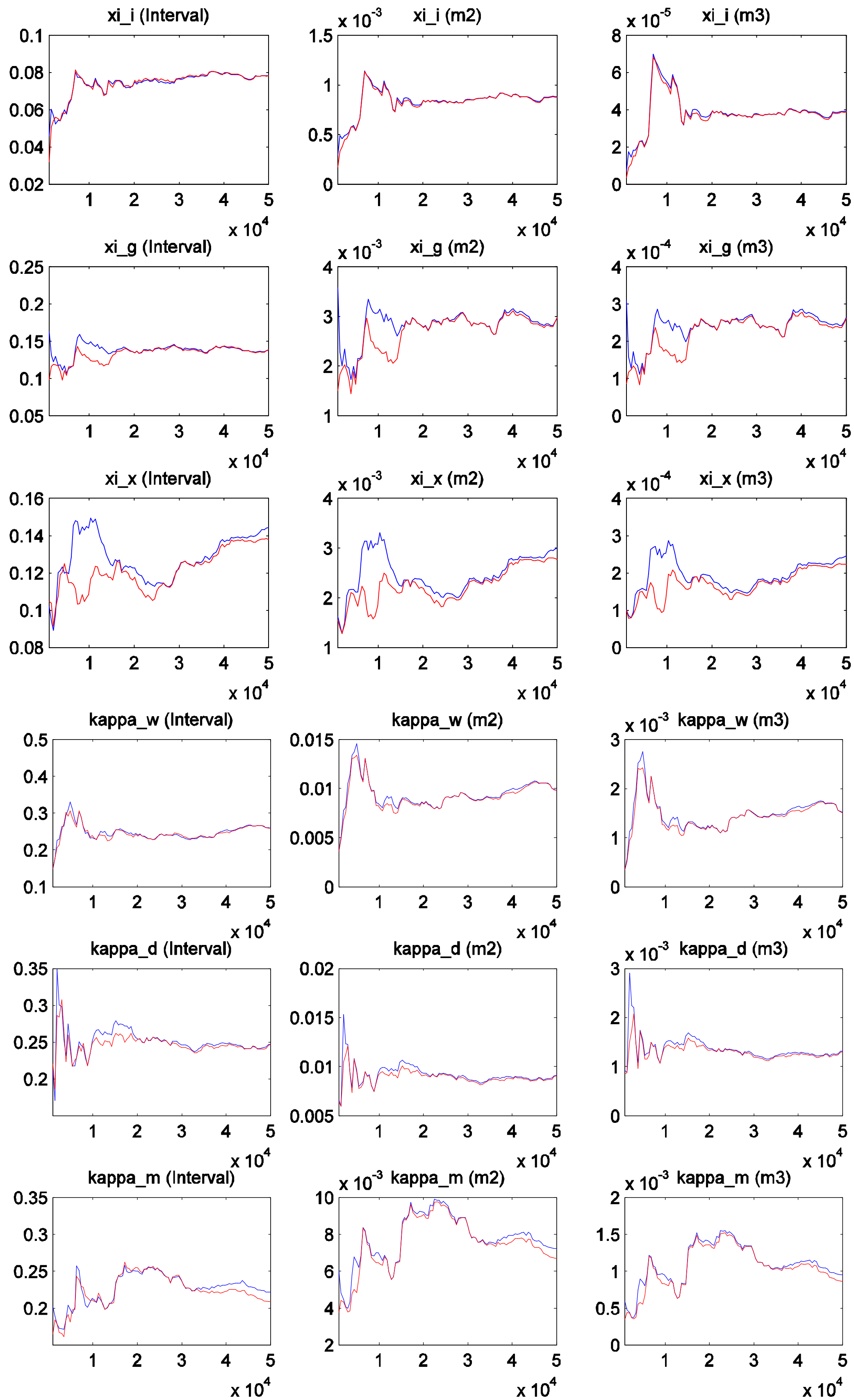

Figure 19:Univariate MH convergence diagnosis (cont.)

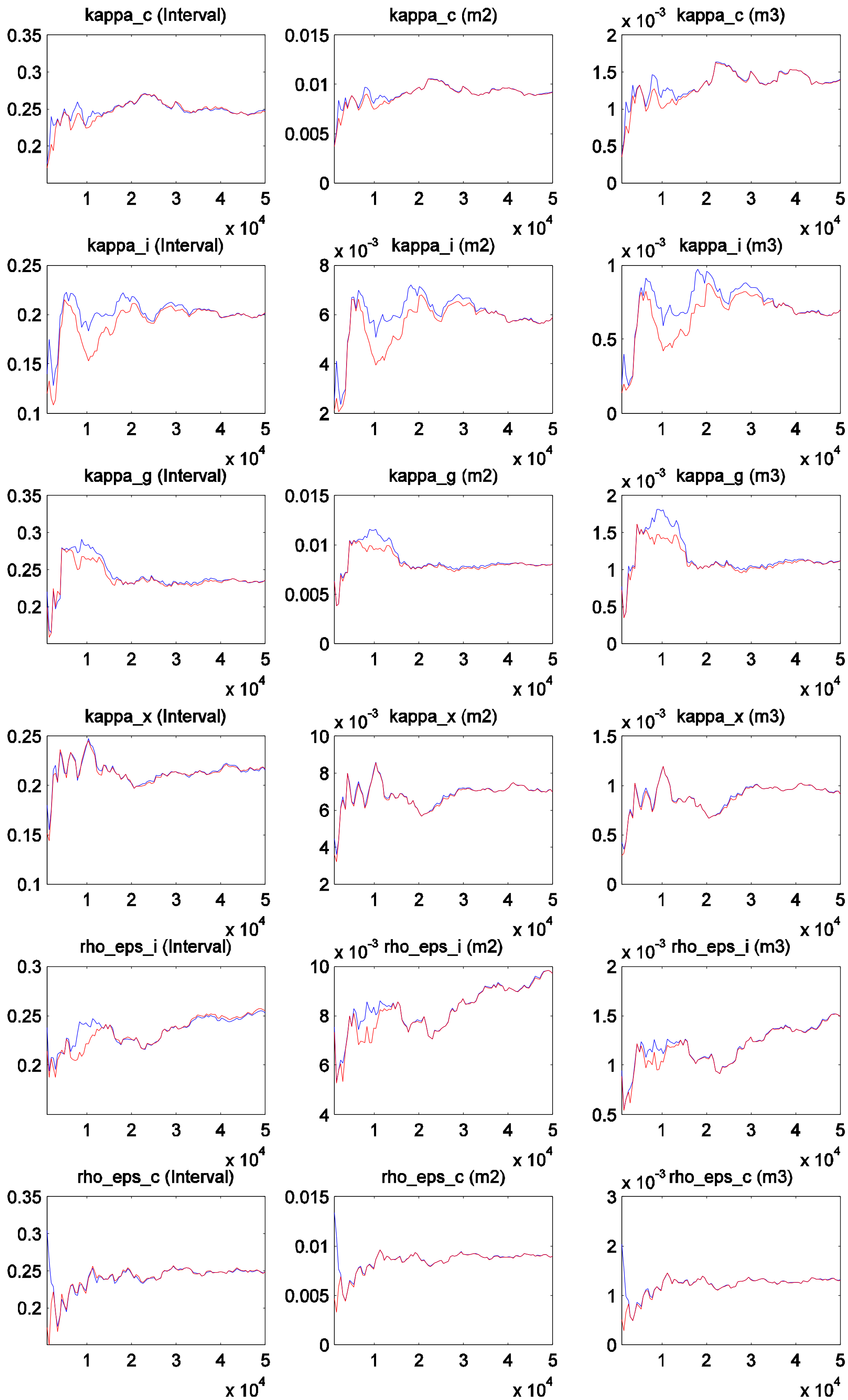

Figure 20:Univariate MH convergence diagnosis (cont.)

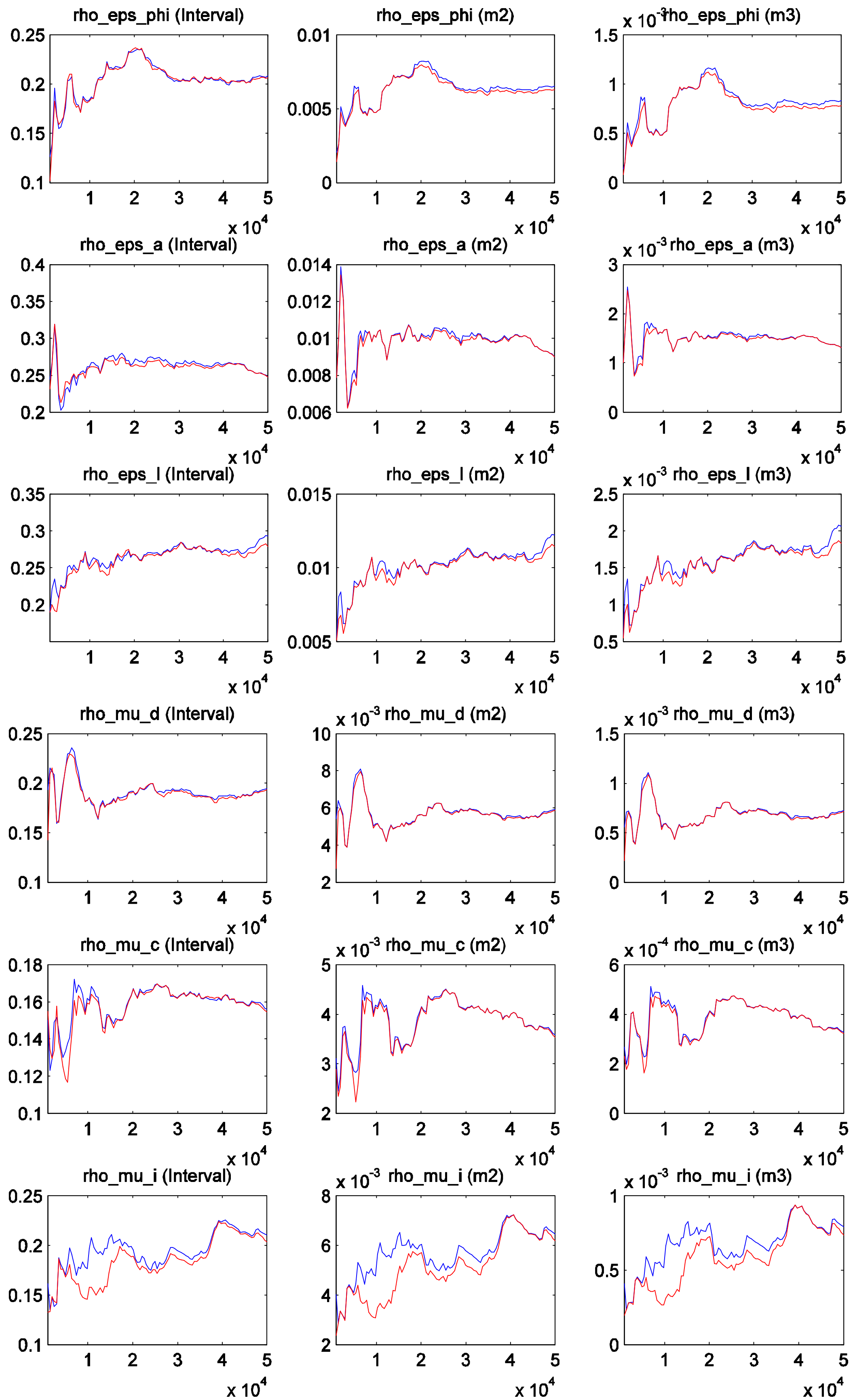

Figure 21: Univariate MH convergence diagnosis (cont.)

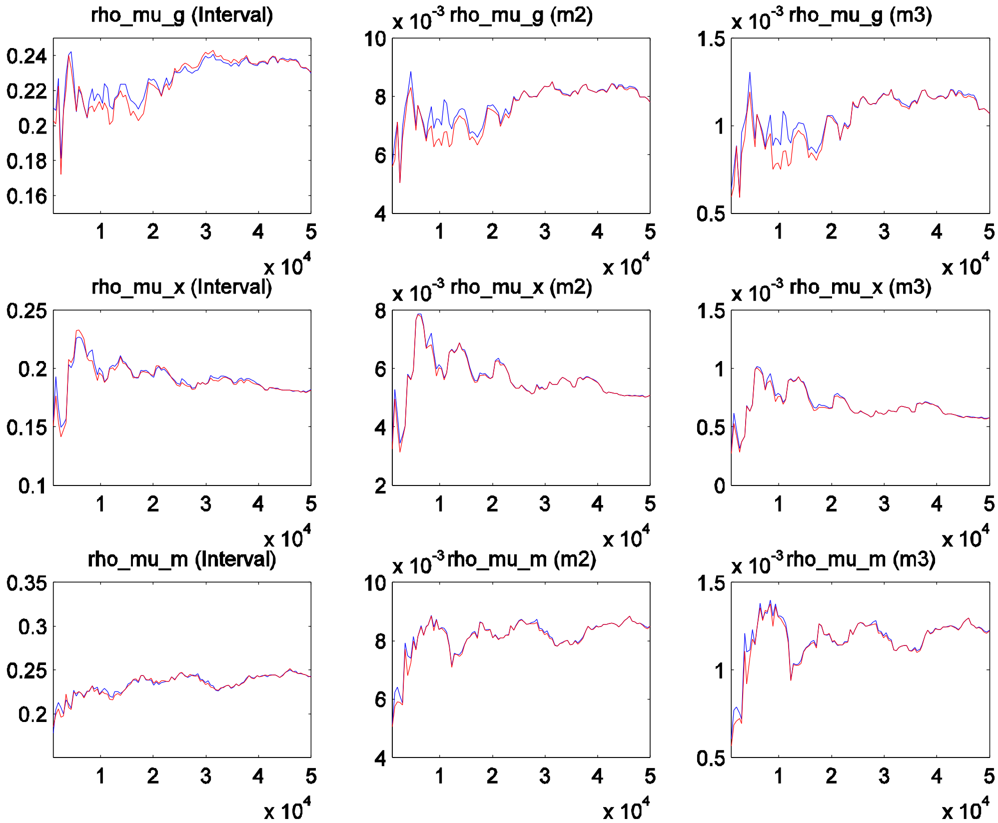

Figure 22:Univariate MH convergence diagnosis (cont.)

Table 1: Priors and Posteriors distributions

Parameter	Prior			Posterior maximisation		Meropolis-Hastling sampling		
	Type	Mean	Stdev	Mode	Stdev	Mean	5%	95%
Markup wage	invg	1,25	0,20	4,68	0,72	4,97	3,95	6,09
Markup domestic	invg	1,15	0,20	3,24	0,86	3,84	2,21	5,36
Markup import	invg	1,20	0,20	1,02	0,15	1,13	0,84	1,44
Markup consumption	invg	1,05	0,20	0,88	0,14	0,98	0,72	1,24
Markup investment	invg	1,05	0,20	0,87	0,14	0,97	0,71	1,24
Markup government	invg	1,05	0,20	0,88	0,14	0,96	0,69	1,23
Markup export	invg	1,05	0,20	0,87	0,14	0,95	0,69	1,21
Subst. elasticity home	invg	0,50	0,10	0,31	0,03	0,33	0,27	0,39
Import good share in composite good prod.	beta	0,40	0,10	0,09	0,04	0,17	0,07	0,28
Subst. elasticity foreign	invg	0,50	0,10	0,46	0,08	0,50	0,35	0,64
Investment adjustment cost	norm	7,60	1,50	1,12	0,28	2,76	0,87	4,54
Calvo wages	beta	0,84	0,10	0,32	0,07	0,29	0,19	0,40
Calvo domestic prices	beta	0,79	0,10	0,34	0,05	0,34	0,26	0,42
Calvo investment prices	beta	0,63	0,10	0,79	0,03	0,79	0,74	0,84
Calvo government	beta	0,63	0,10	0,50	0,06	0,53	0,44	0,61
Calvo export	beta	0,44	0,10	0,68	0,05	0,74	0,65	0,83
Indexation wages	beta	0,50	0,10	0,51	0,11	0,51	0,35	0,67
Indexation domestic prices	beta	0,50	0,10	0,51	0,10	0,50	0,34	0,65
Indexation import prices	beta	0,50	0,10	0,32	0,08	0,38	0,24	0,53
Indexation comsumption prices	beta	0,50	0,10	0,57	0,10	0,57	0,41	0,72
Indexation investment prices	beta	0,50	0,10	0,34	0,07	0,39	0,26	0,53
Indexation government prices	beta	0,50	0,10	0,38	0,09	0,39	0,24	0,54
Indexation export prices	beta	0,50	0,10	0,43	0,09	0,44	0,30	0,58
AR Investment shock	beta	0,60	0,10	0,57	0,11	0,52	0,37	0,69
AR Consumption shock	beta	0,60	0,10	0,60	0,10	0,59	0,44	0,75
AR Risk premium shock	beta	0,60	0,10	0,70	0,09	0,72	0,59	0,85
AR Technology shock	beta	0,60	0,10	0,62	0,10	0,61	0,45	0,77
AR Labor supply shock	beta	0,60	0,10	0,60	0,10	0,55	0,38	0,73
AR Domestic markup shock	beta	0,60	0,10	0,60	0,08	0,61	0,48	0,73
AR Consumption markup shock	beta	0,60	0,10	0,55	0,06	0,57	0,47	0,67
AR Investment markup shock	beta	0,60	0,10	0,53	0,08	0,64	0,51	0,77
AR Govern. Spend. Markup shock	beta	0,60	0,10	0,69	0,10	0,65	0,50	0,78
AR Export markup shock	beta	0,60	0,10	0,65	0,09	0,64	0,53	0,77
AR Import markup shock	beta	0,60	0,10	0,50	0,10	0,49	0,33	0,64
AR Technology growth rate shock	beta	0,60	0,10	0,65	0,09	0,62	0,47	0,77
AR Foreign technology growth rate shock	beta	0,60	0,10	0,56	0,09	0,56	0,42	0,69
AR Labor tax shock	beta	0,60	0,10	0,55	0,11	0,54	0,37	0,72
AR Consumption tax shock	beta	0,60	0,10	0,61	0,11	0,61	0,45	0,76
AR Government spending shock	beta	0,60	0,10	0,63	0,07	0,62	0,50	0,75
AR Foreign inflation shock	beta	0,60	0,10	0,62	0,10	0,61	0,45	0,77
AR Foreign domestic good shock	beta	0,60	0,10	0,74	0,07	0,73	0,62	0,84
AR Foreign interest rate shock	beta	0,60	0,10	0,84	0,04	0,81	0,74	0,89
AR Inflation target shock	beta	0,60	0,10	0,61	0,11	0,60	0,44	0,77
Investment shock	invg	0,15	0,15	0,11	0,05	0,34	0,08	0,58
Consumption shock	invg	0,15	0,15	0,07	0,02	0,08	0,05	0,11
Risk premium shock	invg	0,02	0,02	0,31	0,06	0,38	0,26	0,50
Technology shock	invg	0,02	0,02	0,01	0,00	0,01	0,01	0,02
Labor supply shock	invg	0,15	0,15	0,09	0,04	0,16	0,05	0,28
Domestic markup shock	invg	0,15	0,15	0,71	0,20	0,83	0,42	1,24
Consumption markup shock	invg	0,15	0,15	0,39	0,08	0,47	0,30	0,64
Investment markup shock	invg	0,15	0,15	0,91	0,40	0,89	0,35	1,51
Govern. Spend. Markup shock	invg	0,15	0,15	0,49	0,28	0,91	0,29	1,54
Export markup shock	invg	0,15	0,15	0,70	0,34	0,92	0,32	1,51
Import marup shock	invg	0,15	0,15	0,31	0,08	0,38	0,22	0,53
Technology growth rate shock	invg	0,15	0,15	0,06	0,01	0,06	0,04	0,08
Foreign technology growth rate shock	invg	0,15	0,15	0,55	0,07	0,58	0,46	0,69
Labor tax shock	invg	0,15	0,15	0,19	0,07	0,14	0,05	0,24
Consumption tax shock	invg	0,02	0,02	0,01	0,00	0,02	0,01	0,02
Government spending shock	invg	0,02	0,02	0,40	0,06	0,45	0,33	0,56
Foreign inflation shock	invg	0,02	0,02	0,01	0,00	0,02	0,01	0,03
Foreign domestic good shock	invg	0,02	0,02	0,01	0,00	0,01	0,01	0,01
Foreign interest rate shock	invg	0,02	0,02	0,31	0,04	0,33	0,25	0,40
Inflation target shock	invg	0,02	0,02	0,01	0,00	0,02	0,01	0,03

Table 2: Sensitivity analysis with respect to frictions

	Posterior Mode				
Parameter	Benchmark	No price stick	No wage stick	No habit persist	No inv. adj. cost
Markup wage	4,677	1,430	1,413	1,404	4,142
Markup domestic	3,245	2,207	6,046	1,110	6,255
Markup import	1,022	1,735	1,031	2,363	1,023
Markup consumption	0,876	1,062	0,907	5,478	0,879
Markup investment	0,873	1,249	0,951	1,540	0,875
Markup government	0,877	1,129	0,910	0,809	0,963
Markup export	0,874	1,327	0,985	0,890	0,877
Subst. elasticity home	0,306	0,336	0,351	0,287	0,293
Import good share in composite good prod.	0,091	0,162	0,179	0,104	0,073
Subst. elasticity foreign	0,459	0,495	0,464	0,416	0,461
Investment adjustment cost	1,122	7,556	6,340	7,384	
Calvo wages	0,323	0,113		0,105	0,390
Calvo domestic prices	0,342		0,346	0,396	0,397
Calvo investment prices	0,793		0,719	0,776	0,810
Calvo government	0,501		0,475	0,580	0,813
Calvo export	0,680		0,660	0,651	0,654
Indexation wages	0,512	0,706	0,588	0,539	0,529
Indexation domestic prices	0,511	0,718	0,535	0,598	0,555
Indexation import prices	0,320	0,603	0,351	0,383	0,281
Indexation consumption prices	0,569	0,410	0,531	0,509	0,553
Indexation investment prices	0,335	0,776	0,335	0,380	0,310
Indexation government prices	0,383	0,606	0,376	0,360	0,422
Indexation export prices	0,433	0,643	0,497	0,502	0,465
AR Investment shock	0,568	0,595	0,529	0,563	0,582
AR Consumption shock	0,604	0,653	0,552	0,656	0,596
AR Risk premium shock	0,699	0,680	0,663	0,678	0,666
AR Technology shock	0,618	0,655	0,620	0,602	0,613
AR Labor supply shock	0,599	0,727	0,543	0,592	0,549
AR Domestic markup shock	0,601	0,630	0,599	0,603	0,618
AR Consumption markup shock	0,552	0,518	0,547	0,476	0,577
AR Investment markup shock	0,527	0,532	0,596	0,501	0,489
AR Govern. Spend. Markup shock	0,691	0,672	0,663	0,693	0,615
AR Export markup shock	0,652	0,666	0,640	0,675	0,756
AR Import markup shock	0,503	0,528	0,562	0,594	0,459
AR Technology growth rate shock	0,651	0,613	0,654	0,574	0,677
AR Foreign technology growth rate shock	0,555	0,510	0,574	0,522	0,576
AR Labor tax shock	0,553	0,578	0,481	0,548	0,596
AR Consumption tax shock	0,614	0,588	0,560	0,647	0,614
AR Government spending shock	0,634	0,678	0,651	0,649	0,693
AR Foreign inflation shock	0,618	0,641	0,616	0,610	0,614
AR Foreign domestic good shock	0,739	0,755	0,738	0,699	0,738
AR Foreign interest rate shock	0,837	0,842	0,853	0,801	0,858
AR Inflation target shock	0,611	0,565	0,601	0,570	0,611
Investment shock	0,106	0,111	0,116	0,697	0,082
Consumption shock	0,069	0,059	0,098	0,064	0,100
Risk premium shock	0,314	0,394	0,363	0,822	0,308
Technology shock	0,010	0,014	0,010	0,205	0,013
Labor supply shock	0,089	0,069	0,087	0,059	0,316
Domestic markup shock	0,706	0,711	0,970	1,142	1,632
Consumption markup shock	0,389	0,387	0,337	0,444	0,391
Investment markup shock	0,911	0,882	0,830	0,894	1,176
Govern. Spend. Markup shock	0,485	0,483	0,450	0,458	0,087
Export markup shock	0,701	0,764	0,693	0,631	0,494
Import markup shock	0,312	0,386	0,379	0,380	0,368
Technology growth rate shock	0,062	0,068	0,050	0,635	0,062
Foreign technology growth rate shock	0,553	0,537	0,538	0,678	0,556
Labor tax shock	0,190	0,195	0,115	0,175	0,092
Consumption tax shock	0,011	0,020	0,012	0,014	0,011
Government spending shock	0,405	0,486	0,463	0,411	0,364
Foreign inflation shock	0,012	0,017	0,012	0,017	0,012
Foreign domestic good shock	0,007	0,008	0,008	0,006	0,007
Foreign interest rate shock	0,312	0,334	0,332	0,381	0,308
Inflation target shock	0,011	0,039	0,015	0,012	0,011
Log marginal likelihood	-19033,97	-19936,99	-19087,24	-19228,76	-19612,08

Table 3: Sensitivity analysis with respect to shocks

Parameter	Benchmark	No Investment Shock	No Consumption Shock	No Risk Premium Shock	No technology shock	No Labor Supply Shock	No Markup Shocks	No Import-Export markup Shock	No Fiscal Shock	No Inflation Target Shock
Markup wage	4,677	4,703	5,747	4,427	1,537	3,891	1,434	1,480	5,784	3,813
Markup domestic	3,245	2,761	3,554	4,525	6,255	6,255	4,203	5,847	2,595	6,255
Markup import	1,022	1,017	1,015	1,026	1,142	1,023	1,034	1,141	1,024	1,030
Markup consumption	0,876	0,841	0,897	0,879	1,052	0,879	0,964	5,898	0,881	1,026
Markup investment	0,873	0,845	0,833	0,875	0,918	0,876	0,965	0,978	0,878	0,894
Markup government	0,877	0,854	0,937	0,877	0,868	0,963	0,968	1,244	0,878	0,905
Markup export	0,874	0,883	0,838	0,876	0,989	0,877	0,962	0,983	0,971	0,929
Subst. elasticity home	0,306	0,304	0,320	0,315	0,352	0,292	0,517	0,571	0,323	0,362
Imp. good share in prod	0,091	0,133	0,152	0,071	0,830	0,067	0,089	0,794	0,236	0,773
Subst. elasticity foreign	0,459	0,463	0,467	0,461	0,439	0,461	0,526	0,715	0,459	0,448
Investment adj. cost	1,122	1,222	2,426	1,359	5,059	1,478	7,212	14,489	1,513	3,662
Calvo wages	0,323	0,313	0,242	0,308	0,545	0,406	0,631	0,097	0,265	0,416
Calvo domestic prices	0,342	0,359	0,314	0,296	0,609	0,401	0,986	0,982	0,288	0,488
Calvo investment prices	0,793	0,785	0,753	0,793	0,602	0,805	0,852	0,970	0,733	0,653
Calvo government	0,501	0,505	0,523	0,505	0,371	0,812	0,746	0,813	0,477	0,534
Calvo export	0,680	0,728	0,703	0,631	0,622	0,648	0,674	0,797	0,781	0,623
Indexation wages	0,512	0,491	0,492	0,531	0,496	0,530	0,551	0,507	0,563	0,504
Indexation domestic prices	0,511	0,466	0,474	0,545	0,369	0,552	0,343	0,872	0,488	0,408
Indexation import prices	0,320	0,339	0,340	0,325	0,484	0,280	0,741	0,388	0,444	0,474
Indexation cons. prices	0,569	0,506	0,575	0,562	0,542	0,554	0,804	0,687	0,428	0,548
Indexation inv. prices	0,335	0,353	0,374	0,339	0,457	0,324	0,770	0,832	0,464	0,458
Indexation gov. prices	0,383	0,372	0,424	0,386	0,322	0,423	0,706	0,702	0,375	0,351
Indexation export prices	0,433	0,427	0,448	0,438	0,401	0,464	0,344	0,250	0,413	0,399
AR Investment shock	0,568		0,519	0,576	0,666	0,583	0,546	0,469	0,582	0,691
AR Consumption shock	0,604	0,599		0,584	0,623	0,590	0,659	0,581	0,593	0,597
AR Risk premium shock	0,699	0,749	0,722		0,876	0,658	0,843	0,632	0,772	0,888
AR Technology shock	0,618	0,609	0,619	0,611		0,615	0,657	0,633	0,613	0,626
AR Labor supply shock	0,599	0,612	0,609	0,590	0,613		0,655	0,554	0,564	0,599
AR Domestic markup shock	0,601	0,613	0,625	0,563	0,573	0,621		0,581	0,623	0,623
AR Con. markup shock	0,552	0,568	0,540	0,546	0,512	0,575		0,371	0,524	0,538
AR Investment markup shock	0,527	0,567	0,673	0,504	0,562	0,514		0,663	0,548	0,633
AR Gov. Spen. markup shock	0,691	0,716	0,623	0,675	0,505	0,615		0,356	0,714	0,480
AR Export markup shock	0,652	0,624	0,692	0,684	0,573	0,754	0,645		0,612	0,562
AR Import markup shock	0,503	0,456	0,524	0,523	0,611	0,462	0,699		0,498	0,650
AR Tech. growth rate shock	0,651	0,635	0,615	0,626	0,701	0,674	0,634	0,281	0,672	0,682
AR Foreign tech grow r. shock	0,555	0,552	0,543	0,579	0,432	0,582	0,420	0,603	0,528	0,448
AR Labor tax shock	0,553	0,572	0,591	0,426	0,357	0,528	0,662	0,641		0,491
AR Consumption tax shock	0,614	0,625	0,617	0,613	0,603	0,614	0,659	0,842		0,599
AR Government spend. shock	0,634	0,596	0,637	0,621	0,596	0,695	0,564	0,552	0,597	0,640
AR Foreign inflation shock	0,618	0,630	0,615	0,613	0,584	0,614	0,658	0,566	0,619	0,634
AR Foreign dom. good shock	0,739	0,737	0,728	0,738	0,739	0,738	0,754	0,643	0,739	0,740
AR Foreign interest rate shock	0,837	0,726	0,830	0,876	0,800	0,860	0,829	0,444	0,809	0,805
AR Inflation target shock	0,611	0,607	0,594	0,610	0,609	0,611	0,649	0,501	0,779	
Investment shock	0,106	0,164	0,279	0,097	0,662	0,089	0,042	0,565	0,173	0,477
Consumption shock	0,069	0,067	0,086	0,078	0,088	0,105	0,097	0,411	0,068	0,088
Risk premium shock	0,314	0,374	0,354	0,169	0,500	0,305	0,475	0,408	0,404	0,538
Technology shock	0,010	0,010	0,010	0,011	0,011	0,012	0,012	0,011	0,010	0,012
Labor supply shock	0,089	0,088	0,093	0,083	0,086	0,093	0,086	0,530	0,171	0,087
Domestic markup shock	0,706	0,608	0,695	0,911	2,398	0,639	1,115	0,780	0,491	1,755
Consumption markup shock	0,389	0,376	0,415	0,377	0,063	0,389	0,081	0,901	0,352	0,073
Investment markup shock	0,911	0,774	0,443	0,957	0,186	1,067	1,328	0,145	0,473	0,226
Govern. Spend. Markup shock	0,485	0,422	0,924	0,534	0,656	0,087	0,668	0,998	0,383	1,898
Export markup shock	0,701	0,815	0,509	0,643	0,087	0,485	0,086	0,616	0,087	0,093
Import markup shock	0,312	0,362	0,303	0,286	0,086	0,361	0,126	0,877	0,429	0,168
Technology growth rate shock	0,062	0,064	0,059	0,061	0,086	0,063	0,120	0,998	0,061	0,086
Foreign tech growth rate shock	0,553	0,554	0,552	0,557	0,515	0,557	0,548	0,776	0,553	0,541
Labor tax shock	0,190	0,180	0,117	0,244	1,970	0,271	0,388	0,599	0,102	0,235
Consumption tax shock	0,011	0,011	0,011	0,011	0,014	0,011	0,015	0,787	0,012	0,015
Government spending shock	0,405	0,406	0,419	0,369	0,439	0,367	0,421	0,461	0,445	0,467
Foreign inflation shock	0,012	0,013	0,012	0,012	0,056	0,012	0,016	0,445	0,012	0,015
Foreign domestic good shock	0,007	0,007	0,008	0,007	0,007	0,007	0,007	0,909	0,007	0,007
Foreign interest rate shock	0,312	0,315	0,313	0,305	0,323	0,308	0,317	0,165	0,318	0,320
Inflation target shock	0,011	0,011	0,011	0,011	0,011	0,011	0,012	0,744	0,236	0,012
Log marginal likelihood	-19 034	-19 949	-20 563	-19 041	-20 104	-19 425	-20 963	-21 310	-20 598	-19 129

Table 4: Sensitivity analysis with respect to priors

Parameter	Case 1				Case 2				Case 3			
	Mean	stdev	Mode	stdev	Mean	stdev	Mode	stdev	Mean	stdev	Mode	stdev
Markup wage	1,250	0,200	4,677	0,724	1,380	0,220	4,413	0,004	1,250	0,240	4,522	0,004
Markup domestic	1,150	0,200	3,245	0,859	1,270	0,220	2,852	0,000	1,150	0,240	3,404	0,046
Markup import	1,200	0,200	1,022	0,153	1,320	0,220	1,024	0,917	1,200	0,240	1,034	0,917
Markup consumption	1,050	0,200	0,876	0,138	1,160	0,220	0,868	0,250	1,050	0,240	1,562	0,250
Markup investment	1,050	0,200	0,873	0,138	1,160	0,220	0,911	0,225	1,050	0,240	0,940	0,225
Markup government	1,050	0,200	0,877	0,139	1,160	0,220	0,876	0,261	1,050	0,240	0,873	0,261
Markup export	1,050	0,200	0,874	0,138	1,160	0,220	0,813	0,862	1,050	0,240	0,955	0,862
Subst. elasticity home	0,500	0,100	0,306	0,032	0,550	0,110	0,381	0,000	0,500	0,120	0,183	0,129
Import good share in prod.	0,400	0,100	0,091	0,037	0,440	0,110	0,085	0,000	0,400	0,120	0,096	0,261
Subst. elasticity foreign	0,500	0,100	0,459	0,082	0,550	0,110	0,572	0,125	0,500	0,120	0,183	0,125
Investment adjustment cost	7,600	1,500	1,122	0,278	8,360	1,650	1,309	0,123	7,600	1,800	1,325	0,046
Calvo wages	0,840	0,100	0,323	0,075	0,920	0,110	0,393	0,047	0,840	0,120	0,333	0,047
Calvo domestic prices	0,790	0,100	0,342	0,051	0,870	0,110	0,382	0,003	0,790	0,120	0,360	0,003
Calvo investment prices	0,630	0,100	0,793	0,033	0,690	0,110	0,781	0,125	0,630	0,120	0,796	0,261
Calvo government	0,630	0,100	0,501	0,059	0,690	0,110	0,566	0,033	0,630	0,120	0,596	0,033
Calvo export	0,440	0,100	0,680	0,053	0,480	0,110	0,729	0,030	0,440	0,120	0,611	0,030
Indexation wages	0,500	0,100	0,512	0,106	0,550	0,110	0,588	0,116	0,500	0,120	0,520	0,116
Indexation domestic prices	0,500	0,100	0,511	0,098	0,550	0,110	0,488	0,065	0,500	0,120	0,486	0,065
Indexation import prices	0,500	0,100	0,320	0,078	0,550	0,110	0,313	0,124	0,500	0,120	0,320	0,124
Indexation cons. prices	0,500	0,100	0,569	0,100	0,550	0,110	0,517	0,121	0,500	0,120	0,520	0,121
Indexation inv. prices	0,500	0,100	0,335	0,069	0,550	0,110	0,372	0,090	0,500	0,120	0,380	0,090
Indexation gov. prices	0,500	0,100	0,383	0,093	0,550	0,110	0,422	0,100	0,500	0,120	0,202	0,100
Indexation export prices	0,500	0,100	0,433	0,087	0,550	0,110	0,409	0,052	0,500	0,120	0,480	0,052
AR Investment shock	0,600	0,100	0,568	0,105	0,660	0,110	0,506	0,081	0,600	0,120	0,538	0,081
AR Consumption shock	0,600	0,100	0,604	0,101	0,660	0,110	0,617	0,127	0,600	0,120	0,538	0,127
AR Risk premium shock	0,600	0,100	0,699	0,086	0,660	0,110	0,679	0,119	0,600	0,120	0,638	0,119
AR Technology shock	0,600	0,100	0,618	0,104	0,660	0,110	0,690	0,000	0,600	0,120	0,538	0,000
AR Labor supply shock	0,600	0,100	0,599	0,103	0,660	0,110	0,564	0,109	0,600	0,120	0,538	0,109
AR Domestic markup shock	0,600	0,100	0,601	0,084	0,660	0,110	0,606	0,074	0,600	0,120	0,693	0,074
AR Cons. markup shock	0,600	0,100	0,552	0,063	0,660	0,110	0,642	0,125	0,600	0,120	0,593	0,125
AR Inv. markup shock	0,600	0,100	0,527	0,076	0,660	0,110	0,492	0,120	0,600	0,120	0,593	0,120
AR Gov. Sp. markup shock	0,600	0,100	0,691	0,098	0,660	0,110	0,675	0,129	0,600	0,120	0,693	0,129
AR Export markup shock	0,600	0,100	0,652	0,086	0,660	0,110	0,673	0,058	0,600	0,120	0,693	0,058
AR Import markup shock	0,600	0,100	0,503	0,099	0,660	0,110	0,585	0,079	0,600	0,120	0,593	0,079
AR Tech. growth rate shock	0,600	0,100	0,651	0,087	0,660	0,110	0,705	0,129	0,600	0,120	0,693	0,261
AR Foreign tech. growth rate shock	0,600	0,100	0,555	0,090	0,660	0,110	0,622	0,119	0,600	0,120	0,538	0,119
AR Labor tax shock	0,600	0,100	0,553	0,114	0,660	0,110	0,491	0,113	0,600	0,120	0,538	0,113
AR Consumption tax shock	0,600	0,100	0,614	0,106	0,660	0,110	0,584	0,129	0,600	0,120	0,538	0,129
AR Gov. spending shock	0,600	0,100	0,634	0,075	0,660	0,110	0,625	0,132	0,600	0,120	0,693	0,132
AR Foreign inflation shock	0,600	0,100	0,618	0,104	0,660	0,110	0,626	0,126	0,600	0,120	0,693	0,126
AR For. domest. good shock	0,600	0,100	0,739	0,068	0,660	0,110	0,771	0,072	0,600	0,120	0,793	0,072
AR For. interest rate shock	0,600	0,100	0,837	0,044	0,660	0,110	0,872	0,129	0,600	0,120	0,893	0,129
AR Inflation target shock	0,600	0,100	0,611	0,106	0,660	0,110	0,697	0,115	0,600	0,120	0,538	0,115
Investment shock	0,150	0,150	0,106	0,053	0,170	0,170	0,161	0,072	0,150	0,180	0,355	0,046
Consumption shock	0,150	0,150	0,069	0,016	0,170	0,170	0,117	0,060	0,150	0,180	0,166	0,060
Risk premium shock	0,020	0,020	0,314	0,059	0,020	0,020	0,311	0,004	0,020	0,024	0,099	0,004
Technology shock	0,020	0,020	0,010	0,003	0,020	0,020	0,048	0,315	0,020	0,024	0,021	0,129
Labor supply shock	0,150	0,150	0,089	0,037	0,170	0,170	0,050	0,757	0,150	0,180	0,083	0,757
Domestic markup shock	0,150	0,150	0,706	0,202	0,170	0,170	0,547	0,528	0,150	0,180	0,438	0,528
Consumption markup shock	0,150	0,150	0,389	0,083	0,170	0,170	0,306	0,046	0,150	0,180	0,264	0,046
Investment markup shock	0,150	0,150	0,911	0,402	0,170	0,170	0,931	0,315	0,150	0,180	0,598	0,005
Gov.. Spend. Markup shock	0,150	0,150	0,485	0,280	0,170	0,170	0,506	0,146	0,150	0,180	0,372	0,146
Export markup shock	0,150	0,150	0,701	0,342	0,170	0,170	0,659	0,072	0,150	0,180	0,525	0,261
Import markup shock	0,150	0,150	0,312	0,083	0,170	0,170	0,362	0,126	0,150	0,180	0,316	0,129
Tech. growth rate shock	0,150	0,150	0,062	0,012	0,170	0,170	0,028	0,072	0,150	0,180	0,081	0,115
For tech growth rate shock	0,150	0,150	0,553	0,069	0,170	0,170	0,590	0,315	0,150	0,180	0,503	0,315
Labor tax shock	0,150	0,150	0,190	0,075	0,170	0,170	0,176	0,126	0,150	0,180	0,156	0,005
Consumption tax shock	0,020	0,020	0,011	0,004	0,020	0,020	0,012	0,004	0,020	0,024	0,064	0,004
Government spending shock	0,020	0,020	0,405	0,063	0,020	0,020	0,510	0,528	0,020	0,024	0,746	0,261
Foreign inflation shock	0,020	0,020	0,012	0,005	0,020	0,020	0,011	0,004	0,020	0,024	0,414	0,004
For domestic good shock	0,020	0,020	0,007	0,001	0,020	0,020	0,007	0,001	0,020	0,024	0,020	0,001
Foreign interest rate shock	0,020	0,020	0,312	0,040	0,020	0,020	0,520	0,528	0,020	0,024	0,403	0,129
Inflation target shock	0,020	0,020	0,011	0,004	0,020	0,020	0,012	0,005	0,020	0,024	0,062	0,005
Log marginal likelihood	-19033,9724				-20829,3575				-21624,7426			