An Open-Economy DSGE Model for the Philippines

Ruperto Majuca and Lawrence Dacuyucuy
School of Economics
De La Salle University - Manila

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1. Introduction

This paper identifies various model elements to constitute the necessary theoretical core of a dynamic macroeconomic model, estimates impulse responses through advanced techniques and analyses how remittances and key macroeconomic outcomes are affected by various shocks, all of which reflect the state of the art in open economy Dynamic Stochastic General Equilibrium (DSGE) modelling. The objective is to set the stage for an estimable DSGE model that hopefully will capture the features and dynamics of the Philippine economy and will prove as the basis for the construction of other models that explore and explain different macroeconomic problems. Integrated into this paper are some of the essential structures characterizing open economy DSGE models that will help explain macroeconomic dynamics and possibly to provide an analytical platform for future forecasting work and counterfactual analyses.

DSGE models are fast becoming the workhorses of modern macroeconomics. Many central banks have their own DSGE models to determine how certain policies or shocks affect the dynamics of key variables of interest. Burriel, Villaverde, and Ramirez (2010) [henceforth referred to as BVR] developed a medium scale open economy DSGE model for Spain that takes into account immigration and growth issues. Known as MEDEA, the model uses Bayesian methods to estimate the parameters and employs higher order approximation methods. As noted in BVR, some of the central banks like European Central Bank, Bank of Canada, Bank of Spain, and Bank of Sweden have their own DSGE models. The Philippines’ Central Bank has its own open economy DSGE model also.

As identified in the literature, an interesting field of inquiry concerns the dynamic impact of remittances which are being hailed, partly due to their stability, as a vital anchor and safeguard against unwanted fluctuations. Several authors have started to analyze the consequences of remittance inflows. Mandelman (2011) analyzed the impact of monetary and exchange rate policy under remittance fluctuations using Philippine data. The study

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2 A major challenge for macroeconomic modelling is the availability of high-quality data since DSGE requires mapping of observables to model variables which are theoretically easier to handle but pose formidable measurement issues especially for a country such as the Philippines.
analyzes the role of having Ricardian households but stays away from fielding a model with a New Keynesian theoretical core.

As a major source of skilled migrant labour, the Philippines continues to benefit from sustained inflows of remittances. Amounting to billions of dollars per year, remittances are expected to sustain higher levels of household consumption, modify investment patterns and potentially prolong the boom in residential building construction. Despite this, some analysts have observed the heightened appreciation of the Philippine currency and they attribute this to remittances. As a matter of fact, some researchers have pointed out the double edge nature of remittances in the sense that they may cause Dutch disease which may affect the state of competitiveness of the country’s tradable sectors and may promote the expansion of our nontradable sector.

Our model generally subscribes to the standard modelling platform that seeks to explain macroeconomic outcomes in a dynamic, general equilibrium setting. The model seeks to embed remittances in an open economy DSGE model by combining useful features found in three important studies written by Adolfson, Laseen, Linde, and Villani (2007) [henceforth referred to as ALLV], Acosta, Larrey, and Mandelman (2009) [henceforth referred to as ALM] and some features of BVR. ALLV’s model is an open economy model that incorporates incomplete exchange rate pass – through but largely subscribes to the New Keynesian features while ALM developed a model that explains how remittances may induce Dutch disease and may lead to economic problems. The critical differences pertain to how nominal rigidities would affect the external and domestic sectors as well.

We modify the model structure by introducing firm heterogeneity, thereby distinguishing the optimal behaviour of nontradable and tradable intermediate and final goods producers and modifying ALLV’s equation on how net foreign assets evolve when remittances are included as part of the model.

Our theoretical core is heavily influenced by New Keynesian theories that feature nominal rigidities aside from the usual components like preference structures, consumption habits, fiscal and monetary authorities, capital adjustment costs. We necessarily include endogenous pricing mechanisms to model rigidities in terms of nominal price adjustments in export, import and domestic production because empirically, they do matter as shown in ALLV (2005). It also takes care of long – term growth through the incorporation of technological change which is seen as a major source of fluctuations. While the Philippines continue to send thousands of workers annually, we do not capture this in the model just like in BVR who introduced population growth.

A clear limitation of our model is the way assumptions were formed about sectoral dynamics and agent heterogeneity. In ALM’s model, for instance, it is clear that the labor market is markedly competitive, allowing the frictionless movement of labor from the tradable to nontradable sectors leading to the same wage. The model also assumes no labor market frictions. However, when no such assumptions are made and heterogeneous agents are introduced, job search becomes a critical model component. In households, it is possible that some members are employed and others are unemployed. Of those employed, some are working in the tradable sector while the rest are in the non – tradable sector. In this scenario, wages are determined in a game theoretic environment. In some studies like Christiano Trabandt and Walentin (2011) [henceforth referred to as CTW] and Zhang (2011), modelling sectoral labor allocation is more involved as it relies on the incorporation of job
search to endogenize the selection of household members into the sectors. Wages are also determined through bargaining which may put to question the ability of households to determine the level of wages in the traditional optimization sense (a la Calvo pricing). It also requires entrepreneurs which introduces financial frictions into the model (Villaverde (2012), CTW). The advantage of such models is that they elevate the status of labor market frictions as an important source of model dynamics.

The model follows an assumption that the Philippine economy is small relative to the rest of the world. It is similar to the treatment in ALLV, BVR and ALM. The open economy features are modelled by assuming that there is incomplete exchange rate pass-through which is triggered by local currency price stickiness.

We outline the basic structure of the combined ALLV-ALM-BVR model.

i. The presence of a continuum of households who consume domestic and foreign goods, hold non–interest earning assets or money, save and invest in domestic and foreign bonds, supply capital and labor services, determine wages, and receive remittances from close and distant relatives.

ii. To capture labor market rigidities, households are assumed to exercise market power by offering differentiated labor which will be aggregated by a perfectly competitive labor packer. We make a simplified assumption that only wages in the tradable sector are set by households, not wages in the nontradable sector.

iii. There are two sectors, namely tradable and non-tradable sectors. The existence of two distinct sectors imply firm heterogeneity. The final domestic good is manufactured by a competitive final goods producer who optimally sets the demand for intermediate domestic goods produced by monopolistically competitive firms that buy labor and capital services.

iv. There is a firm that buys and imports a homogeneous good that gets converted into final domestic consumption and investment goods.

v. Export firms buy final domestic goods and differentiate them by brand naming. They sell a continuum of export goods to foreign households, the demand for which depends on foreign preferences. Export prices are assumed to be sticky.

vi. Import firms buy a homogeneous imported good and sell a continuum of import goods to domestic households. There is incomplete exchange rate pass through, indicating that import prices are sticky.

vii. Aside from a tradable sector, the model encompasses a nontradable sector in order to fully understand the mechanism through which remittances would affect exchange rate dynamics, sectoral dynamics and monetary and fiscal policies. Output in this economy is equal to the sum of output in tradable and non–tradable sectors.

viii. There is a monetary authority that sets one-period nominal interest rate through a Taylor rule, an approximation that includes exchange rate, output gap and deviations from inflation targets.

ix. There is a fiscal policy regulator and assume that tax rates including government expenditures are exogenous.

x. Unit roots are assumed to be found in aggregate technology and prices.
The organization of the paper is as follows: Section 2 details the theoretical structure of the model, using and augmenting ALLV’s theoretical model by integrating remittances. Section 3 provides a review of key empirical strategies and discusses relevant issues on measurement, estimation feasibility and expected output from simulation exercises that are expected to generate impulse response functions (IRFs). Section 4 discusses how shocks affect macroeconomic outcomes such as remittances and identify the transmission mechanisms at work. The last section concludes and highlight directions for future DSGE research.

2. The theoretical structure of an Open Economy DSGE model for the Philippines

The model focuses on the optimal behaviour of households, firms, and monetary authority. Because the proposed model simply incorporates remittances into the ALLV model, we acknowledge at this point that the latter provides the model structure, thereby allowing us to use notations used in the ALLV paper.

2.1 The households

There is a continuum of households indexed by \( j \in (0,1) \). Following ALLV, the representative household’s preferences are described by a utility function that is separable in consumption, non-interest earning assets or real money balances and hours worked.

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \xi_t \log(C_{j,t} - h^cC_{j,t-1}) + A_q \left( \frac{Q_{j,t}}{x_{t+1}} \right)^{1-\theta_q} - \xi_t A_{\ell} \left( \ell_{j,t} \right)^{1+\theta_{\ell}} \right\}
\]

where \( h^c \) is the parameter that captures habit persistence in consumption, \( \theta_{\ell} \) is the inverse of labor supply elasticity and \( \ell_{j,t} \) is labor supply.

Following BVR and ALLV, we included preference shocks to capture changes in valuations between future and present consumption. The shock to labor is supposed to capture changes in labor supply over the business cycle. The laws of motion of the said shocks are represented as follows:

\[
\xi_t = \rho_{\xi} \xi_{t-1} + \varepsilon_{\xi}
\]
\[
\xi_t = \rho_{\xi} \xi_{t-1} + \varepsilon_{\xi}
\]

To ensure consistency with standard open economy models, we assume that within the household, there are two types of labor, namely workers in the tradable and nontradable sectors. We do not model unemployment and other labor market frictions for they necessitate the introduction of bargaining processes and other agents such as employment agencies and entrepreneurs. The ad hoc assignment of workers in the nontradable sector is important because we assume that output in the said sector depends on a linear technology. We assume that there is no perfect mobility, indicating that wages between the two sectors may diverge and assume that only those in the tradable sector can have market power in setting wages. The way wages are determined may run counter to CTW and Zhang’s game theoretic approach to determine wages through wage bargaining mechanisms.
Aggregate consumption $C_t$ is a CES composite of tradable and nontradable goods represented by a CES index. In turn, we also define the tradable component of aggregate consumption in terms of goods bought abroad (imports) and consumption goods produced domestically. Thus,

$$C_t = \left[ (1 - \omega_N)^{1/\eta_c} \left( C_{T,t} \right)^{(\eta_c - 1)/\eta_c} + \omega_N^{1/\eta_c} \left( C_{N,t} \right)^{(\eta_c - 1)/\eta_c} \right]^{\eta_c/\eta_c}$$

(2.3)

where $\omega_N$ is the share of nontradables in (tradable plus nontradable) consumption and tradable consumption, and where $\eta_c$ is the elasticity of substitution between tradable and nontradable consumption. $C_{T,t}$ is defined as

$$C_{T,t} = \left[ (1 - \omega_m)^{1/\eta_T} \left( C_{T,t}^{d} \right)^{(\eta_T - 1)/\eta_T} + \omega_m^{1/\eta_T} \left( C_{T,t}^{m} \right)^{(\eta_T - 1)/\eta_T} \right]^{\eta_T/(\eta_T - 1)}$$

(2.4)

where $\eta_T$ refers to the elasticity of substitution between domestic and imported consumption goods, $C_{T,t}^{d}$ is the domestically produced tradable consumption good, and $C_{T,t}^{m}$ is the imported consumption good.

The demand functions are given by

$$C_{T,t}^{d} = (1 - \omega_m) \left[ \frac{P_{T,t}}{P_{T,t}^e} \right]^{-\eta_T} C_{T,t}$$

(2.5)

$$C_{T,t}^{m} = \omega_m \left[ \frac{P_{T,t}^{m,c}}{P_{T,t}^e} \right]^{-\eta_T} C_{T,t}$$

(2.6)

$$C_{N,t} = \frac{\omega_c}{1 - \omega_c} \left[ \frac{P_{N,t}}{P_{T,t}^e} \right]^{-\eta_c} C_{T,t}$$

(2.7)

There are now two price indexes. One for the CPI price index which is defined as the minimum expenditure required to buy a unit of consumption good and another for the tradable good.

$$P_{t}^c = \left[ (1 - \omega_N) \left( P_{T,t}^e \right)^{1-\eta_c} + \omega_N \left( P_{N,t} \right)^{1-\eta_c} \right]^{1/(1-\eta_c)}$$

(2.8)

$$P_{T,t}^e = \left[ (1 - \omega_m) \left( P_{T,t} \right)^{1-\eta_T} + \omega_m \left( P_{T,t}^{m,c} \right)^{1-\eta_T} \right]^{1/(1-\eta_T)}$$

(2.9)
Aside from allocating resources to consumption, households invest in state contingent securities and hold government bonds that pay gross nominal interest rate. It is also assumed that households can purchase foreign bonds expressed in terms of domestic currency. Households also make provisions for capital expenditures.

Similar to consumption, investments are also modelled by assuming a CES structure. Following ALLV, it is assumed that total investment is an aggregate of domestic and imported investment goods, thus:

$$I_t = \left(1 - \omega_t\right)^{\eta_i/(\eta_i-1)} \left[\left(1 - \omega_t\right)^{\eta_i/(\eta_i-1)} + \omega_t I_t^d\right]^{\eta_i/(\eta_i-1)}$$

(2.10)

The demand functions are given by

$$I_t^d = (1 - \omega_t) \left[\frac{P_t^d}{P_t}\right]^{-\eta_i} I_t$$

(2.11)

$$I_t^m = \omega_t \left[\frac{P_t^m}{P_t} I_t\right]^{-\eta_i}$$

(2.12)

The price index for an investment good is given by

$$P_t^i = \left[(1 - \omega_t)(P_t)^{1-\eta_i} + \omega_t(P_t^m)^{1-\eta_i}\right]^{\eta_i/(1-\eta_i)}$$

(2.13)

The representative household’s budget constraint is similar to ALLV, with the addition of remittances, $\Sigma_t$, as a source of income, thus,

$$M_{j,t+1} + S_t B_{j,t+1}^* + P_t^C J_{j,t}(1 + \tau_t^C) + P_t^d I_{j,t} + P_t^m (a(j_{t-1})\bar{k}_{j,t} + P_k d_t K_{j,t})$$

$$= R_{t-1} (M_{j,t} - Q_{j,t}) + Q_{j,t} + (1 - \tau_t^C) w_{j,t} h_{j,t} + (1 - \tau_t^C) R_{t-1}^e u_{j,t} \bar{k}_{j,t}$$

$$+ R_{t-1}^e \Phi \left(\bar{\tau}_{t-1}, \phi_{t-1}\right) S_t B_{j,t}$$

$$- \tau_t^C (R_{t-1} - 1)(M_{j,t} - Q_{j,t}) + \left(R_{t-1}^e \Phi \left(\bar{\tau}_{t-1}, \phi_{t-1}\right) - 1\right) S_t B_{j,t}^*$$

$$+ B_{j,t}^*(S_t - S_{t-1}) + TR_t + D_{j,t} + \Sigma_t$$

(2.14)
where $P_t$ is the price of the domestic final good, $P_t^e$ is the price of consumption good, $P_t^i$ is the price of the final investment good, the difference $(M_{j,t} - Q_{j,t})$ refers to the amount of resources that earn interest income, $(1 - \tau_t^e)\Pi_t$ represents net profits that goes to households, $u_{j,t}$ is the utilization rate that may be increased by households, thereby incurring capital adjustment costs $a(u_{j,t})K_{j,t}$ or simply augment existing capital through investments, $S_tB_{j,t}$ is the amount in domestic currency of foreign bonds and $\Phi(\frac{\lambda_{t-1}}{\lambda_{t-1}}, \tilde{\phi}_t)$ represents a function that determines the premium associated with foreign bonds. As explained in ALLV and BVR, given incomplete international markets and the fact that not all idiosyncratic shocks can be insured against, the introduction of the said function is to ensure a well-defined steady state for consumption and assets in the international market (ALLV, p.15 and BVR, p. 181). $TR_t$ represents lump sum transfers, $\Xi_t$ pertains to remittances. It is assumed that remittance flows can be tracked to household recipients. We closely follow ALM’s specifications on remittance related functions that largely reflect processes associated with the motives of remittance sending agents. Exogenous tax rates on capital, labor income and wage income are given by $\tau_t^k, \tau_t^y, \tau_t^w$. We assume that wage income earned in the tradable and nontradable sectors are taxed similarly. Interest rates on domestic and foreign assets are given by $r_t$ and $\tilde{r}_t$, respectively. Following ALM, $\Xi_t$ is defined as $P_t^{mc}(\Xi_t^p + \Xi_t^3) + P_t^{mi}\Xi_t^4$, where $\Xi_t^p = \varepsilon_t^pY_t^p$ is assumed to be remittances which are procyclical with development in the host country; $\Xi_t^3 = (\gamma_t)^n$ are remittances which are countercyclical to domestic economy’s development, and serves as insurance against negative economic shocks; and $\Xi_t^4 = \mu_\Xi I_t^n$ are self-interested remittances motivated by the sender’s desire to invest in the home country, and are assumed to finance a fraction $\mu_\Xi$ of the imported investment good. As can be seen from the specification, it is clear that no exogenous shocks affect the level and timing of remittances. However, it does not mean that they are not theoretically plausible. For instance, $\Xi_t^p$ may be affected by host country – specific shocks while $\Xi_t^3$ is affected by destination country – specific shocks.

As in standard in the literature, investment’s law of motion is given by the following

$$K_{t+1} = [(1 - \delta)K_t + Y_tF(I_t, I_{t-1})] + \Delta_t \tag{2.15}$$

where $\delta$ is the depreciation rate and, $\Delta_t$ is the purchase cost of capital, and

$$F(I_t, I_{t-1}) = (1 - S(A_t))I_t, A_t = \frac{I_t}{I_{t-1}} \tag{2.16}$$

It is clear that when no installation costs are incurred, $F(I_t, I_{t-1}) = I_t$. Based on the way the function is specified, we discount the possibility that there are investment – specific technology shocks which have been established as one of the major sources of fluctuations in the United States (BVR, Greenwood (1997, 2000), Justiniano, Primiceri and Tambalotti (2010)).

We now specify the household’s optimization problem.
The first order conditions are:

\[ \beta E \left[ \frac{\psi_{z,t+1} R_t}{\mu_{z,t+1} \pi_{t+1}} - \frac{\psi_{z,t+1} \tau_{t+1}^k}{\mu_{z,t+1} \pi_{t+1}} (R_t - 1) \right] = \psi_{z,t} \]

(2.18)

\[ \omega_t = \psi_t P_{k',t} \]

(2.19)

\[ \psi_{z,t} \left[ (1 - \tau_t^k) r_t^k - a(u_{j,t}) \right] = 0 \]

(2.20)

\[ \beta E \left[ \frac{\psi_{z,t+1}}{\mu_{z,t+1} \pi_{t+1}} \left( (1 - \tau_{t+1}^k) R_{t+1}^k \frac{u_{j,t}}{P_{t+1}} - \frac{P_{t+1}}{P_{t+1}} a(u_{j,t+1}) \right) \right] + (1 - \delta) P_{k',t+1} \psi_{z,t+1} = \psi_{z,t} P_{k',t} \]

(2.21)

\[ \beta E \left[ \frac{\psi_{z,t+1}}{\mu_{z,t+1} \pi_{t+1}} \left( \frac{R_t}{\bar{z}_t^k} \Phi \left( \frac{A_t}{\bar{z}_t}, \Phi_t \right) S_{t+1} \right) \right] = \psi_{z,t} S_t \]

(2.22)
2.2 Labor demand and wage decisions

We follow the usual mathematical structure of how households determine their own wages. Following ALLV and BVR, we assume that each household is a supplier of differentiated labor service and that only a proportion of these households \((1 - \theta_h)\) can re-optimize every period using Calvo pricing as the endogenous mechanism for modeling wage stickiness. As noted in BVR and McCandless, assumptions on the behavior of non-optimizing households are critical in determining the dynamics in the labor market.

In the labor market, we assume a competitive labor aggregator or a labor packer who is responsible for aggregating differentiated labor supplied by households, producing a homogeneous good for intermediate firms to use. Following ALLV and BVR, the CES production function is used. As remarked in McCandless, the nature of the production technology enables household to exercise market power.

Let the production function of the competitive labor packer be

\[
L_t = \left( \int_0^1 \frac{1}{\lambda w} \frac{1}{\lambda w} \frac{1}{\lambda w} \int_0^1 \frac{1}{\lambda w} \frac{1}{\lambda w} \frac{1}{\lambda w} \right)^{\lambda w} , \quad 1 \leq \lambda w \leq \infty
\]  

where \(\lambda w\) is the wage mark-up.

Maximizing profits, the labor demand function for each labor type is given by

\[
e_{jt} = \left( \frac{w_{jt}}{w_t} \right)^{\lambda w - 1} L_t
\]

where \(e_{jt}\) is total labor demand.

Aggregate wages follow the following familiar process

\[
\left( \frac{Q_{jt}}{P_t} \right)^{-\alpha q} = (1 - \tau^k_t) u_t (R_{t-1} - 1)
\]

\[
\frac{\psi_{zt} P_t}{z_p} + \psi_{zt} P_{k', t} y_t F_1 (i_t, i_{t-1}, \mu_{zt}) + \beta E [\psi_{zt+1} P_{k', t+1} + y_{t+1} F_2 (i_{t+1}, i_t, \mu_{zt+1})] = 0
\]

\[
\frac{\zeta_t}{c_t - b c_{t-1}} - b \beta E_t \frac{\zeta_{t+1}}{c_{t+1} \mu_{zt+1} - b c_t} - \psi_{zt} \frac{P_t}{P_t} (1 + \tau^k_t) = 0
\]
As noted in BVR and ALLV, idiosyncratic risk arises because households follow Calvo’s pricing mechanism to set wages. In some papers, wage rigidities are modelled as convex adjustment cost for nominal wages (see Zubairy, 2010).

As is standard in the literature, we assume a Calvo-type of staggered price setting. Thus, a proportion of households $1 - \theta_h$ will be able to re-optimize per period while the remainder will simply follow rules of thumb. We follow ALLV’s wage setting rule for nonoptimizing households where they can only partially index their wages to past inflation and current inflationary targets.

$$W_{j, t+1} = \pi_t^{cW}(\tilde{\pi}_{t+1}^{c})^{1-\kappa_W} \mu_{z, t+1} W_{f, t}$$  \hspace{1cm} (2.29)

$\kappa_w$ is the indexation parameter. Note that when $\kappa_w = 1$, wages are indexed to past inflation. If a nonoptimizing household cannot optimize its wages in $s$ periods, the wage in period $t + s$ is

$$W_{j, t+s} = \left( \prod_{\tau=0}^{s-1} \pi_{\tilde{t}+\tau}^{c} \right)^{\kappa_w} \left( \prod_{\tau=0}^{s} \tilde{\pi}_{\tilde{t}+\tau}^{c} \right)^{1-\kappa_W} \left( \prod_{\tau=0}^{s} \mu_{z, \tilde{t}+\tau} \right) W_{f, t}^{NEW}$$  \hspace{1cm} (2.30)

Wages are determined by maximizing the following:

$$\max_{W_{j, t}^{NEW}} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta \theta_h)^s \left( \sum_{p} \left( \frac{\ell_{j, t+s}^{p}}{1 + \theta_f} \right)^{1+\theta_f} \right)$$

$$+ v_{t+s} \left( \frac{1 - \tau_r^{w}}{1 + \tau_w^{t+s}} \right) \left( \prod_{\tau=0}^{s-1} \pi_{\tilde{t}+\tau}^{c} \right)^{\kappa_w} \left( \prod_{\tau=0}^{s} \tilde{\pi}_{\tilde{t}+\tau}^{c} \right)^{1-\kappa_W} \left( \prod_{\tau=0}^{s} \mu_{z, \tilde{t}+\tau} \right) W_{f, t}^{NEW} \ell_{jt+s}$$  \hspace{1cm} (2.31)

subject to

$$\ell_{jt+s} = \left( \frac{W_{j, t}^{NEW}}{w_{t+s}^{-1}} \right)^{\frac{\lambda_w}{1-\kappa_w}} L_{t+s}.$$

Substituting the constraint into the objective function, we have
For households that can optimize, households maximize with respect to $W_{j,t}^{NEW}$. As noted in BVR, these households set the same wage due to complete market, implying that $W_{j,t}^{NEW} = W_t^{NEW}$. The first order condition is

$$E_t \sum_{s=0}^{\infty} (\beta_t \theta_h) \left[ -\zeta_{t+s}^{\ell} \eta_{t+s}^{\ell} [\ell_{j,t+s}] \right]^\theta \frac{\lambda_W}{1 - \lambda_W} \frac{W_{j,t}^{NEW}}{W_{t+s}} \frac{\lambda_W}{1 - \lambda_W} \frac{1}{W_{t+s}} L_{t+s}$$

$$+ \nu_{t+s} \left( \frac{1 - \tau_t^y}{1 + \tau_t^w} \right) \left( \prod_{\tau=0}^{s-1} \pi_{t+\tau}^c \right) ^{\frac{\kappa_w}{1 - \kappa_w}} \left( \prod_{\tau=0}^{s} \bar{\pi}_{t+\tau}^c \right) ^{1 - \kappa_w} \left( \prod_{\tau=0}^{s} \nu_{\mu_{t+\tau}} \right) W_{j,t}^{NEW}$$

$$\times \left( \frac{W_{j,t}^{NEW}}{W_{t+s}} \right) ^{\frac{\lambda_w}{1 - \lambda_w}} L_{t+s}$$

$$= 0$$

$$E_t \sum_{s=0}^{\infty} (\beta_t \theta_h) \ell_{j,t+s} \left[ -\zeta_{t+s}^{\ell} \eta_{t+s}^{\ell} [\ell_{j,t+s}] \right]^\theta \frac{\lambda_W}{1 - \lambda_W} \frac{W_{j,t}^{NEW}}{W_{t+s}} \frac{\lambda_W}{1 - \lambda_W} \frac{1}{W_{t+s}} L_{t+s}$$

$$+ \nu_{t+s} \left( \frac{1 - \tau_t^y}{1 + \tau_t^w} \right) \left( \prod_{\tau=0}^{s-1} \pi_{t+\tau}^c \right) ^{\frac{\kappa_w}{1 - \kappa_w}} \left( \prod_{\tau=0}^{s} \bar{\pi}_{t+\tau}^c \right) ^{1 - \kappa_w} \left( \prod_{\tau=0}^{s} \nu_{\mu_{t+\tau}} \right) \ell_{j,t+s}$$

$$\times \left( \frac{W_{j,t}^{NEW}}{W_{t+s}} \right) ^{\frac{\lambda_w}{1 - \lambda_w}} L_{t+s}$$

$$= 0$$
Letting \((\prod_{s=0}^{\infty} \pi_{t+s}^c)_{W} = (p_{t+s-1}^{\pi_{t-1}})^{K_w}\) and \((\prod_{s=0}^{\infty} \mu_{t+t+s}) = \frac{p_{t+s}^d}{p_{t-1}^d}\), we have

\[
E_t \sum_{s=0}^{\infty} (\beta \theta_h) \ell_{t+s} \left[ -\gamma_{t+s} + \gamma_{t+s}^{\text{p}} \right] \lambda \frac{1}{1 - \lambda} W_{t, t}^{\text{NEW}}
\]

\[
+ u_{t+s} \left( \frac{1 - \tau_{t+s}^{\gamma}}{1 + \tau_{t+s}^{\gamma}} \right) \frac{p_{t+s}^{c_{t+s}}}{p_{t-1}^{c_{t-1}}} \left( \prod_{t=0}^{S} \bar{\pi}_{t+s}^c \right)^{1 - \lambda} \frac{1}{1 - \lambda}
\] = 0

We can simply write the first order condition by following Villaverde (2010) and BVR.

\[
E_t \sum_{s=0}^{\infty} (\beta \theta_h) \left[ \ell_{t+s}^{\gamma} \right] \gamma_{t+s}^{\text{p}}
\]

\[
= E_t \sum_{s=0}^{\infty} (\beta \theta_h) \frac{W_{t, t}^{\text{NEW}}}{z_t p_t} \frac{z_{t+s} p_{t+s} u_{t+s}}{\lambda_t} \left( \frac{1 - \tau_{t+s}^{\gamma}}{1 + \tau_{t+s}^{\gamma}} \right) \frac{p_{t+s}^{c_{t+s}}}{p_{t-1}^{c_{t-1}}} \left( \prod_{t=0}^{S} \bar{\pi}_{t+s}^c \right)^{1 - \lambda}
\]

Given the fact that the fraction \(1 - \theta h\) of households is able to set their wages optimally and the remaining households can only partially index their wages to the previous period’s wage and current inflationary targets, the wage index evolves as

\[
W_t = \theta_h \left( \pi_{t-1}^{c_{t-1}} (\bar{\pi}_{t}^c)^{1 - \lambda} W_{t-1} \right) \left( 1 - \theta_h \right) W_{t, t}^{\text{NEW}} \frac{1}{1 - \lambda}
\] (2.33)

### 2.3 The production and distribution sectors
We follow the usual theoretical structure that will detail the expected behaviour of firms, their optimality decisions and some stylized features of the production sector. Following BVR and ALLV, we further group firms under two classifications, namely those that produce final and intermediate goods domestically and those that engage in imports and exports.

2.3.1 Nontradable goods sector

Following ALLV, we have three types of firms. First, as shown above, labor packers use differentiated labour from households to produce a homogenous input good that will be used by a continuum of intermediate goods firms. Intermediate goods firms behave rather monopolistically since they produced differentiated goods that will be utilized or packed by the final goods producer, a competitive firm in the distribution process. For intermediate goods and final goods firms, however, we take into account firm heterogeneity in terms of sectoral affiliation. As an open economy model, the differentiation between tradable and nontrable sectors is critical. For tradable sector firms, they transform inputs into intermediate outputs using labor and capital. However, for nontradable sector firms, only labor services are included as part of the inputs. We also assume that shocks are sector specific, indicating no interaction among firms belonging to different sectors.

2.3.1.1 Nontradable final goods firm

The final goods firm in the nontradable sector uses a CES production function to aggregate differentiated inputs produced by intermediate nontradable goods firms.

Consider an environment wherein firms produce units of homogeneous final good. Following BVR and ALLV, we assume that there is a continuum of intermediate goods producers which are monopolistically competitive firms. Indexed by \( n \in (0,1) \), let the production function be represented by \( Y_{N,t} \).

\[
Y_{N,t} = \left[ \frac{1}{\int_0^{\frac{\lambda_{N,t}}{n_{N,t}}} Y_{N,t} dN_t} \right]^{\lambda_{N,t}}, \quad 1 \leq \lambda_{N,t} < \infty \tag{2.34}
\]

where \( \lambda_{N,t} \) is the time varying mark-up in the domestic goods market which is assumed to follow a stochastic process. As explained in ALLV, there is a relationship between the stochastic mark – up and the usual specification involving the elasticity between intermediate goods.

The process that generates the observed mark – up is given by

\[
\lambda_{N,t} = (1 - \rho_N)\lambda_N + \rho_N \lambda_{N,t} + \varepsilon_{\lambda_{N,t}} \quad \sim (iid)N(0, \sigma_{\lambda_{N,t}}^2) \tag{2.35}
\]

Competitive final goods firms minimize costs by deciding on how much of intermediate inputs to use. Equivalently, these firms maximize profits which is just revenue minus costs with respect to intermediate inputs used, that is,
\[ \pi_{NT} = P_{NT} Y_{NT} - \int_0^1 P_{NL} Y_{NL} dN_t. \] (2.36)

As monopolistic firms, they can set prices \( P_t(k) \). Competitive final goods producers have access to CRS technology which transform intermediate goods into final goods.

The final goods pricing rule is given by

\[ P_{N,t} = \left[ \frac{1}{\int_0^1 P_{NL,t}^{1-\lambda_{NL}} dN_t} \right]^{1-\lambda_{NL}} \] (2.37)

while the demand function for firm \( k \)'s output is given by

\[ \frac{Y_{N,t}}{Y_{N,t}} = \left( \frac{P_{N,t}}{P_{NL,t}} \right)^{\lambda_{NL}} \] (2.38)

### 2.3.1.2 Nontradable Intermediate goods producer

To produce a unit of intermediate good, a firm needs labor only. The production function be specified as

\[ Y_{N,t} = z_{N,t} \epsilon_{t} H_{N,t} - z_{N,t} \phi_{N} \] (2.39)

where \( \phi_{N} \) represents fixed costs. Let \( \frac{z_{N,t}^{\mu}}{\epsilon_{t}^{\mu-1}} = \mu_{x,t}^{N} \).

\[ \mu_{x,t}^{N} = (1 - \rho_{\mu_{\mu}^{N}})\mu_{x}^{N} + \rho_{\mu_{x}^{N}} \mu_{x,t}^{N} + \epsilon_{x,t}^{N}, \epsilon_{x,t}^{N} \sim (iid) N(0, \sigma_{x}^{2}) \] (2.40)

Firms minimize the following problem subject to the production constraint:

\[ \min_{W_{t}^{N}, R_{t}^{f}} \left[ W_{t}^{N} R_{t}^{f} H_{t}^{N} + \lambda_{t}^{N} p_{t}^{N} Y_{N,t} - z_{t}^{N} \epsilon_{t}^{N} H_{t}^{N} + z_{t}^{N} \phi \right] \] (2.41)

Based on the stochastic production function, the marginal products of labor and capital are

\[ W_{t}^{N} R_{t}^{f} = \lambda_{t}^{N} p_{t}^{N} z_{t}^{N} \epsilon_{t}^{N} \] (2.42)

\[ m_{t}^{N} = \lambda_{t}^{N} = \bar{w}_{t} R_{t}^{f} \frac{1}{\epsilon_{t}^{N}} \] (2.43)

The nontradable intermediate goods firm follows Calvo pricing, implying that there is a fraction of firms that can set prices optimally.

#### 2.3.2 Tradable goods sector

Similar to nontradable final goods firms, we assume that there is a continuum of intermediate goods producers which are monopolistically competitive firms. Hence,
\[
Y_{T,t} = \left[ \int_0^t Y_{T(h),t} \frac{1}{2 \pi T} \right]^{\frac{1}{2}} \leq \lambda_{T,t} < \infty
\] (2.44)

where \(\lambda_{T,t}\) is the time varying mark-up in the domestic goods market which is assumed to follow a stochastic process. The process that generates the observed mark – up is given by

\[
\lambda_{T,t} = (1 - \rho_{\lambda t}) \lambda_{t} + \rho_{\lambda t} \lambda_{t-1} + \epsilon_{\lambda t, h} \epsilon_{\lambda t} \sim (iid) N(0, \sigma_{\lambda t}^2)
\] (2.45)

Competitive final goods firms minimize costs by deciding on how much of intermediate inputs to use. Equivalently, these firms maximize profits which is just revenue minus costs with respect to intermediate inputs used, that is,

The final goods pricing rule is given by

\[
P_{T,t} = \left[ \int_0^1 P_{T(h),t} \frac{1}{2 \pi T} dh \right]^{(1 - \lambda_{T,t})}
\] (2.46)

The demand function for firm \(h\)'s output is given by

\[
\frac{Y_{T(h),t}}{Y_{T,t}} = \left( \frac{P_{T,t}}{P_{T(h),t}} \right)^{\frac{\lambda_{T,t}}{\lambda_{T,t-1}}}
\] (2.47)

To produce a unit of intermediate good, the tradable goods firm needs to combine capital and labor. The tradable goods production function is specified as

\[
Y_{T(h),t} = z_{T,t} \epsilon_{T,t}^{1-\theta} \epsilon_{T,t}^{\theta} H_{T,h,t}^{1-\theta} - z_{T,t} \phi_{T}
\] (2.48)

where \(\phi_{T}\) represents fixed costs. Let \(\frac{z_{T,t}}{z_{T,t-1}} = \mu_{z,t}^T\).

\[
\mu_{z,t}^T = (1 - \rho_{z,t}) \mu_{z}^T + \rho_{z,t} \mu_{z,t-1}^T + \epsilon_{z,t}^T \epsilon_{z,t} \sim (iid) N(0, \sigma_{\epsilon_{z,t}}^2)
\] (2.49)

with \(\epsilon_{T,t} = \rho_{\epsilon_{T}} \epsilon_{T,t-1} + \epsilon_{\epsilon_{t}, h} \epsilon_{\epsilon_{t}} \sim (iid) N(0, \sigma_{\epsilon_{t}}^2)\)

To save on notation, we let \(h\) represent the \(T(h)\) index of tradable goods firm. Intermediate goods firms in the tradable goods sector thus have the following minimization problem:

\[
\min_{K_{h,t}} W_t R_t^f H_{h,t} + R_t K_{h,t} + \lambda_{h,t} P_{h,t} (Y_{h,t} - z_{T,t}^{1-\theta} \epsilon_{T,t}^{1-\theta} H_{T,h,t}^{1-\theta} - z_{T,t}^T \phi)
\] (2.50)

For the rest of this subsection (which refers only to tradable goods sector), and when possible to do so without causing confusion, we dispense with the subscript/superscript \(T\), in

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order to save on notation. We make distinction again on the subscript/superscripts for tradables and non-tradables at appropriate parts of the paper. Sometimes we also use the subscripts $d$ to refer to the domestically produced tradable goods.

Based on the stochastic production function, the marginal products of labor and capital are

$$W_t R^I_t = (1 - \theta) \lambda_{h,t} P_{h,t} z_t^{1-\theta} \epsilon_t K_h^{\theta} H_{h,t}^{-\theta}$$  \hspace{1cm} (2.51)

$$R^k_t = \theta \lambda_{h,t} P_{h,t} z_t^{1-\theta} \epsilon_t K_h^{\theta} H_{h,t}^{-\theta}.$$  \hspace{1cm} (2.52)

From the first order conditions, we have $\frac{R^k_t}{W_t R^I_t} = \frac{\theta \lambda_{h,t} P_{h,t} z_t^{1-\theta} \epsilon_t K_h^{\theta} H_{h,t}^{-\theta}}{(1 - \theta) \lambda_{h,t} P_{h,t} z_t^{1-\theta} \epsilon_t K_h^{\theta} H_{h,t}^{-\theta}}$, implying that

$$r^k_t = \frac{\theta}{(1 - \theta)} w H_{h,t} K_{h,t}^{-1} R^f_t.$$  \hspace{1cm} (2.53)

Substituting the optimal input demand functions into the linear cost function and differentiating with respect to $Y_t$, we have

$$mc_t = \left(\frac{1}{1 - \theta}\right)^{1-\theta} \left(\frac{1}{\theta}\right) \left(\frac{r^k_t}{w R^f_t}\right)^{\theta} \left(\frac{1}{\epsilon_t}\right).$$  \hspace{1cm} (2.54)

The price setting problem is similar to BVR, ALLV and Smets and Wouters. Because not all firms can re-optimize each period by adjusting their prices due to staggered pricing, the probability that some firms can adjust is just $(1 - \theta_f)$. Following Rubaszek and Skrzypczynski (2008), we have the following:

$$P_{t+1} = (\pi^{t+1}_c) \pi^{t+1}_d (\pi^{t+1}_c)^{1-\kappa_d} P_t.$$  \hspace{1cm} (2.55)

If a non-optimizing household cannot optimize its wages during $s$ periods ahead, the wage in period $t + s$ is

$$P_{j,t+s} = (\prod_{t=0}^{s-1} \pi^{t+1}_c) \pi^{t+1}_d (\prod_{t=0}^{s-1} \pi^{t+1}_d) P_t^{NEW}.$$  \hspace{1cm} (2.56)

Prices are determined by maximizing the following:

$$\max_{P_{t+1}^{NEW}} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta \theta_f)^s v_{t+s} \left( \prod_{t=0}^{s-1} \pi^{t+1}_c \right)^{\kappa_d} \left( \prod_{t=0}^{s} \pi^{t+1}_d \right)^{1-\kappa_d} P_t^{NEW} Y_{i,t+s} - MC_{h,t+s} (Y_{i,t+s} - z_{t+s} \phi)$$  \hspace{1cm} (2.57)
\[
E_t \sum_{s=0}^{\infty} (\beta \theta_f)^s p_{t+s} v_{t+s} Y_{t+s} \left\{ \left( 1 - \frac{\lambda_{d,t+s}}{\lambda_{d,t+s} - 1} \right) \left( X_{t,s} \tilde{p}_t \right)^{-\frac{\lambda_{d,t+s}}{\lambda_{d,t+s} - 1}} \right. \\
- \frac{MC_{h,t+s}}{p_{t+s}} \left( -\frac{\lambda_{d,t+s}}{\lambda_{d,t+s} - 1} \right) \left( X_{t,s} \tilde{p}_t \right)^{-\frac{\lambda_{d,t+s}}{\lambda_{d,t+s} - 1}} \left] = 0 \right. 
\]

Given the fact that the fraction 1 - \theta_f of intermediate goods firms is able to set their prices optimally and the remaining firms can only partially index their wages to the previous period’s wage and current inflationary targets, the wage index evolves as
\[ p_t = \left( \int_0^{\xi_d} (P_{t-1}(\pi_{t-1})^\kappa d(\nu_t^c)^{1-\kappa d})^{\frac{1}{1-\lambda_d,t}} + \int_{\xi_d}^{1} (P_{t}^{new})^{\frac{1}{1-\lambda_d,t}} \right) \right)^{1-\lambda_d,t} \\
= \theta_f(P_{t-1}(\pi_{t-1})^\kappa d(\nu_t^c)^{1-\kappa d})^{\frac{1}{1-\lambda_d,t}} + (1 - \theta_f)(P_{t}^{new})^{\frac{1}{1-\lambda_d,t}} \right)^{1-\lambda_d,t} \quad (2.58) \]

Hence, the loglinearized Phillips curve for the tradable goods, after putting back the subscript/superscript \( T \) to represent the tradable goods sector, is

\[ \hat{\pi}_t^T = \hat{\pi}_t^c + \left( \frac{\beta}{1 + \kappa_T \beta} \right) (\hat{\pi}_{t+1}^T - \rho_n \hat{\pi}_t^c) + \left( \frac{\kappa_T}{1 + \kappa_T \beta} \right) (\hat{\pi}_{t-1}^T - \hat{\pi}_t^c) \]
\[ + \frac{(1 - \xi_T)(1 - \beta \xi_T)}{\xi_T(1 + \kappa_T \beta)} (\hat{m}_c^T) + \lambda_{d,t} = \frac{\kappa_T \beta (1 - \rho_n)}{1 + \kappa_T \beta} \hat{\pi}_t^c \quad (2.59) \]

The counterpart equation for the nontradable goods is similar, with the index replaced by index \( N \), *mutatis mutandis*. Appendix A lists down all the loglinearized equations of the model.

### 2.3.2 Foreign sector

In modelling the foreign sector, we generally follow ALLV but there is a fundamental difference between their approach and BVR. In the latter, there are final consumption and investment goods producers which are competitive. They source their inputs from a continuum of importing firms that buy goods from abroad.

#### 2.3.2.1 Importing firms

In modelling the foreign sector, we closely follow ALLV specifically in formulating the respective objective functions and deriving the implied optimal behaviour of firms that are able to adjust and those that cannot. In BVR, there is a distributor that combines differentiated imported goods to produce the final imported good. These goods come from a continuum of importing firms that buy a foreign homogeneous good.

There are two kinds of importing firms, namely, investment and consumption firms. They essentially buy a homogeneous good at price \( P_t^* \). There is incomplete exchange rate pass through to the prices, by assuming that there is local currency price stickiness (ALLV, p. 8).

Following the logic of Calvo pricing, let \((1 - \theta_m)\) be the proportion of consumption good producing-importing firms that can change their prices optimally. Based on ALLV, the reoptimized price is denoted by \( P_{new,c}^{m,c} \). However, for a firm that cannot change its prices, its price evolves according to the following rule:
\[ P_{t+1}^{m,c} = (\pi_t^{m,c})^\kappa_{m,c}(\bar{\pi}_{t+1}^{c})^{1-\kappa_{m,c}}P_t^{m,c}. \] (2.60)

For a firm that cannot adjust for \( s \) periods, the price in \( t + s \) is given by
\[ P_{t+s}^{m,c} = (\prod_{t=0}^{s-1} \pi_{t+\tau}^{m,c})^{\kappa_{m,c}}(\prod_{t=0}^{s} \bar{\pi}_{t+\tau}^{c})^{1-\kappa_{m,c}}P_{new,t}^{m,c}. \]

Thus, the objective function is given by the following:
\[
\max_{P_{new,t}} \sum_{s=0}^{\infty} \left( \int_{0}^{1} \frac{C_{t+s}^{m}}{P_{new,t}^{m,c}} \right) \left( \prod_{t=0}^{s-1} \pi_{t+\tau}^{m,c} \right)^{\kappa_{m,c}} \left( \prod_{t=0}^{s} \bar{\pi}_{t+\tau}^{c} \right)^{1-\kappa_{m,c}} - S_{t+s} P_{t+s} \ast \left( C_{t+s}^{m} - z_{t+s} \phi^{m,c} \right)
\] (2.61)

The final imported good \( C_t^M \) is a composite of differentiated imported consumption goods supplied by different firms.

\[ c_{t}^{m} = \left[ \left( C_{t+1}^{\lambda^{m,c}} \right)^{\lambda_{m,c}} \right]^{1}_{0} \lambda_{t}^{m,c} \leq \infty, \] (2.60)

Expectedly, the demand for each firm’s imported consumption goods is shown by
\[ C_{t+s}^{m} = \left( \frac{P_{t+s}^{m,c}}{P_{t}^{m,c}} \right)^{-\frac{\lambda_{t}^{m,c}}{\lambda_{t}^{m,c} - 1}} C_{t}^{M}. \] (2.61)

The mark-up is modelled by the autoregressive time varying processes.
\[ \lambda_{t}^{m,c} = (1 - \rho_{\lambda}^{m,c})\lambda_{t-1}^{m,c} + \rho_{\lambda}^{m,c} \lambda_{t-1}^{m,c} + e_{\lambda_c,t}, \] (2.62)

Using the demand function \( C_{t+s}^{M} \), the objective function is written as
\[
\max_{P_{new,t}} \sum_{s=0}^{\infty} \left( \int_{0}^{1} \frac{C_{t+s}^{m}}{P_{new,t}^{m,c}} \right) \left( \prod_{t=0}^{s-1} \pi_{t+\tau}^{m,c} \right)^{\kappa_{m,c}} \left( \prod_{t=0}^{s} \bar{\pi}_{t+\tau}^{c} \right)^{1-\kappa_{m,c}} - S_{t+s} \left( \frac{P_{t+s}^{m,c}}{P_{t}^{m,c}} \right)^{-\frac{\lambda_{t}^{m,c}}{\lambda_{t}^{m,c} - 1}} C_{t+s}^{m} \] (2.63)

The first order condition is given by
The price index for differentiated consumption goods is given by
\[
P_t^{m,j} = \left[ \theta_m \left( (\pi_t^{c,i})^{\kappa_m} (\bar{n}_t^{c,i})^{1-\kappa_m} p_t^{m,j} \right) \frac{1}{1-\rho \pi_t^{c,i}} \right]^{1-\kappa_m} p_{new,t}^{m,j} (1-\theta_m) \left( p_{new,t}^{m,j} \right)^{1-\kappa_m} \right]^{1-\kappa_m} p_{t+1}^{m,j} \tag{2.65}
\]

\[
(\bar{n}_t^{m,j} - \bar{n}_t^{c,i}) = \frac{\beta}{1 + \kappa_{m,j} \beta} (\bar{n}_t^{m,j} - \rho n_t^{c,i}) + \frac{\kappa_{m,j} \beta (\bar{n}_t^{m,j} - \rho n_t^{c,i})}{1 + \kappa_{m,j} \beta} \left( \bar{n}_t^{m,j} - \rho n_t^{c,i} \right) \tag{2.66}
\]

where \( m_{c,t}^{m,j} = \hat{p}_t^{m,i} - s_t - \hat{p}_t^{m,i} \) for \( j = \{c,i\} \)

### 2.3.2.2 Investment goods

Following the logic of Calvo pricing, let \((1 - \theta_i)\) be the proportion of consumption good producing-importing firms that can change their prices optimally. Following ALLV, the reoptimized price is denoted by \( p_{new,t}^{m,i} \). However, for a firm that cannot change its prices, its price evolves based on the following rule:

\[
p_{t+1}^{m,i} = \left( \pi_t^{m,i} \right)^{\kappa_{m,i}} (\bar{n}_t^{m,i})^{1-\kappa_{m,i}} p_{t+1}^{m,i} \tag{2.67}
\]

For a firm that cannot adjust for \( s \) periods, the price in \( t + s \) is given by

\[
p_{t+1}^{m,i} = \left( \pi_t^{m,i} \right)^{\kappa_{m,i}} (\bar{n}_t^{m,i})^{1-\kappa_{m,i}} p_{t+1}^{m,i} \tag{2.68}
\]
The aggregator function for differentiated investment goods is given by the following:

\[ I_t^M = \left( \int_0^1 I_t^M \frac{1}{\lambda_{m,t}} \, dk \right)^{\lambda_{d,t}} \]  

(2.69)

As a profit maximizing firm, the demand function for each investment good is

\[ I_t^M = \left( \frac{I_t^m \lambda_{m,t}^{-\lambda_{m,t}^i}}{p_t} \right)^{\lambda_{m,t}^i} I_t^M \]  

(2.70)

The mark-ups are modelled by the following time varying process.

\[ \lambda_{t}^{m,i} = \rho \lambda_{m}^{m,i} \lambda_{t-1}^{m,i} + \varepsilon_{m,t} \]  

(2.71)

Substituting the demand function, we have

\[
\max_{p_t} E_t \sum_{s=0}^{\infty} (\theta_d)^s v_{t+s} \left( \left( \prod_{s=0}^{t-1} \right)^{\lambda_{t+s+1}^{m,i}} \left( \prod_{s=0}^{t} \right)^{1-\lambda_{t+s+1}^{m,i}} \left( \frac{p_{m,i}}{I_{t+s}^m} \right) \right) I_{t+s}^M \]

Maximizing yields the following familiar result.

\[
E_t \sum_{s=0}^{\infty} (\beta \varepsilon_{m,s})^s v_{t+s} \left( \left( \prod_{s=0}^{t-1} \right)^{\lambda_{t+s+1}^{m,i}} \left( \prod_{s=0}^{t} \right)^{1-\lambda_{t+s+1}^{m,i}} \left( \frac{p_{m,i}}{I_{t+s}^m} \right) \right) I_{t+s}^M \]

(2.72)
The price index for differentiated investment goods is given by

$$
p_{t}^{i,j} = \theta_{i} \left( \left( \pi_{t}^{m,i} \right)^{\kappa_{i}} (\bar{p}_{t}^{i})^{1-\kappa_{i}} p_{t-1}^{m,i} \right) \bar{\lambda}_{t}^{-\lambda_{t}^{m,i}} + (1 - \theta_{i}) \left( \left( \frac{p_{t}^{m,i}}{\bar{p}_{new,t}^{m,i}} \right)^{1-\lambda_{t}^{m,i}} \right) \right)^{1-\lambda_{t}^{m,i}} \tag{2.73}
$$

### 2.3.2.3 Exporting firms

Following the logic in ALLV and BVR, the exporting firms purchase the final domestic good to produce a good differentiated through brand naming. Because of their orientation, the differentiated products are sold to foreign households. Calvo pricing still persist as a way of determining the price that will optimize firm’s profits but export firms remain unable to achieve complete exchange rate pass through.

Following the logic of Calvo pricing, let \((1 - \theta_{x})\) be the proportion of consumption good producing-importing firms that can change their prices optimally. Using ALLV’s notation, the reoptimized price is denoted by \(p_{new,t}^{x}\).

For firms unable to set their prices optimally in \(t+1\), the evolution of prices in the export sector is given by

$$
p_{t+1}^{x} = (\pi_{t}^{x})^{\kappa_{x}} (\bar{p}_{t+1}^{c})^{1-\kappa_{x}} p_{t}^{x} \tag{2.74}
$$

The objective function is

$$
\max_{p_{new,t}^{x}} E_{t} \sum_{s=0}^{\infty} \left( \beta \theta_{x} \right)^{s} u_{t+s} \left( \left( \prod_{t=0}^{s-1} \pi_{t}^{x} \right)^{\kappa_{x}} \left( \prod_{t=0}^{s} \bar{p}_{t+s}^{c} \right)^{1-\kappa_{x}} \right) p_{new,t}^{x} \tilde{y}_{t+s}^{x} - \frac{p_{t+s}}{S_{t+s}} \left( \tilde{y}_{t+s}^{x} - z_{t+s} \phi_{t+s}^{x} \right) \tag{2.75}
$$

With the demand function be specified by

$$
\tilde{X}_{t} = \left( \frac{p_{t}^{x}}{\bar{p}_{t}^{x}} \right)^{-\lambda_{x,t}} \bar{X}_{t} \tag{2.76}
$$

Substituting the demand function into the objective function, we have
Given that the domestic economy is small enough to influence the foreign economy. We assume that the following functional relationships hold:

\[ I_t = \left( C_t^X \right)^{\eta_f-1} \eta_f + \left( C_t^c \right)^{\eta_f-1} \eta_f \]  

(2.77)

\[ I_t = \left[ (1 - \omega_i)^{1/\eta_i} \left( I_{d,t} \right)^{\eta_i-1} \eta_i + (\omega_c)^{1/\eta_c} \left( I_{m,t} \right)^{\eta_i-1} \eta_i \right] \]  

(2.78)

\[ C_t^X = (1 - \omega_i) \left[ \frac{p_t^X}{p_t^*} \right]^{-\eta_f} C_t^c \]  

(2.79)

\[ I_t^X = (1 - \omega_i) \left[ \frac{p_t^X}{p_t^*} \right]^{-\eta_f} I_t^c \]  

(2.80)

### 2.4. Relative prices

As ALLV explained, the consideration of open economy shocks in a DSGE model is important in determining key macroeconomic outcomes, given the possibility that there is a high elasticity of substitution between domestic and imported goods (ALLV, 2005).

\[ \gamma_t^{mc,d} = \frac{p_t^{mc}}{p_t} \]  

(2.81)

\[ \gamma_t^{ml,d} = \frac{p_t^{ml}}{p_t} \]  

(2.82)

\[ \gamma_t^{c,d} = \frac{p_t^c}{p_t} \]  

(2.83)
2.5 The monetary authority

Monetary policy in the Philippines is conducted independently by the Central Bank, contrary to the European system wherein it is delegated to the European Central Bank. The nominal interest rate follows the Taylor rule:

Following ALLV and BVR, we assume that the short run interest rate will be adjusted based on the deviation of the inflation rate from the target, the output gap and the real exchange rate. The log – linear form of the monetary policy rule is given by

\[
\hat{r}_t = \rho_r \hat{r}_{t-1} + \lambda \left( \hat{r}_t^c + \eta_{t-1}^c (\hat{r}_{t-1}^c - \hat{r}_t^c) + r_y^c \hat{y}_{t-1}^c + \lambda \Delta \hat{r}_t^c + \nu_y \Delta \hat{y}_t^c + \nu_{\hat{r}_t} \Delta \hat{r}_t^c + \epsilon_{R,t} \right) \tag{2.91}
\]

\( \epsilon_{R,t} \) is interpreted as a random shock to monetary policy.

Log-linearized exchange rate is given by
CPI inflation rate index is given by the following equation:

\[ \hat{\pi}_t^c = \left(1 - \omega_N\right)(\gamma^{T,c}(1 - \eta_C)) \hat{\pi}_t^c + \left(\omega_N\right)(\gamma^{N,c}(1 - \eta_C)) \hat{\pi}_t^N \]  

(2.92)

The deviation of the inflation target from the steady-state inflation rate is assumed to follow the process

\[ \hat{\pi}_t^c = \rho_{\hat{\pi}} \hat{\pi}_{t-1}^c + \epsilon_{\hat{\pi},t} \]  

(2.93)

### 2.6 The government problem

The budget constraint consists of the level of outstanding debt, the stochastic process that determines government consumption, and taxes and transfers.

\[ P_t G_t + TR_t = R_{t-1}(M_{t+1} - M_t) + \tau_t^c P_t^c G_t + (\tau_t^w + \tau_t^v) \frac{W_t}{1 + \tau_t^w} L_t \]

\[ + \tau_t^k \left[ (R_{t-1} - 1)(M_{t+1} - Q_t) + R_t^k u_{j,t} K_{j,t} \right. \]

\[ + \left. \left( R_{t-1} \Phi \left( \frac{A_{t-1}}{z_{t-1}}, \phi_{t-1} \right) - 1 \right) S_t B_{j,t} \right] + \Pi_t \]  

(2.94)

### 2.7 Aggregation

Closing the model requires aggregation conditions for the goods, labor, and import and export markets. We closely follow BVR and ALLV. We first specify aggregate demand of the domestic final good which is equal to domestic consumption, domestic investment government spending, and exported consumption and investment goods. Aggregate output is given by

\[ Y_t = Y_{t,t} + Y_{N,t} + G_t \]  

(2.95)

where \( Y_{t,t} = C_t^d + I_t^d + G_t + C_t^x + I_t^x \).

Formally, it is represented by

\[ C_t^d + I_t^d + G_t + C_t^x + I_t^x \leq z_t^{1-\theta} e_t K_t^a H_t^{1-\theta} - z_t \phi - a(u_t) K_t \]  

(2.96)
2.8 Evolution of net foreign assets

Following BVR and ALLV, specifying the evolution of the net foreign assets will close the foreign sector. We integrate remittances by following ALM. The balance of payments evolves as

\[ S_t B_{t+1}^* = S_t P^x_t (C_t^x + I_t^x) - S_t P^x_t (C_t^m + I_t^m) + R_t^{*-1} \Phi (a_{t-1}, \phi_{t-1}) S_t B_t^* + \varepsilon_t \]  

(2.97)

\[ S_t B_{t+1}^* = S_t P^x_t (C_t^x + I_t^x) - S_t P^x_t (C_t^m + I_t^m) + R_t^{*-1} \Phi (a_{t-1}, \phi_{t-1}) S_t B_t^* + \rho_t^{m,c} (\varepsilon_t^p + \varepsilon_t^e) + \rho_t^{m,i} \varepsilon_t^i \]  

(2.98)

\[ a_t = \frac{S_t B_{t+1}}{P_t z_t} \]

Divide through by \( P_t z_t \)

\[ \frac{S_t B_{t+1}^*}{P_t z_t} = \frac{S_t P^x_t}{P_t} \frac{Y_t^*}{z_t} - \frac{S_t P^x_t}{P_t} \left( \frac{C_t^m}{z_t} + \frac{I_t^m}{z_t} \right) + \frac{R_t^{*-1} \Phi (a_{t-1}, \phi_{t-1})}{P_t z_t} \frac{S_{t-1} B_t^*}{P_t z_t} - \frac{R_t^{*-1} \Phi (a_{t-1}, \phi_{t-1})}{P_t z_t} \frac{S_{t-1} B_{t-1}}{P_t z_t} \]

\[ + \frac{\rho_t^{m,c} (\varepsilon_t^p + \varepsilon_t^e)}{P_t z_t} + \frac{\rho_t^{m,i} \varepsilon_t^i}{P_t z_t} \]

Stationarized NFA equation:

\[ a_t = (mc_t^x)^{-1} (y_t^{x,*})^{-\eta} (y_t^f)^{-1} (c_t^m + i_t^m) + R_t^{*-1} \Phi (a_{t-1}, \phi_{t-1}) \frac{a_{t-1}}{\pi_t \mu_{zt}} \frac{S_t}{S_{t-1}} \]

(2.99)

\[ + \frac{\rho_t^{m,c} (\varepsilon_t^p + \varepsilon_t^e)}{P_t z_t} + \frac{\rho_t^{m,i} \varepsilon_t^i}{P_t z_t} \]

Totally differentiating, we arrive at:

Linearized equation for NFA:
\[ \hat{a}_t = -y^*\hat{m}_t^c - \eta_f y^*y^x_t + y^*\hat{y}_t^s + y^*\hat{k}_t^s + (c^m + i^m)\hat{y}_t^f \\
- c^m (\eta_c (1 - \omega_c) (y^c, d)^{-(1 - \eta_c)} y^mc, d + \hat{e}_t) + i^m (\eta_f (1 - \omega_f) (y^b, d)^{-(1 - \eta_f)} y^mb, d + \hat{l}_t) + \frac{R}{\bar{\pi}_t} \hat{a}_{t-1} \]

(2.100)

2.9. Loan market clearing

\[ v_t M_t - Q_t = (2.101) \]

Stationarized form:

\[ v_t \bar{M}_t = \frac{\mu_t \bar{M}_t}{\bar{\pi}_t \bar{\mu}_t} - q_t \]

(2.102)

2.10 Foreign economy

We consider three foreign economy variables, namely, foreign output, interest rate and inflation rate. Following ALLV, we model the exogenous variables using a VAR process.

\[ F_0X_t^* = F(L)X_{t-1}^* + \varepsilon_{x^*,t}^* \sim N(0, \Sigma_{x^*}) \]

(2.103)

3.0 Empirics of an Open Economy DSGE model

3.1 Introduction

For several years now, Bayesian methodologies have provided the estimation framework of choice among macroeconomists, especially those who are estimating medium and large scale macroeconometric models that do not have explicit closed form solutions.

Deciphering the reasons for this prevalent preference is not hard. Villaverde (2010) highlights some advantages of the Bayesian technique. First, Bayesian techniques generate more relevant and useful estimates. Second, even with limited data points, such techniques utilize what Villaverde calls pre–sample information which may be hard to incorporate in a frequentist – based approach. In the case of remittances, for instance, one can incorporate microeconomic – based theories in determining priors. Third, Bayesian techniques are capable of estimating many objects of interest, such as the entire distribution of a particular statistic. For instance, suppose we want to measure how remittances affect welfare. Bayesian techniques can give us the entire distribution of such an effect. Fourth, compared with other estimation platforms, Bayesian methods account for the various model elements and not
only confined within equilibrium relationships (Grifolli, 2008). Finally, Bayesian techniques do not prescribe a true model nor tries to replicate the frequentist objective of searching for the true parameter value. In this sense, we cannot make an assertion that the DSGE model is outrightly false relative to a ‘true’ model.

In their review of Bayesian techniques for estimating DSGE models, Guerron – Quintana and Nason (2012) [henceforth referred to as GQN], notes that the Bayesian method does not endorse a particular model as the true model, contrary to other known estimation platforms that subscribe to the classical approach. As explained in GQN, this view is deeply anchored on the likelihood principle which means that the evidence should be provided by the data and that probabilistic statements made should pertain to the conditional likelihood, not relative to a data generating process (DGP) that is assumed to be true. In fact, Bayesian methods allow the comparison of models based on model fit (Grifolli, 2008).

As shown in ALLV and BVR, open economy DSGEs are described by a complicated and interdependent model structures. The incorporation of such structures necessarily lead to a problem of high dimensionality which is not easily addressed using conventional estimation platforms such as the maximum likelihood estimator (Vilaverde, 2010).

In this section, we review existing Bayesian methodologies and examine the feasibility of estimating the base model that may embed remittance shocks in ALLV’s open economy DSGE model. While estimating ‘deep parameters’ remains a key objective, data imperfections prevent us from implementing Bayesian methodologies. Section 3.2 discusses the computational requisites prior to estimating parameters of the model. Section 3.3 discusses how the empirical methodology is applied. Section 3.4 briefly discusses the estimation of the model’s impulse response functions.

3.2 A review of computational requisites

3.2.1 Bayesian methods

Bayesian methods will be used to estimate some of the key parameters of the model. In the literature, Bayesian methods are empirically appealing with the parameters assumed to be random, contrary to the classical assumption that the model is generated by an underlying data generating process (DGP). The objective of classical methods is to estimate unknown parameters that are assumed to be true. Bayesian methods overcome the inherent difficulty of maximum likelihood estimation to include non-sample information and avoid intricacies involved when the distributional assumption is inconsistent with the data. It essentially acts as the bridge between calibration and maximum likelihood (Grifolli, 2008). As noted in Villaverde (2010) sometimes it is not interesting to determine the significance of parameter estimates in repeated samples. Bayesian analysis requires the prior distribution, the data and the likelihood function in order to derive the posterior distribution (see GQN).

Formally, consider the vector $\psi$ that stacks up all parameters in the model. The parameter vector may vary across DSGE models due to the imposition of plausible restrictions based on economic theory. The prior density is given by $p(\psi)$. Priors act as weights in the estimation process and helps in the identification of parameters (Grifolli, 2008). The model implies a likelihood $p(Y^T | \psi) = L(\psi | Y^T)$ for some observed data. The posterior distribution of the vector of parameters is given by
The density of parameters given the data \( p(\psi|Y^T) \) can also be written as

\[
p(\psi|Y^T) \propto p(Y^T|\psi)p(\psi)
\]

Following Grifolli (2008), the posterior density associated with model \( M \) is given by

\[
p(\psi_M|Y^T, M) = p(Y^T|\psi_M, M) \times p(\psi_M|M) / p(Y^T|M)
\]

and the marginal density is

\[
p(Y^T|M) =
\]

To complete the picture, the posterior kernel is given by

\[
p(\psi_M|Y^T, M) = p(Y^T|\psi_M, M)p(\psi_M|M)
\]

The posterior distribution for DSGE models is difficult to characterize, thereby necessitating the use of simulation methods to generate draws using the Metropolis-Hastings (MH) algorithm. We use Kalman filter to estimate the likelihood function and the posterior kernel is simulated using the MH algorithm.

### 3.2.2 Estimating DSGE: a general procedure

1. There is a need to stochastically detrend because of the presence of nonstationary prices and technology or productivity shocks. Following ALLV, GQN and BVR, detrending is usually applied to the first order and equilibrium conditions.
2. We log–linearized the solution of the DSGE open economy model, duly accounting for non–stationary behavior induced by price level and technological change. We use the first order Taylor or linear approximation.
3. Following De Jong and Dave (2007) and GQN, equilibrium conditions are portrayed as expectational stochastic difference equations.
4. Consistent with other studies, we specify the prior distributions of a set of estimable parameters. The choice of priors is not a trivial exercise.
5. Determine the likelihood via Kalman filter. In this step, there is a need to utilize tools of state space modeling and filtering theory (Villaverde, 2010). There are two critical components of the state space representation, namely a transition equation relating a state vector to a vector of innovations and parameters and a measurement equation which in turn, relates observed variables to shocks. To avoid the problem of stochastic singularity, the number of observed series should be equal to the number of shocks in the model. As mentioned in Villaverde (2010), one needs to determine the set of observed variables because they have implications on inference. In using the Kalman filter, we assume that both the transition and measurement equations are linear and the shocks are normally distributed (Villaverde, p. 17). This necessitates
solving the model and approximating the same using a first order linear approximation.
7. Compute the marginal likelihood numerically.
8. Compute statistics of interest. We are interested in computing the posterior distribution of estimable parameters.

3.2.3 The Linearized Model and its solution

The basis of the linearized model is the theoretical model elements identified in ALLV and section 2. In the said references, the structure of the model consists of first order optimality conditions, equilibrium conditions, relative prices and shock processes. As explained in BVR and GQN, since the DSGE model does not have a closed form solution, one needs to determine a model that is linearized around a non-stochastic steady state in order to determine the model solution using linear algebraic solution methods.

Following ALLV, we will also stationarize model variables to account for trends induced by technology or productivity shocks. This is known as stochastic detrending and it is done by dividing trended real variables by the productivity shock. To implement stochastic detrending, trending real variables are divided by the productivity shock. Nominal wages are divided by the product of the price and productivity shock.

Linearization can be achieved using Uhlig’s log-linearization or by way of first order Taylor approximation. In other studies, higher order approximations are used to avoid biases that may arise when the valid degree of approximation is not linear.

The solution can be cast as an expectational stochastic difference equation. Largely borrowing from ALLV and GQN, we have the expectational stochastic difference equation as

$$E_t[G(N_{t+1}, N_t, X_{t+1}, X_t)] = 0$$

Where $X_t$ is the vector of predetermined states and $N_t$ includes non–predetermined controls. As shown in GQN, the solution of the model takes the form of

$$X_t = \Psi X_{t-1} + \Phi \xi_t$$
$$N_t = \Xi X_t$$

The first is a system of equations that pertain to linear approximate equilibrium decision rules of the state variables. $\xi_t$ contains the vector of structural innovations in the model.

3.3 Bayesian estimation of the model: a roadmap

Bayesian estimation uses the Kalman filter to construct the likelihood of the model. Then priors are proposed because they are used to compute for the posteriors.

3.3.1 Evaluating the likelihood using the Kalman Filter

The solution of a DSGE model is based on the system of log – linearized equations. To be able to estimate the parameters, the likelihood principle should be involved. A necessary step
is to be able to evaluate the likelihood function that is based on the solution to the log-linearized system.

To provide an exposition, we use Villaverde (2010), GQN (2012) and DD. For the Kalman filter to work, there are several assumptions, namely, linearity of the transition and measurement equations and normally distributed shocks. The Kalman filter projects the state of linear approximate solution. The filter is useful for evaluating the likelihood because the forecasts are optimal within a class of models.

The start point is to specify the state-space representation of the solution to the model. Similar to GQN, we have the critical equations.

\[ X_t = GX_{t-1} + H\epsilon_t, \quad \epsilon_t \sim NID(0, I_m) \]

\[ \Psi_t = Q + JX_t + \epsilon_{u,t}, \quad \epsilon_{u,t} \sim NID(0, \Sigma_u) \]

Following GQN, \( \Psi_t \) corresponds to the vector of observables, \( X_t = [N_t', S_t'] \) simply combines the vectors of non-predetermined variables and states, G and H are functions of the structural matrices and J relates the model’s definitions to the data. As noted in GQN, \( \epsilon_{u,t} \) is a measurement error.

We define the following linear projections.

\[ E[X_t|X_1, X_2, \ldots, X_{t-1}] = X_{t|t-1} \]
\[ E[X_t|Y_t] = S_{t|t} \]

The first is the conditional expectation of \( X_t \) given its previous history. The second conditions the mean of the state variable on \( Y_t \). The covariance matrix is

\[ P_{t-1|t-1} = E[(X_{t-1} - X_{t-1|t-1})(X_{t-1} - X_{t-1|t-1})'] \]

The likelihood of the linearized model, \( L(S_{t-1}|\Theta) \) is built up by generating forecasts from the state space system period by period

\[ L(Y_t|\Theta) = \prod_{t=1}^{T} L(Y_t|Y_{t-1}, \Theta) \]

As GQN states, \( L(Y_{t}, Y_{t-1}, \Theta) \) is the likelihood conditional on the information up to date \( t-1 \).
The steps are given in GQN, DD and Villaverde (2010). Closely following GQN, we will simply repeat them here for exposition purposes.

1. Set the conditional forecast of $X_{t-1}$ to zero. The projection $p_{t-1} = GP_{t-1}G + HH'$
2. On the basis of conditional forecasts, compute for the value of $Y_{t-1} = JX_{t-1} = 0$, $\Omega_{t-1} = E[(Y_t - Y_{t-1})(Y_t - Y_{t-1})'] = J'p_{t-1}J + \Sigma_u$
3. The predictions made in steps 1 and 2 produce the date 1 likelihood. The likelihood for the observable vector conditional on the parameters is given by

$$L(Y_1|\Theta) = (2\pi)^{-m/2} [\Omega_{t-1}^{-1}]^{1/2} \exp \left( -1/2 Y_1 \Omega_{t-1}^{-1} Y_1 \right)$$

4. Update the date 1 forecasts.

$$X_{t-1} = X_{t-1} + p_{t-1} \Omega_{t-1}^{-1} (Y_t - Y_{t-1})$$

$$p_{t-1} = p_{t-1} - p_{t-1} \Omega_{t-1}^{-1} J'p_{t-1}$$

5. Repeat steps 2, 3, and 4 to generate Kalman filter predictions (see GQN)

$$X_t = X_t + p_t \Omega_t^{-1} (Y_t - Y_{t-1})$$

$$p_t = p_t - p_t \Omega_t^{-1} J'p_t$$

3.3.2 The Metropolis – Hastings algorithm

As recognized by Grifolli, (2008), the MH algorithm allows one to simulate the posterior distribution by generating a Markov chain of samples. Unlike statistical problems wherein the distribution can easily derived, DSGE models give rise to nonlinear function of deep parameters (Grifolli, 2008). The algorithm is initialized by selecting a starting point which is usually the posterior mode. Then a proposal parameter vector is drawn from a jumping distribution. Then the acceptance ratio is computed and a rule is proposed in order to set the decision rule on the proposal parameter.

3.4 Model and estimates

3.4.1 Log linearized equations
As explained in GQN, ALLV and Villaverde, the solution elements of DSGE models are mostly nonlinear. Closely following ALLV, we have the system of log – linearized equations that form the basis for the estimation procedure. The said log linearized equations are found in the model block of the DYNARE code found in Appendix B.

To estimate the impulse response functions, we used DYNARE, a software that specializes in DSGE computation. It is embedded on MATHLAB. As shown in the program used by ALLV, the initial step involves the declaration of endogenous and exogenous variables and parameters. The specification of the linearized model comes next. This is the most important component of the DYNARE program. To arrive at a steady state solution, the program requires inputting parameter values. There is a possibility that a steady state may not be found. Then using the Blanchard – Khan procedure, the program now evaluates whether a key condition for computational feasibility and identification is satisfied.

3.4.2 Impulse response functions

Central to DSGE modelling is the co – existence of shocks which may or may not perturb macroeconomic variables. Because of the integrated nature of the model, even a shock in one sector can affect the outcomes in other sectors. There are about 22 shock processes in the model and 8 outcome variables of interest.

In estimating the impact of the shocks, we can include more outcome variables but we decided to focus on the more important ones that provide policy guidance. The outcome variables are: domestic tradable goods inflation, domestic nontradable goods inflation, total remittances, the real wage, consumption, investment, exchange rate and output.

The shock variables are grouped into the following: (a) technology and investment shocks which include tradable and nontradable sector specific shocks, unit root technology shocks, asymmetric technology shocks and investment – specific shocks; (b) fiscal and monetary policy shocks; (c) substitution elasticity shocks; (d) household preference shocks; (e) foreign variable shocks; (f) price mark-up shocks; (g) trade related variables; and (h) others not elsewhere classified.

One of the most useful results are the impulse response function, which shows how a certain shock affects outcome variables temporally. Estimated impulse response functions are found in Figures 1 to 22.

4.0 Examining the macroeconomic impact on remittances

This section focuses on how remittances react to various shocks. For the analyses to be more informative, we will study the respective responses of total remittances and its components. In the model, we did not include shocks to remittances so the objective is to simply understand how shocks affect remittances themselves. Based on the way we defined total remittances in section 2, we can immediately discern key determinants, namely, domestic output, international output, exchange rate, investment, household's consumption habits and labor supply preferences, and domestic and foreign inflation, to name a few concrete ones. This implies that when there is a permanent shock to output through an improvement in production processes, remittances will be affected. The introduction of two sectors, the consideration of policy shocks and preference shocks appear to alter remittance behaviour. Based on the way remittances are modelled, we know that remittances respond to domestic conditions and investment opportunities. However, it is safe to presume that the respective
components of total remittances will respond to the above-mentioned determinants differently.

Whether such an impact is significant or not, we can appreciate how remittances are affected by a host of economic shocks.

**4.1 Impulse response of total remittances**

We start by only looking at total remittances. As shown in Figures 1 and 2, sector – specific stationary technological shocks appear to dampen remittances. Though not substantive an evidence, it simply highlights the sensitivity of remittances to improvements in sectoral economic conditions. The more permanent the shock, the higher is the negative effect on remittances. This is the case of unit root technology shocks since they induce permanent changes in the level of output. An increase though may occur, especially when there is a labor supply preference and asymmetric technology shocks. Asymmetric technology shocks relate the level of a given country’s technology to the rest of the world. As shown in Figure 21, a positive shock to labor supply would be expected to boost initial real wages, dampen consumption and investment. Surprisingly, it will reduce output which may partly explain why remittances will decrease.

In terms of fiscal policy variables, an exogenous increase in government spending will reduce remittances. The link between government spending and output is positive, as clearly shown in Figure 6. This may partly explain why the initial impact on remittances is negative. Over time, as the impact of the government spending shock diminishes, remittances will be increasing. The immediate impact of shocks to tax rates is insignificant but over time but obviously, they induce a downward response from remittances.

Foreign variables also affect remittances. Consider foreign inflation shock. A positive shock will result in reduced remittances because inflation negatively affects the purchasing power of workers. It certainly is more favourable in countries where monetary policy aims to maintain price stability.

In terms of mark – up shocks, a positive will push remittances upwards while a domestic tradable mark-up results in a negative initial remittance response.

**4.2 Impulse response of remittances, by components**

Results showing the various impulse response functions are given in Figures 23 to 44. As noted in section 2, total remittances have cyclical, procyclical and strategic components. Thus, the analyses will turn out to be more informative than when we simply rely on total remittances.

When there is a positive government spending shock, the initial reaction of cyclical remittances is negative, compared with favourable increases in procyclical and strategic remittances.

Now let us examine how technological shocks affect remittance components. Sector specific stationary technological shocks appear to have divergent effects on remittance components. A positive shock in the tradable sector appears to induce increases in procyclical and strategic remittances after 7 – 10 years. On the other hand, if the shock emanates from the nontradable sector, there is a robust positive effect on strategic remittances. Unit root
technological shocks robustly cause a decline in strategic remittances but not on countercyclical remittances. For asymmetric technology shock, it is clear that the observed increase in total remittances come from its procyclical component. It is also notable that the strategic component will increase remittances after 4 quarters and will sustain its upward trend, thereby compensating the downward trends in procyclical and countercyclical remittances.

As expected, a consumption preference shock will increase remittances via its procyclical and countercyclical components but the effect diminishes quickly. As shown in figure 42, the strategic component does not react positively to such a shock at all.

Investment specific shocks as shown in Figure 41 indicates that the positive over-all effect on total remittances come consistently from the strategic component. The Figure shows that there is a very sizable increase in remittances after the occurrence of the shock.

Shocks to monetary policy appear to induce an increase in countercyclical and procyclical remittance but dampens robustly strategic remittances.

In terms of mark-ups, domestic shocks induce a reduction in cyclical remittances but causes an increase in strategic remittances.

5.0 Concluding remarks

In this paper, we augment the existing open economy DSGE model of ALLV by distinguishing the nontradable and tradable sectors and including remittances. This makes our model more stylized given the fact that the Philippines remain as one of the top remittance – receiving countries in the world. We estimated the dynamics of various macroeconomic variables after individually considering exogenous shock processes. We focused our analysis on the response of remittances on shock processes. This is an important undertaking because of the role remittances play in stabilizing foreign exchange markets and providing support to economic activities involving households and firms.

While the model appears to capture fairly well some stylized facts, we recognize that there are some inadequacies. First, the paper did not define a stochastic process for remittances. Doing so would allow us to understand how remittance shocks affect key macroeconomic outcomes like labor supply, output, real wages, domestic inflation, elasticity of substitution, real interest rate, to name a few. Second, the impulse response functions, while informative, were based on stochastic simulation methods, not actual data. As mentioned, data transformations must be meticulously mapped against model variables which are not always properly measured. Third, the model made the assumption that while there are two sectors with their own production processes for their respective intermediate goods firms, there is only one real wage which implies total labor was the one considered. Fourth, the model assumes that households have access to capital markets, which may not be reflective of the real situation as other households can be classified as rule – of –thumb households. Fifth, the model does not integrate the financial markets and its various agents, thereby ignoring financial frictions as one probable cause of economic fluctuations.
Bibliography


**APPENDIX B:**

The Loglinearized Model

\[
\hat{\Pi}_t^T = \hat{\Pi}_t^C + \left( \frac{1}{1 + \kappa_T \beta} \right) (\hat{\Pi}_{t+1}^T - \rho_{\pi} \hat{\Pi}_t^C) + \left( \frac{\kappa_T}{1 + \kappa_T \beta} \right) (\hat{\Pi}_{t-1}^T - \hat{\Pi}_t^C)
\]

\[
+ \left( \frac{1 - \xi_T}{\xi_T (1 + \kappa_T \beta)} \right) (\hat{m} \hat{c}_t^T) + \hat{\lambda}_{d, t} - \frac{\kappa_T \beta (1 - \rho_{\pi})}{1 + \kappa_T \beta} \hat{\Pi}_t^C
\]
\[ \hat{n}_t^N = \hat{n}_t^N + \left( \frac{\beta}{1 + \kappa_N \beta} \right) (\hat{n}_{t+1}^N - \rho \hat{n}_t^N) + \left( \frac{\kappa_N}{1 + \kappa_N \beta} \right) (\hat{n}_{t-1}^N - \hat{n}_t^N) + \frac{(1 - \xi_N)(1 - \beta \xi_N)}{\xi_N(1 + \kappa_N \beta)} (\hat{m}_t^N) + \lambda_{N,t} - \frac{\kappa_N \beta(1 - \rho_N)}{1 + \kappa_N \beta} \hat{n}_t^N \]

\[ \hat{n}_t^{m,c} = \hat{n}_t^c + \frac{\beta}{1 + \kappa_{m,c} \beta} (\hat{n}_{t+1}^{m,c} - \rho \hat{n}_t^c) + \frac{\kappa_{m,c}}{1 + \kappa_{m,c} \beta} (\hat{n}_{t-1}^{m,c} - \hat{n}_t^c) + \frac{(1 - \xi_{m,c})(1 - \beta \xi_{m,c})}{\xi_{m,c}(1 + \kappa_{m,c} \beta)} (\hat{m}_{t}^{m,c}) + \hat{\eta}_{m,c} - \frac{\kappa_{m,c} \beta(1 - \rho_N)}{1 + \kappa_{m,c} \beta} \hat{n}_t^c \]

\[ \hat{n}_t^{m,i} = \hat{n}_t^c + \frac{\beta}{1 + \kappa_{m,i} \beta} (\hat{n}_{t+1}^{m,i} - \rho \hat{n}_t^c) + \frac{\kappa_{m,i}}{1 + \kappa_{m,i} \beta} (\hat{n}_{t-1}^{m,i} - \hat{n}_t^c) + \frac{(1 - \xi_{m,i})(1 - \beta \xi_{m,i})}{\xi_{m,i}(1 + \kappa_{m,i} \beta)} (\hat{m}_{t}^{m,i}) + \hat{\eta}_{m,i} - \frac{\kappa_{m,i} \beta(1 - \rho_N)}{1 + \kappa_{m,i} \beta} \hat{n}_t^c \]

\[ \hat{\eta}_t = \frac{1}{n_1} \left[ \eta_1 \hat{\omega}_{t-1} + \eta_2 \hat{\omega}_{t+1} + \eta_3 \hat{\omega}_t + \eta_4 \hat{\omega}_t^d + \eta_5 \hat{\omega}_c + \eta_6 \hat{\omega}_{c,t+1} + \eta_7 \hat{\psi}_{z,t} + \eta_8 \hat{\psi}_t + \eta_9 \hat{\psi}_{c,t} + \eta_{10} \hat{\psi}_{c,t} + \eta_{11} \hat{\psi}_{c,t+1} \right] \]

\[ \hat{\psi}_{TOTAL,t} = -\left( \frac{1}{\mu_N + b N} \right) \left[ -b \beta \mu \xi_t - b \mu_N (\hat{\mu}_z - \beta \hat{\mu}_{z,t+1}) + (\mu - b \beta)(\mu - b \hat{\psi}_{z,t} + \frac{\hat{\psi}_{z,t}}{1 + \xi_N})(\mu - b \beta)(\mu - b \hat{\psi}_{z,t+1}) \right] \]

\[ \hat{c}_t^d = \eta_c \hat{c}_t^{d,c} + \hat{c}_t \]

\[ \hat{c}_t^d = \eta_i \hat{c}_t^{d,i} + \hat{c}_t \]

\[ \hat{c}_t^m = -\eta_c (1 - \omega_c)(\gamma_c - \eta_c) \hat{c}_t^{m,c} + \hat{c}_t \]
\[
\begin{align*}
\hat{c}_{t}^{\text{TRAD}} &= \left[ (1 - \omega_m)^{1/\eta_T} \left( \frac{c^d}{c} \right)^{(\eta_T^{-1})/\eta_c} \right] \hat{c}_t^d + \left[ \omega_m^{1/\eta_T} \left( \frac{c^m}{c} \right)^{(\eta_T^{-1})/\eta_T} \right] \hat{c}_t^m \\
&- \left[ \omega_N^{1/\eta_c} \left( \frac{c^N}{c^T} \right)^{(\eta_c^{-1})/\eta_C} \right] \hat{c}_t^N = \hat{c}_{\text{TOTAL}, t} - \left[ (1 - \omega_N)^{1/\eta_c} \left( \frac{c^{\text{TRAD}}}{c^T} \right)^{(\eta_c^{-1})/\eta_c} \right] \hat{c}_t^T
\end{align*}
\]

\[
\hat{e}_{N, t} = \hat{y}_{N, t}
\]

\[
\dot{i}_t = \left[ \frac{1}{(S''\mu_z^2)(1 + \beta)} \right] \left[ (\hat{S}'\mu_z^2)(\dot{i}_{t-1} + \beta \dot{i}_{t+1} - \dot{\mu}_z + \beta \dot{\mu}_{z, t+1} + \hat{p}_{k', t} + \hat{y}_{i, t} - \hat{y}_{i, t}^d) \right]
\]

\[
\dot{\hat{y}}_{z, t} = \dot{\hat{y}}_{z, t+1} - \mu_{z, t+1} + \frac{1}{\mu_z} \left( \mu_t - \beta \dot{\mu}_{t+1}^k \right) \hat{R}_{t} - \hat{\pi}_{t+1}^d + \frac{1}{\mu_t} \left( \frac{\tau_t}{1 - \tau_t} \right) (\beta_t - \mu_t) \dot{\hat{r}}_{t+1}^k
\]

\[
\dot{\hat{p}}_{k', t} = -\dot{\hat{y}}_{z, t} - \mu_{z, t+1} + \dot{\hat{y}}_{z, t+1} + \left( \frac{\beta (1 - \delta)}{\mu} \right) \dot{\hat{p}}_{k', t+1}
\]

\[
- \left( \frac{\tau_t}{1 - \tau_t} \right) \left( \frac{\mu_z - \beta (1 - \delta)}{\mu} \right) \dot{\hat{r}}_{t+1}^k + \left( \frac{\mu_z - \beta (1 - \delta)}{\mu} \right) \hat{p}_{t+1}^k
\]

\[
(1 - \hat{\phi}_s) \Delta \hat{S}_{t+1} = \hat{\phi}_s \Delta \hat{S}_t - (\hat{R}_t - \hat{R}_t^*) - \hat{\phi}_a \hat{\alpha}_t + \hat{\phi}_t = 0
\]

RiskPremium

\[
= \left( (1 - \hat{\phi}_s) \Delta \hat{S}_{t+1} - \hat{\phi}_s \Delta \hat{S}_t - (\hat{R}_t - \hat{R}_t^*) - \hat{\phi}_a \hat{\alpha}_t + \hat{\phi}_t \right)
\]

\[
\hat{H}_{T, t}[\lambda_d(1 - \alpha)]
\]

\[
= \left[ (1 - \omega_c) (y^{c, d})^{\eta_c} \left( \hat{e}_t + \eta_c \hat{y}_t^{c, d} \right) \right]
\]

\[
= \left[ (1 - \omega_c) (y^{i, d})^{\eta_i} \left( \hat{e}_t + \eta_i \hat{y}_t^{i, d} \right) + \frac{g}{y} \hat{g}_t + (y')^{\eta_f} \frac{v^*}{y} \left( \hat{y}_t^* - \eta_f \hat{y}_t^{x, *} + \hat{z}_t^* \right) \right]
\]

\[
+ (1 - \tau^k) \tau^k \hat{k} \left( \frac{\mu_z}{\mu_{z, t-1}} - \lambda_d \hat{e}_t - \lambda_d \alpha (k_t - \mu_{z, t}) \right)
\]

\[
\hat{y}_{N, t} = \omega_N (y^{T, N})^{\eta_c} \frac{c^T}{y} (\hat{e}_{T, t} + \eta_c \hat{y}_{T, t}^{T, N})
\]

\[
\hat{y}_t = \frac{y_T}{y} y^{T, t} (\hat{y}_t^{T, t} + \hat{y}_{T, t}) + \frac{y_N}{y} y^{N, t} (\hat{y}_t^{N, t} + \hat{y}_{N, t})
\]

\[
\hat{y}_t^{T, t} - \hat{y}_{T, t-1} = \hat{\pi}_{T, t} - \hat{\pi}_t
\]
\[\hat{\pi}_t = (1 - w)\gamma_t^{\pi,t} \hat{\pi}_t^{\pi,t} + w\gamma_t^{N,t} \hat{\pi}_t^{N,t}\]

\[\hat{k}_t = (1 - \delta) \frac{1}{\mu_x} \hat{k}_{t-1} - (1 - \delta) \frac{1}{\mu_x} \mu_{z,t} + \left(1 - (1 - \delta) \frac{1}{\mu_x}\right) \hat{\gamma}_t + \left(1 - (1 - \delta) \frac{1}{\mu_x}\right) \hat{\lambda}_t\]

\[\hat{k}_t = \hat{k}_{t-1} + \frac{1}{\sigma_x} \hat{\pi}_t - \frac{1}{\sigma_x (1 - \tau^k)} \hat{\pi}_t^k\]

\[\hat{q}_t = \frac{1}{\sigma_q} \left[\hat{q}_t^d + \frac{\tau^k}{1 - \tau^k} \hat{\pi}_t^k - \hat{\psi}_{z,t} - \frac{R}{R - 1} \hat{r}_{t-1}\right]\]

\[\hat{m}_{t-1} = \hat{m}_t + \hat{\pi}_t + \mu_{z,t} - \hat{\mu}_t\]

\[\frac{\mu_m}{\mu_{z,t}} \hat{\mu}_t = -\frac{\mu_m}{\mu_{z,t}} \hat{m}_{t-1} + \frac{\mu_m}{\mu_{z,t}} \hat{\pi}_t + \frac{\mu_m}{\mu_{z,t}} \mu_{z,t} + \hat{q}_t + \bar{\nu} \bar{w} H(\bar{v}_t + \hat{\omega}_t + \bar{H}_t)\]

\[\hat{a}_t = -y^* \bar{m} \hat{c}_t^* - \eta_f y^* \gamma^* x_t^* + y^* \hat{\gamma}_t^* + y^* \hat{\lambda}_t^* + (c^* + i^*) \hat{\gamma}_t^f - c^m(\eta_c (1 - \omega_c) (y^{cd})^{-1 - \eta_c} \hat{\gamma}_{mc,d}^t + \hat{\epsilon}_t) + i^m \left(\eta_l (1 - \omega_l) (y^{ld})^{-1 - \eta_l} \hat{\gamma}_{mi,d}^t + \hat{\epsilon}_t\right) + \frac{R}{\mu_{z,t}} \hat{a}_{t-1} + y^{mc,t} \bar{t} \bar{r} \bar{p} \bar{c} \bar{t} \bar{r} \bar{p} \bar{c} \bar{t} + y^{mc,t} \bar{t} \bar{r} \bar{p} \bar{c} \bar{t} \bar{r} \bar{p} \bar{c} \bar{t} + y^{mi,t} \bar{t} \bar{r} \bar{p} \bar{c} \bar{t} \bar{r} \bar{p} \bar{c} \bar{t}\]

\[\hat{R}_t^f = \frac{vR}{vR + 1 - v} \hat{R}_{t-1}\]

\[\hat{r}_t^k = \mu_{z,t} + \hat{\omega}_t + \hat{R}_t^f + \bar{H}_t - \hat{k}_t\]

\[\hat{m} \hat{c}_t = a(\mu_{z,t} + \bar{H}_t - \hat{k}_t) + \hat{\omega}_t + \hat{R}_t^f - \hat{e}_t\]

\[\hat{m} \hat{c}_t^N = \bar{\omega}_t + \hat{R}_t^f - \hat{e}_t^N\]

\[\hat{\gamma}_t^{cd} = \omega_c (y^{cd})^{-1 - \eta_c} \hat{\gamma}_{mc,d}^t\]

\[\hat{\gamma}_t^{TC,N} = (1 - \omega_N) (y^{TC,trad})^{-1 - \eta_C} \hat{\gamma}_{trad,N}^t\]

\[\hat{\gamma}_t^{Trad,N} = \hat{\gamma}_{t-1}^{Trad,N} + \hat{\pi}_t^{Trad} - \hat{\pi}_t^{N}\]

\[\hat{\gamma}_t^{id} = \omega_i (y^{imi})^{-1 - \eta_l} \hat{\gamma}_{mi,d}^t\]

\[\hat{\gamma}_t^{mc,d} = \gamma_{t-1}^{mc,d} + \hat{\pi}_t^{mc,c} - \hat{\pi}_t^{d}\]
\begin{align*}
\hat{y}^{\text{mid}}_{t} &= \hat{y}^{\text{mid}}_{t-1} + \hat{n}^{\text{mid}}_{t} - \hat{n}^{d}_{t} \\
\hat{y}^{f}_{t} &= \hat{m}^{c}_{t} + \hat{y}^{x,s}_{t} \\
\hat{y}^{\text{mct}}_{t} &= \hat{y}^{\text{mct}}_{t-1} + \hat{n}^{\text{mct}}_{t} - \hat{n}^{t}_{t} \\
\hat{y}^{\text{mit}}_{t} &= \hat{y}^{\text{mit}}_{t-1} + \hat{n}^{\text{mit}}_{t} - \hat{n}^{t}_{t} \\
\hat{y}^{x,s}_{t} &= \hat{y}^{x,s}_{t-1} + \hat{n}^{x} - \hat{n}^{t}_{t} \\
\hat{x}_{t} &= -\omega_{c} (y^{\text{c,mc}})^{(1-\eta_{c})}\hat{y}^{\text{mct}}_{t} - \hat{y}^{x,s}_{t} - \hat{m}^{c}_{t} \\
\hat{m}^{c}_{t}^{\text{mct}} &= -\hat{m}^{c}_{t} - \hat{y}^{x,s}_{t} - \hat{y}^{\text{mct}}_{t} \\
\hat{m}^{c}_{t}^{\text{mit}} &= -\hat{m}^{c}_{t} - \hat{y}^{x,s}_{t} - \hat{y}^{\text{mit}}_{t} \\
\hat{m}^{c}_{t}^{x} &= \hat{m}^{c}_{t-1} + \hat{n}_{t} - \hat{n}^{x}_{t} - \Delta S_{t} \\
\hat{R}_{t} &= \rho_{R} \hat{R}_{t-1} + (1 - \rho_{R}) \left[ \hat{p}^{c}_{\text{C}} + \rho_{\text{C}} (\hat{p}^{\text{C}}_{t-1} - \hat{p}^{c}_{t}) + \rho_{\text{Y}} \hat{y}^{\text{Y}_{t-1}} + \rho_{\text{X}} \hat{x}_{t-1} \right] + r_{\Delta} (\hat{n}^{c}_{t} - \hat{n}^{c}_{t-1}) + \hat{\epsilon}_{\text{R},t} \\
\hat{p}^{c}_{t} &= \left( (1 - \omega_{c}) (y^{d,c})^{1-\eta_{c}} \right) \hat{p}^{d}_{t} + \left( (\omega_{c}) (y^{\text{mct}})^{1-\eta_{c}} \right) \hat{p}^{\text{mct}}_{t} \\
\hat{p}^{\text{CTAD}}_{t} &= \left( (1 - \omega_{N}) (y^{\text{TRAD},t})^{1-\eta_{CT}} \right) \hat{p}^{\text{CTAD}}_{t} + \left( (\omega_{N}) (y^{N,t})^{1-\eta_{CT}} \right) \hat{p}^{N}_{t} \\
\hat{p}^{\text{CTAD}}_{t} &= \left( (1 - \omega_{m}) (y^{\text{TRAD},\text{cTRAD}})^{1-\eta_{T}} \right) \hat{p}^{\text{T}}_{t} + \left( (\omega_{m}) (y^{\text{mc,TRAD}})^{1-\eta_{T}} \right) \hat{p}^{\text{mc}}_{t} \\
\hat{y}^{T}_{t} &= \lambda_{d} \left( (1 - \alpha) \hat{p}^{T}_{t} + \alpha \hat{p}^{c}_{t} - \alpha \hat{p}^{x}_{t} + \hat{\epsilon}_{T} \right) \\
\hat{x}_{t} &= -\omega_{c} (y^{\text{c,mc}})^{(1-\eta_{c})}\hat{y}^{\text{mct}}_{t} - \hat{y}^{x,s}_{t} - \hat{m}^{c}_{t} \\
\hat{y}_{N_{1},t} &= \lambda_{N} (\hat{I}_{N_{1},t} + \hat{\epsilon}_{N_{1},t}) \\
\hat{y}_{N_{1},t} &= \hat{e}_{N_{1},t} \\
\hat{H}_{t} &= \frac{\hat{H}_{1}}{\hat{H}} \hat{p}^{T}_{t} + \frac{\hat{H}_{N}}{\hat{H}} \hat{p}_{N_{1},t} \\
\hat{\epsilon}_{\text{RM},t}^{p} &= \xi (\hat{\gamma}_{t}^{c} + \hat{\zeta}_{t}^{c}) \\
\hat{\epsilon}_{\text{RM},t}^{c} &= \eta \hat{y}_{t} \\
\hat{\epsilon}_{\text{RM},t}^{i} &= \hat{I}_{t}
\end{align*}
APPENDIX B

Figure 1. Impulse responses to a stationary tradable sector – specific technology shock
Figure 2. Impulse responses to a stationary nontradable sector – specific technology shock
Figure 3. Impulse responses to a monetary policy shock
Figure 4. Impulse responses to a import substitution elasticity shock (consumption)
Figure 5. Impulse responses to a import substitution elasticity shock (investment)
Figure 6. Impulse responses to a government spending shock
Figure 7. Impulse responses to a domestic mark-up shock
Figure 8. Impulse responses to a domestic nontradable mark-up shock
Figure 9. Impulse responses to an export mark-up shock
Figure 10. Impulse responses to a unit root technology shock
Figure 11. Impulse responses to a risk premium shock
Figure 12. Impulse responses to a foreign inflation shock
Figure 13. Impulse responses to an inflation target shock
Figure 14. Impulse responses to a foreign interest rate shock
Figure 15. Impulse responses to a consumption tax shock
Figure 16. Impulse responses to a capital tax shock
Figure 17. Impulse responses to a labor tax shock
Figure 18. Impulse responses to an income tax shock
Figure 19. Impulse responses to an investment specific shock
Figure 20. Impulse responses to a consumption preference shock
Figure 21. Impulse responses to a labor supply preference shock
Figure 22. Impulse responses to an asymmetric technology shock
Figure 23. Impulse responses to a stationary tradable sector – specific technology shock
Figure 24. Impulse responses to a stationary nontradable sector – specific technology shock
Figure 25. Impulse responses to a monetary policy shock
Figure 26. Impulse responses to a import substitution elasticity shock (consumption)
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Figure 30. Impulse responses to a domestic nontradable mark-up shock
Figure 31. Impulse responses to an export mark-up shock
Figure 32. Impulse responses to a unit root technology shock
Figure 33. Impulse responses to a risk premium shock
Figure 34. Impulse responses to a foreign inflation shock
Figure 35. Impulse responses to an inflation target shock
Figure 36. Impulse responses to a foreign interest rate shock
Figure 37. Impulse responses to a consumption tax shock
Figure 38. Impulse responses to a capital tax shock
Figure 39. Impulse responses to a labor tax shock
Figure 40. Impulse responses to an income tax shock
Figure 41. Impulse responses to an investment specific shock
Figure 42. Impulse responses to a consumption preference shock
Figure 43. Impulse responses to a labor supply preference shock
Figure 44. Impulse responses to an asymmetric technology shock