ARGEMmy: an intermediate DSGE model calibrated/estimated for Argentina

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1The opinions expressed in this paper are the author’s and do not necessarily reflect those of the Central Bank of Argentina. The research assistance of Enzo Cerletti during July and August 2007 is gratefully acknowledged.
ARGEMmy: an intermediate DSGE model calibrated/estimated for Argentina

1. Introduction

The purpose of this paper is to advance in the construction and calibration/estimation of an intermediate DSGE model for Argentina. The BCRA’s research department currently uses a very small and non-micro founded model (MEP: Modelo Económico Pequeño (see Elosegui, Escudé, Garegnani and Sotes Paladino 2007)) as the backbone for a system of macro and monetary projections. During 2007 I constructed the much larger DSGE model ARGEM, mainly for research purposes. It seemed that there was need for an intermediate sized DSGE model that could be of help in bridging the gap between the two. ARGEMmy is the result of this new effort. Hopefully, it will help in bringing the DSGE modeling strategy closer to the policy environment.

The new model has much of the fundamental structure of ARGEM: it includes banks as well as the ability to model a managed float, a pure float, or a pure peg. It also has some features that may be seen as an advance on ARGEM. In particular, instead of including a feedback rule on international reserves (aside from the typical feedback rule on the short run interest rate), as in the current version of ARGEM, I replace it with a feedback rule on the rate of nominal depreciation. This seems closer to the way Central Banks that intervene in the foreign exchange market actually conceptualize their intervention, although, as I show in Escudé (2007), one can usually go from one feedback rule to the other without fundamentally changing the functioning of the intervention policy.

The features of ARGEM that are suppressed in order to simplify the model include the following: 1) investment, and hence the capital stock and its intensity of utilization, implying that what is called consumption in ARGEMmy should actually be interpreted as absorption (consumption plus investment), 2) the deposit rate, which is collapsed with the Central Bank bond rate under the assumption that they are perfect substitutes, 3) bank reserves in the Central Bank and Bank demand for foreign and domestic currency cash, 4) manufactured exports, which makes exports exclusively primary. As a consequence of 4) in (this version of) ARGEMmy there is no Phillips equations for manufactured exports and all exports are commodities. Nevertheless, there is still abundant nominal rigidity in ARGEMmy since it includes three Phillips equations (wages, domestic goods, and imported goods), all with Calvo style stickiness plus full indexation to the previous period’s inflation for those who do not optimize currently. Also, imported goods prices are set in domestic (local) currency, generating a slow pass-through of both foreign prices and the exchange rate to domestic import prices.

Making concrete assumptions on monetary and exchange rate policy in Argentina is not trivial. Argentina fixed its exchange rate to the U.S. dollar during the Convertibility period (April 1991-December 2001) but since the dollar floated against other currencies (which represented 85% of Argentina’s trade), its multilateral exchange rate also floated. After the demise of Convertibility and an interim

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period of turbulence, the nominal exchange rate once again tended to be stable against the dollar, albeit at around 3 pesos per dollar (instead of 1, as during Convertibility). However, there has been some movement of the nominal exchange rate within an informal band that has usually ranged between 2.9 and 3.1. But there are no institutional restrictions on changing the nominal exchange rate as there was during Convertibility, nor on influencing the domestic rate through monetary policy. The Central Bank regularly intervenes both in the money market and in the foreign exchange market.

To estimate some of the parameters of ARGEMmy in both subperiods will be helpful. But then the model must be sufficiently flexible to be used with both types of policies. For this reason, I built the model so that it can handle two policy rules (one for the interest rate and another for the rate of nominal depreciation), which may or may not be feedback rules. When they are both feedback rules, the both respond to deviations of the year on year ‘consumption’ inflation rate from a target and deviations of GDP and the trade balance to GDP ratio from their nonstochastic steady state values. In ARGEM and in previous versions of ARGEMmy I used the consumption multilateral exchange rate instead of the trade balance to GDP ratio. They are quite equivalent. However, I found it convenient here to use the trade balance to GDP ratio, basically because it was easier to express its steady state value in terms of parameters that may be estimated (in order to eliminate it from the model) instead of imposing a steady state value that would introduce an unnecessary restriction in the estimation process. But it may also be more natural to think in terms of an equilibrium long run trade balance to GDP ratio, which reflects the net foreign debt servicing in the steady state (which is highly connected to the foreign public debt), than an equilibrium long run multilateral real exchange rate. Nevertheless, the model can be formulated either way.

For didactical purposes, I construct the model from first principles and include a detailed calibration of all the parameters. This calibration was used to construct a MATLAB m.file that interacts with Dynare in simulations or estimations. In this paper I present preliminary results on the Bayesian estimation of a subset of the parameters in ARGEMmy using data from the post-Convertibility period.

2. Households
Infinitely lived households are monopolistic competitors in the supply of differentiated labor. There is a domestic market for state-contingent securities that are held by households, insuring them against profit and wage idiosyncratic risks (see Woodford (2003)). This makes households essentially the same in equilibrium, and allows us to maintain the representative household fiction (i.e. dispense with the complexities that stem from household heterogeneity). Aside from these state-contingent securities, they hold financial wealth in the form of domestic currency ($M^t_0$) and peso denominated one period nominal deposits issued by domestic commercial banks ($D_t$) that pay a nominal interest rate $i_t$. They consume a bundle of domestic and imported goods and are unable to insure their real incomes against the effect of domestic and foreign inflation and exchange rate developments. I assume that the Central Bank fully and credibly insures depositors, so the deposit rate is considered riskless.
2.1 The household optimization problem

The household holds cash $M^0_t$ because doing so it economizes on transactions costs. I assume that consumption transactions involve the use of real resources and that these transactions costs per unit of expenditure are a decreasing and convex function $\tau_M$ of the currency/consumption ratio $\varpi_t$:

$$\tau_M(\varpi_t) \equiv \frac{M^0_t}{P^C_t C_t} = \frac{M^0_t}{P_t^C / P_t^C C_t},$$

where $C_t$ is a consumption index, and $P_t$ and $P^C_t$ are the price indexes of domestic goods and of the the consumption bundle, respectively. For convenience, I have defined the relative price of consumption goods in terms of domestic goods:

$$p^C_t \equiv \frac{P^C_t}{P_t}. $$

All price indexes are in monetary units. The two basic price indexes in the SOE are those of domestically produced (‘domestic’) goods, $P_t$, and imported goods $P_t^N$. The consumption price index is a CES composite of these basic price indexes, as I detail below. The assumption in (1) is that when the currency/consumption ratio $\varpi_t$ increases, transactions costs per unit of consumption decrease, but at a decreasing rate that reflects a diminishing marginal productivity of currency in the reduction of transactions costs.

I model nominal stickiness as in ARGEM (Escudé (2007)). In particular, households set wages under monopolistic competition with sticky nominal wages. Household $h \in [0,1]$ is the sole supplier of labor of type $h$, and makes the wage setting decision taking the aggregate wage index and labor supply as parametric. Every period, each household has a probability $1 - \alpha_w$ of being able to set the optimum wage for its specific labor type. This probability is independent of when it last set the optimal wage. When it can’t optimize, the household adjusts its wage rate by fully indexing to last period’s overall rate of wage inflation. Hence, when it can set the optimal wage rate it must take into account that in any future period $j$ there is a probability $\alpha^i_w$ that its wage will be the one it sets today plus full indexation. Hence, the household faces a wage survival constraint, according to which the wage rate it sets at $t$, $W_t(h)$, has a probability $\alpha^i_w$ of surviving (indexed) until period $t+j$:

$$W_{t+j}(h) = W_t(h) \frac{W_t}{W_{t-1}} \frac{W_{t+1}}{W_t} ... \frac{W_{t+j-1}}{W_{t+j-2}} \equiv W_t(h) \pi^W_t \pi^W_{t+1} ... \pi^W_{t+j-1} \equiv W_t(h) \Psi^W_{t,j},$$

where the rate of wage inflation is defined as $\pi^w_t \equiv W_t / W_{t-1}$, and the cumulative wage inflation between $t + j - 2$ and $t$, $\Psi^w_{t,j}$, with $\Psi^w_{t,0} \equiv 1$. In deriving the first order condition for $W_t(h)$ below the following identity is used :

$$\frac{W_t(h)}{W_{t+j}} \Psi^w_{t,j} = \frac{W_t(h)}{W_t} \frac{\pi^W_t \pi^W_{t+1} ... \pi^W_{t+j-1}}{\pi^W_{t+j}} = \frac{W_t(h)}{W_t} \frac{\pi^W_{t+j}}{\pi^W_{t+j}}.$$
The household also faces the labor demand function for its particular type of labor as a constraint:

\[ h_t(h) = h_t \left( \frac{W_t(h)}{W_t} \right)^{-\psi}, \]  

where \( W_t \) is the aggregate wage index, defined as:

\[ W_t = \left( \int_0^\infty W_t(h)^{1-\psi} dh \right)^{1/(1-\psi)}, \]

and where \( \psi \) is the elasticity of substitution between differentiated labor services\(^3\). When \( h \) sets the optimal wage, it must take into account that there is a probability \( \alpha_{W} \) that at time \( t + j \) its wage will be the \( W_t(h)\Psi_{t,j}^{w} \), and that hence the labor demand it faces is:

\[ h_{t+j}(h) = h_{t+j} \left( \frac{W_t(h)\Psi_{t,j}^{w}}{W_{t+j}} \right)^{-\psi}. \]

The household receives income from profits, wage, and interest, and spends on consumption, taxes, and transactions costs. Its real budget constraint in period \( t \) is:

\[ \frac{M^0_t(h)}{P_t} + \frac{D_t(h)}{P_t} = \frac{\Pi_t(h)}{P_t} + \frac{W_t(h)h_t(h)}{P_t} - \frac{T_t(h)}{P_t} + \frac{\Upsilon_t(h)}{P_t} + \frac{M^{i-1}_t(h)}{P_t} + (1 + i_t - 1) \frac{D_{t-1}(h)}{P_t} - \left[ 1 + \tau_M \left( \frac{M^0_t(h)/P_t}{P^C_t C_t(h)} \right) \right] p^C_t C_t(h), \]  

where \( \Pi_t(h) \) is nominal profits, \( h_t(h) \) is hours of work, \( T_t(h) \) is lump sum taxes net of transfers, and \( \Upsilon_t(h) \) is the income obtained in \( t \) from holding state-contingent securities.

Household \( h \) maximizes an inter-temporal utility function which is additively separable in the consumption of private goods \( C_t \) and leisure:

\[ E_t \sum_{j=0}^{\infty} \beta^j \left\{ z_{t+j}^C \log \left[ C_{t+j}(h) - \xi C_{t+j-1}(h) \right] + \left[ h - \eta z_{t+j}^H \frac{h_{t+j}(h)^{1+\chi}}{1+\chi} \right] \right\}, \]

where \( \beta \) is the intertemporal discount factor, \( h \) is the maximum labor time available (and hence the term in square brackets is "leisure"), \( \eta \) is a constant, \( \chi \) is the inverse of the elasticity of labor supply with respect to the real wage, \( z_{t+j}^C \) and \( z_{t+j}^H \) are consumption demand and labor supply shocks that are common to all households. Consumption nests habit formation, where \( \xi \) is a positive parameter less than unity.

The household’s inter-temporal solvency is guaranteed by its inability to incur in debt, which I assume does not bind in any finite time:

\[ D_{t+T} \geq 0, \quad \forall T \geq 0. \]  

Household \( h \) chooses \( C_{t+j}(h), D_{t+j}(h), M_{t+j}^{0,H}(h), (j=1,2,...) \) and \( W_t(h) \), by maximizing (8) subject to its sequence of budget constraints (7), its combined

---

\(^3\)I derive these equations from domestic intermediate firms’ cost minimization below.
labor demands and wage survival constraints (6), and its “no debt” constraints (9). Substituting for the labor demand constraints, the Lagrangian is hence:

\[
E_t \sum_{j=0}^{\infty} \beta^j \left\{ z_{t+j}^C \log \left[ C_{t+j}(h) - \xi C_{t+j-1}(h) \right] + \bar{h}_t - \left( \alpha_W \right)^j \frac{\eta z_{t+j}^H}{1} \left( \omega_{t+j} \left( \frac{W_t(h) \psi_{t,j}^w}{W_{t+j}} \right)^\psi \right)^{1+\psi} \right\} + \lambda_{t+j}(h) \left\{ \Pi_{t+j}(h) - T_{t+j}(h) \right\} + (\alpha_W)^j \frac{W_t(h) \psi_{t,j}^w}{P_{t+j}} h_{t+j} \left( \frac{W_t(h) \psi_{t,j}^w}{W_{t+j}} \right)^\psi
\]

\[
= \left[ 1 + \lambda_{t+j}(h) \left\{ \Pi_{t+j}(h) - T_{t+j}(h) \right\} + (\alpha_W)^j \frac{W_t(h) \psi_{t,j}^w}{P_{t+j}} h_{t+j} \left( \frac{W_t(h) \psi_{t,j}^w}{W_{t+j}} \right)^\psi \right]
\]

where \( \beta^j \lambda_{t+j}(h) \) are the Lagrange multipliers, and can be interpreted as the marginal utility of real income.

Since households only differ on whether they can choose the optimal wage, I eliminate the household index below, and use \( \hat{W}_t \) to distinguish the newly optimal wage from the aggregate wage index \( W_t \) (which includes both optimal and indexed wages). The first order conditions for an optimum (including the transversality condition) are the following:

\[
C_t : \quad \frac{z_{t}^C}{C_t} = \frac{z_{t+1}^C}{C_{t+1}} - \frac{\beta \xi E_t \left( \frac{z_{t+1}^C}{C_{t+1}} \right)}{\xi C_t} = \lambda_t \varphi_M \left( \frac{M_{t+1}^0}{P_{t+1}} \right) \psi
\]

\[
D_t : \quad \lambda_t = \beta \left( 1 + i_t \right) E_t \left( \frac{\lambda_{t+1}}{\pi_{t+1}} \right)
\]

\[
M_t^0 : \quad \lambda_t \left[ 1 + \tau'_M \left( \frac{M_{t+1}^0}{P_{t+1}} \right) \right] = \beta E_t \left( \frac{\lambda_{t+1}}{\pi_{t+1}} \right)
\]

\[
W_t : \quad 0 = E_t \sum_{j=0}^{\infty} \left( \beta \alpha_W \right)^j \lambda_{t+j} h_{t+j} \frac{W_{t+j}}{P_{t+j}} \left( \frac{\pi_{t+j}^W}{\pi_{t+j}} \right) \varphi_i
\]

\[
\times \left\{ \left( \frac{\tilde{W}_t \pi_{t+j}^W}{\tilde{W}_t \pi_{t+j}^W} \right) - \frac{\varphi_i \eta^{X}_{t+j} (h_{t+j})^X}{\psi_t - 1} \lambda_{t+j} W_{t+j}/P_{t+j} \left( \frac{\tilde{W}_t \pi_{t+j}^W}{\tilde{W}_t \pi_{t+j}^W} \right)^{-\psi^X} \right\}
\]

\[
\lim_{t \to \infty} \beta^j D_t = 0.
\]

In (13) and (14) the domestic goods inflation rate \( \pi_{t+1} \equiv P_{t+1}/P_t \) has been defined, and in (12) the auxiliary function \( \varphi_M \) gives the total effect on expenditure (i.e., including transactions cost related expenditures) of a marginal increase in consumption. It is defined as:\(^4\)

\[
\varphi_M (\varpi_t) \equiv 1 + \tau_M (\varpi_t) - \varpi_t \tau'_M (\varpi_t),
\]

\[^4\varphi_M(m/a)\text{ is the partial derivative of } [1 + \tau_M(m/a)] a \text{ with respect to } a.\]
which implies:
\[ \varphi_M' (\bar{\omega}_t) = -\varphi_M'' (\bar{\omega}_t) < 0. \]

(12) shows that in equilibrium the utility gain from a marginal increase in consumption (left side of the equality), equals the foregone marginal utility of real income it generates, including that which is related to transactions costs (given by \( \varphi_M(\cdot) \)). (13) states that the loss in utility from marginally increasing the holding of deposits equals the discounted expected utility of the addition to real interest income it generates next period. And (14) states that the net loss of utility from marginally increasing the holding of cash after taking into account the reduction in transactions costs it generates, is equal to the discounted expected marginal utility of having it available tomorrow with its purchasing power corrected for inflation.

Combining (13) and (14) yields:
\[ \varphi_M' (\bar{\omega}_t) = \frac{1}{1 + \bar{i}_t}, \]
which shows that the optimum stock of currency as a fraction of expenditure in consumption is such that the reduction in transactions costs generated by a marginal increase in this ratio equals the opportunity cost of holding cash. Inverting \( \varphi_M' \) gives the following demand function for cash as a vehicle for transactions (sometimes called ‘liquidity preference’ function):
\[ M_t^0 / P_t = \mathcal{L} (1 + \bar{i}_t) \bar{p}_t^C C_t, \]
where \( \mathcal{L}(\cdot) \) is defined as:
\[ \mathcal{L} (1 + \bar{i}_t) \equiv (-\varphi_M')^{-1} \left( 1 - \frac{1}{1 + \bar{i}_t} \right), \]
and is strictly decreasing, since:
\[ \mathcal{L}' (1 + \bar{i}_t) = \left[ (-\varphi_M') (1 + \bar{i}_t)^2 \right]^{-1} < 0. \]

From here on I replace the first order condition (14) by (19) and use (19) to eliminate the household currency to consumption ratio wherever it appears through the use of the following auxiliary functions:
\[ \tilde{\varphi}_M (1 + \bar{i}_t) \equiv \varphi_M (\mathcal{L} (1 + \bar{i}_t)), \quad \tilde{\tau}_M (1 + \bar{i}_t) \equiv \tau_M (\mathcal{L} (1 + \bar{i}_t)). \]

In particular, (12) can be written as:
\[ \frac{z_t^C}{C_t - \bar{\xi}C_{t-1}} - \beta \bar{\xi}E_t \left( \frac{z_{t+1}^C}{C_{t+1} - \bar{\xi}C_t} \right) = \lambda_t \tilde{\varphi}_M (1 + \bar{i}_t) \bar{p}_t^C \eta \]

In (15), since all households that can set their optimal wage in \( t \) make the same decision, the optimum wage rate is denoted \( \tilde{W}_t \). Hence, (5) and (2) imply the following law of motion for the aggregate wage rate (after taking into account that in the Calvo setup, because optimizers are randomly chosen from the population,
their average wage rate in \( t - 1 \) is equal to the average overall wage level (indexed by wage inflation) no matter when they optimized for the last time):

\[
W_{t-1}^{1-\theta} = \alpha_W \left( W_{t-1} \pi_{t-1}^W \right)^{1-\theta} + (1 - \alpha_W) \bar{W}_{t}^{1-\theta}.
\] (22)

Defining the real wage in terms of domestic goods and the relative wage between the optimizers and the general level:

\[
w_t = \frac{W_t}{P_t}, \quad \bar{w}_t = \frac{\bar{W}_t}{W_t},
\]

the first order condition for \( W_t \) becomes:

\[
0 = E_t \sum_{j=0}^{\infty} (\beta \alpha_W)^j \lambda_{t+j} h_{t+j} w_{t+j} \left( \pi_{t+j}^W \right)^{\psi_t} \left( \bar{W}_{t} \pi_{t}^W \right)^{-\psi_t \lambda_{t+j} w_{t+j}} \left( \pi_{t+j}^W \right)^{-\psi_t \lambda_{t+j} w_{t+j}} \left( \bar{W}_{t} \pi_{t}^W \right)^{-\psi_t \lambda_{t+j} w_{t+j}} .
\] (23)

And dividing through (22) by \( W_{t-1}^{1-\theta} \) and rearranging gives:

\[
\bar{w}_t \pi_t^W = \left( \frac{\pi_t^\psi}{1 - \alpha_W} \right) \left( \pi_{t-1} \alpha_W \right)^{1-\theta} \left( \frac{1}{1 - \alpha_W} \right)^{1-\theta}^{1-\theta} \left( \frac{1}{1 - \alpha_W} \right)^{1-\theta} .
\] (24)

Hence, (23) becomes the non-linear Phillips equation that determines the dynamics of wage inflation:

\[
0 = E_t \sum_{j=0}^{\infty} (\beta \alpha_W)^j \lambda_{t+j} h_{t+j} w_{t+j} \left( \pi_{t+j}^W \right)^{\psi_t-1} \left( \bar{W}_{t} \pi_{t}^W \right)^{-\psi_t \lambda_{t+j} w_{t+j}} \left( \pi_{t+j}^W \right)^{-\psi_t \lambda_{t+j} w_{t+j}} \left( \bar{W}_{t} \pi_{t}^W \right)^{-\psi_t \lambda_{t+j} w_{t+j}} .
\] (25)

Further below I obtain a recursive three equation version of this equation which is actually used for simulation and estimation.

2.2. Domestic and imported consumption
So far I have ignored the open economy attributes of consumption as well as product differentiation. I now distinguish between domestic and imported consumption goods. The consumption index used in the household optimization problem is actually a constant elasticity of substitution (CES) aggregate consumption index of domestic and imported goods:

\[
C_t = \left( a_D \bar{C}_t^D \right)^{\frac{1}{\theta^C}} + a_N \bar{C}_t^N \right)^{\frac{1}{\theta^C}} , \quad a_D + a_N = 1.
\] (26)

\( \theta^C (> 0) \) is the elasticity of substitution between domestic and imported consumption goods. Also, \( C_t^D \) and \( C_t^N \) are themselves CES aggregates of the domestic and
imported (respectively) varieties of goods available:

\[
C_t^D = \left( \int_0^1 C_t^D(i)^{\frac{\theta - 1}{\theta}} \, di \right)^{\frac{\theta}{\theta - 1}}, \quad \theta > 1 \tag{27}
\]

\[
C_t^N = \left( \int_0^1 C_t^N(i)^{\frac{\theta_N - 1}{\theta_N}} \, di \right)^{\frac{\theta_N}{\theta_N - 1}}, \quad \theta_N > 1. \tag{28}
\]

where \(\theta\) and \(\theta_N\) is the elasticities of substitution between varieties of domestic and imported goods in household expenditure, respectively. Total consumption expenditure is:

\[
P_t^C C_t = P_t C_t^D + P_t^N C_t^N. \tag{29}
\]

Then minimization of (29) subject to (26) for a given \(C_t\), yields the following relations:

\[
P_t = a_D^{\frac{1}{\theta}} P_t^C \left( \frac{C_t^D}{C_t} \right)^{-\frac{1}{\theta}}, \tag{30}
\]

\[
P_t^N = a_N^{\frac{1}{\theta}} P_t^C \left( \frac{C_t^N}{C_t} \right)^{-\frac{1}{\theta}}. \tag{31}
\]

Introducing these in (26) yields the consumption price index:

\[
P_t^C = \left( a_D (P_t)^{1-\theta_C} + a_N (P_t^N)^{1-\theta_C} \right)^{\frac{1}{1-\theta_C}}. \tag{32}
\]

Furthermore, it is readily seen that \(a_D\) and \(a_N\) in (26) are the shares of domestic and imported consumption in total consumption expenditures:

\[
a_D = \frac{P_t C_t^D}{P_t^C C_t}, \quad a_N = 1 - a_D = \frac{P_t^N C_t^N}{P_t^C C_t}. \tag{33}
\]

We will calibrate \(a_D\) below as to have home bias \((a_D > 0.5 > a_N)\).

Conditions (30), and (31) are necessary for the optimal allocation of household expenditures across domestic and imported goods. Similarly, for the optimal allocation across varieties of domestic and imported goods within these classes, and using (27), (28), the following conditions hold:

\[
P_t(i) = P_t \left( \frac{C_t^D(i)}{C_t^D} \right)^{-\frac{1}{\theta}}
\]

\[
P_t^N(i) = P_t^N \left( \frac{C_t^N(i)}{C_t^N} \right)^{-\frac{1}{\theta}}.
\]

Finally, dividing (32) through by \(P_t\) yields:

\[
p_t^C = \left[ a_D + (1 - a_D)(p_t^N)^{1-\theta_C} \right]^{\frac{1}{1-\theta_C}}.
\]
3. Domestic goods firms

3.1. Final domestic goods

There is perfect competition in the production (or bundling) of final domestic output $Q_t$, with the output of intermediate firms as inputs. A representative final domestic output firm uses the following CES technology:

$$Q_t = \left( \int_0^1 Q_t(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}}, \quad \theta > 1$$  \hspace{1cm} (34)

where $\theta$ is the elasticity of substitution between any two varieties of domestic goods and $Q_t(i)$ is the output of the intermediate domestic good $i$. The final domestic output representative firm solves the following problem each period:

$$\max_{Q_t(i)} P_t \left( \int_0^1 Q_t(i)^{\frac{\theta-1}{\theta}} di \right)^{\frac{\theta}{\theta-1}} - \int_0^1 P_t(i)Q_t(i)di,$$ \hspace{1cm} (35)

the solution of which is the demand for each type of domestic good as a fraction of aggregate domestic output that is itself an inverse function of the good’s price relative to the aggregate domestic price index:

$$Q_t(i) = Q_t \left( \frac{P_t(i)}{P_t} \right)^{-\theta}.$$ \hspace{1cm} (36)

Introducing (36) in (34) and simplifying, it is readily seen that the domestic goods price index is:

$$P_t = \left( \int_0^1 P_t(i)^{1-\theta} di \right)^{\frac{1}{1-\theta}}.$$ \hspace{1cm} (37)

Also, introducing (36) into the cost part of (35) yields:

$$\int_0^1 P_t(i)Q_t(i)di = P_tQ_t.$$ \hspace{1cm} (38)

3.2. Intermediate domestic goods

A continuum of monopolistically competitive firms produce intermediate domestic goods using labor and imported inputs, with no entry or exit. They face perfectly competitive bundlers of import goods and labor types. The production function of firm $i$ is:

$$Q_t(i) = \epsilon_t (z_t h_t(i))^{b_D} N_t^D(i)^{1-b_D}$$ \hspace{1cm} (39)

where $\epsilon_t$ and $z_t$ are industry-wide productivity shocks (transitory and permanent, respectively), $N_t^D$ is the consumption in production of intermediate imported inputs, and $h_t(i)$ is a CES index of all the labor types:

$$h_t(i) = \left( \int_0^1 h_t(h, i)^{\frac{\psi_t}{\psi_t+1}} dh \right)^{\frac{\psi_t}{\psi_t+1}},$$ \hspace{1cm} (40)

where $h_t(h, i)$ is the amount of labor type $h$ used by the domestic firm $i$. 

3.3. Marginal cost and input demands

I assume that a stochastic and possibly time-varying fraction $\zeta_t$ of the cost bill is financed by the domestic banking system. Let $i_t^L$ be the bank nominal loan rate. During period $t$ the firm formulates its demand for bank loans taking into account its expected financing needs in period $t+1$. Its total variable cost in period $t$ is:

$\left(1 + \zeta_t i_{t-1}^L\right) \left[W_t h_t(i) + P_t^N N^D_t(i)\right]$

To maximize profits, the firm must minimize costs. It takes as given the wages $W_t(h)$ set by the different households. Consider first the minimization of total labor cost:

$$\int_0^1 W_t(h) h_t(h, i) dh$$

subject to a constant aggregate index of labor types (39). I call the Lagrange multiplier $W_t$. It does not depend on $i$ since the problem is the same for all firms. Then the minimization results in $i$’s inverse demand function for labor type $h$:

$$W_t(h) = W_t \left(\frac{h_t(h, i)}{h_t(i)}\right)^{-\frac{1}{1-\psi_t}}.$$  

(41)

Defining the aggregate demand (over all firms) for labor of type $h$:

$$h_t(h) = \int_0^1 h_t(h, i) di,$$

and the aggregate demand (over all firms) for the labor bundle (over all households):

$$h_t = \int_0^1 h_t(h) dh,$$

(41) implies the labor demand function (4) I used for the household problem. Furthermore, introducing (41) in (39) yields:

$$W_t = \left(\int_0^1 W_t(h)^{1-\psi_t} di\right)^{\frac{1}{1-\psi_t}},$$

confirming that the Lagrange multiplier is indeed the aggregate wage index as the notation implied. And introducing (41) in (40) yields a more convenient expression for the wage bill of firm $i$:

$$\int_0^1 W_t(h) h_t(h, i) dh = W_t h_t(i).$$

I now obtain factor and bank loan demands by solving the following cost minimization problem:

$$\min_{h_t(i), N^D_t(i)} \left\{ \left(1 + \zeta_t i_{t-1}^L\right) \left[W_t h_t(i) + P_t^N N^D_t(i)\right] \right\}$$
subject to (38), where \( Q_t(i) \) is given. The problem is the same for all firms, so I eliminate the firm index. The first order conditions are:

\[
(1 + \zeta_t^L L_{t-1}) W_t h_t = b^D MC_t Q_t \tag{42}
\]

\[
(1 + \zeta_t^L L_{t-1}) P_t^N N_t^D = (1 - b^D) MC_t Q_t, \tag{43}
\]

where \( MC_t \) is the Lagrange multiplier (and has the obvious interpretation of marginal cost). Adding these equations term by term and dividing by \( P_t \) gives:

\[
(1 + \zeta_t^L L_{t-1}) \left( W_t h_t + P_t^N N_t^D \right) = mc_t Q_t, \tag{44}
\]

where I defined the real wage \( w_t \), the SOE’s internal terms of trade \( p_t^N \) (ITT) and real marginal cost \( mc_t \):

\[
w_t \equiv \frac{W_t}{P_t}, \quad p_t^N \equiv \frac{P_t^N}{P_t}, \quad mc_t \equiv \frac{MC_t}{P_t}.
\]

Furthermore, introducing the first order conditions (42)-(43) in the production function (38) yields the following expression for the real marginal cost:

\[
mc_t = \frac{1}{\kappa\epsilon_t} \left( 1 + \zeta_t^L L_{t-1} \right) \left( \frac{w_t}{z_t} \right)^{b^D} \left( \frac{p_t^N}{P_t} \right)^{1-b^D}, \tag{45}
\]

where

\[
\bar{w}_t = \frac{W_t}{z_t P_t} \equiv \frac{w_t}{z_t}
\]

is the efficiency wage and

\[
\kappa \equiv \left( b^D \right)^{b^D} \left( 1 - b^D \right)^{1-b^D}.
\]

Aggregate demand functions for \( h_t \) and \( N_t^D \) are obtained directly from (42)-(43) and (45):

\[
h_t = \frac{1}{\kappa \epsilon_t} b^D \left( \frac{p_t^N}{P_t^N} \right)^{1-b^D} Q_t / z_t \tag{46}
\]

\[
N_t^D = \frac{1}{\kappa \epsilon_t} \left( 1 - b^D \right) \left( \frac{P_t^N}{P_t} \right)^{b^D} Q_t. \tag{47}
\]

Also, dividing (42) by (43) term by term gives the relation:

\[
w_t h_t = \frac{b^D}{1 - b^D} p_t^N N_t^D. \tag{48}
\]

Finally, the aggregate real demand for bank loans by firms in period \( t \) is:

\[
\frac{L_t}{P_t} = \zeta_t E_t \left( w_{t+1} h_{t+1} + p_{t+1}^N N_{t+1}^D \right) = \frac{\zeta_t}{b^D} E_t \left( w_{t+1} h_{t+1} \right). \tag{49}
\]
3.4. Sticky nominal price setting

Firms make pricing decisions taking the aggregate price and quantity indexes as parametric. Every period, each firm has a probability $1 - \alpha_D$ of being able to set the optimum price for its specific type of good and whenever it can't optimize it adjusts its price by fully indexing to last period's overall rate of domestic inflation. Hence, when it can set its optimal price it must take into account that in any future period $j$ there is a probability $\alpha_D^j$ that its price will be the one it sets today plus full indexation. Hence, the firm's price survival constraint states that the price it sets at $t$, $P_t(i)$ has a probability $\alpha_D^j$ of surviving (indexed) until period $t+j$:

$$P_{t+j}(i) = P_t(i)\pi_t\pi_{t+1}...\pi_{t+j-1} \equiv P_t(i)\Psi_{t,j}^p,$$

where $\Psi_{t,0}^p \equiv 1$. Below I make use of the following identity:

$$\frac{P_t(i)}{P_{t+j}}\Psi_{t,j}^p = \frac{P_t(i)}{P_t} \frac{\pi_t}{\pi_{t+j}}.$$

Hence, I can express the firm's pricing problem as:

$$\max_{P_t(i)} E_t \sum_{j=0}^{\infty} \alpha_D^j \Lambda_{t,t+j}^D \left\{ \frac{P_t(i)}{P_{t+j}}\Psi_{t,j}^p - mc_{t+j}(i) \right\} Q_{t+j}(i)$$

subject to

$$Q_{t+j}(i) = Q_{t+j} \left( \frac{P_t(i)}{P_{t+j}}\Psi_{t,j}^p \right)^{-\theta}.$$

$\Lambda_{t,t+j}^D$ is the pricing kernel used by domestic firms for discounting, which is equal to households' intertemporal marginal rate of substitution in the consumption of domestic goods between periods $t+j$ and $t$:

$$\Lambda_{t,t+j}^D \equiv \beta^j \frac{U_{CD,t+j}}{U_{CD,t}}.$$

Note that the marginal utility of consuming domestic goods may be obtained from the marginal utility of consuming the aggregate bundle of (domestic and imported) goods. Specifically:

$$U_{CD,t} = U_{C,t} \frac{dC_t}{dC_t^D} = U_{C,t} a_D^\frac{1}{\sigma} \left( \frac{C^D_t}{C_t} \right)^{-\sigma} = U_{C,t} \frac{P_t}{P^C_t} = U_{C,t} \frac{1}{P^C_t},$$

where the second equality if obtained by differentiating (26) with respect to $C^D_t$, and the third comes from (30). Hence, using (21), the pricing kernel of domestic firms is:

$$\Lambda_{t,t+j}^D \equiv \beta^j \frac{U_{CD,t+j}}{U_{CD,t}} = \beta^j \frac{\lambda_{t+j} \bar{\gamma}_M}{\lambda_t \bar{\gamma}_M} (1 + i_{t+j}) \equiv \beta^j \frac{\bar{X}_{t+j}^D}{\bar{X}_t^D},$$

where the equality derives from (21).

The first order condition is the following:

$$0 = E_t \sum_{j=0}^{\infty} (\beta \alpha)^j \bar{X}_{t+j}^D Q_{t+j}(\pi_{t+j})^\theta \left\{ \frac{P_t}{P_{t+j}} \frac{\pi_t}{\pi_{t+j}} - \frac{\theta}{\theta - 1} mc_{t+j} \right\}.$$

$$\sum_{j=0}^{\infty} (\beta \alpha)^j \bar{X}_{t+j}^D Q_{t+j}(\pi_{t+j})^\theta \left\{ \frac{P_t}{P_{t+j}} \frac{\pi_t}{\pi_{t+j}} - \frac{\theta}{\theta - 1} mc_{t+j} \right\}. \quad (53)$$
Since all optimizing firms make the same decision I call the optimum price $\tilde{P}_t$ and drop the firm index. In the (modified) Calvo setup, because optimizers are randomly chosen from the population their average price in $t-1$ is equal to that period’s overall price index (indexed by the previous period’s inflation) no matter when they optimized for the last time. Hence, (37) implies the following law of motion for the aggregate domestic goods price index:

$$P_t^{1-\theta} = \alpha_D (P_{t-1} \pi_{t-1})^{1-\theta} + (1 - \alpha_D) \tilde{P}_t^{1-\theta}. \quad (54)$$

Dividing through by $P_{t-1}^{1-\theta}$ and rearranging yields:

$$\tilde{p}_t \pi_t = \left( \frac{(\pi_t)^{1-\theta} - \alpha_D (\pi_{t-1})^{1-\theta}}{1 - \alpha_D} \right)^{\frac{1}{1-\theta}}. \quad (55)$$

where I define the optimal to average domestic relative price:

$$\tilde{p}_t = \frac{\tilde{P}_t}{P_t}.$$ 

Hence, using (55) I can express (53) as the (non-linear) Phillips equation that determines the dynamics of domestic inflation:

$$0 = E_t \sum_{j=0}^{\infty} (\beta \alpha)^j \mathcal{N}_{t+j}^D Q_{t+j} (\pi_{t+j})^{\theta-1} \left\{ \left( \frac{(\pi_t)^{1-\theta} - \alpha_D (\pi_{t-1})^{1-\theta}}{1 - \alpha_D} \right)^{\frac{1}{1-\theta}} - \frac{\theta}{\theta-1} mc_{t+j} \pi_{t+j} \right\}.$$

4. Foreign trade firms

There are two types of foreign trade firms: competitive primary goods producing firms that export all their output, and monopolistically competitive importers that operate under instant pass-through of price and exchange rate changes to local import prices.

4.1 Primary exports producing firms

Firms in the export sector use domestic goods and "land" (representing natural resources) to produce an export commodity. Land is assumed to be fixed in quantity, hence generating diminishing returns. I assume that the export good is a single homogenous primary good (a commodity). Firms in this sector sell their output in the international market at the dollar price $P_t^{**XU}$. They are price takers in factor and product markets. The price of primary goods in terms of the domestic currency is merely the exogenous international price multiplied by the nominal exchange rate (vis a vis the dollar): $S_t P_t^{**XU}$. I also assume that there is a mean one i.i.d. "climate" shock $z_t^A$ that can make the harvest greater or smaller than expected. In order to obtain a lagged response in a simple way I assume that in period $t$ export firms sign contracts by which they commit to delivering their (as yet unknown due to the "climate" shock) $(t+4)$-period harvest (i.e., next year, same quarter) at known $t$-period unit prices and exchange rates. Hence, though in $t$ their export revenues have predetermined prices and exchange rate they earn more or less than they expected according to the realization of the "climate" shock.
Let the production function employed by firms in the export sector be the following:

\[ X_t = (z_{t-4})^{1-b^A} (Q_{t-4}^{DX})^{b^A} z_t^A, \quad b^A < 1, \quad (56) \]

where \( Q_{t-4}^{DX} \) is the amount of domestic goods used as input in the export sector, and \( z_t \) is the same permanent productivity shock we used for domestic sector firms. These firms maximize expected profit

\[ E_t \Pi_{t+4}^X = S_t P_{t}^{**X} E_t X_{t+4} - P_t Q_t^{DX} \]

subject to (56). The first order condition yields the export sector’s (factor) demand for domestic goods:

\[ Q_t^{DX} = z_t (b^A e_t^{**})^{\frac{1}{1-b^A}} \quad (57) \]

or equivalently:

\[ Q_t^{DX} = b^A e_t^{**} E_t X_{t+4}, \quad (58) \]

where I defined the SOE’s real exchange rate (RER) and external terms of trade (XTT):

\[ e_t = \frac{S_t P_t^{**NU}}{P_t}, \quad p_t^{**} = \frac{P_t^{**XU}}{P_t^{**NU}}, \]

where \( P_t^{**NU} \) is the price index of the dollar price of the SOE’s imports. The XTT is exogenous as it is completely determined in the Rest of the World (RW). Also, inserting the factor demand function in the production function shows that optimal exports vary directly with the lagged product of the RER and the XTT:

\[ X_t = z_{t-4} (b^A e_{t-4}^{**})^{\frac{b^A}{1-b^A}} z_t^A. \quad (59) \]

According to my assumptions, the real value of exports in terms of domestic goods is:

\[ \frac{S_{t-4} P_{t-4}^{**X} X_t}{P_t} = \frac{e_{t-4} P_{t-4}^{**X} X_t}{\tilde{\pi}_t} = z_{t-4} \left( b^A e_{t-4}^{**} \right)^{\frac{1}{1-b^A}} z_t^A, \quad (60) \]

where I defined the year on year domestic inflation at \( t \) as:

\[ \tilde{\pi}_t = \pi_t \pi_{t-1} \pi_{t-2} \pi_{t-3}. \]

Henceforth, a tilde over a variable will have the same year on year meaning, with the exception of the auxiliary functions \( \tilde{\varphi}^M(.) \) and \( \tilde{\tau}^M(.) \).

4.2. Imported goods firms
Final imported goods

Perfectly competitive importing firms produce (or bundle) final imported goods using the output of monopolistically competitive intermediate imported goods producers. The representative firm in this sector uses the following CES technology:

\[ N_t = \left( \int_0^1 N_t(i) \frac{\theta^N - 1}{\theta^N - 1} di \right)^{\frac{\theta^N - 1}{\theta^N}} \], \quad \theta^N > 1,
where \( \theta^N \) is the elasticity of substitution between varieties of imported goods in consumption. Maximizing profits (as in (35) for final domestic output firms) gives the demand function that the intermediate importer of good \( i \) faces:

\[
N_t(i) = N_t \left( \frac{P^N_t(i)}{P^N_t} \right)^{-\theta^N}.
\]

The resulting (domestic currency) price index for imported goods is:

\[
P^N_t = \left( \int_0^1 P^N_t(i) \left( \frac{1}{1-\theta^N} \right)^{1-\theta^N} \, di \right)^{\frac{1}{1-\theta^N}},
\]

and the import cost bill is:

\[
\int_0^1 P^N_t(i) N_t(i) \, di = P^N_t N_t.
\]

**Intermediate imported goods**

A continuum of monopolistically competitive firms generate intermediate imported goods. They buy a bundled final good abroad at the foreign price and turn it into differentiated goods to be sold in the domestic market in domestic currency. They purchase the bundled final good at the price \( S_t P^* N_t \), where \( P^* N_t \) is the foreign currency price index of the imported bundle and \( S_t \) is the nominal exchange rate (pesos per unit of foreign currency). Notice that \( S_t P^* N_t \) is thus the marginal cost for these firms. Their pricing (in the domestic currency) follows the same setup we used for firms producing domestic intermediate goods, with a probability \( 1 - \alpha_N \) of optimal price setting and full indexation when they can’t optimize price. According to the price survival constraint, the price \( P^N_t(i) \) the firm sets at \( t \) has a probability \( \alpha^j_N \) of surviving (indexed) until \( t + j \):

\[
P^N_{t+j}(i) = P^N_t(i) \pi^N_{t+j} \equiv P^N_t(i) \Psi^N_{t+j}, \quad (\Psi^N_{t,0} \equiv 1).
\]

When the firm optimizes it takes into account that there is a probability \( \alpha^j_N \) that the demand for its good in \( t + j \) will be:

\[
N_{t+j}(i) = N_{t+j} \left( \frac{P^N_t(i) \Psi^N_{t+j}}{P^N_{t+j}} \right)^{-\theta^N}.
\]

Hence, they solve:

\[
\max_{P^N_t(i)} E_t \sum_{j=0}^{\infty} \alpha^j N \Lambda^N_{t,t+j} N_{t+j}(i) \left\{ \frac{P^N_t(i) \Psi^N_{t+j}}{P^N_{t+j}} - \frac{S_{t+j} P^* N_{t+j}}{P^N_{t+j}} \right\}
\]

subject to (64). \( \Lambda^N_{t,t+j} \) is the pricing kernel used by importing firms for discounting. It is equal to households’ intertemporal marginal rate of substitution in the consumption of imported goods between periods \( t + j \) and \( t \):

\[
\Lambda^N_{t,t+j} \equiv \beta^j U^N_{t+j} \frac{U^N_t}{U^N_{t}}.
\]
The marginal utility of consuming imported goods may be obtained from the marginal utility of consuming the aggregate bundle of (domestic and imported) goods. Specifically:

\[
U_{CN,t} = U_{CN,t} \frac{dC_t}{dC^N_t} = U_{CN,t} \alpha_N \left( \frac{C^N_t}{C_t} \right)^{-\frac{1}{\theta_N}} = U_{CN,t} \frac{P^N_t}{P_t} = U_{CN,t} \frac{P^N_t}{P_t^N},
\]

where the second equality if obtained by differentiating (26) with respect to \(C^N_t\), and the third comes from (31). Hence, using (21) the pricing kernel of import sector firms is:

\[
\lambda^N_{t;j+1} \equiv \beta^j \frac{U_{CN,t+j}}{U_{CN,t}} \equiv \beta^j \frac{\lambda_{j+1} \overset{\phi}{\varphi}_M (1 + i_{t+j}) \lambda_{t}^N}{\lambda_{t} \overset{\phi}{\varphi}_M (1 + i_{t}) \lambda_{t}^N} \equiv \beta^j \frac{\lambda^N_{t;j+1}}{\lambda_{t}^N}.
\] (65)

After eliminating the firm index, the first order condition for intermediate importing firms is:

\[
0 = E_t \sum_{j=0}^{\infty} (\beta \alpha_N)^j \lambda^N_{t;j+1} N_{t+j}(\pi^N_{t+j})^\theta_N \left\{ \frac{\tilde{p}^N_t \pi^N_t}{\pi^N_{t+j}} - \frac{\theta_N}{\theta_N - 1} \frac{S_{t+j} p^{**N}_{t+j}}{\tilde{p}^N_{t+j}} \right\}.
\]

Since all optimizing firms make the same decision, I call the optimal import price \(\tilde{P}^N_t\). Hence (62) and (63) imply the following law of motion for the aggregate domestic currency import price index:

\[
(P^N_t)^{1-\theta_N} = \alpha_N (P^N_{t-1} \pi^N_{t-1})^{1-\theta_N} + (1 - \alpha_N) \left( \tilde{P}^N_t \right)^{1-\theta_N}.
\] (66)

Using the definitions of \(e_t\) and \(p^N_t\), I can express the preceding equations as:

\[
0 = E_t \sum_{j=0}^{\infty} (\beta \alpha_N)^j \lambda^N_{t;j+1} N_{t+j}(\pi^N_{t+j})^\theta_N \left\{ \frac{\tilde{p}^N_t \pi^N_t}{\pi^N_{t+j}} - \frac{\theta_N}{\theta_N - 1} \frac{e_{t+j}}{p^N_{t+j}} \right\}
\]

\[
(P^N_t)^{1-\theta_N} = \alpha_N \left( \pi^N_{t-1} \right)^{1-\theta_N} + (1 - \alpha_N) \left( \tilde{p}^N_t \pi^N_t \right)^{1-\theta_N},
\]

where

\[
\tilde{p}^N_t \equiv \frac{\tilde{p}^N_t}{p^N_t}
\]

is the relative price between optimized and overall imported goods. Eliminating \(\tilde{p}^N_t \pi^N_t\), yields:

\[
0 = E_t \sum_{j=0}^{\infty} (\beta \alpha_N)^j \lambda^N_{t;j+1} N_{t+j}(\pi^N_{t+j})^{\theta_N - 1}
\]

\[
\times \left\{ \left( \pi^N_{t} \right)^{1-\theta_N} - \alpha_N \left( \pi^N_{t-1} \right)^{1-\theta_N} \right\} \left( \frac{1}{1-\alpha_N} \right)^{1-\theta_N} + \frac{\theta_N}{\theta_N - 1} \frac{e_{t+j}}{p^N_{t+j}} \right\}.
\]

Notice that

\[
\frac{e_t}{p^N_t} = \frac{S_t p^{**N}}{P^N_t}
\]

measures the deviation (whenever it differs from 1) from the Law of one Price for imported goods.
5. Banks

I assume that there is a competitive banking industry, with no entry, exit, or mergers. Banks are owned by households, and are price takers in financial markets. They obtain funds in the international market $B_t^{CB}$, supply one period deposit facilities to households $D_t$, and use the proceeds to supply one period loans to firms $L_t$, lend (or borrow) in the interbank market, and purchase (or sell) Central Bank bonds $B_t^{CB}$. Any interbank loans cancel out and profits that arise from period t-1 operations are distributed to owners in period t, so the balance sheet constraint for the representative bank is:

$$L_t + B_t^{CB} = D_t + S_t B_t^{*B}. \tag{67}$$

I assume that deposits are perfect substitutes for Central Bank bonds (so they earn the same interest rate $i_t$) but households may not invest directly in these bonds (possibly because there is a minimum amount allowed for such investments which only the banks can achieve). I assume that interest on banks’ foreign debt is paid out in the following period, just before profits are distributed to owners. Since banks’ business is assumed to be in domestic currency, they face ( uninsurable) exchange rate uncertainty. For every unit of foreign currency they repay they must expect to have pesos in the amount of

$$E_t \delta_{t+1} (1 + i_t^B),$$

where $i_t^B$ is the nominal interest rate they are charged abroad and $\delta_{t+1}$ is the nominal rate of currency depreciation:

$$\delta_{t+1} = \frac{S_{t+1}}{S_t}.$$

I assume that banks must pay a (risk and/or liquidity) premium over the international riskless rate $i_t^*$ for the funds they obtain abroad. Since I do not model the rest of the world, the premium (function) is exogenously given. It has an exogenous stochastic and time-varying component $\phi_t^{**B}$ (that can represent general liquidity conditions in the international market) as well as an endogenous (more risk-related) component $p_B(.)$ that is an increasing convex function of the GDP adjusted (individual) bank foreign debt. Individual banks thus fully internalize the fact that their individual foreign debt decision determines the foreign currency interest rate they face, which is:

$$1 + i_t^B = (1 + i_t^*) \phi_t^{**B} \left[ 1 + p_B \left( \frac{S_t B_t^{*B}}{P_t Y_t} \right) \right], \tag{68}$$

where I assume $p_B' > 0$ and $p''_B > 0$.

Banks have a real cost function that depends on the ( previous period’s) real loan creating activities of the bank. I assume this cost function is quadratic. Specifically, I assume the following real cost function:

$$C_{t+1}^B = \frac{1}{2} b^B \left( \frac{L_t}{z_t P_t} \right)^2 \quad (b^B > 0).$$
The representative bank maximizes expected profit each period:

\[ E_t \Pi_{t+1} = i_t^L L_t + i_t (B_t^{CB} - D_t) - E_t \delta_{t+1} i_t B_t^{*B} S_t - P_t \frac{1}{2} b^B \left( \frac{L_t}{z_t P_t} \right)^2 \]

subject to its balance sheet constraint (67), and its supply of foreign funds constraint (68). The solution to this problem gives the supply of loans as a simple linear function of the loan margin \( i_t^L - i_t \) (69) and the optimal amount of foreign funding in the form of a "risk-adjusted uncovered interest parity" relation (70):

\[
\frac{L_t^S}{z_t P_t} = \frac{1}{b^B} (i_t^L - i_t) \tag{69}
\]

\[
i_t = E_t \delta_{t+1} \left\{ (1 + i_t^{**}) \phi_t^{**B} \left[ 1 + \varphi_B \left( \frac{S_t B_t^{*B}}{P_t Y_t} \right) \right] - 1 \right\}, \tag{70}
\]

where the following auxiliary function has been defined:

\[
\varphi_B (a) \equiv p_B (a) + a p_B' (a) = p_B (a) [1 + \varepsilon_B (a)], \tag{71}
\]

where

\[
\varepsilon_B (a) \equiv a \frac{p_B' (a)}{p_B (a)}
\]

is the elasticity of the endogenous risk premium function.

Given \( L_t^S, D_t^S, \) and \( B_t^{*B} \), the aggregate bank demand for Central Bank bonds is given by the aggregate bank balance sheet constraint:

\[
B_t^{CB,D} = D_t^S + S_t B_t^{*B} - L_t^S. \tag{72}
\]

6. The public sector

The public sector is made up of the Government and the Central Bank.

6.1. The Government

The Government issues foreign currency denominated bonds in the international markets and pays interest on these bonds, spends on goods, and collects taxes. We assume that fiscal policy consists of exogenous paths for nominal lump-sum tax collection \( T_t \) and real expenditures \( G_t \). The Government finances any resulting deficit by issuing foreign currency denominated bonds \( B_t^{*G} \). I assume that an integral component of fiscal policy is the (credible) commitment to achieve a long run target for the foreign debt to GDP ratio \( \gamma^{GT} \). To hold foreign currency denominated government bonds, foreign investors charge a risk premium over the risk-free foreign interest rate. As in the case of banks, the risk premium (function) is exogenously given and is assumed to have an exogenous stochastic component (an external financing shock) and an endogenous component. I assume that the latter is an increasing function of the public sector net foreign liability to GDP ratio. Hence the gross interest rate on the government’s foreign debt is:

\[
1 + i_t^G = (1 + i_t^{**}) \phi_t^{**G} \left[ 1 + p_G \left( \frac{S_t (B_t^{*G} - R_t^{*CB})}{P_t Y_t} \right) \right]. \tag{73}
\]

where \( p_G > 0, \) and \( R_t^{*CB} \) is the Central Bank’s international reserves.

The Government flow budget constraint is:

\[
S_t B_t^{*G} = P_t G_t - T_t + (1 + i_t^{G}) S_t B_t^{*G}. \tag{74}
\]
6.2. The Central Bank

The Central Bank issues currency \(M_0^t\) and domestic currency bonds \(B_{t}^{CB}\), and holds international reserves \(R_{t}^{*CB}\) in the form of foreign currency denominated riskless bonds issued by the RW. I assume that Central Bank bonds are only held by domestic banks. The (flow) budget constraint of the Central Bank is:

\[
M_0^t + B_{t}^{CB} - S_t R_{t}^{*CB} = M_{t-1}^0 + (1 + i_{t-1}) B_{t-1}^{CB} - (1 + i_{t-1}^*) S_{t-1} R_{t-1}^{*CB} \tag{75}
\]

The second term in square brackets after the last equality is the Central Bank’s quasi-fiscal surplus \((QF_t)\). It includes interest earned and capital gains on international reserves minus the interest paid on its bonds. I assume that the Central Bank transfers its quasi-fiscal surplus (or deficit) to the Government every period. Hence, its net wealth is constant. Furthermore, assuming it is zero, the Central Bank’s balance sheet "constraint" is always preserved:

\[
M_0^t + B_{t}^{CB} - S_t R_{t}^{*CB} = M_{t-1}^0 + B_{t-1}^{CB} - S_{t-1} R_{t-1}^{*CB} = 0. \tag{76}
\]

The Central Bank supplies whatever amount of cash is demanded by households, and can influence these supplies by changing \(R_{t}^{*CB}\) or \(B_{t}^{CB}\), i.e. intervene in the foreign exchange market or in the interbank cum Central Bank bond market.

6.3. The consolidated public sector

Adding (74) and (75) term by term and using (76) gives the consolidated public sector budget constraint:

\[
S_t B_t^G = (1 + i_{t-1}^* S_t R_{t-1}^{*CB}) - (T_t - P_t G_t) - QF_t, \tag{77}
\]

where \(QF_t\) is the Central Bank’s quasi-surplus:

\[
QF_t = \left[ i_{t-1}^* + (1 - S_{t-1}/S_t) \right] S_t R_{t-1}^{*CB} - i_{t-1} B_{t-1}^{CB} \tag{78}
\]

The Government sells foreign currency bonds in international capital markets to the extent that the sum of its capital repayments and interest payments on these bonds exceeds the sum of the domestic currency value of the Central Bank’s quasi-surplus and the Government’s primary surplus.

7. Market clearing equations, GDP, and the balance payments

In the labor market, the household supply of labor \(h_t\) equals domestic firms’ demand \((46)\):

\[
h_t = \frac{b_{t}^{D}}{\kappa_{t}} \left( \frac{p_{t}^{N}}{w_{t}} \right)^{1-b_{t}^{D}} \frac{Q_{t}}{z_{t}}. \tag{79}
\]

In the loan market, bank loan supply \((69)\) equals loan demand by firms \((49)\), yielding the following expression for the loan rate:

\[
i_{t}^{L} = i_{t} + \frac{b_{t}^{B}}{b_{t}^{D} z_{t}} E_{t} (w_{t+1} h_{t+1}) = i_{t} + \frac{b_{t}^{B}}{b_{t}^{D}} E_{t} \left( \frac{z_{t+1}}{z_{t}} w_{t+1} h_{t+1} \right). \tag{80}
\]
In the domestic goods market, the output of domestic firms $Q_t$ must satisfy final demand from households and the Government, as well as intermediate demand from the export and banking sectors:

$$Q_t = [a_D + \tilde{\tau}_M (1 + i_t)] p_t^C C_t + G_t + z_t \left(b^A e_t p_t^{**}\right) \frac{1}{1-b^A} + \frac{z_t}{2b^D} \left(i_t^L - i_t\right)^2. \quad (81)$$

Expenditure in total imports $p_t^N N_t$, is the sum of household and firm demand:

$$p_t^N N_t = (1 - a_D) p_t^C C_t + p_t^N N_t^D \quad (82)$$
$$= (1 - a_D) p_t^C C_t + \frac{1 - b^D}{b^D} w_t h_t,$$

where the second equality makes use of (48).

GDP in terms of domestic goods is the sum of consumption (private and public) and exports minus imports:

$$Y_t = p_t^C C_t + G_t + e_{t-4} p_{t-4}^{**} X_t - p_t^N N_t \quad (83)$$
$$= a_D p_t^C C_t + G_t + z_{t-4} \left(\frac{b^A e_{t-4} p_{t-4}^{**}}{\tilde{\pi}_t b^A}\right) \frac{1}{1-b^A} z_t^A - \frac{1 - b^D}{b^D} w_t h_t.$$

The second equality above uses (33), (60) and (82). Note that domestic output and GDP are related by the following equation:

$$Q_t = Y_t + \frac{1 - b^D}{b^D} w_t h_t + z_t \left(b^A e_t p_t^{**}\right) \frac{1}{1-b^A} - z_{t-4} \left(\frac{b^A e_{t-4} p_{t-4}^{**}}{\tilde{\pi}_t b^A}\right) \frac{1}{1-b^A} z_t^A$$
$$+ \tilde{\tau}_M (1 + i_t) p_t^C C_t + \frac{z_t}{2b^D} \left(i_t^L - i_t\right)^2.$$

For the balance of payments imports must be expressed in terms of payments abroad, i.e., the monopolistic markup that is charged domestically (see (43)) must be eliminated. Hence, using (82) import payments abroad are:

$$P_t^{**N} N_t = P_t^{**N} \left[(1 - a_D) p_t^C C_t + \frac{1 - b^D}{b^D} w_t h_t\right] \frac{1}{\tilde{\pi}_t e_t^{N-1}}.$$

Therefore, the balance of payments and trade balance equations are:

$$B_t^{*G} + B_t^{*B} - R_t^{*CB} = (1 + i_t^{G}) B_{t-1}^{*G} + (1 + i_t^{B}) B_{t-1}^{*B} - (1 + i_t^{**}) R_{t-1}^{*CB} - T B_t, \quad (84)$$

$$TB_t = P_{t-4}^{**X} X_t - P_t^{**N} N_t = P_t^{**N} \left(\frac{P_{t-4}^{**N} X_t - N_t}{\tilde{\pi}_t} \right) \quad (85)$$
$$= P_t^{**N} \left\{\frac{P_{t-4}^{**N} z_{t-4} \left(b^A e_{t-4} p_{t-4}^{**}\right) \frac{1}{1-b^A} z_t^A}{\tilde{\pi}_t} - \left[(1 - a_D) p_t^C C_t + \frac{1 - b^D}{b^D} w_t h_t\right] \frac{1}{\tilde{\pi}_t} e_t^{N-1}\right\}.$$

where in the latter I use the year on year import inflation at $t$:

$$\frac{\tilde{\pi}_t^{**N}}{\tilde{\pi}_t} = \frac{\pi_t^{**N} \pi_{t-1}^{**N} \pi_{t-2}^{**N} \pi_{t-3}^{**N}}{\pi_t^{**N} \pi_{t-1}^{**N} \pi_{t-2}^{**N} \pi_{t-3}^{**N}}.$$
8. Monetary Policy

The model allows for different monetary and exchange rate policy regimes. As a baseline, I take what I call a Managed Exchange rate Float (MEF) regime. In this regime, the Central Bank, through its regular interventions in the money and foreign exchange markets, is able to aim for the achievement of two operational targets: one for the interbank interest rate \(i_t\), and another for the rate of nominal depreciation \(\delta_t\). Using fairly general feedback rules, the Central Bank responds to deviations of the consumption year on year inflation rate \((\pi^C_t)\) from a target \((\pi^C_t)\), and to deviations of detrended GDP and the trade balance to GDP ratio (and possibly its lagged value) from certain targets that should represent welfare relevant levels (see De Paoli (2006)). I assume that these targets eventually converge to the nonstochastic steady state levels of the respective variables. In this paper, however, I simply collapse these targets to the steady state levels. Variables without a time subscript denote non-stochastic steady state values. I assume that the long run inflation target is positive: \(\pi^C_t > 1\). I also introduce history dependence in the two feedback rules through the presence of the lagged operational target variable, as well as a long run target for international reserves in the case of foreign exchange market intervention. The simple feedback rules are the following:

\[
1 + i_t = \Xi^{TR}(1 + i_{t-1})^{h_0} \left( \frac{\pi^C_t}{\pi^{TR}_t} \right)^{h_1} \left( \frac{Y_t/z_t}{(Y_t/z_t)^T} \right)^{h_2} \left( \frac{S_t T B_t/P_t Y_t}{\gamma^{TBT}} \right)^{h_3}, \tag{86}
\]

where

\[
\Xi^{TR} \equiv \left( \frac{\mu^{z*z}_t \pi}{\beta} \right)^{1-h_0}, \quad h_0 \geq 0, \quad h_1 > 0, \quad h_2 \geq 0, \quad h_3 \leq 0. \tag{87}
\]

and

\[
\delta_t = \Xi^{FXI}(\delta_{t-1})^{k_0} \left( \frac{\pi_t}{\pi^{TR}_t} \right)^{k_1} \left( \frac{Y_t/z_t}{(Y_t/z_t)^T} \right)^{k_2} \left( \frac{S_t T B_t/P_t Y_t}{\gamma^{TBT}} \right)^{k_3} \times \left( \frac{S_t R_t^{CB}/(P_t Y_t)}{\gamma^{CBT}} \right)^{k_5} \exp(\varepsilon^\delta_t), \tag{88}
\]

where

\[
\Xi^{FXI} \equiv \left( \frac{\pi}{\pi^{**N}} \right)^{1-k_0}, \quad k_5 \neq 0. \tag{89}
\]

\(\varepsilon^\delta_t\) is an i.i.d. nominal depreciation rate policy shock (without persistence). The multiplicative terms \((\Xi^{TR})\) and \((\Xi^{FXI})\) in the feedback rules are designed so as to obtain a non-stochastic steady state where the inflation target is achieved and the nominal rate of depreciation is consistent with it.\(^5\) During the transition, the coefficients in these feedback rules indicate the direction and magnitude of Central Bank responses to deviations of each of these variables from their targets. They translate the Central Bank high frequency actions (hourly, daily or weekly) to modifications of the operational targets to the interest rate and the nominal rate

\(^5\)Notice that I could just as well say that "the nominal rate of depreciation target is achieved and the inflation rate is consistent with it".
of depreciation at the model frequency (quarterly). \( \gamma^{CBT} \) is a long run target for the Central Bank reserves to GDP ratio, and \( \gamma^{TBT} \) is a long run target for the trade balance to GDP ratio. The latter should be consistent with the country’s long run foreign debt service (and, hence, with the fiscal assumptions which are explicit in the model). I deal with the steady state at length in the Appendix.

In order to be able to accommodate non-feedback policies, either one of the feedback rules (or both) can be replaced by a simple autorregresive rule: the nominal depreciation rate feedback rule by an AR rule on the same variable or on Central Bank international reserves, and the interest rate feedback rule by an AR(1) on Central Bank bonds or, if there is a feedback rule for the nominal interest rate, on Central Bank international reserves. Such non-feedback rules imply policies more akin to an ‘automatic pilot’ type of monetary and/or exchange rate policy.

9. The non-linear system
In this section I put together most of the non-linear equations that conform the model. In section 12 I also include the productivity growth equation and an additional identity.

Dynamics of Consumption:

\[
\frac{z^C_t}{C_t - \xi C_{t-1}} - \beta \xi E_t \left( \frac{z^C_{t+1}}{C_{t+1} - \xi C_t} \right) = \lambda_t \tilde{\varphi}_M (1 + i_t) p_t^C
\]

Marginal utility of real income:

\[
\lambda_t = \beta (1 + i_t) E_t \left( \frac{\lambda_{t+1}}{\pi_{t+1}} \right)
\]

Wage inflation Phillips equation:

\[
0 = E_t \sum_{j=0}^{\infty} (\beta \alpha W)^j \lambda_{t+j} h_{t+j} w_{t+j} (\pi^W_{t+j})^{\psi_{t-1}} \\
\left\{ \left( \frac{(\pi^W_t)^{1-\theta} - \alpha_W (\pi^W_{t-1})^{1-\theta}}{1 - \alpha_W} \right)^{\frac{1+\psi_{t+j}}{\psi_{t+j}}} - \frac{\psi_{t+j}}{\psi_t - 1} \frac{\eta_{z^{H}}^{H}(h_{t+j})^{\chi}}{\lambda_{t+j} w_{t+j} (\pi^W_{t+j})^{1+\psi_t}} \right\}
\]

Domestic inflation Phillips equation:

\[
0 = E_t \sum_{j=0}^{\infty} (\beta \alpha D)^j \tilde{\lambda}_{t+j} Q_{t+j} (\pi_{t+j})^{\theta-1} \left\{ \left( \frac{(\pi_t)^{1-\theta} - \alpha_D (\pi_{t-1})^{1-\theta}}{1 - \alpha_D} \right)^{\frac{1}{\theta}} - \frac{\theta}{\theta - 1} m_{t+j} \tilde{\pi}_{t+j} \right\}
\]

Imported inflation Phillips equation:

\[
0 = E_t \sum_{j=0}^{\infty} (\beta \alpha N)^j \tilde{\lambda}_{t+j} N_{t+j} (\pi_{t+j})^{\theta N-1} \\
\left\{ \left( \frac{(\pi^N_t)^{1-\theta N} - \alpha_N (\pi^N_{t-1})^{1-\theta N}}{1 - \alpha_N} \right)^{\frac{1}{1-\theta N}} - \frac{\theta N}{\theta N - 1} \frac{e_{t+j}}{p_{t+j}^{N}} \tilde{\pi}_{t+j} \right\}
\]
Balance of Payments:
\[
\frac{B_t^{*G}}{P_t} + \frac{B_t^{*B}}{P_t} - \frac{R_t^{*CB}}{P_t} = (1 + i_t^{-1}) \frac{1}{\pi_t^{*N}} \frac{B_t^{*G}}{P_t} + (1 + i_t^{B-1}) \frac{1}{\pi_t^{*N}} \frac{B_t^{*B}}{P_t} - (1 + i_t^{*B}) \frac{1}{\pi_t^{*N}} \frac{B_t^{*B}}{P_t} - TB_t
\]

Trade Balance:
\[
e_t \frac{B_t^{*G}}{P_t} = \frac{\tilde{\delta}_t}{\pi_t} \left( \frac{b^A e_t - p_t^{*N}}{b^A} \right) \frac{1}{\pi_t} \frac{1}{\pi_t} \left( 1 - a_D \right) p_t^C C_t + \frac{1 - b^D}{b^D} w_t h_t \right] \frac{\theta_t}{\theta_t} - 1
\]

Central Bank balance:
\[
\frac{B_t^{CB}}{P_t} = e_t \frac{R_t^{CB}}{P_t} - \mathcal{L} (1 + i_t) p_t^C C_t
\]

Government foreign debt interest rate:
\[
1 + i_t^G = (1 + i_t^{*G}) \phi_t^G \left[ 1 + p_G \left( \frac{e_t}{\bar{Y}_t} \left( \frac{B_t^{*G}}{P_t^{*N}} - \frac{R_t^{*CB}}{P_t^{*N}} \right) \right) \right].
\]

Fiscal:
\[
e_t \frac{B_t^{*G}}{P_t} = (1 + i_t^{-1}) \frac{e_t}{\pi_t^{*N}} \frac{B_t^{*G}}{P_t} - (T_t - G_t) - (1 + i_t^{*B}) \frac{1}{\delta_t} \frac{e_t}{\pi_t^{*N}} \frac{R_t^{*CB}}{P_t^{*N}} + i_t^{-1} \frac{B_t^{*B}}{\pi_t P_t}
\]

Bank foreign debt interest rate:
\[
1 + i_t^B = (1 + i_t^{*B}) \phi_t^{**B} \left[ 1 + p_B \left( \frac{e_t}{\bar{Y}_t} \frac{B_t^{*B}}{P_t^{*N}} \right) \right]
\]

Risk-adjusted uncovered interest parity:
\[
i_t = E_t \delta_t \left\{ (1 + i_t^{*B}) \phi_t^{**B} \left[ 1 + \varphi_B \left( \frac{e_t}{\bar{Y}_t} \frac{B_t^{*B}}{P_t^{*N}} \right) \right] - 1 \right\}
\]

Loan market clearing:
\[
i_t^L = i_t + \frac{b^S_t}{b^D} E_t \left( \frac{z_{t+1}}{z_t} \frac{w_{t+1}}{w_t} h_{t+1} \right).
\]

Real marginal cost:
\[
m_{ct} = \frac{1}{\kappa_{ct}} \left( 1 + \varsigma_t i_t^L \right) \left( \frac{p_t^{*N}}{w_t} \right)^{1-b^D} \left( p_t^{*N} \right)^{1-b^D}
\]

Labor market clearing:
\[
h_t = \frac{b^D}{\kappa} \left( \frac{p_t^{*N}}{w_t} \right)^{1-b^D} \frac{Q_t}{z_t \epsilon_t}
\]

Domestic goods market clearing:
\[
Q_t = [a_D + \tilde{\gamma}_M (1 + i_t)] p_t^C C_t + G_t + z_t \left( b^A e_t p_t^{*N} \right) \frac{1}{1-b^A} + \frac{z_t}{2b^B} \left( i_t^t - i_t \right)^2
\]
Real GDP:

\[ Y_t = p_t^C C_t + G_t + \frac{z_t^A}{\pi_t} z_{t-4} \left( \frac{b^A e_{t-4} \pi_t^{P_t^*}}{b^A} \right)^{1-\eta} - \left[ (1 - a_D) p_t^C C_t + \frac{1 - b^D}{b^D} w_t h_t \right] \]

Consumption relative price:

\[ p_t^C = \left[ a_D + (1 - a_D) \left( p_t^C \right)^{1-\theta} \right]^{1-\theta} \]

Consumption MRER:

\[ e_t^C = \frac{e_t}{p_t^C} \]

Interest rate feedback rule:

\[ 1 + i_t = \left( \frac{\mu^{zz} \pi}{\bar{\beta}} \right)^{1-h_0} (1 + i_{t-1})^{d_0} \left( \frac{\pi_t^C}{\pi_t^{P_t^*}} \right)^{k_1} \left( \frac{Y_t}{z_t} \right)^{k_1} \left( \frac{S_t TB_t / P_t Y_t}{\gamma^{TBT}} \right)^{k_2} \]

(or, alternatively) Central Bank bond rule:

\[ B_t^{CB} = \left( \frac{B_{t-1}^{CB}}{z_{t-1} P_{t-1}} \right)^{\rho^{CB}} \left( \delta^{CB} \right)^{1-\rho^{CB}} \exp(\varepsilon_t^{CB}) \]

Nominal depreciation feedback rule:

\[ \delta_t = \left( \frac{\pi_t^T}{\pi^{N_N}} \right)^{1-k_0} \left( \delta_{t-1} \right)^{d_0} \left( \frac{\pi_t^C}{\pi_t^{P_t^*}} \right)^{k_1} \left( \frac{Y_t}{z_t} \right)^{k_2} \left( \frac{S_t TB_t / P_t Y_t}{\gamma^{TBT}} \right)^{k_3} \left( \frac{e_t P_t^{CB} / P_t^{N_N} Y_t}{\gamma^{CBT}} \right)^{k_5} \exp(\varepsilon_t^\delta) \]

(or, alternatively) Nominal depreciation rule:

\[ \delta_t = (\delta_{t-1})^{d_0} (\delta^*)^{1-\rho^*} \exp(\varepsilon_t^\delta) \]

Identities:

\[ \frac{\pi_t}{\pi_{t-1}} = \frac{\pi_t^{**N}}{\pi_t}, \quad \frac{\pi_t^C}{\pi_t^{P_t^*}} = \frac{p_t^C}{p_t^{P_t^*}}, \quad \frac{\pi_t^W}{\pi_t^{W_t}} = \frac{w_t}{w_{t-1}}, \quad \frac{\pi_t^N}{\pi_t^{N_t}} = \frac{p_t^N}{p_t^{N_t}} \]

\[ \tilde{\pi}_t = \pi_t \pi_t^{P_t^*}, \quad \tilde{\pi}_t^C = \pi_t^C \pi_t^{P_t^*}, \quad \tilde{\pi}_t^C = \pi_t^C \pi_t^{P_t^*}, \quad \tilde{\pi}_t^T = \pi_t^T \pi_t^{P_t^*}, \quad \tilde{\pi}_t^{**N} = \pi_t^{**N} \pi_t^{P_t^*}, \quad \tilde{\delta}_t = \delta_t \delta_{t-1} \delta_{t-2} \delta_{t-3}, \quad \tilde{\mu}_t = \mu_t \mu_t^{P_t^*} \mu_t^{P_t^*} \mu_t^{P_t^*} \]

10. The non-linear system in stationary format

In this section, I rewrite the model equations, expressing them in terms of stationary variables. For this, I deflate the real variables by the permanent productivity shock \( \zeta_t \), and add a superscript \( \text{°} \) to the Lagrange multiplier to denote that it is inflated by the same factor. Hence I define the following new variables:
Imported inflation Phillips equation:

\[ m_t^0 = \frac{M_t^0}{z_t P_t}, \quad d_t = \frac{D_t}{z_t P_t}, \quad \ell_t = \frac{L_t}{z_t P_t}, \quad b_t^{CB} = \frac{B_t^{CB}}{z_t P_t}, \quad t_t = \frac{T_t}{z_t P_t}, \]

\[ g_t = \frac{G_t}{z_t}, \quad r_t^{CB} = \frac{R_t^{CB}}{z_t P_t^{**N}}, \quad b_t^* = \frac{B_t^*}{z_t P_t^{**N}}, \quad t_b = \frac{T B_t}{z_t P_t^{**N}}, \]

\[ b_t^{CB} = \frac{B_t^{CB}}{z_t}, \quad b_t^* = \frac{B_t^*}{z_t P_t^{**N}}, \quad c_t = \frac{C_t}{z_t}, \quad q_t = \frac{Q_t}{z_t}, \quad y_t = \frac{Y_t}{z_t}, \]

\[ q_t^{DX} = \frac{Q_t^{DX}}{z_t}, \quad \lambda_t^0 = \lambda_t z_t, \quad \bar{\Lambda}_t^D = \bar{\Lambda}_t^D z_t, \quad \bar{\Lambda}_t^N = \bar{\Lambda}_t^N z_t \quad x_t = \frac{X_t}{z_t}, \]

\[ n_t^D = \frac{N_t^D}{z_t}, \quad z_t^o = \frac{z_t^*}{z_t}, \quad \mu_t^z = \frac{z_t}{z_{t-1}}. \]

Notice that \( z_t^0 \) is the relative (permanent) productivity shock between the RW and the SOE. Its dynamics is specified in section 12 below. I have also introduced the gross rate of growth of the SOE’s productivity \( \mu_t^z \).

The transformed equations are the following:

Dynamics of Consumption:

\[ \mu_t^z \left( \frac{z_t^C}{c_t \mu_t^z - \xi c_{t-1}} \right) - \beta \xi E_t \left( \frac{z_{t+1}^C}{c_{t+1} \mu_{t+1} - \xi c_t} \right) = \lambda_t^0 t (1 + i_t) p_t^C \]

Marginal utility of real income:

\[ \lambda_t^i = \beta (1 + i_t) E_t \left( \frac{\lambda_{t+1}^0}{\mu_{t+1}^z \pi_{t+1}} \right) \]

Wage inflation Phillips equation:

\[ 0 = E_t \sum_{j=0}^{\infty} (\beta \alpha W)^j \lambda_{t+j}^W h_{t+j} w_{t+j} (\pi_{t+j}^W)^{\psi_{t-1}} \left\{ \left( \frac{\pi_{t}^{W-1-\theta} - \alpha W (\pi_{t-1}^W)^{1-\theta}}{1 - \alpha W} \right)^{1+\psi X} - \frac{\psi_t}{\psi_t - 1} \eta_{t+j} (h_{t+j})^X \left( \pi_{t+j}^W \right)^{1+\psi X} \right\}. \]

Domestic inflation Phillips equation:

\[ 0 = E_t \sum_{j=0}^{\infty} (\beta \alpha)^j \bar{\Lambda}_t^D \eta_{t+j} (\pi_{t+j})^{\theta-1} \left\{ \left( \frac{\pi_{t}^{1-\theta} - \alpha D (\pi_{t-1}^1)^{1-\theta}}{1 - \alpha D} \right)^{1-\theta} - \frac{\theta}{\theta - 1} m c_{t+j} \pi_{t+j} \right\}. \]

Imported inflation Phillips equation:

\[ 0 = E_t \sum_{j=0}^{\infty} (\beta \alpha N)^j \bar{\Lambda}_t^N n_{t+j} (\pi_{t+j}^N)^{\theta N-1} \left\{ \left( \frac{\pi_{t}^{1-\theta N} - \alpha N (\pi_{t-1}^N)^{1-\theta N}}{1 - \alpha N} \right)^{1-\theta N} - \frac{\theta N}{\theta N - 1 p_{t+j}^N} \right\}. \]
Balance of Payments:
\[ b_t^* + b_t^* - r_t^{*CB} = (1 + i_t^-) \frac{b_t^G}{\mu_t^2 \pi_t^N} + (1 + i_t^-) \frac{b_t^B}{\mu_t^2 \pi_t^N} - (1 + i_{t-1}^*) \frac{r_{t-1}^{*CB}}{\mu_t^2 \pi_t^N} - tb_t \]

Trade Balance:
\[ e_t b_t = \frac{\tilde{\gamma}_t}{\mu_t^2 \pi_t^N} \left( b_A e_t^- p_t^{**} \right) \frac{1 - i_t^A}{b_A} - \left[ (1 - a_D) p_t^C c_t + \frac{1 - b_D}{b_D} \bar{w}_t h_t \right] \frac{\theta^N - 1}{\theta^N} \]

Central Bank balance:
\[ b_t^{CB} = e_t r_t^{*CB} - \mathcal{L} (1 + i_t) p_t^C c_t \]

Government foreign debt interest rate:
\[ 1 + i_t^G = (1 + i_t^*) \phi^{**G} \left[ 1 + p_G \left( e_t \left( b_t^G - r_t^{*CB} \right) / y_t \right) \right]. \]

Fiscal:
\[ e_t b_t^G = (1 + i_t^G) \frac{e_t b_t^{*G}}{\mu_t^2 \pi_t^N} - (t_t - g_t) - \left( 1 + i_{t-1}^* \frac{1}{\delta_t} \right) \frac{e_t r_{t-1}^{*CB}}{\mu_t^2 \pi_t^N} + i_{t-1} \frac{b_t^{CB}}{\mu_t^2 \pi_t} \]

Bank foreign debt interest rate:
\[ 1 + i_t^B = (1 + i_t^*) \phi^{**B} \left[ 1 + p_B \left( e_t b_t^B / y_t \right) \right] \]

Risk-adjusted uncovered interest parity:
\[ i_t = E_t \delta_{t+1} \left\{ (1 + i_t^*) \phi^{**B} \left[ 1 + \varphi_B \left( e_t b_t^B / y_t \right) \right] - 1 \right\} \]

Loan market clearing:
\[ i_t^L = i_t + \frac{b_D \zeta_t}{b^D} E_t \left( \mu_t \pi_t^N \bar{w}_t h_{t+1} \right) \]

Real marginal cost:
\[ mc_t = \frac{1}{\kappa c_t} \left( 1 + \zeta c_{t-1}^L \right) \left( \frac{p_t^N}{\bar{w}_t} \right)^{b_D} \left( p_t^N \right)^{1-b_D} \]

Labor market clearing:
\[ h_t = \frac{b_D}{\kappa} \left( \frac{p_t^N}{\bar{w}_t} \right)^{1-b_D} \frac{q_t}{\epsilon_t} \]

Domestic goods market clearing:
\[ q_t = [a_D + \tilde{\gamma}_M (1 + i_t)] p_t^C c_t + g_t + (b_A e_t p_t^{**}) \frac{1}{1-b_A} + \frac{1}{2b_D} \left( i_t^L - i_t \right)^2 \]

Real GDP:
\[ y_t = p_t^C c_t + g_t + \frac{z_t^A}{\mu_t^2 \pi_t} \left( b_A e_t^- p_t^{**} \right) \frac{1 - i_t^A}{b_A} - \left[ (1 - a_D) p_t^C c_t + \frac{1 - b_D}{b_D} \bar{w}_t h_t \right] \]
Consumption relative price:

\[ p_t^C = \left( a_D + (1 - a_D) \left( p_t^N \right)^{1-\theta_C} \right)^{\frac{1}{1-\theta_C}} \]

Consumption MRER:

\[ e_t^C = \frac{e_t}{p_t^C}. \]

Interest rate feedback rule:

\[ 1 + i_t = \left( \frac{\mu^{\ast\ast}\pi}{\beta} \right)^{1-h_0} \left( 1 + i_{t-1} \right)^{h_0} \left( \frac{\tilde{\pi}_t^C}{\pi_t^T} \right)^{h_1} \left( \frac{y_t}{y_t^T} \right)^{h_2} \left( \frac{e_{t} b_t / y_t}{\gamma_{TBT}} \right)^{h_3} \]

(or, alternatively) Central Bank international reserves policy:

\[ e_t r_t^{CB} = (e_{t-1} r_{t-1}^{CB})^{\rho_r^{CB}} \left( \gamma_{TBT} y \right)^{1-\rho_r^{CB}} \exp(\varepsilon_{t}^{CB}) \]

(or, alternatively) Central Bank bond policy:

\[ \delta_t^{CB} = (b_{t-1}^{CB})^{\rho^\delta} \left( b^{CB} \right)^{1-\rho^\delta} \exp(\varepsilon_{t}^{\delta}) \]

Nominal depreciation feedback rule:

\[ \delta_t = \left( \frac{\pi^T}{\pi^{**N}} \right)^{1-k_0} (\delta_{t-1})^{k_0} \left( \tilde{\pi}_t^C / \pi_t^T \right)^{k_1} \left( y_t / y_t^T \right)^{k_2} \left( e_t b_t / y_t \right)^{k_3} \left( e_t r_t^{CB} / y_t \right)^{k_4} \exp(\varepsilon_{t}^{\delta}). \]

(or, alternatively) Nominal depreciation rule:

\[ \delta_t = (\delta_{t-1})^{\rho^\delta} (\delta^T)^{1-\rho^\delta} \exp(\varepsilon_{t}^{\delta}) \]

(or, alternatively if not used above) Central Bank international reserves policy:

\[ e_t r_t^{CB} = (e_{t-1} r_{t-1}^{CB})^{\rho_r^{CB}} \left( \gamma_{TBT} y \right)^{1-\rho_r^{CB}} \exp(\varepsilon_{t}^{CB}) \]

Identities:

\[ \frac{e_t}{e_{t-1}} = \frac{\delta_t \pi^{**N}}{\pi_t}, \quad \pi_t^C = \pi_t \frac{p_t^C}{p_{t-1}^C}, \quad \pi_t^W = \pi_t \mu_t^z \frac{w_t}{w_{t-1}}, \quad \pi_t^N = \pi_t \frac{p_t^N}{p_{t-1}^N} \]

\[ \tilde{\pi}_t = \pi_t \tilde{\pi}_{t-1} \tilde{\pi}_{t-2} \tilde{\pi}_{t-3}, \quad \tilde{\pi}_t^C = \pi_t^C \tilde{\pi}_{t-1}^{**C} \tilde{\pi}_{t-2}^{**C} \tilde{\pi}_{t-3}^{**C}, \quad \tilde{\pi}_t^T = \pi_t^T \tilde{\pi}_{t-1}^T \tilde{\pi}_{t-2}^T \tilde{\pi}_{t-3}^T \]

\[ \tilde{\pi}_t^{**N} = \frac{\pi_t^{**N}}{\pi_t^{**N}} \tilde{\pi}_{t-1}^{**N} \tilde{\pi}_{t-2}^{**N} \tilde{\pi}_{t-3}^{**N}, \quad \tilde{\pi}_t^{**} = \delta_t \delta_{t-1} \delta_{t-2} \delta_{t-3}, \quad \tilde{\mu}_t^z = \mu_t^z \tilde{\mu}_{t-1}^z \tilde{\mu}_{t-2}^z \tilde{\mu}_{t-3}^z. \]

This set of equations, along with the non-linear versions of the productivity growth equation which is introduced in section 12 (and the new identity that is introduced with it), and the AR(1) equations for the shock variables, constitute the system’s core set of equations. Of course, various other variables can also be determined. For example, (19) determines the market clearing stock of cash \( m_t^0 \):

\[ m_t^0 = \mathcal{L} (1 + i_t) p_t^C c_t, \]
(69) gives the real loan supply
\[ \ell_t = \frac{1}{b} \left( i_t^L - i_t \right), \]
and the Bank balance sheet gives the stock of deposits:
\[ d_t = b_t^{CB} + \ell_t - e_t b_t^{*B}. \]
However, the equilibrium values for these variables can be obtained after the solution for the previous variables have been obtained, being the complete system decomposable. The number of equations can be reduced considerably by simple substitution. However, there is no need for this, since it is much more convenient to keep the equations simple and let the software handle the algebra.

11. Functional forms for the auxiliary functions
The specific functional form I use for the transactions cost function is the following:
\[ \tau_M (\omega_t) \equiv a_M \omega_t + \omega_t^{-b_M} + c_M, \quad a_M, b_M > 0. \quad (92) \]
There is a satiation level of the cash/consumption ratio after which the function becomes increasing in its argument. Obviously, only the decreasing portion of the function is relevant. There are three parameters for calibration: \( a_M, b_M, c_M \).
According to (19), the resulting liquidity preference function is:
\[ \omega_t = \frac{m_t^0}{p_t^C c_t} = \mathcal{L} (1 + i_t) \equiv \left[ \frac{b_M}{a_M + 1 - \frac{i_t}{1+i_t}} \right]^{1+b_M}. \quad (93) \]
Also, the resulting elasticity of cash demand (as a fraction of consumption) with respect to the gross interest rate is:
\[ \varepsilon_t^{m^0} = \frac{\omega_t^{1+b_M}}{(1+b_M) b_M (1+i_t)}. \quad (94) \]
And the resulting auxiliary function for the total effect on expenditure of a marginal increase in consumption (17) is:
\[ \varphi_M (\omega_t) = 1 + c_M + (1+b_M) \omega_t^{-b_M}. \]
For the bank risk premium I use the following functional form:
\[ p_B \left( e_t b_t^{*B} / y_t \right) \equiv \frac{\alpha_1^B}{1 - \alpha_2^B e_t b_t^{*B} / y_t}, \quad \alpha_1^B > 0, \alpha_2^B > 0. \quad (95) \]
Hence, in the risk-adjusted uncovered interest parity equation (71) \( \varphi_B (.) \) is:
\[ \varphi_B \left( e_t b_t^{*B} / y_t \right) = \frac{\alpha_1^B}{(1 - \alpha_2^B e_t b_t^{*B} / y_t)^2}, \quad (96) \]
and the elasticity of \( p_B (.) \) is:
\[ \varepsilon_B \left( e_t b_t^{*B} / y_t \right) \equiv \frac{1}{1 - \alpha_2^B (e_t b_t^{*B} / y_t)} - 1. \quad (97) \]
Notice that the following relation holds:
\[ \varphi_B \left( e_t b_t^B / y_t \right) = p_B \left( e_t b_t^B / y_t \right) \left[ 1 + \varepsilon_B \left( e_t b_t^B / y_t \right) \right]. \]  
(98)

The government risk premium has the same functional form as the one for banks:
\[ p_G \left( e_t \left( b_t^G - r_t^{CB} \right) / y_t \right) \equiv \frac{\alpha_G}{1 - \alpha_G e_t \left( b_t^G - r_t^{CB} \right) / y_t}, \quad \alpha_G^G > 0, \alpha_G^G > 0. \]  
(99)

12. Permanent productivity shocks

Growth is introduced in the model through the SOE’s permanent productivity shock \( z_t \) and its relation with its equivalent in the RW \( z_t^{*} \). I assume that the RW’s permanent productivity growth \( \mu_t^{**} \equiv z_t^{**} / z_{t-1}^{**} \) is governed by an exogenous process:
\[ \mu_t^{**} = (\mu_t^{**})^{\rho_{**}} (\mu_t^{**})^{1-\rho_{**}} \exp (\varepsilon_t^{**}), \]
where \( \varepsilon_t^{**} \) is an i.i.d. technology shock. On the other hand, the SOE’s permanent productivity growth \( \mu_t \equiv z_t / z_{t-1} \) is assumed to be governed by the following stochastic process:
\[ \mu_t = (\mu_t) (\mu_t) \left( z_t / z_{t-1} \right)^{\alpha_t} \exp (\varepsilon_t), \]
where \( \varepsilon_t \) is an i.i.d. technology shock and \( z_t / z_{t-1} \) is the ratio between the permanent productivity levels in the SOE and the RW. Notice that the following identity holds:
\[ \frac{\mu_t^{**}}{\mu_t} = \frac{z_t^{**} / z_{t-1}^{**}}{z_t / z_{t-1}} = \frac{z_t^0}{z_{t-1}^0}, \]
I assume that in the non-stochastic SS the productivity levels and growth rates in the RW and the SOE are equal: \( z^0 = 1 \) and \( \mu^z = \mu^{**} \). Hence, in log-deviation from non-stochastic steady state values, the last three equations are:
\[ \hat{\mu}_t^{**} = \rho_{**} \hat{\mu}_{t-1}^{**} + \varepsilon_t^{**}, \]  
(100)
\[ \hat{\mu}_t = \rho_{**} \hat{\mu}_{t-1} + (1 - \rho_{**}) \hat{\mu}_{t-1}^{**} + \alpha_{\mu} z_t^0 + \varepsilon_t, \]  
(101)
\[ \hat{z}_t - \hat{z}_{t-1} = \hat{\mu}_t^{**} - \hat{\mu}_t. \]  
(102)

During the transition, the growth rate of the RW influences the growth rate of the SOE through the coefficient \( 1 - \rho^z \), while the growth rate of the SOE has no influence on the rate of growth of the RW. Also, the persistence coefficients may be different, and the disturbance terms may be correlated. (100)-(102) are additional model equations.

I am hence assuming that there is a cointegrating relation between the (logs of the) permanent technology shocks in the LRW and the SOE which includes a direct lagged influence of the LRW’s rate of technological growth on that of the SOE but no reciprocal influence. This appears consistent with the intuitive notion of a SOE that is also less developed and hence its technological innovations have an insignificant influence on the LRW’s innovations but absorbs a significant fraction of the LRW’s innovations.
13. The recursive versions of the Phillips equations

In order to implement the nonlinear Phillips equations in Dynare it is necessary to get rid of the infinite summations. In this section I reformulate the Phillips equations recursively.

13.1 Domestic inflation

First, I rewrite (91) as:

\[
\left( \frac{(\pi_t)^{1-\theta} - \alpha_D (\pi_{t-1})^{1-\theta}}{1 - \alpha_D} \right)^{\frac{1}{1-\theta}} \Gamma_t^D = \Psi_t^D.
\]

(103)

where I defined:

\[
\Gamma_t^D = E_t \sum_{j=0}^{\infty} (\beta) j \lambda_{t+j}^D q_{t+j} (\pi_{t+j})^{\theta-1},
\]

\[
\Psi_t^D = \frac{\theta}{\theta - 1} E_t \sum_{j=0}^{\infty} (\beta) j \lambda_{t+j}^{D0} q_{t+j} (\pi_{t+j})^{\theta-1} mc_{t+j}.
\]

Second, note that the infinite sums involved in the definitions of \(\Gamma_t^D\) and \(\Psi_t^D\) can be written recursively:

\[
E_t \sum_{j=0}^{\infty} (\beta) j \lambda_{t+j}^{D0} q_{t+j} (\pi_{t+j})^{\theta-1} = \lambda_{t}^{D0} q_{t} (\pi_{t})^{\theta-1} + E_t \sum_{j=1}^{\infty} (\beta) j \lambda_{t+j}^{D0} q_{t+j} (\pi_{t+j})^{\theta-1}
\]

\[
= \lambda_{t}^{D0} q_{t} (\pi_{t})^{\theta-1} + \beta \alpha E_{t+1} \sum_{j=0}^{\infty} (\beta) j \lambda_{t+1+j}^{D0} q_{t+1+j} (\pi_{t+1+j})^{\theta-1},
\]

\[
\frac{\theta}{\theta - 1} E_t \sum_{j=0}^{\infty} (\beta) j \lambda_{t+j}^{D0} q_{t+j} (\pi_{t+j})^{\theta-1} mc_{t+j} = \frac{\theta}{\theta - 1} \lambda_{t}^{D0} q_{t} (\pi_{t})^{\theta} mc_{t} + \frac{\theta}{\theta - 1} E_t \sum_{j=1}^{\infty} (\beta) j \lambda_{t+j}^{D0} q_{t+j} (\pi_{t+j})^{\theta} mc_{t+j}
\]

\[
= \frac{\theta}{\theta - 1} \lambda_{t}^{D0} q_{t} (\pi_{t})^{\theta} mc_{t} + \frac{\theta}{\theta - 1} \beta \alpha E_{t+1} \sum_{j=0}^{\infty} (\beta) j \lambda_{t+1+j}^{D0} q_{t+1+j} (\pi_{t+1+j})^{\theta} mc_{t+1+j}
\]

i.e.,

\[
\Gamma_t = \lambda_t^{D0} q_t (\pi_t)^{\theta-1} + \beta \alpha \Gamma_{t+1},
\]

\[
\Psi_t = \frac{\theta}{\theta - 1} \lambda_t^{D0} q_t (\pi_t)^{\theta} + \beta \alpha \Psi_{t+1}.
\]

Third, using the definition of \(\lambda_{t+j}^{D0}\) (52):

\[
\lambda_{t+j}^{D0} = \lambda_t^D z_{t+j} = \lambda_t^D (1 + \iota_t) z_{t+j} = \lambda_t^D (1 + \iota_t),
\]

\[
\lambda_{t+j}^{D0} = \lambda_t^D z_{t+j} = \lambda_t^D (1 + \iota_t) z_{t+j} = \lambda_t^D (1 + \iota_t),
\]
I can now rewrite the definitions of $\Gamma_t^D$ and $\Psi_t^D$ as well as their recursive formulations in terms of the system’s variables:

$$\Gamma_t^D = E_t \sum_{j=0}^{\infty} (\beta \alpha)^j \lambda_{t+j}^\circ \tilde{\varphi}_M (1 + i_{t+j}) q_{t+j} \left( \pi_{t+j} \right)^{\theta - 1},$$

$$\Psi_t^D = \frac{\theta}{\theta - 1} E_t \sum_{j=0}^{\infty} (\beta \alpha)^j \lambda_{t+j}^\circ \tilde{\varphi}_M (1 + i_{t+j}) q_{t+j} \left( \pi_{t+j} \right)^{\theta} m c_{t+j}.$$

Finally, note that (103) can be rewritten as:

$$\pi_t = \alpha_D \left( \pi_{t-1} \right)^{1-\theta} + (1 - \alpha_D) \left( \frac{\Psi_t^D}{\Gamma_t^D} \right)^{1-\theta} \left( \frac{1}{1-\psi} \right). \tag{106}$$

The last 3 equations conform the recursive formulation of the Phillips equation that I use for the non-linear system. This block of equations may be interpreted as determining variables $\Gamma_t^D$, $\Psi_t^D$, and $\pi_t$, of which only the last is of interest.

13.2 Wage inflation
In the case of wage inflation, I can write:

$$0 = E_t \sum_{j=0}^{\infty} (\beta \alpha_W)^j \lambda_{t+j}^\circ h_{t+j} w_{t+j} \left( \pi_{t+j} \right)^{\psi_t - 1}$$

$$\left\{ \left( \frac{(\pi_t^W)^{1-\theta} - \alpha_W (\pi_{t-1}^W)^{1-\theta}}{1 - \alpha_W} \right) \psi_t - \frac{\eta_{z_t^{H,j}} (h_{t+j})^\chi}{\lambda_{t+j}^\circ w_{t+j}} \left( \pi_{t+j}^W \right)^{1+\psi_t} \right\}.$$

in the form:

$$\left( \frac{(\pi_t^W)^{1-\psi} - \alpha_W (\pi_{t-1}^W)^{1-\psi}}{1 - \alpha_W} \right)^{\frac{1+\psi_t}{1-\psi}} \Gamma_t^W = \Psi_t^W. \tag{107}$$

where I defined:

$$\Gamma_t^W = E_t \sum_{j=0}^{\infty} (\beta \alpha_W)^j \lambda_{t+j}^\circ h_{t+j} w_{t+j} \left( \pi_{t+j}^W \right)^{\psi_t - 1},$$

$$\Psi_t^W = \frac{\psi_t}{\psi_t - 1} E_t \sum_{j=0}^{\infty} (\beta \alpha_W)^j \eta_{z_t^{H,j}} (h_{t+j})^\chi \left( \pi_{t+j}^W \right)^{1+\psi_t} \left( \pi_{t+j}^W \right)^{1+\psi_t}. \tag{108}$$
Second, I write the infinite sums involved in the definitions of $\Gamma_t$ and $\Psi_t$ recursively:

$$E_t \sum_{j=0}^{\infty} (\beta \alpha W)^j \lambda_t^{\psi-i} h_{t+j} \bar{W}_{t+j} (\pi_t^{W})^{\psi-i-1}$$

$$= \lambda_t^i h_t \bar{W}_t (\pi_t^{W})^{\psi-i-1} + E_t \sum_{j=1}^{\infty} (\beta \alpha)^j \lambda_t^{\psi-i} h_{t+j} \bar{W}_{t+j} (\pi_t^{W})^{\psi-i-1}$$

$$= \lambda_t^i h_t \bar{W}_t (\pi_t^{W})^{\psi-i-1} + \beta \alpha E_t \sum_{j=0}^{\infty} (\beta \alpha)^j \lambda_t^{\psi-i} h_{t+1+j} \bar{W}_{t+1+j} (\pi_t^{W})^{\psi-i-1} ,$$

$$\frac{\psi_t}{\psi_t - 1} E_t \sum_{j=0}^{\infty} (\beta \alpha W)^j \eta z_{t} H (h_{t+j})^{1+\chi} (\pi_t^{W})^{\psi-i(1+\chi)}$$

$$= \frac{\psi_t}{\psi_t - 1} \eta z_{t} H (h_{t})^{1+\chi} (\pi_t^{W})^{\psi-i(1+\chi)} + \frac{\psi_t}{\psi_t - 1} E_t \sum_{j=1}^{\infty} (\beta \alpha W)^j \eta z_{t} H (h_{t+j})^{1+\chi} (\pi_t^{W})^{\psi-i(1+\chi)}$$

$$= \frac{\psi_t}{\psi_t - 1} \eta z_{t} H (h_{t})^{1+\chi} (\pi_t^{W})^{\psi-i(1+\chi)} + \beta \alpha W \frac{\psi_t}{\psi_t - 1} E_t \sum_{j=0}^{\infty} (\beta \alpha W)^j \eta z_{t+1+j} (h_{t+1+j})^{1+\chi} (\pi_t^{W})^{\psi-i(1+\chi)}$$

i.e.,

$$\Gamma^W_t = \lambda_t^i h_t \bar{W}_t (\pi_t^{W})^{\psi-i-1} + \beta \alpha W \Gamma^W_{t+1}$$

$$\Psi^W_t = \frac{\psi_t}{\psi_t - 1} \eta z_{t} H (h_{t})^{1+\chi} (\pi_t^{W})^{\psi-i(1+\chi)} + \beta \alpha W \Psi^W_{t+1} .$$

Finally, (107) can be written as:

$$\frac{\alpha_t W (\pi_t^{W})^{1-\psi-i} + (1 - \alpha_t W) \left( \frac{\psi_t W}{\Gamma^W_t} \right)^{\frac{1-\psi}{1+\psi-i}}}{\Gamma_t^N} = \psi_t^N$$

13.3 Imported goods inflation

In the case of imported goods inflation I have:

$$0 = E_t \sum_{j=0}^{\infty} (\beta \alpha N)^j \bar{N}_{t+j} N_{t+j} (\pi_t^{N})^{\theta N-1}$$

$$\times \left\{ \left( \frac{(\pi_t^{N})^{1-\theta N} - \alpha_N (\pi_t^{N})^{1-\theta N} \frac{1}{1 - \alpha_N}}{1 - \alpha_N} \right)^{\frac{1}{1-\theta N}} - \frac{\theta_N}{\theta_N - 1 \frac{p_{t+j}}{p_{t+j}^{N}}} \right\} .$$

$$\left( \frac{(\pi_t^{N})^{1-\theta N} - \alpha_N (\pi_t^{N})^{1-\theta N} \frac{1}{1 - \alpha_N}}{1 - \alpha_N} \right)^{\frac{1}{1-\theta N}} \Gamma_t^N = \Psi_t^N .$$

where I defined:

$$\Gamma_t^N = E_t \sum_{j=0}^{\infty} (\beta \alpha N)^j \bar{N}_{t+j} N_{t+j} (\pi_t^{N})^{\theta N-1}$$

$$\Psi_t^N = \frac{\theta_N}{\theta_N - 1} E_t \sum_{j=0}^{\infty} (\beta \alpha N)^j \bar{N}_{t+j} N_{t+j} (\pi_t^{N})^{\theta N} \frac{e_{t+j}}{p_{t+j}^{N}}$$
The recursions are:

\[
E_t \sum_{j=0}^{\infty} (\beta \alpha_N)^j \Lambda_{t+j}^{N_0} n_{t+j}(\pi_{t+j}^N)^{\theta_N-1}
\]

\[
= \Lambda_{t}^{N_0} n_t(\pi_t^N)^{\theta_N-1} + E_t \sum_{j=1}^{\infty} (\beta \alpha_N)^j \Lambda_{t+j}^{N_0} n_{t+j}(\pi_{t+j}^N)^{\theta_N-1}
\]

\[
= \Lambda_{t}^{N_0} n_t(\pi_t^N)^{\theta_N-1} + \beta \alpha_N E_{t+1} \sum_{j=0}^{\infty} (\beta \alpha_N)^j \Lambda_{t+1+j}^{N_0} n_{t+1+j}(\pi_{t+1+j}^N)^{\theta_N-1},
\]

\[
\frac{\theta_N}{\theta_N - 1} E_t \sum_{j=0}^{\infty} (\beta \alpha_N)^j \Lambda_{t+j}^{N_0} n_{t+j}(\pi_{t+j}^N)^{\theta_N e_{t+j}} \frac{e_{t+j}}{p_i^{N}}
\]

\[
= \frac{\theta_N}{\theta_N - 1} \Lambda_{t}^{N_0} n_t(\pi_t^N)^{\theta_N} \frac{e_t}{p_i^{N}} + \beta \alpha_N \frac{\theta_N}{\theta_N - 1} E_{t+1} \sum_{j=0}^{\infty} (\beta \alpha_N)^j \Lambda_{t+1+j}^{N_0} n_{t+1+j}(\pi_{t+1+j}^N)^{\theta_N e_{t+1+j}} \frac{e_{t+1+j}}{p_i^{N}}
\]

i.e.,

\[
\Gamma_t^N = \Lambda_{t}^{N_0} n_t(\pi_t^N)^{\theta_N-1} + \beta \alpha_N \Gamma_{t+1}^N
\]

\[
\Psi_t^N = \frac{\theta_N}{\theta_N - 1} \Lambda_{t}^{N_0} n_t(\pi_t^N)^{\theta_N} \frac{e_t}{p_i^{N}} + \beta \alpha_N \Psi_{t+1}^N.
\]

Third, using the definition of \(\Lambda_{t+j}^N\) (65):

\[
\Lambda_{t}^{N_0} = \Lambda_{t}^{N} z_t = \lambda_t \check{\varphi}_M (1 + i_t) p_t^N z_t = \lambda_t \check{\varphi}_M (1 + i_t) p_t^N,
\]

I rewrite the definitions of \(\Gamma_t^N\) and \(\Psi_t^N\) as well as their recursive formulations in terms of the system’s variables:

\[
\Gamma_t^N = \lambda_t \check{\varphi}_M (1 + i_t) p_t^N n_t(\pi_t^N)^{\theta_N-1} + \beta \alpha_N \Gamma_{t+1}^N
\]

\[
\Psi_t^N = \frac{\theta_N}{\theta_N - 1} \lambda_t \check{\varphi}_M (1 + i_t) p_t^N n_t(\pi_t^N)^{\theta_N} \frac{e_t}{p_i^{N}} + \beta \alpha_N \Psi_{t+1}^N.
\]

Finally, note that (108) can be rewritten as:

\[
\pi_t^N = \left[ \alpha_N \left( \pi_{t-1}^N \right) ^{1-\theta_N} + (1 - \alpha_N) \left( \frac{\Psi_t^N}{\Gamma_t^N} \right) ^{1-\theta_N} \right] ^{\frac{1}{1-\theta_N}}. \tag{109}
\]

14. Baseline calibration, and dogmatic priors

Appendix 1 includes an analysis of the nonstochastic steady state and a detailed baseline calibration. The steps shown there (with some inessential changes) were implemented in a MATLAB m-file that interacts with the Dynare mod-file that contains the model and stochastic simulation or estimation instructions. A number
of great ratios and structural parameters jointly determine the steady state values of the endogenous variables. Since I have different strengths of opinion for different great ratios and since substantial identification problems have to be surpassed by means of the imposition of ‘dogmatic priors’ for some of the parameters, I have divided them in two categories. For the first group I use dogmatic priors and impose them on the model. For the second group my priors are less strong and hence I allow them to vary endogenously with the parameter values that are either estimated or imposed. I also impose the steady state values of a small subset of the endogenous variables.

The great ratios (to GDP) I imposed are: the Government’s expenditure ratio \( g/y = 0.16 \) and foreign debt ratio \( \gamma^{GT} = eb^*G/y = 0.2 \), households’ cash ratio \( m^0/y = 0.08 \), the Central Bank’s international reserves ratio \( \gamma^{CBT} = ec^*CB/y = 0.13 \), which hence implies its domestic bonds ratio \( (b^CB/y = 0.05) \), Banks’ foreign debt ratio \( (eb^B/y = 0.0658) \) and loan ratio \( (\ell/y = 0.23) \), which hence implies their deposit ratio \( (d/y = 0.2142) \), and the economy’s imports ratio \( (p^N N/y = 0.22) \). I also imposed households’ transactions cost to consumption expenditures ratio \( (\tau_M = \tau_M c = 0.001) \).

The parameter values I imposed are the intertemporal discount rate \( \beta = 0.999 \), the share of domestic goods in household expenditures (or home bias parameter \( a_D = 0.8610526316 \)), the inverse of the elasticity of labor supply with respect to the real wage \( \chi = 0.7 \), the elasticities of the endogenous risk premia for the government \( (\varepsilon_G = 0.833397207) \) and banks \( (\varepsilon_B = 1.15745156) \), the interest elasticity of cash demand by households \( (\varepsilon_M = 0.85) \), and the persistence parameters for the consumption shock \( (\rho^u = 0.85) \) and the Central Bank international reserves policy rule (whenever it was used: \( \rho^*s^{CB} = 0.1 \)).

The only steady state values for endogenous variables that were imposed were the trend adjusted GDP (at 10% above the 2005 level at constant 1993 prices: \( y = 585.5 \)), the Government foreign debt interest rate \( (1 + \iota^G = 1.070^{0.25}) \), and the bank loan interest rate \( (1 + i^L = 1.129^{0.25}) \). I also imposed the Central Bank inflation target (which determined the domestic inflation rates: \( \pi^T = 1.065^{0.25} \)) and the steady state values of a few of the RW shock variables subject to autorregressive processes: the exogenous risk/liquidity premia for banks and the government \( ((\phi^{**B})^4 = (\phi^{**G})^4 = 1.005) \) and the external terms of trade shock \( (p^s = 0.0047634357) \).

The estimated parameters are the elasticities of substitution (ES) between imported varieties \( (\theta^N) \) and between labor varieties \( (\psi) \), the ES between domestic and imported goods in consumption \( (\theta^C) \), the parameters in the production functions of the domestic \( (b^D) \) and export goods \( (b^A) \) sectors, the habit parameter \( (\xi) \), the Calvo probabilities of not setting the optimal price for domestic goods \( (\alpha_D) \), imported goods \( (\alpha_N) \) and wages \( (\alpha_W) \) setting, and the parameters related to the evolution of the rate of growth of productivity \( (\alpha_z, \rho^z) \). The remaining persistence parameters were also estimated:

\[
\rho^H, \quad \rho^i, \quad \rho^c, \quad \rho^zA, \quad \rho^p, \quad \rho^sN, \quad \rho^i*, \quad \rho^*B, \quad \rho^*G, \quad \rho^z*, \quad \rho^g,
\]

along with the standard deviations of the exogenous shocks.

The values of the remaining parameters and great ratios are determined endogeneously from the previous estimated or imposed values using steady state equations.
These are:

\[ \theta, \eta, b^B, \alpha_1^G, \alpha_2^G, \alpha_2^B, \alpha_1^B, a_M, b_M, c_M, \]

\[ \frac{q}{y}, \frac{p_C}{y}, \frac{wh}{y}, \frac{etb}{y}, \frac{(b^Aep^*)^{1-m}}{b^A}, \frac{\omega}{m^0}, \frac{q^{DX}}{y}, \frac{n^D}{n}. \]

15. Numerical solution with Dynare and policy parameter stability ranges

For numerical solution of ARGEMmy using Dynare I wrote the model block using the nonlinear equations and let Dynare calculate the loglinear approximations. In order to satisfy the Blanchard-Kahn stability conditions it was necessary to introduce some forward-lookingness in the policy rules. Although other variants involving Central Bank policy rules were available, the most convenient for my purposes was to assume that the tax collection process is a forward-looking AR(1) (i.e. with a persistence parameter greater than 1). This can be interpreted as representing a (lump sum) tax collection policy that is geared to obtaining fiscal solvency. To avoid unnecessary complications, the persistence parameter in this equation was calibrated (\( \rho^f = 1.6 \)) and the equation was not shocked.

All variants of the Central Bank policy rules satisfied the Blanchard-Kahn conditions for a baseline set of calibrated parameters. To get an idea of how much the coefficients could depart from the baseline level, I performed a sensitivity analysis for the nine policy rule coefficients. Starting from a baseline calibration for the coefficients in the two policy feedback rules I looked for the largest connected intervals (to one decimal in the vicinity of zero and to one digit otherwise) within which each of the coefficients could be moved individually (and leaving the rest at the baseline value) without altering the Blanchard-Kahn conditions for existence and determinacy of model solution. I didn’t check for parameter values above 10 or for negative values for the inertial parameters or the next two parameters in the interest rate feedback rule (inflation and GDP). The baseline values of the policy coefficients in the simple policy feedback rules were the following, where I repeat the policy rules for the reader’s convenience:

Interest rate feedback rule:

\[ 1 + i_t = \Xi^{TR} \left(1 + i_{t-1}\right)^{h_0} \left(\frac{\tilde{\pi}^C_t}{\tilde{\pi}^T_t}\right)^{h_1} \left(\frac{y_t}{y}\right)^{h_2} \left(\frac{etb_t/y_t}{\gamma^{TBT}}\right)^{h_3} \left(\frac{e_{t-1}tb_{t-1}/y_{t-1}}{\gamma^{TBT}}\right)^{h_4} \]

Nominal depreciation feedback rule:

\[ \delta_t = \Xi^{FXI} \left(\delta_{t-1}\right)^{k_0} \left(\frac{\tilde{\pi}^C_t}{\tilde{\pi}^T_t}\right)^{k_1} \left(\frac{y_t}{y}\right)^{k_2} \left(\frac{etb_t/y_t}{\gamma^{TBT}}\right)^{k_3} \left(\frac{e_{t-1}tb_{t-1}/y_{t-1}}{\gamma^{TBT}}\right)^{k_4} \left(\frac{et^*_{t}CB_t/y_t}{\gamma^{CBT}}\right)^{k_5} \]
Table 1 shows the stability results. Both of the inertial coefficient intervals of stability were quite wide around zero, both going into high superinertial levels. In the case of the interest rate rule, there were no upper bounds (up to 10) for the reactions to GDP, and the parameter on the contemporary trade balance to GDP ratio had to be negative. The Taylor Principle did not hold, for the coefficient on inflation could go down to 0 without impairing stability. In the case of the second feedback rule, there were no upper or lower bounds for the response to inflation, GDP, or the contemporary trade balance to GDP ratio. The coefficient on the international reserves to GDP ratio $k_5$, only had to be outside of a small interval around zero. Because unity is included in the feasible intervals for $h_0$ and $k_0$, one or both of the simple policy rules can be implemented as the feedback response of the first difference (in the interest rate or the depreciation rate) to the various arguments on the r.h.s.

**TABLE 1**

**Individual policy parameter stability ranges**

**Interest rate feedback rule:**

- $h_0 \in [0, 10]$
- $h_1 \in [0, 6]$
- $h_2 \in [0, 10]$
- $h_3 \in [-10, -0.5]$
- $h_4 \in [-0.5, 0.5]$

**Nominal depreciation feedback rule:**

- $k_0 \in [0, 10]$
- $k_1 \in [-10, 10]$
- $k_2 \in [-10, 10]$
- $k_3 \in [-10, 10]$
- $k_4 \in [-10, 3]$
- $k_5 \notin [-0.1, 0.2]$

These approximate bounds proved to be useful for instructing Dynare to limit the search for the estimated parameters.

16. **Bayesian estimation**

In this section I show preliminary results on the Bayesian estimation of a subset of the model parameters. As is well known, unlike GMM estimation, Bayesian estimation is system-based. It fits the solution of the DSGE model to a vector of time series (An and Schorfheide (2007)). Also, like maximum likelihood estimation it is based on the likelihood function generated by the DSGE model, but through prior densities it also incorporates the additional information the researcher may have (e.g. his expert opinion on how the model is supposed to behave). However, the Bayesian estimation of DSGE models is plagued with pitfalls. Lack of identification of some of the parameters of interest is usual and it is one of the most difficult issues to tackle (Canova (2007), Canova and Sala (2005), Iskrev (2007)). In countries like Argentina there are additional difficulties related to lack of trustworthy data series, structural breaks through frequent deep crises, changes of policy regimes, etc. Although life is not easy for applied researchers in less developed countries, Bayesian methods constitute an important venue for bridging some of
the difficulties. However, the lack of identification of a significant subset of the parameters of interest whenever the model is relatively large makes it mandatory to resort to a mixed calibration/estimation strategy.

In this section I show some very preliminary results on the calibration/estimation of ARGEMmy using Dynare/MATLAB. The fact that Dynare is still in a less than user-friendly stage makes its use difficult and very time consuming when one as a relatively large model. However, there is some consolation in verifying that it is being constantly improved upon. Hopefully the day is near when the error messages it produces will be more helpful in locating and correcting errors.

The preliminary results shown below pertain to the post-Convertible era. I use only 22 observations between 2002:3 and 2007:4 for 10 observable variables. The first four are the quarter to quarter rates of growth of GDP, Private Absorption (i.e., Private Consumption plus Investment), Government current expenditures, and Imports. These series are from the national accounts measured in 1993 prices. The next three observable variables are the quarter to quarter rates of growth of Deposits (Bank deposits subject to reserve requirements), and Cash (Bills and Coins), and the Multilateral Real Exchange Rate (in level). These are BCRA (Central Bank of Argentina) series. The last three are the quarter to quarter inflation rates for domestic and imported goods and for wages. For the domestic and imported prices I use the GDP and imports deflators from the national accounts, and I proxied wages by the remunerations reflected in the pension system (Gross average remunerations with accrued 13th annual remuneration -‘aguinaldo’) because it is much more representative than any existing wage series.

As soon as I increased the number of observable variables to more than just a few I began to have problems in the initial search for the posterior mode with any of the first five Dynare mode_compute options, including Sims’ csminwel. The sixth option, which unfortunately has very scant documentation (see DynareWiki in the Dynare website), instead of using a standard optimization routine (Newton type), uses a Monte Carlo optimization algorithm. It looks for a point in the parameters space with high posterior density and a good covariance matrix to be used by the jumping distribution in the second Metropolis Hastings process. It uses a MH algorithm with a starting diagonal covariance matrix to repeatedly update the posterior covariance matrix, the posterior mean and the posterior mode estimates through Metropolis Hastings draws. The number of simulations and the number of times the process is repeated can be established through options specific to the ‘mode_compute=6’ option. Another advantage of this option is that it also tunes the scale factor for the jumping distribution used in the second (and usual) Metropolis Hastings algorithm so that the acceptance ratio is around one third.

This option proved to be extremely helpful. However, even with this option increasing the number of observable series used and the number of parameters to be estimated was not an easy task. There were often warning signs indicating a poorly conditioned Hessian matrix or an insufficiently large support of the weighting density for the calculation of the Modified Harmonic Mean estimate (for the marginal density of the data conditional on the model). Such difficulties, probably related to lack of identification or poor identification of some of the parameters and possibly problems with some of my data, led me to reduce the number of parameters I had initially set out to estimate as well as the number of observable
series I had initially included in my data file.

It is quite clear that the exchange rate remained a central concern for monetary policy in Argentina in the post-Convertibility period. Although the dollar exchange rate is the most visible the monetary authorities pay attention to the multilateral (or ‘effective’) real exchange rate. A preliminary estimation compared the model where the Central Bank uses the two feedback rules to the model where it uses only the foreign exchange intervention feedback rule and an autorregresive equation for the domestic value of the Central Bank’s international reserves. The second model systematically generated a significantly higher marginal data density conditional on the model. Hence, below I show only (preliminary) results from the second model.

The estimation process was nevertheless iterative. After making a preliminary exploration of the parameter space I decided on a set of prior means for the structural parameters and performed a second or third estimation after correcting much of the discrepancies between the prior and estimated posterior means of 1) the standard errors of the shocks, 2) the corresponding persistence parameters (when these existed and where estimated), and 3) the feedback rule parameters (the \(k_i\)). The fact that these parameters do not affect the model’s nonstochastic steady state made this easier (than also correcting the priors for the main structural parameters). The assumptions on priors and some of the information produced on the posteriors and are in Table 2 below. And some of the voluminous additional Dynare output is shown in the Appendix.
### Table 2

ESTIMATION RESULTS

Log data density is 134.624146

<table>
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<tr>
<th>Parameters</th>
<th>prior mean</th>
<th>post. mean</th>
<th>confidence interval</th>
<th>prior pstdev</th>
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<td>0.7992</td>
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Standard deviation of shocks

<table>
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<th>confidence interval</th>
<th>prior pstdev</th>
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<td>eps_zC</td>
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17. Conclusion

This paper constructs an intermediate DSGE model and calibrates/estimates it for the Argentinian economy using Dynare. It takes as a benchmark the larger DSGE model ARGEM (see Escudé (20007)) and generates a simpler model. The features of ARGEM that are suppressed include the following: 1) investment, and hence the capital stock and its intensity of utilization, 2) the deposit rate, which is collapsed with the Central Bank bond rate through the assumption of perfect substitution, 3) regulated bank reserves in the Central Bank and Bank demand for foreign and domestic currency cash, 4) manufactured exports (making exports exclusively
primary with perfect and immediate pass-through). However, ARGEMmy (as I call the simpler model) has most of the fundamental structure of ARGEM: it includes 1) banks that are at the center of the financial aspects of the model and generate the model’s uncovered interest parity equation, 2) growth introduced through a permanent productivity shock that is cointegrated with its equivalent for the rest of the world, 3) a full-fledged fiscal sector (with a minimal tax structure), and 4) the ability to model a monetary policy which uses two simultaneous policy rules which may or may not involve feedback. The model has some features that may be seen as an advance on ARGEM. In particular, the three nonlinear Phillips curves are formulated recursively and the whole set of nonlinear equations is implemented in Dynare, which calculates the loglinear approximation to the model equations and finds the solution to the DSGE model. Also, in this paper I also show in detail the baseline calibration and calculation of the nonstochastic steady state that is implemented in the MATLAB m-file that interacts with the Dynare model. Furthermore, results from a very preliminary estimation of a subset of the model’s parameters are shown.

Appendix 1: Model parameters and great ratios
The non-policy benchmark parameters and great ratios of the model are in Table A1 below. Parameters followed by (***) are those that are estimated. All values followed by (*) are imposed. The remaining steady state values of endogenous variables or great ratios and values for parameters are derived from imposed or estimated values.
Table A1

Steady state values of variables, great ratios and parameters

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<th><strong>REST OF THE WORLD</strong></th>
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<tr>
<td>Risk-free interest rate</td>
<td>$i^{**}$</td>
<td>$1.06^{0.25} - 1$</td>
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<tr>
<td>Inflation (*)</td>
<td>$\pi^{**}, \pi^{**N}$</td>
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<tr>
<td>Productivity growth (*)</td>
<td>$\mu^{**}$</td>
<td>$1.033^{0.25}$</td>
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<table>
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<tr>
<th><strong>HOUSEHOLDS</strong></th>
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<tr>
<td>Intertemporal discount factor (*)</td>
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<tr>
<td>Inverse of labor supply elasticity (*)</td>
<td>$\gamma$</td>
<td>$0.7$</td>
</tr>
<tr>
<td>Share of domestic goods in consumption (*)</td>
<td>$a_D$</td>
<td>$0.8610526316$</td>
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<tr>
<td>Habit persistence (**)</td>
<td>$\xi$</td>
<td>$0.8901$</td>
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<tr>
<td>Labor parameter in utility</td>
<td>$\eta$</td>
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<tr>
<td>Probability of not optimizing wages (**)</td>
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<td>$0.5808$</td>
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<table>
<thead>
<tr>
<th><strong>DOMESTIC SECTOR FIRMS</strong></th>
<th></th>
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</thead>
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<tr>
<td>Fraction of factors bill that is bank financed</td>
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<td>$0.30537629$</td>
</tr>
<tr>
<td>Production function parameter (**)</td>
<td>$b^D$</td>
<td>$0.8903$</td>
</tr>
<tr>
<td>Probability of not optimizing prices (**)</td>
<td>$\alpha_D$</td>
<td>$0.6133$</td>
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<table>
<thead>
<tr>
<th><strong>PRIMARY SECTOR FIRMS</strong></th>
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</thead>
<tbody>
<tr>
<td>Production function parameter (**)</td>
<td>$b^A$</td>
<td>$0.0729$</td>
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</tbody>
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<table>
<thead>
<tr>
<th><strong>EXOGENOUS GREAT RATIOS</strong></th>
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</thead>
<tbody>
<tr>
<td>Government expenditures/GDP (*)</td>
<td>$G/Y$</td>
<td>$0.16$</td>
</tr>
<tr>
<td>Imports/GDP (*)</td>
<td>$p^N N/Y$</td>
<td>$0.22$</td>
</tr>
<tr>
<td>Cash/GDP (*)</td>
<td>$m^0/Y$</td>
<td>$0.08$</td>
</tr>
<tr>
<td>Loan/GDP (*)</td>
<td>$\ell/y$</td>
<td>$0.23$</td>
</tr>
<tr>
<td>Central Bank bonds/GDP</td>
<td>$b^{CB}/y$</td>
<td>$0.05$</td>
</tr>
<tr>
<td>Bank Foreign debt/GDP (*)</td>
<td>$eb^*B/y$</td>
<td>$0.0658$</td>
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<tr>
<th><strong>BANKS</strong></th>
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<tr>
<td>Cost function parameter</td>
<td>$b^B$</td>
<td>$2.6471135748 \times 10^{-5}$</td>
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<tr>
<td>Foreign debt steady state exogenous risk premium (*)</td>
<td>$\phi^{**B}$</td>
<td>$1.005$</td>
</tr>
<tr>
<td>Foreign debt endogenous risk premium elasticity (*)</td>
<td>$\varepsilon_B$</td>
<td>$1.15745156$</td>
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<td>Foreign debt endogenous risk premium parameter</td>
<td>$\alpha^B_1$</td>
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<tr>
<td>Foreign debt endogenous risk premium parameter</td>
<td>$\alpha^B_2$</td>
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<th><strong>MONEY DEMAND</strong></th>
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<tr>
<td>Transactions cost function interest elasticity (*)</td>
<td>$\varepsilon_M$</td>
<td>$0.85$</td>
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<tr>
<td>Transactions cost function parameter</td>
<td>$a_M$</td>
<td>$1.04572957542459$</td>
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<tr>
<td>Transactions cost function parameter</td>
<td>$b_M$</td>
<td>$0.0722273891212$</td>
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<tr>
<td>Transactions cost function parameter</td>
<td>$c_M$</td>
<td>$-0.70487661051072$</td>
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<tr>
<td>Money/consumption ratio</td>
<td>$\varpi$</td>
<td>$0.08091690836698$</td>
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Table 1 (continued)

**POLICY**

<table>
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<tr>
<th>Target inflation rate (*)</th>
<th>(\pi^T)</th>
<th>1.065^{0.25}</th>
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<tbody>
<tr>
<td>Target International Reserves/GDP (*)</td>
<td>(\gamma_{CBT})</td>
<td>0.13</td>
</tr>
<tr>
<td>Target Gov. Debt/GDP (*)</td>
<td>(\gamma_{GT})</td>
<td>0.20</td>
</tr>
</tbody>
</table>

**OTHER RATES AND RELATIVE PRICES**

| Central Bank bond interest rate | \(i\) | 0.025172608 |
| Loan rate (*) | \(i^L\) | 1.12^{0.25} - 1 |
| Nominal depreciation rate | \(\delta\) | 1.041055718^{0.25} |

**LEVEL**

| GDP (*) | \(y\) | 585.5 |

**ELASTICITIES OF SUBSTITUTION**

| Elasticity of substitution for labor types (**) | \(\psi\) | 7.3116 |
| Elasticity of substitution for domestic goods | \(\theta\) | 1.902214507 |
| Elasticity of substitution for imported goods (**) | \(\theta^N\) | 1.1754 |
| Elast. of subst. between domestic and imported goods (**) | \(\theta^C\) | 0.9895 |

**PRODUCTIVITY GROWTH**

| Coef. on relative productivity level (**) | \(\alpha_Z\) | 0.0151 |
| Persistence (**) | \(\rho^z\) | 0.6733 |

**GOVERNMENT**

| Foreign debt steady state exogenous risk premium (*) | \(\phi^{**B}\) | 1.005 |
| Foreign debt endogenous risk premium elasticity (*) | \(\varepsilon_G\) | 0.833397207 |
| Foreign debt endogenous risk premium parameter | \(\alpha_1^G\) | 6.006093674 \times 10^{-4} |
| Foreign debt endogenous risk premium parameter | \(\alpha_2^G\) | 6.49377796598 |

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Appendix 2. Analysis of the steady state and baseline calibration of the parameters

Underlying any consistent dynamic model is a static theory of how the macroeconomy functions in the ‘long run’. In this appendix I consider this underlying theory implicit in ARGEMmy. For this, I first replace the stationary variables in the nonlinear equations by their non-stochastic steady state values (which I denote by the same variables without any time index). For simplicity, I normalize the consumption shock, the labor shock, the transitory technology shock, and the harvest shock to unity in the steady state: \( z^C = z^H = \epsilon = z^A = 1 \). I have assumed in section 12 that the technology levels and growth rates are the same in the SOE as in the RW (\( z^o = 1 \) and \( \mu^o = \mu^{**} \)) so there is no need to now consider the new equations introduced there. The remaining model equations with the variables at their SS values are the following:

Dynamics of Consumption:

\[
\lambda^c \tilde{\varphi}_M (1 + i) p^c c = \frac{\mu^{**} - \beta \xi}{\mu^{**} - \xi} \equiv F > 1
\]  

(110)

Marginal utility of real income:

\[ \mu^{**} \pi = \beta (1 + i) \]  

(111)

Wage inflation Phillips equation:

\[ \bar{w} = \frac{\psi}{\psi - 1} \lambda^c \]  

(112)

Domestic inflation Phillips equation:

\[ 1 = \frac{\theta}{\theta - 1} mc. \]  

(113)

Imported inflation Phillips equation:

\[ p^N = \frac{\theta^N}{\theta^N - 1} e \]  

(114)

Balance of Payments:

\[ \gamma^G T \left[ \frac{1 + i^G}{\mu^{**} \pi^{**} N} - 1 \right] + \frac{eb^B}{y} \left[ \frac{1 + i^B}{\mu^{**} \pi^{**} N} - 1 \right] - \frac{er^{*CB}}{y} \left[ \frac{1 + i^{**}}{\mu^{**} \pi^{**} N} - 1 \right] = e \frac{tb}{y} \]  

(115)

Trade Balance:

\[ etb = \left( \frac{\delta}{\mu^{**} \pi} \right)^4 \left( \frac{b^A e p^{**}}{b^A} \right)^{1 - \pi} \left[ (1 - a_D) p^c c + \frac{1 - b^D}{b^D \bar{w} h} \right] \frac{\theta^N}{\theta^N - 1} \]  

(116)

Central Bank balance:

\[ \frac{b^{CB}}{y} = \frac{er^{*CB}}{y} - \mathcal{L} (1 + i) \frac{p^c c}{y} \]
Government foreign debt interest rate:

\[ 1 + i^G = (1 + i^{**}) \phi^{**G} \left[ 1 + p_G \left( \gamma^{GT} - e_{r*CB}^* / y \right) \right]. \quad (117) \]

Fiscal:

\[ \frac{1}{y} (t - g) = \left( \frac{1 + i^G}{\mu^{z*} \pi^{z*N}} - 1 \right) \gamma^{GT} - \left( \frac{1 + i^{**} - 1/\delta}{\mu^{z*} \pi^{z*N}} \right) \frac{e_{r*CB}^*}{y} + \frac{i}{\mu^{z*} \pi} \frac{b_{CB}^*}{y} \quad (118) \]

Bank foreign debt interest rate:

\[ 1 + i^B = (1 + i^{**}) \phi^{**B} \left[ 1 + p_B \left( \frac{e_{B}^*}{y} \right) \right] \quad (119) \]

Risk-adjusted uncovered interest parity:

\[ i = \delta \left\{ (1 + i^{**}) \phi^{**B} \left[ 1 + \phi_B \left( \frac{e_{B}^*}{y} \right) \right] - 1 \right\} \quad (120) \]

Loan market clearing:

\[ i^L = i + \frac{b_B}{b_D} \mu^{z*} \bar{w} h \quad (121) \]

Real marginal cost:

\[ mc = \frac{1}{\kappa} (1 + \zeta i^L) \bar{w}^{b_D} \left( p_N^{1-b_D} \right) \quad (122) \]

Labor market clearing:

\[ h = \frac{b_D}{\kappa} \left( \frac{p_N}{\bar{w}} \right)^{1-b_D} \quad q. \quad (123) \]

Domestic goods market clearing:

\[ q = [a_D + \bar{\tau}_M (1 + i)] p^C c + g + (b^A e_{p}^{**})^{1-b_A} + \frac{1}{2b_B} (i^L - i)^2 \quad (124) \]

Real GDP:

\[ y = p^C c + g + \frac{1}{(\mu^{z*} \pi)^{\frac{1}{b_A}}} \left( b^A e_{p}^{**} \right)^{\frac{1}{1-b_A}} - \left[ (1 - a_D) p^C c + \frac{1 - b_D}{b_B} \frac{1}{\bar{w}} w \right] \quad (125) \]

Consumption relative price:

\[ \left( p^C \right)^{1-\theta^C} = a_D + (1 - a_D) \left( p_N \right)^{1-\theta^C} \quad (126) \]

Consumption MRER:

\[ e^C = \frac{e}{p^C}. \]

Interest rate feedback rule:

\[ 1 + i = \frac{\pi}{\beta / \mu^{z*}} \left( \frac{p^C}{\pi^{T}} \right)^{\frac{4b_1}{1-b_0}} \quad (127) \]
(or, alternatively) Central Bank international reserves policy:

\[ \frac{er^{CB}}{y} = \gamma^{TBT} \]

(or, alternatively) Central Bank bond policy:

\[ b^{CB} = b^{CB} \]  \hspace{1cm} (128)

Nominal depreciation feedback rule:

\[ \delta = \left( \frac{\pi}{\pi^{**N}} \right) \left( \frac{er^{CB}/y}{\gamma^{CBT}} \right)^{\frac{k_5}{1-k_0}}. \]  \hspace{1cm} (129)

(or, alternatively) Nominal depreciation rule:

\[ \delta = \delta^T \]

(or, alternatively if not used above) Central Bank international reserves policy:

\[ \frac{er^{CB}}{y} = \gamma^{TBT} \]

Identities:

\[ \delta = \pi / \pi^{**N} \]  \hspace{1cm} (130)

\[ \pi^C = \pi, \hspace{1cm} \pi^W = \pi \mu^z, \hspace{1cm} \pi^N = \pi \]  \hspace{1cm} (131)

\[ \tilde{\pi}^C = \left( \pi^C \right)^4, \hspace{1cm} \tilde{\pi}^C = \left( \pi^C \right)^4, \hspace{1cm} \tilde{\pi}^T = \left( \pi^T \right)^4, \hspace{1cm} \tilde{\mu}^z = \left( \mu^z \right)^4. \]

A first glance at these equations shows that several of the steady state variables are readily determined. All three domestic inflation rates for goods are equal and (111) gives the SS interest rate:

\[ 1 + i = \frac{\mu^{**}}{\beta} \pi. \]  \hspace{1cm} (132)

In the case of an interest rate feedback rule, combining this equation with (127) yields

\[ \pi^C = \pi = \pi^N = \pi^T. \]

And using (130) in (129) shows that the Central Bank attains its foreign reserves target:

\[ er^{*CB}/y = \gamma^{CBT}. \]

(113) shows that the real marginal cost in the domestic sector equals the inverse of the markup factor:

\[ mc = \frac{\theta - 1}{\theta}. \]  \hspace{1cm} (133)
In the rest of this section I build a baseline calibration of the structural parameters and calculation of the nonstochastic steady state for ARGEMmy. I used this process as input to produce a MATLAB m-file that generates the nonstochastic steady state and interacts with the Dynare mod-file that implements the model. In the construction of this m-file, however, many changes were introduced to better reflect my dogmatic priors. Hence, some of the calibrations below that appear imposed but for which I do not have strong priors were later made endogenous and made to depend on parameters that I decided to estimate with Bayesian methods.

The assumptions on the RW’s variables are similar to those in ARGEM. Using annual rates, the SS gross growth rate is assumed to be \((\mu^{**})^4 = 1.033\), and the foreign (export and "domestic") inflation rates are: \((\pi^{**N})^4 = (\pi^{**})^4 = 1.023\). The riskfree nominal interest is assumed to be \((1 + i^{**})^4 = 1.06\) which implies a real (riskfree) annual interest rate of:

\[
\left( \frac{1 + i^{**}}{\mu^{**} \pi^{**}} \right)^4 = \frac{1.06}{1.033 \times 1.023} = 1.003066924.
\]

I also assume that the intertemporal discount rate is \(\beta^4 = 0.999^4\), and that the SS detrended annual GDP level is 10% above the 2005 level (in billions of pesos and in terms of 1993 prices):

\[
y = 532.270 \times 1.10 = 585.5.
\]

The calibrations that depend on the balance of payments or the banking system, however, must suffer some significant changes due to the simplifications in ARGEMmy vis a vis ARGEM. I use the Central Bank and Bank balance sheet constraints to calibrate the ratios to GDP of assets and liabilities:

\[
\frac{er^{*CB}}{y} = \frac{m^0}{y} + \frac{b^{CB}}{y} = 0.13 = 0.08 + 0.05.
\]

\[
\frac{b^{CB}}{y} + \frac{\ell}{y} = \frac{eb^{*B}}{y} + \frac{d}{y} = 0.05 + 0.23 = 0.0658 + 0.2142
\]

The assumptions on Central Bank international reserves and peso cash is the same as in ARGEM (except that since banks do not hold cash here, households have all the cash). The same can be said for the assumption on loans to GDP (except that here firms obtain all the loans since the government does not receive bank credit) and on Banks’ foreign debt to GDP. Hence, the ratio of Central Bank bonds to GDP must be 5%, which is somewhat larger than in ARGEM, and the deposits to GDP ratio is 21.42, slightly lower than in ARGEM.

In the SS the UIP condition (70) is:

\[
\frac{i}{\beta} + 1 = \frac{\pi^{**N} (\frac{\mu^{**}}{\beta} - \frac{1}{\pi}) + 1}{1 + i^{**}} = \phi^{**B} \left[ 1 + \varphi_B \left( \frac{eb^{*B}}{y} \right) \right]. \tag{134}
\]
Given the assumptions on $\mu^{**o}$, $\beta$, $i^{**}$, and $\pi^{**N}$, it is readily seen that the minimum SS rate of inflation that guarantees a positive risk premium (i.e. the r.h.s. of (134) greater than one) is:

$$\pi > \frac{1}{\frac{\mu^{**o}}{\beta} - \frac{i^{**}}{\pi^{**N}}} = \frac{1}{\frac{1.0350.25}{0.999} - \frac{1.060.25}{1.0230.25}} = 1.005461341,$$

$$\pi^4 > 1.022024974.$$

I choose a significantly larger SS inflation (more in line with the policy environment):

$$\pi^4 = 1.065, \quad \pi = 1.015868285,$$

which implies that the annual nominal interest rate and nominal rate of currency depreciation are:

$$(1 + i)^4 = \left(\frac{\mu^{**o} \pi}{\beta}\right)^4 = 1.104556599, \quad 1 + i = 1.025172608
\delta^4 = \left(\frac{\pi}{\pi^{**N}}\right)^4 = 1.041055718, \quad \delta = 1.010109588.$$

The choice for SS inflation also implies that the value of the gross UIP risk premium is:

$$\phi^{**B} [1 + \varphi_B (0.0658)] = \frac{i}{\delta} + \frac{1}{1 + i^{**}}$$

$$= \frac{0.025172608}{1.010109588} + 1 = 1.010098638.$$

I make the further assumption that in the SS the value of the exogenous component of the risk premium for banks as well as the government is half of a percentage point:

$$\left(\phi^{**B}\right)^4 = \left(\phi^{**G}\right)^4 = 1.005$$

$$\phi^{**B} = \phi^{**G} = (1.005)^{0.25} = 1.001247663.$$

Hence, using (96) yields:

$$\varphi_B (0.0658) = \frac{\alpha_B}{(1 - 0.0658 \alpha_B)^2} = \frac{1.010098638}{\phi^{**B}} - 1$$

$$= \frac{1.010098638}{1.005^{0.25}} - 1 = 0.008839945664.$$

Additional information on the coefficients in the risk premium can be obtained using the balance of payments (115), or country resource constraint, which expressed in terms of GDP, and using (117), (119), (95) and the assumptions made
above is:

\[
\frac{e^{tb}}{y} = \gamma^{GT} \left[ \left( \frac{1.06 \times 1.005}{1.033 \times 1.023} \right)^{0.25} \left( 1 + \frac{\alpha_1^G}{1 - (\gamma^{GT} - \gamma^{CBT}) \alpha_2^G} \right) - 1 \right] + 0.0658 \left[ \left( \frac{1.06 \times 1.005}{1.033 \times 1.023} \right)^{0.25} \left( 1 + \frac{\alpha_1^B}{1 - 0.0658 \alpha_2^B} \right) - 1 \right] - 0.13 \left[ \left( \frac{1.06}{1.033 \times 1.023} \right)^{0.25} - 1 \right].
\] (138)

The Government’s foreign debt (i.e. its debt to non-residents) amounted to US$ 60.9 billion at the end of 2005 (representing 33.5% of GDP) and declined to US$ 56.2 billion at the end 2006 (26.4% of GDP). I assume that the Government aims for and achieves a SS foreign debt of 20% of GDP. Hence \( \gamma^{GT} = 0.20 \). Also, I assume that the Central Bank aims for and achieves international reserves amounting to 13% of GDP. Hence \( \gamma^{CBT} = 0.13 \).

As background information for my assumption below for the interest rate the Government faces on its external debt, it is known that this foreign debt has an average maturity of 14.36 years (weighted average of US$ 14 bn. debt to international organizations with average maturity of 5.7 years and US$ 46 bn. debt mainly in bonds with average maturity of 17 years). Also, the weighted average interest rate on the Government’s foreign debt stands at 5.24% (weighted average of 5.6% on its debt to international organizations and 5% on its bond debt). I am simplifying by assuming that all the foreign debt is dollar denominated whereas in fact only around 77% of it is. My assumption is that in the SS the government faces an average 7% annual interest rate abroad. Hence,

\[ 1 + i^G = 1.07^{0.25} = 1.017058525. \]

Therefore, (117) and (99) imply that \( \alpha_1^G \) and \( \alpha_2^G \) must satisfy:

\[ 1 + i^G = 1.07^{0.25} = (1.06 \times 1.005)^{0.25} \left( 1 + \frac{\alpha_1^G}{1 - 0.07 \alpha_2^G} \right) \]

i.e.:

\[ p_G(0.07) = \frac{\alpha_1^G}{1 - 0.07 \alpha_2^G} = \left( \frac{1.07}{1.06 \times 1.005} \right)^{0.25} = 0.001101156. \] (139)

In order to calibrate these coefficients, I use the fact that \( \alpha_2^G \) defines the elasticity

\[ \varepsilon_G(0.07) \equiv \frac{1}{\alpha_2^G(0.07)} - 1 \]

and \( \alpha_1^G \) defines the level of the risk premium function. In fact, the function

\[ \frac{\alpha_1^G}{1 - x \alpha_2^G} \]

crosses the \( y \) axis at \( x = \alpha_1^G \) and tends to infinity as \( x \to 1/\alpha_2^G \). To obtain an elasticity of, say, 1, I need

\[ \alpha_2^G = 7.142857143, \]
Then (139) gives:

\[ \alpha_1^G = 0.0005505780000 \]

(which implies that even a very small positive net debt would command an endogenous risk premium of around 0.05%). I will use these calibrations in the sequel. Also, the fiscal balance equation (118) gives the primary surplus needed to sustain the government debt:

\[
\frac{1}{y} (t - g) = \left( \frac{1 + i^G}{\mu^{**} \pi^{**} N} - 1 \right) \gamma^{GT} - \left( \frac{1 + i^{**} - 1/\delta}{\mu^{**} \pi^{**} N} \right) \frac{\epsilon' y CB}{y} + \frac{i}{\mu^{**} \pi} \frac{B^{CB}}{y} \\
= \left( \frac{1.07^{0.25}}{(1.033 \times 1.023)^{0.25} - 1} \right) 0.2 - \left( \frac{1.06^{0.25} - 0.13}{(1.033 \times 1.023)^{0.25}} \right) 1.033 \times 1.065^{0.25} 0.05 \\
= -0.001312188863
\]

I also assume that SS government expenditures are 16% of GDP (13% for public consumption and 3% for public investment). Hence:

\[
\frac{t}{y} = 0.1586878111, \quad t = 92.9117134.
\]

The balance of payments (138) hence yields:

\[
\frac{e}{y} tb = 0.20 \left[ \left( \frac{1.07}{1.033 \times 1.023} \right)^{0.25} - 1 \right] \\
+ 0.0658 \left[ \left( \frac{1.06 \times 1.005}{1.033 \times 1.023} \right)^{0.25} \left( 1 + \frac{\alpha_1^B}{1 - 0.0658 \alpha_2^B} \right) - 1 \right] \\
- 0.13 \left[ \left( \frac{1.06}{1.033 \times 1.023} \right)^{0.25} - 1 \right] \\
= 0.0006565601244 + 0.06593255209 \frac{\alpha_1^B}{1 - 0.0658 \alpha_2^B},
\]

or:

\[
p_B (0.0658) \equiv \frac{\alpha_1^B}{1 - 0.0658 \alpha_2^B} = 15.1670149 \frac{e}{y} tb - 0.00995805719. \tag{140}
\]

Therefore, (140), (97), (141) and (137) imply:

\[
\frac{\varphi_B (0.0658)}{p_B (0.0658)} = 1 + \varepsilon_B (0.0658) = \frac{1}{1 - \alpha_2^B (0.0658)} = \frac{0.008839945664}{15.1670149 \frac{e}{y} tb - 0.00995805719}. \tag{141}
\]
As the following figure illustrates, to have both a positive elasticity as well as a risk premium that is greater than one it is necessary that the trade balance to GDP ratio fall in the following interval:

\[
6.565601244 \times 10^{-4} < \frac{e}{y}tb < 1.239400302 \times 10^{-3}
\]

To calibrate \(\alpha_1^B\) and \(\alpha_2^B\) I first choose \(etb/y\) within this interval, say

\[etb/y = 9.479802132 \times 10^{-4},\]

which is exactly the midpoint in the interval and in which \(\varepsilon_B = 1\). According to (141) this value for the elasticity determines \(\alpha_2^B\):

\[
1 + 1 = \frac{1}{1 - \alpha_2^B (0.0658)}
\]

\[
\alpha_2^B = 7.598784195
\]

And (140) determines \(\alpha_1^B\) (and hence we have \(p_B\)):

\[
\alpha_1^B = (1 - 0.0658 * 7.598784195) \left(15.1670149 \frac{e}{y}tb - 0.00995805719 \right)
\]

\[
= 0.002209986414
\]

\[p_B \equiv \frac{\alpha_1^B}{1 - 0.0658 \alpha_2^B} = \frac{0.002209986414}{1 - 0.0658 * 7.598784195} = 0.004419972828.
\]

These are the calibrated values I use in the sequel. From (119) I now obtain the bank foreign financing rate:

\[
1 + i^B = (1.06 * 1.005)^{0.25} * (1 + 0.004419972828) = 1.020430244.
\]

The following graph shows the bank risk premium as it is found in the balance of payments equation (the lower curve) and in the UIP equation (the upper curve) The vertical distance between them is the elasticity of the risk premium function times the gross risk premium in the balance of payments. The coefficients \(\alpha_1^B\) and \(\alpha_2^B\) employed are the ones calculated above.
I assume as in ARGEM that SS imports are 22% of GDP. Hence, (125) yields:

\[
1 = a_D \frac{p^c c}{y} + g \frac{y}{y} + \frac{(b^A e p^{**})}{(\mu^{**})^4} b^A y - \frac{1 - b^D \pi h}{b^D} y
\]

\[
= \frac{p^c c}{y} + g \frac{y}{y} + \frac{1}{(\mu^{**})^4} \frac{b^A e p^{**}}{b^A y} - \left[ (1 - a_D) \frac{p^c c}{y} + \frac{1 - b^D \pi h}{b^D} y \right]
\]

\[
= \frac{p^c c}{y} + 0.16 + \frac{1}{1.033 * 1.065} \frac{(b^A e p^{**})}{b^A 585.5} - 0.22
\]

This gives:

\[
\frac{(b^A e p^{**})}{585.5 \alpha_A}^{\frac{1}{1 - b^A}} = 1.033 * 1.065 \left( 1 + 0.22 - 0.16 - \frac{p^c c}{y} \right) \tag{142}
\]

Also, (116) yields.

\[
\frac{e}{yb} = 0.0009479802132
\]

\[
= \left( \frac{\delta}{\mu^{**} \pi} \right)^4 \frac{(b^A e p^{**})^{\frac{1}{1 - b^A}}}{y \alpha_A} - \left[ (1 - a_D) \frac{p^c c}{y} + \frac{1 - b^D \pi h}{b^D} y \right] \theta^N - 1
\]

\[
= \frac{1.041055718}{1.033 * 1.065} \frac{(b^A e p^{**})^{\frac{1}{1 - b^A}}}{585.5 \alpha_A} - 0.22 \frac{\theta^N - 1}{\theta^N}
\]

and hence:

\[
\frac{(b^A e p^{**})}{585.5 \alpha_A}^{\frac{1}{1 - b^A}} = \frac{1.033 * 1.065}{1.041055718} \left[ 0.0009479802132 + 0.22 \frac{\theta^N - 1}{\theta^N} \right] \tag{143}
\]

(142) and (143) imply the following restriction for the calibration of \( \frac{\theta}{\theta - 1} \):

\[
\frac{p^c c}{y} = 1 + 0.22 - 0.16 - \frac{1}{1.041055718} \left( 0.0009479802132 + 0.22 \frac{\theta^N - 1}{\theta^N} \right)
\]
I assume that private consumption (absorption, since there is no investment here) is 85.5\% of GDP, which would correspond to 67\% for private consumption and 18.5\% for private investment, in a model with investment such as ARGEM. Hence:

\[
\frac{\theta^N}{\theta^N - 1} = 1.03544789, \\
\theta^N = 29.21042381, \\
\frac{p^C c}{y} = 0.855.
\]

\[
\frac{(b_A \epsilon p^{**})}{b_A^{1-\epsilon^x}} = 1.033 \times 1.065 \times 585.5 \times (1 + 0.22 - 0.16 - 0.855) \quad (144)
\]

\[
= 132.0476540
\]

Also as in ARGEM, I assume that 46\% of imports are inputs:

\[
\frac{p^N N^D}{p^N N} = 0.46.
\]

Hence, 54\% of imports are for private consumption (absorption). Since imports are 22\% of GDP, the share of imports and domestic goods in consumption (absorption) expenditures are:

\[
a_N = \frac{0.22 \times 0.54}{0.855} = 0.1389473684, \\
a_D = 0.8610526316,
\]

and the ratio of imported inputs to GDP is:

\[
\frac{p^N N^D}{Y} = \frac{(0.46)(0.22)}{0.08} = 0.1012. \quad (145)
\]

Given previous assumptions, the SS cash/consumption ratio is:

\[
\varpi \equiv \frac{m^0}{y} = \frac{0.08}{0.855} = 0.09356725146.
\]

I now use the assumed functional form for the transactions cost function (93) and the resulting functional form for the gross interest rate elasticity (94), as well as additional assumptions, to calibrate the three parameters involved. First, assuming that the SS gross interest rate elasticity of private demand for cash is 0.85 yields:\(^7\)

\[
\varepsilon_M = 0.85 = \frac{\varpi^{1 + b_M}}{(1 + b_M) b_M (1 + i)} = \frac{(0.09356725146)^{1 + b_M}}{(1 + b_M) b_M (1.025172608)}.
\]

\(^7\)A rough calculation for the elasticity of Argentina’s currency demand (as a fraction of absorption) with respect to the gross interest rate during the period 1994-2005 yields 0.84, which is equivalent to an elasticity with respect to the interest rate of 0.09. The latter figure is much lower than the typical estimate for the U.S. and other developed countries, which is in a neighborhood of 0.5. This may be due (at least partly) to the much smaller fraction of the population that uses the banking system in Argentina.
Hence:

\[ b_M = 0.08089510761. \]

Second, I use the cash demand function (as a ratio of private absorption) to obtain the value for \( a_M \):

\[
\varpi = 0.09356725146 = \left( \frac{b_M}{a_M + 1 - \frac{1}{1+i}} \right)^{1+b_M} = \left( \frac{0.08089510761}{a_M + 1 - \frac{1}{1.025172608}} \right)^{1+0.08089510761},
\]

\[ a_M = 1.022645002. \]

Finally, I calibrate the remaining parameter in the transactions cost function, \( c_M \), so that the SS transactions cost in terms of domestic goods \( \tau_M \) is only 0.01% of private consumption (which in units of GDP is 0.05006025 = 0.0001(0.855(585.5))):

\[
0.05006025 = \tau_M \equiv a_M \varpi + \varpi^{-b_M} + c_M
\]

\[ = 1.022645002 * 0.09356725146 + 0.09356725146^{-0.08089510761} + c_M. \]

which implies:

\[ c_M = -1.256868176. \]

These calibrations imply that in the SS the total effect on expenditure (i.e., including transactions cost related expenditures) of a marginal increase in consumption is:

\[
\varphi_M(\varpi) = 1 + c_M + (1 + b_M) \varpi^{-b_M} = 1 - 1.256868176 \\
+ (1 + 0.08089510761) 0.09356725146^{-0.08089510761} \\
= 1.052357748,
\]

and that the SS real cash stock in the hands of households is:

\[ m^0 = \varpi p^C = 0.9356725146 * 0.855 * 585.5 = 46.84. \]

Now I use the bank loan supply function \((69)\) to calibrate both the loan rate and the coefficient in the bank cost function. Dividing this expression by GDP and using the assumed loan to GDP ratio gives:

\[
0.23 = \frac{\ell}{y} = \frac{1}{b^B * 585.5} (i^L - \hat{i}).
\]
I assume that the loan rate is

\[(i^L)^4 = 0.12, \quad i^L = 0.028737345\]

which implies:

\[b^B = \frac{1}{0.23 \times 585.5} (0.028737345 - 0.025172608) = 2.647114692 \times 10^{-5}.
\]

Under the assumption that the share of wage income is 0.7129, which is the sum of wage income and rent income from physical capital (which does not exist here) in ARGEM, I use (48) and (145) to calibrate the domestic sector production function:

\[
\frac{wh}{y} = 0.7129 = \frac{b^D}{1 - b^D} \frac{p^N n^D}{y} = \frac{b^D}{1 - b^D} \cdot 0.1012
\]

\[b^D = 0.8756909471.
\]

And dividing the SS loan demand (49) by GDP and using the previous assumptions I obtain the fraction of domestic firm cost that is bank financed:

\[
\zeta = \frac{\ell / y}{wh/y \mu^{**}} = \frac{0.23 \times 0.8756909471}{0.7129 \times 1.0330.25} = 0.280236694.
\]

As in ARGEM, I use INDEC’s 1997 input-output table to calibrate the domestic sector inputs used by the primary producing sector (given by (57)) as 3.9% of GDP:

\[q^{DX} / y = (b^A e^{**}) \frac{1}{1-b^A} = 0.039.
\]

Along with (142), this equation yields:

\[\left( b^A e^{**} \right) \frac{1}{1-b^A} = 132.047654 \alpha_A = 0.039 \times 585.5
\]

\[b^A = \frac{0.039 \times 585.5}{132.047654} = 0.1729262074,
\]

and hence I obtain the SS value of \(e^{**}\):

\[\left( b^A e^{**} \right) \frac{1}{1-b^A} = \frac{(0.1729262074 e^{**})^{\frac{1}{1-b^A}}}{0.1729262074} = 132.047654
\]

\[e^{**} = 76.87667886.
\]

I can now use the domestic goods market clearing equation (124) to obtain the domestic output to GDP ratio:

\[
\frac{q}{y} = \left[a_D + \tilde{\tau}_M (1 + i) \right] \frac{p^C c}{y} + \frac{g}{y} + \frac{(b^A e^{**})^{\frac{1}{1-b^A}}}{y} + \frac{(i^L - i)^2}{2yb^D}
\]

\[= (0.8610526316 + 0.05006025) (0.855) + 0.16 + 0.039
\]

\[+ (0.028737345 - 0.025172608)^2
\]

\[= 0.9784114585,
\]
and (44) to obtain marginal cost:

\[ mc = \frac{(1 + \zeta i^L) \left( \frac{\sigma h}{y} + \frac{\sigma n L y}{y} \right)}{q/y} = \frac{(1 + 0.280236694 \times 0.028737345) (0.7129 + 0.1012)}{0.9784114585} = 0.8387638459. \]

Hence, using (133), the markup in the domestic goods sector is:

\[ \frac{\theta}{\theta - 1} = \frac{1}{mc} = 1.192230691, \]

and the elasticity of substitution between varieties of domestic goods is:

\[ \theta = 6.202082949. \]

Furthermore, under the assumption that \( \xi = 0.2 \) (110) directly gives the SS value of the marginal utility of real income:

\[ F = \frac{\mu_{z^*} - \beta \xi}{\mu_{z^*} - \xi} = \frac{1.033^{0.25} - 0.999 \times 0.2}{1.033^{0.25} - 0.2} = 1.000247479, \]

\[ \lambda^o = \frac{F}{\varphi_M \frac{\mu}{y}} = \frac{1.000247479}{0.52357748 \times 0.855 \times 585.5} = 0.00189867682. \]

(112) and the assumption on labor share gives the SS supply of labor, and hence the real wage, in terms of three related parameters:

\[ h = \left( \frac{0.7129 \times 585.5 \times 0.00189867682}{s^\psi \eta} \right)^{\frac{1}{\psi + 1}} = \left( \frac{0.7925133058}{s^\psi \eta} \right)^{\frac{1}{\psi + 1}}. \]

I assume \( \chi = 1 \) and the steady state wage gross markup \( s^\psi = 1.1 \), and calibrate \( \eta \) so that the \( h \) can be interpreted as the number of hours worked in a quarter. Let the number of hours be 528 (=8 hours, 22 days per month, 3 months). Hence

\[ \left( \frac{0.7925133058}{1.1 \eta} \right)^{\frac{1}{\psi + 1}} = 528 = h, \]

\[ \eta = 2.584318475 \times 10^{-6} \]

\[ \psi = 11.0. \]

The SS real wage is hence:

\[ \bar{w} = \frac{0.7129 \times 585.5}{528} = 0.7905358902. \]
Now, labor market equilibrium yields the RER, and hence the domestic terms of trade:

\[ 528 = h = \frac{h^D}{\kappa} \left( \frac{\theta e}{\theta - 1} \right)^{1-b^D} \]

\[ = 0.8756909471 \left( \frac{1.03544789e}{0.7905358902} \right)^{1-0.8756909471} \]

\[ e = 0.05624118063, \]

\[ p^N = 1.03544789 * 0.05624118063 = 0.05823481181. \]

Also, (126) gives a relation between \( p^C \) and \( \theta^C \):

\[ p^C = \left( 0.8610526316 + (1 - 0.8610526316) (0.05823481181)^{1-\theta^C} \right)^{\frac{1}{1-\theta^C}} \]

 Choosing \( \theta^C = 1.1 \) gives

\[ p^C = 0.6396589143 \]

\[ \theta^C = 1.1 \]

\[ e^C = e/p^C = 0.08792370336. \]

Hence, the SS consumption index is:

\[ c = \frac{0.855 \times 585.5}{0.6396589143} = 782.6084946. \]

Finally, the external terms of trade is:

\[ p^{**} = \frac{e^{**}}{e} = \frac{76.87667886}{0.05624118063} = 1366.910829. \]

For the steady state of the recursive form of the Phillips equation in the domestic sector, (104) and (105) yield:

\[ \Gamma^D = \frac{1}{1-\beta \alpha_D} \lambda^0 \varphi_M q^{\theta-1} \]

\[ \Psi^D = \frac{\theta}{\theta - 1} \frac{1}{1-\beta \alpha_D} \lambda^0 \varphi_M q^{\theta} mc. \]

Hence,

\[ \frac{\Psi^D}{\Gamma^D} = \frac{\theta}{\theta - 1} mc. \]

Inserting this in the SS version of (106) and eliminating \( \pi \) gives, as before:

\[ \frac{\theta}{\theta - 1} mc = 1. \]
Numerically, assuming $\alpha_D = 0.5$ the steady states for the two new variables are:

$$
\Gamma^D = \frac{1}{1 - \beta \alpha_D} \lambda^0 \tilde{\varphi}_M q \pi^{\theta - 1} \\
= \frac{1}{1 - 0.999 \times 0.5} \times 0.00189867682 \times 1.052357748 \times 0.9784114585 \times 585.5 \times \left(1.065^{0.25}\right)^{6.202082936 - 1} \\
= 2.482147188,
$$

$$
\Psi^D = \frac{\theta}{\theta - 1 - \beta \alpha_D} \frac{1}{1 - \beta \alpha_D} \lambda^0 \tilde{\varphi}_M q \pi^{\theta} m c \\
= 1.192230691 \times \frac{1}{1 - 0.999 \times 0.5} \times 0.00189867682 \times 1.052357748 \times 0.9784114585 \times 585.5 \times \left(1.065^{0.25}\right)^{6.202082936 \times 0.8387638459} \\
= 2.521534606.
$$

For the steady state of the recursive form of the Phillips wage equation I assume that $\alpha_W = 0.6$. Then the steady states for the two new variables are:

$$
\Gamma^W = \frac{1}{1 - \beta \alpha_W} \lambda^0 h w \left(\pi^W\right)^{\psi - 1} \\
= \frac{1}{1 - 0.999 \times 0.6} \times 0.00189867682 \times 0.7129 \times 585.5 \times \left(1.033^{0.25} \times 1.065^{0.25}\right)^{11 - 1} \\
= 2.511426316,
$$

$$
\Psi^W = \frac{\psi}{\psi - 1 - \beta \alpha_W} \eta (h)^{1 + \chi} \left(\pi^W\right)^{\psi(1 + \chi)} \\
= \frac{1}{1 - 0.999 \times 0.6} \times (2.584318475 \times 10^{-6}) \times (528)^{1 + 1} \times \left(1.033^{0.25} \times 1.065^{0.25}\right)^{11(1 + 1)} \\
= 3.344030491.
$$

Finally, for the steady state of the recursive form of the Phillips equation in the import sector I assume $\alpha_N = 0.4$. Then the steady states for the two new variables are:

$$
\Gamma^N = \frac{1}{1 - \beta \alpha_N} \lambda^0 \tilde{\varphi}_M D^N n (\pi^N)^{\theta - 1} \\
= \frac{1}{1 - 0.999 \times 0.4} \times 0.00189867682 \times 1.052357748 \times 0.05823481181 \times (0.22 \times 585.5 / 0.05823481181) \times \left(1.065^{0.25}\right)^{29.21042381 - 1} \\
= 0.6683583135.
$$
\[ \Psi^N = \frac{1}{1 - \beta \alpha \theta^N} \frac{\theta^N}{1 - \beta \alpha \theta^N} \lambda e \varphi_M \varphi_N n(\pi^N)^{\theta^N} \frac{e}{p^N} \]

\[ = \frac{1}{1 - 0.999 \times 0.5} \times 1.03544789 \times 0.00189867682 \times 1.052357748 \times 0.05823481181 \times (0.22 \times 585.5/0.05823481181) \times (1.065^{0.25})^{29.21042381} \times (0.05624118063/0.05823481181) \]

\[ = 0.6789640136. \]
Appendix 3
Impulse Response Functions
This Appendix shows the IRFs for the model using the estimated parameters. Because they are many I select the 27 most interesting endogenous variables.

Response to a consumption demand shock $\varepsilon^c_t$, 

![Graphs of various endogenous variables showing responses to a consumption demand shock $\varepsilon^c_t$.]
Response to a (negative) labor supply $\xi^H_t$, 

\begin{align*}
\text{(a) } l & = \text{ flat line} \\
\text{(b) } d & = \text{ flat line} \\
\text{(c) } m0 & = \text{ flat line} \\
\text{(d) } bCB & = \text{ flat line} \\
\text{(e) } rStarCB & = \text{ flat line} \\
\text{(f) } bStarB & = \text{ flat line} \\
\text{(g) } bStarG & = \text{ flat line}
\end{align*}
Response to a domestic firm loan demand shock $\varepsilon_t$,
Response to a harvest shock $\varepsilon_t^H$,
Response to a terms of trade shock $\varepsilon_{t}^{JL}$,
Response to a RW inflation shock $\varepsilon_{l}^{**N}$.
Response to a domestic transitory productivity shock $\epsilon^*_t$, 

- $c$, $pCc$, $y$, $pXx$, $n$, $pNn$, $eC$, $\Delta M$, $tb$, $mc$, $h$, $wbarh$, $ri$, $\pii$, $pN$, $pW$.
Response to a domestic permanent productivity growth shock $\xi_t^\ast$, 

\[ \begin{align*} 
I & \quad d \\ b_{CB} & \quad r_{StarCB} \\ b_{StarB} & \quad b_{StarG} \\ c & \quad p_{Cc} \\ p_{Xx} & \quad n \\ p_{NN} & \quad \delta M \\ e_C & \quad \delta M \\ t_b & \quad t_b 
\end{align*} \]
Response to a RW permanent productivity growth shock $\epsilon_t^{\mu,***}$,
Response to a Government expenditure shock $c_{t+1}^g$, 

\begin{align*}
\text{l} & \quad \text{d} & \quad \text{m0} \\
\text{bCB} & \quad \text{rStarCB} & \quad \text{bStarB} \\
\text{bStarG} & \quad \text{muz} & \quad \text{z0} \\
\text{c} & \quad \text{pCc} & \quad \text{y} \\
\text{pXx} & \quad \text{n} & \quad \text{pNh} \\
\text{eC} & \quad \delta M & \quad \text{lb}
\end{align*}
Response to a policy nominal depreciation shock $\varepsilon^d_t$, 

![Graphs showing the response of various economic variables to a nominal depreciation shock.](image-url)
Response to a foreign interest rate shock $c_t^*$.
Response to a foreign exogenous Bank risk premium shock $\phi_{X_t}$. 
Response to a foreign exogenous Government risk premium shock $\varepsilon_t^G$, 

\begin{align*}
\text{Response to a foreign exogenous Government risk premium shock } & \varepsilon_t^G, \\
\end{align*}
Forecasts of observable variables

Mean forecasts for observable variables

Point forecasts for observable variables
Observable variables

Smoothed shocks
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