A Floating versus Managed Exchange Rate Regime in a DSGE Model of India*

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Abstract

We first develop a two-bloc model of an emerging open economy interacting with the rest of the world calibrated using Indian and US data. The model features a financial accelerator and is suitable for examining the effects of financial stress on the real economy. Three variants of the model are highlighted with increasing degrees of financial frictions. The model is used to compare two monetary interest rate regimes: domestic Inflation targeting with a floating exchange rate (FLEX(D)) and a managed exchange rate (MEX). Both rules are characterized as a Taylor-type interest rate rules. MEX involves a nominal exchange rate target in the rule and a constraint on its volatility. We find that the imposition of a low exchange rate volatility is only achieved at a significant welfare loss if the policymaker is restricted to a simple domestic inflation plus exchange rate targeting rule. If on the other hand the policymaker can implement a complex optimal rule then an almost fixed exchange rate can be achieved at a relatively small welfare cost. This finding suggests that future research should examine alternative simple rules that mimic the fully optimal rule more closely.

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Contents

1 Introduction

While there is a substantial body of literature devoted to understanding business cycle dynamics in developed economies, research focusing on emerging economies is relatively sparser. Data limitations have often been identified as a cause, but the real challenge is to provide sensible explanations for the markedly distinct observed fluctuations in these economies. Indeed, some stylized facts may be pointed out: output growth tends to be subject to larger swings in developing countries, private consumption, relative to income, is substantially more volatile, terms of trade and output are strongly positively correlated, while real interest rates and net exports are countercyclical (see Agenor *et al.* (2000) and Neumeyer and Perri (2005), for example). Emerging market economies are also vulnerable to sudden and sharp reversals of capital inflows, the "sudden stops" highlighted in Calvo (1998). Understanding these differences and carefully modeling the transmission mechanism of internal and external shocks is crucial to the design of stabilization programs and the conduct of economic policies.

Thus, in this paper we develop a two-bloc model of an emerging open economy interacting with the rest of the world. Alongside standard features of small open economies (SOE) such as a combination of producer and local currency pricing for exporters and oil imports, our model incorporates financial frictions in the form of a financial accelerator, where capital financing is partly or totally in foreign currency, as in Gertler *et al.* (2003) and Gilchrist (2003)). This intensifies the exposure of a SOE to internal and external shocks in a manner consistent with the stylized facts listed above. In addition, we allow for liability dollarization and liquidity-constrained households, which further amplify the effects of financial stress. We then focus on monetary policy analysis, calibrating the model using data for India and the US economy. The Indian economy is small in relation to the world economy and we therefore treat it as a small open economy.

Many emerging economies conduct their monetary and fiscal policy according to the 'three pillars macroeconomic policy framework': a combination of a freely floating exchange rate, an explicit target for inflation over the medium run, and a mechanism that ensures a stable government debt-GDP ratio around a specified long run, but may allow for counter-cyclical adjustments of the fiscal deficit over the business cycle. By contrast, the currency monetary policy stance of the Indian Reserve Bank intervenes in the foreign exchange market to prevent what it regards as excessive volatility of the exchange rate. On the fiscal side, Central Government has a rigid fiscal deficit target of 3% of GDP irrespective of whether the economy is in boom or recession (Shah (2008)). Thus, our framework allow us to contrast these implied policy prescriptions for interest rate rules.

There is now a growing literature that compares alternative monetary policy regimes in their ability to stabilize emerging economies when faced with shocks and financial frictions. Some papers close to ours include Gertler *et al.* (2003), Cespedes *et al.* (2004), Cook (2004), Devereux *et al.* (2006) and Curdia (2008). All these papers confirm the result in this paper that flexible exchange rate regimes outperform a peg. Only Curdia (2008) compares these regimes with the optimal policy, but only in deterministic exercise in which optimal policy is designed following a sudden stop. By contrast our rules are optimal or, the case of simple rules optimized within the category or rule in anticipation of a range of future stochastic shocks. An important feature of our work is the introduction of a zero lower bound into the construction of policy rules.

The rest of the paper is organized as follows. Section 2 presents the model. Sections 3 sets out the form of monetary and fiscal rules under investigation. Section 4 describes three variants of the model and examines the workings of the financial accelerator. Section 5 presents the main results of the paper and Section 6 concludes.

2 The Model

Our modelling strategy is to start from a fairly standard two-bloc 'New Open Economy' micro-founded DSGE model and then proceed to introduce various features appropriate to an emerging economy such as India. The benefits of this step-by-step approach are two-fold: first, it builds upon a large emerging literature and second, it enables the researcher to assess both the policy implications and the empirical relevance of each modelling stage.

First the standard model: the two blocs are asymmetric and unequally-sized, each one with different household preferences and technologies. The single (relatively) small open economy then emerges as the limit when the relative size of the larger bloc tends to infinity. Households are Ricardian, and work, save and consume tradable goods produced both at home and abroad. In a Wicksellian framework with a nominal interest rate target as the monetary instrument, we assume a 'cashless economy' and thus ignore seigniorage from money creation. There are three types of firms: wholesale, retail and capital producers. Wholesale firms borrow from households to buy capital used in production and capital producers build new capital in response to the demand of wholesalers. Monopolistic retailers adopt staggered price-setting with both producer and local currency pricing for exports in the home bloc, but only producer currency pricing in the large foreign bloc. Households supply a differentiated factor input which provides a further source of market power. In principle we could introduce staggered wage setting, but in accordance with labour market conditions in India we assume that wages are flexible. Oil imports enter into consumption and production in both blocs.

With these foundations we now proceed to some important features of emerging markets and here our focus is on *financial frictions*. In many developing countries including India, firms face significant capital market imperfections when they seek external funds to finance new investment. Along the lines of Bernanke *et al.* (1999), Gertler *et al.* (2003), Gilchrist (2003) (see also Cespedes *et al.* (2004) and Curdia (2008)), we introduce a 'financial accelerator' in the form of an external finance premium for wholesale firms that increases with leverage. We assume that part of the the debt of wholesale firms is financed in foreign currency (dollars), because it is impossible for firms to borrow 100 percent in domestic currency owing to 'original sin' type constraints – a phenomenon dubbed 'liability dollarization'. There are two further forms of financial frictions: first households face a risk premium when borrowing in world financial markets which introduces a 'national financial accelerator' as in Benigno (2001). Liability dollarization and the national financial accelerator departures add additional dimensions to openness.[1] Finally we assume that a significant proportion of households are excluded altogether from credit markets, do not save and can only consume out of current post-tax and transfer income.

Details of the model are as follows.

2.1 Ricardian Households

There are ν households in the 'home', emerging economy bloc and ν^* households in the 'foreign' bloc. A representative household h in the home country maximizes

$$E_t \sum_{t=0}^{\infty} \beta^t U\left(C_t(h), H_{C,t}, L_t(h)\right) \tag{1}$$

where E_t is the expectations operator indicating expectations formed at time t, β is the household's discount factor, $C_t(h)$ is a Dixit-Stiglitz index of consumption defined below in (5), $H_{C,t} = h_C C_{t-1}$ is 'external habit' in consumption and $L_t(h)$ are hours worked. An analogous symmetric intertemporal utility is defined for the 'foreign' representative household and the corresponding variables (such as consumption) are denoted by $C_t^*(h)$, etc.

We incorporate financial frictions facing households as in Benigno (2001). There are two non-contingent one-period bonds denominated in the currencies of each bloc with payments in period t, $B_{H,t}$ and $B_{F,t}^*$ respectively in (per capita) aggregate. The prices of

[1] See also Batini *et al.* (2007) for a SOE model with these features and, in addition, transactions dollarization owing to the assumption that households derive utility from holdings of both domestic and foreign currency.

these bonds are given by

$$P_{B,t} = \frac{1}{1+R_{n,t}}; \quad P^*_{B,t} = \frac{1}{(1+R^*_{n,t})\phi(\frac{B_t}{P_{H,t}Y_t})} \tag{2}$$

where $\phi(\cdot)$ captures the cost in the form of a risk premium for home households to hold foreign bonds, B_t is the aggregate foreign asset position of the economy denominated in home currency and $P_{H,t}Y_t$ is nominal GDP. We assume $\phi(0) = 0$ and $\phi' < 0$. $R_{n,t}$ and $R^*_{n,t}$ denote the nominal interest rate over the interval $[t, t+1]$. The representative household h must obey a budget constraint:

$$\begin{aligned} & (1+\tau_{C,t})P_tC_t(h) + P_{B,t}B_{H,t}(h) + P^*_{B,t}S_tB^*_{F,t}(h) + TL_t \\ = \;& W_t(h)(1-\tau_{L,t}))L_t(h) + B_{H,t-1}(h) + S_tB^*_{F,t-1}(h) \\ + \;& (1-\tau_{\Gamma,t})\Gamma_t(h) \end{aligned} \tag{3}$$

where P_t is a Dixit-Stiglitz price index defined in (13) below, $W_t(h)$ is the wage rate, TL_t are lump-sum taxes net of transfers, $\tau_{C,t}$, $\tau_{L,t}$ and $\tau_{\Gamma,t}$ are sales, labour income and profits tax rates respectively and $\Gamma_t(h)$ dividends from ownership of firms. In addition, if we assume that households' labour supply is differentiated with elasticity of supply η, then (as we shall see below) the demand for each consumer's labor supplied by ν identical households is given by

$$L_t(h) = \left(\frac{W_t(h)}{W_t}\right)^{-\eta} L_t \tag{4}$$

where $W_t = \left[\frac{1}{\nu}\sum_{r=1}^{\nu} W_t(h)^{1-\eta}\right]^{\frac{1}{1-\eta}}$ and $L_t = \left[\left(\frac{1}{\nu}\right)\sum_{r=1}^{\nu} L_t(h)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$ are the average wage index and average employment respectively.

Let the number of differentiated goods produced in the home and foreign blocs be n and n^* respectively. We assume that the the ratio of households to firms are the same in each bloc. It follows that n and n^* (or ν and ν^*) are measures of size. The per capita consumption index in the home country is given by

$$C_t(h) = \left[\mathrm{w}_C^{\frac{1}{\mu_C}} C_{Z,t}(h)^{\frac{\mu_C-1}{\mu_C}} + (1-\mathrm{w}_C)^{\frac{1}{\mu_C}} C_{O,t}(h)^{\frac{\mu_C-1}{\mu_C}}\right]^{\frac{\mu_C}{\mu_C-1}} \tag{5}$$

where μ_C is the elasticity of substitution between and composite of home and foreign final goods and oil imports,

$$C_{Z,t}(h) = \left[\mathrm{w}_Z^{\frac{1}{\mu_Z}} C_{H,t}(h)^{\frac{\mu_Z-1}{\mu_Z}} + (1-\mathrm{w}_Z)^{\frac{1}{\mu_Z}} C_{F,t}(h)^{\frac{\mu_Z-1}{\mu_Z}}\right]^{\frac{\mu_Z}{\mu_Z-1}} \tag{6}$$

where μ_Z is the elasticity of substitution between home and foreign goods,

$$
\begin{aligned}
C_{H,t}(h) &= \left[\left(\frac{1}{n}\right)^{\frac{1}{\zeta}} \sum_{f=1}^{n} C_{H,t}(f,h)^{(\zeta-1)/\zeta}\right]^{\zeta/(\zeta-1)} \\
C_{F,t}(h) &= \left[\left(\frac{1}{n^*}\right)^{\frac{1}{\zeta}} \left(\sum_{f=1}^{n^*} C_{F,t}(f,h)^{(\zeta-1)/\zeta}\right)\right]^{\zeta/(\zeta-1)}
\end{aligned}
$$

where $C_{H,t}(f,h)$ and $C_{F,t}(f,h)$ denote the home consumption of household h of variety f produced in blocs H and F respectively and $\zeta > 1$ is the elasticity of substitution between varieties in each bloc. Analogous expressions hold for the foreign bloc which indicated with a superscript '$*$' and we impose $\zeta = \zeta^*$ for reasons that become apparent in section 2.2.3.[2] Weights in the non-oil consumption baskets in the two blocs are defined by

$$
\mathrm{w}_Z = 1 - \frac{n}{n+n^*}(1-\omega)\,; \quad \mathrm{w}_Z^* = 1 - \frac{n^*}{n+n^*}(1-\omega^*) \tag{7}
$$

In (7), ω, $\omega^* \in [0,1]$ are a parameters that captures the degree of 'bias' in the two blocs. If $\omega = \omega^* = 1$ we have autarky, while $\omega = \omega^* = 0$ gives us the case of perfect integration. In the limit, as the home country becomes small $n \to 0$ and $\nu \to 0$. Hence $\mathrm{w}_Z \to \omega$ and $\mathrm{w}_Z^* \to 1$. Thus the foreign bloc becomes closed, but as long as there is a degree of home bias and $\omega > 0$, the home country continues to consume foreign-produced consumption goods.

Denote by $P_{H,t}(f)$, $P_{F,t}(f)$ the prices in domestic currency of the good produced by firm f in the relevant bloc. Then the optimal intra-temporal decisions are given by standard results:

$$
C_{H,t}(r,f) = \left(\frac{P_{H,t}(f)}{P_{H,t}}\right)^{-\zeta} C_{H,t}(h)\,; \;\; C_{F,t}(r,f) = \left(\frac{P_{F,t}(f)}{P_{F,t}}\right)^{-\zeta} C_{F,t}(h) \tag{8}
$$

$$
C_{Z,t}(h) = \mathrm{w}_C \left(\frac{P_{Z,t}}{P_t}\right)^{-\mu_C} C_t(h)\,; \;\; C_{O,t}(h) = (1-\mathrm{w}_C)\left(\frac{P_{O,t}}{P_t}\right)^{-\mu_C} C_t(h) \tag{9}
$$

$$
C_{H,t}(h) = \mathrm{w}_Z \left(\frac{P_{H,t}}{P_{Z,t}}\right)^{-\mu_Z} C_{Z,t}(h)\,; \;\; C_{F,t}(h) = (1-\mathrm{w}_Z)\left(\frac{P_{F,t}}{P_{Z,t}}\right)^{-\mu_Z} C_{Z,t}(h) \tag{10}
$$

[2]Consistently we adopt a notation where subscript H or F refers to goods H or F produced in the home and foreign bloc respectively. The presence (for the foreign bloc) or the absence (for the home country) of a superscript '$*$' indicates where the good is consumed or used as an input. Thus $C_{H,t}^*$ refers to the consumption of the home good by households in the foreign bloc. Parameter w and w* refer to the home and foreign bloc respectively, etc.

where aggregate price indices for domestic and foreign consumption bundles are given by

$$P_{H,t} = \left[\frac{1}{n}\sum_{f=1}^{n} P_{H,t}(f)^{1-\zeta}\right]^{\frac{1}{1-\zeta}} \quad (11)$$

$$P_{F,t} = \left[\frac{1}{n^*}\sum_{f=1}^{n^*} P_{F,t}(f)^{1-\zeta}\right]^{\frac{1}{1-\zeta}} \quad (12)$$

and the domestic consumer price index P_t given by

$$P_t = \left[\mathrm{w}_C(P_{Z,t})^{1-\mu_C} + (1-\mathrm{w}_C)(P_{O,t})^{1-\mu_C}\right]^{\frac{1}{1-\mu_C}} \quad (13)$$

$$P_{Z,t} = \left[\mathrm{w}_Z(P_{H,t})^{1-\mu_Z} + (1-\mathrm{w}_Z)(P_{F,t})^{1-\mu_Z}\right]^{\frac{1}{1-\mu_Z}} \quad (14)$$

with a similar definition for the foreign bloc.

Let S_t be the nominal exchange rate. If the law of one price applies to differentiated goods then $\frac{S_t P^*_{F,t}}{P_{F,t}} = \frac{S_t P^*_{H,t}}{P_{H,t}} = 1$. Then it follows that the non-oil real exchange rate $RER_{Z,t} \equiv \frac{S_t P^*_t}{P_t}$. However with local currency pricing the real exchange rate and the terms of trade, defined as the domestic currency relative price of imports to exports $\mathcal{T}_t = \frac{P_{F,t}}{P_{H,t}}$, are related by the relationships

$$RER_{Z,t} \equiv \frac{S_t P^*_{Z,t}}{P_t} = \frac{\left[\mathrm{w}^*_Z + (1-\mathrm{w}^*_Z)\mathcal{T}_t^{\mu^*_Z - 1}\right]^{\frac{1}{1-\mu^*_Z}}}{\left[1-\mathrm{w}_Z + \mathrm{w}_Z\mathcal{T}_t^{\mu_Z-1}\right]^{\frac{1}{1-\mu_Z}}} \quad (15)$$

$$RER_t \equiv \frac{S_t P^*_t}{P_t} = RER_{Z,t}\frac{\left[\mathrm{w}^*_C + (1-\mathrm{w}^*_C)\mathcal{O}_t^{\mu^*_C-1}\right]^{\frac{1}{1-\mu^*_C}}}{\left[\mathrm{w}_C + (1-\mathrm{w}_C)\mathcal{O}_t^{\mu_C-1}\right]^{\frac{1}{1-\mu_C}}} \quad (16)$$

$$\mathcal{O}_t \equiv \frac{P_{O,t}}{P_{Z,t}} \quad (17)$$

Thus if $\mu_C = \mu^*_C$, then $RER_t = RER_{Z,t}$ and the law of one price applies to the aggregate price indices iff $\mu_Z = \mu^*_Z$ and $\mathrm{w}^*_Z = 1 - \mathrm{w}_Z$. The latter condition holds if $\omega = \omega^* = 0$ and home bias disappears. If there is home bias, the real exchange rate appreciates (RER_t falls) as the terms of trade deteriorates.

We assume flexible wages. Then maximizing (1) subject to (3) and (4), treating habit as exogenous, and imposing symmetry on households (so that $C_t(h) = C_t$, etc) yields standard results:

$$P_{B,t} = \beta E_t\left[\frac{U_{C,t+1}}{U_{C,t}}\frac{P_t(1+\tau_{C,t})}{P_{t+1}(1+\tau_{C,t+1})}\right] \quad (18)$$

$$P^*_{B,t} = \beta E_t\left[\frac{U_{C,t+1}}{U_{C,t}}\frac{S_{t+1}P_t(1+\tau_{C,t})}{S_t P_{t+1}(1+\tau_{C,t+1}}\right] \quad (19)$$

$$\frac{W_t(1-\tau_{L,t})}{P_t(1+\tau_{C,t})} = -\frac{\eta}{(\eta-1)}\frac{U_{L,t}}{U_{C,t}} \quad (20)$$

where $U_{C,t}$ and $-U_{L,t}$ are the marginal utility of consumption in the two currencies and the marginal disutility of work, respectively.

(18) is the first order condition for holdings of domestic bonds and equates the real marginal utility from one unit of home currency in the current period with the discounted expected real marginal utility from the payoff in the next period from a domestic bond. (19) is the analogous first order condition for holdings of foreign bonds. In (20) the real disposable wage is proportional to the marginal rate of substitution between consumption and leisure, $-\frac{U_{L,t}}{U_{C,t}}$, and the constant of proportionality reflects the market power of households that arises from their monopolistic supply of a differentiated factor input with elasticity η.

In what follows we assume that this and other all tax rates are held fixed and only lump-sum taxes of transfers are used for stabilization. Then combining (18) and (19) we arrive at the *modified UIP condition*

$$\frac{P_{B,t}}{P^*_{B,t}} = \frac{E_t\left[U_{C,t+1}\frac{P_t}{P_{t+1}}\right]}{E_t\left[U_{C,t+1}\frac{S_{t+1}P_t}{S_tP_{t+1}}\right]} \tag{21}$$

In the absence of an international risk premium, $\phi(\cdot) \to 0$ and (21) reduces to the standard UIP condition.[3]

2.2 Non-Ricardian Households

Suppose now there are two groups of households, a fixed Ricardian proportion $1-\lambda$ without credit constraints and the remaining proportion of non-Ricardian, 'rule of thumb' (RT) households λ who consume out of post-tax income. Ricardian households own retail firms and earn monopolistic profits. They also accumulate wealth in the form of domestic and overseas assets. Non-Ricardian households accumulate no wealth and in the absence of collateral are excluded from credit markets.

Let $C_{1,t}(h)$, $W_{1,t}(h)$ and $L_{1,t}(h)$ be the per capita consumption, wage rate and labour supply respectively for the Ricardian group. Then the optimizing households are denoted as before with $C_t(h)$, $W_t(h)$ and $L_t(h)$ replaced with $C_{2,t}(h)$, $W_{2,t}(h)$ and $L_{2,t}(h)$. Utility for the two groups is still given by (1). External habit for each group is $H_C = h_C C_{i,t}\,; i = 1, 2$, that is each group makes a within-group comparison only, ignoring the consumption of the other group and indeed that of a third group, entrepreneurs, considered later when we model the financial accelerator.

The budget constraint of the RT consumers is given by

$$P_t(1+\tau_{C,t})C_{1,t}(h) = (1-\tau_{L,t})W_{1,t}(h)L_{1,t}(r) + TL_{1,t} \tag{22}$$

[3] In log-linearized form this becomes $\log(1+R_{n,t}) - \log(1+R_{n,t}) = E_t[\log S_{t+1}] - S_t$.

where $TL_{1,t}$ is net lump-sum *transfers* received per credit-constrained household. Following Erceg *et al.* (2005) we further assume that RT households set their wage to be the average of the optimizing households. Then, since RT households face the same demand schedule as the optimizing ones, they also work the same number of hours. Hence in a symmetric equilibrium of identical households of each type, the wage rate is given by $W_{1,t}(r) = W_{1,t} = W_{2,t}(r) = W_{2,t} = W_t$ and hours worked per household is $L_{1,t}(h) = L_{2,t}(h) = L_t$. The only difference between the income of the two groups of households is that optimizing households as owners receive the profits from the mark-up of domestic monopolistic firms.

As before, optimal intra-temporal decisions are given by

$$C_{1H,t}(h) = \mathrm{w}\left(\frac{P_{H,t}}{P_t}\right)^{-\mu} C_{1,t}(h)\,;\;\; C_{1F,t}(h) = (1-\mathrm{w})\left(\frac{P_{F,t}}{P_t}\right)^{-\mu} C_{1,t}(h) \qquad (23)$$

and average consumption per household over the two groups is given by

$$C_t = \lambda C_{1,t} + (1-\lambda)C_{2,t} \qquad (24)$$

Aggregates $C^*_{1H,t}$, $C^*_{1F,t}$, C^*_t etc are similarly defined.

2.3 Firms

There are three types of firms, wholesale, retail and capital producers. Wholesale firms are run by a third group of households, risk-neutral entrepreneurs who purchase capital and employ household labour to produce a wholesale goods that is sold to the retail sector. The wholesale sector is competitive, but the retail sector is monopolistically competitive. Retail firms differentiate wholesale goods at no resource cost and sell the differentiated (repackaged) goods to households. The capital goods sector is competitive and converts the final good into capital. The details are as follows.

2.3.1 Wholesale Firms and The Financial Accelerator

Wholesale goods are homogeneous and produced by entrepreneurs who combine differentiated labour, capital and oil inputs with and a technology

$$Y_t^W = A_t K_t^{\alpha_1} L_t^{\alpha_2} (\mathrm{OIL}_t)^{\alpha_3} \qquad (25)$$

where K_t is beginning-of-period t capital stock,

$$L_t = \left[\left(\frac{1}{\nu}\right)^{\frac{1}{\eta}} \sum_{r=1}^{\nu} L_t(h)^{(\eta-1)/\eta}\right]^{\eta/(\eta-1)} \qquad (26)$$

where we recall that $L_t(h)$ is the labour input of type h, A_t is an exogenous shock capturing shifts to trend total factor productivity in this sector.[4] Minimizing wage costs $\sum_{h=1}^{\nu} W_t(h)L_t(h)$ gives the demand for each household's labour as

$$L_t(h) = \left(\frac{W_t(h)}{W_t}\right)^{-\eta} L_t \tag{27}$$

Wholesale goods sell at a price $P_{H,t}^W$ in the home country. Equating the marginal product and cost of aggregate labour gives

$$W_t = P_{H,t}^W \alpha_2 \frac{Y_t^W}{L_t} \tag{28}$$

Similarly letting $P_{O,t}$ be the price of oil in home currency, we have

$$P_{O,t} = P_{H,t}^W \alpha_3 \frac{Y_t^W}{\text{OIL}_t} \tag{29}$$

$$\tag{30}$$

Let Q_t be the real market price of capital in units of total household consumption. Then noting that profits per period are $P_{H,t}^W Y_t - W_t L_t - P_{O,t}\text{OIL}_t = \alpha_1 P_{H,t}^W Y_t$, using (28), the expected return on capital, acquired at the beginning of period t, net of depreciation, over the period is given by

$$E_t(1+R_t^k) = \frac{\frac{P_{H,t}^W}{P_t}\alpha_1 \frac{Y_t}{K_t} + (1-\delta)E_t[Q_{t+1}]}{Q_t} \tag{31}$$

where R_t^k (as with R_t) is the return on capital over the period $[t, t+1]$ and δ is the depreciation rate of capital. This expected return must be equated with the expected cost of funds over $[t, t+1]$, taking into account credit market frictions.[5] Wholesale firms borrow from home and foreign financial intermediaries in both currencies, with exogenously given proportion[6] of the former given by $\varphi \in [0,1]$, so that this expected cost is

$$\begin{aligned}
& (1+\Theta_t)\varphi E_t\left[(1+R_{n,t})\frac{P_t}{P_{t+1}}\right] + (1+\Theta_t)(1-\varphi)E_t\left[(1+R_{n,t}^*)\frac{P_t^*}{P_{t+1}^*}\frac{RER_{t+1}}{RER_t}\right] \\
= \; & (1+\Theta_t)\left[\varphi E_t\left[(1+R_t)\right] + (1-\varphi)E_t\left[(1+R_t^*)\frac{RER_{t+1}}{RER_t}\right]\right]
\end{aligned} \tag{32}$$

[4]Following Gilchrist *et al.* (2002) and Gilchrist (2003), we ignore the managerial input into the production process and later, consistent with this, we ignore the contribution of the managerial wage in her net worth.

[5]We assume all financial returns are taxed at the same rate and therefore do not affect arbitrage conditions.

[6]We do not attempt to endogenize the decision of firms to partially borrow foreign currency; this lies outside the scope of this paper.

If $\varphi = 1$ or if UIP holds this becomes $(1+\Theta_t)E_t[1+R_t]$. In (32), $RER_t \equiv \frac{P_t^* S_t}{P_t}$ is the real exchange rate, $R_{t-1} \equiv \left[(1+R_{n,t-1})\frac{P_{t-1}}{P_t}\right] - 1$ is the ex post real interest rate over $[t-1,t]$ and $\Theta_t \geq 0$ is the external finance premium given by

$$\Theta_t = \Theta\left(\frac{B_t}{N_t}\right) \; ; \; \Theta'(\cdot) > 0, \, \Theta(0) = 0, \; \Theta(\infty) = \infty \tag{33}$$

where $B_t = Q_t K_t - N_t$ is bond-financed acquisition of capital in period t and N_t is the beginning-of-period t entrepreneurial net worth, the equity of the firm.[7] Note that the *ex post* return at the beginning of period t, R_{t-1}^k, is given by

$$1 + R_{t-1}^k = \frac{\frac{P_{H,t-1}^W}{P_{t-1}}\alpha_1 \frac{Y_{t-1}}{K_{t-1}} + (1-\delta)Q_t}{Q_{t-1}} \tag{34}$$

and this can deviate from the *ex ante* return on capital.

Assuming that entrepreneurs exit with a given probability $1-\xi_e$, net worth accumulates according to

$$N_t = \xi_e V_t + (1-\xi_e)D_t \tag{35}$$

where D_t are transfers from exiting to newly entering entrepreneurs continuing, and V_t, the net value carried over from the previous period, is given by

$$\begin{aligned} V_t &= \Big[(1+R_{t-1}^k)Q_{t-1}K_{t-1} \\ &- (1+\Theta_{t-1})\left(\varphi(1+R_{t-1}) + (1-\varphi)(1+R_{t-1}^*)\frac{RER_t}{RER_{t-1}}\right)(Q_{t-1}K_{t-1} - N_{t-1})\Big] \end{aligned} \tag{36}$$

A reasonable assumption is that $D_t = \nu V_t$. Note that in (36), $(1+R_{t-1}^k)$ is the ex post return on capital acquired at the beginning of period $t-1$, $(1+R_{t-1})$ is the ex post real cost of borrowing in home currency and $(1+R_{t-1}^*)\frac{RER_t}{RER_{t-1}}$ is the ex post real cost of borrowing in foreign currency. Also note that net worth N_t at the beginning of period t is a non-predetermined variable since the ex post return depends on the current market value Q_t, itself a non-predetermined variable.

Along a deterministic balanced growth path (BGP) with balanced trade and therefore no net overseas assets we have that $\bar{N}_t = (1+g)\bar{N}_{t-1}$ and $1 + R^k = (1+\Theta)(1+R) = 1+\Theta)(1+R^*)$. Therefore

$$\bar{N}_t = (1+g)\bar{N}_{t-1} = (\xi_e + (1-\xi_e)\nu)\bar{V}_t = (\xi_e + (1-\xi_e)\nu)(1+\Theta)(1+R)\bar{N}_{t-1} \tag{37}$$

[7] The entrepreneur borrows from a financial intermediary that in turn obtains funds from households at a real ex post cost $R_{t-1} = (1+R_{n,t-1})\frac{P_t}{P_{t-1}}$. Entrepreneurs can borrow up to $K_t Q_t$. The return to capital is subject to idiosyncratic shocks for which the lender pays a monitoring cost to observe. Bernanke *et al.* (1999) show that the optimal financial contract between a risk-neutral intermediary and entrepreneur takes the form of a risk premium given by (33). Thus the risk premium is an increasing function of leverage of the firm. Following these authors, in the general equilibrium we ignore monitoring costs.

Thus from (36), given values for ξ_e, Θ and R, for a BGP the remaining parameter ν must be set such that $(\xi_e + (1-\xi_e)\nu)(1+\Theta)(1+R) = 1+g$.

Exiting entrepreneurs consume C_t^e, the remaining resources, given by

$$C_t^e = (1-\xi_e)(V_t - D_t) = (1-\xi_e)(1-\mu)V_t = \frac{(1-\xi_e)(1-\nu)}{\xi_e + (1-\xi_e)\nu} N_t \tag{38}$$

of which consumption of the domestic and foreign goods, as in (9), are given respectively by

$$C_{H,t}^e = \mathrm{w}_Z \left(\frac{P_{H,t}}{P_t}\right)^{-\mu_Z} C_{Z,t}^e; \quad C_{F,t}^e = (1-\mathrm{w}_Z)\left(\frac{P_{F,t}}{P_t}\right)^{-\mu_Z} C_{Z,t}^e \tag{39}$$

$$C_{Z,t}^e = \mathrm{w}_C \left(\frac{P_{Z,t}}{P_t}\right)^{-\mu_C} C_t^e \tag{40}$$

2.3.2 Retail Firms

Retail firms are monopolistically competitive, buying wholesale goods and differentiating the product at a fixed resource cost F. In a free-entry equilibrium profits are driven to zero. Retail output for firm f is then $Y_t(f) = Y_t^W(f) - F$ where Y_t^W is produced according to production technology (25). We provide a general set-up in which a fixed proportion θ of retailers set prices in the Home currency (producer currency pricers, PCP) and a proportion $1-\theta$ set prices in the dollars (local currency pricers, LCP).[8] Details are as follows:

2.3.3 PCP Exporters

Assume that there is a probability of $1-\xi_H$ at each period that the price of each good f is set optimally to $\hat{P}_{H,t}(f)$. If the price is not re-optimized, then it is held constant.[9] For each producer f the objective is at time t to choose $\hat{P}_{H,t}(f)$ to maximize discounted profits

$$E_t \sum_{k=0}^{\infty} \xi_H^k D_{t,t+k} Y_{t+k}(f) \left[\hat{P}_{H,t}(f) - P_{H,t+k}\mathrm{MC}_{t+k}\right]$$

where $D_{t,t+k}$ is the discount factor over the interval $[t, t+k]$, subject to a common[10] downward sloping demand from domestic consumers and foreign importers of elasticity ζ

[8] As with the foreign currency borrowing parameter φ, we make no attempt to endogenize the choice of PCP and LCP.

[9] Thus we can interpret $\frac{1}{1-\xi_H}$ as the average duration for which prices are left unchanged.

[10] Recall that we have imposed a symmetry condition $\zeta = \zeta^*$ at this point; i.e., the elasticity of substitution between differentiated goods produced in any one bloc is the same for consumers in both blocs.

as in (8) and $MC_t = \frac{P^W_{H,t}}{P_{H,t}}$ are marginal costs. The solution to this is

$$E_t \sum_{k=0}^{\infty} \xi_H^k D_{t,t+k} Y_{t+k}(f) \left[\hat{P}_{Ht}(f) - \frac{\zeta}{(\zeta - 1)} P_{H,t+k} \mathrm{MC}_{t+k} \right] = 0 \tag{41}$$

and by the law of large numbers the evolution of the price index is given by

$$P^{1-\zeta}_{H,t+1} = \xi_H \left(P_{H,t}\right)^{1-\zeta} + (1-\xi_H)(\hat{P}_{H,t+1}(f))^{1-\zeta} \tag{42}$$

For later use in the evaluation of tax receipts, we require monopolistic profits as a proportion of GDP. This is given by

$$\frac{\Gamma_t}{P_{H,t}Y_t} \equiv \frac{P_{H,t}Y_t - P^W_{H,t}Y^W_t}{P_{H,t}Y_t} = 1 - \mathrm{MC}_t \left(1 + \frac{F}{Y}\right) \tag{43}$$

For good f imported by the home country from PCP foreign firms the price $P^p_{F,t}(f)$, set by retailers, is given by $P^p_{F,t}(f) = S_t P^*_{F,t}(f)$. Similarly $P^{*\,p}_{H,t}(f) = \frac{P_{H,t}(f)}{S_t}$.

2.3.4 LCP Exporters

Price setting in export markets by domestic LCP exporters follows is a very similar fashion to domestic pricing. The optimal price in units of domestic currency is $\hat{P}^{*\,\ell}_{H,t} S_t$, costs are as for domestically marketed goods so (41) and (42) become

$$E_t \sum_{k=0}^{\infty} \xi_H^k D_{t,t+k} Y^*_{T,t+k}(f) \left[\hat{P}_{H,t}(f)^{*\,\ell} S_{t+k} - \frac{\zeta}{(\zeta - 1)} P_{H,t+k} \mathrm{MC}_{t+k} \right] = 0 \tag{44}$$

and by the law of large numbers the evolution of the price index is given by

$$(P^{*\,\ell}_{H,t+1})^{1-\zeta} = \xi_H (P^{*\,\ell}_{H,t})^{1-\zeta} + (1-\xi_H)(\hat{P}^{*\,\ell}_{H,t+1}(f))^{1-\zeta} \tag{45}$$

Foreign exporters from the large ROW bloc are PCPers so we have

$$P_{F,t} = S_t P^*_{F,t} \tag{46}$$

Table 1 summarizes the notation used.

Origin of Good	Domestic Market	Export Market (PCP)	Export Market(LCP)
Home	P_H	$P^{*\,p}_H = \frac{P_H}{S_t}$	$P^{*\,\ell}_H \neq \frac{P_H}{S_t}$
Foreign	P^*_F	$P^p_F = S_t P^*_F$	non-existent

Table 1. Notation for Prices

2.3.5 Capital Producers

Capital adjustment costs are borne by capital producers, a convenient modelling device in the context of the FA. As in Smets and Wouters (2003) we introduce a delayed response of investment observed in the data. Capital producers combine existing capital, K_t, leased from the entrepreneurs to transform an input I_t, gross investment, into new capital according to

$$K_{t+1} = (1-\delta)K_t + (1 - S\left(I_t/I_{t-1}\right))I_t\,;\;\; S',\, S'' \geq 0\,;\; S(1) = S'(1) = 0 \tag{47}$$

This captures the ideas that adjustment costs are associated with *changes* rather than *levels* of investment.[11] Gross investment consists of domestic and foreign final goods

$$I_t = \left[\mathrm{w}_I^{\frac{1}{\rho_I}} I_{H,t}^{\frac{\rho_I - 1}{\rho_I}} + (1-\mathrm{w}_I)^{\frac{1}{\rho_I}} I_{F,t}^{\frac{\rho_I - 1}{\rho_I}} \right]^{\frac{\rho_I}{1-\rho_I}} \tag{48}$$

where weights in investment are defined as in the consumption baskets, namely

$$\mathrm{w}_I \;\; = \;\; 1-(1-n)(1-\omega_I)\,; \quad \mathrm{w}_I^* = 1 - n(1-\omega_I^*) \tag{49}$$

with investment price given by

$$P_{I,t} = \left[\mathrm{w}_I (P_{H,t})^{1-\rho_I} + (1-\mathrm{w}_I)(P_{F,t})^{1-\rho_I}\right]^{\frac{1}{1-\rho_I}} \tag{50}$$

Capital producers choose the optimal combination of domestic and foreign inputs according to the same form of intra-temporal first-order conditions as for consumption:

$$I_{H,t} = \mathrm{w}_I \left(\frac{P_{H,t}}{P_{I,t}}\right)^{-\rho_I} I_t\,;\;\; I_{F,t} = (1-\mathrm{w}_I)\left(\frac{P_{F,t}}{P_{I,t}}\right)^{-\rho_I} I_t \tag{51}$$

The capital producing firm at time 0 then maximizes expected discounted profits[12]

$$E_t \sum_{t=0}^{\infty} D_{0,t} \left[Q_t(1 - S\left(I_t/I_{t-1}\right))I_t - \frac{P_{I,t} I_t}{P_t} \right]$$

which results in the first-order condition

$$Q_t(1-S(I_t/I_{t-1}) - I_t/I_{t-1} S'(I_t/I_{t-1})) + E_t\left[\frac{1}{(1+R_{t+1})} Q_{t+1} S'(I_{t+1}/I_t)\frac{I_{t+1}^2}{I_t^2}\right] = \frac{P_{I,t}}{P_t} \tag{52}$$

[11] This is modification of Bernanke *et al.* (1999) where adjustment costs $S = S\left(\frac{I_t}{K_t}\right)$. This change is motivated by the successful attempts at fitting DSGE models such as Smets and Wouters (2003) with our form of adjustment costs to data. However our results are not very sensitive to different formulations of these costs. In a balanced growth steady state adjustment costs are associated with change relative to trend so that the conditions on $S(\cdot)$ along the balanced growth path become $S(1+g) = S'(1+g) = 0$.

[12] This ignores leasing costs which Gertler *et al.* (2003) show to be of second order importance.

2.4 The Government Budget Constraint and Foreign Asset Accumulation

The government issues bonds denominated in home currency. The government budget identity is given by

$$P_{B,t}B_{G,t} = B_{G,t-1} + P_{H,t}G_t - T_t \tag{53}$$

Taxes are levied on labour income, monopolistic profits, consumption and capital returns at rates $\tau_{L,t}$, τ_Γ, $\tau_{C,t}$, $\tau_{K,t}$ respectively. Then adding lump-sum taxes[13] levied on all consumers, $\mathrm{TL}_{2,t}$, and subtracting net lump-sum transfers to the constrained consumers, $\mathrm{TL}_{1,t}$, per capita total taxation net of transfers is given

$$T_t = \tau_{L,t}W_tL_t + \tau_{\Gamma,t}\Gamma_t + \tau_{C,t}P_tC_t - \lambda \mathrm{TL}_{1,t} + (1-\lambda)\mathrm{TL}_{2,t} + \tau_{K,t}R^k_{t-1}P_tQ_tK_t \tag{54}$$

In what follows, we take lump-sum taxes and transfers to be the dynamic fiscal instruments keeping tax rates constant at their steady-state values. For later use we then write T_t in (54) as a sum of the instrument $T^I_t = -\lambda\mathrm{TL}_{1,t} + (1-\lambda)\mathrm{TL}_{2,t}$ and remaining taxes which change endogenously, T^{NI}_t.

Turning to foreign asset accumulation, let $\sum_{h=1}^{\nu} B_{F,t}(h) = \nu B_{F,t}$ be the net holdings by the household sector of foreign bonds. An convenient assumption is to assume that home households hold no foreign bonds so that $B_{F,t} = 0$, and the net asset position of the home economy $B_t = -B^*_{H,t}$; i.e., minus the foreign holding of domestic government bonds.[14] Summing over the household budget constraints (including entrepreneurs and capital producers), and subtracting (53), we arrive at the accumulation of net foreign assets:

$$\begin{aligned} P_{B,t}B_t &= B_{t-1} + W_tL_t + \Gamma_t + (1-\xi_e)P_tV_t + P_tQ_t(1-S(X_t))I_t \\ &- P_tC_t - P_tC^e_t - P_{I,t}I_t - P_{H,t}G_t - P_{O,t}\mathrm{OIL}_t \\ &\equiv B_{t-1} + TB_t \end{aligned} \tag{55}$$

where the trade balance, TB_t, is given by the national accounting identity

$$P_{H,t}Y_t - P_{O,t}\mathrm{OIL}_t = P_tC_t + P_tC^e_t + P_{I,t}I_t + P_{H,t}G_t + \mathrm{TB}_t \tag{56}$$

Terms on the left-hand-side of (56) are oil revenues and the value of *net* output; on the right-hand-side are public and private consumption plus investment plus the trade surplus.

[13] If tax rates are held fixed, then the 'lump-sum tax' can be considered to be minus the income tax rate times the threshold at which labour income tax starts to operate. An decrease in the threshold is then equivalent to an increase in a lump-sum tax.

[14] An alternative assumption with the same effect is to assume that and the government issues bonds denominated in foreign currency (see Medina and Soto (2007)).

So far we have aggregated consumption across constrained and unconstrained consumers. To obtain separately per capita consumption within these groups, first consolidate the budget constraints (53) and (3), to give

$$\begin{aligned} & (1+\tau_{C,t})P_tC_{2,t} + P_{B,t}\frac{B_t}{1-\lambda} + TL_{2,t} \\ = \quad & W_t(1-\tau_{L,t}))L_t(h) + \frac{B_{t-1}}{1-\lambda} + \frac{T_t - P_{H,t}G_t}{1-\lambda} + + \frac{(1-\tau_{\Gamma,t})}{1-\lambda}\Gamma_t \end{aligned}$$

Then using (22) and (55), we arrive at

$$C_{2,t} = C_{1,t} + \frac{\frac{1}{1-\lambda}\left[-TB_t + T_t - P_{H,t}G_t + (1-\tau_{\Gamma,t})\Gamma_t - \lambda TL_{1,t}\right] - TL_{2,t}}{(1+\tau_{C,t})P_t} \tag{57}$$

In a balanced growth steady state with negative net foreign assets and government debt, the national and government budget constraints require a primary trade surplus ($TB > 0$) and a primary government surplus ($T > P_HG$). Since private sector assets are exclusively owned by unconstrained consumers this may result in a higher consumption per head by that group. The same applies to profits from retail firms since they are assumed to also be exclusively owned by unconstrained consumers. On the other hand lump-sum transfers to constrained consumers plus lump-sum taxes on unconstrained consumers, $-\lambda TL_{1,t} + (1-\lambda)TL_{2,t}$ tend to lower the consumption gap.

2.5 The Equilibrium

In equilibrium, final goods markets, money markets and the bond market all clear. Equating the supply and demand of the home consumer good and assuming that government expenditure, taken as exogenous, goes exclusively on home goods we obtain for the final goods market[15]

$$Y_t \quad = \quad C_{H,t} + C^e_{H,t} + I_{H,t} + \frac{1-\nu}{\nu}\left[C^*_{H,t} + C^{e\,*}_{H,t} + I^*_{H,t}\right] + G_t \tag{58}$$

This completes the model. Given nominal interest rates $R_{n,t}, R^*_{n,t}$ the money supply is fixed by the central banks to accommodate money demand. By Walras' Law we can dispense with the bond market equilibrium conditions. Then the equilibrium is defined at $t = 0$ as stochastic sequences $C_{1,t}$, $C_{2,t}$, C_t, C^e_t, $C_{H,t}$, $C_{F,t}$, $P_{H,t}$, $P_{F,t}$, P_t, $P_{O,t}$, M_t, $B_{H,t} = B_{G,t}$, $B_{F,t}$, W_t, Y_t, L_t, $P^0_{H,t}$, P^I_t, K_t, I_t, Q_t, V_t, foreign counterparts $C^*_{1,t}$, etc, RER_t, and S_t, given the monetary instruments $R_{n,t}$, $R^*_{n,t}$, the fiscal instruments and exogenous processes.

[15]Note that all aggregates, Y_t, $C_{H,t}$, etc are expressed in per capita (household) terms.

2.6 Specialization of The Household's Utility Function

The choice of utility function must be chosen to be consistent with the balanced growth path (henceforth BGP) set out in previous sections. As pointed out in Barro and Sala-i-Martin (2004), chapter 9, this requires a careful choice of the form of the utility as a function of consumption and labour effort. As in Gertler *et al.* (2003), it is achieved by a utility function which is non-separable. A utility function of the form

$$U \equiv \frac{\left[\Phi(h)^{1-\varrho}(1-L_t(h))^{\varrho}\right]^{1-\sigma}}{1-\sigma} \tag{59}$$

where $\Phi_t = C_t(h) - h_C C_{t-1}$ and where labour supply, $L_t(h)$, is measured as a proportion of a day, normalized at unity, satisfies this requirement.[16]

2.7 State Space Representation

We linearize around a deterministic zero inflation, zero net private sector debt, balanced growth steady state. We can write the two-bloc model in state space form as

$$\begin{aligned}\begin{bmatrix} \mathsf{z}_{t+1} \\ E_t\mathsf{x}_{t+1} \end{bmatrix} &= A\begin{bmatrix} \mathsf{z}_t \\ \mathsf{x}_t \end{bmatrix} + B\mathsf{o}_t + C\begin{bmatrix} r_{n,t} \\ r^*_{n,t} \end{bmatrix} + D\mathsf{v}_{t+1} \\ \mathsf{o_t} &= H\begin{bmatrix} \mathsf{z}_t \\ \mathsf{x}_t \end{bmatrix} + J\begin{bmatrix} r_{n,t} \\ r^*_{n,t} \\ tl_{1,t}-p_{H,t} \\ tl_{2,t}-p_{H,t} \\ tl^*_{1,t}-p^*_{F,t} \\ tl^*_{2,t}-p^*_{F,t} \end{bmatrix}\end{aligned} \tag{60}$$

where z_t is a vector of predetermined exogenous variables, x_t are non-predetermined variables, and o_t is a vector of outputs. The monetary instruments are the two nominal interest rates $r_{n,t}$ and $r^*_{n,t}$ in the home and foreign blocs respectively. The fiscal instruments are real lump-sum taxes on Ricardian households $tl_{2,t}-p_{H,t}$ and $tl^*_{2,t}-p^*_{F,t}$ and real lump-sum transfers to non-Ricardian households $tl_{1,t}-p_{H,t}$ and $tl^*_{1,t}-p^*_{F,t}$.[17] Matrices A, B, etc are functions of model parameters. Rational expectations are formed assuming an information set $\{z_{1,s}, z_{2,s}, x_s\}$, $s \leq t$, the model and the monetary rule. Details of the linearization are provided in Appendix B.

[16] A BGP requires that the real wage, real money balances and consumption grow at the same rate at the steady state with labour supply constant. It is straightforward to show that (59) has these properties.

[17] We define all lower case variables as proportional deviations from this baseline steady state except for rates of change which are absolute deviations. That is, for a typical variable X_t, $x_t = \frac{X_t - X}{X} \simeq \log\left(\frac{X_t}{X}\right)$ where X is the baseline steady state. For variables expressing a rate of change over time such as the nominal interest rate $r_{n,t}$ and inflation rates, $x_t = X_t - X$.

We subject the model to nine exogenous and independent shocks that form the vector v_{t+1}: total factor productivity (a_t), government spending (g_t) in both blocs; the external risk premium facing firms, $\epsilon_{P,t}$ in the home country; a copper price shock; an oil shock; a risk premium shock to the modified UIP condition, $\epsilon_{UIP,t}$; and a shock to the foreign interest rate rule $\epsilon^*_{R,t}$. The foreign bloc is fully articulated, so the effect of these shocks impacts on the domestic economy through changes in the demand for exports, though since the domestic economy is small, there is no corresponding effect of domestic shocks on the ROW.

2.8 The Small Open Economy

Following Felices and Tuesta (2006), we can now model a SOE by letting its relative size in the world economy $n \to 0$ whilst retaining its linkages with the rest of the world (ROW). In particular the demand for exports is modelled in a consistent way that retains its dependence on shocks to the home and ROW economies. We now need a fully articulated model of the ROW. From (7) we have that $\mathrm{w}_Z \to \omega$ and $\mathrm{w}^*_Z \to 1$ as $n \to 0$. Similarly for investment we have $\mathrm{w}_I \to \omega_I$ and $\mathrm{w}^*_I \to 1$ as $n \to 0$. It seems at first glance then that the ROW becomes closed and therefore exports from our SOE must be zero. However this is not the case. Consider the linearized form of the output demand equations in the two blocs:

$$\begin{aligned} y_t &= \alpha_{C,H}c_{Z,t} + \alpha^e_{C,H}c^e_{Z,t} + \alpha^*_{C,H}c^*_{Z,t} + \alpha_{I,H}i_t + \alpha^*_{I,H}i^*_t + \alpha_G g_t \\ &+ [\mu_Z(\alpha_{C,H} + \alpha^e_{C,H})(1 - \mathrm{w}_Z) + \rho_I \alpha_{I,H}(1 - \mathrm{w}_I)]\tau_t - [\mu^*_Z \alpha^*_{C,H}\mathrm{w}^*_Z + \rho^*_I \alpha^*_{I,H}\mathrm{w}^*_I]\tau^*_t \end{aligned} \tag{61}$$

$$\begin{aligned} y^*_t &= \alpha^*_{C,F}c^*_{Z,t} + \alpha_{C,F}c_{Z,t} + \alpha^e_{C,F}c^e_t + \alpha^*_{I,F}i^*_t + \alpha_{I,F}i_t + \alpha^*_G g^*_t \\ &- [\mu^*(\alpha^*_{C,F}(1 - \mathrm{w}^*_Z) + \mu\alpha_{C,F}\mathrm{w}_Z + \rho^*_I\alpha^*_{I,F}(1 - \mathrm{w}^*_I) + \rho_I\alpha_{I,F}\mathrm{w}_I]\tau_t \end{aligned} \tag{62}$$

where the elasticities and their limits as $n \to 0$ are given by

$$\begin{aligned} \alpha_{C,H} &= \frac{\mathrm{w}_Z(1 - s_e)C}{Y} \to \frac{\omega(1 - s_e)C}{Y} \\ \alpha^e_{C,H} &= \frac{\mathrm{w}_Z s_e C}{Y} \to \frac{\omega s_e C}{Y} \\ \alpha^*_{C,H} &= \frac{(1 - \mathrm{w}^*_Z)C^*}{Y^*}\,\frac{(1 - n)Y^*}{nY} \to \frac{(1 - \omega^*)C^*}{Y^*}\,\frac{Y^*}{Y} \\ \alpha_G &= \frac{G}{Y} \end{aligned}$$

$$
\begin{aligned}
\alpha_{I,H} &= \frac{\mathrm{w}_I I}{Y} \rightarrow \frac{\omega_I I}{Y} \\
\alpha^*_{I,H} &= \frac{(1-\mathrm{w}^*_I)I^*}{Y^*}\,\frac{(1-n)Y^*}{nY} \rightarrow \frac{(1-\omega^*_I)I^*}{Y^*}\frac{Y^*}{Y} \\
\alpha^*_{C,F} &= \frac{\mathrm{w}^*_Z C^*}{Y^*} \rightarrow \frac{C^*}{Y^*} \\
\alpha^{e*}_{C,F} &= 0 \\
\alpha_{C,F} &= \frac{(1-\mathrm{w}_Z)C}{Y}\,\frac{nY}{(1-n)Y^*} \rightarrow 0 \\
\alpha^e_{C,F} &= \frac{(1-\mathrm{w}_Z)(1-\xi^e)n_k k_y}{\xi_e}\,\frac{nY}{(1-n)Y^*} \rightarrow 0 \\
\alpha^*_G &= \frac{G^*}{Y^*} \\
\alpha^*_{I,F} &= \frac{\mathrm{w}^*_I I^*}{Y^*} \rightarrow \frac{I^*}{Y^*} \\
\alpha_{I,F} &= \frac{(1-\mathrm{w}_I)I}{Y^*}\,\frac{nY}{(1-n)Y^*} \rightarrow 0
\end{aligned}
$$

Thus we see that from the viewpoint of the ROW our SOE becomes invisible, but not vice versa. Exports to and imports from the ROW are now modelled explicitly in a way that captures all the interactions between shocks in the ROW and the transmission to the SOE.

2.9 Calibration

For simplicity, and as a preliminary simulation exercise, we calibrate the parameters of the model. The calibration is partly based on the fitting of the steady state of the model to macroeconomic data. In other places we draw upon the micro-econometrics literature. This is explained next.

2.9.1 Calibration of Home Bias Parameters

The bias parameters we need to calibrate are: ω, ω^*, ω_I and ω^*_I. Let in the steady state $C^e = s_e C$ be consumption by entrepreneurs, and $c_y = \frac{C}{Y}$. Let $cs_{imports}$ be the GDP share of imported consumption of the foreign (F) consumption good. Let $cs_{exports}$ be the GDP share of exports of the home (H) consumption good. Then we have that

$$
\begin{aligned}
\alpha_{C,H} &= \frac{C_H}{Y} = \frac{\omega C}{Y} = (c_y - cs_{imports})(1-s_e) \\
\alpha^e_{C,H} &= \frac{C_H}{Y}^e = \frac{\omega C^e}{Y} = (c_y - cs_{imports})s_e \\
\alpha^*_{C,H} &= \frac{C^*_H}{Y} = \frac{(1-\omega^*)C^*}{Y^*}\frac{Y^*}{Y} = cs_{exports}
\end{aligned}
$$

Similarly for investment define $is_{imports}$ to be the GDP share of imported investment of the F investment and $is_{exports}$ be the GDP share of exports of H investment good. Then with $i_y = \frac{I}{Y}$, we have

$$\begin{aligned} \alpha_{I,H} &= \frac{I_H}{Y} = \frac{\omega_I I}{Y} = i_y - is_{imports} \\ \alpha^*_{I,H} &= \frac{I^*_H}{Y} = \frac{(1-\omega^*_I)I^*}{Y^*}\frac{Y^*}{Y} = is_{exports} \end{aligned}$$

in the steady state. We linearize around a zero trade balance $TB = 0$, so we require

$$cs_{imports} + is_{imports} = cs_{exports} + is_{exports} \tag{63}$$

in which case $\alpha_{C,H} + \alpha^e_{C,H} + \alpha^*_{C,H} + \alpha_{I,H} + \alpha^*_{I,H} = c_y + i_y$ as required. Thus we can use trade data for consumption and investment goods, consumption shares and relative per capita GDP to calibrate the bias parameters ω, ω^*, ω_I and ω^*_I. We need the home country biases elsewhere in the model, but for the ROW we simply put $\omega^* = \omega^*_I = 1$ everywhere else, so these biases are not required as such.

2.9.2 Calibration of Household Preference Parameter

We now show how observed data on the household wage bill as a proportion of total consumption can be used to calibrate the preference parameters ϱ in (59). From (20) we have

$$\frac{(\eta-1)}{\eta}\frac{W(1-\tau_L)(1-L)}{P(1+\tau_C)C} = \frac{\varrho\Phi}{C\Phi_C(1-\varrho)} = \frac{\varrho}{(1-\varrho)} \tag{64}$$

since $\Phi = C\Phi_C = (1-h_C)C$. In (64), $\frac{W(1-\tau_L)L}{P(1+\tau_C)C}$ is the household post-tax wage bill as a proportion of total consumption, which is observable.

2.9.3 Calibration of Remaining Parameters

We begin with estimates of the processes describing the exogenous shocks.

Shock parameters

The shock processes for India in the following table are based upon fitting AR(1) models to detrendend macroeconomic India data for TFP and government spending. As for (21), we impose the modified UIP condition using the rupee-dollar real exchange rate, the India-US interest real bank rate differential and India's net foreign asset position as a proportion of nominal GDP (in steady-state deviation form), thus estimating δ_r and fitting an AR(1) to the corresponding residual term. US processes are taken from the posterior estimates for the ROW fitted to US data.

India Parameter	Value	Source	ROW Parameter	Value	Source
ρ_a	0.85	cal	ρ_a^*	0.95	SW07
sd_a	0.03	cal	sd_a^*	0.45	SW07
ρ_g	0.85	cal	ρ_g^*	0.97	SW07
sd_g	0.05	cal	sd_g^*	0.52	SW07
n.a.	n.a.	n.a.	ρ_r^*	0.12	SW07
n.a.	n.a.	n.a.	sd_r^*	0.24	SW07
ρ_{UIP}	0.2	cal	n.a.	n.a.	n.a.
sd_{UIP}	0.04	cal	n.a.	n.a.	n.a.
ρ_P	0.85	cal	ρ_P^*	0.92	GLY
sd_P	0.5	cal	sd_P^*	1.41	GLY
n.a.	n.a.	n.a.	ρ_{oil}^*	0.97	MS
n.a.	n.a.	n.a.	sd_{oil}^*	12.0	MS

Table C1. Parameterization of Shock Processes

Deep parameters values are provided for India in part by NIPFP partners (these are underlined). Otherwise standard or parameters used for Chile are used.

Preferences

Risk Aversion Parameters: Estimates in the literature suggests range $\sigma \in [2, 5]$. However, for the US Bayesian estimates suggest a range $\sigma^* \in [2, 3]$. Our estimates are $\underline{\sigma = 2.5, 3.14}$, $\sigma^* = 2$.

Discount Factors: A standard choice is $\beta = \beta^* = 0.99$

Working Day: A standard value is $L^* = 0.40$ for the US. We choose a higher value $\underline{L = 9/16 = 0.56}$ for India.

Oil Consumption Shares: $1 - w_C = 1 - w_C^* = 0.02$ (MS)

Habit Parameters: $\underline{h_C = 0.6}$, $h_C^* = 0.70$ (SW07)

Substitution Elasticites: A standard choice for open economies is $\mu_Z = \mu_Z^* = 1.5$.
$\mu_C = \mu_C^* = 0.3$ (MS)

Technology

Depreciation Rates: A standard choice is $\delta^* = 0.025$, $\underline{\delta = 1 - (1 - 0.25)^{0.25} = 0.069}$, converting to an quarterly basis.

Common World Growth Rate: We choose a common world growth rates: $g = g^* = 4\%$ per annum

Investment Adjustment Costs: $S''(1 + g) = 2.0$ (MS), $(S''(1 + g))^* = 4.0$ from SW07

Production Shares: $\underline{\alpha_2 = 0.77}$, $\underline{\alpha_1 = 0.20}$, $\alpha_3 = 1 - \alpha_1 - \alpha_2 - \alpha_3 = 0.01$ $\alpha_2^* = 0.69$, $\alpha_1^* = 0.29$, $\alpha_3^* = 0.01 = 1 - \alpha_1^* - \alpha_2^* - \alpha_3^* = 0.01$ (SW07)
Investment Substitution Elasticities: $\rho_I = \rho_I^* = 0.5$ (MS)

Financial Accelerators
Elasticity: $\chi_\theta = -0.065$, $\chi_\theta^* = -0.05$ (BGG)
Home currency borrowing for capital: $\varphi \in [0, 1]$
Survival rate: $\xi_e = \xi_e^* = 0.97$ (GGN)
Asset/Debt Ratio:$\underline{\frac{QK}{B} = 1.7} = \frac{1}{1-n_k}$; hence $n_k = 0.412$. $n_k^* = 0.7$ (BGG)
FA Risk Premium: $\Theta = \Theta^* = 0.035/4$ on a quarterly basis (BGG)
UIP Risk Premium: $\delta_r = 0.01$

Market Power
Labour Market Power: Elasticity of labour demand with respect to the relative wage is $\eta = 3$ (SW), corresponding to a 50% mark-up, $\eta^* = 6$, corresponding to a 20% mark-up.
Product Market Power: $\zeta = 7.67$ corresponding to a 15% (SW, LOWW).

Pricing
Calvo Contract: a standard value $\underline{\xi_H = \xi_F^* = 0.75}$, corresponding to 4 quarter price contracts on average (see MS)

Consumption, Investment and Trade Shares
Standard values for the US are $c_y^* = 0.6$, $i_y^* = 0.2$ and $g_y = 0.2$ For India we choose $\underline{c_y = 0.58}$, $\underline{i_y = 0.32}$, $\underline{g_y = 0.10}$, $tb = 0.0$ which is consistent with the choice of zero net asset-GDP ratio below.
Trade Shares: Ignoring trade in energy and raw materials we require $0.25 = cs_{imports} + is_{imports} = cs_{exports} + is_{exports}$ for balanced trade. NIPFS provide: $\underline{cs_{imports} = 0.15}$, $\underline{is_{imports} = 0.05}$, $\underline{cs_{exports} = 0.10}$ and $\underline{is_{exports} = 0.03}$. To make this consistent with balanced trade put $cs_{imports} = 0.08$

Fiscal Deficit and Overseas Assets
$\frac{FS}{P_H Y} = -0.03 \times 4$, $\frac{\hat{B}_G^*}{P_F^* Y^*} = 0.4 \times 4$ on a quarterly basis;
Assume $\frac{\hat{B}}{P_H Y} = 0.0$.
Profits
$\frac{\Gamma}{P_H Y} = 0.1$.
Liquidity Constraints

NIPFP provide a figure of 27.5% living below the poverty line. Compare this with $\lambda = 0.6$ for Chile (MS) and $\lambda^* = 0.4$ for the US (KL). We must conclude that non-Ricardian households extend beyond the poor. Use Chile for now.

Tax Rates and Transfers
Since the tax rates impact at the margin on fluctuations in tax, we use marginal rates: $\underline{\tau_L = 0.2}$, $\underline{\tau_C = 0.125}$, $\underline{\tau_K = \tau_\Gamma = 0.30}$. Guess at $\frac{TL_1}{P_H Y}$=0.05, $\frac{TL_2}{P_H Y} = 0.05$ in both blocs. Standard values for ROW are: $\tau_L^* = \tau_C = 0.2$; $\tau_K^* = \tau_\Gamma = 0.05$

3 Monetary and Fiscal Policy Rules

In this section we specify the monetary and fiscal rules. Monetary instruments are nominal interest rates $r_{n,t}$ and $r_{n,t}^*$ in the home and foreign blocs respectively. The fiscal instruments are real lump-sum taxes on Ricardian households $tl_{2,t} - p_{H,t}$ and $tl_{2,t}^* - p_{F,t}^*$ and real lump-sum transfers to non-Ricardian households $tl_{1,t} - p_{H,t}$ and $tl_{1,t}^* - p_{F,t}^*$.

3.1 Monetary Rules

In line with the literature on open-economy interest rate rules (see, for example, Benigno and Benigno (2004)), we assume that the central bank in the emerging market bloc has three options : (i) set the nominal interest to keep the exchange rate fixed (fixed exchange rates, 'FIX'); (ii) set the interest rate to track deviations of domestic or CPI inflation from a predetermined target (inflation targeting under fully flexible exchange rates, 'FLEX(D)' or 'FLEX(C)'); or, finally (iii) follow a hybrid regime, in which the nominal interest rates responds to both inflation deviations from target and exchange rate deviations from a certain level (managed float, 'MEX'). Many emerging market countries follow one or another of these options and most are likely to in the near future.[18] Formally, the rules are:

Fixed Exchange Rate Regime, 'FIX'. This is implemented by

$$r_{n,t} = \rho r_{n,t-1} + \theta_s s_t \tag{65}$$

where θ_s is chosen to be very large. In fact we implement 'FIX' as a 'MEX' regime below, with feedback coefficients chosen to minimize a loss function that includes a large penalty

[18] Mallick (2009) estimates a structural VAR with the exchange rate and provides evidence of exchange rate targeting by the RBI.

on exchange rate variability. (Note that values for the loss function reported below remove the latter contribution).

Inflation Targets under a Fully Flexible Exchange Rate, 'FLEX(D)' or 'FLEX(C)'. This takes the form of Taylor rule with domestic or CPI inflation and output targets:

$$r_{n,t} = \rho r_{n,t-1} + \theta_\pi \pi_{H,t} + \theta_y y_t \quad (66)$$

$$r_{n,t} = \rho r_{n,t-1} + \theta_\pi \pi_t + \theta_y y_t \quad (67)$$

where $\rho \in [0,1]$ is an interest rate smoothing parameter.

Managed Exchange Rate, 'MEX'. In this rule the exchange rate response is direct rather than indirect as in the CPI inflation rule, (67):[19]

$$r_{n,t} = \rho r_{n,t-1} + \theta_\pi \pi_{H,t} + \theta_y y_t + \theta_s s_t \quad (68)$$

subject to a nominal exchange rate volatility constraint $\sum_{t=0}^{\infty} \beta^t \text{var}(s_t) \leq \overline{VS}$ where $\overline{VS}$ is an upper bound on the average discounted future variance of the exchange rate at time $t = 0$. Alternatively we can impose a constraint that $\text{var}(s_t) \leq \overline{VS}$ in the stochastic steady state.

In all cases we assume that the central bank and the fiscal authorities in the emerging market bloc enjoy full credibility. Although this assumption may have been considered heroic a few years ago, today there are several emerging market countries that have succeeded in stabilizing inflation at low levels and have won the trust of, including economies with a history of high or hyper-inflation (e.g. Brazil, Israel, Peru and Mexico, among others. See Batini *et al.* (2006). Accounting for imperfect credibility of the central bank remains nonetheless important for many other emerging market countries, and can lead to higher stabilization costs than under full credibility (under inflation targeting and floating exchange rate, see Aoki and Kimura (2007) or even sudden stops and financial crises (under fixed exchange rates, see IMF (2005)).

3.2 Fiscal Rules

Since the focus of this paper is on monetary policy we chose very rudimentary fiscal rules with no stabilization role. The fiscal rule for lump-sum taxes on Ricardian households $tl_{2,t}$

[19]Rule (67) describes one of many possible specifications of a managed float, namely one where the central bank resists deviations of the exchange rate from a certain level–considered to be the equilibrium– as well as deviations of inflation from target and output from potential. An equally plausible specification involves a feedback on the rate of change of the exchange rate, in which case the central bank aim is to stabilize exchange rate volatility, i.e. the pace at which the domestic currency appreciates or depreciates over time. For a discussion see Batini *et al.* (2003). To limit the number of simulations and results to be compared, here we limit ourselves to one specification only.

is simply that real tax receipts as a proportion of GDP stabilizes government debt as as a proportion of GDP. Lump-sum transfers to non-Ricardian households $tl_{2,t}$ are held fixed in real terms. Denoting $b_{G,t} = \frac{\hat{B}_{G,t}}{P_{H,t}Y_t} - \frac{\hat{B}_G}{P_H Y}$, the fiscal rule in linearized form is

$$\mathrm{tl}_{2,t} = p_{H,t-1} + \alpha_{bg} b_{G,t-1} \tag{69}$$

$$\mathrm{tl}_{1,t} = p_{H,t} \tag{70}$$

3.3 Policy in the Foreign Bloc

The foreign bloc is closed from its own viewpoint so we can formulate its optimal policy without any strategic considerations. Since our focus is on the home country we choose a standard model without a FA in the foreign bloc and very simple monetary and fiscal rules of the form

$$r^*_{n,t} = \rho^* r^*_{n,t-1} + \theta^*_\pi \pi^*_{F,t} + \theta^*_y y^*_t + \epsilon^*_{r,t} \tag{71}$$

$$tl^*_{2,t} = p^*_{F,t-1} + y^*_{t-1} + \alpha^*_{bg} b^*_{G,t-1} \tag{72}$$

$$\mathrm{tl}^*_{1,t} = p^*_{F,t-1} - (\mathrm{tl}^*_{2,t} - p^*_{F,t-1}) \tag{73}$$

Maximizing the quadratic discounted loss function in the four parameters $\rho^* \in [0, 1]$, $\theta^*_\pi \in [1, 10]$,[20] α^*_y, $\alpha^*_{bg} \in [0, \infty]$ and imposing a ZLB constraint in a way described in detail below for the home country, we obtain for the calibration in that bloc: $\rho^* = 1$, $\theta^*_\pi = 10$, $\theta^*_y = 0$ and $\alpha^*_{bg} = 0.87$. The optimized monetary rule then is of a difference or 'integral' form that aggressively responds to any deviation of inflation from its zero baseline but does not react to deviations of output.[21]

With the foreign bloc now completely specified we turn to policy in the home country. In the following section we confine ourselves to a simple ad hoc monetary and fiscal rules without any attempt to optimize welfare

4 The Financial Accelerator and Model Variants

We parameterize the model according to three alternatives, ordered by increasing degrees of frictions:

- **Model I**: no financial accelerator and no liability dollarization. ($\chi_\theta = \chi^*_\theta = 0$, $\Theta = \Theta^* = 0$, $\epsilon_p = \epsilon^*_p = 0$, $\varphi = 1$). This is a fairly standard small open-economy

[20] We restrict our search to $\pi^*_\theta \in [1, 10]$: the lower bound ensures the rule satisfies the 'Taylor Principle' for all ρ and the imposed upper bound avoids large initial jumps in the nominal interest rate.

[21] The latter feature is a common one in the DSGE literature - see, for example, Schmitt-Grohe and M.Uribe (2005).

model similar to many in the New Keynesian open-economy literature with the only non-standard features being a non-separable utility function in money balances, consumption, and leisure consistent with a balanced growth path and a fully articulated ROW bloc;

- **Model II**: financial accelerator (FA) only; ($\chi_\theta, \chi_\theta^* < 0$, $\Theta, \Theta^* > 0$, $\epsilon_p, \epsilon_p^* \neq 0$, $\varphi = 1$).
- **Model III**: financial accelerator (FA) and liability dollarization (LD), assuming that firms borrow a fraction of their financing requirements $1-\varphi \in [0,1]$ in dollars.($\chi_\theta, \chi_\theta^* < 0$, $\Theta, \Theta^* > 0$, $\epsilon_p, \epsilon_p^* \neq 0$, $\varphi \in [0,1)$)

4.1 The Workings of the Financial Accelerator

To understand how the transmission of policy and shocks for different levels of frictions and dollarization, we need first to take a step back and illustrate some of the mechanisms driving the real exchange rate, and the behavior of net worth of the wholesale firms sector.

Movements in the real exchange rate (and the related terms of trade) are critical for understanding our results. Linearization of the modified UIP condition (21) gives

$$rer_t = E_t rer_{t+1} + E_t(r_t^* - r_t) - \delta_r b_{F,t} + \epsilon_{UIP,t} \tag{74}$$

Solving (74) forward in time we see that the real exchange rate is a sum of future expected real interest rate differentials with the ROW plus a term proportional to the sum of future expected net liabilities plus a sum of expected future shocks $\epsilon_{UIP,t}$. The real exchange will depreciate (a rise in rer_t) if the sum of expected future interest rate differentials are positive and/or the sum of expected future net liabilities are positive and/or a positive shock to the risk premium, $\epsilon_{UIP,t}$ occurs.

Also crucial to the understanding of the effects of the FA and LD is the behaviour of the net worth of the wholesale sector. In linearized form this is given by

$$\begin{aligned} n_t &= \frac{\xi_e}{1+g}\Big[\frac{1}{n_k} r_{t-1}^k + (1+\Theta)(1+R)n_{t-1} \\ &+ \left(1 - \frac{1}{n_k}\right)\big[(1+R)\theta_{t-1} + (1+\Theta)(\varphi r_{t-1} + (1-\varphi)(r_{t-1}^* + (1+R)(rer_t - rer_{t-1})\big]\Big] \end{aligned} \tag{75}$$

where the ex post real interest rates in period $t-1$ are in linearized form defined as

$$r_{t-1} = r_{n,t-1} - (1+R)\pi_t \tag{76}$$

$$r_{t-1}{}^* = r_{n,t-1}^* - (1+R)\pi_t^* \tag{77}$$

and where the ex ante cost of capital is given by r^k_{t-1}. In (75) since leverage $\frac{1}{n_k} > 1$ we can see that net worth increases with the ex post return on capital at the beginning of period t, r^k_{t-1}, and decreases with the risk premium θ_{t-1} charged in period $t-1$ and the the ex post cost of capital in home currency and dollars, $\varphi r_{t-1} + (1-\varphi)(r^*_{t-1} + (1+R)(rer_t - rer_{t-1}))$, noting that $(rer_t - rer_{t-1})$ is the real depreciation of the home currency.

Starting at the steady state at $t = 0$, from (75) at $t = 1$ we have

$$n_1 = \frac{\xi_e}{1+g}\left[(1-\delta)q_1 + \left(1 - \frac{1}{n_k}\right)(1+\Theta)[(1-\varphi)(1+R)rer_1 - \varphi\pi_1 - (1-\varphi)\pi^*_1]\right] \quad (78)$$

Thus net worth falls if Tobin's Q falls and if some borrowing is in dollars ($\varphi < 1$), we see that a *depreciation* of the real exchange rate ($rer_1 > 0$) brings about a further drop in net worth. However an *appreciation* of the real exchange rate ($rer_1 < 0$) will offset the drop in net worth. Finally net worth also falls the domestic and foreign inflation rates fall and thereby increase the ex post real interest rates and therefore the ex post cost of capital. If net worth falls, output also falls through two channels: first, a drop in Tobin's Q and a subsequent fall in investment demand and second, through a reduction in consumption demand by entrepreneurs.

Finally we confirm that for a fixed exchange rate regime with $r_{n,t} = r^*_{n,t}$ (i.e., no financial friction in the international bond market) liability dollarization has no impact on net worth. For this regime $rer_t = p^*_t - p_t$ and therefore $\Delta rer_t = \pi^*_t - \pi_t$. Then it is straightforward to show that (75) becomes

$$\begin{aligned} n_t &= \frac{\xi_e}{1+g}\Big[\frac{1}{n_k} r^k_{t-1} + (1+\Theta)(1+R)n_{t-1} \\ &+ \left(1 - \frac{1}{n_k}\right)[(1+R)\theta_{t-1} + (1+\Theta)r_{t-1}]\Big] \end{aligned} \quad (79)$$

which corresponds to the accumulation of net worth in the absence of LD.

4.2 A Credit Crunch: Impulse Responses to a Risk Premium Shock

Further insights into monetary and fiscal policy transmission mechanisms with a financial accelerator can be obtained from impulses following an unanticipated 1% risk premium shock with AR1 process $\epsilon_{P,t+1} = 0.95\epsilon_{P,t}$.[22] We confine ourselves to very simple ad hoc

[22] This is a very similar exercise to the study of a "sudden stop" as in Curdia (2008). In his paper he provides a deeper formulation of the origin of the shock as arising from shifts in the perceptions of the foreign lender.

rules of the form

$$r_{n,t} = \rho r_{n,t-1} + (1-\rho)(\theta_\pi \pi_{H,t} + \theta_y y_t) \tag{80}$$

$$\mathrm{tl}_{2,t} = p_{H,t} + \alpha_{bg} b_{G,t-1} \tag{81}$$

$$\mathrm{tl}_{1,t} = p_{H,t} \tag{82}$$

Thus the real transfers to non-Ricardian households are held fixed and the implementation lag problem is ignored. Figure 1 shows various impulse response functions for the three model variants. For model III with LD we choose a modest degree of foreign currency borrowing with $\varphi = 0.9$. Fiscal policy only impacts on government debt and is otherwise independent of the parameter α_{bg}. For the monetary Taylor rule we choose the following parameters estimated for Chile by Medina and Soto (2007): $\rho = 0.74$, $\theta_\pi = 1.67$, $\theta_y = 0.39$ which are in the standard range for estimated rules.

Following the 1% risk premium shock ($\epsilon_{P,0} = 1$) there is an immediate output rise which is driven by the immediate increase in demand following the fall in the terms of trade. This occurs because the commitment rule promises a drawn out period where the nominal interest rate is below the foreign rate and so the nominal exchange rate depreciates. The increase in the cost of capital drives Tobin's Q down and investment falls. However installation costs ensure this negative demand effect is gradual; after a few quarters it begins to dominate the terms of trade effect on demand and output starts to fall. Net worth falls as a result of the increase in the cost of capital and the FA accentuates both these effects. The FA plus the LD accentuates these further and in turn 'accelerates' the fall in output and investment.

5 Optimal Monetary Policy

With both fiscal policy and the foreign bloc now completely specified we can now turn to the design of monetary policy in the home country. Results for the model variant I are presented with those for models II and III to follow. First we must formulate a linear-quadratic approximation of the optimization problem facing the monetary authority. This is particularly convenient as we can then summarize outcomes in terms of unconditional (asymptotic) variances of macroeconomic variables and the local stability and determinacy of particular rules. The framework also proves useful for addressing the issue of the zero lower bound on the nominal interest rate.

5.1 Quadratic Approximation of the Loss Function

Following Woodford (2003), a 'small distortions' quadratic approximation to the household's single period utility is appropriate accurate as long as the zero-inflation steady state is close to the social optimum. There are three distortions that result in the steady state output being below the social optimum: namely, output and labour market distortions from monopolistic competition and distortionary taxes required to pay for government-provided services. Given our calibration these features would make our distortions far from small. However there is a further distortion, external habit in consumption, that in itself raises the equilibrium steady state output above the social optimum. If the habit parameter h_C is large enough the two sets of effects can partly cancel out and thus justify our small distortions approximation. If this is not the case the small distortions case is only justified if there is a subsidy in place that to retail firms that brings the market-determined level of output in line with the social optimum.[23]

Results obtained below are for a single-period quadratic approximation $L_t = \mathsf{y}_t' Q \mathsf{y}_t$ obtained numerically following the procedure set out in From Appendix D. Insight into the result can be gleaned from the special case where there are no oil inputs into production or consumption and copper is not a production input either. Then the quadratic approximation to the household's intertemporal expected loss function is given by

$$\Omega_0 = E_t \left[(1-\beta) \sum_{t=0}^{\infty} \beta^t L_t \right] \tag{83}$$

where

$$\begin{aligned} 2L_t &= w_c \left(\frac{c_t - h_C c_{t-1}}{1-h_C} \right)^2 + w_\tau \tau_t^2 + w_{cl} \left(\frac{c_t - h_C c_{t-1}}{1-h_C} \right) l_t + w_l l_t^2 \\ &+ w_k (k_{t-1} - l_t)^2 - w_{ay} y_t a_t + w_{ci\tau} ci_t \tau_t + w_{cls\tau} cls_t \tau_t + w_\pi \pi_{H,t}^2 \\ ci_t &\equiv \mu\omega(1-\omega) c_y c_t + \mu(1-\omega^*) c_y c_t^* + \rho_I \omega_I (1-\omega_I) i_y i_t + \rho_I^* (1-\omega_I^*) i_y i_t^* \\ cls_t &\equiv [(1-\sigma)(1-\varrho) - 1] \frac{c_t^* - h c_{t-1}^*}{1-h} - (1-\sigma)\varrho \frac{L^* l_t^*}{1-L^*} \end{aligned} \tag{84}$$

and the weights w_c, w_τ, etc are defined in Appendix D. Thus from (84) welfare is reduced as a result of volatility in consumption adjusted to external habit, $c_t - h_C c_{t-1}$; the terms of trade, τ_t, labour supply l_t, domestic inflation $\pi_{H,t}$ and foreign shocks. There are also some covariances that arise from the procedure for the quadratic approximation of the loss function. The policymaker's problem at time $t = 0$ is then to minimize (83) subject to the model in linear state-space form given by (60), initial conditions on predetermined

[23] See Levine *et al.* (2007) and Levine *et al.* (2008a) for a discussion of these issues. The former paper provides details of all the optimization procedures in this paper.

variables z_0 and the Taylor rule followed by the ROW. Our focus is on stabilization policy in the face of stochastic shocks, so we set $z_0 = 0$. The monetary instruments is the nominal interest rate and the fiscal instrument consists of lump-sum taxes net of transfers. By confining fiscal policy to lump-sum taxes on Ricardian households only we eliminate its stabilization contribution; this we refer to as 'monetary policy alone'. Details of the optimization procedure are provided in Levine *et al.* (2007).

5.2 The Nominal Interest Rate Zero Lower Bound (ZLB) and Exchange Rate Upper Bound Constraints

We now modify our interest-rate rules to approximately impose an interest rate ZLB so that this event hardly ever occurs. Our quadratic approximation to the single-period loss function can be written as $L_t = \mathsf{y}_t' Q \mathsf{y}_t$ where $\mathsf{y}_t' = [\mathsf{z}_t', \mathsf{x}_t']'$ and Q is a symmetric matrix. As in Woodford (2003), chapter 6, the ZLB constraint is implemented by modifying the single period welfare loss to $L_t + w_r r_{n,t}^2$. Then following Levine *et al.* (2008b), the policymaker's optimization problem is to choose w_r and the unconditional distribution for $r_{n,t}$ (characterized by the steady state variance) shifted to the right about a new non-zero steady state inflation rate and a higher nominal interest rate, such that the probability, p, of the interest rate hitting the lower bound is very low. This is implemented by calibrating the weight w_r *for each of our policy rules* so that $z_0(p)\sigma_r < R_n$ where $z_0(p)$ is the critical value of a standard normally distributed variable Z such that prob $(Z \leq z_0) = p$, $R_n = \frac{1}{\beta(1+g_{u_c})} - 1 + \pi^*$ is the steady state nominal interest rate, $\sigma_r^2 = \text{var}(r_n)$ is the unconditional variance and π^* is the new steady state inflation rate. Given σ_r the steady state positive inflation rate that will ensure $r_{n,t} \geq 0$ with probability $1 - p$ is given by[24]

$$\pi^* = \max[z_0(p)\sigma_r - \left(\frac{1}{\beta(1+g_{u_c})} - 1\right) \times 100, 0] \tag{85}$$

In our linear-quadratic framework we can write the intertemporal expected welfare loss at time $t = 0$ as the sum of stochastic and deterministic components, $\Omega_0 = \tilde{\Omega}_0 + \bar{\Omega}_0$. Note that $\bar{\Omega}_0$ incorporates in principle the new steady state values of all the variables; however the NK Phillips curve being almost vertical, the main extra term comes from the

[24] If the inefficiency of the steady-state output is negligible, then $\pi^* \geq 0$ is a credible new steady state inflation rate. Note that in our LQ framework, the zero interest rate bound is very occasionally hit. Then interest rate is allowed to become negative, possibly using a scheme proposed by Gesell (1934) and Keynes (1936). Our approach to the ZLB constraint (following Woodford, 2003) in effect replaces it with a nominal interest rate variability constraint which ensures the ZLB is hardly ever hit. By contrast the work of a number of authors including Adam and Billi (2007), Coenen and Wieland (2003), Eggertsson and Woodford (2003) and Eggertsson (2006) study optimal monetary policy with commitment in the face of a non-linear constraint $i_t \geq 0$ which allows for frequent episodes of liquidity traps in the form of $i_t = 0$.

π^2 term in (D.11). By increasing w_r we can lower σ_r thereby decreasing π^* and reducing the deterministic component, but at the expense of increasing the stochastic component of the welfare loss. By exploiting this trade-off, we then arrive at the optimal policy that, in the vicinity of the steady state, imposes the ZLB constraint, $r_t \geq 0$ with probability $1-p$.

The imposition of the upper bound exchange rate volatility constraint is more straightforward. Now the quadratic single period welfare loss is modified to $L_t + w_r r_{n,t}^2 + w_s s_t^2$. For each value of w_s optimal policy is evaluated with the imposition of the ZLB as above. Then we increase the weight w_s from $w_s = 0$ for the floating exchange rate case to a sufficient level that satisfies the upper bound on the exchange rate variance. As for the ZLB the equilibrium welfare is then assessed by evaluating the loss after resetting $w_r = w_s = 0$.

5.3 The Optimized FLEX(D) Rule and Optimal Policy

First consider the welfare-optimal form of the domestic inflation-targeting rule FLEX(D) with a floating exchange rate $w_s = 0$. Table 2 and Figure 1 impose the ZLB constraint as described in the previous section. We choose $p = 0.001$. For each value of w_r we compute the values of the feedback parameters $\rho \in [0,1]$, $\theta_\pi \in [1,10]$ and $\theta_y \geq 0$ that minimizes the conditional (stochastic) welfare loss in the vicinity of the steady state. Given w_r, denote the expected inter-temporal loss (stochastic plus deterministic components) at time $t = 0$ by $\Omega_0(w_r)$. This includes a term penalizing the variance of the interest rate which does not contribute to utility loss as such, but rather represents the interest rate lower bound constraint. Actual utility, found by subtracting the interest rate term, is given by $\Omega_0(0) = \Omega_0$ in the table. The steady-state inflation rate, π^*, that will ensure the lower bound is reached only with probability $p = 0.001$ is computed using (85). Given π^*, we can then evaluate the deterministic component of the welfare loss, $\bar{\Omega}_0$. Since in the new steady state the real interest rate is unchanged, the steady state involving real variables are also unchanged, so from (84) we can write $\bar{\Omega}_0(0) = \frac{1}{2} w_\pi \pi^{*2}$.

The optimized form of FLEX(D) under the constraint that the ZLB is violated with a probability $p = 0.001$ per period (in our quarterly model, once every 250 years) occurs when we put $w_r = 9.75$ and the steady state quarterly inflation rises to $\pi^* = 0.98\%$ or around 4% per year. The form of the rule is interesting: it is an *integral* rule where the quarterly *change* in the nominal interest rate responds aggressively to domestic inflation, not at all to output deviations about the steady state and slightly to exchange rate deviations. The absence of a feedback from output is a familiar result – inflation-targeting provides sufficient stabilization since output and inflation move together. Some response to exchange rate changes are welfare-enhancing since they impact on real consumption.

However, although the imposition of the ZLB lowers exchange rate volatility, at the optimum the standard deviation of the exchange rate deviation about the steady state is still over 5%.

w_r	w_s	ρ	θ_π	θ_y	θ_s	$\sigma^2_{\Delta s}$	σ^2_s	σ^2_r	$\tilde{\Omega}$	π^*	$\bar{\Omega}_0$	Ω_0
0	0	0.00	7.13	0.08	0.05	7.67	59.7	1.96	4.18	1.76	5.93	10.11
1.0	0	0.00	7.92	0.05	0.08	7.58	38.4	1.90	4.20	1.70	5.50	9.70
3.0	0	0.25	10.0	0.00	0.13	7.41	29.7	1.67	4.42	1.43	3.93	8.35
5.0	0	0.50	10.0	0.00	0.14	7.33	28.1	1.53	4.70	1.28	3.07	7.77
7.0	0	0.79	10.0	0.00	0.14	7.27	27.2	1.39	5.10	1.10	2.31	7.41
9.0	0	1.00	10.0	0.00	0.15	7.21	26.4	1.31	5.44	098	1.85	7.2871
9.75	**0**	**1.00**	**10.0**	**0.00**	**0.17**	**7.20**	**26.2**	**1.30**	**5.45**	**0.98**	**1.84**	**7.2870**
10.0	0	1.00	10.0	0.00	0.18	7.18	25.9	1.30	5.46	0.98	1.84	7.2873

Table 2. Floating Exchange Rate FLEX(D) Rule with a ZLB Constraint.

Notation: $\pi^* = \max[z_0(p)\sigma_r - (\frac{1}{\beta(1+g_{u_c})} - 1) \times 100, 0] = \max[3.00\sigma_r - 2.44, 0]$ with $p = 0.001$ probability of hitting the ZLB and $\beta = 0.99$, $g_{u_c} = -0.014$. $\bar{\Omega} = \frac{1}{2}w_\pi \pi^{*2} = 3.829\pi^{*2}$. $\Omega = \tilde{\Omega} + \bar{\Omega}$ = stochastic plus deterministic components of the welfare loss.

Table 3 and Figure 2 repeats the same exercise for the optimal policy. This can only be implemented using a rather complex form of rule – hence the emphasis in the literature on implementable simple rules – but the optimal form of policy is useful as a benchmark to ascertain the welfare costs of particular simple rules.[25] Now as w_r increases the steady state variance of the interest rate falls more sharply. At the optimum with a ZLB constraint, $w_r = 1.25$, $\pi^* = 0$, but the exchange rate volatility is higher with a standard deviation around 6% ($\sigma^2_s = 37.9$).

w_r	w_s	σ^2_r	σ^2_s	$\sigma^2_{\Delta s}$	$\tilde{\Omega}_0$	π^*	$\bar{\Omega}_0$	Ω_0
0.0	0	1.54	35.9	7.25	2.58	1.28	3.13	5.71
0.5	0	0.96	35.0	7.43	2.59	0.49	0.47	3.06
0.75	0	0.83	35.5	7.53	2.61	0.28	0.15	2.76
1.0	0	0.73	36.6	7.62	2.63	0.12	0.03	2.66
1.25	**0**	**0.65**	**37.9**	**7.69**	**2.65**	**0**	**0**	**2.65**
1.5	0	0.59	39.7	7.76	2.67	0	0	2.67

Table 3. Optimal Floating Exchange Rate Policy with a ZLB Constraint.

[25]See Currie and Levine (1993), Woodford (2003).

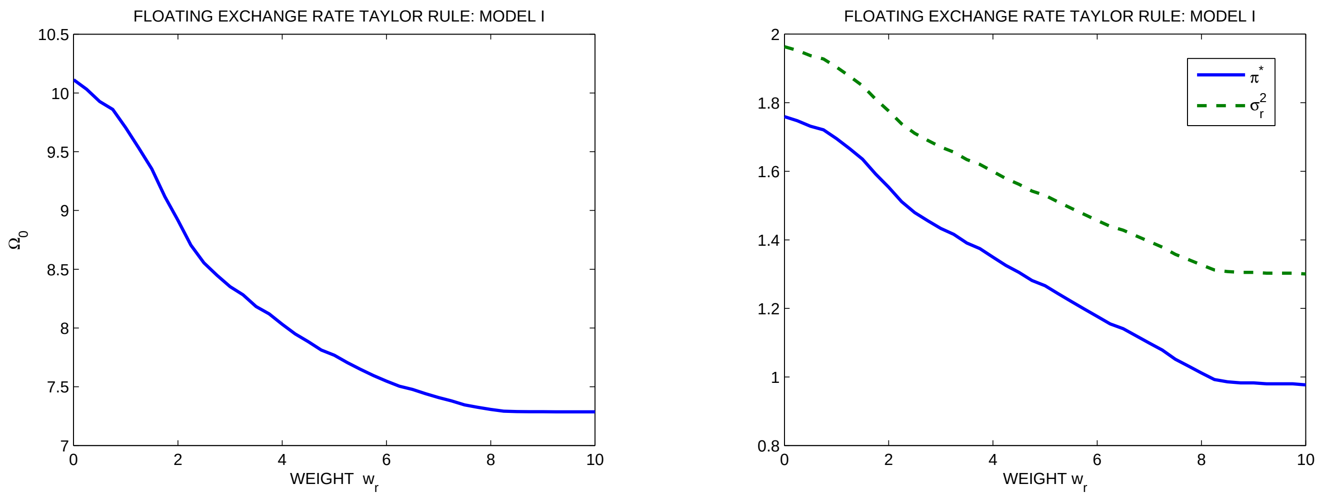

Figure 1: **Imposition of ZLB: Floating Exchange Rate FLEX(D) Rule**

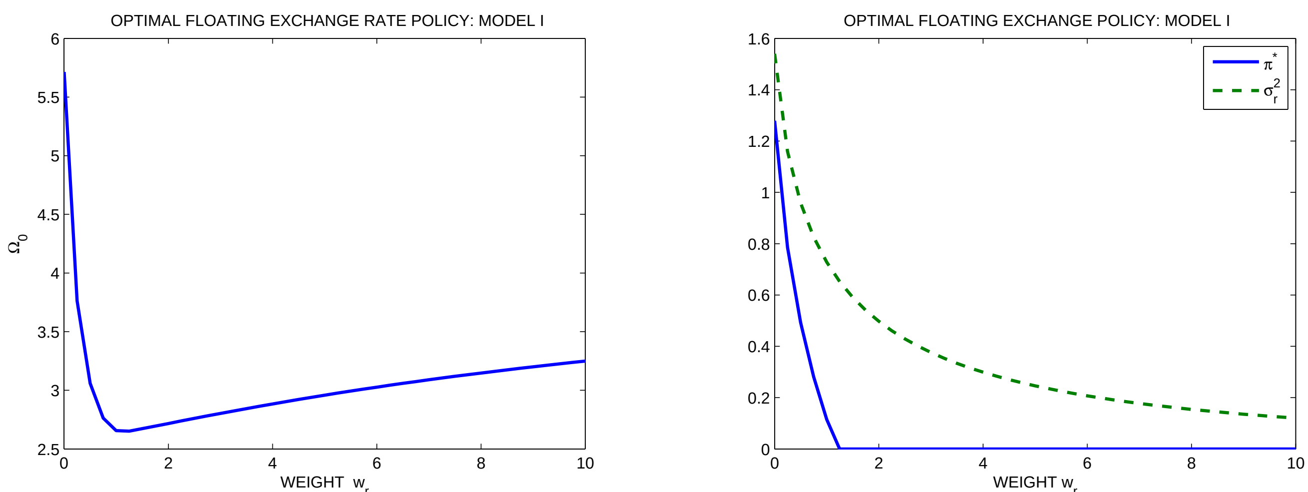

Figure 2: **Imposition of ZLB: Optimal Floating Exchange Rate Policy**

5.4 The Optimized MEX Rule and Optimal Managed Exchange Rate Policy

Now we turn to the MEX regime. For each value of w_s the previous ZLB exercise is repeated in Table 4. Here for comparison the first row sets out the $w_s = 0$ case from the $w_r = 1.25$ row of Table 3 . It is of interest in the final column to compare the welfare outcome with that under optimal policy. From Appendix D in consumption equivalent terms this is given by

$$c_e^{MF} = \frac{(\Omega_0^{MEX} - \Omega_0^{OPT})}{(1-\varrho)(1-h_C)c_y} \times 10^{-2} \;\; (\%) \tag{86}$$

For the floating exchange rate case $w_s = 0$ we see that the welfare cost of simplicity for the FLEX(D) rule is a not insignificant with $c_e = 0.29\%$. As the lower nominal exchange rate volatility is imposed by raising w_s its standard deviation is lowered to just over 3% ($\sigma_s^2 = 9.27$) at $w_s = 2.0$ obtained by a rule that feeds back from the exchange rate deviation strongly with $\theta_s = 2.37$ with low interest rate persistence $\rho = 0.15$. This comes at a welfare cost compared with the optimal rule of $c_e = 0.4\%$. To achieve a still lower standard deviation of 2.67% ($\sigma_s^2 = 7.11$) requires a rule with no persistence and a feedback $\theta_s = 3.13$; i.e, a 1% depreciation must be met with a 3% increase in the quarterly interest rate. This pattern continues until ultimately a regime very close to a fixed exchange rate is achieved with a highly aggressive rule, but at an enormous welfare cost compared with the optimal rule of $c_e = 30.4\%$.

Can low exchange rate volatility be achieved at a much lower cost by relaxing the constraint implied by the form of simplicity of FLEX(D)? The final table 5 shows that this is indeed the case and indeed a near-fixed exchange rate can be reached with $c_e = 0.59\%$.

w_r	w_s	ρ	θ_π	θ_y	θ_s	$\sigma^2_{\Delta s}$	σ^2_s	σ^2_r	$\tilde{\Omega}$	π^*	$\bar{\Omega}_0$	Ω_0	c_e
9.75	0	1.00	10.0	0.00	0.17	7.20	26.2	1.30	5.45	0.98	1.84	7.29	0.29
7.75	1.0	0.69	10.0	0.13	1.54	5.36	12.7	1.21	8.43	0.87	1.45	9.88	0.46
0.15	2.0	0.00	10.0	0.26	2.37	4.55	9.27	1.29	10.94	0.97	1.82	12.76	0.64
0.0	3.0	0.00	10.0	0.30	3.13	3.90	7.11	1.20	14.21	0.85	1.38	15.59	0.82
0.0	4.0	0.00	10.0	0.33	3.80	3.41	5.76	1.14	17.26	0.76	1.10	18.36	1.00
0.0	5.0	0.00	10.0	0.35	4.42	3.03	4.86	1.10	20.00	0.69	0.92	20.92	1.16
0.0	1000	0.60	0.00	0.00	10.0	0.01	0.01	1.26	105.7	0.92	1.63	107.3	30.8

Table 4. Managed Exchange Rate Taylor Rule with a ZLB Constraint.

Notation: c_e = welfare loss in as a permanent percentage change in consumption relative to the steady state.

w_r	w_s	σ_r^2	σ_s^2	$\sigma_{\Delta s}^2$	$\tilde{\Omega}_0$	π^*	$\bar{\Omega}_0$	Ω_0	c_e
1.25	0	0.65	37.9	7.69	2.65	0	0	2.65	0
2.75	1.0	0.69	4.09	1.65	4.95	0.04	0.004	4.91	0.14
5.75	2.0	0.68	1.89	0.98	6.16	0.02	0.001	6.16	0.22
9.75	3.0	0.66	1.26	0.81	6.84	0	0	6.84	0.27
30.0	10.0	0.73	0.50	0.41	8.26	0	0	8.26	0.36
0	1000	1.43	0.0001	0.0000	9.13	1.14	2.51	11.6	0.59

Table 5. Optimal Managed Exchange Rate Policy with a ZLB Constraint.

6 Conclusions and Future Research

This preliminary paper has set out a DSGE model of an emerging open economy fitted to Indian data. We have found that the imposition of a low exchange rate volatility is only achieved at a significant welfare loss if the policymaker is restricted to a simple domestic inflation plus exchange rate targeting rule. If on the other hand the policymaker can implement an optimal complex rule then an almost fixed exchange rate can be achieved at a relatively small welfare cost. This finding suggests that future research should examine alternative simple rules that mimic the fully optimal rule more closely.

We have only examined the FLEX(D) and MEX rules for the model I without a financial accelerator (FA). FLEX(C) remains to be studied as do models II (with a FA) and III (FA plus LD). Previous research in Batini *et al.* (2007) using a DSGE model of the Peruvian economy found that the welfare-optimizing form of these rules were welfare-ranked as follows: FLEX(D) $\succ$ FLEX(C) $\succ$ FIX where FIX is our extreme form of MEX with a fixed exchange rate. Increasing degrees of financial frictions as one moves from model I to III created bigger welfare-differences between the three regimes and so strengthened the case for a floating exchange rate with domestic inflation targeting. Future research on the policy side will examine whether these results carry over to the model in this paper. We will also study welfare-optimized simple commitment rules that include optimized fiscal rules as in Batini *et al.* (2009).

Finally future modelling developments will include the introduction of a large informal sector into our DSGE model and an attempt to estimate the model by Bayesian-Maximum-Likelihood methods using the calibration here as priors. In doing so we will confront the data limitations associated especially with the informal and partly hidden economy by adopting a consistent partial information assumption for the econometrician and private sector alike, as in Justiniano *et al.* (2008).

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A The Steady State

The zero-inflation, BGP steady state with net worth, consumption, wholesale output, the wage and capital stock are growing at a rate g per period, a balanced growth path must satisfy

$$\bar{N}_t = (1+g)\bar{N}_{t-1} = (\xi_e + (1-\xi_e)\nu)(1+\Theta)(1+R)\bar{N}_{t-1} \tag{A.1}$$

$$\frac{\bar{K}_{t+1}}{\bar{K}_t} = \frac{\bar{Y}_{t+1}}{\bar{Y}_t} = \frac{\bar{C}_{t+1}}{\bar{C}_t} = \frac{\bar{W}_{t+1}}{\bar{W}_t} = 1+g \tag{A.2}$$

$$\frac{\bar{A}_{t+1}}{\bar{A}_t} = 1 + (1-\alpha_1)g \tag{A.3}$$

Since there are no investment adjustment costs at the steady state it follows that

$$\bar{K}_{t+1} = (1-\delta)\bar{K}_t + \bar{I}_t \tag{A.4}$$

It follows from (A.1) that

$$\bar{I}_t = (g+\delta)\bar{K}_t \tag{A.5}$$

and hence the previous assumptions regarding $S(\cdot)$ become $S(g+\delta) = g+\delta$ and $S'(g+\delta) = 1$.

In what follows we denote the (possibly trended) steady state of X_t by X. Then given the long-run asset position of the home country, $\hat{B}$, the rest of the steady state is given by

$$C_H = \mathrm{w}_Z \left(\frac{P_H}{P_Z}\right)^{-\mu_Z} C_Z \tag{A.6}$$

$$C_F = (1-\mathrm{w}_Z)\left(\frac{P_F}{P_Z}\right)^{-\mu_Z} C_Z \tag{A.7}$$

$$P_Z = \left[\mathrm{w}_Z P_H^{1-\mu_Z} + (1-\mathrm{w}_Z)P_F^{1-\mu_Z}\right]^{\frac{1}{1-\mu_Z}} \tag{A.8}$$

$$C_Z = \mathrm{w}_C \left(\frac{P_Z}{P}\right)^{-\mu_C} C \tag{A.9}$$

$$C_O = (1-\mathrm{w}_C)\left(\frac{P_O}{P}\right)^{-\mu_C} C \tag{A.10}$$

$$P = \left[\mathrm{w}_C P_Z^{1-\mu_C} + (1-\mathrm{w}_C)P_O^{1-\mu_C}\right]^{\frac{1}{1-\mu_C}} \tag{A.11}$$

$$\frac{W(1-\tau_L)}{P(1+\tau_C)} = -\frac{1}{\left(1-\frac{1}{\eta}\right)}\frac{U_L}{U_C} \tag{A.12}$$

$$1 = \beta(1+R_n)(1+g_{u_c}) = \beta(1+R)(1+g_{u_c}) \tag{A.13}$$

where g_{u_c} is the growth rate of the marginal utility of consumption in the steady state,

$$g_{u_c} = (1+g)^{(1-\varrho)(1-\sigma)-1} - 1 \tag{A.14}$$

$$1 + R^k = (1+\Theta)(1+R) \tag{A.15}$$

$$\Theta = \Theta\left(\frac{B}{N}\right) = \Theta\left(\frac{QK}{N} - 1\right) \tag{A.16}$$

$$Y^W = AK^{\alpha_1}L^{\alpha_2}\mathrm{OIL}^{\alpha_3} \tag{A.17}$$

$$\frac{WL}{P_H^W Y^W} = \alpha_2 \tag{A.18}$$

$$\frac{Q(R^k+\delta)K}{P_H^W Y^W} = \alpha_1 \tag{A.19}$$

$$\frac{P^O \mathrm{OIL}}{P_H^W Y^W} = \alpha_3 \tag{A.20}$$

$$\tag{A.21}$$

$$I = (g+\delta)K \tag{A.22}$$

$$I = \left[\mathrm{w}_I^{\frac{1}{\rho_I}} I_H^{\frac{\rho_I - 1}{\rho_I}} + (1-\mathrm{w}_I)^{\frac{1}{\rho_I}} I_F^{\frac{\rho_I - 1}{\rho_I}}\right]^{\frac{\rho_I}{1-\rho_I}} \tag{A.23}$$

$$\frac{I_H}{I_F} = \frac{\mathrm{w}_I}{1-\mathrm{w}_I}\left(\frac{P_H}{P_F}\right)^{-\rho_I} \tag{A.24}$$

$$P_I = \left[\mathrm{w}_I P_H^{1-\rho_I} + (1-\mathrm{w}_I)P_F^{1-\rho_I}\right]^{\frac{1}{1-\rho_I}} \tag{A.25}$$

$$QS'\left(\frac{I}{K}\right) = \frac{P_I}{P} \tag{A.26}$$

$$P_H = \hat{P}_H = \frac{P_H^W}{\left(1 - \frac{1}{\zeta}\right)} \tag{A.27}$$

$$MC = \frac{P_H^W}{P_H} \tag{A.28}$$

$$Y = C_H + \frac{1}{\nu}[C_H^e + C_H^{e*} + I_H + I_H^*] + \frac{1-\nu}{\nu}C_H^* + G \tag{A.29}$$

$$C_{H,t}^e = (1-\xi_e)V = (1-\xi_e)(1+R^k)N \equiv s_e C_{H,t} \tag{A.30}$$

$$\mathrm{TB} = P_H Y - P_O \mathrm{OIL} - PC - PC^e - P_I I - P_H G \tag{A.31}$$

$$\frac{\Gamma}{P_H Y} = 1 - \text{MC}\left(1 + \frac{F}{Y}\right) \tag{A.32}$$

$$R_g = \frac{1 + R_n}{1 + g} - 1 \tag{A.33}$$

$$\frac{PS}{P_H Y} \equiv \frac{(T - G)}{P_H Y} = R_g \frac{\hat{B}_G}{P_H Y} \tag{A.34}$$

$$\frac{TB}{P_H Y} = -R_g \frac{\hat{B}}{P_H Y} \tag{A.35}$$

$$C_2 = C_1 + \frac{\frac{1}{1-\lambda}\left[-TB + PS + (1 - \tau_\Gamma)\Gamma - \lambda TL_1\right] - TL_2}{(1 + \tau_C)P} \tag{A.36}$$

plus the foreign counterparts.

The steady steady is completed with

$$\mathcal{T} = \frac{P_F}{P_H} \tag{A.37}$$

$$RER = \frac{SP^*}{P} \tag{A.38}$$

$$U_C = U_C^* \frac{z_0}{RER} \tag{A.39}$$

Units of output are chosen so that $P^O = P^C = P_H = P_F = 1$. Hence $\mathcal{T} = P = P_I = 1$. Hence with our assumptions regarding $S(\cdot)$ we have that $Q = 1$. We also normalize $S = 1$ in the steady state so that $P_F^* = P_H^* = P^* = P_I^* = 1$ as well. Then the steady state of the risk-sharing condition (A.39) becomes $C = kC^*$ where k is a constant.

B Linearization

Exogenous processes:

$$a_{t+1} = \rho_a a_t + v_{a,t+1} \tag{B.1}$$

$$a_{t+1}^* = \rho_a^* a_t^* + v_{a,t+1}^* \tag{B.2}$$

$$g_{t+1} = \rho_g g_t + v_{g,t+1} \tag{B.3}$$

$$g_{t+1}^* = \rho_g^* g_t^* + v_{g,t+1}^* \tag{B.4}$$

$$p_{O,t+1}^* - p_{t+1}^* = \rho_{oil}(p_{O,t}^* - p_t^*) + v_{oil,t+1} \tag{B.5}$$

$$\varepsilon_{UIP,t+1} = \rho_{UIP}\varepsilon_{UIP,t} + v_{UIP,t+1} \tag{B.6}$$

$$\varepsilon_{P,t+1} = \rho_P \varepsilon_{P,t} + v_{P,t+1} \tag{B.7}$$

$$\varepsilon_{P,t+1}^* = \rho_P^* \varepsilon_{P,t}^* + v_{P,t+1}^* \tag{B.8}$$

(Note $gr_t = g_t - y_t$ is estimated as a proportion of GDP.)

Predetermined variables

$$k_{t+1} = \frac{1-\delta}{1+g}k_t + \frac{\delta+g}{1+g}i_t \tag{B.9}$$

$$k^*_{t+1} = \frac{1-\delta^*}{1+g}k^*_t + \frac{\delta^*+g}{1+g}i^*_t \tag{B.10}$$

$$\begin{aligned} n_t &= \frac{\xi_e}{1+g}\Big[\frac{1}{n_k}r^k_{t-1} + (1+\Theta)(1+R)n_{t-1} \\ &+ \left(1-\frac{1}{n_k}\right)\big[(1+R)\theta_{t-1} + (1+\Theta)(\varphi r_{t-1} + (1-\varphi)(r^*_{t-1} + (1+R)(rer_t - rer_{t-1})\big]\Big] \end{aligned} \tag{B.11}$$

$$n^*_t = \frac{\xi^*_e}{1+g}\Big[\frac{1}{n^*_k}r^{k*}_{t-1} + (1+\Theta^*)(1+R)n^*_{t-1} + \left(1-\frac{1}{n^*_k}\right)\big[(1+R)\theta^*_{t-1} + (1+\Theta^*)r^*_{t-1}\big]\Big] \tag{B.12}$$

where $r_{t-1} = r_{n,t-1} - (1+R)\pi_t$ and $r^*_{t-1} = r^*_{n,t-1} - (1+R)\pi^*_t$ are the *ex post* real interest rates.

$$s_t = s_{t-1} + rer_t - rer_{t-1} + \pi_t - \pi^*_t \tag{B.13}$$

$$b_{G,t} = \frac{1}{\beta(1+g)}b_{G,t-1} + \frac{B_G}{P_H Y}r_{g,t-1} + g_y(g_t - y_t) - t_t \tag{B.14}$$

$$b^*_{G,t} = \frac{1}{\beta(1+g)}b^*_{G,t-1} + \frac{B^*_G}{P^*_F Y^*}r^*_{g,t-1} + g^*_y(g^*_t - y^*_t) - t^*_t \tag{B.15}$$

$$b_{F,t} = \frac{1}{\beta(1+g)}b_{F,t-1} + \frac{\hat{B}_{F,t}}{P_{H,t}Y_t}r_{g,t-1} + tb_t \tag{B.16}$$

$$\Delta\tau_t = \pi_{F,t} - \pi_{H,t} \tag{B.17}$$

$$\Delta\tau^*_t = \pi^*_{H,t} - \pi^*_{F,t} \tag{B.18}$$

$$\Delta o_t = \pi_{O,t} - \pi_{Z,t} \tag{B.19}$$

$$\Delta o^*_t = \pi^*_{O,t} - \pi^*_{Z,t} \tag{B.20}$$

$$\Delta(p^*_t - p^*_{Z,t}) = (1 - \mathrm{w}^*_C)(\pi^*_{O,t} - \pi^*_{Z,t}) \tag{B.21}$$

$$(\text{Note: } p^*_{Z,t} = p^*_{F,t})$$

$$\Delta(p_t - p_{Z,t}) = (1 - \mathrm{w}_C)(\pi_{O,t} - \pi_{Z,t}) \tag{B.22}$$

Non-predetermined variables:

$$
\begin{aligned}
(1-\delta)E_t(q_{t+1}) &= (1+R^k)q_t - (R^k+\delta)x_t \\
&+ E_t(r_t^k) && \text{(B.23)} \\
(1-\delta^*)E_t(q_{t+1}^*) &= (1+R^{k*})q_t^* - (R^{k*}+\delta^*)x_t^* \\
&+ E_t(r_t^{k*}) && \text{(B.24)} \\
E_t u_{c,t+1} &= u_{c,t} - \frac{r_{n,t}}{1+R} + E_t\pi_{t+1} && \text{(B.25)} \\
E_t u_{c,t+1}^* &= u_{c,t}^* - \frac{r_{n,t}^*}{1+R} + E_t\pi_{t+1}^* && \text{(B.26)} \\
\beta E_t\pi_{H,t+1} &= \pi_{H,t} - \lambda_H mc_t && \text{(B.27)} \\
\beta E_t\pi_{F,t+1}^* &= \pi_{F,t}^* - \lambda_F^* mc_t^* && \text{(B.28)} \\
\beta E_t\pi_{H,t+1}^{*\ell} &= \pi_{H,t}^{*\ell} - \lambda_H^*(mc_t - \phi_{H,t} + p_{H,t} - p_{H,t}^{\ell}) && \text{(B.29)}
\end{aligned}
$$

$$
\left(1+\frac{1+g}{1+R}\right)i_t = \frac{1+g}{1+R}E_t i_{t+1} + i_{t-1} + \frac{1}{(1+g)^2 S''(1+g)}(q_t - (p_{I,t}-p_{Z,t}) + p_{Z,t} - p_t) \tag{B.30}
$$

$$
\left(1+\frac{1+g}{1+R}\right)i_t^* = \frac{1+g}{1+R}E_t i_{t+1}^* + i_{t-1}^* + \frac{1}{(1+g)^2 S''(1+g)}(q_t^* - (p_{I,t}^*-p_{Z,t}^*) + p_{Z,t}^* - p_t^*) \tag{B.31}
$$

$$
E_t[rer_{t+1}^d] = rer_t^d + \delta_r b_{F,t} + \varepsilon_{UIP,t} \tag{B.32}
$$

Instruments

$$
\begin{aligned}
r_{n,t} &= \text{exogenous instrument} && \text{(B.33)} \\
tl_{1,t} - p_{H,t} &= \text{exogenous instrument} && \text{(B.34)} \\
tl_{2,t} - p_{H,t} &= \text{exogenous instrument} && \text{(B.35)}
\end{aligned}
$$

Outputs:

$$
\begin{aligned}
mc_t &= u_{l,t} - u_{c,t} + l_t - \frac{1}{\phi_F}y_t + p_t - p_{H,t} && \text{(B.36)} \\
mc_t^* &= u_{l,t}^* - u_{c,t}^* + l_t^* - \frac{1}{\phi_F^*}y_t^* + p_t^* - p_{Z,t}^* && \text{(B.37)} \\
u_{c,t} &= \frac{(1-\varrho)(1-\sigma)-1}{1-h_C}(c_{2,t} - h_C c_{2,t-1}) - \frac{L\varrho(1-\sigma)}{1-L}l_t && \text{(B.38)} \\
u_{c,t}^* &= \frac{(1-\varrho^*)(1-\sigma^*)-1}{1-h_C^*}(c_{2,t}^* - h_C^* c_{2,t-1}^*) - \frac{L^*\varrho^*(1-\sigma^*)}{1-L^*}l_t^* && \text{(B.39)}
\end{aligned}
$$

$$
\begin{aligned}
u_{l,t} &= \frac{1}{1-h_C}(c_{2,t} - h_C c_{2,t-1}) + \frac{L}{1-L} l_t + u_{c,t} \\
&+ \varpi_L [\bar{a} r_{n,t} + (1-\bar{a}) r^*_{n,t}] && \text{(B.40)} \\
u^*_{l,t} &= \frac{1}{1-h^*_C}(c^*_{2,t} - h^*_C c^*_{2,t-1}) + \frac{L^*}{1-L^*} l^*_t + u^*_{c,t} + \varpi^*_L r^*_{n,t} && \text{(B.41)} \\
c_{1,t} &= \gamma_1 (w_t + l_t - p_t) + \gamma_2 (\mathrm{tl}_{1,t} - p_t) \\
&= \gamma_1 (u_{l,t} - u_{c,t} + l_t) + \gamma_2 (\mathrm{tl}_{1,t} - p_{H,t} - (p_t - p_{H,t})) && \text{(B.42)} \\
c^*_{1,t} &= \gamma^*_1 (w^*_t + l^*_t - p^*_t) + \gamma^*_2 (\mathrm{tl}^*_{1,t} - p^*_t) = \gamma^*_1 (u^*_{l,t} - u^*_{c,t} + l^*_t) \\
&+ \gamma^*_2 (\mathrm{tl}^*_{1,t} - p^*_{F,t} + p^*_{Z,t} - p^*_t) && \text{(B.43)} \\
c_t &= \frac{\lambda C_1}{C} c_{1,t} + \frac{(1-\lambda) C_2}{C} c_{2,t} && \text{(B.44)} \\
c^*_t &= \frac{\lambda^* C^*_1}{C^*} c^*_{1,t} + \frac{(1-\lambda^*) C^*_2}{C^*} c^*_{2,t} && \text{(B.45)} \\
y_t &= \alpha_{C,H} c_{Z,t} + \alpha^e_{C,H} c^e_{Z,t} + \alpha^*_{C,H} c^*_{Z,t} + \alpha_{I,H} i_t + \alpha^*_{I,H} i^*_t + \alpha_G g_t \\
&+ [\mu_Z (\alpha_{C,H} + \alpha^e_{C,H})(1 - \mathrm{w}_Z) + \rho_I \alpha_{I,H} (1 - \mathrm{w}_I)] \tau_t - [\mu^*_Z \alpha^*_{C,H} \mathrm{w}^*_Z + \rho^*_I \alpha^*_{I,H} \mathrm{w}^*_I] \tau^*_t \\
& && \text{(B.46)} \\
y^*_t &= \alpha^*_{C,F} c^*_{Z,t} + \alpha^{*e}_{C,F} c^{*e}_{Z,t} + \alpha_{C,F} c_{Z,t} + \alpha^e_{C,F} c^e_{Z,t} + \alpha^*_{I,F} i^*_t + \alpha_{I,F} i_t + \alpha^*_G g^*_t \\
&- [\mu^*_Z (\alpha^*_{C,F} + \alpha^{*e}_{C,F})(1 - \mathrm{w}^*_Z) + \mu_Z \alpha_{C,F} \mathrm{w}_Z + \rho^*_I \alpha^*_{I,F} (1 - \mathrm{w}^*_I) + \rho_I \alpha_{I,F} \mathrm{w}_I] \tau_t \\
&= c^*_y c^*_{Z,t} + i^*_y i^*_t + g^*_y g^*_t && \text{(B.47)} \\
c_{Z,t} &= c_t - \mu_C (p_Z - p_t) && \text{(B.48)} \\
c^*_{Z,t} &= c^*_t - \mu^*_C (p^*_Z - p^*_t) && \text{(B.49)} \\
c^e_{Z,t} &= c^e_t - \mu_C (p_Z - p_t) && \text{(B.50)} \\
c^{e*}_{Z,t} &= c^{e*}_t - \mu^*_C (p^*_Z - p^*_t) && \text{(B.51)}
\end{aligned}
$$

(Note SOE results: $\mathrm{w} = \omega$, $\mathrm{w}_I = \omega_I$, $\mathrm{w}^* = \mathrm{w}^*_I = 1$)

$$
\begin{aligned}
c^e_t &= n_t && \text{(B.52)} \\
c^{e*}_t &= n^*_t && \text{(B.53)} \\
rer^r_t &= u^*_{c,t} - u_{c,t} && \text{(B.54)}
\end{aligned}
$$

$$\theta_t = \chi_\theta(n_t - k_t - q_t) + \epsilon_{P,t} \tag{B.55}$$

$$\theta_t^* = \chi_\theta^*(n_t^* - k_t^* - q_t^*) + \epsilon_{P,t}^* \tag{B.56}$$

$$\begin{aligned} E_t(r_t^k) &= (1+R)\theta_t + (1+\Theta)(\varphi E_t(r_t) \\ &+ (1-\varphi)\left[E_t(r_t^*) + (1+R)(E_t(rer_{t+1}) - rer_t)\right)] \end{aligned} \tag{B.57}$$

$$E_t(r_t^{k*}) = (1+R)\theta_t^* + (1+\Theta^*)E_t(r_t^*) \tag{B.58}$$

$$r_{t-1}^k = (1-\delta)q_t - (1+R^k)q_{t-1} + (R^k+\delta)x_{t-1} \tag{B.59}$$

$$r_{t-1}^{k*} = (1-\delta^*)q_t^* - (1+R^{k*})q_{t-1}^* + (R^{k*}+\delta^*)x_{t-1}^* \tag{B.60}$$

$$E_t(r_t) = r_{n,t} - E_t(\pi_{t+1}) \tag{B.61}$$

$$E_t(r_t^*) = r_{n,t}^* - E_t(\pi_{t+1}^*) \tag{B.62}$$

$$p_{Z,t} - p_{H,t} = (1-\mathrm{w}_Z)\tau_t \to (1-\omega)\tau_t \text{ as } n \to 0 \tag{B.63}$$

$$(\text{ Note } p_{Z,t}^* - p_{F,t}^* = (1-\mathrm{w}_Z^*)\tau^* \to 0)$$

$$p_{I,t} - p_{Z,t} = (\mathrm{w}_Z - \mathrm{w}_I)\tau_t \to (\omega - \omega_I)\tau_t \tag{B.64}$$

$$(\text{ Note } p_{I,t}^* - p_{Z,t}^* = (1-\mathrm{w}_I^*)\tau_t \to 0)$$

$$\pi_t = \mathrm{w}_C\pi_{Z,t} + (1-\mathrm{w}_C)\pi_{O,t} \tag{B.65}$$

$$\pi_t^* = \mathrm{w}_C^*\pi_{Z,t}^* + (1-\mathrm{w}_C^*)\pi_{O,t}^* \tag{B.66}$$

$$\pi_{Z,t} = \omega\pi_{H,t} + (1-\omega)\pi_{F,t} \tag{B.67}$$

$$(\text{Note: } \pi_{Z,t}^* = \pi_{F,t}^*)$$

$$\pi_{F,t} = \Delta rer_t + \pi_t - \pi_t^* + \pi_{F,t}^* \tag{B.68}$$

$$\pi_{H,t}^* = \theta\pi_{H,t}^{*p} + (1-\theta)\pi_{H,t}^{*\ell} \tag{B.69}$$

$$\pi_{H,t}^{*p} = -\Delta rer_t + \pi_t^* - \pi_t + \pi_{H,t} \tag{B.70}$$

$$rf_t = \chi_R(r_{n,t} - r_{n,t}^*) \tag{B.71}$$

$$\alpha_2 l_t = \frac{1}{\phi_F}y_t - a_t - \alpha_1 k_t - \alpha_3 \mathrm{oil}_t \tag{B.72}$$

$$\alpha_2^* l_t^* = \frac{1}{\phi_F^*}y_t^* - a_t^* - \alpha_1^* k_t^* - \alpha_3^* \mathrm{oil}_t^* \tag{B.73}$$

$$x_t^* = y_t^* + mc_t^* + p_{Z,t}^* - p_t^* - k_t^* \tag{B.74}$$

$$E_t\pi_{Z,t+1} = \mathrm{w}_Z E_t\pi_{H,t+1} + (1-\mathrm{w}_Z)E_t\pi_{F,t+1} \tag{B.75}$$

$$E_t\pi_{t+1} = \mathrm{w}_C E_t\pi_{Z,t+1} + (1-\mathrm{w}_C)E_t\pi_{O,t+1} \tag{B.76}$$

$$E_t\pi_{F,t+1} = E_t rer_{t+1} - rer_t + E_t\pi_{t+1} - E_t\pi_{t+1}^* + E_t\pi_{F,t+1}^* \tag{B.77}$$

$$E_t rer_{t+1} = E_t u_{c,t+1}^* - E_t u_{c,t+1} + E_t[rer_{t+1}^d] \tag{B.78}$$

$$r_{n,t}^* = \rho_i^* r_{n,t-1}^* + (1-\rho_i^*)\theta_\pi^* \pi_{F,t}^* + \theta_y \Delta y_t^* + \varepsilon_{R,t}^* \tag{B.79}$$

$$q_t^k = q_t - p_{I,t} + p_t \tag{B.80}$$

$$(\text{ Note } q_t^{k*} = q_t^*)$$

$$r_{g,t} = (1+R_g)\left(\beta r_{n,t} - \pi_{H,t} - \frac{y_t - y_{t-1}}{1+g}\right) \tag{B.81}$$

$$r_{g,t}^* = (1+R_g^*)\left(\beta r_{n,t}^* - \pi_{F,t}^* - \frac{y_t^* - y_{t-1}^*}{1+g}\right) \tag{B.82}$$

$$\begin{aligned} t_t &= s_L(w_t - p_{H,t} + l_t - y_t) + s_C(p_t - p_{H,t} + c_t - y_t) \\ &+ s_K(p_t - p_{H,t} + q_t + k_t - y_t + \frac{r_t^k}{R^k}) \\ &- \lambda \frac{TL_1}{P_H Y}(tl_{1,t} - p_{H,t} - y_t) + (1-\lambda)\frac{TL_2}{P_H Y}(tl_{2,t} - p_{H,t} - y_t) \\ &+ s_\Gamma \gamma_t \end{aligned} \tag{B.83}$$

$$\begin{aligned} t_t^* &= s_L^*(w_t^* - p_t^* + l_t^* - y_t^*) + s_C^*(c_t^* + p_t^* - p_{Z,t}^* - y_t^*) \\ &+ s_K^*(q_t^* + k_t^* - y_t^* + \frac{r_t^{k*}}{R^{k*}}) \\ &- \lambda^* \frac{TL_1^*}{P_F^* Y^*}(tl_{1,t}^* - p_{F,t}^* - y_t^*) + (1-\lambda^*)\frac{TL_2^*}{P_F^* Y^*}(tl_{2,t}^* - p_{F,t}^* - y_t^*) \\ &+ s_\Gamma^* \gamma_t^* \end{aligned} \tag{B.84}$$

$$tl_{1,t} - p_{H,t} = -\frac{TL_2 k(1-\lambda)}{TL_1\,(1-k)\lambda}(tl_{2,t} - p_{H,t}) \tag{B.85}$$

$$tl_{1,t}^* - p_{F,t}^* = -\frac{TL_2^* k^*(1-\lambda^*)}{TL_1^*\,(1-k^*)\lambda^*}(tl_{2,t}^* - p_{F,t}^*) \tag{B.86}$$

$$tl_{2,t}^* - p_{F,t}^* = y_t^* + \alpha_B^* b_{G,t}^* \tag{B.87}$$

$$t_t^{NI} = t_t + \lambda \frac{TL_1}{P_H Y}(tl_{1,t} - p_{H,t} - y_t) - (1-\lambda)\frac{TL_2}{P_H Y}(tl_{2,t} - p_{H,t} - y_t) \quad \text{(B.88)}$$

$$t_t^{I} = -\lambda \frac{TL_1}{P_H Y}(tl_{1,t} - p_{H,t} - y_t) + (1-\lambda)\frac{TL_2}{P_H Y}(tl_{2,t} - p_{H,t} - y_t) \quad \text{(B.89)}$$

$$w_t - p_{H,t} = u_{l,t} - u_{c,t} + p_t - p_{H,t} \quad \text{(B.90)}$$

$$w_t^* - p_t^* = u_{l,t}^* - u_{c,t}^* \quad \text{(B.91)}$$

$$\gamma_t = -\phi_F mc_t \quad \text{(B.92)}$$

$$\gamma_t^* = -\phi_F^* mc_t^* \quad \text{(B.93)}$$

$$\begin{aligned} tb_t &= y_t - \alpha_{C,H} c_t - \alpha_{C,H}^e c_t^e - i_y i_t - g_y g_t \\ &- (c_y + i_y)(p_t - p_{H,t}) - i_y(p_{I,t} - p_t) \\ &- (1 - \alpha_1 - \alpha_2)\left(\frac{1}{\phi_F} y_t + mc_t\right) \end{aligned} \quad \text{(B.94)}$$

$$rer_t = rer_t^r + rer_t^d \quad \text{(B.95)}$$

$$rer_t^r = u_{c,t}^* - u_{c,t} \quad \text{(B.96)}$$

$$p_{H,t} - p_{H,t}^{\ell} = \frac{\theta}{1-\theta}(-rer_{Z,t} - (1-\omega)\tau_t - \tau_t^*) \quad \text{(B.97)}$$

$$\phi_{H,t} = rer_{Z,t} + \tau_t^* + (1-\omega)\tau_t \quad \text{(B.98)}$$

$$rer_{Z,t} = rer_t + (1 - \mathrm{w}_C)o_t - (1 - \mathrm{w}_C^*)o_t^* \quad \text{(B.99)}$$

$$\pi_{O,t} = \Delta rer_t + \pi_{O,t}^* + \pi_t - \pi_t^* \quad \text{(B.100)}$$

$$\pi_{O,t}^* = p_{O,t}^* - p_t^* - (p_{O,t-1}^* - p_{t-1}^*) + \pi_t^* \quad \text{(B.101)}$$

$$p_t - p_{H,t} = p_t - p_{Z,t} + p_{Z,t} - p_{H,t} \quad \text{(B.102)}$$

$$\begin{aligned} E_t \pi_{O,t+1} &= E_t rer_{t+1} - rer_t + E_t \pi_{O,t+1}^* + E_t \pi_{t+1} - E_t \pi_{t+1}^* \\ &= E_t rer_{t+1} - rer_t + (\rho_{oil} - 1)p_{O,t}^* + E_t \pi_{t+1} - E_t \pi_{t+1}^* \end{aligned} \quad \text{(B.103)}$$

$$E_t \pi_{t+1}^* = w_C^* E_t \pi_{F,t+1}^* + (1 - w_C^*)(\rho_{oil} - 1)p_{O,t}^* \quad \text{(B.104)}$$

$$oil_t = \frac{1}{\phi_F} y_t + mc_t + p_{H,t} - p_t + p_t - p_{O,t} \quad \text{(B.105)}$$

$$oil_t^* = \frac{1}{\phi_F^*} y_t^* + mc_t^* + p_{Z,t}^* - p_t^* + p_t^* - {p_{O,t}}^* \quad \text{(B.106)}$$

$$p_{O,t} - p_t = rer_t + {p_{O,t}}^* - p_t^* \quad \text{(B.107)}$$

$$c_{O,t} = c_t - \mu_Z(p_{O,t} - p_t) \quad \text{(B.108)}$$

$$\textbf{check}: c_t = \mathrm{w}_C c_{Z,t} + (1 - \mathrm{w}_C)c_{O,t} \quad \text{(B.109)}$$

The quadratic loss function for the home and ROW require the following:

$$cmcl_t = \frac{c_t - h_C c_{t-1}}{1 - h_C} \tag{B.110}$$

$$kml_t = k_{t-1} - l_t \tag{B.111}$$

$$ccii_t = \mu\omega(1-\omega)c_y c_t + \mu(1-\omega^*)c_y c_t^* + \rho_I \omega_I (1-\omega_I) i_y i_t + \rho_I^*(1-\omega_I^*) i_y i_t^* \tag{B.112}$$

$$ccsls_t = [(1-\sigma)(1-\varrho)-1]\frac{c_t^* - h_C c_{t-1}^*}{1-h_C} - (1-\sigma)\varrho\frac{L^* l_t^*}{1-L^*} \tag{B.113}$$

$$cmcl_t^* = \frac{c_t^* - h_C^* c_{t-1}^*}{1 - h_C^*} \tag{B.114}$$

$$kml_t^* = k_{t-1}^* - l_t^* \tag{B.115}$$

C Derived Calibrated Parameters

Given these estimates and data observations we can now calibrate the following parameters:

Preference Parameter ϱ is found from

$$\begin{aligned} \frac{W(1-L)}{PC} &= \frac{\alpha_2(1-L)}{c_y L} \\ \varrho &= \frac{(1-\frac{1}{\eta})W(1-\tau_L)(1-L)/P(1+\tau_C)C}{1+(1-\frac{1}{\eta})W(1-\tau_L)(1-L)/P(1+\tau_C)C} \end{aligned}$$

Demand elasticities calibrated from trade data:

$$\begin{aligned} \alpha_{C,H} &= (c_y - cs_{imports})(1-s_e) \\ \alpha_{C,H}^e &= (c_y - cs_{imports})s_e \\ \alpha_{C,H}^* &= cs_{exports} \\ \alpha_{I,H} &= i_y - is_{imports} \\ \alpha_{I,H}^* &= is_{exports} \end{aligned}$$

$$
\begin{aligned}
\alpha^*_{C,F} &= c^*_y \\
\alpha^{e\,*}_{C,F} &= 0 \\
\alpha_{C,F} &= 0 \\
\alpha^*_{I,F} &= i^*_y \\
\alpha_{I,F} &= 0 \\
\alpha_G &= g_y \\
\alpha^*_G &= g^*_y
\end{aligned}
$$

Note the SOE implication that $\alpha_{C,F} = \alpha_{I,F} = 0$. Then we have

$$
\begin{aligned}
\omega &= \frac{\alpha_{C,H} + \alpha^e_{C,H}}{c_y} = \frac{c_y - cs_{imports}}{c_y} \\
\omega_I &= \frac{\alpha_{I,H}}{i_y}
\end{aligned}
$$

Remaining calibrated parameters are:

$$
\begin{aligned}
g_{u_c} &= (1+g)^{(1-\varrho)(1-\sigma)-1} - 1 \\
R &= \frac{1}{\beta(1+g_{u_c})} - 1 \\
R^k &= (1+\Theta)(1+R) - 1 \\
\lambda_H &= \frac{(1-\beta\xi_H)(1-\xi_H)}{\xi_H} \\
k_y &= \frac{i_y}{g+\delta} \\
s_e &= \frac{(1-\xi_e)n_k k_y}{\xi_e c_y} \\
\frac{F}{P_H Y} &= \frac{1 - \frac{\Gamma}{P_H Y}}{1 - \frac{1}{\zeta}} - 1 \\
R_g &= \frac{1+R_n}{1+g} - 1 \\
\frac{PS}{P_H Y} &= R_g \frac{\hat{B}_G}{P_H Y} \\
\frac{TB}{P_H Y} &= R_g \frac{\hat{B}_F}{P_H Y} \\
\frac{C_2}{C} &= 1 + \frac{1}{(1+\tau_C)c_y}\Big[\frac{1}{1-\lambda}\Big(- \frac{TB}{P_H Y} + \frac{PS}{P_H Y} + \frac{(1-\tau_\Gamma)\Gamma}{P_H Y} - \frac{\lambda T L_1}{P_H Y}\Big) - \frac{TL_2}{P_H Y}\Big] \\
\frac{C_1}{C} &= \frac{1-(1-\lambda)\frac{C_2}{C}}{\lambda}
\end{aligned}
$$

$$
\begin{aligned}
\gamma_1 &= \frac{1-\tau_L}{1+\tau_C}\frac{WL}{PC_1} \\
\gamma_2 &= \frac{1}{1+\tau_C}\frac{TL_1}{PC_1} \\
\frac{WL}{PC_1} &= \frac{\alpha_2\phi_F}{c_y}\frac{C}{C_1} \\
\frac{TL_1}{PC_1} &= \frac{TL_1}{P_HY}\frac{C}{c_yC_1} \\
s_L &= \tau_L\frac{WL}{P_HY} = \tau_L\alpha_2\phi_F \\
s_C &= \tau_C\frac{P_CC}{P_HY} = \tau_Cc_y \\
s_K &= \tau_K\frac{Q(R^k+\delta)K}{P_HY} = \tau_K\alpha_1\phi_F
\end{aligned}
$$

Fixed Costs: From (A.27), (A.28) and (A.32)

$$
\phi_F \equiv 1+\frac{F}{Y} = \frac{1-\frac{\Gamma}{P_HY}}{MC} = \frac{1-\frac{\Gamma}{P_HY}}{1-\frac{1}{\zeta}}
$$

Transfer to new entrepreneurs ν. Finally ν is derived from

$$
(\xi_e+(1-\xi_e)\nu)(1+\Theta)(1+R) = 1+g
$$

Foreign parameters follow in an analogous way.

D Quadratic Approximation of the Welfare Loss

Following Levine *et al.* (2008a), an accurate quadratic approximation to the utility function can be obtained by the following procedure.

1. Set out the Lagrangian of the deterministic Ramsey Problem.

2. Calculate the first order conditions and its steady state.

3. *Keeping the multipliers at the steady state*, calculate a second-order Taylor series approximation of the Hamiltonian, about the steady state.

4. Calculate a first-order Taylor series approximation, about the steady state, of the first-order conditions including constraints.

5. Use 3. to eliminate the steady-state Lagrangian multipliers in 4. Then the Hamiltonian and the constraints can be expressed in minimal form as a *quadratic form* and

linear state representation respectively. This is our accurate LQ approximation of the original non-linear optimization problem.

To implement this procedure let ϵ be the proportion of entrepreneurial households. Then $(1-\epsilon)\lambda$ and $(1-\epsilon)(1-\lambda)$ are the proportions of non-Ricardian worker and Ricardian worker-households respectively. Let $U(C_t, H_C, 1, L_t)$ be a general single-period utility function in terms of consumption, habit and labour supply considered in the main text. Then the Ramsey problem for a utilitarian benevolent welfare-maximizing policymaker to maximize with respect to monetary and fiscal instruments

$$\sum_{t=0}^{\infty} \beta^t [(1-\epsilon)(\lambda U(C_{1,t}, H_{1C,t}, L_{1,t}) + (1-\lambda)U(C_{2,t}, H_{2C,t}, L_{2,t})) + \epsilon U(C_t^e, H_{C,t}^e, 0)] \quad \text{(D.1)}$$

subject to the constraints of the model.

The general solution above must be conducted numerically. However insights in the nature of the quadratic utility function can be obtained if we adopt a 'small distortions' approximation which is accurate as long as the zero-inflation steady state is close to the social optimum. As we have noted in the main text, the existence of external consumption habit offsets the distortions in the product and labour markets. For our calibrated high value for the habit parameter h_C, this leaves the steady state of the decentralized economy reasonably close to the social optimum, justifying the small distortions approximation. An analytical solution is available for the case of no oil inputs into production or consumption and for a simple form of the social welfare function that aggregate all household types into a single entity. Define $C_t^a = (1-\epsilon)(\lambda C_{1,t} + (1-\lambda)C_{2,t}) + \epsilon C_t^e$ be aggregate consumption across the non-Ricardian worker households, non-Ricardian worker households and entrepreneurs. We then consider a the social planner's problem to maximize

$$\sum_{t=0}^{\infty} \beta^t \frac{(C_t^a - h_C C_{t-1}^a)^{(1-\varrho)(1-\sigma)}(1-L_t)^{\varrho(1-\sigma)}}{1-\sigma} \quad \text{(D.2)}$$

subject to the (resource) constraints:

$$1-\omega+\omega T_t^{\mu-1} = \text{RER}_t^{\mu-1} \qquad 1-\omega_I+\omega_I T_t^{\rho_I-1} = \text{RER}_{It}^{\rho_I-1} \qquad K_t = (1-\delta)K_{t-1}+I_t \quad \text{(D.3)}$$

$$Y_t+\Phi = A_t K_{t-1}^{\alpha} L_t^{1-\alpha} = \omega \text{RER}_t^{-\mu} \mathcal{T}_t^{\mu} C_t + (1-\omega^*) T_t^{\mu} C_t^* + \omega_I \text{RER}_{It}^{-\rho_I} \mathcal{T}_t^{\rho_I} I_t + (1-\omega_I^*) \mathcal{T}_t^{\rho_I^*} I_t^* + G_t \quad \text{(D.4)}$$

where $\text{RER}_{I,t} = S_t P_{I,t}^* / P_{I,t}$, so that $\text{RER}_t^{1-\mu} = P_{F,t}^{1-\mu} / (\omega P_{H,t}^{1-\mu} + (1-\omega) P_{F,t}^{1-\mu})$. There is a risk-sharing condition given by

$$\text{RER}_t = U_{C_t^*}^* / U_{C_t} \qquad \Rightarrow \qquad \text{RER}_t C_t^{(1-\varrho)(1-\sigma)-1}(1-L_t)^{\varrho(1-\sigma)} = C_t^{*(1-\varrho)(1-\sigma)-1}(1-L_t^*)^{\varrho(1-\sigma)} \quad \text{(D.5)}$$

where we assume initial wealth per capita is the same in each country.

From Batini *et al.* (2007) this leads to the following quadratic form in this case. First we define

$$cmcl_t = \frac{c_t - h_C c_{t-1}}{1-h_C} \tag{D.6}$$

$$kml_t = k_{t-1} - l_t \tag{D.7}$$

$$ccii_t = \mu\omega(1-\omega)c_y c_t + \mu(1-\omega^*)c_y c_t^* + \rho_I\omega_I(1-\omega_I)i_y i_t + \rho_I^*(1-\omega_I^*)i_y i_t^* \tag{D.8}$$

$$ccsls_t = [(1-\sigma)(1-\varrho)-1]\frac{c_t^* - h_C c_{t-1}^*}{1-h_C} - (1-\sigma)\varrho\frac{L^* l_t^*}{1-L^*} \tag{D.9}$$

$$\lambda = \frac{\varrho c_y(1-h_C)}{\frac{(1-\alpha)R_K\omega_I k_y}{\alpha}\frac{1-L}{L} + \frac{\varrho(1-\sigma)}{\omega}[\mu(\omega^2-1)c_y + \rho_I(\omega_I^2-1)i_y - \frac{\Upsilon}{Y}]} \tag{D.10}$$

Converting the welfare approximation into welfare loss, and dividing by FY leads to

$$\begin{aligned} 2W &= -(1-h_C)c_y\Bigg((1-\varrho)[(1-\sigma)(1-\varrho)-1]cmcl_t^2 \\ &\quad -2(1-\sigma)\varrho(1-\varrho)cmcl_t\frac{Ll_t}{1-L} + \frac{\varrho[(1-\sigma)\varrho-1]L^2 l_t^2}{(1-L)^2}\Bigg) \\ &- \Bigg(\lambda c_y\mu[2\omega^3 - 3\omega + 1 + \mu\omega(1-\omega)^2] \\ &\quad + \frac{\lambda i_y\rho_I}{2}[(1-\omega_I)^2(\mu\omega - 3\omega - \mu) + 1 - \omega_I^3 + \rho_I(1 - 3\omega_I^2 + 2\omega_I^3)]\Bigg)\tau_t^2 \\ &- \lambda\frac{F+Y}{Y}\alpha(1-\alpha)kml_t^2 + 2\lambda\frac{F+Y}{Y}y_t a_t - 2\lambda ccii_t\tau_t - 2\lambda ccsls_t\tau_t \\ &+ \frac{\varrho L(1-h_C)}{(1-L)}\frac{\zeta\xi_H}{(1-\xi_H)(1-\beta\xi_H)}\pi_t^2 \end{aligned} \tag{D.11}$$

which corresponds to (84) in the main text.

The change in welfare for a small change in consumption-equivalent over all periods is given by

$$\begin{aligned} \Delta\Omega &= (1-\rho)\sum_{t=0}^{\infty}\beta^t C(1-h_C)^{(1-\sigma)(1-\rho)-1}(1-L)^{\rho(1-\sigma)}(\Delta C - h_C\Delta C) \\ &= \frac{(1-\rho)(1-h_C)c_y}{1-\beta}FYc_e \end{aligned} \tag{D.12}$$

Ignoring the term in $FY = C(1-h_C)^{(1-\sigma)(1-\rho)-1}(1-L)^{\rho(1-\sigma)}Y$, since all the welfare loss terms have been normalized by this, we can rewrite this as

$$c_e = \frac{(1-\beta)\Delta\Omega}{(1-\rho)(1-h_C)c_y} \tag{D.13}$$

Furthermore, if all welfare loss terms have been further normalized by $(1-\beta)$, and that all variances are expressed in $\%^2$, it follows that we can write c_e in % terms as

$$c_e = \frac{\Delta\Omega}{(1-\rho)(1-h_C)c_y} \times 10^{-2} \tag{D.14}$$

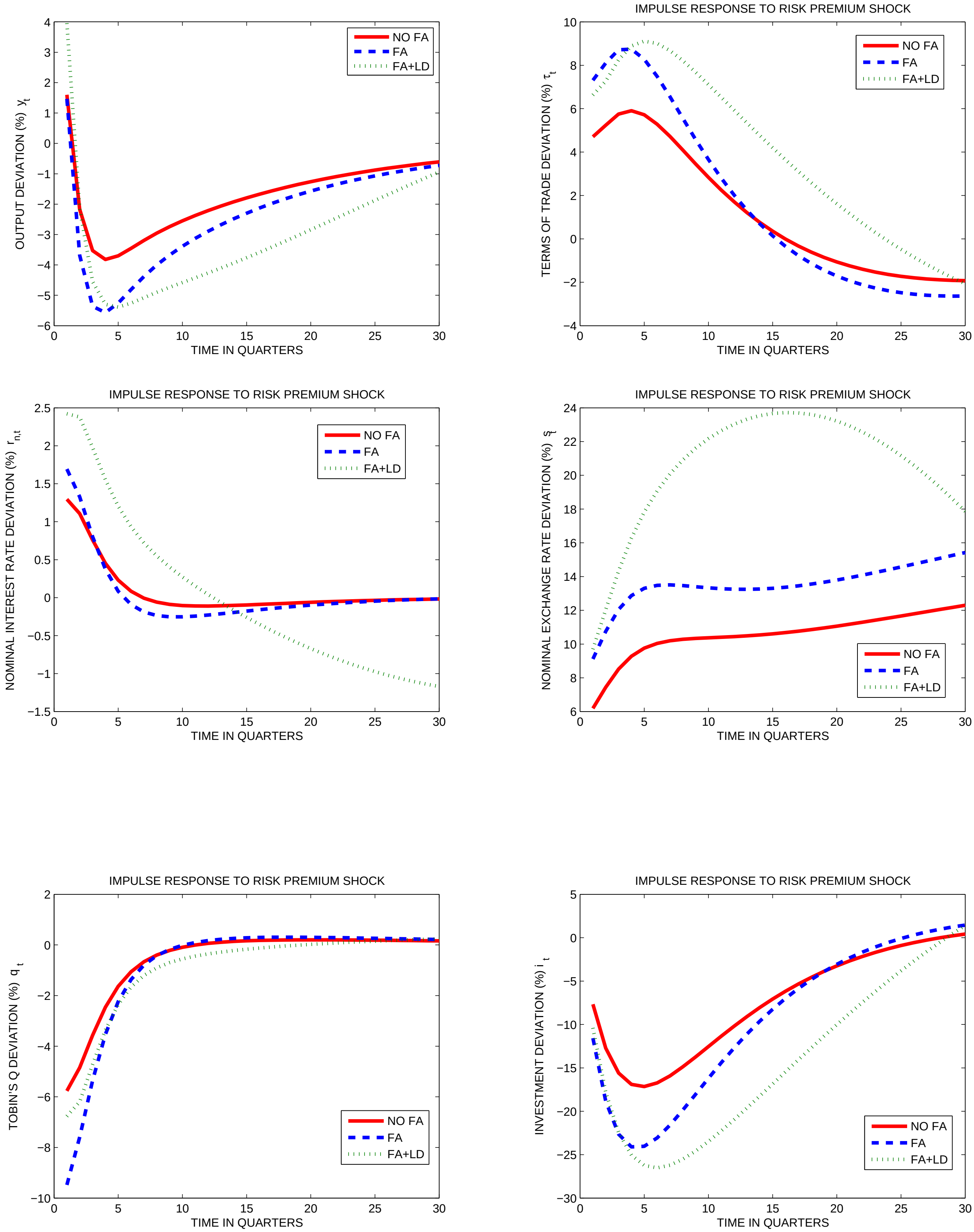

Figure 3: **A Credit Crunch: Impulse Responses to a 1% External Finance Premium AR1 Shock** $\epsilon_{P,t+1} = 0.95\epsilon_{P,t}$**.**