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"Monetary and Fiscal Rules in an Emerging Small Open Economy"

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and Joseph Pearlman

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Abstract

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We develop a optimal rules-based interpretation of the 'three pillars macroeconomic policy framework': a combination of a freely floating exchange rate, an explicit target for inflation, and a mechanism than ensures a stable government debt-GDP ratio around a specified long run. We show how such monetary-fiscal rules need to be adjusted to accommodate specific features of emerging market economies. The model takes the form of two-blocs, a DSGE emerging small open economy interacting with the rest of the world and features, in particular, financial frictions It is calibrated using Chile and US data. Alongside the optimal Ramsey policy benchmark, we model the three pillars as simple monetary and fiscal rules including and both domestic and CPI inflation targeting interest rate rules alongside a 'Structural Surplus Fiscal Rule' as followed recently in Chile. A comparison with a fixed exchange rate regime is made. We find that domestic inflation targeting is superior to partially or implicitly (through a CPI inflation target) or fully attempting to stabilizing the exchange rate. Financial frictions require fiscal policy to play a bigger role and lead to an increase in the costs associated with simple rules as opposed to the fully optimal policy.

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I. INTRODUCTION

Over the past decade, key emerging markets including Brazil, Chile, the Czech Republic, Mexico and South Africa,have adopted sound macroeconomic frameworks that have made them more resilient to domestic and external economic shocks. Many of these frameworks are characterized by 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.

In this paper we develop a optimal rules-based interpretation of the "three pillars" and show how such monetary-fiscal rules need to be adjusted to accommodate specific features of emerging market small open economies (SOEs). Such emerging SOEs face substantially different policy issues from those of advanced, larger, more closed economies. The price of consumer goods depends on the exchange rate and exporting firms typically set their prices in foreign currency and bear the risk of currency fluctuations. They often borrow from international capital markets in foreign currency, so that debt repayment is similarly affected. Foreign shocks have significant effects on the domestic economy. Thus, we expect monetary and fiscal policy prescriptions in a emerging SOE to be fundamentally different from those in a advanced closed economy.

There is a large literature on optimal monetary and fiscal policy in response to exogenous shocks; Kirsonova et al. (2006); Schmitt-Grohe et al. (2007); Chadha et al. (2007); and Leith et al. (2007) are some recent examples for the closed economy; Wren-Lewis (2007) provides an insightful overview. We depart from these works in three principal ways. First, our focus is on a small open economy (SOE). Second, we want to consider an emerging economy where frictions and distortions are quantitatively important. To this end, we introduce financial frictions in the form of a "financial accelerator". Finally we will impose a zero lower bound (ZLB) constraint on the nominal interest rate that limits its variability and increases the role for fiscal stabilization policy, a feature again absent in almost all the literature Schmitt-Grohe et al. (2007) is an exception).

We build a two-bloc DSGE emerging markets SOE - rest of the world model to examine the implications of financial frictions for the relative contributions of optimal Ramsey fiscal and monetary stabilization policy and the simple rules that will, as far as possible, mimic the Ramsey policy. Alongside standard features of SOE economies such as local

currency pricing for exporters, a commodity sector, oil imports, our model incorporates liability dollarization,[1] as well as financial frictions including a financial accelerator, where capital financing is partly or totally in foreign currency as in Gertler et al. (2003) and Gilchrist (2003). The model is calibrated to Chile and US data and uses estimates of shock processes taken from Medina et al. (2007b).

The rest of the paper is organized as follows. Section 2 presents the model. Sections 3 and 4 set out the form of monetary and fiscal rules under investigation. Section 5 addresses the requirement that monetary rules should be 'operational' in the sense that, in the face of shocks, the zero lower bound constraint on the nominal interest rate is very rarely hit. In Section 6 we examine the benchmark Ramsey policy as first the financial accelerator and then liability dollarization are introduced. In section 7 we derive and compare alternative simple monetary and fiscal policy rules including the 'Structural Fiscal Stability Rule' (SFSR) followed by Chile.[2] Section 8 provides concluding remarks.

II.   THE MODEL

We start from a standard two-bloc microfounded model along the lines of Obstfeld and Rogoff (1995) to then incorporate many of the nominal and real frictions that have been shown to be empirically important in the study of closed economies (e.g. Smets and Wouters, 2003). The blocs are asymmetric and unequally-sized, each one with different household preferences and technologies. The single SOE then emerges as the limit when the relative size of the larger bloc tends to infinity. Households work, save and consume tradable goods produced both at home and abroad. At home there are three types of firms: wholesale, retail and capital producers. As in Gertler et al. (2003), wholesale firms borrow from households to buy capital used in production and capital producers build new capital in response to the demand of wholesalers. Wholesalers' demand for

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[1] The proportion of corporate-sector dollar-denominated liabilities in Latin American countries in 2001 ranged from 21% in Chile to 78% in Uruguay (see Armas et al. (2006), chapter 4, Table 4.10).

[2] Although the message of the paper is a general one aimed at emerging SOEs, at the same time in our calibration and study of the SFSR it has a particular focus on Chile. Following a series of reforms begun in the early 1990s, Chile now has a forward-looking and transparent macroeconomic framework centered on three pillars: an explicit target for inflation, a floating exchange rate and a fiscal rule, the SFSR, that targets a structural surplus of 0.5% of GDP aimed at eliminating the pro-cyclical bias of fiscal policy. This framework is examined in this paper with a more general interpretation of the third, fiscal pillar.

capital in turn depends on their financial position which varies inversely with wholesalers' net worth. Retailers engage in local currency pricing for exports, there is a commodity (that throughout we refer for simplicity as "copper") sector and oil imports enter into consumption and production.

There are three departures from the standard open-economy model that lead to interesting results. First, money enters utility in a non-separable way and results in a direct impact of the interest rate on the supply side.[3] Second, along the lines of Gilchrist (2003) (see also Cespedes et al (2004)), firms face an external finance premium that increases with leverage and 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. Although not all emerging markets face this constraint, many have in the past and still do, for example Peru, where a great proportion of borrowing by firms continues to be in U.S. dollars–a phenomenon dubbed "liability dollarization". Finally, there are frictions in the world financial markets facing households as in Benigno (2001). Departures two and three add an additional dimensions to openness.[4] Details of the model are as follows.

A.   Households

Normalizing the total population to be unity, there are ν households in the "home", emerging economy bloc and $(1 - \nu)$ households in the "foreign" bloc. A representative household h in the home country maximizes

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

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), $M_t(h)$ is the end-of-period holding of nominal domestic money balances, P_t is a Dixit-Stiglitz price index defined in (14) below, and $L_t(h)$ are hours worked. An

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[3]See Woodford (2003), Chapter 4. A "cost channel", as in Ravenna et al. (2006), has a similar supply-side effect on the Phillips curve.

[4]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.

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 risk-free 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 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:

$$(1 + \tau_{C,t})P_t C_t(h) + P_{B,t}B_{H,t}(h) + P_{B,t}^* S_t B_{F,t}(h) + M_t(h) + TF_t$$
$$= W_t(h)(1 - \tau_{L,t}))L_t(h) + B_{H,t-1}(h) + S_t B_{F,t-1}(h) + M_{t-1}(h)$$
$$+ (1 - \tau_{\Gamma,t})\Gamma_t(h) + P_t^C(1 - \tau_{cop})(1 - \chi)\overline{COP}_t(h) \tag{3}$$

where $W_t(h)$ is the wage rate, TF_t are flat rate taxes net of transfers, $\tau_{L,t}$ and $\tau_{\Gamma,t}$ are labor income and profits tax rates respectively and $\Gamma_t(h)$, dividends from ownership of firms, P_t^C is the price of copper), $(1 - \chi)\overline{COP}_t(h)$ is an exogenous endowment of copper owned by household h, χ being the overall share of the government and τ_{cop} is the tax rate on copper income. In addition, if we assume that households' labor 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

$(1-n)$ respectively, again normalizing the total number of goods in the world at unity. We also assume that the the ratio of households to firms are the same in each bloc. It follows that n and $(1-n)$ (or ν and $(1-\nu)$) 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,

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

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

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 2.2.2.[5] Weights in the consumption baskets in the two blocs are defined by

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

In (7), $\omega, \omega^* \in [0,1]$ 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 $\mathrm{w} \to \omega$ and $\mathrm{w}^* \to 1$. Thus the foreign bloc becomes closed, but as long as there is a

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[5]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.

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:

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

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

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

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

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

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

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 so that $\frac{S_t P_{F,t}^*}{P_{F,t}} = \frac{S_t P_{H,t}^*}{P_{H,t}} = 1$. Then it follows that the real exchange rate $RER_t = \frac{S_t P_t^*}{P_t}$. 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

$$RER_{Z,t} \equiv \frac{S_t P_{Z,t}^*}{P_t} = \frac{\left[w_Z^* + (1 - w_Z^*)\mathcal{T}_t^{\mu_Z^* - 1}\right]^{\frac{1}{1-\mu_Z^*}}}{\left[1 - w_Z + w_Z \mathcal{T}_t^{\mu_Z - 1}\right]^{\frac{1}{1-\mu_Z}}} \tag{15}$$

$$RER_t \equiv \frac{S_t P_t^*}{P_t} = RER_{Z,t} \frac{\left[w_C^* + (1 - w_C^*)\mathcal{O}_t^{\mu_C^* - 1}\right]^{\frac{1}{1-\mu_C^*}}}{\left[w_C + (1 - w_C)\mathcal{O}_t^{\mu_C - 1}\right]^{\frac{1}{1-\mu_C}}} \tag{16}$$

$$\mathcal{O}_t \equiv \frac{P_{O,t}}{P_{Z,t}} \tag{17}$$

Thus if $\mu = \mu^*$, then $RER_t = 1$ and the law of one price applies to the aggregate price indices iff $w^* = 1 - w$. The latter condition holds if there is no home bias. 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:

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

$$U_{M_H,t} = U_{C,t} \left[\frac{R_{n,t}}{1 + R_{n,t}} \right] \tag{19}$$

$$U_{M_F,t} = U_{C,t} \left[\frac{R_{n,t}^*}{1 + R_{n,t}^*} \right] \tag{20}$$

$$\frac{W_t(1 - \tau_{L,t})}{P_t(1 + \tau_{C,t})} = -\frac{\eta}{(\eta - 1)} \frac{U_{L,t}}{U_{C,t}} \tag{21}$$

where $U_{C,t}$, $U_{M_H,t}$, $U_{M_F,t}$ and $-U_{L,t}$ are the marginal utility of consumption, money holdings in the two currencies and the marginal disutility of work respectively. $\tau_{C,t}$ is a consumption tax rate. Taking expectations of (18), the familiar Keynes-Ramsey rule, and its foreign counterpart, we arrive at the *modified UIP condition*

$$\frac{P_{B,t}}{P_{B,t}^*} = \frac{E_t \left[U_{C,t+1} \frac{P_t}{P_{t+1}} \right]}{E_t \left[U_{C,t+1} \frac{S_{t+1} P_t}{S_t P_{t+1}} \right]} \tag{22}$$

In (19), the demand for money balances depends positively on the marginal utility of

consumption and negatively on the nominal interest rate. If, as is common in the literature, one adopts a utility function that is separable in money holdings, then given the central bank's setting of the latter and ignoring seignorage in the government budget constraint money demand is completely recursive to the rest of the system describing our macro-model. However separable utility functions are implausible (see Woodford 2003,chapter 3, section 3.4) and following Felices et al. (2006) we will not go down this route. Finally, in (21) 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.

1. Rule of Thumb (RT) Households

Suppose now there are two groups of household, a fixed proportion $1 - \lambda$ without credit constraints and the remaining proportion λ who consume out of post-tax income. Let $C_{1,t}(h)$, $W_{1,t}(h)$ and $L_{1,t}(h)$ be the per capita consumption, wage rate and labor supply respectively for this latter 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 $L_{2,t}(h)$. We then have the budget constraint of the RT consumers

$$P_t(1 + \tau_{C,t})C_{1,t}(h) = (1 - \tau_{L,t})W_{1,t}(h)L_{1,t}(r) + TF_{1,t} \qquad (23)$$

where $TF_{1,t}$ is net flat-rate *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

$$C_{1H,t}(h) = \text{w}\left(\frac{P_{H,t}}{P_t}\right)^{-\mu} C_{1,t}(h); \;\; C_{1F,t}(h) = (1 - \text{w})\left(\frac{P_{F,t}}{P_t}\right)^{-\mu} C_{1,t}(h) \qquad (24)$$

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

$$C_t = \lambda C_{1,t} + (1 - \lambda) C_{2,t} \tag{25}$$

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

B. Firms

There are three types of firms, wholesale, retail and capital producers. Wholesale firms are run by risk-neutral entrepreneurs who purchase capital and employ household labor 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 good at no resource cost and sell the differentiated (re-packaged) goods to households. The capital goods sector is competitive and converts the final good into capital. The details are as follows.

1. Wholesale Firms

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

$$Y_t^W = A_t K_t^{\alpha_1} L_t^{\alpha_2} (\text{OIL}_t)^{\alpha_3} (\text{COP}_t)^{1-\alpha_1-\alpha_2-\alpha_3} \tag{26}$$

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

$$L_t = \left[\left(\frac{1}{\nu} \right)^{\frac{1}{\eta}} \sum_{r=1}^{\nu} L_t(h)^{(\eta-1)/\eta} \right]^{\eta/(\eta-1)} \tag{27}$$

where we recall that $L_t(h)$ is the labor input of type h, A_t is an exogenous shock capturing shifts to trend total factor productivity in this sector. The latter will provide the source of demand for copper shock that feeds into its world price.[6] Minimizing wage

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[6]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.

costs $\sum_{h=1}^{\nu} W_t(h)L_t(h)$ gives the demand for each household's labor as

$$L_t(h) = \left(\frac{W_t(h)}{W_t}\right)^{-\eta} L_t \tag{28}$$

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

$$W_t = P_{H,t}^W \alpha_2 \frac{Y_t^W}{L_t} \tag{29}$$

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

$$P_{O,t} = P_{H,t}^W \alpha_3 \frac{Y_t^W}{\text{OIL}_t} \tag{30}$$

$$P_{C,t} = P_{H,t}^W (1 - \alpha_1 - \alpha_2 - \alpha_3) \frac{Y_t^W}{\text{COP}_t} \tag{31}$$

Let Q_t be the real market price of capital in units of total household consumption. Then noting that profits per period are $P_{H,t}^W Y_t - W_t L_t - P_{O,t}\text{OIL}_t - P_{C,t}\text{COP}_t = \alpha_1 P_{H,t}^W Y_t$, using (29), the expected return on capital, acquired at the beginning of period t, net of depreciation, over the period is given by

$$E_t(1 + R_t^k) = \frac{\frac{P_{H,t}^W}{P_t}\alpha_1 \frac{Y_t}{K_t} + (1 - \delta)E_t[Q_{t+1}]}{Q_t} \tag{32}$$

where 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.[7] Wholesale firms borrow in both home and foreign currency, with exogenously given proportion[8] of the former given by $\varphi \in [0, 1]$, so that this expected cost is

$$(1 + \Theta_t)\varphi E_t\left[(1 + R_{n,t})\frac{P_t}{P_{t+1}}\right] + (1 + \Theta_t)(1 - \varphi)E_t\left[(1 + R_{n,t}^*)\frac{P_t^*}{P_{t+1}^*}\frac{RER_{t+1}}{RER_t}\right]$$

$$= (1 + \Theta_t)\left[\varphi E_t\left[(1 + R_t)\right] + (1 - \varphi)E_t\left[(1 + R_t^*)\frac{RER_{t+1}}{RER_t}\right]\right] \tag{33}$$

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

[8]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 (33), $RER_t \equiv \frac{P_t^* S_t}{P_t}$ 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

$$\Theta_t = \Theta\left(\frac{B_t}{N_t}\right) ; \ \Theta'(\cdot) > 0, \ \Theta(0) = 0, \ \Theta(\infty) = \infty \tag{34}$$

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. Note that the *ex post* return at the beginning of period t, R_{t-1}^k, is given by

$$1 + R_{t-1}^k = \frac{\frac{P_{H,t-1}^W}{P_{t-1}}\alpha_1 \frac{Y_{t-1}}{K_{t-1}} + (1 - \delta)Q_t}{Q_{t-1}} \tag{35}$$

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

$$N_t = \xi_e V_t \tag{36}$$

where V_t the net value carried over from the previous period is given by

$$
\begin{aligned}
V_t &= \Big[(1 + (1 - \tau_{t-1}^k)R_{t-1}^k)Q_{t-1}K_{t-1} \\
&\quad - (1 + \Theta_{t-1})\left(\varphi(1 + R_{t-1}) + (1 - \varphi)(1 + R_{t-1}^*)\frac{RER_t}{RER_{t-1}}\right)(Q_{t-1}K_{t-1} - N_{t-1})\Big]
\end{aligned}
\tag{37}
$$

where τ_t^k is the tax rate applied to capital returns. Note that in (37), $(1 + R_{t-1}^k)$ is the ex post pre-tax 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.

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

$$C_t^e = (1 - \xi_e)V_t \tag{38}$$

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

respectively by

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

$$
C^e_{Z,t} = \mathrm{w}_C \left(\frac{P_{Z,t}}{P_t} \right)^{-\mu_C} C^e_t \tag{40}
$$

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 $Y_t(f) = Y^W_t(f) - F$ where Y^W_t is produced according to production technology (26). We provide a general set-up in which a fixed proportion $1 - \theta$ of retailers set prices in the Home currency (producer currency pricers, PCP) and a proportion θ set prices in the dollars (local currency pricers, LCP).[9] In the model used for the policy exercises we assume LCP only ($\theta = 1$). Details are as follows:

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.[10] For each producer f the objective is at time t to choose $\hat{P}_{H,t}(f)$ to maximize discounted profits

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

where $D_{t,t+k}$ is the discount factor over the interval $[t, t + k]$, subject to a common[11] downward sloping demand from domestic consumers and foreign importers of elasticity

---

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

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

[11]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.

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

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

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

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

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

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

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 $P^{*\,p}_{H,t}(f) = \frac{P_{H,t}(f)}{S_t}$.

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

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

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

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

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

$$P_{F,t} = S_t P^*_{F,t} \qquad (46)$$

Table 1 summarizes the notation used.

5. Capital Producers

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

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

This captures the ideas that adjustment costs are associated with *changes* rather than *levels* of investment.[12] Gross investment consists of domestic and foreign final goods

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

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

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

with investment price given by

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

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:

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

The capital producing firm at time 0 then maximizes expected discounted profits[13]

---

[12]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 $S(1 + g) = S'(1 + g) = 0$.

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

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

which results in the first-order condition

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

C. The Government Budget Constraint and Foreign Asset Accumulation

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

$$P_{B,t}B_{G,t} + M_t = B_{G,t-1} + P_{H,t}G_t - T_t + M_{t-1}$$
(53)

Taxes are levied on labor income, monopolistic profits, consumption, capital returns and copper revenue at rates $\tau_{L,t}$, τ_{Γ}, $\tau_{C,t}$, $\tau_{K,t}$ and $\tau_{cop,t}$ respectively. In the copper market, copper supply is an exogenous endowment given by $\overline{\text{COP}}_t$ and $\overline{\text{COP}}_t^*$ in the home and ROW blocs respectively. The government owns a share χ of the copper sector, but taxes this public firm at the same rate $\tau_{cop,t}$. Then adding flat rate taxes[14] levied on all consumers, $\text{TF}_{2,t}$, and subtracting net flat rate transfers to the constrained consumers, $\text{TF}_{1,t}$, per capita total taxation net of transfers is given

$$
\begin{aligned}
T_t &= \tau_{L,t}W_tL_t + \tau_{\Gamma,t}\Gamma_t + \tau_{C,t}P_tC_t - \lambda\text{TF}_{1,t} + (1-\lambda)\text{TF}_{2,t} + \tau_{K,t}R_{t-1}^k P_tQ_tK_t \\
&+ \tau_{cop,t}P_{C,t}\overline{\text{COP}}_t
\end{aligned}
$$
(54)

In what follow we take flat rate 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 $T_t^I = -\lambda\text{TF}_{1,t} + (1-\lambda)\text{TF}_{2,t}$ and remaining taxes which change endogenously, T_t^{NI}.

---

[14]If tax rates are held fixed, then the "flat rate tax" can be considered to be minus the income tax rate times the threshold at which labor income tax starts to operate. An decrease in the threshold is then equivalent to an increase in a flat rate tax.

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. A 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.[15] Summing over the household budget constraints (including entrepreneurs and capital producers), and subtracting (53), we arrive at the accumulation of net foreign assets:

$$
\begin{aligned}
P_{B,t}B_t &= B_{t-1} + W_t L_t + \Gamma_t + (1 - \xi_e)P_t V_t + P_t Q_t(1 - S(X_t))I_t + P_{C,t}\overline{\text{COP}}_t \\
&- P_t C_t - P_t C_t^e - P_{I,t}I_t - P_{H,t}G_t - P_{O,t}\text{OIL}_t - P_{C,t}\text{COP}_t \\
&\equiv B_{t-1} + TB_t
\end{aligned}
\tag{55}
$$

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

$$
P_{C,t}\overline{\text{COP}}_t + P_{H,t}Y_t - P_{O,t}\text{OIL}_t - P_{C,t}\text{COP}_t = P_t C_t + P_t C_t^e + P_{I,t}I_t + P_{H,t}G_t + \text{TB}_t \tag{56}
$$

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.

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

$$
\begin{aligned}
&(1 + \tau_{C,t})P_t C_{2,t} + P_{B,t}\frac{B_t}{1 - \lambda} + TF_{2,t} \\
&= W_t(1 - \tau_{L,t}))L_t(h) + \frac{B_{t-1}}{1 - \lambda} + \frac{T_t - P_{H,t}G_t}{1 - \lambda} + + \frac{(1 - \tau_{\Gamma,t})}{1 - \lambda}\Gamma_t + \frac{P_{C,t}(1 - \tau_{cop})(1 - \chi)\overline{COP}_t}{1 - \lambda}
\end{aligned}
$$

Then using (23) and (55), we arrive at

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

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 $(T > P_H G)$. 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 and income from copper firms since they are assumed to also be exclusively owned by unconstrained consumers. On the other hand flat rate transfers to constrained consumers plus flat rate taxes on unconstrained consumers, $-\lambda TF_{1,t} + (1 - \lambda)TF_{2,t}$ tend to lower the consumption gap.

D.   The Equilibrium

In equilibrium, final goods markets, the copper market, 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[16]

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

The law of one price applies in the copper market so we have

$$S_t P_t^{C\,*} = P_{C,t} \tag{59}$$

In this set-up, copper price shocks originate in shocks to copper supply. Other shocks are to technology in wholesale goods sectors, government spending in the two blocs, the interest rate rule in the foreign bloc and to the risk premia facing unconstrained households, in the modified UIP condition (22) and facing wholesale firms in their external finance premium given by (34). Following Medina et al. (2007b) we assume Chile is a small copper producer relative to world supply and therefore faces an exogenous copper price in dollars. The real price in dollars follows a process

$$\log \left(\frac{P_{t+1}^{C\,*}}{P_{t+1}^*} \right) = \rho_{cop} \log \left(\frac{P_t^{C*}}{P_t^*} \right) + v_{cop,t+1} \tag{60}$$

---

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

The rationale for this modeling strategy is that whereas the rest of the world is reasonably captured by a US type economy for determining demand for non-copper exports, this is less plausible when it comes to copper exports where the two large emerging economies China and India are increasingly influential.

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, $P_{C,t}$, 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.

E.   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 et al. (2004), chapter 9, this requires a careful choice of the form of the utility as a function of consumption and labor effort. As in Gertler et al (2003), it is achieved by a utility function which is non-separable. A utility function of the form

$$U \equiv \frac{[\Phi(h)^{1-\varrho}(1 - L_t(h))^\varrho]^{1-\sigma}}{1-\sigma} \tag{61}$$

where

$$\Phi_t(h) \equiv \left[b(C_t(h) - h_C C_{t-1})^{\frac{\theta-1}{\theta}} + (1-b)\left(\frac{M_t}{P_t}\right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} \tag{62}$$

and where labor supply, $L_t(h)$, is measured as a proportion of a day, normalized at unity, satisfies this requirement.[17] For this function, $U_{\Phi L} > 0$ so that consumption and money holdings together, and leisure (equal to $1 - L_t(h)$) are substitutes.

---

[17]A BGP requires that the real wage, real money balances and consumption grow at the same rate at the steady state with labor supply constant. It is straightforward to show that (61) has these properties.

F.   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

$$
\begin{bmatrix} \mathsf{z}_{t+1} \\ E_t \mathsf{x}_{t+1} \end{bmatrix} = A \begin{bmatrix} \mathsf{z}_t \\ \mathsf{x}_t \end{bmatrix} + B \mathsf{o}_t + C \begin{bmatrix} r_{n,t} \\ r_{n,t}^* \end{bmatrix} + D \mathsf{v}_{t+1}
$$

$$
\mathsf{o_t} = H \begin{bmatrix} \mathsf{z}_t \\ \mathsf{x}_t \end{bmatrix} + J \begin{bmatrix} r_{n,t} \\ r_{n,t}^* \\ tr_t \\ tr_t^* \end{bmatrix} \tag{63}
$$

where z_t is a vector of predetermined exogenous variables, x_t are non-predetermined variables, and o_t is a vector of outputs.[18] Matrices A, B, etc are functions of model parameters. Rational expectations are formed assuming an information set $\{z_{1,s}, z_{2,s}, x_s\}$, $s \le t$, the model and the monetary rule. Details of the linearization are provided in Appendix B.

G.   The Small Open Economy

Following Felices et al. (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 modeled 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 $\mathsf{w} \to \omega$ and $\mathsf{w}^* \to 1$ as $n \to 0$. Similarly for investment we have $\mathsf{w}_I \to \omega_I$ and $\mathsf{w}_I^* \to 1$ 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

---

[18]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, $x_t = X_t - X$.

equations in the two blocs:

$$
\begin{aligned}
y_t &= \alpha_{C,H} c_{Z,t} + \alpha_{C,H}^e c_{Z,t}^e + \alpha_{C,H}^* c_{Z,t}^* + \alpha_{I,H} i_t + \alpha_{I,H}^* i_t^* + \alpha_G g_t \\
&\quad + \; [\mu(\alpha_{C,H} + \alpha_{C,H}^e)(1 - \mathrm{w}_Z) + \mu^* \alpha_{C,H}^* \mathrm{w}_Z^* + \rho_I \alpha_{I,H}(1 - \mathrm{w}_I) + \rho_I^* \alpha_{I,H}^* \mathrm{w}_I^*] \tau_t \quad (64) \\
y_t^* &= \alpha_{C,F}^* c_{Z,t}^* + \alpha_{C,F} c_{Z,t} + \alpha_{C,F}^e c_t^e + \alpha_{I,F}^* i_t^* + \alpha_{I,F} i_t + \alpha_G^* g_t^* \\
&\quad - \; [\mu^*(\alpha_{C,F}^*(1 - \mathrm{w}_Z^*) + \mu \alpha_{C,F} \mathrm{w}_Z + \rho_I^* \alpha_{I,F}^*(1 - \mathrm{w}_I^*) + \rho_I \alpha_{I,F} \mathrm{w}_I] \tau_t \quad (65)
\end{aligned}
$$

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

$$
\begin{aligned}
\alpha_{C,H} &= \frac{\mathrm{w}(1 - s_e)C}{Y} \to \frac{\omega(1 - s_e)C}{Y} \\[2mm]
\alpha_{C,H}^e &= \frac{\mathrm{w} s_e C}{Y} \to \frac{\omega s_e C}{Y} \\[2mm]
\alpha_{C,H}^* &= \frac{(1 - \mathrm{w}^*)C^*}{Y^*} \frac{(1 - n)Y^*}{nY} \to \frac{(1 - \omega^*)C^*}{Y^*} \frac{Y^*}{Y} \\[2mm]
\alpha_G &= \frac{G}{Y} \\[2mm]
\alpha_{I,H} &= \frac{\mathrm{w}_I I}{Y} \to \frac{\omega_I I}{Y} \\[2mm]
\alpha_{I,H}^* &= \frac{(1 - \mathrm{w}_I^*)I^*}{Y^*} \frac{(1 - n)Y^*}{nY} \to \frac{(1 - \omega_I^*)I^*}{Y^*} \frac{Y^*}{Y} \\[2mm]
\alpha_{C,F}^* &= \frac{\mathrm{w}^* C^*}{Y^*} \to \frac{C^*}{Y^*} \\[2mm]
\alpha_{C,F}^{e\,*} &= 0 \\[2mm]
\alpha_{C,F} &= \frac{(1 - \mathrm{w})C}{Y} \frac{nY}{(1 - n)Y^*} \to 0 \\[2mm]
\alpha_{C,F}^e &= \frac{(1 - \mathrm{w})(1 - \xi^e)n_k k_y}{\xi_e} \frac{nY}{(1 - n)Y^*} \to 0 \\[2mm]
\alpha_G^* &= \frac{G^*}{Y^*} \\[2mm]
\alpha_{I,F}^* &= \frac{\mathrm{w}_I^* I^*}{Y^*} \to \frac{I^*}{Y^*} \\[2mm]
\alpha_{I,F} &= \frac{(1 - \mathrm{w}_I)I}{Y^*} \frac{nY}{(1 - n)Y^*} \to 0
\end{aligned}
$$

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 modeled explicitly in a way that captures all the interactions between shocks in the ROW and the transmission to the SOE.

H. Calibration

1. 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

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

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

$$
cs_{imports} + is_{imports} = cs_{exports} + is_{exports} \tag{66}
$$

in which case $\alpha_{C,H} + \alpha_{C,H}^e + \alpha_{C,H}^* + \alpha_{I,H} + \alpha_{I,H}^* = c_y + i_y$ 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.   Calibration of Household Preference Parameters

We now show how observed data on the household wage bill as a proportion of total consumption, real money balances as a proportion of consumption and estimates of the elasticity of the marginal utility of consumption with respect to total money balances can be used to calibrate the preference parameters ϱ, b and θ in (61).

Calibrating parameters to the BG steady state, we first note that from (21) we have

$$\frac{(\eta - 1)}{\eta} \frac{W(1 - L)}{PC} = \frac{\varrho \Phi}{C\Phi_C(1 - \varrho)} \tag{67}$$

In (67), $\frac{WL}{PC}$ is the household wage bill as a proportion of total consumption, which is observable. From the definition of Φ in (62), we have that

$$\frac{\Phi}{C\Phi_C} = \frac{(1 - b)cz^{\frac{1-\theta}{\theta}} + b}{b} \tag{68}$$

where $cz \equiv \frac{C(1-h_C)}{Z}$ is the "effective-consumption" –real money balance ratio (allowing for external habit). From (61), the elasticity the marginal utility of consumption with respect to total money balances, Ψ say is given by

$$\frac{ZU_{CZ}}{U_C} \equiv \Psi = \frac{(1 - b)[(1 - \varrho)(1 - \sigma) - 1 + \frac{1}{\theta}]}{bcz^{\frac{\theta-1}{\theta}} + 1 - b} \tag{69}$$

From the first-order conditions in the steady state (A.30) and (??) with $R_n = R_n^* = R$ we have

$$\frac{b(1 - h_C)}{1 - b} cz^{-\frac{1}{\theta}} = \frac{1 + R}{R} \tag{70}$$

Thus given σ, β, g, h_C, $\frac{W(1-L)}{PC}$, cz and Ψ, equations (67)–(70) can be solved for ϱ, b and θ. The calculations for these parameters for the calibrated values of σ, β, g, h_C, $\frac{W(1-L)}{PC}$ and cz are out in Appendix C[19] of $\Psi \in [0, 0.01]$. Since $\Psi > 0$ we impose on our calibration the property that money and consumption are *complements*.

---

[19] See **?**, chapter 2 for a discussion of this parameter.

3. Remaining Parameters

As far as possible parameters are chosen based on quarterly data for Chile. Elsewhere
the parameters reflect broad characteristics of emerging economies. A variety of sources
are used: for Chile we draw upon Kumhof et al. (2008) (KL) and Medina et al. (2007a),
Medina et al. (2007b) (MS). For emerging economies more generally and for parameters
related to the financial accelerator we use Gertler et al. (2003, "GGN") and Bernanke et
al. (1999, "BGG"). The rest of the world is represented by U.S. data. Here we draw upon
Levin et al. (2006) (LOWW). In places we match Chilean with European estimates using
Smets and Wouters (2003) (SW). Appendix C provides full details of the calibration.

III. MONETARY POLICY INTEREST RATE RULES

In line with the literature on open-economy interest rate rules (see, for example, Benigno
et al. (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, "HYB"). Many emerging market countries follow one or
another of these options and most are likely to in the near future. Formally, the rules are:

Fixed Exchange Rate Regime, "FIX". In a simplified model without an exchange rate
premium analyzed in section 4 we show this is implemented by

$$r_{n,t} = r_{n,t}^* + \theta_s s_t \tag{71}$$

where any $\theta_s > 0$ is sufficient to the regime. In our full model with an exchange rate
premium, we implement "FIX" as a "HYB" regime below, with feedback coefficients
chosen to minimize a loss function that includes a large penalty 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:

$$r_{n,t} = \rho r_{n,t-1} + \theta_\pi \pi_{H,t} + \theta_y y_t \tag{72}$$

$$r_{n,t} = \rho r_{n,t-1} + \theta_\pi \pi_t + \theta_y y_t \tag{73}$$

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

Managed Float, "HYB". In this rule the exchange rate response is direct rather than indirect as in the CPI inflation rule, (73):[20]

$$r_{n,t} = \rho r_{n,t-1} + \theta_\pi \pi_{H,t} + \theta_y y_t + \theta_s s_t \tag{74}$$

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 private agents, including economies with a history of high or hyper-inflation (e.g. Brazil, Israel, Peru and Mexico, among others. See IMF (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 et al (2007) or even sudden stops and financial crises (under fixed exchange rates, see IMF (2005)).

---

[20]Rule (73) 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.

IV. FISCAL RULES

First we rewrite the government budget identity (53) in terms of the market price of bonds $\hat{B}_{G,t} = P_{B,t}^* B_{G,t}$ to give

$$\hat{B}_{G,t} = (1 + R_{n,t-1})\hat{B}_{G,t-1} + G_t - T_t \equiv \hat{B}_{G,t-1} - FS_t \tag{75}$$

where FS_t is the fiscal surplus. In terms of GDP ratios this can be written as

$$\frac{\hat{B}_{G,t}}{P_{H,t}Y_t} = (1 + R_{g,t-1})\frac{\hat{B}_{G,t-1}}{P_{H,t}Y_t} + \frac{G_t}{P_{H,t}Y_t} - \frac{T_t}{P_{H,t}Y_t} \equiv \frac{\hat{B}_{G,t-1}}{P_{H,t}Y_t} - \frac{FS_t}{P_{H,t}Y_t} \tag{76}$$

defining a growth-adjusted real interest rate $R_{g,t-1}$ over the interval $[t-1, t]$ by

$$1 + R_{g,t-1} = \frac{1 + R_{n,t-1}}{(1 + \pi_{H,t})(1 + \Delta y_t)} \tag{77}$$

where $\pi_{H,t} \equiv \frac{P_{H,t} - P_{H,t-1}}{P_{H,t-1}}$ is the home price inflation rate and $\Delta y_t \equiv \frac{Y_t - Y_{t-1}}{Y_{t-1}}$ is output growth.

Given a target steady-state government debt-to-GDP ratio $\frac{\hat{B}_G}{P_H Y}$, the steady state primary (PS) and overall fiscal surpluses are given by

$$\frac{PS}{P_H Y} \equiv \frac{(T - G)}{P_H Y} = R_g \frac{\hat{B}_G}{P_H Y} \tag{78}$$

$$\frac{FS}{P_H Y} = \left(\frac{1}{(1 + \pi_H)(1 + g_y)} - 1\right)\frac{\hat{B}_G}{P_H Y} \tag{79}$$

Thus if inflation and growth are zero the steady state fiscal surplus is zero, but if inflation and/or growth are positive, then a steady state *fiscal deficit* (but positive primary surplus) is sustainable.

In the exercises that follow fiscal policy is carried out in using a component of taxation as the instrument, keeping government spending exogenous. Then we can write total tax revenues as a sum of the chosen instrument T_t^I plus remaining non-copper taxes T_t^{NI} which change endogenously at fixed tax rates plus copper revenue TCOP_t ; i.e,.

$$T_t \equiv T_t^I + T_t^{NI} + \text{TCOP}_t \tag{80}$$

where $TCOP_t = \tau_{cop}P_{C,t}\overline{COP}_t$. Since it is desirable to avoid frequent changes of distortionary taxes, our chosen tax instrument consists of flat-rate tax receipts paid by Ricardian households $(1-\lambda)TF_{2,t}$ minus flat-rate transfers to constrained households $\lambda TF_{1,t}$. Thus we have

$$T_t^I = (1-\lambda)\text{TF}_{2,t} - \lambda\text{TF}_{1,t} \tag{81}$$

All other tax rates are kept fixed at their steady-state values.[21]

We consider tax rules that acknowledge the following: while interest rates can be set very frequently, often monthly, fiscal policy is set less frequently and involves an implementation lag. We assume in fact that the fiscal authority set tax rates every two periods (quarters in our calibration) whereas the central bank changes the nominal interest rate every period. This means in quarter t, a state-contingent fiscal policy can only respond to outcomes in quarter $t-1$ or earlier. It follows that the fiscal instrument Taylor-type (fixed feedback) commitment rule that is compatible with a two-period fiscal plan must take one of two forms

$$
\begin{align}
T_t^I &= f\left(\mathsf{X}_{t-1}\right) \tag{82} \\
T_t^I &= f\left(E_{t-1}(\mathsf{X}_t)\right) \tag{83}
\end{align}
$$

where X_t is a vector of macroeconomic variables that define the simple fiscal rule. We can express the rule in terms of adjustments to the two groups of households by writing (81) in linear-deviation form

$$t_t^I = -\frac{\lambda\text{TF}_1}{T^I}\text{tf}_{1,t} + \frac{(1-\lambda)\text{TF}_2}{T^I}\text{tf}_{2,t} \tag{84}$$

where $t_t^I = \frac{T_t^I - T^I}{T^I}$, $\text{tf}_{1,t} = (TF_{1,t} - TF_1)/TF_1$ etc are proportional changes in tax receipts relative to steady state values. We assume that

$$
\begin{align}
\text{tf}_{1,t} - p_{H,t-1} &= -\frac{k}{1-k}(\text{tf}_{2,t} - p_{H,t-1}) \tag{85} \\
\text{tf}_{1,t} - E_{t-1}p_{H,t} &= -\frac{k}{1-k}(\text{tf}_{2,t} - E_{t-1}p_{H,t}) \tag{86}
\end{align}
$$

---

[21]An alternative instrument choice would be government spending. In our welfare-based analysis, this would require us to model the welfare implications of changes in government spending. We have chosen not to undertake this approach, but we anticipate that the results would not change dramatically.

corresponding to forms (82) and (83) respectively. Thus fiscal expansion (contraction) involves reducing (increasing) real taxes for group 2 and increasing (reducing) real transfers to group 1. If $k = 0$ all the adjustment is borne by the unconstrained second group and if $k = 1$ by the constrained first group. In our results we put $k = 0.5$. It remains to specify the rule for $tf_{2,t}$.

A. A Conventional Fiscal Rule

The form of our first fiscal rule is fairly standard: real tax receipts as a proportion of GDP feeds back on government debt as a proportion of GDP, $\frac{\hat{B}_{G,t}}{P_{H,t}Y_t}$, and output, Y_t. 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 corresponding to (82) and (83) is

$$\text{tf}_{2,t} = p_{H,t-1} + (1 + \alpha_y)y_{t-1} + \alpha_{bg}b_{G,t-1} \tag{87}$$

$$\text{tf}_{2,t} = E_{t-1}[p_{H,t} + (1 + \alpha_y)y_t + \alpha_{bg}b_{G,t}] \tag{88}$$

B. The Structural Fiscal Surplus Rule

Chile is a strong commodity exporter, and its fiscal policy is designed to isolate fiscal spending from the large and unpredictable fluctuations in fiscal revenues that can ensue from swings in the price of its main exported commodity. Thus Chile's fiscal rule, based on an explicit target for the structural surplus, is interesting for emerging markets that depend heavily on exports of commodities. In practice, Chile's Structural Fiscal Surplus Rule (SFSR) is a *targeting rule* for the fiscal surplus of the form

$$FS_t = FS + \alpha_{tax}\left(T_t^I - \widehat{T}_t^I + T_t^{NI} - \widehat{T}_t^{NI}\right) + \alpha_{cop}\left(\text{TCOP}_t - \widehat{\text{TCOP}}_t\right) \tag{89}$$

where FS denotes the BGP steady state, α_{tax} and α_{cop} are constant feedback parameters set by the fiscal authority and $\widehat{T}_t^I$, $\widehat{T}_t^{NI}$ and $\widehat{\text{TCOP}}_t$ are revenues 'at potential'; i.e., at *current* tax rates, but steady state levels of the economy.

Noting by definition that $\widehat{T}_t^{NI} = T^{NI}$ (but $\widehat{T}_t^I \neq T^I$) and $\widehat{\text{TCOP}}_t = \text{TCOP}$, we can now combine (76), (80) and (89) to obtain a *fiscal instrument rule* of the form

$$\Delta\left(\frac{T_t^I}{P_{H,t}Y_t}\right) = \frac{\alpha_{tax}}{1-\alpha_{tax}}\Delta\left(\frac{\widehat{T}_t^I}{P_{H,t}Y_t}\right) - \Delta\left(\frac{T_t^{NI}}{P_{H,t}Y_t}\right) - \left(\frac{1-\alpha_{cop}}{1-\alpha_{tax}}\right)\Delta\left(\frac{\text{TCOP}_t}{P_{H,t}Y_t}\right)$$

$$+ \frac{1}{(1-\alpha_{tax})}\Delta\left(\frac{R_{n,t-1}\hat{B}_{G,t-1}}{P_{H,t}Y_t} + \frac{G_t}{P_{H,t}Y_t}\right) \tag{90}$$

where $\Delta X_t \equiv X_t - X$ denotes the deviation of the variable X_t about its BGP steady state. Notice if the instrument is either of the two lump sum taxes/subsidies $TF_{1,t}$ or $TF_{2,t}$ then $\widehat{T}_t^I = T_t^I$ and the rule becomes

$$\Delta\left(\frac{T_t^I}{P_{H,t}Y_t}\right) = -(1-\alpha_{tax})\Delta\left(\frac{T_t^{NI}}{P_{H,t}Y_t}\right) - (1-\alpha_{cop})\Delta\left(\frac{\text{TCOP}_t}{P_{H,t}Y_t}\right)$$

$$+ \Delta\left(\frac{R_{n,t-1}\hat{B}_{G,t-1}}{P_{H,t}Y_t} + \frac{G_t}{P_{H,t}Y_t}\right) \tag{91}$$

Thus for $\alpha_{tax} \in [0,1)$ the rule adjusts the tax instrument in a negative direction in response to a rise in non-instrument tax and copper revenues, but positively to a rise in government spending and interest payments on accumulated debt. With an appropriate choice of $\alpha_{tax} \in [0,1)$, it is the latter feature that stabilizes the government debt-to-GDP ratio about a BGP steady state with $FS_t = FS$.

In linear form the SFSR becomes

$$tr_t^I \equiv \frac{T^I}{P_H Y}(t_t^I - p_{H,t} - y_t)$$

$$= -(1-\alpha_{tax})tr_t^{NI} - (1-\alpha_{cop})tc_t + \left(\frac{1}{\beta(1+g)} - 1\right)b_{G,t-1} + \frac{B_G}{P_H Y}r_{g,t-1} + gr_t \tag{92}$$

where $tr_t^I \equiv \left(\frac{T_t^I}{P_{H,t}Y_t} - \frac{T^I}{P_H Y}\right)$ is the absolute deviation of flat-rate tax receipts as a proportion of GDP with tr_t^I, tc_t, $b_{G,t1}$ and gr_t similarly defined. However this form of the rule requires period-by-period state-contingent changes to the tax instrument. Substituting (84) and (85), the two forms of the rule that allow for a two-period fiscal

planning horizon as in (82) and (83) are

$$
\frac{1}{P_H Y}\left(\frac{k\lambda \text{TF}_1}{(1-k)} + (1-\lambda)\text{TF}_2\right)(\text{tf}_{2,t} - p_{H,t-1}) = \frac{T^I}{P_H Y} y_{t-1} - (1-\alpha_{tax})tr_{t-1}^{NI} - (1-\alpha_{cop})tc_{t-1}
$$
$$
+ \left(\frac{1}{\beta(1+g)} - 1\right) b_{G,t-1} + \frac{B_G}{P_H Y} r_{g,t-1} + gr_{t-1}
$$

(93)

$$
\frac{1}{P_H Y}\left(\frac{k\lambda \text{TF}_1}{(1-k)} + (1-\lambda)\text{TF}_2\right)(\text{tf}_{2,t} - E_{t-1}p_{H,t}) = \frac{T^I}{P_H Y} E_{t-1}y_t - (1-\alpha_{tax})E_{t-1}tr_t^{NI}
$$
$$
- (1-\alpha_{cop})E_{t-1}tc_t + \left(\frac{1}{\beta(1+g)} - 1\right) b_{G,t-1}
$$
$$
+ \frac{B_G}{P_H Y} r_{g,t-1} + E_{t-1}gr_t
$$

(94)

V. IMPOSING THE NOMINAL INTEREST RATE ZERO LOWER BOUND

We now modify our interest-rate rules to approximately impose an interest rate ZLB so that this event hardly ever occurs. Although so far only a few emerging market countries have experienced deflationary episodes (Peru and Israel in 2007 are examples of this), most inflation-targeting emerging market countries have chosen low single digit inflation targets (see IMF, 2005), which makes the design of rules robust to ZLB problems germane. Our quadratic approximation to the single-period loss function can be written as $L_t = y_t' Q y_t$ where $y_t' = [z_t', x_t']'$ 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. (2007), 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[22]. Our approach to the ZLB

---

[22]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

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 et al. (2007), Coenen et al. (2003), Eggertsson et al. (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 $i_t = 0$.

$$\pi^* = \max[z_0(p)\sigma_r - \left(\frac{1}{\beta(1 + g_{u_c})} - 1\right) \times 100, 0] \tag{95}$$

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 π^2 term in (D.30). 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 $1 - p$.

VI.   OPTIMAL MONETARY AND FISCAL POLICY WITH FINANCIAL FRICTIONS

How do financial frictions in emerging market economies affect the transmission mechanism of monetary and fiscal policy and the subsequent contributions of each to stabilization in the face of shocks? To answer this question we parameterize three representations of the model with increasing frictions and solve them subject to the corresponding optimal monetary and fiscal policy rules based on maximizing the household's utility. This then provides a benchmark against which to assess the welfare implications of the fixed-exchange rate regime and various Taylor-type flexible exchange rate rules alongside the fiscal policy.

We adopt a linear-quadratic framework for 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

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interest rate is allowed to become negative, possibly using a scheme proposed by Gesell (1934) and Keynes (1936)

and determinacy of particular rules. The framework also proves useful for addressing the issue of the zero lower bound on the nominal interest rate.

Following Woodford (2003), we adopt a "small distortions" quadratic approximation to the household's single period utility which is 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 labor 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 cancel out and thus justify our small distortions approximation. In fact this is the case in our calibration.[23]

Results obtained below are for a single-period quadratic approximation $L_t = y_t' Q y_t$ 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

$$\Omega_0 = E_t \left[(1 - \beta) \sum_{t=0}^{\infty} \beta^t L_t \right] \tag{96}$$

where

$$
\begin{aligned}
2L_t &= w_c \left(\frac{c_t - h_C c_{t-1}}{1 - h_C} \right)^2 + w_\tau \tau_t^2 + w_{cl} \left(\frac{c_t - h_C c_{t-1}}{1 - h_C} \right) l_t + w_l l_t^2 \\
&+ w_k (k_{t-1} - l_t)^2 - w_{ay} y_t a_t + w_{ci\tau} ci_t \tau_t + w_{cls\tau} cls_t \tau_t + w_\pi \pi_{H,t}^2 \\
ci_t &\equiv \mu \omega (1 - \omega) c_y c_t + \mu (1 - \omega^*) c_y c_t^* + \rho_I \omega_I (1 - \omega_I) i_y i_t + \rho_I^* (1 - \omega_I^*) i_y i_t^* \\
cls_t &\equiv [(1 - \sigma)(1 - \varrho) - 1] \frac{c_t^* - h c_{t-1}^*}{1 - h} - (1 - \sigma) \varrho \frac{L^* l_t^*}{1 - L^*}
\end{aligned}
\tag{97}
$$

and the weights w_c, w_τ, etc are defined in Appendix D. Thus from (97) 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, labor supply l_t, domestic inflation $\pi_{H,t}$ and foreign shocks. There

---

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

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 (96) subject to the model in linear state-space form given by (63), initial conditions on predetermined 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 flat-rate taxes net of transfers. By confining fiscal policy to flat-rate 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).

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 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.($\chi_\theta, \chi_\theta^* < 0$, $\Theta, \Theta^* > 0$, $\epsilon_p, \epsilon_p^* \neq 0$, $\varphi \in [0, 1)$)

We subject all these variants of the model to nine exogenous and independent shocks: 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.

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

$$r^*_{n,t} = \rho^* r^*_{n,t-1} + \theta^*_\pi \pi^*_{F,t} + \theta^*_y y^*_t + \epsilon^*_{r,t} \tag{98}$$

$$tf^*_{2,t} = p^*_{F,t-1} + y^*_{t-1} + \alpha^*_{bg} b^*_{G,t-1} \tag{99}$$

$$\text{tf}^*_{1,t} = p^*_{F,t-1} - (\text{tf}^*_{2,t} - p^*_{F,t-1}) \tag{100}$$

Maximizing the quadratic discounted loss function in the four parameters $\rho^* \in [0,1]$, $\theta^*_\pi \in [1,10]$,[24] 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.[25]

With the foreign bloc now completely specified we turn to policy in the home country. Table 2 sets out the essential features of the outcome under optimal monetary and fiscal policy and their relative contributions to stabilization. There are no ZLB considerations at this stage. We report the the conditional welfare loss from fluctuations in the vicinity of the steady state for optimal monetary and fiscal policy and for monetary policy alone as we progress from model I without a financial accelerator (FA) to model III with the FA alongside liability dollarization (LD). We also report the long-run variance of the interest rate.

To assess the contribution of fiscal stabilization policy we calculate the welfare loss difference between monetary policy alone (Ω^M_0) and monetary and fiscal policy together (Ω^{MF}_0). From Appendix D in consumption equivalent terms this is given by

$$c^{MF}_e = \frac{(\Omega^M_0 - \Omega^{F+M}_0)}{(1-\varrho)(1-h_C)c_y} \times 10^{-2} \ (\%) \tag{101}$$

The results appear to indicate that the stabilization role of fiscal policy is rather small,

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[24]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.

[25]The latter feature is a common one in the DSGE literature - see, for example, Schmitt-Grohe et al (2005).

but increases as financial frictions are introduced. At most in model III with both a FA and LD the consumption equivalent contribution of fiscal policy is at most around 0.1%. However this conclusion is misleading because we have ignored the ZLB constraint. The high variances reported in Table 1 indicate a very frequent violation of this constraint in the model economies under these optimal policies.

A.   Imposing the ZLB

Table 3 imposes the ZLB constraint as described in the previous section. We first consider monetary policy alone. We choose $p = 0.001$. 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 $\Omega_0(0)$. The steady-state inflation rate, π^*, that will ensure the lower bound is reached only with probability $p = 0.001$ is computed using (95). 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 (97) we can write $\bar{\Omega}_0(0) = w_\pi \pi^{*2}$.[26]

The optimal policy 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 $w_r = 3.75$ and the steady state quarterly inflation rises to $\pi^* = 0.29$.

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 4 repeats this exercise for monetary and fiscal policy together. With the benefit of fiscal stabilization policy the ZLB constraint is now more easily imposed at values $w_r = 0.5$ and without any rise in the inflation rate from its zero baseline value. Figure 1

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[26]The ex ante optimal deterministic welfare loss that results from guiding the economy from a zero-inflation steady state to $\pi = \pi^*$ differ from $\bar{\Omega}_0(0)$ (but not by much because the steady-state contributions by far outweighs the transitional one)

presents the same results in graphical form with Figure 2 providing analogous results for Model III.

Finally in this subsection we return to the question of how much stabilization role there is for fiscal policy, but now with the ZLB imposed. Table 5 recalculates the consumption equivalent contribution of fiscal stabilization with a ZLB. We now find this contribution to be significant, rising from $c_e = 0.10\%$ to $c_e = 0.64\%$ as we move from Model I to Model III.
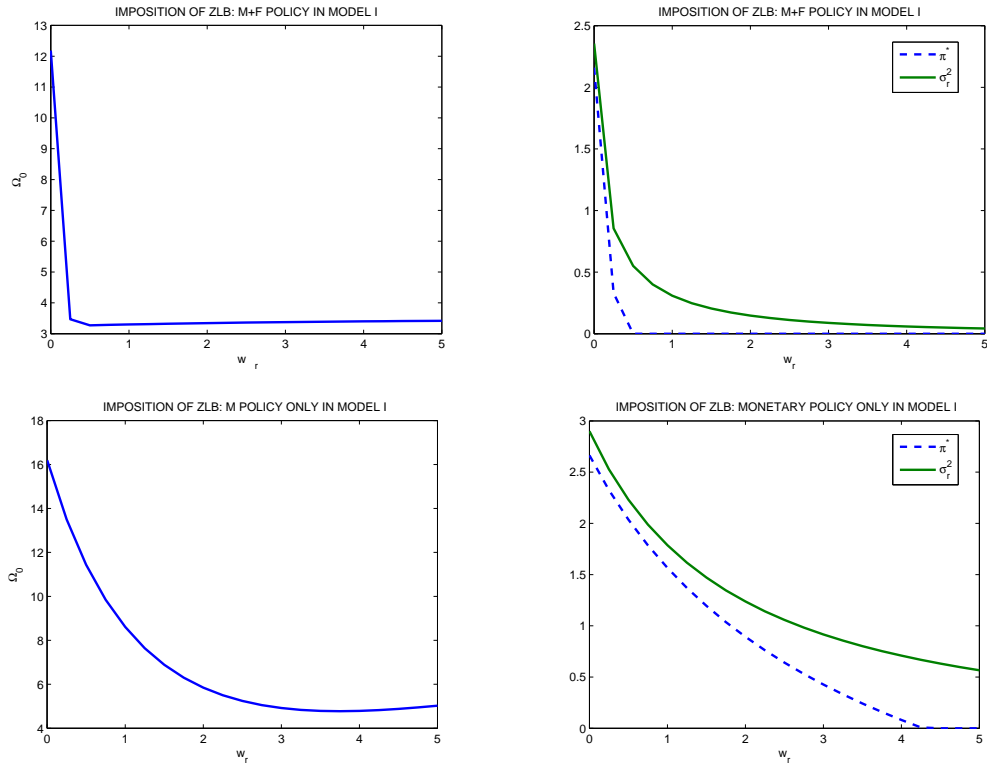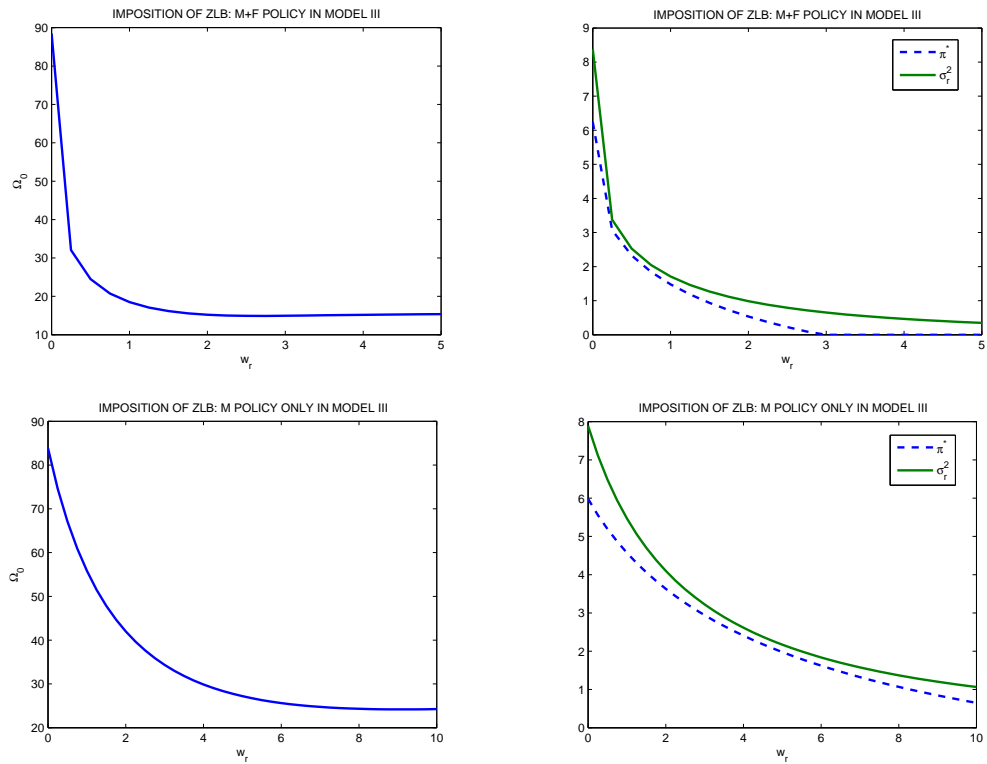
Figure 1. Imposition of ZLB: Model I

Figure 2. Imposition of ZLB: Model III

B. Welfare Decomposition

Which shocks contribute the most to the welfare loss under optimal monetary and fiscal policy? We address this question in the three models by subjecting them to the nine shock processes one at a time. Table 6 shows the 'welfare decomposition' as % contributions to the whole welfare loss when all shocks are present.[27] From the table we see that in Model I (no FA) the home productivity shock and the oil and copper price shocks contribute almost 96% of the loss from fluctuations. In model II with the FA this comes down by about 20%, the contribution from the volatility of the risk premium. Adding LD in model III (with 25% of firms' finance requirements in dollars) has a dramatic effect on the decomposition. Now the contribution of foreign demand (g_t^*) and supply (a_t^*) rise from 2.3% to almost 46%. These shocks impact on the FA through fluctuations in the real exchange rate and consequently net worth if there is LD.

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

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

(102)

where the ex ante cost of capital is given by r_{t-1}^k. In (102) 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_{t-1}^k, 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. Using

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

(103)

and starting at the steady state at $t=0$, from (102) at $t=1$ we then have

$$
n_1 = \frac{\xi_e}{1+g}\Big[(1-\delta)q_1 + \Big(1-\frac{1}{n_k}\Big)(1+\Theta)(1-\varphi)(1+R)rer_1\Big]
$$

(104)

---

[27]This is analogous to a variance decomposition of the effects of each shock on the volatility of output.

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. Output 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 by entrepreneurs.

C. Impulse Responses

Insights into the working of optimal monetary and fiscal policy and of the transmission mechanism can be obtained deriving impulses responses of the model(s) following an unanticipated 1% negative productivity shock in Figure 3. Large welfare losses are associated with inflation so to prevent this happening both monetary and fiscal policy are tightened by raising the nominal interest rate ($r_{n,t}$) and flat rate taxes as a proportion of GDP (t_t^I). As we introduce financial frictions and proceed from model I to model III, monetary policy becomes more constrained by the ZLB and fiscal policy plays a bigger role. Both the nominal and the expected interest rate falls with financial frictions and this offsets the downward effect on investment to some extent. Output falls as a direct result of the fall in productivity and indirectly owing to the fall in capital stock. This downward effect is offset by an increase in labor supply. In models I and II the real exchange rate appreciates, but in model III with LD a drawn out period lasting about 20 quarters sees the nominal interest rate drop below the baseline ($r_{n,t}$ becomes negative) causing both the nominal and real exchange rate to depreciate (rer_t becomes positive). This offsets the negative impact on investment of the FA plus the rise in foreign liabilities denominated in dollars.

Figure 3. Impulse Reponses to a -1% Technology Shock. Models I, II and III.
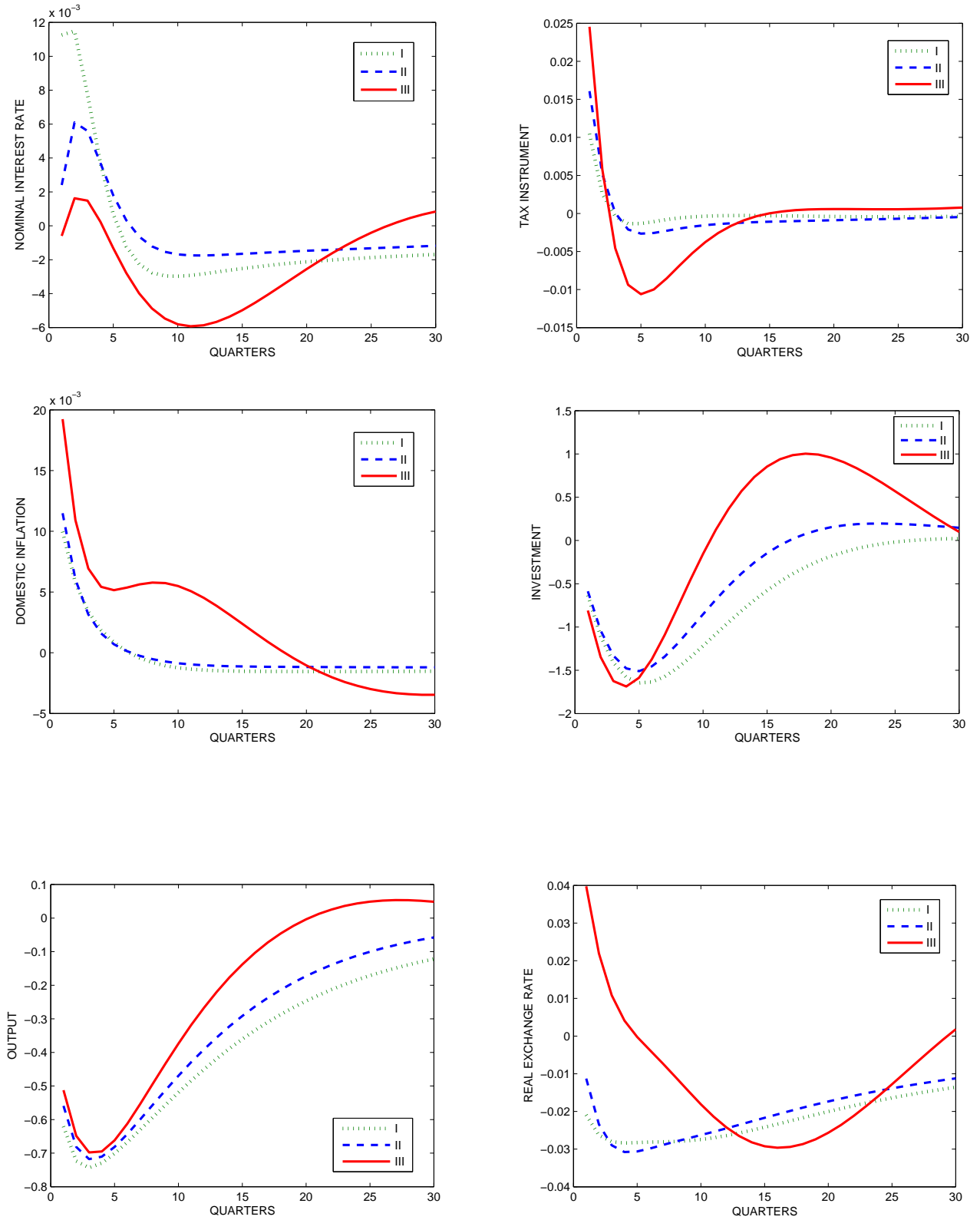
VII. The Performance of Optimized Simple Rules

The optimal monetary and fiscal policy with commitment considered up to now can be implemented as feedback rules but, as now acknowledged in the literature, the form these take is complex and would not be easy to monitor (see for example, Levine et al (1987a), Currie et al.(1993), Woodford (2003)). This point has added force when the need for a planning horizon of more than one period for fiscal policy is introduced into policy design. We therefore turn to simple rules and examine the ranking of various options and the extent to which they can match the fully optimal benchmark. For monetary policy we examine two of the options discussed in section 3: FLEX(D) where the nominal interest rate responds to current domestic inflation, $\pi_{H,t}$ and output, y_t, as in (72); and the fixed exchange rate regime as in (71). In the first set of exercises the fiscal rule is the conventional type of the form (85) (with $k = 0.5$) and (87) which allow tax changes to be planned two periods ahead. We now maximize the quadratic discounted loss function in the five parameters $\rho \in [0,1]$, $\theta_\pi \in [1,10]$, θ_y, α_y, $\alpha_{bg} \in [0,5]$ and impose the ZLB constraint as before.

Table 7 summarizes the outcomes under this combination of rules. In addition to the the measure c_e^{MF} which as before quantifies the the contribution to welfare of fiscal stabilization in consumption equivalent terms, we provide a further measure of the costs of simplicity as opposed to implementing the fully optimal benchmark. Denoting the latter by OPT and any simple rule by SIM, this is given by

$$c_e^{SIM} = \frac{(\Omega_0^{SIM} - \Omega_0^{OPT})}{(1 - \varrho)(1 - h_C)c_y} \times 10^{-2} \ (\%) \tag{105}$$

Using this measure we see from Table 7 that the ability of the optimized simple rule to closely match the fully optimal benchmark deteriorates sharply as financial frictions are introduced rising from 0.12% in Model I to 0.66% and 2.07% in Models II and III respectively. The primary reason for this lies in the existence of a lower bound on σ_r^2 as w_r is increased. This is demonstrated in Figures 4 and 5.

What is the welfare cost of maintaining a fixed rate (FIX) and what are the implications of this regime for fiscal policy? We address these questions by introducing the interest rate rule (71) alongside the same simple fiscal rule as before. Table 8 sets out the

outcome after imposing the ZLB.[28]. Under FIX there is no scope for trading off the variance of the nominal exchange rate with other macroeconomic variances that impact on welfare. Thus the *only* ways of reducing the probability of hitting the lower bound are to shift the stabilization burden onto fiscal policy or increase the steady state inflation rate. This imposes a very large welfare losses[29] in all models which as before increase as financial frictions are introduced. This feature is reflected in the very large costs of simplicity c_e^{MF} which rise from almost 5% to over 11% as we progress from model I to III. The higher values for the measure of the role of fiscal policy, c_e^{MF}, indicate the shift to fiscal means of stabilization.

Of course faced with these results there is an alternative of full dollarization, for example via a currency board, that would simply result in $r_{n,t} = r_{n,t}^*$ and the ZLB then ceases to be a concern for the domestic country. However this would still leave a significant welfare losses only slightly lower that those of the FIX regime. These can be calculated from the purely stochastic components of the welfare loss, $\tilde{\Omega}_0$ and the corresponding consumption equivalent measures $\tilde{c}_e^{MF}$ and $\tilde{c}_e^{SIM}$.

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[28]Note there is no 'optimal' FIX regime since the parameter θ_s is simply set at a value sufficiently high to ensure a fixed exchange rate.

[29]It is of interest to compare these losses with 'minimum stabilization' that stabilizes the model economy with a very low interest rate variability. One candidate for such a rule is $\Delta r_{n,t} = 0.01\pi_{H,t}$ alongside no fiscal stabilization. Then for model I we find $\Omega_0 = 101$, $\sigma_r^2 = 0.003$ and $c_e^{SIM} = 7.0\%$, an outcome rather worse than the FIX regime. Thus the latter provides *some* stabilization benefit.

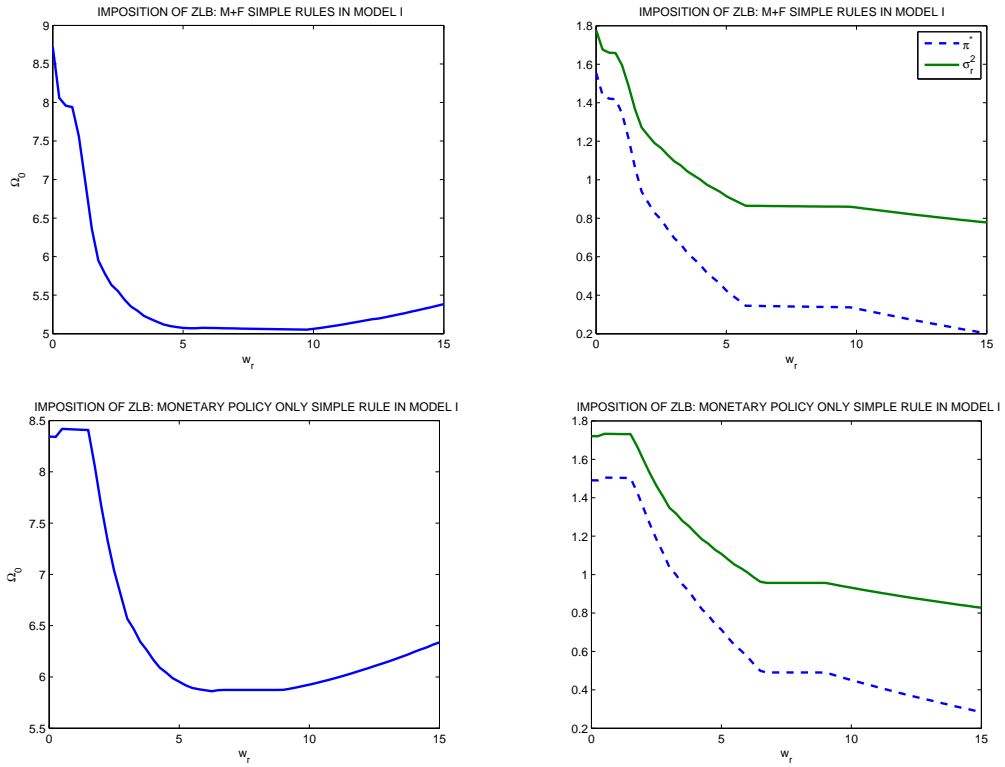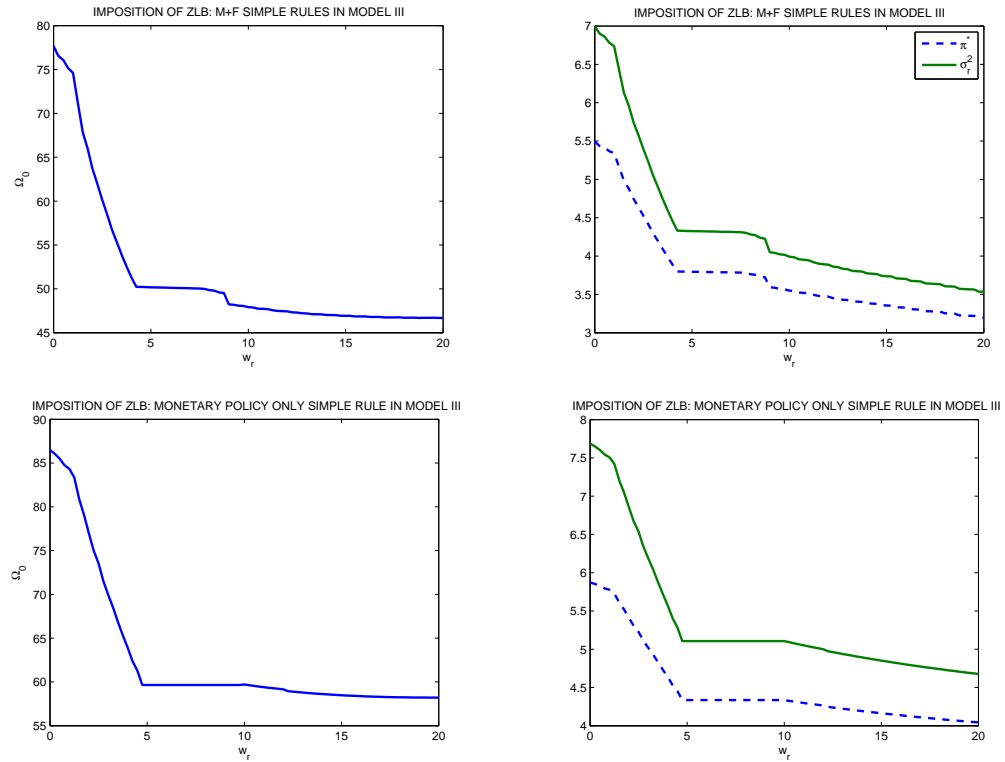Figure 4. Imposition of ZLB: Flex(D)+Conventional Fiscal Rule, Model I

Figure 5. Imposition of ZLB: Flex(D)+Conventional Fiscal Rule, Model III

We have now established that domestic inflation targeting, FLEX(D), alongside a counter-cyclical simple fiscal rule stabilizes the model economy far better than a fixed exchange rate regime. Two questions now remain: would a compromise 'managed float' of the type (74) improve upon FLEX(D)? How does CPI inflation targeting FLEX(C), the usual form of the target, compare with FLEX(D)?

Given the very poor performance of FIX one would not expect a hybrid regime to improve matters; nor do we expect a target that implicitly includes an element of an exchange rate target to outperform the domestic target. Indeed we find this to be the case. We find that the optimal feedback parameter in (74), θ_s with a ZLB imposed to be zero across all three models. Results for FLEX(C) are reported in Table 9. These confirm the FLEX(D) is vastly superior to FLEX(C); the costs of simplicity c_e^{SIM} now rise from 1.41% to 3.37% as we proceed from model I to model III compared with 0.12% to 2.07% for FLEX(D). CPI as opposed to domestic inflation targeting has a welfare cost of over a 1% permanent fall in consumption from the steady-state.

Finally we consider the stabilization performance of the SFSR in the form (93) alongside a FLEX(D) monetary interest rate rule as in Table 7. It turns out that in this exact form its performance is very poor. Instead we consider a *modified SFSR* without any feedback on government spending shocks:

$$
\frac{1}{P_H Y}\left(\frac{k\lambda \text{TF}_1}{(1-k)} + (1-\lambda)\text{TF}_2\right)(\text{tf}_{2,t} - p_{H,t-1}) = \frac{T^I}{P_H Y}y_{t-1} - (1-\alpha_{tax})tr_{t-1}^{NI} - (1-\alpha_{cop})tc_{t-1}
$$
$$
+ \left(\frac{1}{\beta(1+g)} - 1\right)b_{G,t-1} + \frac{B_G}{P_H Y}r_{g,t-1} \quad (106)
$$

This form of the SFSR implies that the fiscal surplus defines in (89) must be defined with government spending assumed to be at its steady state. With this modification we see from Table 9 that the optimized SFSR has a very similar outcome to that of the conventional fiscal rule, but with the advantage that it can be formulated in terms of a state-contingent fiscal surplus rule as in (89) and so has added transparency. It involves a very active response to endogenous and copper taxes a with α_{tax} above unity and α_{cop} below, but close to unity for Model I. In Models II and III this procyclical responses of flat-rate taxes net of transfers is rather less and is switched to a monetary policy, especially in model III.

VIII. CONCLUSIONS

Our results provide broad support for the "three-pillars" macroeconomic framework such as that pursued by Chile in the form of an explicit inflation target, a floating exchange rate and a counter-cyclical fiscal rule either of a conventional type or the SFSR actually pursued in Chile. Domestic inflation targeting is superior to partially or fully attempting to stabilizing the exchange rate. Responding to the exchange rate explicitly or implicitly makes it more expensive in terms of output variability to stabilize inflation. A model corollary is that stabilizing domestic inflation (e.g., measured by changes in the producer price index) enhances welfare outcomes somewhat, since stabilizing changes in the consumer price index implies a partial response to the exchange rate via imported consumer goods.[30]

Financial frictions increase the costs of stabilizing the exchange rate, as shown in GGN and Batini et al. (2007), because the central bank cannot offset a drop in net worth by allowing the exchange rate to adjust. Emerging markets faced with financial frictions should thus "fear to fix" rather than "fear to float".

Results for optimal monetary and fiscal policy compared with monetary stabilization alone indicate that potentially fiscal stabilization can have a significant role and more so if there are financial frictions. However the ability of best simple optimized counterpart to mimic the optimal policy deteriorates sharply as we first introduce the financial accelerator in model II and then liability dollarization in model III. This suggests that future research should explore alternative rules that respond to indicators of financial stress such as the risk premium facing firms in capital markets. Furthermore, given the sharp deterioration of the stabilization performance of both optimal policy and optimized rules as LD is introduced, future developments of the model could usefully attempt to endogenize the decision to borrow in different currencies.[31] Finally, although we have drawn upon consistent Bayesian-ML estimates (BMLE) using Chilean data for the core model, and US data for the ROW, a BMLE of all three variants of the model, using data

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[30]This finding is inherent in the type of models employed by this chapter and does not suggest a different monetary policy objective, given that it is contingent on maximization of the utility of the representative agent as opposed to non-utility-based loss functions used elsewhere in the literature.

[31]Armas et al (2006), chapter 2 provides some possible approaches to this challenge.

from a number of emerging SOEs, would both indicate the empirical importance of various financial frictions and enhance our assessment of the implications for policy.[32]

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[32] See Castillo et al (2006) for a BMLE assessment of transactions and price dollarization in a DSGE model fitted to Peruvian data.

Table 1. Notation for Prices

Origin of Good	Domestic Market	Export Market (PCP)	Export Market(LCP)
Home	P_H	$P_H^{*\,p} = \frac{P_H}{S_t}$	$P_H^{*\ell} \neq \frac{P_H}{S_t}$
Foreign	P_F^*	$P_F^p = S_t P_F^*$	$P_F^\ell \neq S_t P_F^*$

Table 2. Welfare Outcomes under Optimal Policy: No ZLB Constraint

Model	M+F		M		c_e^{MF}
	Ω_0^{MF}	σ_r^2	Ω_0^M	σ_r^2	
I	3.26	2.35	3.35	2.82	0.006
II	3.48	5.01	3.97	4.08	0.034
III	13.92	8.38	15.34	7.89	0.099

Table 3. Optimal Policy with a ZLB Constraint: Monetary Policy Only for Model I

w_r	σ_r^2	$\tilde{\Omega}_0$	π^*	$\bar{\Omega}_0$	Ω_0
0.001	2.82	3.35	2.59	12.84	16.19
1.00	1.84	3.57	1.62	5.04	8.61
2.00	1.32	3.94	1.00	1.90	5.85
3.00	1.00	4.33	0.55	0.59	4.92
3.25	0.94	4.23	0.46	0.41	4.83
3.50	0.88	4.52	0.37	0.27	4.79
3.75	**0.83**	**4.61**	**0.29**	**0.17**	**4.77**
4.00	0.79	4.70	0.22	0.09	4.79

Table 4. Optimal Commitment with a ZLB Constraint. Monetary Plus Fiscal Policy for Model I

w_r	σ_r^2	$\tilde{\Omega}_0$	π^*	$\bar{\Omega}_0$	Ω_0
0.001	2.35	3.25	2.16	8.93	12.18
0.25	0.86	3.26	0.33	0.21	3.47
0.50	**0.55**	**3.27**	**0**	**0**	**3.27**
0.75	0.40	3.29	0	0	3.29
1.00	0.31	3.30	0	0	3.30

Table 5. Welfare Outcomes under Optimal Policy: ZLB Constraint

Model	M+F			M			c_e^{MF}
	Ω_0	σ_r^2	π^*	Ω_0	σ_r^2	π^*	
I	3.27	0.55	0.00	4.77	0.84	0.29	0.104
II	3.74	0.69	0.05	6.98	1.00	0.57	0.225
III	14.90	0.72	0.10	24.19	1.20	0.85	0.644

Table 6. Welfare Decomposition of Shocks(%)

Shock	Model I	Model II	Model III
a_t	54.2	43.4	12.4
a_t^*	2.4	2.1	38.1
g_t	0.1	0.1	0.0
g_t^*	0.1	0.1	13.5
ε_{cop}	20.7	16.8	5.7
ε_{oil}	20.9	15.5	19.9
ε_{UIP}	1.6	1.3	0.6
ε_r^*	0.0	0.0	0.0
ε_P	0	20.1	9.5

Table 7: Welfare Outcomes under Optimized Simple Rules:
FLEX(D) with a Conventional Fiscal Rule. Models I, II and III.

	M+F				M				c_e^{MF}	c_e^{SIM}
	Ω_0	σ_r^2	π^*	$[\rho,\theta_\pi,\theta_y,\alpha_{bg},\alpha_y]$	Ω_0	σ_r^2	π^*	$[\rho,\theta_\pi,\theta_y]$		
I	5.0	0.9	0.3	[1,10,0,0.7,3]	5.9	1	0.5	[1,10,0.05]	0.06	0.12
II	13.2	1.7	1.5	[1,10,0.05,4,2]	13.6	1.8	1.5	[1,10,0.01]	0.03	0.66
III	44.7	3.6	3.3	[1,4,0.3,5,3]	58.2	4.7	4.0	[1,7.8,0]	0.93	2.07

Table 8: Welfare Outcomes under Optimized Simple Rules:
FIX with a Conventional Fiscal Rule. Models I, II and III.

	M+F				M			c_e^{MF}	c_e^{SIM}
	Ω_0	σ_r^2	π^*	$[\alpha_{bg},\alpha_y]$	Ω_0	σ_r^2	π^*		
I	74	0.8	0.3	[10,-0.01]	84	0.8	0.3	0.71	4.9
II	136	1.1	0.7	[6.3,-0.64]	152	1.0	0.6	1.16	9.2
III	175	2.4	2.2	[7.8,0.64]	191	2.4	2.2	1.09	11.1

Table 9: Welfare Outcomes under Optimized Simple Rules:
FLEX(C) with a Conventional Fiscal Rule. Models I, II and III.

	M+F				M				c_e^{MF}	c_e^{SIM}
	Ω_0	σ_r^2	π^*	$[\rho,\theta_\pi,\theta_y,\alpha_{bg},\alpha_y]$	Ω_0	σ_r^2	π^*	$[\rho,\theta_\pi,\theta_y]$		
I	23	1.0	0.6	[1,4,0.3,5,1.5]	23.7	1	0.5	[1,2.5,0.01]	0.04	0.41
II	35	1.5	1.2	[1,2,0.4,5,0.01]	36.7	1.8	1.5	[1,2.6,0.4]	0.10	2.24
III	62	2.6	2.4	[1,1.3,0.1,5,0.01]	64.0	4.7	2.4	[1,1,4,0.1]	0.12	3.37

Table 10. Welfare Outcomes under Optimized Simple Rules: FLEX(D) with a Modified SFSR. Models I, II and III.

	Ω_0	σ_r^2	π^*	$[\rho, \quad \theta_\pi, \quad \theta_y, \quad \alpha_{tax}, \quad \alpha_{cop}]$	c_e^{SIM}
I	5.38	0.96	0.49	[1.0, 10.0, 0.00, 1.10, 0.82]	0.15
II	13.19	1.76	1.53	[1.0, 10.0, 0.06, 0.96, 0.90]	0.66
III	46.74	3.58	3.22	[1.0, 4.13, 0.26, 0.97, 0.69]	2.21

APPENDIX I. THE STEADY STATE

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

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

$$\frac{\bar{A}_{t+1}}{\bar{A}_t} = 1 + (1 - \alpha_1)g \tag{A.2}$$

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

$$\bar{K}_{t+1} = (1 - \delta)\bar{K}_t + \bar{I}_t \tag{A.3}$$

It follows from (A.1) that

$$\bar{I}_t = (g + \delta)\bar{K}_t \tag{A.4}$$

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 the rest of the steady state is given by

$$C_H = \mathrm{w}_Z \left(\frac{P_H}{P_Z}\right)^{-\mu_Z} C_Z \tag{A.5}$$

$$C_F = (1 - \mathrm{w}_Z) \left(\frac{P_F}{P_Z}\right)^{-\mu_Z} C_Z \tag{A.6}$$

$$P_Z = \left[\mathrm{w}_Z P_H^{1-\mu_Z} + (1 - \mathrm{w}_Z)P_F^{1-\mu_Z}\right]^{\frac{1}{1-\mu_Z}} \tag{A.7}$$

$$C_Z = \mathrm{w}_C \left(\frac{P_Z}{P}\right)^{-\mu_C} C \tag{A.8}$$

$$C_O = (1 - \mathrm{w}_C) \left(\frac{P_O}{P}\right)^{-\mu_C} C \tag{A.9}$$

$$P = \left[\mathrm{w}_C P_Z^{1-\mu_C} + (1 - \mathrm{w}_C)P_O^{1-\mu_C}\right]^{\frac{1}{1-\mu_C}} \tag{A.10}$$

$$\frac{W}{P} = -\frac{1}{\left(1 - \frac{1}{\eta}\right)} \frac{U_L}{U_C} \tag{A.11}$$

$$1 = \beta(1 + R_n)(1 + g_{u_c}) = \beta(1 + R)(1 + g_{u_c}) \tag{A.12}$$

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

$$g_{u_c} = (1+g)^{(1-\varrho)(1-\sigma)-1} - 1 \tag{A.13}$$

$$1 + R^k = (1+\Theta)(1+R) \tag{A.14}$$

$$\Theta = \Theta\left(\frac{B}{N}\right) = \Theta\left(\frac{QK}{N} - 1\right) \tag{A.15}$$

$$Y^W = AK^{\alpha_1} L^{\alpha_2} \text{OIL}^{\alpha_3} \text{COP}^{1-\alpha_1-\alpha_2-\alpha_3} \tag{A.16}$$

$$\frac{WL}{P_H^W Y^W} = \alpha_2 \tag{A.17}$$

$$\frac{Q(R^k+\delta)K}{P_H^W Y^W} = \alpha_1 \tag{A.18}$$

$$\frac{P^O \text{OIL}}{P_H^W Y^W} = \alpha_3 \tag{A.19}$$

$$\frac{P^C \text{COP}}{P_H^W Y^W} = 1 - \alpha_1 - \alpha_2 - \alpha_3 \tag{A.20}$$

$$I = (g+\delta)K \tag{A.21}$$

$$I = \left[\text{w}_I^{\frac{1}{\rho_I}} I_H^{\frac{\rho_I-1}{\rho_I}} + (1-\text{w}_I)^{\frac{1}{\rho_I}} I_F^{\frac{\rho_I-1}{\rho_I}}\right]^{\frac{\rho_I}{1-\rho_I}} \tag{A.22}$$

$$\frac{I_H}{I_F} = \frac{\text{w}_I}{1-\text{w}_I}\left(\frac{P_H}{P_F}\right)^{-\rho_I} \tag{A.23}$$

$$P_I = \left[\text{w}_I P_H^{1-\rho_I} + (1-\text{w}_I)P_F^{1-\rho_I}\right]^{\frac{1}{1-\rho_I}} \tag{A.24}$$

$$QS'\left(\frac{I}{K}\right) = \frac{P_I}{P} \tag{A.25}$$

$$P_H = \hat{P}_H = \frac{P_H^W}{\left(1-\frac{1}{\zeta}\right)} \tag{A.26}$$

$$MC = \frac{P_H^W}{P_H} \tag{A.27}$$

$$Y = C_H + \frac{1}{\nu}[C_H^e + C_H^{e*} + I_H + I_H^*] + \frac{1-\nu}{\nu}C_H^* + G \tag{A.28}$$

$$C_{H,t}^e = (1-\xi_e)V = (1-\xi_e)(1+R^k)N \equiv s_e C_{H,t} \tag{A.29}$$

$$U_M = U_C \frac{R_n}{1+R_n} \tag{A.30}$$

$$\frac{\Gamma}{P_H Y} = 1 - \text{MC}\left(1 + \frac{F}{Y}\right) \tag{A.31}$$

$$R_g = \frac{1 + R_n}{1 + g} - 1 \tag{A.32}$$

$$\frac{PS}{P_H Y} \equiv \frac{(T - G)}{P_H Y} = R_g \frac{\hat{B}_G}{P_H Y} \tag{A.33}$$

$$\frac{TB}{P_H Y} = -R_g \frac{\hat{B}}{P_H Y} \tag{A.34}$$

$$C_2 = C_1 + \frac{\frac{1}{1-\lambda}\left[-TB + PS + (1 - \tau_\Gamma)\Gamma + (1 - \chi)(1 - \tau_{cop})P^C \overline{COP} - \lambda TF_1\right] - TF_2}{(1 + \tau_C)P} \tag{A.35}$$

plus the foreign counterparts.

The steady steady is completed with

$$\mathcal{T} = \frac{P_F}{P_H} \tag{A.36}$$

$$RER = \frac{SP^*}{P} \tag{A.37}$$

$$U_C = U_C^* \frac{z_0}{RER} \tag{A.38}$$

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.38) becomes $C = kC^*$ where k is a constant.

APPENDIX II. LINEARIZATION

Exogenous processes:

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

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

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

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

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

$$p_{O,t+1}^* - p_{t+1}^* = \rho_{oil}(p_{O,t}^* - p_t^*) + v_{oil,t+1} \tag{B.6}$$

$$\varepsilon_{UIP,t+1} = \rho_{UIP}\varepsilon_{UIP,t} + v_{UIP,t+1} \tag{B.7}$$

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

$$\varepsilon_{P,t+1}^* = \rho_P^* \varepsilon_{P,t}^* + v_{P,t+1}^* \tag{B.9}$$

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

Predetermined variables

$$k_{t+1} = \frac{1-\delta}{1+g}k_t + \frac{\delta+g}{1+g}i_t \tag{B.10}$$

$$k_{t+1}^* = \frac{1-\delta^*}{1+g}k_t^* + \frac{\delta^*+g}{1+g}i_t^* \tag{B.11}$$

$$
\begin{aligned}
n_t = & \frac{\xi_e}{1+g}\Big[\frac{1}{n_k}r_{t-1}^k + (1+\Theta)(1+R)n_{t-1} \\
& + \left(1 - \frac{1}{n_k}\right)\left[(1+R)\theta_{t-1} + (1+\Theta)(\varphi r_{t-1} + (1-\varphi)(r_{t-1}^* + (1+R)(rer_t - rer_{t-1}))\right]\Big]
\end{aligned} \tag{B.12}
$$

$$
n_t^* = \frac{\xi_e^*}{1+g}\Big[\frac{1}{n_k^*}r_{t-1}^{k*} + (1+\Theta^*)(1+R)n_{t-1}^* + \left(1 - \frac{1}{n_k^*}\right)\left[(1+R)\theta_{t-1}^* + (1+\Theta^*)r_{t-1}^*\right]\Big] \tag{B.13}
$$

where $r_{t-1} = r_{n,t-1} - \pi_t$ and $r_{t-1}^* = r_{n,t-1}^* - \pi_t^*$ are the ex post real interest rates.

$$s_t = s_{t-1} + rer_t - rer_{t-1} + \pi_t - \pi_t^* \tag{B.14}$$

$$b_{G,t} = \frac{1}{\beta(1+g)}b_{G,t-1} + \frac{B_G}{P_H Y}r_{g,t-1} + g_y(g_t - y_t) - t_t \tag{B.15}$$

$$b_{G,t}^* = \frac{1}{\beta(1+g)}b_{G,t-1}^* + \frac{B_G^*}{P_F^* Y^*}r_{g,t-1}^* + g_y^*(g_t^* - y_t^*) - t_t^* \tag{B.16}$$

$$b_{F,t} = \frac{1}{\beta(1+g)}b_{F,t-1} + \frac{\hat{B}_{F,t}}{P_{H,t}Y_t}r_{g,t-1} + tb_t \tag{B.17}$$

$$\Delta\tau_t = \pi_{F,t} - \pi_{H,t} \tag{B.18}$$

$$\Delta\tau_t^* = \pi_{H,t}^* - \pi_{F,t}^* \tag{B.19}$$

$$\Delta o_t = \pi_{O,t} - \pi_{Z,t} \tag{B.20}$$

$$\Delta o_t^* = \pi_{O,t}^* - \pi_{Z,t}^* \tag{B.21}$$

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

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

$$\Delta(p_t - p_{Z,t}) = (1 - \mathrm{w}_C)(\pi_{O,t} - \pi_{Z,t}) \tag{B.23}$$

Non-predetermined variables:

$$(1-\delta)E_t(q_{t+1}) = (1+R^k)q_t - (R^k + \delta)x_t$$
$$+ E_t(r_t^k) \tag{B.24}$$

$$(1-\delta^*)E_t(q_{t+1}^*) = (1+R^{k*})q_t^* - (R^{k*} + \delta^*)x_t^*$$
$$+ E_t(r_t^{k*}) \tag{B.25}$$

$$E_t u_{c,t+1} = u_{c,t} - \frac{r_{n,t}}{1+R} + E_t\pi_{t+1} \tag{B.26}$$

$$E_t u_{c,t+1}^* = u_{c,t}^* - \frac{r_{n,t}^*}{1+R} + E_t\pi_{t+1}^* \tag{B.27}$$

$$\beta E_t\pi_{H,t+1} = \pi_{H,t} - \lambda_H mc_t \tag{B.28}$$

$$\beta E_t\pi_{F,t+1}^* = \pi_{F,t}^* - \lambda_F^* mc_t^* \tag{B.29}$$

$$\beta E_t\pi_{H,t+1}^{*\ell} = \pi_{H,t}^{*\ell} - \lambda_H^*(mc_t - \phi_{H,t} + p_{H,t} - p_{H,t}^\ell) \tag{B.30}$$

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

$$\left(1 + \frac{1+g}{1+R}\right)i_t^* = \frac{1+g}{1+R}E_t i_{t+1}^* + i_{t-1}^* + \frac{1}{(1+g)^2 S''(1+g)}(q_t^* - (p_{I,t}^* - p_{Z,t}^*) + p_{Z,t}^* - p_t^*) \tag{B.32}$$

$$E_t[rer_{t+1}^d] = rer_t^d + \delta_r b_{F,t} + \varepsilon_{UIP,t} \tag{B.33}$$

Instruments

$$r_{n,t} = \text{exogenous instrument} \tag{B.34}$$

$$tf_{2,t} - p_{H,t} = \text{exogenous instrument} \tag{B.35}$$

Outputs:

$$mc_t = u_{l,t} - u_{c,t} + l_t - \frac{1}{\phi_F}y_t + p_t - p_{H,t} \tag{B.36}$$

$$mc_t^* = u_{l,t}^* - u_{c,t}^* + l_t^* - \frac{1}{\phi_F^*}y_t^* + p_t^* - p_{Z,t}^* \tag{B.37}$$

$$u_{c,t} = \frac{(1-\varrho)(1-\sigma)-1}{1-h_C}(c_{2,t} - h_C c_{2,t-1}) - \frac{L\varrho(1-\sigma)}{1-L}l_t$$
$$+ \varpi r_{n,t} \tag{B.38}$$

$$u_{c,t}^* = \frac{(1-\varrho^*)(1-\sigma^*)-1}{1-h_C^*}(c_{2,t}^* - h_C^* c_{2,t-1}^*) - \frac{L^*\varrho^*(1-\sigma^*)}{1-L^*}l_t^*$$
$$+ \varpi^* r_{n,t}^* \tag{B.39}$$

$$u_{l,t} = \frac{1}{1-h_C}(c_{2,t} - h_C c_{2,t-1}) + \frac{L}{1-L}l_t + u_{c,t}$$
$$+ \varpi_L[\bar{a}r_{n,t} + (1-\bar{a})r_{n,t}^*] \tag{B.40}$$

$$u_{l,t}^* = \frac{1}{1-h_C^*}(c_{2,t}^* - h_C^* c_{2,t-1}^*) + \frac{L^*}{1-L^*}l_t^* + u_{c,t}^* + \varpi_L^* r_{n,t}^* \tag{B.41}$$

$$c_{1,t} = \gamma_1(w_t + l_t - p_t) + \gamma_2(\text{tf}_{1,t} - p_t)$$
$$= \gamma_1(u_{l,t} - u_{c,t} + l_t) + \gamma_2(\text{tf}_{1,t} - p_{H,t} - (p_t - p_{H,t})) \tag{B.42}$$

$$c_{1,t}^* = \gamma_1^*(w_t^* + l_t^* - p_t^*) + \gamma_2^*(\text{tf}_{1,t}^* - p_t^*) = \gamma_1^*(u_{l,t}^* - u_{c,t}^* + l_t^*)$$
$$+ \gamma_2^*(\text{tf}_{1,t}^* - p_{F,t}^* + p_{Z,t}^* - p_t^*) \tag{B.43}$$

$$c_t = \frac{\lambda C_1}{C}c_{1,t} + \frac{(1-\lambda)C_2}{C}c_{2,t} \tag{B.44}$$

$$c_t^* = \frac{\lambda^* C_1^*}{C^*}c_{1,t}^* + \frac{(1-\lambda^*)C_2^*}{C^*}c_{2,t}^* \tag{B.45}$$

$$y_t = \alpha_{C,H}c_{Z,t} + \alpha_{C,H}^e c_{Z,t}^e + \alpha_{C,H}^* c_{Z,t}^* + \alpha_{I,H}i_t + \alpha_{I,H}^* i_t^* + \alpha_G g_t$$
$$+ [\mu_Z(\alpha_{C,H} + \alpha_{C,H}^e)(1-\text{w}_Z) + \mu_Z^*\alpha_{C,H}^*\text{w}_Z^* + \rho_I\alpha_{I,H}(1-\text{w}_I) + \rho_I^*\alpha_{I,H}^*\text{w}_I^*]\tau_t \tag{B.46}$$

$$y_t^* = \alpha_{C,F}^* c_{Z,t}^* + \alpha_{C,F}^{*e} c_{Z,t}^{*e} + \alpha_{C,F}c_{Z,t} + \alpha_{C,F}^e c_{Z,t}^e + \alpha_{I,F}^* i_t^* + \alpha_{I,F}i_t + \alpha_G^* g_t^*$$
$$- [\mu_Z^*(\alpha_{C,F}^* + \alpha_{C,F}^{*e})c_{Z,t}^{*e}(1-\text{w}_Z^*) + \mu\alpha_{C,F}\text{w}_Z + \rho_I^*\alpha_{I,F}^*(1-\text{w}_I^*) + \rho_I\alpha_{I,F}\text{w}_I]\tau_t$$
$$= c_y^* c_{Z,t}^* + i_y^* i_t^* + g_y^* g_t^* \tag{B.47}$$

$$c_{Z,t} = c_t - \mu_C(p_Z - p_t) \tag{B.48}$$

$$c_{Z,t}^* = c_t^* - \mu_C^*(p_Z^* - p_t^*) \tag{B.49}$$

$$c_{Z,t}^e = c_t^e - \mu_C(p_Z - p_t) \tag{B.50}$$

$$c_{Z,t}^{e*} = c_t^{e*} - \mu_C^*(p_Z^* - p_t^*) \tag{B.51}$$

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

$$c_t^e = n_t \tag{B.52}$$

$$c_t^{e*} = n_t^* \tag{B.53}$$

$$rer_t^r = u_{c,t}^* - u_{c,t} \tag{B.54}$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$cop_t = \frac{1}{\phi_F}y_t + mc_t + p_{H,t} - p_t + p_t - p_{C,t} \tag{B.74}$$

$$cop_t^* = \frac{1}{\phi_F^*}y_t^* + mc_t^* + p_{Z,t}^* - p_t^* + p_t^* - p_{C,t}^* \tag{B.75}$$

$$x_t = y_t + mc_t + p_{H,t} - p_t - k_t \tag{B.76}$$

$$x_t^* = y_t^* + mc_t^* + p_{Z,t}^* - p_t^* - k_t^* \tag{B.77}$$

$$E_t\pi_{Z,t+1} = w_Z E_t\pi_{H,t+1} + (1 - w_Z)E_t\pi_{F,t+1} \tag{B.78}$$

$$E_t\pi_{t+1} = w_C E_t\pi_{Z,t+1} + (1 - w_C)E_t\pi_{O,t+1} \tag{B.79}$$

$$E_t\pi_{F,t+1} = E_t rer_{t+1} - rer_t + E_t\pi_{t+1} - E_t\pi_{t+1}^* + E_t\pi_{F,t+1}^* \tag{B.80}$$

$$E_t rer_{t+1} = E_t u_{c,t+1}^* - E_t u_{c,t+1} + E_t[rer_{t+1}^d] \tag{B.81}$$

$$r_{n,t}^* = \rho_i^* r_{n,t-1}^* + (1 - \rho_i^*)\theta_\pi^* \pi_{F,t}^* + \theta_y \Delta y_t^* + \varepsilon_{R,t}^* \tag{B.82}$$

$$q_t^k = q_t - p_{I,t} + p_t \tag{B.83}$$

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

$$r_{g,t} = (1 + R_g)\left(\beta r_{n,t} - \pi_{H,t} - \frac{y_t - y_{t-1}}{1 + g}\right) \tag{B.84}$$

$$r_{g,t}^* = (1 + R_g^*)\left(\beta r_{n,t}^* - \pi_{F,t}^* - \frac{y_t^* - y_{t-1}^*}{1 + g}\right) \tag{B.85}$$

$$\begin{aligned}
t_t = {}& s_L(w_t - p_{H,t} + l_t - y_t) + s_C(p_t - p_{H,t} + c_t - y_t) \\
& + s_K(p_t - p_{H,t} + q_t + k_t - y_t + \frac{r_t^k}{R^k}) \\
& - \lambda\frac{TF_1}{P_H Y}(tf_{1,t} - p_{H,t} - y_t) + (1 - \lambda)\frac{TF_2}{P_H Y}(tf_{2,t} - p_{H,t} - y_t) \\
& + s\text{cop}(p_{C,t} - p_t + p_t - p_{H,t} - y_t) + s_\Gamma\gamma_t
\end{aligned} \tag{B.86}$$

$$\begin{aligned}
t_t^* = {}& s_L^*(w_t^* - p_t^* + l_t^* - y_t^*) + s_C^*(c_t^* + p_t^* - p_{Z,t}^* - y_t^*) \\
& + s_K^*(q_t^* + k_t^* - y_t^* + \frac{r_t^{k*}}{R^{k*}}) \\
& - \lambda^*\frac{TF_1^*}{P_F^* Y^*}(tf_{1,t}^* - p_{F,t}^* - y_t^*) + (1 - \lambda^*)\frac{TF_2^*}{P_F^* Y^*}(tf_{2,t}^* - p_{F,t}^* - y_t^*) \\
& + s_\Gamma^*\gamma_t^*
\end{aligned} \tag{B.87}$$

$$tf_{1,t} - p_{H,t} = -\frac{TF_2 k(1 - \lambda)}{TF_1(1 - k)\lambda}(tf_{2,t} - p_{H,t}) \tag{B.88}$$

$$tf_{1,t}^* - p_{F,t}^* = -\frac{TF_2^* k^*(1 - \lambda^*)}{TF_1^*(1 - k^*)\lambda^*}(tf_{2,t}^* - p_{F,t}^*) \tag{B.89}$$

$$tf_{2,t}^* - p_{F,t}^* = y_t^* + \alpha_B^* b_{G,t}^* \tag{B.90}$$

$$t_t^{NI} = t_t + \lambda\frac{TF_1}{P_HY}(tf_{1,t} - p_{H,t} - y_t) - (1-\lambda)\frac{TF_2}{P_HY}(tf_{2,t} - p_{H,t} - y_t)$$
$$- s\text{cop}(p_{C,t} - p_t + p_t - p_{H,t} - y_t) \tag{B.91}$$

$$tcop_t = s\text{cop}(p_{C,t} - p_t + p_t - p_{H,t} - y_t) \tag{B.92}$$

$$t_t^I = -\lambda\frac{TF_1}{P_HY}(tf_{1,t} - p_{H,t} - y_t) + (1-\lambda)\frac{TF_2}{P_HY}(tf_{2,t} - p_{H,t} - y_t) \tag{B.93}$$

$$w_t - p_{H,t} = u_{l,t} - u_{c,t} + p_t - p_{H,t} \tag{B.94}$$

$$w_t^* - p_t^* = u_{l,t}^* - u_{c,t}^* \tag{B.95}$$

$$\gamma_t = -\phi_F mc_t \tag{B.96}$$

$$\gamma_t^* = -\phi_F^* mc_t^* \tag{B.97}$$

$$p_{C,t} - p_t = rer_t + p_{C,t}^* - p_t^* \tag{B.98}$$

$$tb_t = y_t - \alpha_{C,H}c_t - \alpha_{C,H}^e c_t^e - i_y i_t - g_y g_t$$
$$- (c_y + i_y)(p_t - p_{H,t}) - i_y(p_{I,t} - p_t)$$
$$+ \frac{\overline{P^C COP}}{P_HY}(p_{C,t} - p_t + p_t - p_{H,t})$$
$$- (1 - \alpha_1 - \alpha_2)\left(\frac{1}{\phi_F}y_t + mc_t\right) \tag{B.99}$$

$$rer_t = rer_t^r + rer_t^d \tag{B.100}$$

$$rer_t^r = u_{c,t}^* - u_{c,t} \tag{B.101}$$

$$p_{H,t} - p_{H,t}^\ell = \frac{\theta}{1-\theta}(-rer_{Z,t} - (1-\omega)\tau_t - \tau_t^*) \tag{B.102}$$

$$\phi_{H,t} = rer_{Z,t} + \tau_t^* + (1-\omega)\tau_t \tag{B.103}$$

$$rer_{Z,t} = rer_t + (1 - \text{w}_C)o_t - (1 - \text{w}_C^*)o_t^* \tag{B.104}$$

$$\pi_{O,t} = \Delta rer_t + \pi_{O,t}^* + \pi_t - \pi_t^* \tag{B.105}$$

$$\pi_{O,t}^* = p_{O,t}^* - p_t^* - (p_{O,t-1}^* - p_{t-1}^*) + \pi_t^* \tag{B.106}$$

$$p_t - p_{H,t} = p_t - p_{Z,t} + p_{Z,t} - p_{H,t} \tag{B.107}$$

$$E_t\pi_{O,t+1} = E_t rer_{t+1} - rer_t + E_t\pi_{O,t+1}^* + E_t\pi_{t+1} - E_t\pi_{t+1}^*$$
$$= E_t rer_{t+1} - rer_t + (\rho_{oil} - 1)p_{O,t}^* + E_t\pi_{t+1} - E_t\pi_{t+1}^* \tag{B.108}$$

$$E_t\pi_{t+1}^* = \text{w}_C^* E_t\pi_{F,t+1}^* + (1 - \text{w}_C^*)(\rho_{oil} - 1)p_{O,t}^* \tag{B.109}$$

$$oil_t = \frac{1}{\phi_F}y_t + mc_t + p_{H,t} - p_t + p_t - p_{O,t} \tag{B.110}$$

$$oil_t^* = \frac{1}{\phi_F^*}y_t^* + mc_t^* + p_{Z,t}^* - p_t^* + p_t^* - p_{O,t}^* \tag{B.111}$$

$$p_{O,t} - p_t = rer_t + p_{O,t}^* - p_t^* \tag{B.112}$$

$$c_{O,t} = c_t - \mu_Z(p_{O,t} - p_t) \tag{B.113}$$

$$\textbf{check}: c_t = \text{w}_C c_{Z,t} + (1 - \text{w}_C)c_{O,t} \tag{B.114}$$

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

$$cmcl_t = \frac{c_t - h_C c_{t-1}}{1 - h_C} \tag{B.115}$$

$$kml_t = k_{t-1} - l_t \tag{B.116}$$

$$ccii_t = \mu\omega(1-\omega)c_y c_t + \mu(1-\omega^*)c_y c_t^* + \rho_I \omega_I(1-\omega_I)i_y i_t + \rho_I^*(1-\omega_I^*)c_y i_t^* \tag{B.117}$$

$$ccsls_t = [(1-\sigma)(1-\varrho)-1]\frac{c_t^* - h_C c_{t-1}^*}{1 - h_C} - (1-\sigma)\varrho\frac{L^* l_t^*}{1 - L^*} \tag{B.118}$$

$$cmcl_t^* = \frac{c_t^* - h_C^* c_{t-1}^*}{1 - h_C^*} \tag{B.119}$$

$$kml_t^* = k_{t-1}^* - l_t^* \tag{B.120}$$

$$tf_{2,t} - p_{H,t}, \; tf_{2,t}^* - p_{F,t}^* \text{ the instruments}.$$

APPENDIX III.   CALIBRATION AND ESTIMATION

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

Shock parameters

We require the AR1 persistence parameters ρ_a, etc and the corresponding standard deviations of white noise processes, sd_a, etc.

Chile Parameter	Value	Source	ROW Parameter	Value	Source
ρ_a	0.89	MS	ρ_a^*	0.95	SW07
sd_a	1.43	MS	sd_a^*	0.45	SW07
ρ_g	0.65	MS	ρ_g^*	0.97	SW07
sd_g	1.01	MS	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}	0.86	GLY	n.a.	n.a.	n.a.
sd_{UIP}	0.66	GLY	n.a.	n.a.	n.a.
ρ_P	0.34	GLY	ρ_P^*	0.92	GLY
sd_P	4.42	GLY	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
n.a.	n.a.	n.a.	ρ_{cop}^*	0.95	MS
n.a.	n.a.	n.a.	sd_{cop}^*	9.0	MS

Table C1. Parameterization of Shock Processes

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 central estimates are
$$\sigma = 3, \sigma^* = 2.$$

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 slightly higher value $L = 0.5$ for Chile.

Consumption Shares: $w_C = w_C^* = 0.98$ (MS) *Habit Parameters*: $h_C = 0.75$ (MS), $h_C^* = 0.70$ (SW07)

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

Elasticity of the marginal utility of consumption with respect to money balances Ψ, Ψ^*: We examine a range $\Psi, \Psi^* \in [0.01, 0.03]$ for which money balances and consumption are complements.

Technology

Depreciation Rates: A standard choice is $\delta = \delta^* = 0.025$

Common World Growth Rate: We choose a realistic common world growth rates:
$$g = g^* = 3\% \text{ per annum}$$

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

Production Shares: $\alpha_2 = 0.65$, $\alpha_1 = 0.33$, $\alpha_3 = 1 - \alpha_1 - \alpha_2 - \alpha_3 = 0.01$ (MS)
$\alpha_2^* = 0.69$, $\alpha_1^* = 0.29$, $\alpha_3^* = 0.01 = 1 - \alpha_1^* - \alpha_2^* - \alpha_3^* = 0.01$ (SW07)

Investment Substitution Elasticities: $\rho_I = \rho_I^* = 0.5$ (MS)

Financial Accelerator

Elasticity: $\chi_\theta = -0.065$, $\chi_\theta^* = -0.05$ (BGG)

Home currency borrowing for capital: $\varphi \in [0, 1]$

Survival rate: $\xi_e = \xi_e^* = 0.93$ (GGN)

Asset/Debt Ratio: $n_k = 0.4$, $n_k^* = 0.7$ (BGG)

FA Risk Premium: $\Theta = 0.035$, $\Theta^* = 0.05$ (BGG)

UIP Risk Premium: $\delta_r = 0.01$

Market Power

Labor Market Power: $\eta = 3$ (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 $\xi_H = \xi_F^* = 0.75$, corresponding to 4 quarter price contracts on average (see MS)

Consumption, Investment, Money Balance and Trade Shares:

Standard values for the US are $c_y^* = 0.6$, $i_y^* = 0.2$, $g_y = 0.2$ and $z_y = 0.25$ (the latter $z_y = \frac{Z}{PY}$ is money stock as a proportion of quarterly GDP). For Chile we choose $c_y = 0.7$, $i_y = 0.27$, $g_y = 0.12$, $tb = 0.02$ (MS) which is consistent with the choice of the net asset-GDP ratio below, and $z_y = 0.25$ (as for the US).

Trade Shares: Total non-copper exports and imports are around 25% for Chile so $0.25 = cs_{imports} + is_{imports} = cs_{exports} + is_{exports}$ for balanced trade. Data on consumption and capital goods exports show $\frac{is_{imports}}{cs_{imports}} = 1.6$ and $\frac{is_{exports}}{cs_{exports}} = 0.1$. Hence we choose $cs_{imports} = 0.10$, $is_{imports} = 0.15$, $cs_{exports} = 0.23$ and $is_{exports} = 0.02$.

Assets and Liquidity Constraints

$$\frac{\hat{B}_G}{P_H Y} = \frac{\hat{B}_G^*}{P_F^* Y^*} = 0.4 \times 4 \text{ on a quarterly basis; }^2$$

$\frac{\hat{B}}{P_H Y} = 0.3 \times 4$ (MS) on a quarterly basis; $\frac{\Gamma}{P_H Y} = 0.1$; $\lambda = 0.6$ (MS), $\lambda^* = 0.4$ (KL)

Tax Rates and Transfers

From Chile Issue Note, IMF: $\tau_L = 0.1$, $\tau_C = 0.2$, $\tau_K = \tau_\Gamma = 0.02$, $\frac{TF_1}{P_H Y} = 0.05$, $\frac{TF_2}{P_H Y} = 0.05$ in both blocs, $\tau_{cop} = 0.35$

Standard values for ROW are: $\tau_L^* = \tau_C = 0.2$; $\tau_K^* = \tau_\Gamma = 0.05$

Copper Sector (MS)

$$\chi = 0.4, \ \frac{P^C \overline{COP}}{p_H Y} = 0.1$$

Derived Parameters:

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

Preference Parameters, b, θ, ϱ, are found by solving the set of equations

---

[2]Note that officially CHILE has a zero Government-GDP target, but this is regarded as ignoring some government liabilities (see MS)

$$\frac{W(1-L)}{PC} = \frac{(1-\alpha)(1-L)}{c_y L}$$

$$\Psi = \frac{(1-b)[(1-\varrho)\sigma_2 - 1 + \frac{1}{\theta}]}{bcz^{\frac{\theta-1}{\theta}} + 1 - b}$$

$$\frac{\Phi}{C\Phi_C} = \frac{(1-b)cz^{\frac{1-\theta}{\theta}} + b}{b}$$

$$cz \equiv \frac{C(1-h_C)}{Z}$$

$$\varrho = \frac{(1-\frac{1}{\eta})W(1-L)/PC}{\frac{\Phi}{C(1-h_C)\Phi_C} + (1-\frac{1}{\eta})W(1-L)/PC}$$

$$\frac{b(1-h_C)}{1-b}cz^{-\frac{1}{\theta}} = \frac{1+R}{R}$$

For central values of σ, assuming $\Psi = 0.01$, we obtain: $b = 0.975$, $\theta = 0.280$, $\varrho = 0.196$ for Chile data and $b^* = 0.984$, $\theta = 0.368$ and $\varrho = 0.393$ for US data.

Demand elasticities calibrated from trade data:

$$\alpha_{C,H} = (c_y - cs_{imports})(1 - s_e)$$

$$\alpha_{C,H}^e = (c_y - cs_{imports})s_e$$

$$\alpha_{C,H}^* = cs_{exports}$$

$$\alpha_{I,H} = i_y - is_{imports}$$

$$\alpha_{I,H}^* = is_{exports}$$

$$\alpha_{C,F}^* = c_y^*$$

$$\alpha_{C,F}^{e*} = 0$$

$$\alpha_{C,F} = 0$$

$$\alpha_{I,F}^* = i_y^*$$

$$\alpha_{I,F} = 0$$

$$\alpha_G = g_y$$

$$\alpha_G^* = g_y^*$$

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

$$\omega = \frac{\alpha_{C,H} + \alpha_{C,H}^e}{c_y} = \frac{c_y - cs_{imports}}{c_y}$$

$$\omega_I = \frac{\alpha_{I,H}}{i_y}$$

Remaining calibrated parameters are:

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

$$R = \frac{1}{\beta(1+g_{u_c})} - 1$$

$$R^k = (1+\Theta)(1+R) - 1$$

$$\alpha = \left(\frac{(1-b)}{b(1-\beta)}\right)^{\theta}$$

$$b_1 = \frac{b}{\left(b + (1-b)\alpha^{\frac{\theta-1}{\theta}}\right)}$$

$$\varpi = \varpi(a) = \frac{\beta}{1-\beta}[(1 - (1-\varrho)(1-\sigma))\theta - 1](1 - b_1)$$

$$\lambda_H = \frac{(1-\beta\xi_H)(1-\xi_H)}{\xi_H}$$

$$\chi_R = \frac{\chi_M}{R_n(1+R_n)}$$

$$k_y = \frac{i_y}{g+\delta}$$

$$s_e = \frac{(1-\xi_e)n_k k_y}{\xi_e c_y}$$

$$\varpi_L = \frac{\beta}{1-\beta}(1-\theta)(1-b_1)$$

$$\frac{F}{P_H Y} = \frac{1 - \frac{\Gamma}{P_H Y}}{1 - \frac{1}{\zeta}} - 1$$

$$R_g = \frac{1+R_n}{1+g} - 1$$

$$\frac{PS}{P_H Y} = R_g \frac{\hat{B}_G}{P_H Y}$$

$$\frac{TB}{P_H Y} = R_g \frac{\hat{B}_F}{P_H Y}$$

$$\frac{C_2}{C} = 1 + \frac{1}{(1+\tau_C)c_y}\left[\frac{1}{1-\lambda}\left(-\frac{TB}{P_H Y} + \frac{PS}{P_H Y} + \frac{(1-\tau_\Gamma)\Gamma}{P_H Y} + \frac{(1-\chi)(1-\tau_{cop})P^C\overline{COP}}{P_H Y}\right.\right.$$
$$\left.\left. - \frac{\lambda TF_1}{P_H Y}\right) - \frac{TF_2}{P_H Y}\right]$$

$$\frac{C_1}{C} = \frac{1 - (1-\lambda)\frac{C_2}{C}}{\lambda}$$

$$\gamma_1 = \frac{1 - \tau_L}{1 + \tau_C} \frac{WL}{PC_1}$$

$$\gamma_2 = \frac{1}{1 + \tau_C} \frac{TF_1}{PC_1}$$

$$\frac{WL}{PC_1} = \frac{\alpha_2 \phi_F}{c_y} \frac{C}{C_1}$$

$$\frac{TF_1}{PC_1} = \frac{TF_1}{P_H Y} \frac{C}{c_y C_1}$$

$$s_L = \tau_L \frac{WL}{P_H Y} = \tau_L \alpha_2 \phi_F$$

$$s_C = \tau_C \frac{P_C C}{P_H Y} = \tau_C c_y$$

$$s_K = \tau_K \frac{Q(R^k + \delta)K}{P_H Y} = \tau_K \alpha_1 \phi_F$$

$$s_{cop} = \tau_{cop} \frac{P^C COP}{P_H Y}$$

Fixed Costs: From (A.26), (A.27) and (A.31)

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

Foreign parameters follow in an analogous way.

APPENDIX IV.   QUADRATIC APPROXIMATION OF THE WELFARE LOSS

The basic idea is to obtain the quadratic approximation to the social planner's problem, coupled with a term in inflation, which arises from price dispersion. 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 labor markets. For our calibrated high value for the habit parameter h_C, this leaves the steady state of the decentralized economy close to the social optimum, justifying the small distortions approximation.

Consider the social planner's problem to maximize

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

subject to the (resource) constraints:

$$1 - \omega_z + \omega_z T_t^{\mu_z - 1} = E_t^{\mu_z - 1} \qquad 1 - \omega_I + \omega_I T_t^{\rho_I - 1} = E_{It}^{\rho_I - 1} \qquad K_t = (1 - \delta)K_{t-1} + I_t$$

(D.2)

$$Z_t^{\mu_c - 1} = \omega_c + (1 - \omega_c)E_t^{1 - \mu_c} O_t^{*1 - \mu_c}$$

(D.3)

$$\begin{aligned}
\frac{P_{C,t}}{P_{H,t}}\overline{COP}_t + Y_t &= \frac{P_{C,t}}{P_{H,t}}\overline{COP}_t + A_t K_{t-1}^{\alpha_1} L_t^{\alpha_2} Oil_t^{\alpha_3} COP_t^{\alpha_4} - F \qquad &\text{(D.4)} \\
&= \omega_c \omega_z E_t^{-\mu_z} T_t^{\mu_z} Z_t^{-\mu_c} C_t + (1 - \omega_c)O^{*1-\mu_c} E_t^{-\mu_c} Z_t^{-\mu_c} T_t C_t \\
&+ (1 - \omega_z^*)\omega_c^* T_t^{\mu_z} Z_t^{*-\mu_c} C_t^* + \omega_I E_{It}^{-\rho_I} T_t^{\rho_I} I_t + (1 - \omega_I^*)T_t^{\rho_I^*} I_t^* + G_t \\
&+ \frac{P_{C,t}}{P_{H,t}}COP_t + \frac{P_{O,t}}{P_{H,t}}Oil_t \qquad &\text{(D.5)}
\end{aligned}$$

where the first line of (D.5) represents home demand for home consumption plus home demand for oil consumption, the second line represents foreign demand, home demand for investment goods and government spending, while the last line represents demand for copper and oil in production. The terms of trade are given by $T = P_F/P_H$; in addition we define $E = P_F/P_Z$, $Z = P_Z/P$, $O^* = P_O^*/P^*$, $\alpha_4 = 1 - \alpha_1 - \alpha_2 - \alpha_3$.

We also note that

$$\frac{P_C}{P_H} = \frac{SP_C^*}{P_H} = \frac{SP_F^*}{P_H}\frac{P_C^*}{P_F^*} = \frac{SP_F^*}{P_F}\frac{P_F}{P_H}\frac{P_C^*}{P_F^*} = T\frac{P_C^*}{P_F^*}$$

it follows that we may write

$$\frac{P_{C,t}}{P_{H,t}}\overline{COP}_t = T_t \Upsilon_t$$

where $\Upsilon_t = \frac{P_C^*}{P_F^*}\overline{COP}_t$ is exogenous.

There is also a risk-sharing condition given by

$$E_t = U_{C_t^*}^*/U_{C_t} \qquad E_t C_t^{(1-\varrho)(1-\sigma)-1}(1 - L_t)^{\varrho(1-\sigma)} = C_t^{*(1-\varrho)(1-\sigma)-1}(1 - L_t^*)^{\varrho(1-\sigma)} \quad \text{(D.6)}$$

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

Constraint (D.4), (D.5) can be simplified by maximizing $A_t K_{t-1}^{\alpha_1} L_t^{\alpha_2} Oil_t^{\alpha_3} COP_t^{\alpha_4} - \frac{P_{C,t}}{P_{H,t}}COP_t - \frac{P_{O,t}}{P_{H,t}}Oil_t = A_t K_{t-1}^{\alpha_1} L_t^{\alpha_2} Oil_t^{\alpha_3} COP_t^{\alpha_4} - T_t C_t^{p*} COP_t - T_t O_t^* Oil_t$ with respect to COP_t, Oil_t where $C^{p*} = P_C^*/P^*$.

It then follows that the Lagrangian for the problem may be written as

$$\sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - H_t)^{(1-\varrho)(1-\sigma)}(1 - L_t)^{\varrho(1-\sigma)}}{1 - \sigma} + \lambda_{1t}(H_t - h_C C_{t-1}) \right.$$

$$+ \lambda_{2t}(\omega_c \omega_z E_t^{-\mu_z} T_t^{\mu_z} Z_t^{-\mu_c} C_t + (1 - \omega_c)O^{*1-\mu_c} E_t^{-\mu_c} Z_t^{-\mu_c} T_t C_t$$

$$+ (1 - \omega_z^*)\omega_c^* T_t^{\mu_z} Z_t^{*-\mu_c} C_t^* + \omega_I E_{It}^{-\rho_I} T_t^{\rho_I} I_t + (1 - \omega_I^*)T_t^{\rho_I^*} I_t^* + G_t \qquad \text{(D.7)}$$

$$- \Upsilon T_t - B_t T_t^{-\gamma} K_{t-1}^{\alpha} L_t^{1-\alpha} + F)$$

$$+ \lambda_{3t}(1 - \omega + \omega T_t^{\mu-1} - E_t^{\mu-1}) + \lambda_{4t}(1 - \omega_I + \omega_I T_t^{\rho_I-1} - E_{It}^{\rho_I-1})$$

$$+ \lambda_{5t}(E_t(C_t - H_t)^{(1-\varrho)(1-\sigma)-1}(1 - L_t)^{\varrho(1-\sigma)} - U_{C^*}) + \lambda_{6t}(K_t - (1 - \delta)K_{t-1} - I_t)$$

$$\left. + \lambda_{7t}(\omega_c + (1 - \omega_c)E_t^{1-\mu_c} O_t^{*1-\mu_c} - Z_t^{\mu_c-1}) \right] \qquad \text{(D.8)}$$

where $\alpha = \frac{\alpha_1}{\alpha_1 + \alpha_2}$, $B_t = (\alpha_1 + \alpha_2)A_t^{\frac{1}{\alpha_1 + \alpha_2}} (C_t^{p*}/\alpha_4)^{\frac{-\alpha_4}{\alpha_1 + \alpha_2}} (O_t^*/\alpha_3)^{\frac{-\alpha_3}{\alpha_1 + \alpha_2}}$

First-order conditions with respect to $C, H, E, T, E_I, I, L, K, Z$ yield

$$
\begin{aligned}
0 = {} & (1-\varrho)(C-H)^{(1-\varrho)(1-\sigma)-1}(1-L)^{\varrho(1-\sigma)} - \beta\lambda_1 h_C + \lambda_2[\omega_c\omega_z E^{-\mu_z}T^{\mu_z}Z^{mu_c} \\
& +(1-\omega_c)O^{*1-\mu_c}E^{-\mu_c}Z^{-\mu_c}T] + \lambda_5[(1-\sigma)(1-\varrho)-1]\frac{EZ}{Z^*}(C-H)^{(1-\varrho)(1-\sigma)-2}(1-L)^{\varrho(1-\sigma)} \quad\text{(D.9)}
\end{aligned}
$$

$$
\begin{aligned}
0 = {} & -(1-\varrho)(C-H)^{(1-\varrho)(1-\sigma)-1}(1-L)^{\varrho(1-\sigma)} + \lambda_1 \\
& +\lambda_5[(1-\sigma)(1-\varrho)-1]\frac{EZ}{Z^*}(C-H)^{(1-\varrho)(1-\sigma)-2}(1-L)^{\varrho(1-\sigma)} \quad\text{(D.10)}
\end{aligned}
$$

$$
\begin{aligned}
0 = {} & -\lambda_2\mu_z\omega_c\omega_z E^{-\mu_z-1}T_z^{\mu}Z^{-\mu_c}C - \lambda_3(\mu_z-1)E^{\mu_z-2} + \lambda_5\frac{Z}{Z^*}(C-H)^{(1-\varrho)(1-\sigma)-1}(1-L)^{\varrho(1-\sigma)} \\
& -\lambda_2(1-\omega_c)\mu_c O^{*1-\mu_c}E^{-\mu_c-1}Z^{-\mu_c}TC + \lambda_7((1-\mu_c)(1-\omega_c)E^{-\mu_c}O^{*1-\mu_c})
\end{aligned}
$$

$$
\begin{aligned}
0 = {} & \lambda_2 T^{\mu_z-1}\mu_z(\omega_c E^{-\mu_z}Z^{-\mu_c}C + (1-\omega_z)\omega_c Z^{*-\mu_c}C^*) + \lambda_2\rho_I T^{\rho_I-1}(\omega_I E_I^{-\rho_I}I + (1-\omega_I)I^* - \lambda_2\Upsilon \\
& +\lambda_2(1-\omega_c)\mu_c O^{*1-\mu_c}E^{-\mu_c}Z^{-\mu_c}C + \lambda_2\gamma B_t T_t^{-\gamma-1}K_{t-1}^\alpha L_t^{1-\alpha} \quad\text{(D.11)} \\
& +\lambda_3\omega(\mu-1)T^{\mu-2} + \lambda_4\omega_I(\rho_I-1)T^{\rho_I-2} \quad\text{(D.12)}
\end{aligned}
$$

$$
0 = -\lambda_2\rho_I\omega_I E_I^{-\rho_I-1}T^{\rho_I}I - \lambda_4(\rho_I-1)E_I^{\rho_I} \quad\text{(D.13)}
$$

$$
0 = \lambda_2\omega_I E_I^{-\rho_I}T^{\rho_I} - \lambda_6 \quad\text{(D.14)}
$$

$$
\begin{aligned}
0 = {} & -\varrho(C-H)^{(1-\varrho)(1-\sigma)}(1-L)^{\varrho(1-\sigma)-1} - \lambda_2 BT^{-\gamma}(1-\alpha)K^\alpha L^{-\alpha} \\
& -\lambda_5\varrho(1-\sigma)\frac{EZ}{Z^*}(C-H)^{(1-\varrho)(1-\sigma)-1}(1-L)^{\varrho(1-\sigma)-1} \quad\text{(D.15)}
\end{aligned}
$$

$$
0 = -\lambda_2\alpha BT^{-\gamma}K^{\alpha-1}L^{1-\alpha} + \lambda_6(\frac{1}{\beta}-1+\delta) \quad\text{(D.16)}
$$

$$
\begin{aligned}
0 = {} & -\lambda_2\mu_c\omega_c\omega_z E^{-\mu_z}T_z^\mu Z^{-\mu_c-1} - \lambda_2\mu_c(1-\omega_c)E^{-\mu_c}O*1_c^{-\mu}Z^{-\mu_c-1}TC \\
& +\lambda_5\frac{E}{Z^*}(C-H)^{(1-\varrho)(1-\sigma)-1}(1-L)^{\varrho(1-\sigma)} - \lambda_7(\mu_c-1)Z^{\mu_c-2} \quad\text{(D.17)}
\end{aligned}
$$

In steady-state these satisfy

$$
\alpha B\left(\frac{L}{K}\right)^{1-\alpha} = \omega_I(\frac{1}{\beta}-1+\delta) = \omega_I R_K \qquad \lambda_4(1-\rho_I) = \lambda_2\rho_I\omega_I I \qquad\text{(D.18)}
$$

$$
\lambda_3\omega_z(1-\mu_z) = \lambda_2 Y((\mu_z\omega_c+1-\omega_c)c_y+\rho_I(1-\omega_I^2)i_y-\frac{\Upsilon}{Y}+\alpha_3+\alpha_4) \qquad (1-\beta h_C)\lambda_1 = -\omega\lambda_2 \qquad\text{(D.19)}
$$

$$
-[(1-\sigma)(1-\rho)-1]\lambda_5 F = Y[(1-\rho)F + \lambda_2\frac{\mu_z\omega_c+1-\omega_c}{1-\beta h_C}]c_y(1-h_C) \qquad\text{(D.20)}
$$

$$
F = (C(1-h_C))^{(1-\varrho)(1-\sigma)-1}(1-L)^{\varrho(1-\sigma)} \qquad\text{(D.21)}
$$

$$
\lambda_2 = \frac{\varrho\omega_c\omega_z c_y(1-h_C)F}{J} \qquad\text{(D.22)}
$$

where

$$
\begin{aligned}
J &= -\frac{1-\alpha}{\alpha}\omega_c\omega_z R_K\omega_I k_y\frac{1-L}{L} + \varrho(1-\sigma)c_y[\mu_z\omega_c(1-\omega_I^2) + (1-\omega_c)(1-\mu_c(1-\omega_c)\omega_z\omega_c)] \\
&\quad +\rho(1-\sigma)\rho_I(1-\omega_I^2)i_y - \rho(1-\sigma)\frac{\Upsilon}{Y} + \rho(1-\sigma)(\alpha_3+\alpha_4)
\end{aligned}
\tag{D.23}
$$

The second order expansion for the welfare is then obtained by differentiating the utility function twice, and setting the Lagrange multipliers to their steady state values above. For convenience one can normalize this by dividing by FY. The expression is long and detailed, and is available on request.

Added to this second order expansion is a price dispersion term arising from price-setting behavior by firms; this yields a second-order term

$$
-\frac{\varrho L}{2(1-L)}\frac{\zeta\xi_H}{(1-\xi_H)(1-\beta\xi_H)}\pi_t^2
\tag{D.24}
$$

Note that there is an issue here of which values C, L we use in all of these expressions. There is an additional representation of λ_2 for the social planner's problem, which leads ultimately to a linear relationship between C and L, and then via the goods market equation to a complete expression for each of these. One can go through this procedure, or just use the steady state values of observed ratios C/Y, I/Y and G/Y. We choose to do the latter

In the results the quadratic loss using the procedure above is implemented numerically. 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. To obtain the quadratic form in this case, define

$$
cmcl_t = \frac{c_t - h_C c_{t-1}}{1 - h_C} \tag{D.25}
$$
$$
kml_t = k_{t-1} - l_t \tag{D.26}
$$
$$
ccii_t = \mu\omega(1-\omega)c_y c_t + \mu(1-\omega^*)c_y c_t^* + \rho_I\omega_I(1-\omega_I)i_y i_t + \rho_I^*(1-\omega_I^*)i_y i_t \tag{D.27}
$$
$$
ccsls_t = [(1-\sigma)(1-\varrho)-1]\frac{c_t^* - h_C c_{t-1}^*}{1-h_C} - (1-\sigma)\varrho\frac{L^* l_t^*}{1-L^*} \tag{D.28}
$$

Define

$$\lambda = \frac{\varrho c_y (1 - h_C)}{\frac{(1-\alpha)R_K \omega_I k_y}{\alpha} \frac{1-L}{L} + \frac{\varrho(1-\sigma)}{\omega}[\mu(\omega^2 - 1)c_y + \rho_I(\omega_I^2 - 1)i_y - \frac{\Upsilon}{Y}]} \tag{D.29}$$

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

$$
\begin{aligned}
2W &= -(1-h_C)c_y\bigg((1-\varrho)[(1-\sigma)(1-\varrho)-1]cmcl_t^2 \\
&\quad -2(1-\sigma)\varrho(1-\varrho)cmcl_t\frac{Ll_t}{1-L} + \frac{\varrho[(1-\sigma)\varrho-1]L^2l_t^2}{(1-L)^2}\bigg) \\
&\quad -\bigg(\lambda c_y\mu[2\omega^3 - 3\omega + 1 + \mu\omega(1-\omega)^2] \\
&\quad +\frac{\lambda i_y\rho_I}{2}[(1-\omega_I)^2(\mu\omega - 3\omega - \mu) + 1 - \omega_I^3 + \rho_I(1 - 3\omega_I^2 + 2\omega_I^3)]\bigg)\tau_t^2 \\
&\quad -\lambda\frac{F+Y}{Y}\alpha(1-\alpha)kml_t^2 + 2\lambda\frac{F+Y}{Y}y_ta_t - 2\lambda ccii_t\tau_t - 2\lambda ccsls_t\tau_t \\
&\quad +\frac{\varrho L(1-h_C)}{(1-L)}\frac{\zeta\xi_H}{(1-\xi_H)(1-\beta\xi_H)}\pi_t^2
\end{aligned}
\tag{D.30}
$$

which corresponds to (97) in the main text.

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

$$
\begin{aligned}
\Delta\Omega &= (1-\rho)\sum_{t=0}^{\infty}\beta^t C(1-h_C)^{(1-\sigma)(1-\rho)-1}(1-L)^{\rho(1-\sigma)}(\Delta C - h_C\Delta C) \\
&= \frac{(1-\rho)(1-h_C)c_y}{1-\beta}FY c_e
\end{aligned}
\tag{D.31}
$$

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

$$c_e = \frac{(1-\beta)\Delta\Omega}{(1-\rho)(1-h_C)c_y} \tag{D.32}$$

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

$$c_e = \frac{\Delta\Omega}{(1-\rho)(1-h_C)c_y} \times 10^{-2} \tag{D.33}$$

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