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# Modelling Small Open Developing Economies in a Financialized World: A Stock-Flow Consistent Prototype

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# Modelling Small Open Developing Economies in a Financialized World: A Stock-Flow Consistent Prototype Growth Model

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**Abstract**

This paper builds a stock-flow consistent growth model in continuous time in order to analyze the effects of policy rates in financial centres on a small open developing economy with an open capital account and a flexible exchange rate. Using a balance-sheet approach and explicitly modelling real-financial spheres interactions and propagation mechanisms, we show that a fall in global policy rates triggers appreciation-induced boom-bust episodes in the small open economy, driven by portfolio flows and cross-border lending. During the boom, public balances improve, unemployment and inflation fall and current account deficit widens. Our results show that the boom is larger if foreign exchange market adjustment is sluggish, expectations adjust more rapidly, banking sector is monopolistic or risk perception is less sensitive to fundamentals. In the absence of productivity growth differentials between the developing economy and the rest of the world, the balance-of payments constrained growth rate is a strong attractor and the economy gravitates towards this growth rate as financial variables and exchange rates adjust to their new levels.

**Keywords**

Capital Flows, Developing Economies, Stock-Flow Consistent Modelling

**JEL Classification**

D63; J62; N36; O54; R10

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**Original version**

English

**Résumé**

Cet article propose un modèle stock-flow cohérent de croissance en temps continu afin d'analyser les effets des taux directeurs des centres financiers sur un pays en voie de développement en économie ouverte, avec un compte de capital ouvert et un taux de change flexible. En utilisant une approche basée sur les bilans financiers et en modélisant explicitement les interactions et les mécanismes de propagation entre les sphères réelles et financières, nous montrons qu'une baisse des taux directeurs mondiaux déclenche des épisodes de croissance-récession induits par l'appréciation du taux de change dans la petite économie ouverte via les flux de portefeuille et les prêts transfrontaliers. Pendant la phase de croissance, les comptes publics s'améliorent, le chômage et l'inflation diminuent et le déficit du compte courant se creuse. Nos résultats montrent que la phase de croissance est plus marquée si l'ajustement du marché des changes est lent, si les anticipations s'ajustent plus rapidement, si le secteur bancaire est monopolistique ou si la perception du risque est moins sensible aux fondamentaux. En l'absence d'écarts de croissance de la productivité entre l'économie en développement et le reste du monde, le taux de croissance contraint de la balance des paiements est un fort attracteur et l'économie gravite vers ce taux de croissance à mesure que les variables financières et les taux de change s'ajustent à leurs nouveaux niveaux.

**Mots-clés**

Flux de capitaux, économie du développement, modélisation Stock-Flux Cohérente

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This version: February 6, 2020

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**JEL Codes**: F32, F41, F44, G15

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# 1 Capital Inflows and Boom-Bust Episodes in Developing Economies

Following the capital-account liberalization of 1970s and 1980s, developing economies have gone through several episodes of booms and busts associated with capital inflows, currency appreciations, sudden stops and speculative attacks. As documented by Frankel (2010), the capital inflows have historically come in rounds. The first wave, beginning in 1970s and ending in 1982 with the international debt crisis was followed by the second wave between 1989 and 1997 Asian Crisis and subsequently by the third wave between 2002 and the 2008 Global Financial Crisis. Despite a sharp reversal of capital flows in late 2008 and early 2009, zero policy rates and quantitative easing policies refuelled another round of capital inflow bonanza to developing economies. In essence, a large group of developing countries had already experienced severe currency appreciation as end of 2012, exceeding 30% for Turkey, Phillipines and Colombia and 50% for Russia, Nigeria and Brazil compared to 2002 levels (Badia and Segura-Ubiergo, 2014).

This cyclical behavior of capital inflows has led some studies to connect their dynamics with a financial cycle in industrial economies. The existence of such a financial cycle which can be identified using measures of credit gap and property prices was first floated by Drehmann et al. (2012) and further taken up by Borio (2014) among many others. While earlier studies such as Reinhart and Reinhart (2008) had found a strong relationship between US interest rates and capital flow bonanzas, Rey (2015) took a step further and argued that center countries monetary policy is transmitted through leverage and cross border gross flows (particularly credit flows) to the rest of the world even under floating exchange rate regimes. The popular trilemma faced by small open economies therefore has turned into a dilemma as the exchange rate system in place does not matter anymore and independent monetary policy can only be achieved through regulating the capital account. Supporting evidence was provided by Nier et al. (2014) who demonstrated that fundamentals such as high growth prospects and low public debt lose their significance when the global risk appetite is low (proxied by a high VIX) but interest rate differentials still have a statistically significant effect on the amount of capital account, forcing developing economies to raise interest rates in order to curb capital outflows during the downturn of the financial cycle, even with sound economic fundamentals.

For developing economies, capital inflow bonanzas come along with some well-documented regularities in macroeconomic dynamics, some of which were recognised as early as the classical work of Diaz-Alejandro (1985). As summarised in detail by Reinhart and Reinhart (2008), inflows lead to an appreciation of the currency, falling unemployment and inflation, trade and current account deficits, an increase in international reserves and consumption and/or investment booms. Heavy inflows are also associated with credit booms as shown by Sa et al. (2006), Magud et al. (2014) and Baskaya et al. (2016), and asset-price booms (Caballero, 2016). The evidence on public balances is more mixed since public debt dynamics depend on the fiscal stance during inflows and may therefore greatly vary among countries. Although Reinhart and Reinhart (2008) find in a long timeframe that fiscal deficits worsen during capital inflow bonanzas due to procyclical government spending, several developing economies such as Turkey, Colombia and South Africa experienced significant improvements in public deficits and public debt/GDP ratios during the 2002-2008 period, which were sustained during the post 2009 quantitative easing - ZIRP era.

The purpose of this paper is to construct a modelling framework which is able to replicate the empirical regularities in developing economies following a shock to foreign policy rates and capital inflows triggered by this shock. Particularly we aim to explicitly model the channels of transmissions through which capital inflows impact the economy and see how their interplay leads to specific dynamics. The channels identified in the literature[1] indeed have conflicting effects on domestic demand.

1. *Trade channel*: Capital inflows and excess supply in foreign exchange markets lead to an appreciation of the domestic currency, reducing exports, increasing imports and widening the trade deficit. This is the traditional negative effect of currency appreciation on domestic demand.[2] During the inflows and the appreciation phase, there is a shift from growth in tradables sector to higher growth in non-tradable sector (see Frankel (2010) for a general discussion on this shift and de La Torre et al. (2015) in the case of Latin America). Unsterilized central bank interventions in FX markets to prevent appreciation increase domestic bank reserves, reduce financing costs for the domestic banking system and pull down lending rates, leading to further expansionary effects (see Obstfeld, 2015).

2. *Balance Sheet Channel*:

   (a) *Asset Price Booms*: Capital Inflows to developing economy financial assets are strongly associated with asset price booms. While such booms will on the one hand induce an increase in spending via wealth effects, higher asset prices will lead to a fall in borrowing costs, justified by higher collateral values (Schuknecht et al., 2007). This is the classical financial accelerator mechanism described in Bernanke and Gertler (1995), which operate via the impact of capital inflows on asset prices in this context.

   (b) *FX Liabilities*: A similar accelerator effect takes place when borrowers' balance sheets are exchange-rate sensitive. In this case, appreciation leads to stronger firm, government and household balance sheets and falling leverage ratios by reducing the domestic currency value of FX liabilities (Kearns and Patel, 2016).

   (c) *Real Balances*: The appreciation of the currency also lead to an increase in real income for households, fuelling consumption and increasing aggregate demand (Frankel, 2010).

3. *Liquidity Channel and Credit Booms*: Foreign capital inflows result in excess liquidity, potentially leading to an increase in bank credit supply, reducing lending rates and fuelling credit booms Kaminsky et al. (1997). The liquidity channel may also contribute to the asset price bubbles by rewarding high risk-taking strategies by banks, as shown by Acharya and Naqvi (2012).

Evidently, individual country experiences following capital inflows depend on the relative strengths of these channels and policy responses. As we outlined above, for most developing economies, the positive impact of balance sheet and liquidity channels have systematically outweighed the traditional trade channel, causing appreciation-driven consumption and/or investment boom episodes followed by severe busts, rising unemployment, currency crashes and soaring public debt.

[1]Capital inflows can take the form of cross-border banking flows, portfolio flows and FDI. For the rest of the paper, we will focus our attention on portfolio inflows and cross-border lending. However, note that in the absence of productivity-enhancing capacity increasing investment, FDI may also lead to appreciation and Dutch disease, triggering similar dynamics to portfolio and cross-border banking flows (see Botta et al., 2016, for an example on the case of Colombia).

[2]Rising current account deficits financed by these inflows and the subsequent sudden bust is well documented in (Calvo et al., 2004; Eichengreen and Adalet, 2005)

In order to capture the dynamics and the interplay among these channels in a developing economy, we construct a continuous time monetary stock-flow consistent model, in which goods and financial markets are characterised by disequilibria that induce dynamic price and quantity adjustments. Using strict national income accounting, we carefully model the interrelations between the balance sheets for firms, banks, households, government, central bank and the rest of the world and identify the corresponding stock-flow relationships. Our results show that rapid adjustment of exchange rate and/or sales expectations, sluggish adjustment of foreign exchange rate markets and/or a more monopolistic banking sector magnify the boom-bust dynamics following surges in capital flows.

The paper is organized as follows. In Section 2, we present the methodology we develop and apply in section 3, which describes the model in detail, presenting its accounting structure and motivating the behavioral rules. In Section 4, we detail the calibration we used, as well as the initial steady state of our economy. Section 5 presents the simulation results following a shock to foreign policy rate, while section 6 shows the robustness of our results with respect to a large set of model parameters. Section 7 finally concludes with some blueprints for future research.

## 2 Treating stocks and flows in a timely manner

As we noted above, the non-traditional effects of capital flows on aggregate demand (both directly via asset/liability valuation and indirectly via the appreciation of the currency) operate through balance sheet and liquidity channels. This calls for a careful modelling of inter-relations among balance sheets of economic agents. Feedback mechanisms between stock accumulation emerging out of flow dynamics, and flow responses to stock accumulation processes are fundamental in grasping the interactions between international finance and domestic dynamics. For this reason, we follow the Stock-Flow Consistent (SFC) approach pioneered by Godley and Lavoie (2006), which allows to represent the economies as a multilayered networks of financial contracts through asset holder and liability emitter connections.[3] This brings two big advantages, on the one hand it allows us to explicitly model balance sheet dynamics,[4] including price dynamics and the ensuing revaluation of assets and liabilities, and ensures that stock dynamics reflect sectoral surpluses and/or deficits. On the other, the accounting framework is directly constructed on the complete set of national income, including secondary income distribution, flow of funds and balance sheets, warranting the coherence and consistency of the behavioural rules included in the model.

Next, as highlighted by Borio and Disyatat (2015), it is vital to ensure that open economy models are truly monetary and distinguish between the resource constraint, i.e current account, and financing, i.e lending for investment/consumption. In other words, models should acknowledge that while trade flows involves the actual exchange of real resources, payments are in currency and

[3]For a survey of stock-flow consistent modelling, see Caverzasi and Godin (2014) and Nikiforos and Zezza (2017). For examples of SFC model with detailed micro-foundations, see Caiani et al. (2016, 2018).

[4]The importance of balance sheet dyanmics has been highlighted by many scholars. Koo (2011, 2013) for instance argues that firms change their behavior towards debt minimization when their balance sheets are damaged. This generates what Koo (2011) calls 'Balance Sheet Recession' due to the lack of investment and spending following this change in behaviors. Allen et al. (2002) on the other hand highlight the role of risks buried in balance sheets (such as maturity mismatches or capital structures mismatches) in explaining recessions but also, following the work of Krugman (1999), in mitigating the productivity gains that a currency depreciation could create. The role of deleveraging and cross border capital flows in crisis triggering and diffusion are highlighted in Allen et al. (2002); Bruno and Shin (2013); Lane (2013).

require money financing. As a result, although current account and capital account are mirror-images of each other as an accounting identity, they are the outcome of decisions taken by different agents separately and current accounts do not necessarily reveal any information on the pattern of financing. In our model, we assume that investment is financed by (domestic or foreign-financed) bank loans in money and retained earnings from monetary profits. Similarly, foreign inflows are in the form of money flows. This structure overcomes the problems of cannonical open economy models where real resources are borrowed and therefore the real constraint becomes synonymous with financing constraints, as shown by Borio and Disyatat (2015).

Another important issue relates to the concept of equilibrium and the treatment of time in economic modelling. Markets are characterised by continuous disequilbria and imbalances. These imbalances create tensions between demand and supply side responses, which lead to the infamous debate between Marshall and Walras on which market mechanisms eliminates excess demand/supply (Currie and Steedman, 1990). We argue that both quantity adjustment and price adjustment processes operate at the same time with different adjustment speeds, none of which tends towards infinity.[5] With finite speeds, it is essential to explicitly model both adjustment processes since the existence of a long-run attractor of the model and the dynamics of (non)convergence to this attractor will strongly depend on the nature of these processes. Thus, disequililbria in goods and financial markets and quantity/price adjustments to these disequilibria play key roles in our model.

Modelling excess demand adjustment processes in discrete time poses several problems, as demonstrated by Gandolfo (2012). Particularly, if the excess demand function involves both stock variables and variables which are sums of flows over the observation period (such as gross domestic product or aggregate demand), it is difficult to derive a plausible (exact or approximate) discrete time representation for an adjustment process.[6] Further, rapid adjustment speeds in some markets may cause the adjustments to take place within the period in a discrete time model, ensuring that the observed values coincide with the desired values and rendering the estimation of the adjustment speeds impossible. Such empirical problems do not exist in continuous time models, for which adjustment speeds can be asymptotically estimated even with long observation periods (Gandolfo, 1997). In essence, the continuous time structure of our model and our careful treatment of stock-flow interactions enable us to deploy continuous time estimation techniques which can explicitly distinguish between flows and stocks, are independent of the time interval of the dataset and can use mixed frequency data (see Chambers, 2016; Thornton and Chambers, 2017).[7]

Finally, several studies on international capital flows stressed the importance and relevance of tracking gross as well as net flows (see Borio and Disyatat, 2010; Obstfeld, 2012). Such considerations gain particular importance during periods of high volatility and uncertainty; a condition likely to hold in developing economies with historical experiences of high inflation and strong appreciation/depreciation episodes. In our opinion, our continuous-time framework is better equipped to capture the impact of gross flows within a given time-frame, even if outflows offset inflows throughout the reference period to yield zero net flows.

[5] If this were the case for one of them, say price, then price would immediately adjust to its equilibrium value, leaving quantities unchanged, see (Gandolfo, 1997, ch. 13) for more details.

[6] See (Gandolfo, 2012, ch. 3) for an example of the derivation of a (non-intuitive) discrete time representation for an interest rate adjustment process with mixed stock/flow variables in the demand function

[7] This is on its own a research topic and we therefore do not attempt to fit the model to a specific country in this study but rather calibrate it to match (on average) the characteristics of a large set of developing economies at its steady state.

# 3 The model

The overall structure of the model[8] is presented in the Transaction-Flow Matrix, table 1. This matrix represents all the flows taking place in the economy. Respecting a strict accounting framework, each flow has an origin (represented by a '-') in a sector and a destination (with a '+' sign), implying that for each row, the sum of all flows is equal to zero. There are two exceptions to this rule: memo items, i.e. GDP and Gross Operating Surplus (GOS afterward), and Gross National Income, are added for exposition purposes[9] and are equal to the sum of the non-memo items lying above them in the table; and accumulation of physical assets, capital and inventories in this model, which of course do not have counterparts, contrary to financial assets.

The table is divided into three main components, each divided by a solid line; non-financial transactions, accumulation of physical assets, and financial transactions. Non-financial transactions are then subdivided into four blocks. The first block is the construction of GDP from the demand perspective containing consumption, government expenditures, investment in the form of capital or inventories, imports and exports. The second block of variables is the generation of income account under the form of wages, taxes minus subsidies and finally GOS. GOS is then divided in the third block into interests and dividends payment, leading to Gross National Income. The second and third blocks correspond to the primary income distribution account. The fourth block represents the secondary income distribution accounts composed of taxes and subsidies as well as remittances and central bank profits, leading to savings. In the case of firms, banks and central banks, we have distinguished between current and capital transactions, and in these cases, savings moving from the current transactions column to the capital transaction column can be interpreted as retained earnings, which is why they appear as $RE_x$ instead of $S_x$. For the other sectors, savings are memo items added to highlight this accounting item.

Physical asset accumulations are memo item and are added to represent the physical counterparts of the two investment transaction flows. The financial assets flows on the other hands represent the change in assets and liabilities used by each sector in order to either finance their spending or to buy assets as financial investment. Financial investments are outflows and are thus included in the table with a minus sign, even though they lead to an increase in assets. Similarly, the emissions of new liabilities are included with a plus sign because they represent sources of funds for that sector.

## 3.1 Production

We assume a single good which is produced domestically or imported/exported and also used as capital. The goods market is characterized by disequilibrium such that Aggregate Demand ($Y^D$) is not necessarily equal to total production ($Y^P$). Firms form adaptive expectations on expected sales ($Y^e$):

[8] We use the following rule for the use of subscript and superscripts: subscripts represent the sectoral origin of the flow or the liability emitter of the stock while superscripts are a combination of sectoral destination, asset holder, or variable characteristic such as expected ($e$), targeted ($T$), desired ($d$), foreign ($FX$) or domestic ($D$), separated by a comma. The sectors are firms ($F$), households ($H$), banks ($B$), central banks ($CB$), government ($G$) and rest of the world ($W$). If one of the sectors is obvious because there is only one sector that could appear on the subscript or the superscript, it is omitted. So for example $R^{B,FX}$ means foreign reserves held by banks, even though the rest of the world sector has emitted these reserves, it is omitted in the subscript. The dot appearing on top of certain variables signify time derivative of that variable.

[9] This is why they are represented within square brackets.

| | Industry | | Households | Banks | | Central Bank | | Government | RoW | $\Sigma$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | Current | Capital | | Current | Capital | Current | Capital | | | |
| Consumption | $+C_H$ | | $-C_H$ | | | | | | | 0 |
| Investment, capital | $+I^K$ | $-I^K$ | | | | | | | | 0 |
| Govt Spending | $+G_D$ | | | | | | | $-G_D$ | | 0 |
| Imports | $-IM$ | | | | | | | | $+IM$ | 0 |
| Exports | $+X$ | | | | | | | | $-X$ | 0 |
| [GDP] | $[Y]$ | | | | | | | | | $[Y]$ |
| Wages | $-WB$ | | $+WB$ | | | | | | | 0 |
| Taxes on Imports | $-T^{IM}$ | | | | | | | $+T^{IM}$ | | 0 |
| [Gross Operating Surplus] | $[GOS_F]$ | | $[GOS_H]$ | $[GOS_B]$ | | $[GOS_{CB}]$ | | $[GOS_G]$ | | $[GOS]$ |
| Int. on Deposits | | | $+IntD$ | $-IntD$ | | | | | | 0 |
| Int. on Loans | $-IntL^D$ | | | $+IntL^D$ | | | | | | 0 |
| Int. on Firms FX Loans | $-IntL_F^{FX}$ | | | $+IntL_F^{FX}$ | | | | | | 0 |
| Int. on Banks FX Loans | | | | $-IntL_B^{FX}$ | | | | | $+IntL_B^{FX}$ | 0 |
| Int. on Bonds | | | $+IntB^H$ | $+IntB^B$ | | $+IntB^{CB}$ | | $-IntB$ | $+IntB^W$ | 0 |
| Int. on Advances | | | | $-IntA$ | | $+IntA$ | | | | 0 |
| Dividends | $-Div_F$ | | $+Div$ | $-Div_B$ | | | | | | 0 |
| [Gross National Income] | $[GNI_F]$ | | $[GNI_H]$ | $[GNI_B]$ | | $[GNI_{CB}]$ | | $[GNI_G]$ | | $[GNI]$ |
| Remittances | | | $+Rem$ | | | | | | $-Rem$ | 0 |
| Central Bank Profits | | | | | | $-F_{CB}$ | | $+F_{CB}$ | | 0 |
| Taxes on Income and Profits | $-T_F^F$ | | $-T^I$ | $-T_B^F$ | | | | $+T^T$ | | 0 |
| Welfare Spending | | | $+G_E$ | | | | | $-G_E$ | | 0 |
| Savings | $-RE_F$ | $+RE_F$ | $[S_H]$ | $-RE_B$ | $+RE_B$ | 0 | 0 | $[S_G]$ | $[S_W]$ | 0 |
| [Capital] | | $[\dot{K}]$ | | | | | | | | $[\dot{K}]$ |
| [Inventories] | | $[\dot{V}]$ | | | | | | | | $[\dot{V}]$ |
| Deposits | | | $-\dot{D}^D$ | | $+\dot{D}^D$ | | | | | 0 |
| Reserves | | | | | $-\dot{R}^D$ | | $+\dot{R}^D$ | | | 0 |
| Loans | | $+\dot{L}^D$ | | | $-\dot{L}^D$ | | | | | 0 |
| Bonds | | | $-\dot{B}_G^H$ | | $-\dot{B}_G^B$ | | $-\dot{B}_G^{CB}$ | $+\dot{B}_G$ | $-\dot{B}_G^W$ | 0 |
| Advances | | | | | $+\dot{A}$ | | $-\dot{A}$ | | | 0 |
| FX deposits | | $-\dot{D}^{FX}$ | | | $+\dot{D}^{FX}$ | | | | | 0 |
| FX Reserves | | | | | $-\dot{R}^{FX,B}$ | | $-\dot{R}^{FX,CB}$ | | $+\dot{R}^{FX}$ | 0 |
| Firms FX Loans | | $+\dot{L}_F^{FX}$ | | | $-\dot{L}_F^{FX}$ | | | | | 0 |
| Banks FX Loans | | | | | $+\dot{L}_B^{FX}$ | | | | $-\dot{L}_B^{FX}$ | 0 |
| $\Sigma$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 1: Transaction Flow Matrix

$$\dot{Y}^e = \beta_y \left( \frac{Y^D}{p} - Y^e \right) + \left( \alpha_p + \frac{\dot{a}}{a} \right) Y^e, \tag{1}$$

where $p$ is the price level, $\alpha_p$ and $\frac{\dot{a}}{a}$ are population growth rate and labour productivity growth rate respectively, and $\beta_y$ is the speed of expectations adjustment to excess demand.

Aggregate demand is given by

$$Y^D = C_H + G_D + p \cdot I^K + X, \tag{2}$$

with $C_H$ denoting nominal consumption, $G_D$ nominal government spending, $I^K$ real investment and $X$ nominal domestic currency value of exports. Unsold goods accumulate in inventories ($V$), which translate into real investment in inventories ($I^V$):

$$\dot{V} = Y^P - \frac{Y^D}{p} = I^V. \tag{3}$$

As in Franke (1996); Chiarella and Flaschel (2000); Charpe et al. (2011), we assume firms have a desired inventory to expected sales ratio ($\alpha_v$), leading to desired inventories to be defined by

$$V^d = \alpha_v \cdot Y^e. \tag{4}$$

Therefore, the desired level of investment in inventories is given by:

$$I^{V,d} = (V^d - V). \tag{5}$$

Production (6) in each period is then the sum of expected real aggregate demand and production for desired inventory replacement.

$$Y^P = Y^e + I^{V,d} \tag{6}$$

There are no direct imports and all goods are imported via the firm sector first. Domestic production is therefore given by the difference between total production and total imports:

$$Y^{P,D} = Y^P - IM. \tag{7}$$

We assume a constant capital to output ratio ($v$), implying that the utilization rate of capital ($K$) is given by domestic production divided by full-capacity output:

$$u = \frac{Y^{P,D}}{K \cdot v}.$$

Imports in real terms depend on the different time-varying import propensities ($\sigma_{M,i}$) out of real levels of consumption, government spending, investment, and exports:

$$IM = \sigma_{M,C} \cdot \frac{C_H}{p} + \sigma_{M,G} \cdot \frac{G_D}{p} + \sigma_{M,I} \cdot I^K + \sigma_{M,X} \cdot \frac{X}{e^N \cdot p_W}. \tag{8}$$

The propensities to import move towards the target import propensities, which are negative functions[10] of the real exchange rate ($e^R$), import taxes depending on type of goods imported ($\tau_i^M$) and the elasticity of substitution between imported and domestic goods ($\epsilon_i$). However, due to structural constraints, there are minimum thresholds for each targeted import propensity:

$$\dot{\sigma}_{M,i} = \beta_M \left(\sigma_{M,i}^T - \sigma_{M,i}\right) \tag{9}$$

$$\sigma_{M,i}^T = \max\left[\sigma_{M,i}^{\min}, \frac{1}{1+\left[\Gamma_i \cdot e_R \cdot \left(1+\tau_i^M\right)\right]^{\epsilon_i}}\right], \; i = C, G, I, X. \tag{10}$$

Defining $e_N$ as domestic currency per unit of foreign currency, the real exchange rate becomes

$$e^R = \frac{p_W \cdot e^N}{p}. \tag{11}$$

where $p_W$ and $p$ are world and domestic price levels and respectively. Assuming Armington preferences for domestic exports to the rest of the world and denoting export tariffs imposed by the rest of the world with $\tau_W$, total exports become:

$$X = \sigma_X \cdot GDP_W \cdot p_W \cdot e^N \tag{12}$$

$$\dot{\sigma}_X = \beta_X \left(\sigma_X^T - \sigma_X\right) \tag{13}$$

$$\sigma_X^T = \sigma_{X,0} \left(\frac{e^R}{1+\tau_W}\right)^{\sigma_{X,1}} \tag{14}$$

where $\sigma_{X,0} = (\beta_{far}/1 - \beta_{far})$, $\beta_{far}$ is the share parameter in the Armington preference function of the rest of the world as in standard open economy models (see for instance Ruhl, 2008).

The functional form in (14) implies that the elasticity of export share with respect to domestic prices, foreign prices, nominal exchange rate and export tariffs by the Rest of the World must be equal and given by $\sigma_{X,1}$. The same is true for the elasticities $\epsilon_i$ in import share equations given by (10). Despite the widespread use of uniform elasticities, there is a large body of empirical literature such as Ruhl (2008) and Fontagné et al. (2018), which documents that these elasticities differ significantly from each other. For simplicity, we abstract from these considerations in this paper and assume a uniform elasticity both in import and export shares, leaving the study of the relationship between these elasticities and macroeconomic policy making for future work.

[10] The relative price effect can be derived by assuming an Armington-type composite good production ($Q_i$) using domestically demanded goods ($DD_i$) and imported goods ($IM_i$) such that

$$Q_i = \left[\beta_i \cdot DD_i^{\varphi_i} + (1-\beta_i) \cdot IM_i^{\varphi_i}\right]^{\frac{1}{\varphi_i}}$$

from which we can derive

$$\frac{DD_i}{IM_i} = \left[\frac{p_W \cdot e^N \cdot \left(1+\tau_i^M\right)}{p} \cdot \frac{\beta_i}{1-\beta_i}\right]^{\frac{1}{1-\varphi_i}}$$

using usual optimization procedures. Defining the elasticity of substitution between imported and domestic goods $\epsilon_i = \frac{1}{1-\varphi_i}$ and $\Gamma_i = \left(\frac{\beta_i}{1-\beta_i}\right)$, we can then solve for $\sigma_{M,i} = \frac{IM_i}{IM_i + DD_i}$ and get

$$\sigma_{M,i} = \frac{1}{1+\left[\Gamma_i \cdot e_R \cdot \left(1+\tau_i^M\right)\right]^{\epsilon_i}}$$

### 3.2 Pricing

Firms have a desired price level, calculated as an evolving markup ($\mu$) over historical unit costs ($HUC$):

$$p^d = (1 + \mu) \cdot HUC, \tag{15}$$

where the markup takes into account demand conditions and depends negatively on the divergence between the actual and desired inventory to output ratios.

$$\mu = \mu_0 - \mu_1 \cdot \left( \frac{V}{Y^e} - \alpha_v \right). \tag{16}$$

We assume that no collusion (tacit or explicit) takes place in goods markets and therefore $\mu_1 > 0$ and mark-ups are pro-cyclical.[11]

Firms employ a first-in-first-out accounting procedure (Godley and Lavoie, 2006) and therefore historical unit costs follow actual unit costs[12]

$$\dot{HUC} = \zeta \cdot (UC - HUC), \tag{17}$$

where unit costs ($UC$) include domestic labour costs and import costs. We stick to the standard small open economy assumption that the country is a price-taker both in export and import markets (see Frankel, 2010). Unit costs are thus given by:

$$UC = \frac{w \cdot L + IM \cdot p_W \cdot e^N + T^{IM}}{Y^P}, \tag{18}$$

with $T^{IM}$ denoting total import taxes (see section 3.5), $w$ and $L$ wages and employment level (see section 3.7).

[11] A large body of literature following Rotemberg and Saloner (1986) and Chevalier and Scharfstein (1994) have focused on the possibility and micro-foundations of countercyclical mark-ups in the context of collusion by goods producers. We do not pursue such an analysis in this paper and assign an equilibrating role to markups.

[12] To illustrate that this formulation is another form of the historical unit cost approach, assume that; as in Godley and Lavoie (2006), firms first sell the goods in inventories, which are valued at their production costs. Ignoring the inventory carrying cost, historical unit costs at time $t$ in a discrete time setting are given by

$$HUC_t = \sigma^s \cdot UC_{t-h} + (1 - \sigma^s) \cdot UC_t \tag{A}$$

where $\sigma^s = V_{t-h}/Y_t^e$ shows the ratio of inventories in total expected output. Rearranging leads to

$$UC_t - HUC_t = \sigma^s \cdot (UC_t - UC_{t-h}) \tag{A.a}$$

The discrete time representation of (17) combined with (A.a) hence implies

$$HUC_t - HUC_{t-h} = \zeta \cdot \sigma^s \cdot (UC_t - UC_{t-h})$$

On the other hand, lagging (A) by one period and subtracting it from (A) leads to

$$HUC_t - HUC_{t-h} = \sigma^s \cdot (UC_{t-h} - UC_{t-2h}) + (1 - \sigma^s) \cdot (UC_t - UC_{t-h})$$

Since empirically $\sigma^s$ is not high, assuming that

$$UC_{t-h} - UC_{t-2h} \approx UC_t - UC_{t-h}$$

holds, gives:

$$HUC_t - HUC_{t-h} \approx UC_t - UC_{t-h}$$

Therefore, choosing $\zeta = \frac{1}{\sigma^s} = \frac{Y^e}{V}$ in (17) provides a fairly good approximation to the dynamics of historical unit costs in a continuous time setting, especially as the time step used in the simulations, i.e $h$, gets smaller.

It is important to note at this point that we assume the exchange rate pass through to import and export prices is unity. In other words, we implicitly assume that import contracts are in producer currency and foreign exporters do not change markups in response to movements in the exchange rate.[13] As a result, a depreciation of the currency has a one-to-one effect on the prices of imported goods. Similarly, in the absence of market power in its export markets, the goods exported by the small open economy have a given world price in foreign currency and therefore the pass-through to export prices is also one. While empirical studies such as Campa and Goldberg (2005) have found the import price pass-through to be around 0.5 for OECD economies, the pass-through effect is higher in developing economies with a history of high inflation (Calvo and Reinhart, 2002; Devereux and Yetman, 2010). Recent contributions have identified that the import price pass-through displays non-linear dynamics and may be subject to threshold effects (see Brun-Aguerre et al., 2012, for instance) whereby the magnitude of the pass-through depends on the level of appreciation/depreciation of the currency, as well as whether the currency appreciates or depreciates. While we note that this is a crucial issue to consider in empirical models estimated to fit specific country dynamics, we abstain from specifying such non-linearities and thresholds in this prototype model and assume a full pass-through instead. As reported by Brun-Aguerre et al. (2012), only a third of the variation in pass-through elasticities can be explained by observables variations in economic characteristics of the countries and the rest comes from unobservable country-specific effects.

Finally, we assume at each point in time, only a fraction $\beta_p$ of producers adjust their prices and the price dynamics thus become:

$$\dot{p} = \beta_p \cdot \left(p^d - p\right) \tag{19}$$

Note that this framework implies that, in the case of excess supply of goods, the disequilibrium between production and demand in (1) results in a downward quantity adjustment via (3) - (7) and a downward price adjustment via (12), (14), (13) and (19); while in the case of excess demand for goods, upward adjustments in quantity and price take place. In other words, producers respond to the disequilibrium in goods markets by adjusting both prices and volume towards equilibrium.

## 3.3 Firm financing

| **Assets** | **Liabilities** |
|---:|:---|
| Capital Stock ($K$) | Domestic Currency Loans ($L^D$) |
| Inventories ($V$) | FX Loans ($L_F^{FX}$) |
| FX Deposits ($D^{FX}$) | Net Worth ($NW$) |

Table 2: Firms' Balance Sheet

The balance sheet of the NFCs in our model is displayed in table 2. Capital stock evolves according to:

$$\dot{K} = I^K - \delta \cdot K \tag{20}$$

where $I^K$ is real domestic investment.

[13] See Corsetti and Dedola (2005) for pricing-to-market models with variable markups that depend on exchange rates, Choudhri and Hakura (2015) for a mix of local and producer currency pricing and Devereux and Yetman (2010) for a model with slow rate of price adjustment in imported goods.

The investment function depends positively on expected return on capital ($r_F^e$) net of inflation:

$$I^K = K \cdot \left[\kappa_0 + \kappa_1 \cdot \left(r_F^e - \frac{\dot{p}}{p}\right)\right] \tag{21}$$

Gross expected profits for firms can be written

$$GF_F^e = p \cdot Y^e - HUC \cdot Y^P - i_F^{L,D} \cdot L^D - i_F^{L,FX} \cdot L_F^{FX} \cdot e^{N,e}, \tag{22}$$

where $i_F^{L,D}$, $i_F^{L,FX}$, $L^D$, $L_F^{FX}$ are respectively the interest rates on domestic and foreign loans paid by firms and the outstanding stock of domestic and foreign debt of firms.

Profits are taxed at the rate $\tau_F$, thus making net expected profits

$$F_F^e = (1 - \tau_F) \cdot GF_F^e. \tag{23}$$

Expected return per unit of capital, which determines the investment decision, is thus:

$$r_F^e = \frac{F_F^e}{p \cdot K}. \tag{24}$$

Total financing needs of firms is then given by investment in excess of retained earnings ($RE_F$):

$$TFN_F = p \cdot I^K - RE_F, \tag{25}$$

$$RE_F = s_F \cdot F_F^e, \tag{26}$$

where $s_F$ is the constant share of profits held as retained earnings.

Firms desire to finance a certain fraction ($\beta_{LF}$) of their total financing needs via borrowing in foreign currency, FX from now on, from domestic banks. This fraction evolves slowly towards a target which follows a hyperbolic function that depends on the expected arbitrage opportunity between domestic financing and foreign currency financing:

$$\dot{L}_F^{FX,d} = \beta_{LF} \cdot TFN_F / e_N \tag{27}$$

$$\dot{L}_F^{FX} = \min\left[CBL^S - L_F^{FX}, \dot{L}_F^{FX,d}\right] \tag{28}$$

$$\dot{L}^D = TFN_F - \dot{L}_F^{FX} \cdot e^N \tag{29}$$

$$\dot{\beta_{LF}^T} = \beta_{LF,par}\left(\beta_{LF}^T - \beta_{LF}\right) \tag{30}$$

$$\beta_{LF}^T = \beta_{LF}^{\min} + Tanh\left[\beta_1 \cdot arb_F\right] \tag{31}$$

where $arb_F$ is denotes the arbitrage for domestic firms between domestic currency and FX funding costs taking into account expected gains/ losses due to movements in the exchange rate and it is given by:[14]

$$arb_F = \frac{\left(1 + i^{L,D,T}\right) - \left(1 + i_F^{L,FX}\right)\frac{e^{N,e} + \dot{e}^{N,e}}{e^N}}{i^{L,D,T}}, \tag{32}$$

[14] This implies that the non-financial corporations might have open positions where their FX liabilities (and interest payments on these liabilities) may exceed their FX assets and FX earnings. As we will discuss below, this is in line with the empirical observations that in almost all developing and emerging markets, banks are subject to stringent FX open position regulations and net international investment position deficits result mainly out of open positions by the non-financial sector, see Canales Kriljenko (2004) and Terrier et al. (2011) for a discussion of FX open position regulations and Frankel (2010) on the origin of currency mismatches in balance sheets.

with $i^{L,D,T}$ denoting the interest rate on new domestic currency loans and will be defined below. In the case of zero arbitrage, firms finance a minimum fraction ($\beta_{LF}^{min}$) of their financing needs via FX debt, reflecting other behavioural aspects such as portfolio diversification, international holding companies financing their subsidiaries, etc. FX borrowing by firms $L_F^{FX}$ can nonetheless be constrained by cross-border lending supply ($CBL^S$), which we will define below, and firms finance any unsatisfied FX credit demand via domestic currency loans ($L^D$, see 29).

We assume that firms hold FX deposits equal to a certain fraction of their FX debt in the domestic banking sector:

$$\dot{D}^{FX} = \eta \cdot \dot{L}_F^{FX}, \tag{33}$$

where $\eta_{FX}$ is constant.

Actual gross profits of firms are given by the difference between sales income and total costs which consist of labour costs, import costs, including taxes, and interests payments on both domestic and FX debt. Net profits are gross profits minus taxes. Finally, the return rate on capital is computed by dividing net profits by the nominal value of capital stock:

$$GF_F = Y^D - w \cdot L - p_W \cdot IM \cdot e^N - T^{IM} - \dots$$
$$\dots\ i_F^{L,D} \cdot L^D - i_F^{L,FX} \cdot L_F^{FX} \cdot e^N, \tag{34}$$
$$F_F = (1 - \tau_F) \cdot GF_F, \tag{35}$$
$$r_F = \frac{F_F}{p \cdot K}. \tag{36}$$

In the case where firm's expected profits are not equal to realised profits, we assume that dividends absorb the discrepancy, i.e. that firms' dividends is given by the difference between realised profits minus retained earnings and the change in financing of foreign deposits:

$$Div_F = F_F - RE_F - \dot{D}^{FX} \cdot e^N \tag{37}$$

## 3.4 Bank balance sheets and financing

| **Assets** | **Liabilities** |
|---:|:---|
| Government bonds ($B_G^B$) | Domestic Deposits ($D^D$) |
| Domestic Loans to firms ($L^D$) | FX Deposits of firms ($D^{FX}$) |
| FX Loans to firms ($L_F^{FX}$) | FX Debt ($L_B^{FX}$) |
| Reserves at CB ($R^D$) | Advances from CB ($A$) |
| FX Reserves ($R^{B,FX}$) | Own Funds ($OF_B$) |

Table 3: Banks' Balance Sheet

We start with banking sector's aggregate balance sheet, displayed in table 3. On the asset side, banks hold government bonds ($B_G^B$), domestic currency reserves at the central bank ($R^D$), FX reserves ($R^{B,FX}$) and lend to firms in domestic and foreign currency ($L^D$ and $L_F^{FX}$, respectively). Banks' liabilities consist of household deposits in domestic currency ($D^D$), firm deposits in foreign currency ($D^{FX}$), cross-border borrowing from abroad ($L_B^{FX}$) and advances from the central bank ($A$).

Banks' desire to purchase a fraction $\Omega$ of the newly supplied government bonds ($\dot{B}^G$) every period. As in Agénor et al. (2009), this fraction depends positively on the relative magnitude of interest rates on bonds and domestic lending rates, as well as a regulatory compulsory bank bond purchase ratio ($\Omega_0$).

$$\dot{B}_G^{B,d} = \Omega \cdot \dot{B}^G, \tag{38}$$

$$\Omega = \Omega_0 + \Omega_1 \left( \frac{1 + i^{B,G}}{1 + i^{L,D}} \right)^{\sigma_B}. \tag{39}$$

As discussed above, we assume that borrowing in foreign currency by domestic firms takes place via the domestic banking sector. Therefore, domestic banks act as an intermediary between domestic firms and foreign funds, earning a positive spread during the process. In order to keep the formulation simple and tractable, we assume that at each period, banks demand for cross border lending equals the FX loan demanded by firms.

$$\dot{L}_B^{FX} = \dot{L}_F^{FX} \tag{40}$$

To model the dynamics of cross-border foreign supply to the domestic banking sector, we use a modified version of the cross border lending supply in Bruno and Shin (2015), which assumes, as in our model, that global banks which can borrow at the risk free global rate $i^W$ lend to local banks, which then lend to local firms. The desired cross-border credit supply to domestic banks ($CBL^{S,d}$) depends positively on the own funds ($OF^{GB}$) and leverage ratios ($\varpi$) of global banks, as well as the spread between the rate at which global banks borrow and the rate they lend to domestic banks ($i_B^{L,FX}$):

$$CBL^{S,d} = \varrho_1 \frac{OF^{GB}}{1 - \left( \frac{1+i_B^{L,FX}}{1+i^W} \right) \varpi}, \tag{41}$$

$$\varpi = \varpi_0 \cdot rsk^{\sigma_{rs}} (i^W)^{\sigma_\varpi},\ \sigma_{rs},\ \sigma_\varpi < 0 \tag{42}$$

$$OF^{GB} = \varrho_2 \cdot GDP_W \cdot p_W \tag{43}$$

where $rsk$ is country risk to be defined in section 3.8. We assume that global banks leverage depends negatively on the global risk free rate (see Adrian and Shin, 2008; Borio and Zhu, 2012) and country risk, where $\sigma_\varpi < 0$ is the elasticity of global banks' leverage to risk-free interest rate, and $\sigma_{rs}$ is the elasticity of leverage to country risk.[15] Own funds of global banks are a constant fraction ($\varrho_2$) of global GDP.

[15] Bruno and Shin (2015) derive that the equilibrium level of cross-border lending is given by $\frac{OF^{GB}+OF^B}{1-\left(\frac{1+i_B^{L,FX}}{1+i^W}\right).\varpi.\theta}$ where $\theta = \theta(e_N^e)$ is the leverage ratio of domestic banks with $d\theta/de_N^e < 0$, as expectations of appreciation of local currency (i.e a lower $e_N^e$) reduces the probability of default by domestic firms. $\varpi$ is the leverage ratio of global banks and it is determined by a contracting problem exogenously, ensuring that global bank leverage is limited to cover expected losses on cross-border lending. The authors show that in the event of expectations of currency appreciation, either domestic or global banks increase their leverage, thereby increasing the supply of funds available to firms in small open economies.

We instead assume that global banks' leverage ratio which is relevant for our open economy is an index that depends on the risk-free global rate $i^W$ and country risk ($rsk$), which itself is a combination of global risk appetite and country fundamentals as we will present below. Thus, a fall in global risk-free interest rate increases the leverage of global banks directly in our model. Note that with our formulation of the exchange rate expectations below, This formulation is also in line with the empirical literature on the determinants of cross-border banking flows documented by Koepke (2019). Several studies such as Rey (2015); Herrmann and Mihaljek (2013) and Bruno and Shin (2015) have found a negative and significant relationship between global risk aversion and cross-border banking flows, while Hooper and Kim (2007) and Kim and Wu (2008) have found the same negative significant relationship between country risk indicators cross-border lending. Similarly, there is strong evidence that domestic asset returns and domestic economic growth have a strong positive relationship with cross-border banking flows, as found in Herrmann and Mihaljek (2013) and Bruno and Shin (2013), and that the flows are negatively correlated to interest rates in industrialized economies (Bruno and Shin, 2015; Ghosh et al., 2014)

While the quantity of cross-border lending flows is supply-constrained as in section 3.3, we assume that excess demand by firms leads to an increase in the cross-border lending rate:

$$\dot{i}_B^{L,FX} = i_B^{L,FX} \cdot \beta_{FX} \cdot \left(\frac{CBL^D - CBL^S}{CBL^S}\right) \tag{44}$$

$$CBL^D = \dot{L}_F^{FX,d} + L_F^{FX} \tag{45}$$

As mentioned above, local banks implement, for the rate at which they lend in foreign currency to firms ($i_F^{L,FX}$, 46), a premium ($prem$) over the cross-border borrowing rate where this premium is moving towards a targeted premium ($prem^T$, 47 and 48). The target premium depends on the ratio of total debt of non-financial firms to expected net profits, following the financial accelerator literature (Bernanke and Gertler, 1995) and is thus countercyclical as found by Mandelman (2006). In a subsequent study, Mandelman (2010) shows that such countercyclical markups can be derived by modelling new entry into banking industry during expansions seeking to exploit profit opportunities, which induce incumbent banks to reduce markups to deter entry. Consequently, the sensitivity of markups to debt/expected profit ratio, $\zeta_2$ in (48) also measures the degree of competition in the banking industry on top of the traditional risk aversion interpretation.

$$i_F^{L,FX} = i_B^{L,FX} + prem, \tag{46}$$

$$\dot{prem} = \beta_{prem} \cdot \left(prem^T - prem\right), \tag{47}$$

$$prem^T = \zeta_0 + \zeta_1 \cdot \left(\frac{L_F^{FX} \cdot e^{N,e} + L^D}{F_F^e}\right)^{\zeta_2}. \tag{48}$$

Banks are subject to no open position regulations and must maintain a stock of assets denominated in foreign currency larger or equal to their stock of liabilities denominated in foreign currency:

$$L_F^{FX} + R^{B,FX} \geqslant L_B^{FX} + D^{FX}, \tag{NOP}$$

where $R^{B,FX}$ is the holding of foreign reserves by banks.

a fall in global interest rate also implies currency appreciation expectations ceteris paribus. As well as distorting the arbitrage condition in (32) in favour of borrowing in FX, these appreciation expectations reduce the domestic currency value of firms' FX-denominated liabilities, increase their expected gross profits and expected profit rates, triggering investment and further increasing total financing needs of firm. Overall, this leads to higher demand for cross-border borrowing by firms, which is then demanded by domestic banks from global banks.

In our framework, $e_N^e$ also enters the country risk equation in section 3.8 below and therefore expectations of currency appreciation increases the cross-border lending supply by global banks by reducing country risk.

Assuming no portfolio holdings of assets denominated in foreign currency by the banking sector in expectation of capital gains, the inequality holds with equality at all times and banks do not keep an open position. This implies that

$$\dot{R}^{B,FX,NOP} = \dot{D}^{FX} = \dot{R}^{B,FX} \tag{49}$$

where $\dot{R}^{B,FX,NOP}$ is the required regulatory change in bank foreign reserves.[16]

The remaining change in national foreign reserves lies in the central bank balance sheet. In other words, while intervention by the central bank in the foreign currency markets can affect the nominal exchange rate by altering demand for foreign-denominated assets (see section 3.9), its lender of last resort role in domestic currency also extends to foreign currency markets and the final change in its foreign reserves are determined by the decision of firms and banks.[17]

$$\begin{aligned} \dot{R}^{CB,FX} &= \dot{R}^{FX} - \dot{R}^{B,FX} && (50) \\ &= \dot{R}^{FX} - \dot{D}_F^{FX} && (50.\text{A}) \end{aligned}$$

We assume that there is a constant required reserves ratio $rrr$ for household deposits in domestic currency ($D^D$) so that:

$$R^D = rrr \cdot D^D. \tag{RRR}$$

The total domestic currency financing needs of the banking sector *arising from domestic currency transactions* are given by:

$$TFN_B^D = \left[\dot{L}^D + \dot{B}_G^B\right] + rrr \cdot \left(D^D + \dot{D}^D\right) - \left(\dot{D}^D + \dot{OF}\right) - R^D, \tag{51}$$

where $OF$, and $R^D$ are the own funds of banks and domestic reserves held by banks, respectively.

[16]We do not consider regulatory FX reserve liquidity requirements in this paper explicitly and leave it for future work. However, it is possible to show that under a mild assumption on some parameters, the no open position condition ensures that liquidity constraints are also met.

To show this, assume that foreign deposits and loans are both subject to

$$R^{B,FX,LIQ} = \gamma_1 \cdot D^{FX} + \gamma_2 \cdot L_F^{FX} \tag{B}$$

and

$$R^{B,FX,NOP} = D_F^{FX} \tag{49.A}$$

then

$$R^{B,FX,NOP} \geqslant R^{B,FX,LIQ} \Rightarrow D^{FX} \geqslant \gamma_1 \cdot D^{FX} + \gamma_2 \cdot L_F^{FX}.$$

Using (33) and simplifying,

$$\eta \geqslant \frac{\gamma_2}{1-\gamma_1}$$

is necessary and sufficient for our no open position condition in (49) to ensure that liquidity constraints as defined in (B) are also met.

[17]Note that in some emerging market economies, banks hold part of their foreign-denominated assets abroad for transaction purposes and portfolio management but we abstain from modeling these mechanisms in this paper. The same also applies to swap markets, which domestic banks of some emerging markets such as Turkey, Hungary, South Africa etc. can tap into to finance their domestic/foreign currency liquidity needs. In such a case, banks may close part of their open FX positions via short-term swaps in international markets and central bank reserves may thus experience significant increases, masking the vulnerability of the banking sector to global financial conditions. See Ples et al. (2011) for a detailed exposition of swap markets and their prominence in bank financing in emerging markets.

Advances from the central bank are the residual, implying lender of last resort role of the central bank.

$$\dot{A} = TFN_B^D \tag{52}$$

There is a constant capital adequacy requirement ($car$) for domestic and foreign denominated risky assets of the banking sector, leading to the following level of own funds needed to respect this regulation:

$$OF^{CAR} = car \cdot \left(L^D + L_F^{FX} \cdot e^N\right) \tag{53}$$

Retained earnings for banks is a proportion $\beta_{OF}$ of the difference between their actual own funds and this target level and are used to increase own funds.

$$RE_B = \beta_{OF} \cdot \left(OF^{CAR} - OF\right), \tag{54}$$

$$\dot{OF}_B = RE_B. \tag{55}$$

The gross operating profits of banks can be written as:

$$GF_B = i^{L,D} \cdot L^D + i_G^B \cdot B_G^B - i^D \cdot D^D - i_B^{L,FX} \cdot L_B^{FX} \cdot e^N - i^P \cdot A \tag{56}$$

We assume that deposits are perceived as cheap sources of liquidity and hence we set the interest rate on household deposits as a moving mark-down from the central bank policy rate $i^P$. We assume that the mark-down depends on the ratio of advances from the central bank to domestic-currency denominated assets of the banking sector, which is a measure of the lack of liquidity in the banking sector.

$$i^D = i^P - \rho_2 \cdot \left(\frac{L^D + B_G^B}{A}\right)^{\rho_1}. \tag{57}$$

This formulation implies that a lower household saving rate, leading to lower household deposits and thus higher levels of central bank financing ($A$) for the banking sector, will push the banks to increase the deposit rate and pull it closer to the policy rate to induce households to save more and reduce their funding costs. As with $\zeta_2$, the sensitivity of the markdown on deposit rates ($\rho_1$) will thus depend on how competitive the banking sector is and a higher $\rho_1$ would imply a less competitive banking sector in which deposit rates fall more when banks have less need to resort to central bank financing.

Banks apply the same premium with FX loans ($prem$) on the domestic average funding costs ($AFC$) to determine their targeted domestic currency lending costs. While this is the interest rate on new loans and therefore enters the arbitrage equation for firms (32), we nonetheless assume that effective lending rate, which depends on debt turnover and other inertia dynamics, is slowly adapting where $\beta_{iLD}$ is the inverse of average maturity of domestic currency loans to firms:[18]

$$i^{L,D,T} = AFC + prem, \tag{58}$$

$$AFC = \frac{i^D \cdot D^D + i^P \cdot A}{D^D + A}, \tag{59}$$

$$\dot{i}^{L,D} = \beta_{iLD} \cdot \left(i^{L,D,T} - i^{L,D}\right). \tag{60}$$

[18]See appendix B for a brief demonstration of how the relationships implied by (46), (48), (57), and (58) can be derived from a setup where banks optimize deposit and lending rates in order to maximize current profits.

Finally, net profits of banks are equal to their gross profits minus the taxes they pay on it and banks distribute the rest of their earnings to asset owner households as dividends.

$$F_B = (1 - \tau_B) \cdot GF_B, \tag{61}$$
$$Div_B = F_B - RE_B. \tag{62}$$

### 3.5 Government

The government spending has two components: $G_D$ is a constant share ($\varphi_1$) of total nominal production and can be interpreted as normal government spending and ($G_E$) which is the counter-cyclical component in the form of unemployment benefits where the dole level is a constant share ($\varphi_2$) of nominal wages:

$$G_D = \varphi_1 \cdot Y_p \cdot p, \tag{63}$$
$$G_E = \varphi_2 \cdot w \cdot (Pop - L). \tag{64}$$

Total government expenditures are thus the sum of government spending and interest payments:

$$G_T = G_D + G_E + i_G^B \cdot B_G. \tag{65}$$

The government taxes wages, production, and firm and bank profits. Total tax revenues are:

$$T = \tau_W \cdot w \cdot L + \tau_F \cdot GF_F + \tau_B \cdot GF_B + T^{IM}. \tag{66}$$

where $T^{IM}$ is the total import taxes given by:

$$T^{IM} = \sum \tau_i^M \cdot IM_i, \; i = C, G_D, I, X \tag{67}$$

Any governmental deficit is financed through bonds $\left(\dot{B}^G\right)$, bearing in mind that all central banks profits are redistributed to the government:

$$\dot{B}_G = G_T - T - F_{CB}. \tag{68}$$

Bond interest rates are a markup over inflation, which depends on public debt to GDP ratio.

$$i_G^B = \frac{\dot{p}}{p} + \phi_1 \cdot \left(\frac{B_G}{p \cdot Y^e - IM \cdot p_W \cdot e^{N,e}}\right)^{\sigma_{ib}} \tag{69}$$

This specification is in line with the estimation results reported by Peiris (2013), who finds that the yields on long-term government bonds in emerging economies depends positively on the inflation rate, policy rate, FED funds rate and the budget deficit. Instead of the flow deficit, we assume that the rates are a positive function of expected debt-output ratio, with an elasticity of $\sigma_{ib}$. The relationship between domestic bond rates and foreign policy rate operates more indirectly in our model via the arbitrage condition defined in section 3.8 below.

Banks final purchase of government bonds is given as the minimum between their desired demand defined in (38) and the available supply after asset holder households and foreign demand for bonds.

$$\dot{B}_G^B = \min\left[\dot{B}_G^{B,d}, \dot{B}_G - \dot{B}_G^{W,d} - \dot{B}_G^{H,d}\right] \tag{70}$$

| Assets | Liabilities |
|---|---|
| Government bonds ($B_G^{CB}$) | Reserves $R^D$ |
| Advances to Banks ($A$) | |
| Foreign Exchange Reserves ($R^{CB,FX}$) | |

Table 4: Central Bank's Balance Sheet

## 3.6 Central Bank

Table 4 represents the Central Bank's Balance Sheet. We assume the central bank conducts pure inflation targeting using a standard Taylor rule::

$$i_P = \iota_1 + \iota_2 \left(\frac{\dot{p}}{p}\right). \tag{71}$$

The central bank absorbs the supply of governments bonds in excess of demand by banks, asset holder households and the rest of the world:

$$\dot{B}_G^{CB} = \max\left[0, \dot{B}_G - \dot{B}_G^B - \dot{B}_G^W - \dot{B}_G^H\right]. \tag{72}$$

As we discussed in detail above, the central bank intervenes in the FX markets in order to meet its target stock of FX reserves, in line with what IMF (2015) observes. We assume the central bank ensures that it has at least $\phi$ times annual imports worth of FX reserves. Hence, intervention in the FX markets becomes:

$$\dot{R}^{CB,FX,I} = \phi \cdot IM \cdot p_W - R^{CB,FX}. \tag{73}$$

We further assume that when total inflows are positive, central bank does not sell FX even if its reserves are above its target. The final change in central bank FX reserves is always given by (50) above, as banks meet their FX currency needs via FX transactions with the central bank.

$$\dot{R}^{CB,FX} = \dot{R}^{FX} - \dot{R}^{B,FX} = \dot{R}^{FX} - \dot{R}^{B,FX,NOP} = \dot{R}^{FX} - \dot{D}^{FX}. \tag{50.B}$$

Intuitively, the central bank serves as a lender of last resort in FX and its FX reserves are the final source of FX for domestic economic units. Hence, a depletion of national FX reserves is always reflected in the central bank's stock of FX reserves.

Finally, central bank profits are given by

$$F_{CB} = i_G^B \cdot B_G^{CB} + i_P \cdot A. \tag{74}$$

and they are transferred to the government as revenue.

## 3.7 Labour Markets and Households

Population ($Pop$) grows at a constant rate $\alpha_p$. Labour is assumed to be the abundant factor of production. As a result, the utilization rate of capital stock determines production, which then determines employment ($L$):

$$L = \frac{Y^{P,D}}{a}. \tag{75}$$

where $a$ is the output to labour ratio. We assume that this ratio grows at constant rate $\alpha_a$:

$$\dot{a} = a \cdot \alpha_a \tag{76}$$

The Phillips curve is defined in terms of nominal wages in line with the seminal paper by Phillips (1958), where wage negotiations are nominal and depend positively on employment rate and current inflation, with a degree of money illusion measured by $\omega_3$:

$$\dot{w} = w \cdot \left(\omega_0 + \omega_1 \cdot (L/Pop - \omega_2) + \omega_3 \cdot \frac{\dot{p}}{p}\right). \tag{77}$$

We distinguish two sources for households disposable income $(YD_H^i)$ : net labor income and unemployment benefits (78) on the one hand and financial income composed of interest payments, dividends, and remittances[19] (79) on the other:

$$YD_H^L = (1 - \tau_W) \cdot w \cdot L + G_E, \tag{78}$$

$$YD_H^F = i_D \cdot D^D + i_G^B \cdot B_G^H + Div_F + Div_B + Rem. \tag{79}$$

Households have a target consumption level, $C_H^T$, defined by time-varying marginal propensities to consume out of labour income ($m_1$), financial income ($m_2$) and out of wealth ($m_3$), which are functions of the real interest rate, as in Agénor et al. (2009).

$$C_H^T = m_1 \cdot YD_H^L + m_2 \cdot YD_H^F + m_3 \cdot \left(D^D + B_G^H\right) \tag{80}$$

$$m_1 = 1 - \lambda_0^L \cdot (i_D - \dot{p}/p)^{\lambda_1^L} \tag{81}$$

$$m_2 = 1 - \lambda_0^F \cdot (i_D - \dot{p}/p)^{\lambda_1^F} \tag{82}$$

$$m_3 = 1 - \lambda_0^W \cdot (i_D - \dot{p}/p)^{\lambda_1^W} \tag{83}$$

Finally, consumption adjusts to this target level at the speed $\beta_C$:

$$\dot{C}_H = \beta_C \cdot \left(C_H^T - C_H\right). \tag{84}$$

Households hold bank deposits and buy government bonds. Their total savings is the difference between all sources of disposable income and consumption and lead to asset accumulation:

$$S_H = YD_H^L + YD_H^F - C_H \tag{85}$$

$$= \dot{D}^D + \dot{B}_G^H \tag{85.A}$$

The allocation of savings of asset holders between government bonds and deposits depends on the relative returns

$$\dot{B}_G^H = \upsilon_H \cdot S_H \tag{86}$$

$$\dot{D}^D = (1 - \upsilon_H) \cdot S_H \tag{87}$$

where

$$\upsilon_H = \Omega_0^A + \Omega_1^A \cdot \left(\frac{1 + i_G^B}{1 + i_D}\right)^{\sigma_A} \tag{88}$$

[19] Remittances are not financial income *per se* but we distinguish them from labor income.

## 3.8 World trends and Portfolio Flows

Real global GDP grows at a constant rate $\alpha_{gdpw}$ and world inflation is constant at rate $\alpha_{inflw}$. Foreign financial flows entering the domestic economy ($WFF_D$) is a share $\beta_{WFF}$ of world financial flows ($WFF$):

$$WFF_D = \beta_{WFF} \cdot WFF, \tag{89}$$

where total global flows depend on world GDP:

$$WFF = \Phi \cdot GDP_W \cdot p_W \tag{90}$$

The share of total global funds entering the domestic economy (91) depends on the arbitrage condition between expected foreign yield ($r^{W,e}$, 93) and expected domestic yield ($r_G^{B,e}$, 92) which factors in discounted expected exchange rate movements and risk. As documented by Koepke (2019), there is a strong negative relationship between portfolio debt and global risk aversion (Ananchotikul and Zhang, 2014; Milesi-Ferretti and Tille, 2011, among others) and industrialized economy interest rates (Dahlhaus and Vasishtha, 2014; Feroli et al., 2014). Similarly, a positive relationship between domestic asset returns and portfolio flows is reported by Koepke (2018), and Fratzscher (2012).

$$\beta_{WFF} = \beta_{GF}^0 \cdot Tanh\left[\beta_{GF}^1 \cdot \left(\frac{r_G^{B,e} - r^{W,e}}{r^{W,e}}\right)\right] \tag{91}$$

$$r_G^{B,e} = \frac{\left(1 + i_G^B\right)(1 - rsk)}{\frac{e_N^e + \dot{e}_N^e}{e_N}} \tag{92}$$

$$r^{W,e} = 1 + i_G^W \tag{93}$$

where $i_G^W$ is the interest rate on riskless foreign bond and it is equal to foreign policy rate $i^F$ plus a constant real interest rate.

Daude and Fratzscher (2008) on the other hand finds that the flows also depend negatively on country risk. We assume that this country risk follows a sigmoid function which depends on the net international investment position of the country (NIIP), as well as a global risk aversion parameter ($\nu_4$)

$$rsk = \frac{\nu_1}{1 + e^{\nu_2 - \nu_3 \cdot NIIP}} + \nu_4 \tag{94}$$

$$NIIP = -\frac{R^{FX} \cdot e_N - L_B^{FX} \cdot e_N - B_G^W}{Y^P \cdot p - IM \cdot p^W \cdot e_N} \tag{95}$$

## 3.9 Exchange Rate Dynamics

The exchange rate market is characterized by disequilibrium between desired flow FX demand and FX supply, as in (Charpe et al., 2011, Chapter 2). Therefore, the nominal exchange rate $e_N$, measured as domestic currency per unit of foreign currency, increases (decreases) with excess demand (supply):

$$\dot{e}_N = e_N \cdot \beta_{en} \cdot \left(\frac{D^{FX} - S^{FX}}{S^{FX}}\right) \tag{96}$$

with $D^{FX}$ flow foreign exchange demand and $S^{FX}$ flow foreign exchange supply, given by

$$D^{FX} = IM \cdot p_W + \frac{IA}{e_N} + \dot{R}^{B,FX,NOP}, \tag{97}$$

$$S^{FX} = \frac{X}{e_N} + WFF_D + \dot{L}_B^{FX} - \dot{R}^{CB,FX,I}. \tag{98}$$

Taking the first derivative of (11), real exchange rate dynamics follow:

$$\dot{e}_R/e_R = \dot{p}_W/p_W + \dot{e}_N/e_N - \dot{p}/p.$$

The structure of exchange rate expectations has a key role in the dynamics of open economy models. Although numerous studies have utilised the uncovered interest parity condition, there is ample empirical evidence against this formulation. In our continuous time framework, the uncovered interest parity condition could be written as:

$$i^P = i^F + (e_N^e + \dot{e}_N^e - e_N) + rsk$$

Therefore, in the absence of persistent expectation errors, the coefficient in front of expected change in the exchange rate must be unity when regressed on interest rate differentials if the uncovered interest parity holds (Yu, 2013). However, several empirical studies beginning with Frankel (1980) and revived by Engel (1996) have found the coefficient to have a negative sign; a phenomenon termed the "forward premium puzzle" in the literature. In other words, the currency with higher returns also tends to appreciate and persistent positive profits can be made in financial markets via borrowing in low-yield currency and lending in high-yield currency (Burnside et al., 2010; Martin, 2011). In essence, it is precisely the existence of these positive returns that fuels the carry trade from financial centers to peripheral emerging market banking sectors and asset markets, and creates the expected arbitrage opportunities between domestic currency borrowing and FX borrowing for the non-financial sector in these economies (see Brunnermeier et al. (2008) for a review) .

We therefore take into account the empirical observation that higher yield currencies tend to experience an appreciation, and we assume that this is reflected in exchange rate expectations. We postulate that the expected exchange rate dynamics are given by:

$$\dot{e}_N^e = \beta_{e_N^e} \cdot \left[ \Upsilon \cdot \left( \frac{1+i^F}{(1+i^P)(1-rsk)} \right)^{\sigma_{ene}} \cdot e_N - e_N^e \right] \tag{99}$$

Note that setting $\Upsilon \cdot \left( \frac{1+i^F}{(1+i^P)(1-rsk)} \right)^{\sigma_{ene}} = 1$ in (99) gives the well-known backward-looking expectations structure:

$$\dot{e}_N^e = \beta_{e_N^e} (e_N - e_N^e). \tag{99.A}$$

Our specification modifies this by multiplying the current exchange rate with an (implicitly) forward-looking term given by $\Upsilon \cdot \left( \frac{1+i^F}{(1+i^P)(1-rsk)} \right)^{\sigma_{ene}}$, which takes into account the relative return on foreign currency assets with respect to domestic currency assets, measured by $\frac{1+i^F}{1+i^P}$, deflated by the country risk premium $rsk$ and scaled by $\Upsilon$. A higher domestic interest rate and/or a lower currency risk perception will thus lead to an increase in expectations of currency appreciation, provided that unexpected depreciation in the current period given by $e_N - e_N^e$ has not been too large.

### 3.10 Balance of Payments

Domestic residents and firms/banks do not hold foreign assets. Therefore, the income account of the country is given by the difference between remittances and interest payments on foreign debt and domestic bonds held abroad:

$$IA = Rem \cdot e_N - i_G^B \cdot B_G^W - e_N \cdot i_B^{L,FX} \cdot L_B^{FX}. \tag{100}$$

The remittances received from abroad are a linear function of world GDP:

$$Rem = rem \cdot GDP_W \cdot p_W. \tag{101}$$

From the balance of payments constraint, the equality

$$\dot{R}^{FX} = \frac{X}{e_N} - IM \cdot p_W + \frac{\dot{B}_G^W}{e_N} + \dot{L}_B^{FX} + \frac{IA}{e_N} \tag{102}$$

must always hold. As the only financial asset invested in by the rest of the world, the change in foreign holdings of government bonds is equal to financial capital inflows.[20]

$$\dot{B}_G^W = WFF_D \cdot e_N \tag{103}$$

# 4 Calibration

In order to be able to systematically analyze the impact of an external monetary policy shock, we set our economy on a steady state which reflects macroeconomic characteristics of developing economies. Due to the monetary nature of our model, this steady state is strongly related to the calibration of the parameters. We will first describe the nature of the steady state, i.e. the various assumptions made and the constraints that construction of the steady state puts on the model equation and parameter values. We then justify the choices made for the different parameters and show how the calibrated steady state reflects (on average) a group of developing economies.

## 4.1 Constructing the Steady State

We start our description of the steady state with the balance of payments and sectoral savings. On the balance of payments, we need to ensure that exchange rate and expected exchange rate are stationary at the steady state. This implies that there should be no excess demand for foreign currency and the risk-weighted relative policy rates in the expected exchange rate dynamics (99)

[20]It is useful to note at this point that the specifications in (49-50), (97-98) and (102) are consistent with each other.

Subtracting (98) from (97) and using (102) and (103), we find

$$D^{FX} - S^{FX} = \dot{R}_B^{FX,NOP} - \left[\dot{R}^{FX} - \dot{R}_{CB}^{FX,I}\right]$$

which is equal to the difference between regulatory no-open-position level of required change in bank FX reserves and the change in bank reserves after FX transactions and central bank intervention. Thus, $D^{FX} - S^{FX}$ is a measure of excess demand for FX reserves by the banking sector before tapping into the central bank. The complete balance sheet consistency of the model is presented in appendix A.

must be equal to one. We assume that the country is engaged in trading with the rest of the world and has a balanced trade ($X = IM$). We further assume that the income account is balanced as remittances offset the interest payments to the rest of the world. The combination of balanced trade and balanced income account leads to a balanced current account. On the other side of the balance of payments, we assume that there is no foreign demand for public bonds at the steady state, leaving cross-border lending as the only other source of foreign reserves. As a result, the country accumulates an equal amount of FX liabilities ($L_B^{FX}$) and assets ($R^{FX}$) at each point in time and its international investment position remains constant on the balanced growth path. We set the initial stock of FX reserves of the country ($R^{FX}$) equal to its stock of FX liabilities ($L_B^{FX}$) to ensure a zero NIIP at the steady state.

In order to meet the constraints on the nominal exchange rate and trade, domestic and foreign inflation and real growth rates must be equal to each other. Both firm arbitrage and the arbitrage for the rest of the world are also set to zero. For this, domestic currency and FX funding costs for firms are set equal to each other first. We also assume a positive risk term in the expected exchange rate dynamics equation, and set the spread between the domestic and foreign policy rates such that it compensates exactly the exogenous part of the risk, hence ensuring that the constant nominal exchange rate is equal to the expected nominal exchange rate. While gross foreign portfolio inflows to government bonds ($\dot{B}^G_{ROW}$) is zero due to zero arbitrage for portfolio investment, we assume that firms borrow $\beta_{LF}^{\min}.TFN_F$ of their financing needs via cross-border lending even with zero arbitrage and this is equal to bank cross-border borrowing ($\dot{L}_B^{FX}$), which is equal to the net inflow of FX reserves as we mentioned above.

With a positive flow of cross-border following and accumulation, banks' flow demand for FX equals change in firm FX deposits ($\dot{D}^{FX}$) in order to meet no open position regulations. The central bank on the other hand intervenes in the FX market to ensure its FX reserves match its target at each point in time, i.e. the constant fraction of growing imports. In order to ensure that there is no excess demand for FX and the nominal exchange rate is constant, we assume that sum of these two sources of FX demand match the increase in FX reserves given by $\dot{L}_B^{FX}$ so the nominal exchange rate remains constant.

On the balanced growth path, both households and banks are net savers while the government and firms are net borrowers and the rest of the world has neither deficit nor surplus. Banks and households demand for government bonds are set equal to flow bond supply, i.e government deficit, and therefore central bank intervention in bond markets is zero. We further assume positive bank advances from the central bank, growing at the rate of domestic lending growth. In order to assume a constant domestic inflation equal to the foreign inflation, historical unit cost to grow at the same rate as foreign inflation. Wages on the other hand grow at a rate equal to productivity growth and inflation, thus ensuring the wage share stays constant. All growing nominal variables in the model grow at the rate of inflation plus the real growth rate of the economy while the growth rates of all interest rates, exchange rates, trade shares and all arbitrages are zero, as summarized in table 5.

## 4.2 Parameter Calibration

We calibrate the model parameters in line with the empirical literature, developing economy characteristics and regulatory requirements in place. The following sections present the initial values of the parameters of the model for the simulations. We provide an extensive robustness analysis of several key parameters of the model in section (6).

| Growth rate | Variable |
|---|---|
| 0 | $arb^{ROW}$, $arb^{F}$, $e_N$, $e_N^e$, $i^{FXB}$, $i^{L,D}$, $prem$, $\sigma_{M,i}$, $\sigma_X$, $\beta_{LF}$, $B_G^{CB}$, $B_G^W$ |
| $\dot{p}_W/p_W$ | $p$, $HUC$ |
| $\dot{p}/p+\dot{a}/a$ | $w$ |
| $\dot{a}/a+\gamma_p$ | $K$, $Y^e$, $V$, $Y^W$ |
| $\dot{p}/p+\dot{a}/a+\gamma_p$ | $D_H$, $A$, $C$, $R^{FX}$, $R_B^{FX}$, $R_{CB}^{FX}$, $L^D$, $L_F^{FX}$, $L_B^{FX}$, $B_G$, $B_G^H$, $B_G^B$, $OF_B$, $R^D$ |

Table 5: Growth rates at steady state

**Production**

The real growth rate of the economy at the steady state is set to 3%, with 2% due to labour productivity growth and 1% due to population growth, (see Table 4.2). We set population to 50 and labour productivity to 0.95. Initial value of capital stock is 100 units and capital-output ratio at full capacity is 2. Firms desire to hold 10% of their expected sales as inventories.

| Parameter | Value |
|---|---|
| Population growth rate | $\alpha_p = 0.01$ |
| Labour productivity growth rate | $\alpha_a = 0.02$ |
| Output adjustment speed | $\beta_y = 4$ |
| Desired Inventory ratio | $\alpha_v = 0.1$ |
| Labour productivity | $a = 0.95$ |
| Capital productivity | $v = 0.5$ |

Table 6: Parameter value - Production

**Trade**

For simplicity, we set the initial nominal exchange rate, domestic and foreign prices to one, leading to unitary real exchange rate. In order to set the values for the Armington functions , we resort to the findings of Bussière et al. (2013), who calculate the import content of consumption, investment, government spending and exports for a large set of industrialized and developing economies. In line with the values reported in their study for developing economies, we set the import intensity of consumption to 0.2, government spending to 0.075, investment to 0.3 and exports to 0.2. We then fix the elasticities in equation (10) and calculate the share parameters in the Armington function that yield these import intensities.[21] In line with the empirical literature surveyed in Feenstra et al. (2018), we assume the elasticity of consumption to real exchange rate to be close to unity at 0.9, while the elasticity of investment goods and export input goods are 0.3 in order to reflect the relative insensitivity of imports of capital goods and intermediate goods to relative prices in developing countries. (see Agénor et al., 2009, for instance). The elasticity of pure public consumption is lower at 0.25. Since we do not experiment with import taxes and/or tariffs in this paper, we assume they are zero throughout. For the elasticity of exports to real exchange rate, we use the value 0.6 as reported in Ahmed et al. (2015). Finally, setting world GDP to twenty-five

[21] Note that parameters which are solved endogenously are rounded in the tables. See the code for details

times the GDP of the small open economy, we solve $\sigma_{X,0}$ to ensure that trade is balanced at the steady state.

| Parameter | Value |
|---|---|
| Elasticity of consumption imports | $\epsilon_C = 0.9$ |
| Elasticity of investment imports | $\epsilon_I = 0.3$ |
| Elasticity of export-input imports | $\epsilon_X = 0.3$ |
| Elasticity of gov. spending imports | $\epsilon_G = 0.25$ |
| Armington share parameter for consumption bundle | $=\beta_{armc} = 0.823563$ |
| Armington share parameter for investment bundle | $\beta_{armin} = 0.943976$ |
| Armington share parameter for export bundle | $\beta_{armex} = 0.990253$ |
| Armington share parameter for government bundle | $\beta_{armg} = 0.999957$ |
| Minimum import intensity thresholds | $\sigma_{M,i}^{\min} = 0.1$ |
| Tax Rate on Imports | $\tau_i^M = 0$ |
| Elasticity of exports to real exchange rate | $\sigma_{X,1} = 0.6$ |
| Scaling parameter in export share | $\sigma_{X,0} = 0.0080233$ |
| Import adjustment speed | $\beta_M = 1$ |
| Export adjustment speed | $\beta_X = 1$ |
| Tariffs on Exports | $tar = 0$ |

Table 7: Parameter value - Trade

#### Prices

For pricing equations, we assume the speed of adjustment is relatively high compared to values employed in continuous time models such as Asada et al. (2012); Chiarella et al. (2006) for the US and set it to 0.25, since developing economies with high and volatile inflation will have more frequent price adjustments. Capital depreciates at a relatively higher rate than industrialized economies, at 6.5% annually. The desired mark-up is pro-cyclical as we discussed in section 2, with an exogenous mark-up of 0.8 and a (negative) sensitivity of markups to deviation from desired inventory/sales expectations ratio of two.

| Parameter | Value |
|---|---|
| Exogenous mark-up | $\mu_0 = 0.8$ |
| Sensitivity of mark-up to inventories | $\mu_1 = 2$ |
| Percentage of price-adjusting firms | $\beta_p = 0.25$ |

Table 8: Parameter value - Prices

#### Financing

The autonomous investment is set at 1.5% of capital stock, with a high sensitivity of investment to expected real profit rates at 1.5. In line with the values reported in Obstfeld (2015), firms borrow 10% of total financing needs in FX at the steady state and thus $\beta_{LF}^{\min} = 0.1$. Profits are taxed at 20% and firms hold 28.9% of their FX liabilities as FX deposits.

| Parameter | Value |
| --- | --- |
| Depreciation rate | $\delta = 0.065$ |
| Autonomous investment | $\kappa_0 = 0.015$ |
| Sensitivity of investment to expected real profit rate | $\kappa_1 = 1.5$ |
| Profit retention rate | $s_F = 0.5$ |
| Minimum FX borrowing ratio for firms | $\beta_{LF}^{\min} = 0.1$ |
| Tax rate on profits | $\tau_F = 0.2$ |
| Arbitrage parameter for firms | $\beta_1 = 0.9$ |
| Speed of adjustment of firm debt currency allocation | $\beta_{LF,par} = 0.5$ |
| Firm FX deposits ratio to Firm FX debt | $\eta = 0.289$ |

Table 9: Parameter value - Financing

### Banks

We assume that at the steady state, banks purchase 70% of the flow of new government bonds due to regulation/market making activities and the elasticity of bank bond demand to relative returns on government bonds and domestic currency lending is 1. We then calculate the share parameter ($\Omega_1$) in order to set the bank holding at 85%. With zero foreign holdings of government bonds and zero central bank intervention in the steady state, this leaves households holding 15% of the stock and flow of public debt at the steady state.[22]

For the cross-border lending supply, we assume that the own funds of global banks is 10% of world GDP and global bank leverage in equation (42) has an elasticity of -4 both with respect to country risk and global interest rate. The speed of adjustment for cross-border lending rates to domestic banks ($\beta_{FX}$) is 2, implying a smooth cross-border lending market. The speed of adjustment for the premium domestic banks charge over their domestic and FX funding costs, $\beta_{prem}$, is set at two to ensure that risk perceptions on firm debt are updated rapidly. We set the elasticity of premium to total debt/expected profit ratio also to two and the exogenous part of the premium at 0.5% and solve for the scaling parameter $\zeta_1$ to ensure that the premium at the steady state is 4% both for domestic currency and FX lending. As in most countries, banks have a required reserve ratio of 10% for domestic currency deposits and capital adequacy ratio is 12% in accordance with Basel regulations. For the initial calibration, we assume that the sensitivity of markdown on deposit rates to domestic banks' liquidity position at 0.8 and we solve for the scaling parameter ($\rho_1$) to set the markdown at the steady state to 70 basis points below policy rates. The speed of adjustment for the average domestic currency lending rates faced by firms is 0.2, implying a five year average maturity of domestic currency borrowing. And finally, bank profits are taxed at the same rate with firms at 20%.

### Government

The government spends a constant 13.5% of total production (including imports) as pure public consumption. The social security cost per unemployed is set at 40% of average wages, and the

[22]As reported by Peiris (2013), banks hold the largest share of government bonds in emerging economies. Since we do not have institutional non-bank domestic investors in the model, the value we calibrate at 85% is in line with the values reported for the sum of bank and non-bank domestic institutional investors in Peiris (2013).

| Parameter | Value |
|---|---|
| Exogenous share of bank bond demand | $\Omega_0 = 0.7$ |
| Elasticity of bank bond demand to relative lending rates | $\sigma_B = 1$ |
| Scaling parameter for domestic banks' bond demand | $\Omega_1 = 0.155118$ |
| Scaling parameter for global bank leverage | $\varpi_0 = 4.21082 * 10^-14$ |
| Elasticity of global bank leverage to risk | $\sigma_{rs} = -4$ |
| Elasticity of global bank leverage to foreign policy rates | $\sigma_{\varpi} = -4$ |
| Scaling parameter for cross-border lending supply | $\varrho_1$ =0.0426353 |
| Ratio of global banks' own funds to world GDP | $\varrho_2$ =0.1 |
| Speed of adjustment for cross-border lending rate | $\beta_{FX} = 2$ |
| Speed of adjustment for premium on lending rates | $\beta_{prem} = 2$ |
| Exogenous parameter in premium on lending rates | $\zeta_0 = 0.005$ |
| Scaling parameter in premium on lending rates | $\zeta_1 = 0.00096804$ |
| Elasticity of premium to total debt/expected profit ratio | $\zeta_2 = 2$ |
| Required reserve ratio on domestic currency deposits | $rrr = 0.1$ |
| Capital adequacy ratio | $car = 0.12$ |
| Speed of adjustment to regulatory CAR ratio | $\beta_{OF} = 1$ |
| Scaling parameter for markdown on deposit rates | $\rho_1 = 0.00047868$ |
| Elasticity of mark-down on deposit rates to bank liquidity | $\rho_2 = 0.8$ |
| Inverse maturity of domestic currency debt of firms | $\beta_{iLD} = 0.2$ |
| Tax rate on bank profits | $\tau_B = 0.2$ |

Table 10: Parameter value - Banks

average tax rate on wages is 20% as tax rate on profits. The sensitivity of government bonds yields to public debt/GDP ratio is 1 with a scaling parameter of 0.05.

| Parameter | Value |
|---|---|
| Ratio of government spending to total production | $\varphi = 0.135$ |
| Ratio of welfare spending per unemployed to wages | $\varphi_2 = 0.4$ |
| Tax rate on wages | $\tau_W = 0.2$ |
| Scaling parameter on government bond interest rate | $\phi_1 = 0.05$ |
| Sensitivity of interest on bonds to public debt/GDP ratio | $\phi_2 = 1$ |
| Exogenous real interest rate in the Taylor Rule | $\iota_1 = 1\%$ |
| Sensitivity of Taylor Rule to inflation | $\iota_2 = 1.3$ |
| Target FX reserve/Imports ratio for central bank | $\phi = 0.4202$ |

Table 11: Parameter value - Government and Central Bank.

### Central Bank

The central bank sets a real interest rate of 1% over inflation with a sensitivity of policy rate to deviations from target inflation (2%) rate of 1.3. In accordance with the values reported in IMF (2015) for emerging market economies, we set the central bank to target 42% of annual imports as its FX reserves, or in other words five months of imports.

### Households

For the Phillips curve, we assume that wages are fully indexed to inflation ($\omega_3 = 1$), and set $\omega_2 = 0.9$. We then solve for the exogenous growth rate in wage dynamics equation ($\omega_0$) to ensure wages grow at the rate of productivity plus inflation. The sensitivity of wage growth to employment rate ($\omega_1$) is 0.1, in accordance with the values used in Asada et al. (2012).

We assume that initially, the elasticities of marginal propensities to consume out of wages, capital income and wealth are $\lambda_1^L = 0.5, \lambda_1^F = 0.1, \lambda_1^W = 0.05$ respectively, We then solve for the scaling parameters $\lambda_0^L, \lambda_0^F$ and $\lambda_0^W$ that yield $m_1 = 0.85$, $m_2 = 0.4$ and $m_3 = 0.07$ respectively (see Lavoie (2014) for a discussion on propensities to consume out of profits and wealth). The speed of consumption adjustment is 4 and implies a quarterly adjustment to the target level of consumption. Households hold an exogenous 2% their flow change in wealth in bonds, the elasticity of household bond holdings to relative returns on government bonds and deposits is set higher than banks at two in accordance with the findings of Peiris (2013).

| Parameter | Value |
|---|---|
| Speed of adjustment of the Phillips curve | $\beta_w = 1$ |
| Exogenous nominal wage growth rate | $\omega_0 = 1.8467\%$ |
| Sensitivity of nominal wages to employment rate | $\omega_1 = 0.1$ |
| Base employment rate in wage dynamics | $\omega_2 = 0.9$ |
| Sensitivity of nominal wages to inflation | $\omega_3 = 1$ |
| Scaling parameter for mpc out of wages | $\lambda_0^L = 1.15768$ |
| Scaling parameter for mpc out of capital income | $\lambda_0^F = 0.902923$ |
| Scaling parameter for mpc out of wealth | $\lambda_0^W ==1.14086$ |
| Elasticity of mpc out of wages to real deposit rates | $\lambda_1^L = 0.5$ |
| Elasticity of mpc out of capital income to real deposit rates | $\lambda_1^F = 0.1$ |
| Elasticity of mpc out of capital income to real deposit rates | $\lambda_1^W = 0.05$ |
| Adjustment speed of consumption to target | $\beta_C = 4$ |
| Exogenous share of household bond holdings | $\Omega_0^A = 0.02$ |
| Scaling parameter for household bond holdings | $\Omega_1^A = 0.0187262$ |
| Elasticity of household bond holding to relative returns | $\sigma_A = 2$ |

Table 12: Parameter value - Households

### Rest of the World

Finally, for the rest of the world, we assume that global portfolio flows are 4% of world GDP, the arbitrage coefficient for foreign portfolio flows is 0.9 as for domestic firms with a scaling parameter of 0.1. As we will show below, these values ensure that the level of annual portfolio inflows to the domestic economy remain between 1-3% of the country's GDP. We initially assume that the speed of exchange rate adjustment is 0.7 while the speed of expectations adjustment is 0.75, with an elasticity of expectations to risk-weighted policy rate differential of 1. We provide extensive robustness analysis in the next section over these three parameters.

The ratio of remittances to world GDP is endogenously solved to ensure that total receipts of remittances offset the interest payments to the rest of the world, as we also mentioned above. For the sigmoid in the risk function, we set $\nu_1$ to 0.015, the sensitivity of risk to net investment position to 300 and the scaling parameter in the sigmoid to 5 and solve for the exogenous risk at zero net international investment position ($\nu_4$) to yield a value of 0.015 for risk at the steady state. Using these values, we finally solve for foreign policy rate and foreign bond rate to ensure that both growth of exchange rate expectations and interest arbitrage are equal to zero.

| Parameter | Value |
|---|---|
| Ratio of global portfolio flows to world GDP | $\Phi = 4\%$ |
| Scaling coefficient for foreign portfolio flows | $\beta^0_{GF} = 0.1$ |
| Arbitrage parameter for portfolio flows | $\beta^1_{GF} = 0.9$ |
| Speed of exchange rate adjustment | $\beta_{en} = 0.7$ |
| Speed of exchange rate expectations adjustment | $\beta_{e^e_N} = 0.75$ |
| Elasticity of exchange rate expectation to interest differential | $\sigma_{ene} = 1$ |
| Scaling parameter in exchange rate expectations | $\Psi = 1$ |
| Ratio of remittances to world GDP | $rem = 0.000278$ |
| Scaling parameter for risk | $\nu_1 = 0.015$ |
| Scaling parameter for risk sigmoid | $\nu_2 = 5$ |
| Sensitivity of risk to net investment position | $\nu_3 = 300$ |
| Exegenous risk at zero IIP | $\nu_4 = 0.0148996$ |
| Foreign policy rate | $i^W = 0.0537032$ |
| Foreign bond rate | $i^W_G = 0.0505997$ |

Table 13: Parameter value - Rest of the World

**The Steady State**

In table 4.2 below, we present selected macroeconomic variables at the steady state. On the balanced growth path, the economy grows at 3% in real terms with an inflation of 4.6%. Unemployment is at 8.47% and public debt to GDP stands at 41.2% with a 3.15% of GDP annual budget deficit. Investment constitutes 21.8% of GDP and total consumption to GDP is therefore 78.2% of GDP with a zero trade deficit, of which 61% is private consumption. Overall, imports and exports are both equal to 20% of GDP.

The central bank policy rate is at 7%, which gives 6.3% of deposit rates with 70 basis markdown from policy rates as we mentioned above. Thus real interest rate on household deposits is around 1.7%. Government bonds yield 6.7%, which implies a real interest rate of roughly 2.1% on public debt (which reflects the liquidity premium over deposit rates). With a 4% markup over average funding costs, average interest rate and interest rate on new loans in domestic currency loans to firms is at 10.3%. These values are in line with observed averages for a large group of emerging economies over the period 2004 to 2016, as we present in appendix C. Figure 1 displays the transaction flow matrix at the steady state for a clear picture of the economy. The figures shows on the left hand the sectors from which each flow emerges, in the center the nature of the flow and on the right hand the sectors to which each flow goes. A few points are important to note here. We have distinguished between the current and capital accounts for firms and banks in order to show the role of retained earnings and investments. We have also added a flow called *Net Lending Position* which shows that households and banks are financing the two deficit sectors, i.e. firms and government.

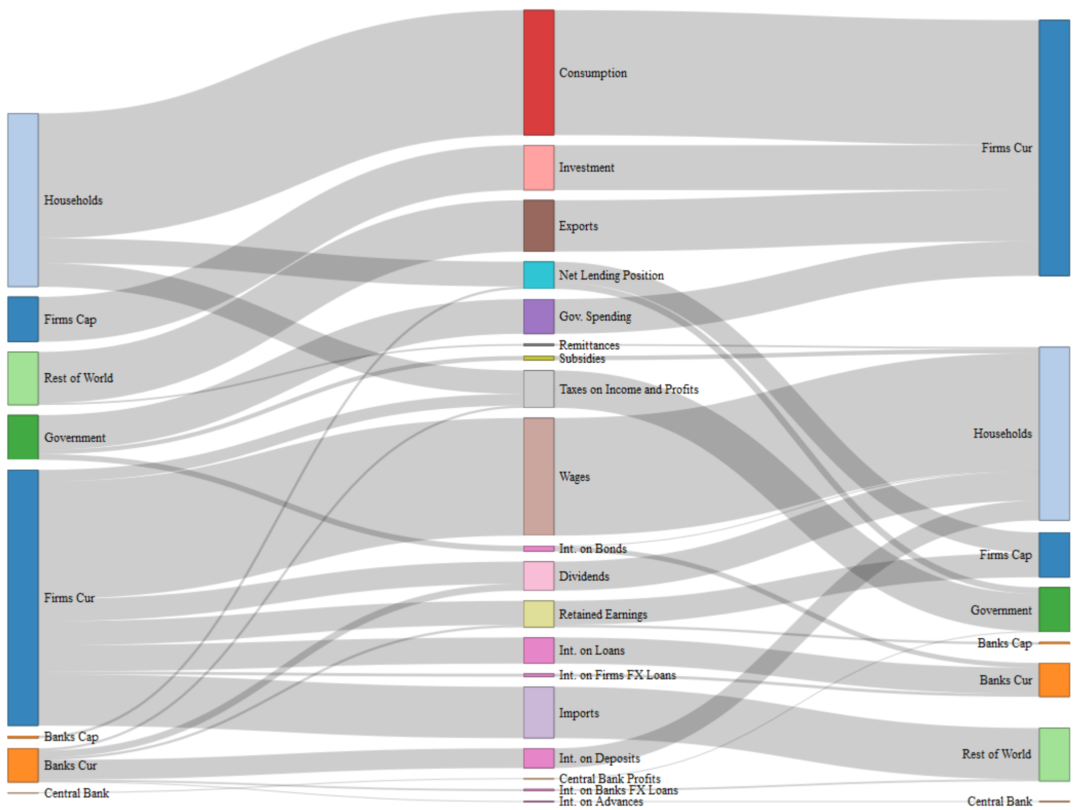


Figure 1: Sankey diagram of the Transaction-flow Matrix at steady state. The size of the each flow reflects its relative monetary value.

# 5 Simulations: A fall in Foreign Policy Rate

We start our analysis with the impact of a fall in foreign policy rate on the small open economy.[23] For this purpose, we impose a 75 basis point reduction in foreign policy rate ($i^W$) at period 5. The dynamics of key macroeconomic variables under this scenario are presented in figure 2.

The fall in the foreign interest rate creates several imbalances and triggers the propagation mechanisms presented in figure 3. First, due to the assumption of constant foreign real interest rates, the fall in the foreign policy rate results in an equal drop in foreign bond rates. Further, the forward premium puzzle in (99) implies that investors now expect an appreciation of the domestic

[23]The code is available from the authors upon request.

| Variable | Value | Variable | Value |
|---|---|---|---|
| Inflation | 4.6% | Imports/Exports as % of GDP | 20% |
| Growth Rate | 3% | Budget Deficit as % of GDP | 3.15% |
| Unemployment | 8.47% | Import Intensity of Consumption | 0.2 |
| Public Debt | 41.2% | Import Propensity of Investment | 0.3 |
| FX Loans/Domestic Loans | 10% | Import Propensity of Exports | 0.2 |
| Deposit Rates | 6.3% | Import Propensity of Gov. Spending | 0.075 |
| Interest on Bonds | 6.7% | Loan to Deposit Ratio | 80% |
| Policy Rate | 7% | Lending rate | 10.3% |
| Investment/GDP | 21.8% | Total Consumption/GDP | 78.2% |

Table 14: Steady state values of selected macroeconomic variables

currency due to the risk-weighted policy rate differential (see panel u where the dashed blue line is expected nominal exchange rate while the solid black line is actual nominal exchange rate). A positive arbitrage therefore opens for foreign investors between domestic yields and foreign yields via (92)-(93), see panel r. This triggers an inflow of financial capital into domestic bonds via (103) (see panel n).

The reduction in foreign policy rate also affects cross-border lending supply and demand. Due to expectations of appreciation of the domestic currency, a positive arbitrage for firms' foreign debt emerges (see panel q) leading to an increase in their demand for FX loans (see equations 27-32 and panel s). On the other hand, the fall in foreign interest rate also increases the supply of cross-border funds via the cross-border lending supply curve in (41). Note that the effect of the fall in the foreign policy rate on cross-border lending supply is twofold: On the one hand, it increases the total available cross-border funds by increasing the interest rate spread for global banks. On the other hand, a lower foreign policy rate increases global banks' leverage directly via equation (42). The overall impact is an increase in cross-border borrowing by banks, constrained by the increase in supply as specified in equation (28).

The increase in portfolio flows to government bonds and cross-border borrowing by domestic banks result in an initial increase in total FX reserves of the country (see panel y), and in the absence of further central bank intervention in FX markets than specified in (73), the excess FX supply causes the domestic currency to appreciate nominally (panel w). The currency appreciation and further appreciation expectations reduce the domestic currency value of firms' FX-denominated liabilities, increase their expected gross profits and nominal expected profit rates. On the other hand, due to complete exchange rate pass-through, the nominal appreciation is passed directly to the domestic currency costs of firms and reduces inflation (panel v). As a result, expected real profit rate increases even more than the nominal one, triggering a surge in investment (panel i and f). This is the balance sheet channel in our model, operating through the FX liabilities of firms as shown by Kearns and Patel (2016).

Since prices are sticky and move more slowly (see 19) than the nominal exchange rate, the domestic currency also appreciates in real terms, reducing country's export share, increasing import contents of production and leading to a trade deficit on impact (panel h).

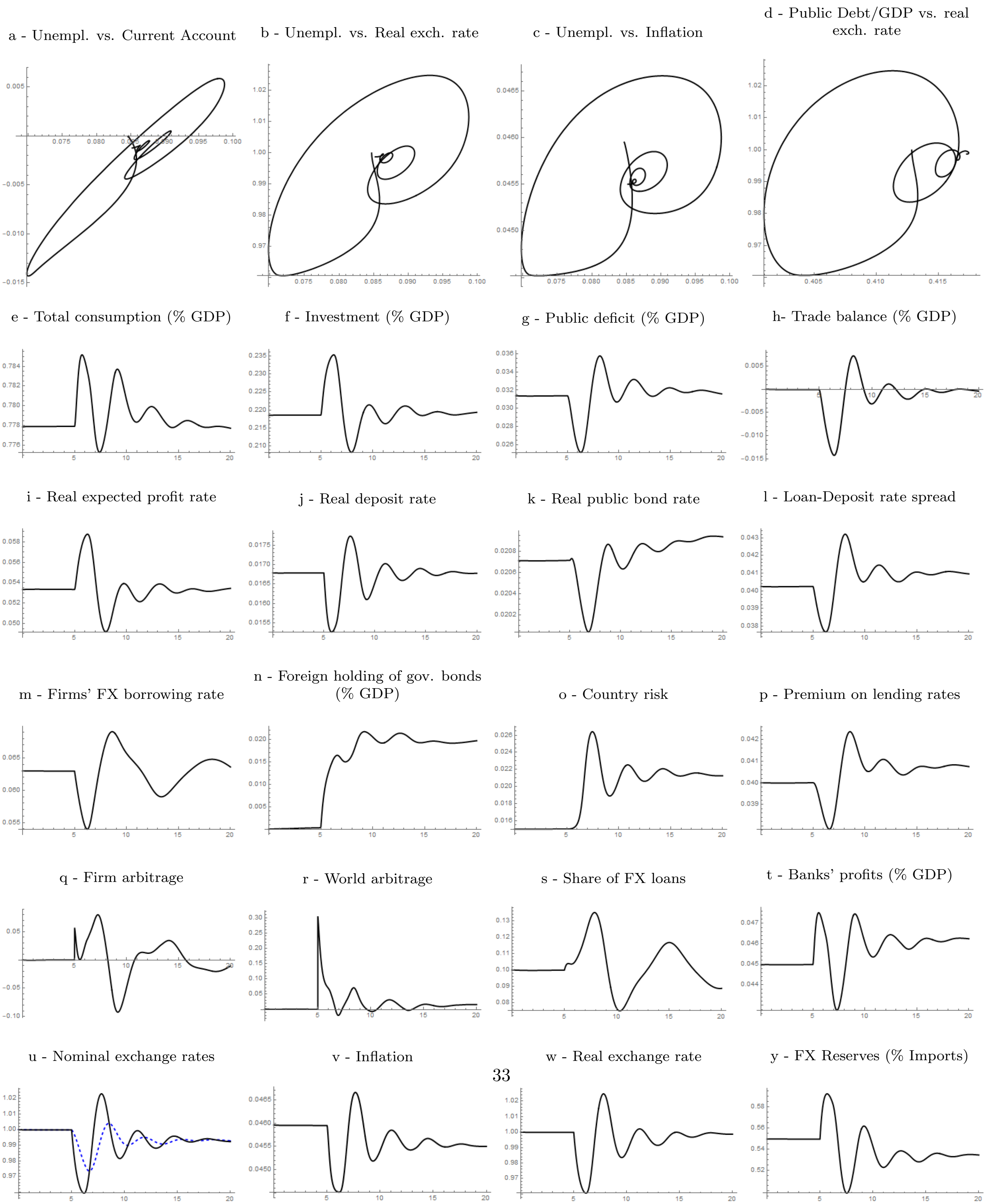


Figure 2: Foreign Policy Shock. Solid line refers to the plot label, blue dashed line is the expected nominal exchange rate. Parametric plots have x-axis vs. y-axis labels.

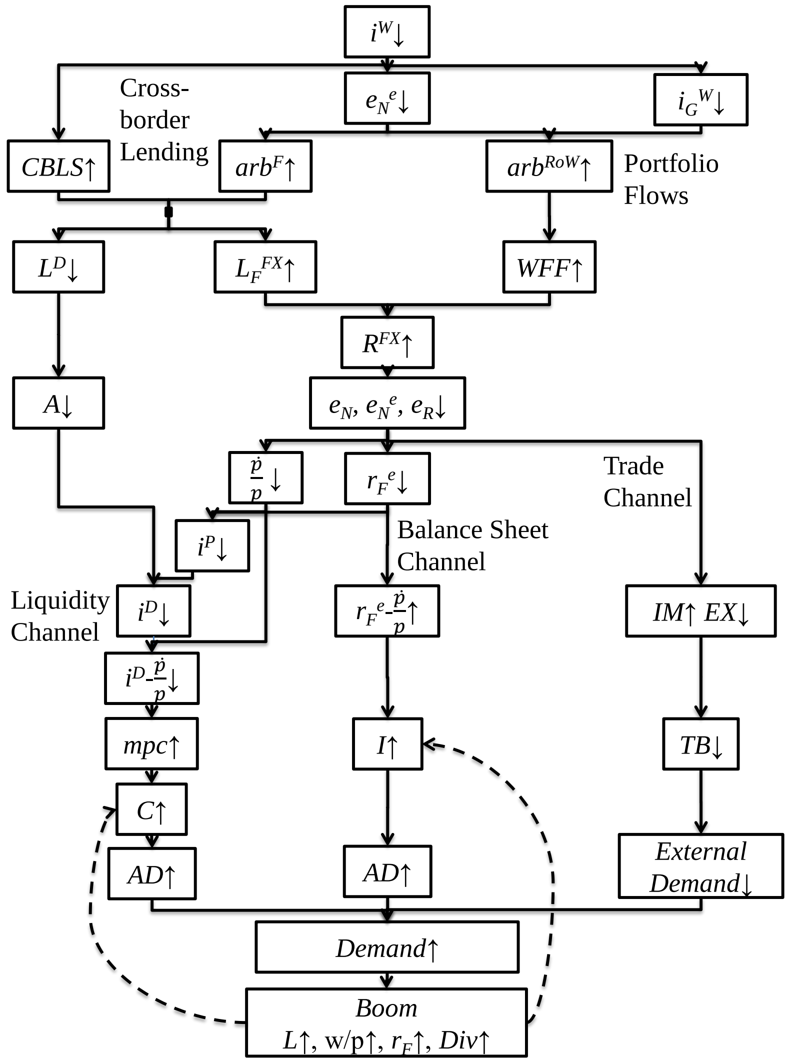


Figure 3: Causality graph showing how the foreign interest rate shock propagates in the economy.

On the other hand, the inflow of FX via portfolio investment and cross-border lending reduces the domestic currency funding needs of the banking sector as firms switch from domestic currency borrowing to FX borrowing. As the banks need less domestic currency financing from the central bank, the endogenous mark-down on domestic currency deposit rates (see 57) increases as cross-border FX borrowing jumps, and deposit rates fall rapidly following the shock (panel l). Coupled with the fall in policy rates due to lower inflation, the real interest rate on domestic currency deposits falls following the FX inflows (panel j). As a result, the marginal propensities to consume in (81- 83) increase, leading to higher target and actual consumption levels (panel e).

Therefore, on impact, there are several conflicting effects on total domestic demand, which determines domestic production and employment levels. In our original calibration, the trade effect dominates in the very short run and appreciation leads to a drop on domestic demand and a slight increase in unemployment in the first months following the shock. In essence, the sign of the effect on domestic demand depends strongly on how much and how rapidly consumption and investment respond relative to the response of trade dynamics. A more rapid adjustment of consumption and/or a stronger surge in investment/consumption would reverse this initial response.

As consumption levels adjusts to the higher target levels (84) though and investment increases further with further appreciation, falling inflation and higher domestic demand, the overall impact of inflow-induced currency appreciation on aggregate demand turns positive very quickly and unemployment starts to fall, leading to increases in real wages and wage share. This process creates a multiplier effect; higher wages, coupled with higher marginal propensities to consume lead to higher profits for firms, higher dividends, and a self-sustaining increase in aggregate demand with a trade deficit financed by portfolio inflows and cross-border borrowing. As the currency keeps on appreciating due to excess supply of FX, the positive appreciation effect on import costs maintains its dominance over the real wage growth effect to cause the inflation to fall further, bringing down policy rates, deposit rates and lending rates further during the boom. With lower unemployment, lower spending on automatic stabilizers by the government, public debt as a ratio of GDP falls (panel g), dragging down government bond rates with it (see 69).[24]

Eventually, the unsustainable boom begins to create its own reversal dynamics. As policy rate, inflation and bond rates keep on falling and the country starts accumulating a negative net international investment position leading to an increase in country risk (panel o), the positive arbitrage for portfolio inflows eventually diminishes and inflows first fall and then turn to outflows. Similarly, as domestic lending rates fall, cross border lending demand increases further, lending rates on FX borrowing start increasing and the positive arbitrage for domestic firms is eliminated via these price movements. The boom-dynamics completely reverse, following the dynamics depicted in figure 4, the currency starts depreciating, unit costs increase leading to an increase in inflation despite increasing unemployment rates, followed by increases in policy rates, deposit rates and lending rates. As a result, real expected profit rates keep on falling and the real interest rate on deposits start increasing along with falling real incomes, consumption and investment fall. With a rapid nominal depreciation, the real exchange rate also depreciates, leading to a fall in the trade deficit. This is the reversal of the interest rates/inflation rate/real exchange rate dynamics and the bust phase of the economy.[25]

The bust leads to an overshooting of the exchange rate as the joint dynamic responses of portfolio investors, firms and the real sector to the disequilibria emerging in goods/currency markets starts a depreciation process which, via its impact on updating of expectations, spirals above its medium-run level. Only after the country has accumulated enough FX reserves with a current account surplus to reduce its perceived risk that capital inflows return, restarting another boom-bust phase at a smaller scale. [26]

It is important to note that as adjustments take place, the economy gravitates towards its

[24] Note that wages act like a non-tradable input denominated in domestic currency in our model, pushing the price level up and the real exchange rate down as in two-sector small open economy models.

[25] Some of the contractionary effects of depreciation of the currency operating in our model such as balance sheet effects and falling real incomes of workers have been analysed in open economy models, as documented in Frankel (2010).

[26] This overshooting of the current account to a surplus after sudden stops is documented in Calvo and Reinhart (2000) for EMs, and in Calvo et al. (2003) for Latin American countries following the Russian 1998 crisis.

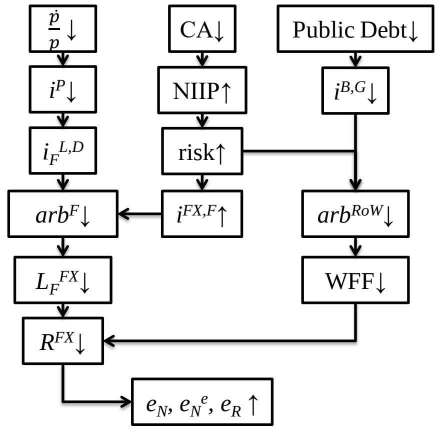


Figure 4: Causality graph showing the reversal dynamics following a shock on the foreign interest rate.

sustainable growth rate with zero current account deficit. As the medium run dynamics reveal, the economy stabilizes with a very small trade deficit and some positive yet very small level of portfolio inflows. The bond rates stay below the initial steady state level and country risk increases due to the accumulation of net foreign liabilities during the boom before stabilizing at a higher value eventually. The country ends up with a negative net international investment position following the adjustment. This is the BOP-constrained growth dynamics put forward by Thirlwall (1979) and Thirlwall and Hussain (1982), which states that in the long-run, no country can grow beyond the growth rate dictated by its balance of payments, as foreign capital would not indefinitely finance deficits. Our specification of risk ensures that this mechanism operates to reduce/reverse capital inflows as net international investment position deteriorates. In other words, it is the national balance sheet effect which causes the reversal of capital flows and currency depreciation in our model.

And finally, the long-run dynamics of real exchange rate in an economy depends on the combination of the capital account effect and Balassa-Samuelson productivity effect, as also shown by Boero et al. (2015). Without an endogenous growth of productivity in our model (dependent on FDI for instance as found in Boero et al. (2015) or export intensity as in (Aw et al., 2000), we only partially demonstrate the dynamics of the capital account effect. In essence, in a two-sector world, portfolio capital/cross-border lending inflows might increase wages in non-tradables, driving up wages in tradable sectors, hampering export competitiveness and reducing export shares, as found for Greece for instance by (Belke et al., 2018). This is in fact the exact mechanism operating in our model, where wages rise across the economy and help reduce exports via exerting an upward pressure on prices. But we do not consider any structural changes in productivity due to this decline in exports and this assumption, combined with our formulation of risk, ensures that the economy converges towards its balance-of payments constrained growth rate in the medium-run. In fact, if productivity gains are mainly concentrated in export-sectors, successive appreciation episodes may lead to a long-run de-industrialization of the economy and an increase in the unemployment rate consistent with the new balance of payments constraint, especially if installation costs of investment is high and/or supply chains and therefore depreciation does not revive exports. This is an interesting avenue of research which we leave for future work in a two-sector framework.

# 6 Sensitivity Analysis

## 6.1 Exchange Rate Adjustment Speed

We start our sensitivity analysis with the exchange rate adjustment speed. Figure 5 presents the dynamics of selected variables for $\beta_{en} = 0.7$ (the baseline, black dotted line), $\beta_{en} = 2.7$ (blue dashed line) and $\beta_{en} = 4.7$ (red solid line). Note that as the parameter increases, the exchange rate moves faster towards the equilibrium level where demand equals supply.[27]

The increase in the adjustment speed has significant effects on the model dynamics. If the financial markets adjust rapidly, nominal and real exchange rates fall sharply following the impact. The rapid appreciation of the nominal and real exchange rates increases real imports due to higher import shares ($\sigma_{M,i}$), reduces real exports due to lower export share ($\sigma_X$), and reduces the domestic currency value of exports. As a result, both nominal aggregate demand and real domestic production fall with respect to the baseline, leading to a larger increase in unemployment immediately following the shock.

With a faster adjustment speed, the larger nominal appreciation leads to lower inflation rate than the baseline during the boom. Consequently, central bank policy rate, domestic currency lending rates ($i^{L,D,T}$) and deposit interest rates all remain lower than the baseline during this phase. Combined with anticipations of overshooting of currency appreciation ($\frac{e^{N,e}+\dot{e}^{N,e}}{e^N} > 1$), firms' arbitrage drops rapidly to negative after the shock and the share of FX-borrowing starts falling as firms deleverage their FX-debt. On the other hand, due to the rapid fall in inflation, real interest rates on deposits stay higher than the baseline, leading to smaller increases in marginal propensities to consume and thus mitigating the impact of the liquidity channel and dampening the consumption boom. The rapid adjustment of the nominal rate also eliminates world arbitrage more rapidly and reduces portfolio inflows compared to the baseline after the shock. As a result, total capital inflows as % GDP falls relative to the baseline as adjustment speed increases and the real appreciation remains more muted.

The rapid appreciation on the other hand has a positive effect on investment, as it increases expected nominal profit rates via lower nominal currency value of firms' FX liabilities due to lower expected nominal exchange rate. With a lower inflation than the baseline, real expected profit rates ($r_F^e - \dot{p}/p$) increase more than the baseline implying that investment as a % of GDP is higher than the baseline during the boom. However, this surge in investment is not sufficient to compensate for lower consumption and higher trade deficit, and domestic demand remains lower than baseline both initially after the shock and during the boom phase. Thus, unemployment is higher than baseline during these periods. As mentioned above, total capital inflows as a % of GDP also remain below the baseline during the boom phase which ensures that the country experiences less appreciation and a smaller current account deficit during the boom, accompanied by a smaller

[27] In order to see this, note that equation (99) can be written as

$$\dot{e}_N = \beta_{en} \cdot \left( \frac{D^{FX} \cdot e_N}{S^{FX}} - e_N \right).$$

which, following (Gandolfo, 1997, pp. 163-164), implies that $e_N$ tends to $\frac{D^{FX} \cdot e_N}{S^{FX}}$ (i.e. $D^{FX} \to S^{FX}$) as $\beta_{en} \to \infty$.

overshooting of the current account surplus during the bust.[28] In sum, a faster adjustment speed reduces macroeconomic volatility as the economy fluctuates within a narrower band following a fall in foreign interest rates. The boom is driven more by a surge in investment rather than consumption, as the real sector adjusts to the rapidly appreciating currency and falling funding costs.

A couple of remarks need to be made on these results. First, one of the main reasons for these dynamics is the specification of the exchange rate expectation structure in (99). With a faster adjustment speed, the portfolio inflows and cross-border lending following the fall in foreign policy rate lead to a large nominal appreciation of the exchange rate beyond the expectations given by (99). Therefore, although economic agents expect to revise their expectation downwards ($\dot{e}^{N,e} < 0$), they also think that the appreciation has overshot and therefore expect a nominal depreciation, i.e $(e^{N,e} + \dot{e}^{N,e})/e^N > 1$. For the firm sector, arbitrage turns negative quickly after the shock and firms demand less and less FX loans. Similarly, world arbitrage falls much more rapidly than the baseline due to this anticipation of overshooting appreciation. An expectation structure which takes into account expectations of future foreign/domestic policy rates, inertia, etc. could reverse these results and lead to sustained expectations of appreciation following the shock even with a rapid adjustment of the nominal exchange rate. Cross-border lending and portfolio inflows could then remain higher for longer periods following the shock, fueling the boom.

Second, as we mentioned in section 3.2, the exchange rate pass-through to import prices are likely to be non-linear and low during appreciation episodes. In such a case, inflation, policy rate and domestic currency lending rates will remain higher, thus attracting more portfolio flows and cross-border borrowing, reintroducing the liquidity channel and aggravating the boom-bust dynamics. Further, high inflation will dampen the investment boom via lower real profit rates and fuel the consumption boom due to lower real interest rates on household deposits. Thus, part of the investment boom brought about by rapid adjustment of the nominal exchange rate and inflation will be replaced by a consumption boom.

Finally, as we show below, a higher sensitivity of exchange rate expectations to interest rate differentials, a lower dependence of risk perception on fundamentals, and/or a more monopolistic banking sector ensure that the boom dynamics, partly mitigated by the rapid adjustment of the exchange rate, can be re-introduced even at very high values of adjustment speed. Therefore, we conclude that while rapid exchange rate adjustment may dampen the appreciation-induced boom-bust phases, it may on its own be unable to offset these dynamics.

## 6.2 Exchange Rate Expectations

We next move on to sensitivity analysis on exchange rate expectation formation. For this purpose, we focus on the adjustment speed of exchange rate expectations (($\beta_{ene}$)) and the sensitivity of expected exchange rate to risk-weighted policy rate differential ($\sigma_{ene}$)

### 6.2.1 Expectations adjustment speed

Figure 6 presents the dynamics of selected macroeconomic variables for $\beta_{ene} = 0.65$, $\beta_{ene} = 0.75$ (baseline) and $\beta_{ene} = 0.85$.[29] The graphs suggest that a more rapid adjustment of exchange

[28] Although we do not report simulations with higher values of $\beta_{en}$ for clarity of graphical presentation, the marginal effect of higher $\beta_{en}$ falls rapidly beyond $\beta_{en} = 5$ while the boom-bust dynamics remain unchanged.

[29] Note that in the absence of any non-linearities in wage negotiations, no nominal downward rigidities on wages or lower bounds for real interest rates, the model becomes explosive beyond a certain value of $\beta_{ene}$ as cycles get larger

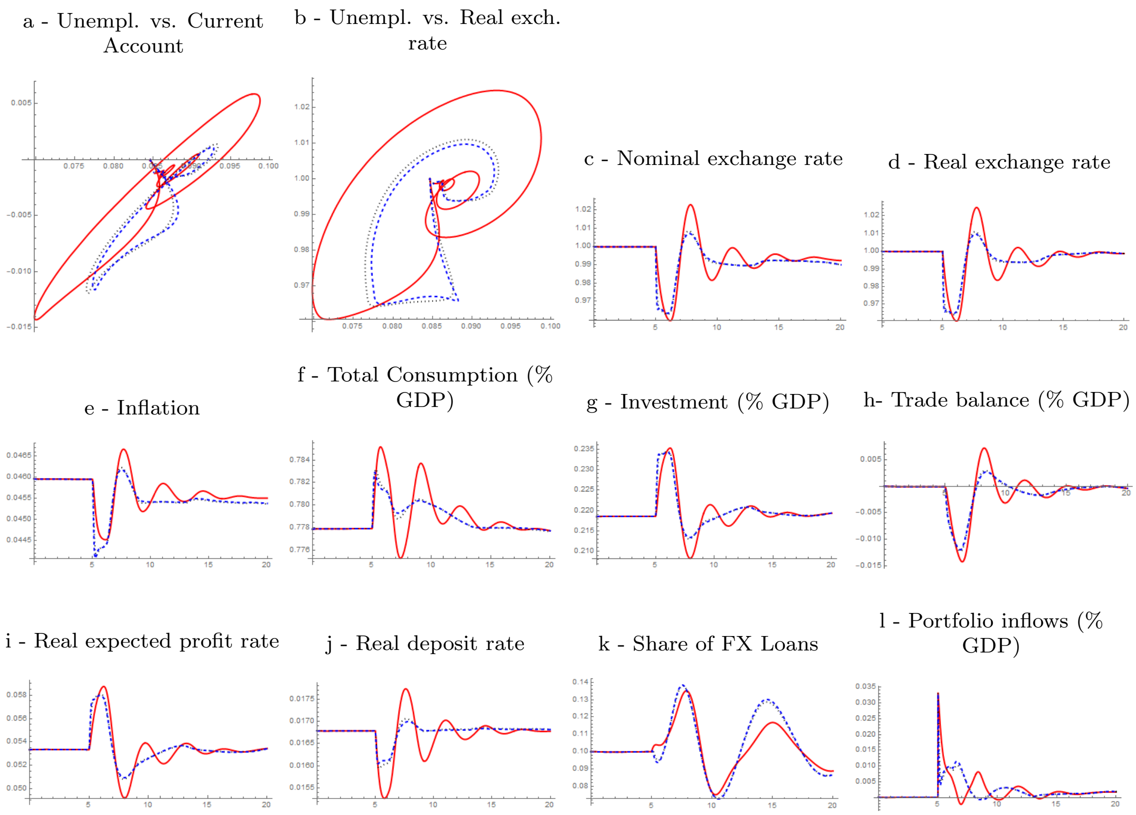


Figure 5: Sensitivity on Exchange Rate Adjustment Speed, red solid is $\beta_{en} = 0.7$, black dotted is $\beta_{en} = 2.7$, blue dashed is $\beta_{en} = 4.7$. Parametric plots have x-axis vs. y-axis labels.

rate expectations has a destabilizing effect on the economy overall. With a higher $\beta_{ene}$, both firm and world arbitrages are higher on impact and throughout the boom phase, thus fuelling larger amounts of capital inflows. As a result, the boom dynamics are aggravated as larger inflows lead to a larger nominal and real appreciation and cause a larger trade deficit. However, the liquidity channel and balance sheet channels also operate more strongly and push up consumption and investment above baseline levels due to higher expected real profits and lower real interest rates on deposits. Overall, as in the baseline, the positive effect of the inflows on consumption and investment dominate and unemployment falls sharply with a larger current account deficit and lower inflation.

The bust phase of the economy is also more severe with a higher speed of exchange rate expectations. As the country's net investment position worsens and its risk premium increases, expectations of currency depreciation is stronger with a higher $\beta_{ene}$, which leads to a net portfolio outflows from government bonds and a sharper reduction in cross-border borrowing. Thus, the nominal and real exchange rate depreciates more than the baseline; real interest rates are higher, real profit rates

in time. The introduction of these non-linearities, as in Chiarella and Flaschel (2000) for instance, would ensure that the economy remains within economically-meaningful boundaries for higher values of $\beta_{ene}$.

lower, with lower consumption, investment and employment during the bust. Consequently, the current account registers a larger surplus due to lack of domestic demand. While inflation, real exchange rate, real deposit rates, real expected profit rates converge to baseline values, albeit in a longer timeframe, nominal exchange rates and inflation remain higher than baseline even in the medium run with a higher $\beta_{ene}$.

#### 6.2.2 Interest-Differential and Exchange Rate Expectations

Figure 7 presents the dynamics of selected variables when $\sigma_{ene} = 0$, $\sigma_{ene} = 1$ and $\sigma_{ene} = 2$. As we discussed in section 3.9, $\sigma_{ene} = 0$ corresponds to the widely adopted backward-looking expectations structure. As $\sigma_{ene}$ increases, agents expect a stronger appreciation of the currency for a given set of values for domestic policy rate, foreign policy rate, country risk and the nominal exchange rate (see equation 99). Unsurprisingly, the qualitative implications of a higher $\sigma_{ene}$ is very similar to the more rapid expectations adjustment case above. Note that in both cases, higher parameter values exacerbate the initial negative response of employment to the inflows since expectations structure also affect the level of portfolio inflows and cross-border banking flows. Hence, higher values of $\beta_{ene}$ and $\sigma_{ene}$ lead to a larger appreciation of the currency and a larger drop in domestic currency value of export receipts immediately following the shock. With a higher $\sigma_{ene}$, the arbitrage for domestic firms and portfolio investors is eliminated in a longer period of time due to stronger appreciation expectations and therefore the boom (bust) that follows the appreciation process is also larger with investment, consumption, trade deficit and current account deficits jumping above (below) baseline levels. Unlike with higher $\beta_{ene}$, however, the country accumulates a larger negative NIIP/GDP ratio during the boom, as expectations of stronger currency appreciation enables the arbitrages to remain positive despite higher values of country risk.

Although higher levels of $\beta_{ene}$ and $\sigma_{ene}$ lead to similar dynamics in the small open economy following a fall in foreign interest rates, the two parameters have distinct interpretations. In essence, the parameter $\sigma_{ene}$ drives the level of appreciation/depreciation expectations given a certain risk-weighted interest rate differential, while $\beta_{ene}$ determines how rapidly exchange rate expectations adjust to this level. Intuitively, we would expect $\sigma_{ene}$ to be higher in countries with a history of strong boom-bust episodes following shocks to global interest rates. Sustained periods of global-interest rate-driven nominal exchange rate movements will strengthen the belief that the economy will go through the same phase in subsequent shocks to global interest rates, pushing up $\sigma_{ene}$ and magnifying the impact of such shocks in the future.

### 6.3 Fundamentals and Risk Perception

As we outlined in section 3.8, the country's risk depends on its net international investment position (NIIP from now on) as % of its GDP. At the steady state, country's foreign assets match its foreign liabilities and the NIIP is zero. At this point, risk is equal to 0.015, as we calibrated in 4. Following the shock, risk increases as the country accumulates a more negative NIIP and the parameter $\nu_3$ gives the slope of the sigmoid in (94). We hence set $\nu_3$ equal to 100, 300 (baseline value) and 500 where a lower value indicates that the sigmoid is flatter in the first quadrant.

With a low sensitivity of risk perception to fundamentals (i.e. a low $\nu_3$) perceived risk remains lower than the baseline, increasing cross-border lending supply and portfolio inflows. The currency appreciates more and reduces inflation to lower levels than the baseline. With lower inflation and

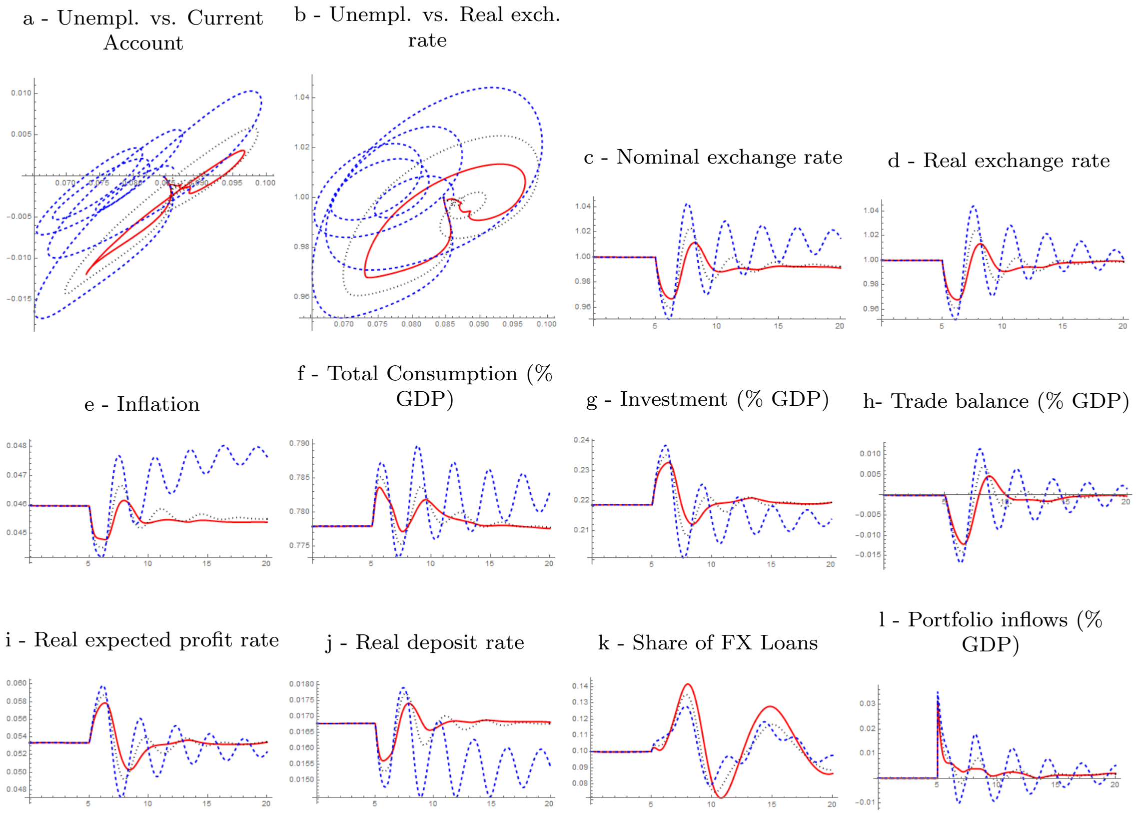


Figure 6: Sensitivity on Expected Exchange Rate Adjustment Speed, red solid is $\beta_{ene} = 0.65$, black dotted is $\beta_{ene} = 0.75$, blue dashed is $\beta_{ene} = 0.85$. Parametric plots have x-axis vs. y-axis labels.

stronger appreciation, expected real profit rates are higher and investment surges. The investment-induced increase in the funding needs of the firm sector, combined with higher level of cross-border lending supply fuels cross-border borrowing, strengthening the liquidity channel, reducing the real interest rates on household deposits and triggering an increase in consumption. Unemployment falls more than the baseline during the boom and remains well below baseline levels for the first few years. The trade deficit and the current account stay negative for longer periods, leading to a larger accumulation of negative NIIP. The boom is sustained for much longer as the large current account deficits are financed by higher capital inflows, which remain positive even during periods of nominal depreciation and increasing public debt.

As with speed of exchange rate expectation speed in the previous part, the bust is also more severe when risk perception is less sensitive to fundamentals. When capital inflows slow down, nominal depreciation is low, the real exchange rate remains significantly more appreciated during the bust since flows fall but continue due to positive arbitrage despite high unemployment and increasing public debt. With the fall in consumption and investment and high import shares due to an appreciated currency, domestic demand collapses as inflows fall, unemployment reaches 11% before the trade deficit can be eliminated due to lack of aggregate demand. Only after this point,

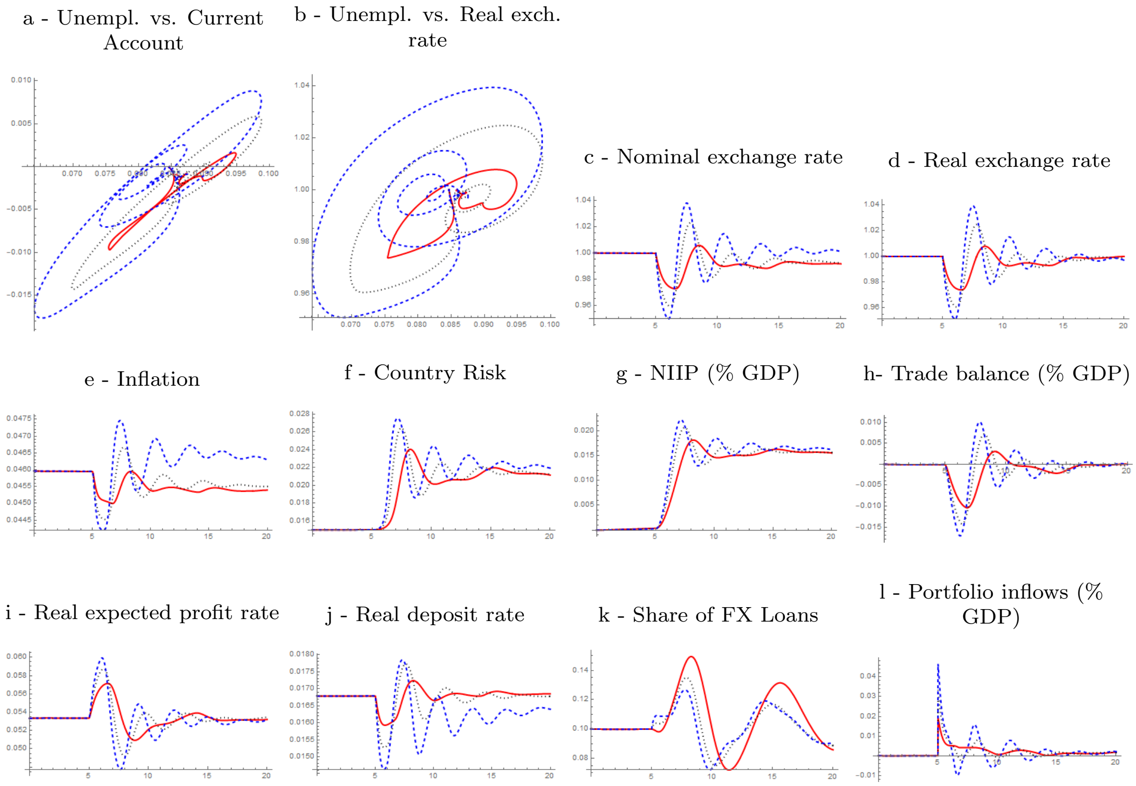


Figure 7: Sensitivity on Elasticity of Expectations to Interest-Differential, red solid is $\sigma_{ene} = 0$, black dotted is $\sigma_{ene} = 1$, blue dashed is $\sigma_{ene} = 2$. Parametric plots have x-axis vs. y-axis labels.

country's NIIP stabilizes, as inflows gain pace again and the economy gravitates towards its baseline growth rate.

## 6.4 Competitiveness of the Banking Sector

The sensitivity ($\rho_1$) of the countercyclical markdown determining the deposit interest rate (see equation 57) captures the degree of competitiveness of the banking sector where a higher sensitivity implies a less competitive sector. We test 3 values for $\rho_1$: 0.3 ,0.8 (baseline) and 1.3. With a higher sensitivity, the lending-deposit rate spread for banks is smaller during the boom, and larger during the bust. In other words, a higher sensitivity implies a more countercyclical lending-deposit rate spread, which is in accordance with the monopolistic competition framework presented in Mandelman (2010). Fluctuations in bank profits, real deposit rates, and the lending-deposit rate spreads are larger in this case. Although banks reduce the margin between lending rates on new loans and deposit rates more during the boom phase, bank profits as % of GDP are higher during the boom with a more monopolistic banking sector. Note that in that case, lower real interest rates on deposits lead to lower household savings. As the economy goes through a consumption boom with lower investment as a share of GDP, the trade deficit worsens and the current account

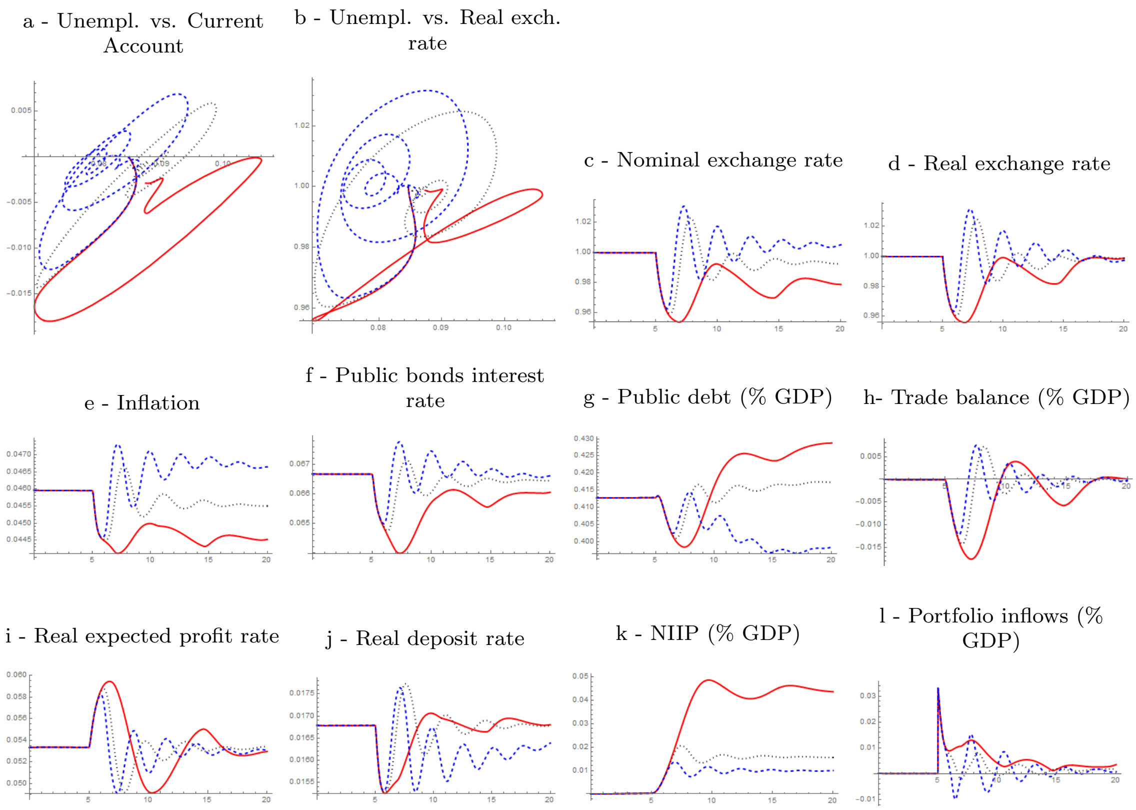


Figure 8: Sensitivity on Fundamentals and Risk Perception, red solid is $\nu_3 = 100$, black dotted is $\nu_3 = 300$, blue dashed is $\nu_3 = 500$. Parametric plots have x-axis vs. y-axis labels.

registers a larger deficit than the baseline. With higher aggregate demand, the fall in inflation is less pronounced.

In sum, our simulations show that, as in Mandelman (2010), a less competitive banking sector implies that the appreciation-induced booms are more likely to occur and the magnitude of business cycle that follows is larger. While the effect operates through real interest rates on domestic currency deposits to household saving rates in our framework, it would be straightforward to disaggregate the wage earner households and introduce household borrowing for consumption to generate the same effect. This is however left for following papers.

## 6.5 Import/Export Adjustment Speeds

We now turn our attention to the adjustment speeds in goods markets. For this purpose, we first present sensitivity of model dynamics to the adjustment speeds of imports ($\beta_M$) and exports ($\beta_X$ ) to their target values. As we mentioned in section 3.1, contracts for future deliveries and transaction costs of changing suppliers implies that import and export shares adjust slowly in response to movements in the real exchange rate. Figure 10 displays the dynamics of selected variables for

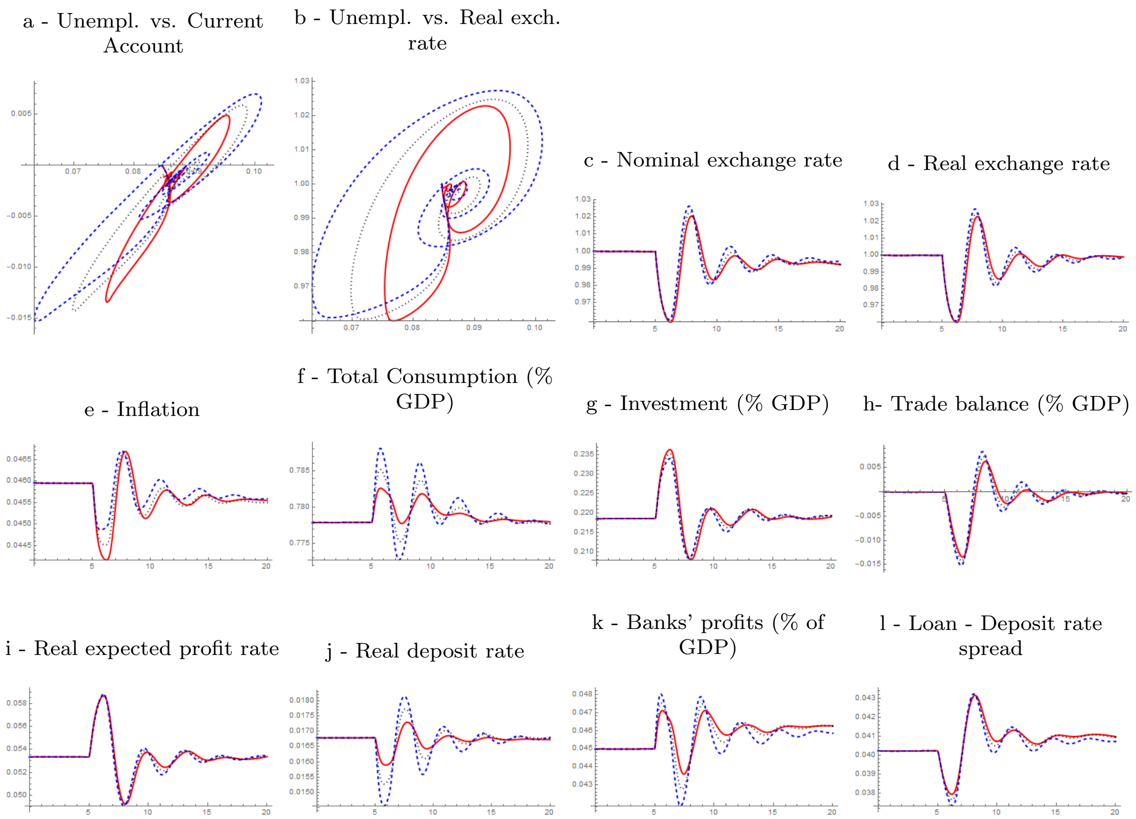


Figure 9: Sensitivity on Competitiveness of Banking Sector, red solid is $\rho_1 = 0.3$, black dotted is $\rho_1 = 0.8$, blue dashed is $\rho_1 = 1.3$. Parametric plots have x-axis vs. y-axis labels.

$\beta_X = \beta_M = 0.5$, 1 (baseline), and 1.5.

Unsurprisingly, a lower adjustment speed of export/import shares magnifies the boom - bust dynamics, as it takes longer for trade dynamics to adjust following the real appreciation of the currency. As a result, the trade deficit stays below the baseline level, ensuring that the NIIP accumulates more slowly, risk is lower and capital inflows are larger. As the currency appreciates more than the baseline and inflation is lower, expected real profit rates increase and fuel investment. With a higher domestic demand, unemployment falls more than the baseline yet creates a smaller current account deficit due to slow adjustment of trade shares.

As above though, the larger boom is also associated with a larger bust, since the economy needs to register over 10% unemployment rate in order to reduce the trade and current account deficits and stabilize its NIIP/GDP ratio. This requires a larger nominal depreciation, higher inflation, lower expected profit rates and higher real interest rates on deposits, with investment and consumption falling more than the baseline during the bust phase.

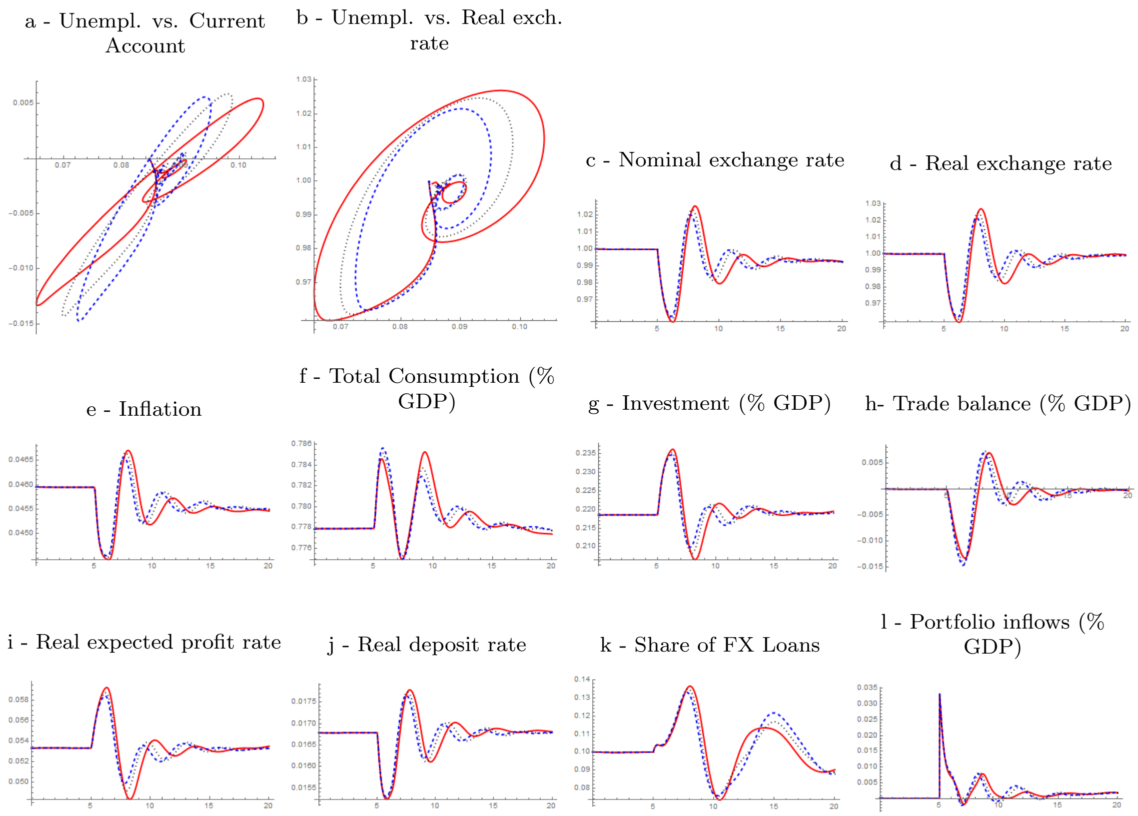


Figure 10: Sensitivity on Import/Export Adjustment Speeds, red solid is $\beta_X = \beta_M = 0.5$, black dotted is $\beta_X = \beta_M = 1$, blue dashed is $\beta_X = \beta_M = 1.5$. Parametric plots have x-axis vs. y-axis labels.

## 6.6 Output Expectations Adjustment Speed

Finally, we focus on the speed of adjustment of sales expectations ($\beta_y$) given in (1) with values equal to 2, 4 (baseline) and 6, see figure 11. With a higher speed, firms adjust their expected sales to actual aggregate demand more rapidly. In this case, firms expect a higher real profit rate due to higher sales expectations during the boom, despite the less appreciated currency. As a result, there is a surge in investment above the baseline levels while consumption falls as a % of GDP. The country also registers higher trade/current account deficits due to higher import propensity of investment. As production increases rapidly to meet excess demand during the boom phase, unemployment falls well below the baseline but inflation remains subdued even with strong demand pressures due to higher production. This is the self-reinforcing boom phase shown in Figure operating more strongly, where rapid adjustment of production to excess demand increases employment, consumption, firm profits and dividends, which feed back into aggregate demand, fuelling further increases in production and investment.

While a rapid adjustment keeps the real appreciation/depreciation within a smaller band between the boom and the bust phases, unemployment fluctuates more as firms also cut investment and production rapidly during the bust. At the peak of the bust, the trade/current account surpluses are thus higher as the heavily import-dependent investment boom bursts.

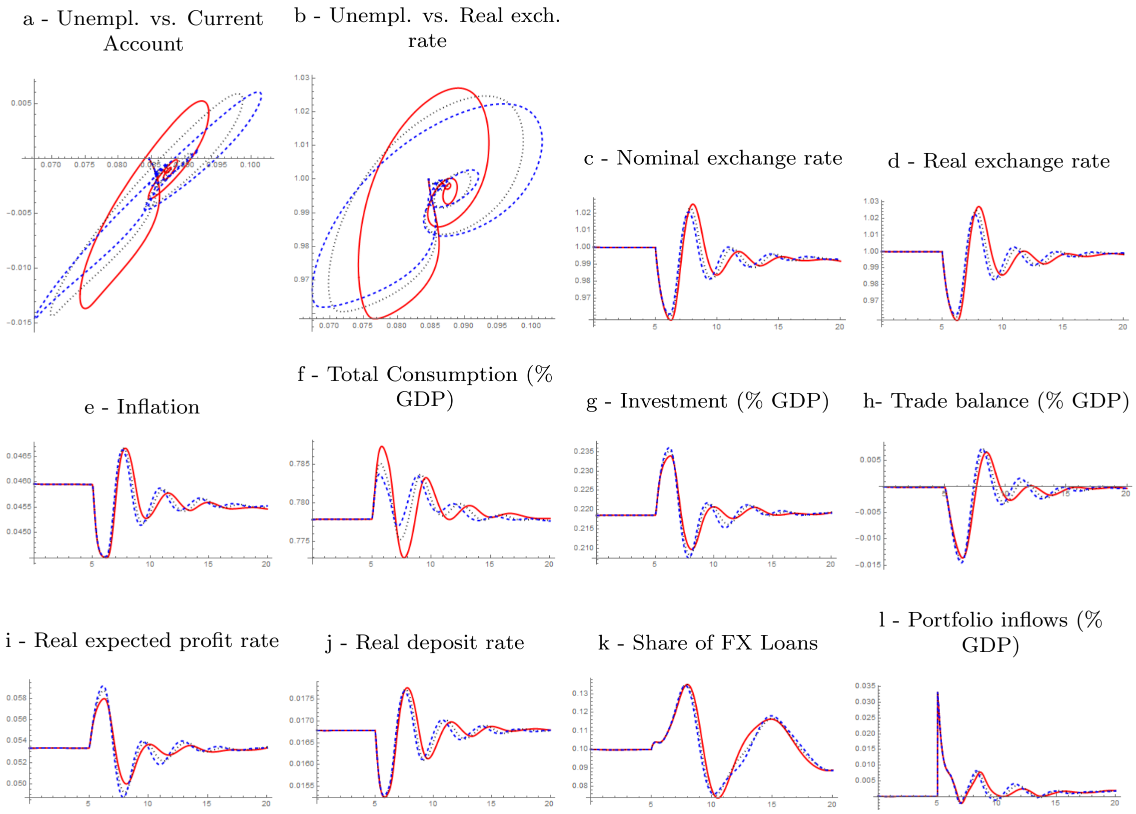


Figure 11: Sensitivity on Expected Output adjustment speed, red solid is $\beta_y = 2$, black dotted is $\beta_y = 4$, blue dashed is $\beta_y = 6$. Parametric plots have x-axis vs. y-axis labels.

# 7 Conclusion

In the last two decades, mounting empirical evidence has demonstrated the strong link between monetary policy in global financial centres and small open developing economies, operating through portfolio and cross-border lending flows. Most developing countries still rely heavily on these flows to finance their current account deficits and experience high growth-low unemployment episodes during loose global monetary policy, only to be followed by busts as monetary policy tightens globally. As a result, the need for analytical tools to analyse the dynamics of these episodes is as great as ever. In this paper, we constructed a continuous time stock-flow consistent model to address several important issues in modelling small open economies, such as consistent stock-flow interactions, interconnected balance sheets, the role of disequilibria and adjustment speeds, and the monetary nature of these economies.

We have shown that our model can generate the empirical regularities observed in developing economies in the aftermath of capital flows triggered by easing of global monetary conditions. Our results highlight the importance of the competitive structure of the domestic financial sector, formation of exchange rate expectations and the speed at which markets adjust in determining the magnitude of the boom-bust cycles. Crucially, although a rapid adjustment in exchange rate markets may mitigate the boom-bust dynamics, neither flexible exchange rates nor smoothly operating foreign exchange markets can totally eliminate these episodes, especially if risk perception is less dependent on country fundamentals and global capital is in search for yield via carry trade opportunities. The boom-bust dynamics are further amplified if exchange rate expectations are formed in acknowledgment of the forward premium puzzle with a high sensitivity to the policy-rate differential between the domestic economy and the financial centres, and if output and/or exchange rate expectations are updated more rapidly.

Although our results provide useful insights with regards to appropriate monetary, fiscal and macroprudential policies to manage these capital inflow-outflow periods; a topic widely investigated both in theoretical and empirical literature (see Qureshi et al., 2011; Ostry et al., 2011; Hoggarth et al., 2016), such policy issues cannot be fully addressed without a model which accounts for the endogeneity of productivity growth and structural change in our opinion. As we mentioned above, sustained periods of appreciation may shrink the export sector, reducing the balance of payments-constrained growth rate of the economy and therefore increasing the level of external financing needed to keep unemployment stable. This strengthens the connection between the global financial cycle and the small open economy and undermines the impact of monetary policy. Further, once export markets are lost, it may be very difficult and/or a long process to re-enter global supply chains. Heavy import-dependence of investment and capital goods and large fixed investment/installation costs may also hamper the growth of export industries, even with a strong depreciation of the currency. These considerations call for a careful investigation of various issues we left out in this study (non-linear/non-symmetric pass-through effects, variable elasticities of trade shares, tariffs, import taxes and subsidies, capital controls, FDI, exchange rate policies, etc.) and provide blueprints for future research.

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# A Model Consistency

In order to show the consistency of our model, we start with the central bank balance sheet identity in flow form.[30]

$$\dot{R^D} = \dot{A} + \dot{B}_G^{CB} + \dot{R}_{CB}^{FX} \cdot e_N \tag{104}$$

Using the definition of required reserves (RRR) and the demand for advances (52) gives:

$$rrr \cdot \dot{D}^D = TFN_B^D + \dot{B}_G^{CB} + \dot{R}_{CB}^{FX} \cdot e_N. \tag{105}$$

Inserting the definition of banks' total financing need (51) and simplifying, we obtain:

$$rrr \cdot \dot{D}^D = [\dot{L}^D + \dot{B}_G^B + \dot{B}_G^H] + rrr(D^D + \dot{D}^D) - (S_H + \dot{OF}_B), \tag{106}$$
$$- Res + (\dot{B}_G - \dot{B}_G^B - \dot{B}_G^H - \dot{B}_G^W) + \dot{R}_{CB}^{FX} \cdot e_N.$$
$$\dot{L}^D = (S_H + \dot{OF}_B) + \dot{B}_G - \dot{B}_G^W + \dot{R}_{CB}^{FX} \cdot e_N \tag{107}$$

Adding $\dot{L}_F^{FX} \cdot e_N = \dot{L}_B^{FX} \cdot e_N$ on both sides, leads to:

$$\dot{L}^D + \dot{L}_F^{FX} \cdot e_N + \dot{B}_G = (S_H + \dot{O}F_B) + \dot{B}_G^W + \dot{L}_B^{FX} \cdot e_N - \dot{R}_{CB}^{FX} \cdot e_N. \tag{108}$$

Noting that the total savings from the firms is $S_F = -\dot{L}^D - \dot{L}_F^{FX} \cdot e_N + \dot{D}_F^{FX} \cdot e_N$ and subtracting $\dot{D}_F^{FX} \cdot e_N$ from both sides gives:

$$-S_F + \dot{B}_G = \left(S_H + \dot{OF}_B\right) + \dot{B}_G^W + \dot{L}_B^{FX} - \dot{R}_{CB}^{FX} \cdot e_N - \dot{D}_F^{FX} \cdot e_N \tag{109}$$

Using $\dot{D}_F^{FX} = \dot{R}_B^{FX}$,

$$-S_F + \dot{B}_G = \left(S_H + \dot{OF}_B\right) + \dot{B}_G^W + \dot{L}_B^{FX} \cdot e_N - \left(\dot{R}_{CB}^{FX} + \dot{R}_B^{FX}\right) \cdot e_N \tag{110}$$

Since $\left(\dot{R}_{CB}^{FX} + \dot{R}_B^{FX}\right) = \dot{R}^{FX}$ and using the balance of payments (102), we thus have:

$$-S_F + \dot{B}^G = \left(S_H + \dot{OF}_B\right) + (IM \cdot p_W \cdot e_N + IA - X) \tag{111}$$

and therefore, denoting $-\dot{B}_G = S_G$ as total savings from the government and $S_B = \dot{OF}_B$ as the savings from the banks, we obtain:

$$0 = S_H + S_B + S_{ROW} + S_F + S_G \tag{112}$$

as can be seen from the Transactions Flow Matrix 1. Therefore, the sectoral balances imply that the central bank balance sheet is also consistent in time.

[30]The central bank registers capital gains/losses on its FX reserves due to depreciation/appreciation of the domestic currency. But such capital gains/losses never materialize on a CB balance sheet and therefore we ignore this. In the simulations reported, the magnitude of this superficial gains/losses ranges between ∓0.1% of GDP.

# B Interest Rates, Banks and Profit Maximization

Assume that banks set lending rates and deposit rates in order to maximize their current profits. The problem can be written as

$$Max[i^{L,D} \cdot (L^D)^R + i^B_G \cdot (B^B_G)^R - i^D \cdot D^D - i^P \cdot A] \tag{113}$$

subject to

$$A = L^D + B^B_G - (1 - rrr) \cdot D^D - OF_B \tag{114}$$

where $(L^D)^R$ and $(B^B_G)^R$ denote respectively banks' expectations of repayment of domestic currency loans and government bonds. Assume that these repayment expectations depend negatively on default expectations, given by $f(def)$ and $g(def)$ respectively such that

$$(L^D)^R = L^D \cdot f(def^P),\ f\prime < 0 \tag{115}$$

$$(B^B_G)^R = B^B_G \cdot g(def^G),\ g' < 0 \tag{116}$$

If banks do not internalize the sensitivity of firm financing needs and household savings to interest rates, the first order conditions to this problem yields:[31]

$$i^{L,D} = i^P / f(def^P) \tag{117}$$

$$i^D = i^P \cdot (1 - rrr) \tag{118}$$

Equation (117) implies that the optimal lending rate is above the central bank funding costs, it is convex and increasing in default expectations. Therefore, our interest rate specification captures the same dynamics via a non-linear premium over funding costs. Since we assumed that banks apply the same level of premium on FX and domestic currency loans, the cost of FX funding costs is $i^{L,FX}_B$ and banks never hold excess FX reserves, the optimality condition for $i^{L,FX}_F$ would similarly yield

$$i^{L,FX}_F = i^{L,FX}_B / f(def^P) \tag{119}$$

On the deposit rate, condition (118) clarifies why deposit rates will lie below the policy rate. In terms of the exact equation, one could argue that individual individual banks observe different changes in deposits rather than looking at the aggregate banking sector flows. Banks recognize the positive relationship between Depdot and iD, and they compete for funds in the deposit market. This competition is more intense when banking sector is short of deposits and ha to resort to central bank funding, measured by the positive relationship of deposit rates with loans to advances ratio $(\frac{L^D + B^B_G}{A})$. The level of competition in the banking sector, measured by $\rho_1$ in 57, determines the sensitivity of deposit rates to bank financing needs. A higher $\rho_1$ means that deposit rates fall more at times of low central bank financing and stay further away from policy rates when banks use high levels of central bank financing, therefore implying a less competitive banking sector.

[31] As can be seen in 29 and 88, $\dot{L}^D = \dot{L}^D(i^{L,D})$ $\dot{D}^D = \dot{D}^D(i^D)$. If banks had full knowledge of these functions, then the evolution of domestic loans and deposits would have to be treated as endogenous to banks' decisions. This is a very strong assumption so instead, endogenizing these considerations for banks properly would require formulating bank expectations on household savings and firm investment decisions.

# C Steady state values

Figure 12 shows how the steady state values described in table 4.2 compare to the mean values observed in 11 emerging economies over the period 2004 to 2016[32], using box-plots. The countries are: Argentina, Brazil, Chile, Colombia, India, Indonesia Mexico, Malaysia, Turkey, Russia and South Africa. Data-sources are the World Bank World Indicator database (World Bank, 2019) for most indicators,[33] Bussière et al. (2013) for the import intensities and the Bank of International Settlements (Bank of International Settlements, 2019) for policy rate data. The red dot is the steady state value for our model, the green dot is the cross-country mean of the mean values over the period.

We can observe that aside from inflation where the calibrated steady state is just below the box and tax rates where the calibrated value is above the plot, all the other indicators show calibrated values within the box plot and very close to the median (the thick horizontal line) and mean (green dot) of the values observed across the countries. In the case of inflation, we had to make a compromise given the constraint of identical inflation rate in the domestic economy and the rest of the world, which is why we settled for a lower inflation rate than observed. The tax rate data does not include social contributions which we do not model explicitly but do consider via unemployment benefits being redistributed. Our definition of taxes has thus a larger scope than the observed data, which explains why we have a larger calibrated value.

[32] Except for the import intensities which are averages over 1995, 2000 and 2005

[33] More precisely: deposit rate (FR.INR.DPST), lending rate (FR.INR.LEND), public debt (GC.DOD.TOTL.GD.ZS), taxes (GC.TAX.TOTL.GD.ZS), consumption (NE.CON.TOTL.ZS), exports (NE.EXP.GNFS.ZS), imports (NE.IMP.GNFS.ZS), inflation (NY.GDP.DEFL.KD.ZG), real growth rate (NY.GDP.MKTP.KD.ZG), unemployment (SL.UEM.TOTL.NE.ZS).

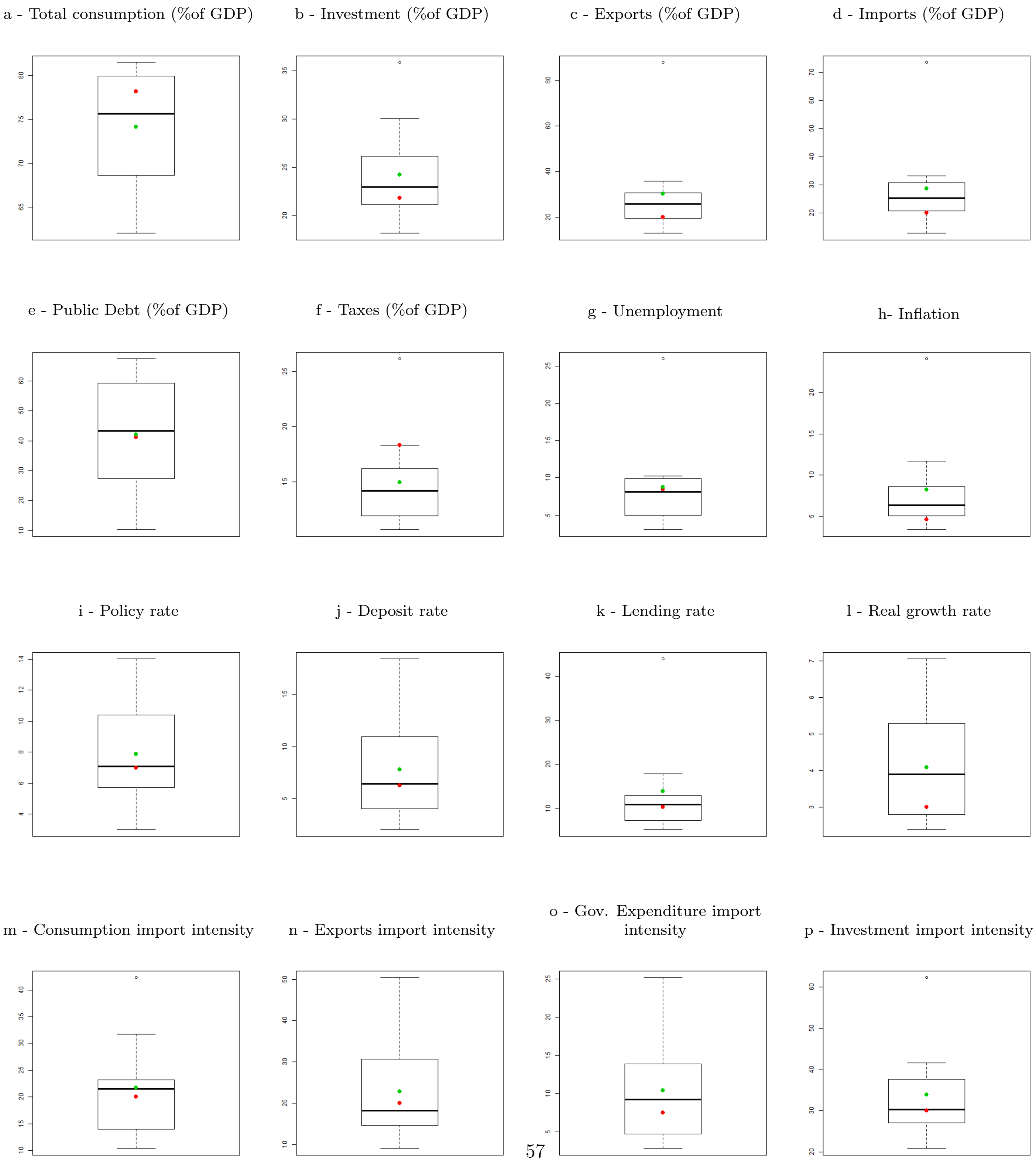




Figure 12: Box plots of 2004-2016 mean values for 11 emerging countries countries for selected variables. Red dot is steady state value, green dot is cross-country mean value over the period. Data: Bank of International Settlements (2019); Bussière et al. (2013); World Bank (2019) and authors' computations.

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