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Policy Responses to Aid Surges in Countries with Limited International Capital Mobility: The Role of the Exchange Rate Regime

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Policy Responses to Aid Surges in Countries with Limited International Capital Mobility: The Role of the Exchange Rate Regime

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Abstract

We study the role of the exchange rate regime, reserve accumulation, and sterilization policies in the macroeconomics of aid surges. Absent sterilization, a peg allows for almost full aid absorption—an increase in the current account deficit net of aid—delivering the same effects as those of a flexible regime but with a necessary increase in inflation. Regardless of the regime, policies that limit absorption—and result in large accumulation of reserves—are welfare reducing: they help reduce the real appreciation (and inflation under the peg), but at the expense of reducing private consumption and investment, and therefore medium-term growth.

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I. Introduction

The macroeconomic effects of aid flows have been the subject of an extensive and ongoing debate in both policy and academic circles. Many have argued that, despite the external financing constraints these flows help alleviate—and the public infrastructure they can help pay for—aid surges can hurt growth by inducing real exchange rate appreciation pressures, to the detriment of growth-promoting exporting industries.[1]

In practice, these concerns have triggered policy responses that have influenced the actual effects of aid. In a canonical aid transaction, the foreign exchange (FX) accrues to the government, which sells it to the central bank in exchange for a local currency deposit, which is then drawn down as the government spends the aid. With a managed float, the central bank in turn decides whether to use the FX to accumulate foreign reserves, and if so whether such accumulation should be sterilized. Berg et al. (2007) document how, during aid surge episodes in several African countries with managed floats (Ghana, Mozambique, Tanzania, Uganda), concerns about real appreciation resulted in large accumulations of reserves. This policy response may have helped contain the appreciation pressures. But it also resulted in a peculiar situation in which the aid was used twice: once to increase government spending, and once to increase the stock of reserves. The private sector was crowded out as a result, mainly through higher interest rates (when the accumulation was sterilized) and in some cases also through the inflation tax (when otherwise).

The crucial role of the central bank in the macroeconomics of aid has received little attention in the academic literature until recently.[2] Indeed, most previous work on the topic is built on the standard treatment of the *transfer problem*, which assumes that, to the extent the aid is being fully spent, it must also result in higher domestic absorption (an increase in the current account deficit net of aid), and by extension that aid cannot be both spent and saved as international reserves at the same time.[3] While this assumption would be viable if the public sector—the direct recipient of the aid—was a single entity, it no longer holds once it is acknowledged that the public sector consists of two separate institutions: the government and the central bank. This duality makes the distinction between spending and absorbing the aid crucial. While the former is determined by fiscal policy, the latter is influenced by the reserve policy of the central bank, especially when capital mobility is limited. In practice there is no institutional arrangement that ensures coordination between the two policies, thus allowing for the *spending without absorbing* policy mix described above.[4]

In previous work, Berg et al. (2010a, 2010b) have used this typology to model the effects of aid surges—episodes of large and persistent yet temporary increases in aid—under managed floats, in both the short and medium term. Berg et al. (2010a) developed a tractable new-Keynesian model with traded and non-traded goods to study short-run effects. Unlike the predictions of the standard transfer

[1] On the more pessimistic view, see Rajan and Subramanian (2011), among many others. On the belief that aid may spur growth by financing much-needed public infrastructure, see Collier (2006).

[2] Notable exceptions include works by Buffie et al. (2008) and Adam et al. (2009).

[3] The modern literature on the transfer problem started with the famous Keynes–Ohlin (1929) controversy.

[4] The distinction between spending and absorption of aid has been used for policy analysis in a number of IMF and non–IMF policy papers, see Berg et al. (2012). Buffie et al. (2010) criticize some of these analyses.

problem analysis, these authors showed that a policy of spending but not absorbing the aid can result in both a real and nominal depreciation if the resulting demand pressures, due to the fiscal expansion, are strong enough to threaten external balance. This can be the case even if the accumulation of reserves is fully sterilized (their default assumption in managed floats). Berg et al. (2010b) extended the model to allow for endogenous capital accumulation, production externalities in the export sector and possible inefficiencies in the conversion of public investment into public capital. When aid is both spent and absorbed, the model predicted a sizeable nominal and real appreciation, sectoral reallocations between the traded and the non-traded sector, and a crowding-in of private investment due to the positive effects of higher infrastructure on the returns to private capital. Instead, when aid is spent but not absorbed, the policy mix can have negative medium-term effects on growth and on welfare because of the crowding out of private investment.[5]

In this paper, we both extend and simplify the model in Berg et al. (2010b) to study the role of the exchange rate regime, and the resulting policy options central banks have at their disposal, in shaping the effects of aid surges. We answer a number of questions. First, are the macroeconomic effects of aid different in fixed versus flexible (managed floats) regimes? Second, what impact do sterilization policies (in pegs) have on aid absorption? Third, what are the welfare implications of alternative policy responses, under either flexible or fixed exchange rates?

Understanding the role of the exchange rate regime in the macroeconomics of aid is, in our opinion, of first-order importance. First, sub-Saharan Africa is evenly divided between pegs and managed floats: 23 of the 44 countries covered by the African department of the IMF have a *de jure* fixed exchange rate regime, while the rest have some type of managed float (see Berg and Portillo, 2008). Second, the importance of aid for both fiscal and balance of payment support cuts across exchange rate regimes, and concerns with the effects of aid are as pervasive in countries with managed floats, e.g., as discussed in Berg et al. (2007), as in hard pegs, e.g., the CFA zone, as documented by Ouattara and Strobl (2008). To our knowledge, this is the first paper that provides a systematic treatment of the exchange rate regime in the macroeconomics of aid from a spending/absorption perspective.

In principle, the ability to influence aid absorption in pegs is limited because the central bank does not have control over its reserve accumulation. In practice, limited capital mobility (a pervasive feature of low-income countries) provides an additional degree of freedom, which is embodied in the central bank's ability to sterilize (or not) any reserve accumulation that follows from the defense of the peg. Assuming that the government spends the aid as it accrues, we study two stylized responses by the central bank: sterilizing or not sterilizing the endogenous accumulation of reserves. For flexible (managed) regimes, on the other hand, we assume the central bank can accumulate aid as reserves and study the macroeconomic consequences of doing so.

Our findings are the following, based on a calibration of the model to a representative sub-Saharan African country:

[5] They also found that not absorbing the aid (accumulating reserves) could be welfare-improving if, as is sometimes feared, public investment is highly inefficient and export externalities are large. However, in this worse case scenario an even better solution is to not spend the aid at all, underscoring the importance of fiscal/central bank coordination.

First, a policy of limited or no sterilization allows for almost (but slightly less than) full absorption of the aid surge and sizeable real appreciation. This is the aid analog of the specie-flow mechanism that dates back to Hume. The initial increase in liquidity that results from spending the aid domestically fuels aggregate demand, inflation and imports, which are then financed with the aid-related FX. The end result is similar to the case of no reserve accumulation in a managed float. Just like in the managed float, the economy experiences a real appreciation and an increase in private consumption, investment, and output. Unlike the managed float, the real appreciation is achieved via an increase in inflation, which can only come about through higher aggregate demand pressures in the short run. The increase in inflation also requires some accumulation of reserves to help accommodate the increase in demand for nominal money balances, which explains why absorption is less than complete.

Second, a policy of complete sterilization in a peg can greatly limit inflation and the real appreciation but at the cost of limiting absorption and crowding out the private sector, similar to a policy of deliberately accumulating aid in reserves in a float. Out of concern for the increase in inflation, either because it signals aggregate demand pressures or because it amounts to a real appreciation and therefore a potential loss of competitiveness, the central bank may decide to engage in open market operations that limit the initial increase in liquidity. By doing so, the central bank is raising real interest rates and forcing the private sector to reduce its spending, which then limits the demand for imports and helps support the accumulation of reserves. The end result is less inflation and a less appreciated real exchange rate, but at the cost of crowding out private investment and affecting output in the medium term.

Third, like in the managed float case, the ability to influence absorption and the real exchange rate is reduced in a fixed regime as international capital mobility increases. This is a well-known result, which is often restated more generally as the inability of the central bank to control short-run inflation in a peg when the capital account is perfectly open. One surprising result from our model is that, even without restrictive monetary policy, the positive effects of aid on private consumption, private investment, and real output can disappear once international capital mobility increases significantly. The reason is that the open capital account activates the uncovered interest parity condition, generating a strong link between domestic real interest rates and expected real depreciation. As the real exchange rate overshoots in the short-run relative to its future value—because the aid surge is temporary—the expected future depreciation acts as a drag on private consumption and investment and increases capital outflows. While we do not wish to overemphasize this result, since it is sensitive to the specific calibration we use, it indicates the real possibility of capital flight in response to the aid surge.[6]

In sum, much of the drama that is present in response to aid surges in managed floats is equally present under fixed exchange rate regimes, with the additional complication that higher inflation is necessary for the aid to be absorbed. Because there are potential trade-offs between inflation (under no sterilization) and private sector crowding out (under full sterilization) in a peg, we therefore undertake a welfare analysis as a selection criterion for sterilization policies under a fixed and for reserve accumulation policies in managed floats.

[6] Intriguingly, there is some evidence that private capital outflows tended to coincide with the aid surges studied in Berg et al. (2007). Aiyar and Ruthbah (2008) find some systematic evidence to the same effect.

The welfare analysis yields a number of interesting findings. First, in our model, policies that encourage aid absorption are welfare dominant, regardless of the exchange rate regime: it is preferable to allow the country as a whole to use the aid-related FX, rather than having it sit in an account in New York. For this reason, in the case of a peg, a policy of no sterilization largely dominates a policy of complete sterilization, while in the case of a managed float, a policy of no reserve accumulation dominates a policy of full reserve accumulation. Second, policies that result in aid absorption have similar welfare effects under pegs and flexible exchange rates, although flexible exchange rates regime are slightly superior. This is because flexible exchange rate regimes can absorb aid with a much smaller aggregate demand boom than pegs, which instead need the boom—the increase in inflation—for aid absorption. At the other end of the spectrum, policies that result in limited aid absorption have larger negative effects on welfare in pegs than in managed floats, mainly because they have larger effects on private investment. Third, for pegs, only when the degree of sterilization reaches a high enough share of the reserve accumulation does this policy limit the degree of aid absorption and, therefore, results in a significant reduction in welfare. This suggests that what matters for aid absorption under a peg is that there is some monetary policy expansion—in order to encourage the private sector to increase its demand for imports.

Previous works in the aid literature have explored some of the policy issues we discuss in this paper. Adam et al. (2009) and Buffie et al. (2004, 2008, 2010) have extensively analyzed the role of monetary policy and exchange rate regimes in the context of aid surges. However, they have done so in models with currency substitution and fiscal dominance, which conflate the direct impact of aid with passive changes in monetary policy and currency-demand induced capital flows. Unlike our paper, these authors do find benefits to reserve accumulation following an aid surge. The main difference between our paper and theirs is twofold. First, we treat the central bank as an independent institution, which raises policy coordination issues with the government. In their setup the central bank does not have complete control over inflation, because of existing fiscal dominance, which then interacts with changes in the demand for currency (domestic and foreign) in ways that amplify the short-run effects of the surge and, therefore, justifies accumulating reserves in order to undo some of the capital inflow. While monetary financing of the deficit is sometimes an important issue in monetary policy in low-income countries, it is not necessary for the macroeconomics of aid flows. Second, we allow for private and public capital accumulation, which raises the (real) output costs of reserve accumulation and sterilization policies.

Another strand of the literature, including Adam and Bevan (2006), Agénor et al. (2008), Agénor and Yilmaz (2013), Arellano et al. (2009), Cerra et al. (2009), and Chatterjee and Turnovsky (2007), among others, explores the macroeconomic effects of aid in the context of real growth models. But these works abstract from central bank policy and therefore are not suitable to discuss fiscal/reserve policy interactions and their real effects, as our modeling approach allows. Furthermore, our work is also related to an older literature on "counterpart funds", the local currency proceeds from the sale within the aid-recipient country of in-kind transfers such as food aid (see Khatkhate, 1963, Roemer, 1988, in this journal, among others). While these papers had identified some of the mechanisms we discuss here, they lack a coherent modeling framework to make sense of the policy responses.

The remainder of this paper is organized as follows. Section II presents the structure of the model.

Section III discusses the calibration of the model. Section IV presents and elaborates on the results of the policy experiments under a fixed exchange rate regime and a managed float. Finally, section V concludes.

II. The Model

Our framework is a simplified version of the model presented in Berg et al. (2010b). It consists of a standard two-sector new-Keynesian model of a small open economy enriched with policy reaction functions that determine the degree of exchange rate commitment, international reserve accumulation, and sterilization.[7] The country produces a non-traded good y_t^N and a traded good y_t^T using private capital k, labor l, and government-supplied infrastructure q. Households may hold both domestic and foreign assets, but the latter are subject to portfolio adjustment costs. These costs capture the degree of international capital mobility, and their calibration allows to study a range of options, from de facto closed to a fully open capital account.

We separate policy decisions: the central bank is in charge of exchange rate and monetary policy (including international reserves accumulation and open-market operations), while the fiscal authority, which is the direct recipient of aid, decides how much of this aid to spend. All quantity variables except labor are de-trended by the labor productivity level, which grows at a constant factor $\mathfrak{n}$—the exogenous long-run gross growth rate of the economy.

We assume that the law of one price holds for the traded good. Therefore $P_t^T = S_t P_t^{T*}$, where P_t^T is the price of traded goods, S_t corresponds to the nominal exchange rate, and P_t^{T*} is the foreign price of traded goods. By denoting the domestic (foreign) Consumer Price Index (CPI) as P_t (P_t^*), we can express the CPI-based real exchange rate as $s_t = \frac{S_t P_t^*}{P_t}$ and the relative price of non-traded goods as $p_t^N = \frac{P_t^N}{Pt}$. We also define real gross domestic product (GDP) as: $y_t = \bar{p}^N y_t^N + \bar{s} y_t^T$, i.e., the sum of the production of the non-traded good, y_t^N, and the traded good, y_t^T, valued at their steady-state relative prices $\bar{p}^N$ and $\bar{s}$.

We proceed to lay out the model in stages, starting with the production side.

A. Firms in the Traded (T) and Non-traded (N) Good Sectors

In each sector $j = T, N$, the representative firm i produces goods with a technology that combines labor (l_{it}^j), firm-specific private capital (k_{it-1}^j), and public capital (q_{t-1}), according to

$$y_{it}^j = z^j \left[\left(k_{it-1}^j \right)^{\phi} (q_{t-1})^{1-\phi} \right]^{1-\alpha} \left(l_{it}^j \right)^{\alpha}, \tag{1}$$

where z^j is a constant productivity parameter, α indicates the production share of labor, and ϕ denotes the share of private capital in total capital used in production. Private capital is accumulated

[7] For a detailed description of the model see the Appendix.

via investment x_{it}^{j} but is subject to depreciation and adjustment costs, as described by

$$\mathfrak{n}k_{it}^{j} = (1-\delta)k_{it-1}^{j} + \left(1 - \mathcal{F}_{it}^{j}\right)x_{it}^{j}, \tag{2}$$

where δ is the depreciation rate and $\mathcal{F}_{it}^{j} \equiv \frac{\kappa}{2}\left(\frac{x_{it}^{j}}{x_{it-1}^{j}} - 1\right)^{2}$ are adjustment costs as in Christiano et al. (2005).

Firms in the traded sector face perfect competition and flexible prices, while firms in the non-traded sector face monopolistic competition and sticky prices. Each monopolist in the non-traded sector ($j = N$) produces a variety i of the non-traded good and is subject to a demand constraint of the Dixit-Stiglitz type with θ measuring the elasticity of substitution of these varieties. Moreover, as in Rotemberg (1982), the monopolist faces price adjustment costs capturing price stickiness, where the parameter ξ quantifies the degree of this stickiness.

Firms in both sectors are profit-maximizers. They choose the amount of labor, private capital, and investment (and the price p_{it}^{N} in the case of firms in the non-traded sector) that maximize the discounted profits. In each sector, there is also a tax distortion ϖ that reduces the value of firms' sales, capturing a broad set of institutional features that keep poor countries from investing at the high rates that might otherwise be justified by the very low stocks of private capital. In this way, we match the observed low investment shares in low-income countries.

B. Households

Consumers must decide how to allocate consumption expenditures among different goods. Consumption of the traded good and the non-traded good, denoted by c_t^T and c_t^N, respectively, are combined into a CES basket $c_t = \left[\varphi^{\frac{1}{\chi}}\left(c_t^N\right)^{\frac{\chi-1}{\chi}} + (1-\varphi)^{\frac{1}{\chi}}\left(c_t^T\right)^{\frac{\chi-1}{\chi}}\right]^{\frac{\chi}{\chi-1}}$, where χ denotes the intratemporal elasticity of substitution, and φ is the degree of home bias in consumption.[8]

The representative consumer maximizes her life-time utility:

$$\sum_{t=0}^{\infty}\beta^{t}U_t, \tag{3}$$

where

$$U_t = \left\{\frac{\eta}{\eta-1}\log\left[\vartheta(c_t)^{\frac{\eta-1}{\eta}} + (1-\vartheta)(m_t)^{\frac{\eta-1}{\eta}}\right] - \frac{\varkappa}{1+\psi}(l_t)^{1+\psi}\right\}, \tag{4}$$

m_t are the holdings of real money balances, and l_t is the amount of labor supplied to firms. The parameter $\beta \in (0,1)$ corresponds to the subjective discount factor, $\vartheta \in (0,1)$ is the share of consumption in utility, $\eta > 0$ measures the elasticity of substitution between c_t and m_t, $\varkappa$ is a scale parameter, and $\psi > 0$ is the inverse of the labor supply elasticity.

[8] We assume investment in both the traded and non-traded sector has the same composite structure and same shares as aggregate consumption.

Labor mobility is limited across sectors and intersectoral wage differentials are possible. Supplied labor is then defined as in Bouakez et al. (2009) by a CES aggregator with $\mathfrak{d}$ measuring the share of labor supplied to the non-traded sector, l_t^N, in total employment, and ϱ corresponding to the elasticity of substitution between labor services provided to the two sectors.

The budget constraint of the representative agent, deflated by the domestic CPI and normalized by the economy's growth rate, is given by:

$$c_t + m_t + b_t^c + s_t b_t^* + s_t \mathcal{P}_t = (1-\tau) w_t l_t + \frac{m_{t-1}}{\mathfrak{n}\pi_t} + i_{t-1}\frac{b_{t-1}^c}{\mathfrak{n}\pi_t} + s_t i_{t-1}^* \frac{b_{t-1}^*}{\mathfrak{n}\pi^*} + \Omega_t, \tag{5}$$

where b_t^c is the consumer's real holdings of domestic bonds issued by the government, which pay a gross nominal interest rate i_t and b_t^* denotes his real holdings of foreign assets that pay i_t^* and are subject to portfolio adjustment costs $\mathcal{P}_t$. Moreover, $w_t l_t$ is total labor income, $\pi_t = \frac{P_t}{P_{t-1}}$ denotes gross domestic inflation, while π^* is foreign inflation, which is assumed to be constant. Ω_t denotes real profits from domestic firms and τ is an income tax rate set by the government.

The portfolio adjustment costs are given by $\mathcal{P}_t \equiv \frac{\upsilon}{2}(b_t^* - \bar{b}^*)^2$, where $\bar{b}^*$ is the steady-state value of real foreign assets. These costs serve two purposes. First, they ensure stationarity of b_t^*.[9] Second, they allow us to model *limited* international capital mobility. When $\upsilon \to +\infty$, the capital account is practically closed; whereas when $0 < \upsilon << \infty$, it is partially open.

The problem of the representative consumer reduces to maximizing (31) with respect to consumption, real money balances, labor supply in both sectors, and domestic and foreign assets, subject to the constraint (35) and a transversality condition associated with all asset holdings.

C. The Government

C.1. Fiscal Policy

The government is the direct recipient of foreign aid A_t^*, which follows the process

$$A_t^* = \bar{A}^* + \rho_{_A}(A_{t-1}^* - \bar{A}^*) + \epsilon_t^A, \tag{6}$$

where $\bar{A}^*$ is the steady state level of aid, ϵ_t^A corresponds to an exogenous increase in aid at time t, and $\rho_{_A} \in (0,1)$ is the degree of persistence of the increase in aid.

Government consumption g_t is a CES basket similar to that of the households, but with ν and χ reflecting the weight on non-traded goods and the elasticity of substitution between traded and non-traded goods, respectively, and with an associated relative price index p_t^g.

The government is subject to a period-by-period budget constraint (in real terms) of the type

$$p_t^g g_t = \tau w_t l_t + s_t A_t^* + \left(b_t - \frac{b_{t-1}}{\mathfrak{n}\pi_t}\right) - \frac{(i_{t-1}-1)b_{t-1}^c}{\mathfrak{n}\pi_t}. \tag{7}$$

[9] See Schmitt-Grohé and Uribe (2003) for alternative methods to ensure stationarity of net foreign assets.

The government can finance its spending $p_t^g g_t$ by taxing labor income $\tau w_t l_t$, using the domestic currency value of aid proceeds, or issuing domestic debt net of amortization. It must however pay interest on the share of government debt held by the private sector (b_t^c). We assume the stock of total government debt (b_t) is constant and is held by either the private sector or by the central bank (b_t^{cb}), with their relative shares varying through open market operations by the central bank.[10] So $b_t = b = b_t^c + b_t^{cb}$.

The previous budget constraint implies that spending will always adjust to satisfy the constraint (44). In addition, spending can be used for public consumption or investment purposes. For simplicity, public investment is a constant share of government spending, i.e., $x_t^g = \mu g_t$ with $\mu \in [0, 1]$. It serves to accumulate public capital q_t following

$$\mathfrak{n} q_t = (1 - \delta_g) q_{t-1} + x_t^g, \tag{8}$$

where δ_g is the depreciation rate of public capital.

D. The Central Bank

We are interested in the implications of different exchange rate regimes for the macroeconomic effects of aid surges. We will first consider the case of a flexible exchange rate regime and use it as a benchmark to understand the effects of having a fixed regime. Then, under a fixed regime, we will analyze the macroeconomic consequences of different sterilization policies, and we will compare them with the outcomes of managed floats.

To organize the discussion, it is helpful to start with the central bank balance sheet in first (real) differences:

$$m_t - \frac{m_{t-1}}{\mathfrak{n}\pi_t} = b_t^{cb} - \frac{b_t^{cb}}{\mathfrak{n}\pi_t} + s_t \left(R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*} \right). \tag{9}$$

That is, real changes in money supply, $m_t - \frac{m_{t-1}}{\mathfrak{n}\pi_t}$, depend on open-market operations, $b_t^{cb} - \frac{b_t^{cb}}{\mathfrak{n}\pi_t}$, and changes in international reserves, $s_t \left(R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*} \right)$. We proceed to describe how the components of this equation are determined. Note that, although the central bank accumulates reserves, the public sector does not derive any revenue from accumulating these assets. In particular, reserves do not enter the government's budget constraint directly. This reflects our assumption that reserves do not earn any interest.

D.1. Exchange Rate Regimes and Reserve Accumulation Policies

We capture different specifications of exchange regimes (managed float versus fixed) by assuming that the central bank implements the following rule for the accumulation of international reserves:

$$R_t^* - \bar{R}^* = \rho_{R^*} \left(R_{t-1}^* - \bar{R}^* \right) + (1 - \omega) \left(A_t^* - \bar{A}^* \right) - \omega_s (\pi_t^S - \bar{\pi}^S), \tag{10}$$

[10] Berg et al. (2010a, 2010b) allow the government to adjust the rate at which it spends the aid, by introducing government deposits at the central bank d_t^g as an additional variable. They study the rate of spending as an additional policy decision. As our emphasis is on central bank policy, we simplify the model and focus on the case where aid is spent as it accrues.

where π_t^S is the nominal depreciation of the currency, and $\bar{R}^*$ and $\bar{\pi}^S$ are the steady-state levels (targets) of reserves and nominal depreciation. The parameter $\omega_s \geq 0$ measures the degree of commitment to a nominal depreciation target. For $\omega_s = 0$, the rule replicates a flexible exchange rate regime, while for $\omega_s >> 0$, the rule captures a fixed regime. Under a flexible exchange rate regime, the central bank can still accumulate reserves in response to *changes* in the volume of aid. In this case the regime becomes a managed float. The coefficient $\omega \in [0, 1]$ measures the fraction of additional aid dollars sold on the market to the private sector by the central bank, i.e., the degree of absorption of aid by the private sector. Under a fixed regime, on the other hand, reserves accumulation is driven by the central bank's commitment to hitting the targeted nominal depreciation $\bar{\pi}^S$.[11] This, of course, implies that aid absorption by the private sector, under a fixed regime, becomes endogenously determined, as we discuss below.

D.2. Monetary and Sterilization Policies

We allow for two alternative money growth rules: either full or zero sterilization. To model full sterilization, we assume that open-market operations (changes in b_t^{cb}) adjust such that nominal reserve money always grows at the rate $\mathfrak{g}$—i.e., $\frac{M_t}{M_{t-1}} = \mathfrak{g}$—implying that

$$m_t = \mathfrak{g}\frac{m_{t-1}}{\mathfrak{n}\pi_t}. \tag{11}$$

This captures the fact that many low-income countries still target money, at least *de jure.* More specifically, full sterilization requires that open-market operations follow:

$$b_t^{cb} - \frac{b_{t-1}^{cb}}{\mathfrak{n}\pi_t} = \frac{m_{t-1}}{\mathfrak{n}\pi_t}(\mathfrak{g} - 1) - s_t\left(R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*}\right). \tag{12}$$

Then if aid is accumulated in international reserves, either in the case of a flexible exchange rate regime or under a fixed regime, open-market operations would increase—the stock of government debt held by the central bank would decrease—in order to fully sterilize the direct monetary injection that would follow from higher aid inflows.

In the alternative specification, central bank purchases of nominal government bonds grow at constant rate $\mathfrak{g}$,:

$$b_t^{cb} - \frac{b_{t-1}^{cb}}{\mathfrak{n}\pi_t} = \frac{b_{t-1}^{cb}}{\mathfrak{n}\pi_t}(\mathfrak{g} - 1). \tag{13}$$

At steady state, this process ensures that nominal money supply grows at the gross rate $\mathfrak{g}$, which pins down the steady-state level of inflation, just like in the previous specification. Outside of the steady state, however, this rule does not ensure a constant growth rate for nominal money. In this case, the money growth rate will increase when aid is accumulated as international reserves.

[11] To be precise, our fixed exchange rate regime is a crawling peg unless $\bar{\pi}^S = 1$.

E. The Balance of Payments

We conclude our presentation of the model with the balance of payments:

$$A_t^* = \underbrace{c_t^T + g_t^T + x_t^{aT} + \mathcal{P}_t - y_t^T - \frac{(i_{t-1}^* - 1)b_{t-1}^*}{\mathfrak{n}\pi^*}}_{\text{CAD}} + \underbrace{b_t^* - \frac{b_{t-1}^*}{\mathfrak{n}\pi^*}}_{\text{KAS}} + \underbrace{R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*}}_{\text{RA}}, \tag{14}$$

where x_t^{aT}corresponds to the traded components of the investments in the traded and non-traded sectors, respectively. Equation (53) makes clear the possible uses of aid: it can finance a higher current account deficit net of aid (CAD), a capital account surplus (KAS), or an accumulation of reserves (RA).

III. Calibration

Our analysis will rely on numerical simulations.[12] To impose discipline, we calibrate most of the parameters of the model to a representative low-income country. As in Berg et al. (2010b), we replicate the Ugandan economy for the period 2008-2009, and assume that the unit of time in the model is a quarter. Uganda captures important features of sub–Saharan African economies: low investment in infrastructure, sizeable dependence on aid with large and persistent shocks to aid flows, low tax revenue as a percent of GDP, among other features. And although Uganda follows a flexible exchange rate regime, we use it as a baseline for at least two reasons. First, the flexible regime case provides a benchmark to understand the implications of fixing the exchange rate, as our comparative analysis will show below. Second, this baseline of a flexible regime, together with no reserve accumulation, is an *optimal benchmark* as it maximizes welfare in our analysis —i.e., it shows the highest positive impact of aid on consumption relative to which other policy scenarios can be considered.

We organize the calibration discussion around two groups of parameters that help pin down (i) technologies and preferences and (ii) policies (see Tables 1 and 2). We now briefly discuss the calibration of some of these parameters, particularly those for which we do *not* use Ugandan specific data or we do *not* normalize.

For the technology parameter ϕ, which determines the impact of public capital on growth, we pick values such that the annual return to public investment is about 20 percent. Estimates of this return vary significantly across empirical studies. However, the weight of the evidence in both micro and macro studies points to a high average return. Foster and Briceño-Garmendia (2010) estimate returns for electricity, water and sanitation, irrigation, and roads range from 17 percent to 24 percent. Similarly, the macro-based estimates in Dalgaard and Hansen (2005) cluster between 15 percent and 30 percent for a wide array of different estimators. The investment adjustment cost parameter (κ) ensures smooth impulse responses for investment, whereas the depreciation rates (δ) are in line with Bu (2004) calculations. The price adjustment cost parameter (ξ) implies price stickiness for almost

[12] The model was simulated with the software Dynare. See http://www.cepremap.cnrs.fr/dynare.

a year, while the elasticity of substitution between non-traded varieties (θ) matches a standard value for markups in the literature of 10 percent.

Table 1. Calibration: Technology and Preference Parameters

Parameters	Values	Source/Method
α	0.7	The sectoral labor's shares are based on Uganda's Input-Output tables
ϕ	0.47	The public capital parameter in production functions ensure an annual return on public capital of 20 percent
κ	25	The private investment adjustment cost parameters ensure smooth impulse responses for investment
$\mathfrak{n}$	1.0171	The trend growth rate matches Uganda's annual growth rate (7 percent)
z^N/z^T	1.06	The ratio of the productivity parameters in the productive sectors ensures the real exchange rate equals 1 at steady state
δ	0.015	The private capital depreciation rates (Bu, 2004)
ξ	47	The price adjustment cost parameter implies prices are sticky for almost one year (standard value in the literature)
φ	0.51	The distribution parameter for consumption of non-traded goods is consistent with Uganda National Income Accounts
χ	0.89	The intertemporal elasticity of substitution between non-traded and traded goods in Uganda (Tokarick, 2009)
θ	12	The inter–temporal elasticity of substitution between varieties matches a markup of 10 percent (standard value in the literature)
$\varkappa$	0.872	The disutility of labor parameter normalizes households employment to one at steady state
ψ	2.5	The inverse of the Frisch elasticity (standard value in the literature)
ϑ	0.999	The share of consumption in utility function helps match Uganda's real money balances in percent of GDP (6 percent)
η	0.180	The real money balances to nominal interest rate semi-elasticity is based on a regression using Uganda's data
$\mathfrak{d}$	0.6	The distribution labor parameter matches the Ugandan share of non-traded production in value added (60 percent)
ϱ	1	The labor services elasticity of substitution (Horvath, 2000)
β	0.995	The discount factor helps match interest rates in Uganda
υ	1000	The portfolio adjustment costs parameter
$\bar{b}^*$	0	The private external debt in the long run is normalized to zero

With respect to the elasticity of substitution between hours worked in the two sectors ϱ, we set it to 1, which corresponds to the econometric estimates provided by Horvath (2000). Assuming very large values for ϱ—perfect labor substitution—does not affect the qualitative results. Similarly, following the macro-labor literature we set the inverse of the Frisch elasticity equal to 2.5. We assume that the economy has a closed capital account, which makes sterilization policies quite effective. While somewhat extreme, this assumption is supported by measures of *de jure* restrictions on cross-border financial transactions in Schindler (2009): on an index that ranges between zero and one, where zero corresponds to perfectly open capital and one corresponds to perfectly closed, the value for the median sub-Saharan African country is 0.76. For comparison, the value for the median OECD country is 0.04. Consequently, we choose a very high value for the portfolio adjustment costs parameter ($\upsilon = 1000$).

Table 2. Calibration: Policy Parameters and Aid Process

Parameters	Value	Source/Method
		Aid process
ρ_A	0.9	The persistence parameter of the aid process implies a half-life of the shock of about one year
$\bar{A}^*$	0.049	The aid to GDP share matches Uganda data (5 percent)
ϵ^A	0.226	The aid shock matches a scaling up on average of 6 percentage points of GDP in 5 years
		The Government
ν	0.7	The distribution parameter of non-traded goods consumed by the government ensures market clearing for non-traded goods
τ	0.188	The tax rate on labor helps match the share of government spending (18 percent of GDP)
μ	0.389	The share of public investment in total government spending matches the public investment to GDP ratio (7 percent)
$\bar{b}^h$	0.085	The stock of government debt held by consumers matches Uganda's domestic government debt to GDP share (4.2 percent)
$\bar{b}^{cb}$	0.094	The stock of government debt held by central bank matches its share to GDP (5 percent)
δ_g	0.015	The public capital depreciation rate (Bu, 2004)
ϖ	0.09	The tax distortion helps match Uganda's private investment share (16 percent of GDP)
		The Central Bank
$\bar{R}^*$	0.365	The international reserves target helps match Uganda's stock of reserves (18 percent of GDP)
ω	1	The policy parameter that determines absorption in the international reserves accumulation rule
ρ_{R^*}	0.95	Persistence in reserve accumulation
ω_s	0 or 5000	The policy parameter that determines the type of exchange rate regime: flexible (0) or fixed (5000)
$\mathfrak{g}$	1.032	The reserve money (gross) growth rate at the steady state is consistent with Uganda's annual inflation (6 percent)

We model a temporary but persistent increase in aid such that, as a result of the scaling up, aid is *on average* six percentage points of GDP higher than its steady-state value over the following five years. Note that the coefficient ρ_A in the process for aid described in (42) results in a half life of the shock of slightly more than a year, which implies the aid increase is front loaded. This stylized path helps us bring out the macroeconomic dynamic responses in a clearer way.

The values of the parameters of the central bank represent the policy experiments that we will study below. We will compare the implications of flexible versus fixed exchange rate regimes. To do so, we set $\omega_s = 0$ and $\omega_s = 5000$ in the rule (48), respectively. When studying flexible exchange rates, we will allow the central bank to accumulate aid in international reserves. When $\omega = 1$ in (48), the central bank does not accumulate aid in reserves—i.e., full aid absorption. While if $\omega = 0$ then the central bank accumulates all aid in reserves—i.e., no aid absorption—with a significant persistence in the accumulation process ($\rho_{R^*} = 0.95$). In the case of pegs, we will focus on either full or no sterilization, as described by (50) or (51), respectively. Below we will also show how we can also write a more general rule that nests these two options as extreme cases in a continuum.

IV. Simulation Results

A. A Flexible Exchange Rate Regime Versus A Fixed Regime: Are They Similar?

To fix ideas, we start by comparing the case of a flexible exchange rate regime ($\omega_s = 0$) and no accumulation of aid in international reserves ($\omega = 1$) with the case of a fixed exchange rate regime ($\omega_s = 5000$) and no sterilization. The results of the simulations are presented in Figure 1, where the annualized impulse responses of selected macroeconomic variables are measured as percentage deviations from steady state, unless otherwise noted.

Focusing on the flexible regime case first (see solid line in Figure 1), we see that government spending of aid drives the short-run macroeconomic effects of the aid surge. Overall government spending increases by a similar magnitude than the increase in aid. Nominal price rigidities imply that the supply of non-traded goods greatly expands in response to greater demand generating a short-lived spike in real GDP. This expansion in non-traded output is partly accomplished through higher labor demand, which contributes to the rapid increase in real wages in the short run (not shown) and translates into higher non-traded good inflation. This, however, does not induce higher CPI inflation. The inflow of aid-related FX results in a nominal appreciation, which causes traded good deflation but more importantly triggers expenditure switching in the private sector and therefore helps reduce aggregate demand pressures somewhat. In the simulations, this deflation more than offsets the increase in non-traded good inflation and, as a result, CPI inflation declines in the first years. This and the neutral policy stance by the central bank lead to a slight decrease in nominal interest rates. Over time, as nominal rigidities dissipate, the demand-driven boom fades away. However, since part of the government spending has been used to increase public investment, the public capital stock accumulates, causing a persistent and positive effect on GDP that accounts for most of the output increase in the medium term. This process is reinforced by higher private investment, which increases in response to the positive effect that higher public capital has on the marginal product of private capital.

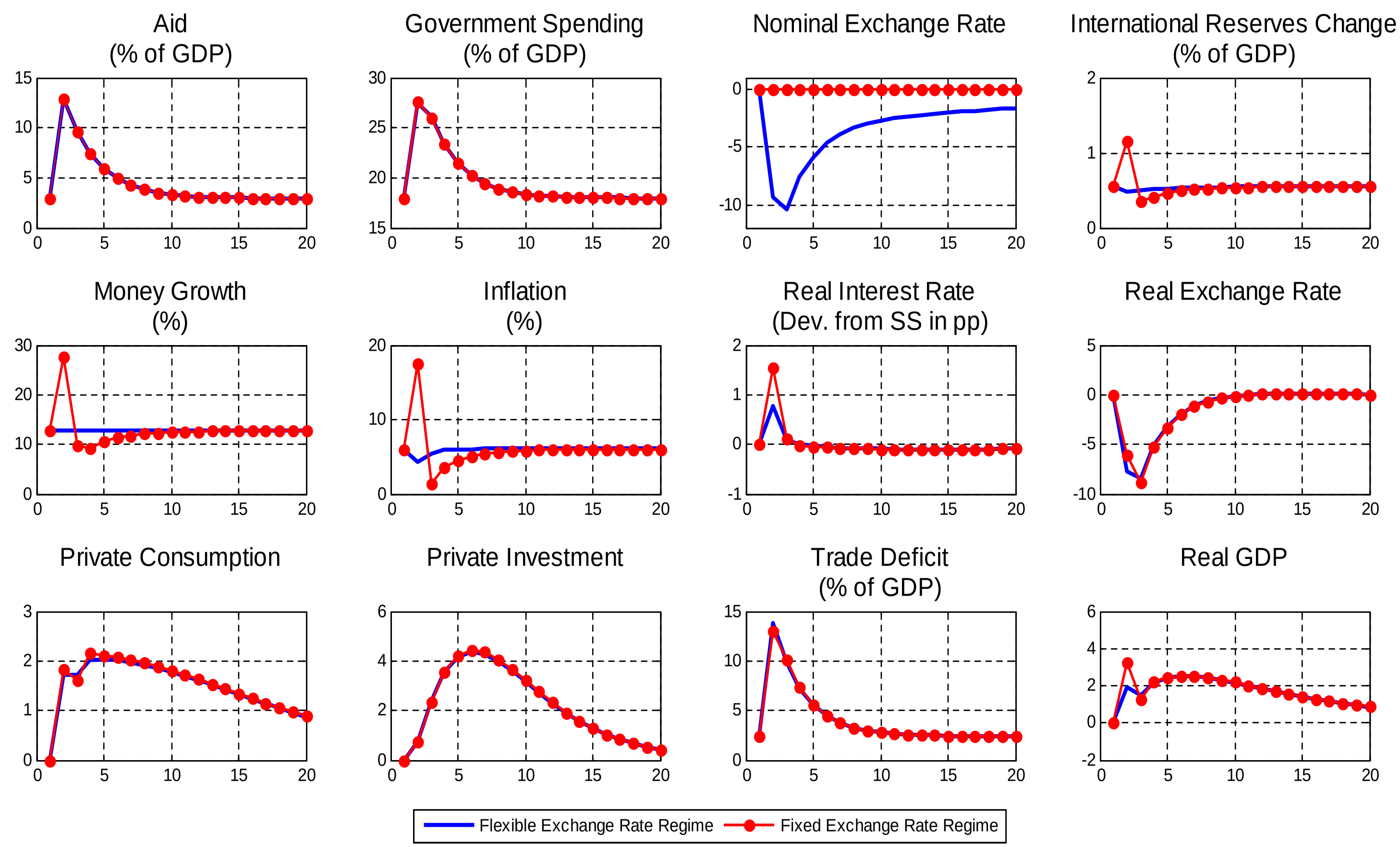

Figure 1: The macroeconomic effects of aid surges under a flexible exchange rate regime and a fixed regime without sterilization. Impulse responses are shown in annual terms and as percentage deviations from steady state, unless otherwise noted.

The central bank's policy of no reserve accumulation allows for a real exchange rate appreciation and leads to a full absorption of aid by the private sector. That is, as the real exchange rate appreciates, imports (consumption and investment of traded goods) increase and traded output declines (not shown), resulting in a widening of the trade deficit. This is made possible by the central bank's policy of selling all the foreign currency counterpart of aid to the private sector. In the end, the increase of the trade deficit is almost as big as the aid surge.

We now compare these results with the case of a fixed exchange rate regime ($\omega_s = 5000$), where the central bank does *not* sterilize the excess of money liquidity induced by any endogenous accumulation of reserves (see solid line with dots in Figure 1). Absent sterilization, a fixed exchange rate regime delivers similar real exchange rate appreciation dynamics to those present under a flexible regime. However, the mechanism that drives this appreciation is different. Under a fixed exchange rate, traded good prices remain constant, so non-traded good inflation has to increase significantly more to bring about the same relative price change. But this also means substantially higher overall inflation, because unlike the flexible regime case, there is no traded-good *deflation*. Higher non-traded good inflation is caused by larger demand pressures in the non-traded sector (again, because of public consumption of non-traded goods), as reflected by a more pronounced short-run spike in GDP, relative to the one in the flexible regime scenario. Over the medium term, however, output responses are practically identical.

With a fixed regime, the accumulation of international reserves is not a policy choice; instead, it is endogenously governed by the need to sell as much foreign exchange as needed to achieve the rate of crawl. In contrast to the flexible exchange rate scenario, where all of the aid inflows are sold, a small fraction of these inflows are accumulated as reserves. Without sterilization, and provided the domestic currency counterpart is fully spent by the government, the reserve accumulation associated with the fixed regime is associated with an expansion of the money supply.[13] The real interest rate increases to help keep inflation expectations anchored, but this increase is moderate (relative to the flexible regime) and short-lived, despite the accommodative monetary policy stance. Overall the money supply expansion is instrumental in accommodating the increase in CPI inflation, which in turn brings about the real appreciation necessary for close-to-full private absorption of the aid inflows. In fact, under the fixed regime (without sterilization), the dynamics of private consumption and private investment, as well as that of the trade deficit, are broadly the same as those under the flexible regime.

B. A Fixed Exchange Rate Regime: Sterilize Versus Don't Sterilize

The results of Figure 1 reveal that, absent sterilization, short-term inflation pressures may arise under a fixed regime. Authorities may find this response problematic for two reasons. First, central banks dislike inflation, especially when such inflation reflects aggregate demand pressures. This is indeed the case under a peg and when there is no sterilization, as can be seen in the temporary spike in GDP in the short run. Second, the increase in inflation signals a sizeable real appreciation, and

[13] This follows from the central bank's balance sheet in equation (47), where the reserve buildup increases the second term on the right-hand side, whereas no sterilization and full government spending keep the first term constant.

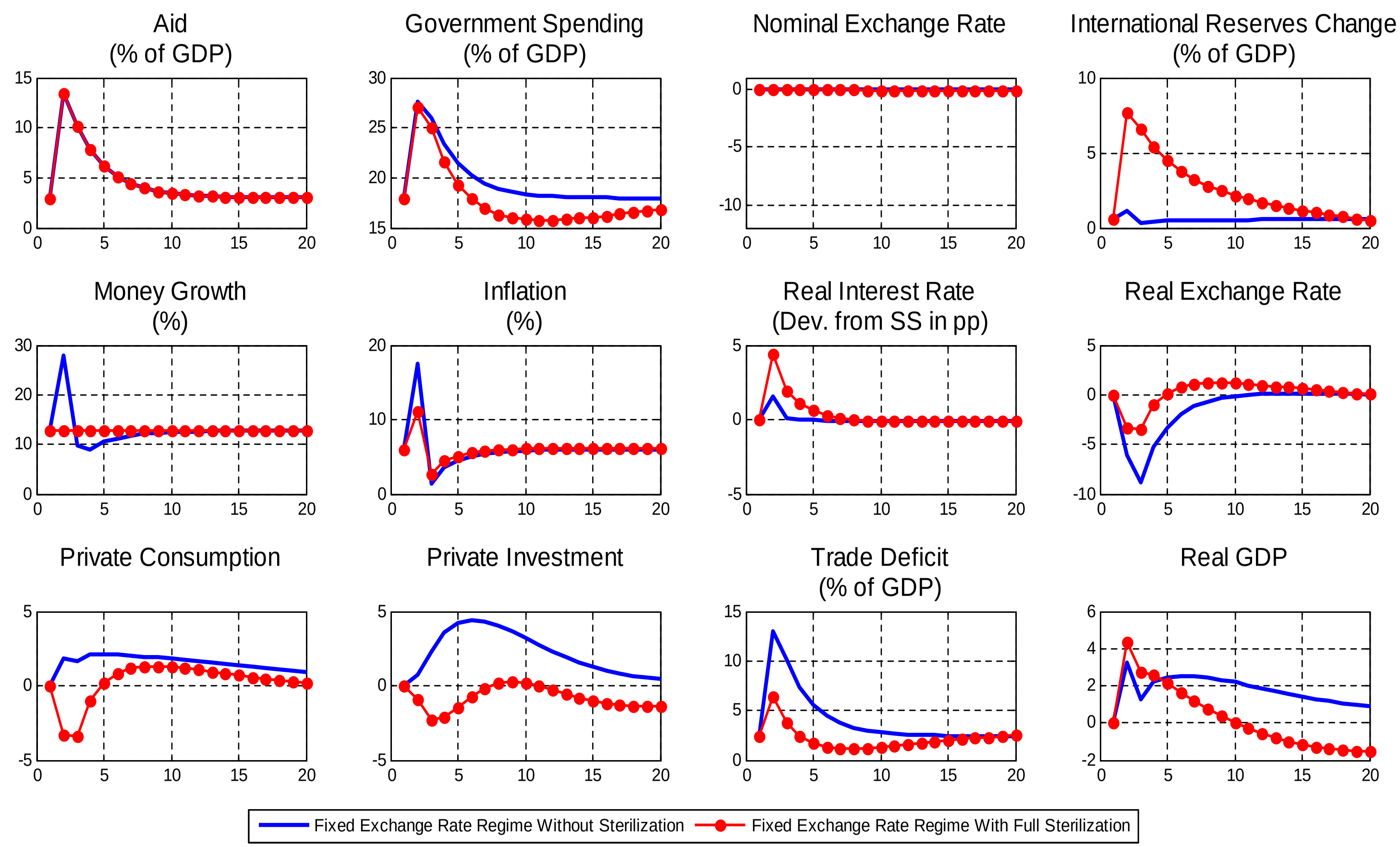

Figure 2: The macroeconomic implications of sterilization policies in a fixed exchange rate regime. Impulse responses are shown in annual terms and as percentage deviations from steady state, unless otherwise noted.

could be interpreted as a loss of competitiveness. Central banks may worry about these developments, especially since it could also be interpreted as a potential threat of the sustainability of the exchange rate regime.

Since these inflationary pressures are associated with the money supply expansion resulting from the foreign reserve accumulation, the central bank may decide to prevent such an expansion through open-market operations, i.e., sterilizing the reserve accumulation.[14] We now proceed to analyze the consequences of full sterilization, which are presented in Figure 2.

Sterilization policies under the fixed exchange rate regime can certainly reduce the inflationary pressures, but they may also lead to significant private-sector crowding out in the short term and negative effects on real output in the medium term (see solid line with dots in Figure 2). With full sterilization, the monetary policy stance becomes considerably tighter—to keep (nominal) reserve money growing at the rate $\mathfrak{g}$—with real interest rates increasing by more than before and remaining high for a longer period than in the case of no sterilization. This is effective to contain the inflationary pressures in the short term. Moreover the endogenous reserve accumulation ends up being much larger, as agents no longer have the aid-related liquidity to buy foreign currency as was the case before. The interest rates increase force private consumption and private investment to decline in the short term. And the associated reduction in private sector import demand limits the economy-wide absorption as well as the real exchange rate appreciation. As a result, the trade deficit does not widen as much as in the case of no sterilization. Furthermore, the reduction in private investment (capital accumulation) has a significant adverse impact on real GDP in the medium term. Hence, full sterilization policies under a fixed regime come at a significant cost in terms of private sector spending and real output.

C. Fixed and Managed Float Regimes: The Role of Sterilization and Reserve Accumulation

Figure 1 shows that, absent sterilization, the real macroeconomic effects of a fixed regime are very similar to those of a flexible regime. But can the real macroeconomic effects of a fixed exchange rate regime with full sterilization be replicated with a flexible regime? The answer depends on the role of reserve accumulation in the flexible regime. In particular, one can consider regimes where the accumulation of aid in reserves is exogenously determined by the central bank making a flexible regime a managed float. To capture a managed float regime, we can simulate the model under a flexible regime with no aid absorption—i.e., we set $\omega_s = 0$ and $\omega = 0$ in (48) so all the aid surge is accumulated in reserves. From a policy perspective, the rationale of considering such experiment lies on the concerns that policy makers have about the significant real appreciation and loss of competitiveness associated with a fully flexible exchange rate regime (see Figure 1). As a result, the central bank may decide to contain some of the real appreciation by limiting the amount of foreign exchange sales to the market and using the aid inflows instead to build up foreign exchange reserves.[15]

[14] An important caveat is that sterilization is feasible only with a sufficiently closed capital account, as is the case with the Uganda calibration used here.

[15] Berg et al. (2007) find that this is exactly what many sub-Saharan central banks with flexible exchange rate regimes did during aid surges.

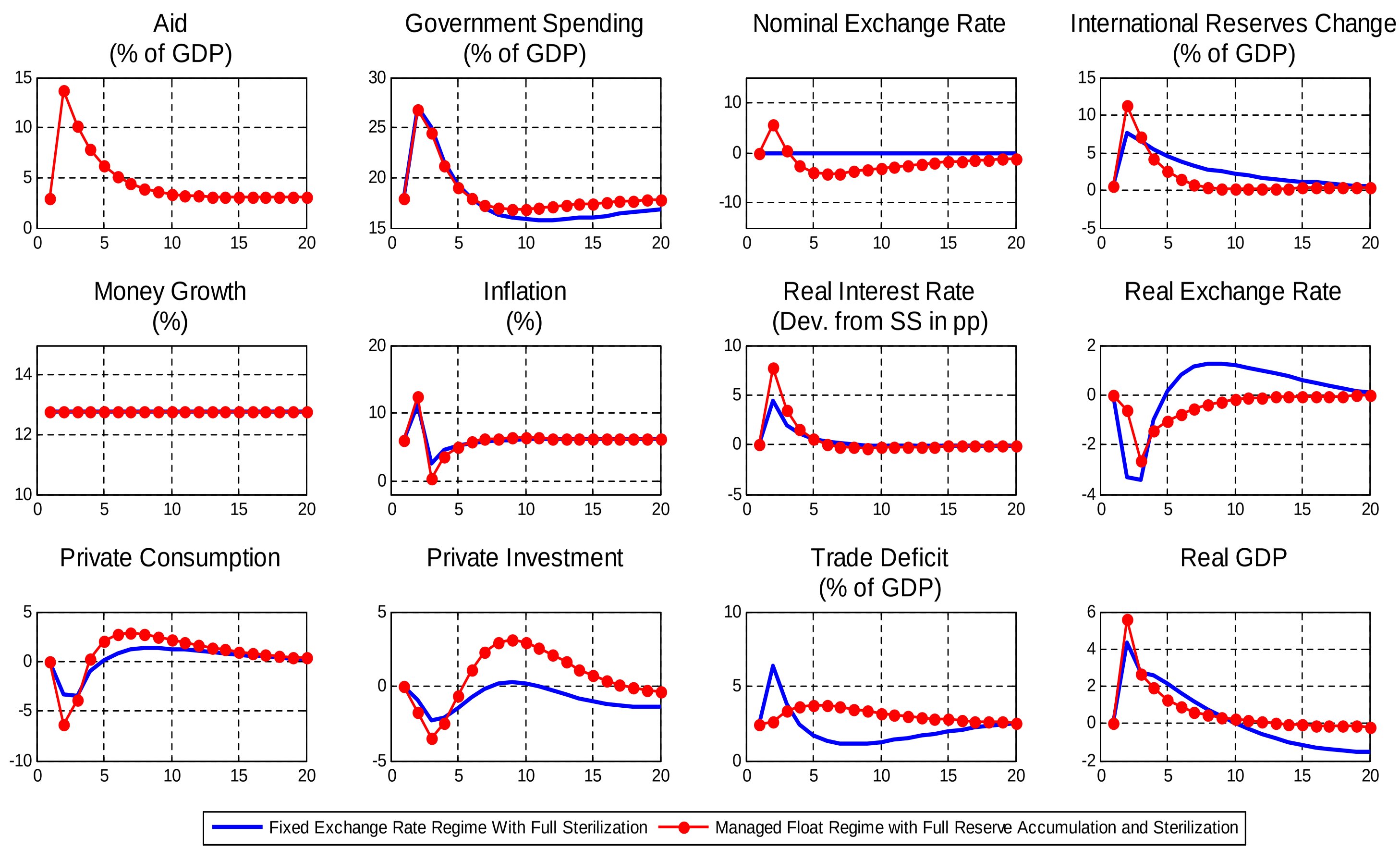

Figure 3: A comparison of the macroeconomic effects of a fixed exchange rate regime versus the effects of a managed float regime with full reserve accumulation. Full sterilization is assumed in both cases. Impulse responses are shown in annual terms and as percentage deviations from steady state, unless otherwise noted.

Figure 3 presents a comparison of the macroeconomic effects between a fixed regime ($\omega_s = 5000$) and a managed float regime. In both cases we assume *full sterilization,* so (nominal) reserve money keeps growing at the rate $\mathfrak{g}$. With the managed float regime, limiting the sale of aid-related foreign exchange (accumulating international reserves) is indeed effective in reducing the appreciation, both in nominal and real terms. As a result, the trade deficit widens by much less than the increase in aid, which implies no absorption of aid inflows. Given the increase in government spending, partial absorption at an economy-wide level must imply a reduction in private sector demand. This implies a significant private sector consumption and investment crowding out, which takes place in the first three to five years. Moreover, the reduction in private investment has a significant adverse impact on real GDP, roughly halving the positive GDP effect of scaled-up aid over the five-to-ten-year horizon. Hence, in a managed float, limiting foreign exchange sales may come at a significant real cost.

Comparing these aid macroeconomic effects of the managed float regime with those of a fixed regime, under full sterilization, show important similarities particularly regarding the crowding out of the private sector. The crux of the equivalence lies on the following fact: whereas government spending of aid normally corresponds to an externally-financed increase in spending, the central bank *use* of the foreign exchange counterpart of aid to accumulate reserves or to maintain the exchange rate peg (*combined with* the sterilization policies) transforms this into domestically-financed spending. Externally- and domestically-financed government spending have very different impacts on the private sector. In an externally-financed case, the foreign exchange inflows are used for financing a larger current account and trade deficits. This allows government spending to increase without crowding out private sector demand. In the case where the foreign counterpart of aid inflows is accumulated in reserves—either as an exogenous outcome as in the managed float or an endogenous outcome as in the fixed regime—the trade deficits do not increase as much as in the case of no accumulation. Consequently, higher government spending necessitates a lower private sector demand (crowding out), unless there is a very large supply response.

D. A Fixed Exchange Rate Regime: Closed Versus Open Capital Account

With a fixed exchange rate regime, the positive short-term effects of no sterilization on private consumption and investment depend on the degree of international capital mobility. So far we have assumed that the capital account is fully closed to private capital inflows (or outflows). But once the economy becomes more integrated to international capital markets, a policy of no sterilization under a fixed exchange rate regime can also cause crowding out of the private sector, as shown in Figure 4.[16] With almost perfect international capital mobility, the domestic nominal interest rate is tied down by an uncovered interest parity condition. While inflation increases on impact, it is expected to decrease, thus resulting in an increase in long-run real interest rates (not shown). This increase is reflected in the spread between domestic and foreign real interest rates. As the spread widens, domestic agents tend to demand more foreign bonds (accumulate net foreign assets) and, in doing so, reduce private consumption and investment. Hence, the private sector crowding out occurs in the short term. And since private capital accumulation falls, medium-term real output is not as high as in the case of

[16] To open the capital account we set the portfolio adjustment costs parameter υ equal to 0.001.

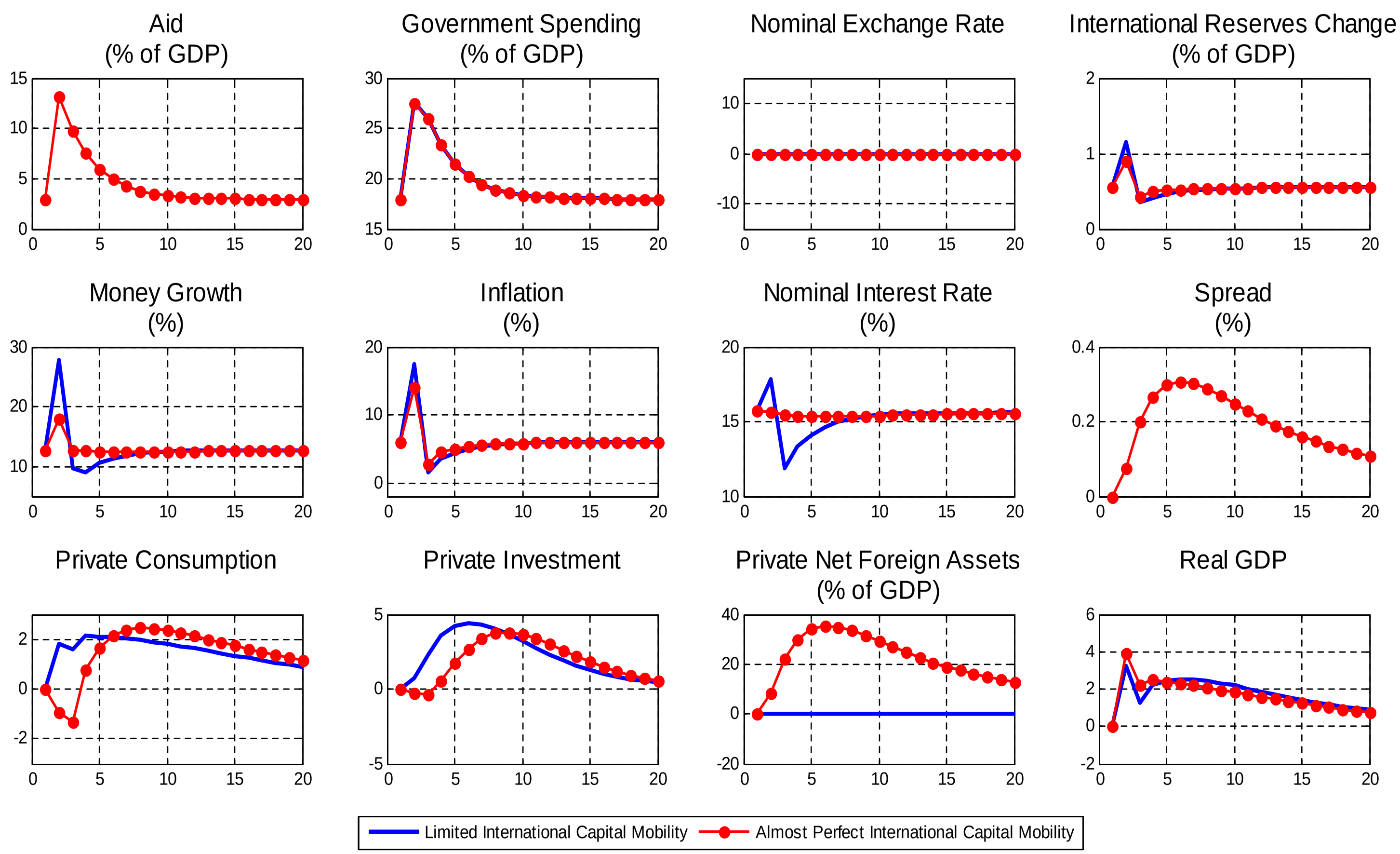

Figure 4: The role of international capital mobility in a fixed exchange rate regime without sterilization. Impulse responses are shown in annual terms and as percentage deviations from steady state, unless otherwise noted.

limited international capital mobility.

On the other hand, and as is well known, with almost perfect international capital mobility, full sterilization policies become less effective in controlling inflation under a fixed regime. With an open capital account, any attempt to raise interest rates as part of the sterilization effort would attract private sector capital inflows. This in turn would add to the foreign reserve buildup and, therefore, to the sterilization need, thereby quickly overwhelming the central bank's ability to control the money supply and inflation, while maintaining a fixed exchange rate.

E. Welfare

Our previous analysis has underscored the role of sterilization policies, in a fixed exchange rate regime, and reserve accumulation policies, in a managed (flexible) regime, in shaping the macroeconomic effects of aid surges. There are interesting trade-offs. In a fixed regime, full sterilization of the money supply expansion, resulting from accumulation of international reserves, can contain the associated inflationary pressures but at the cost of crowding out the private sector, including consumption. In a managed regime, full accumulation in reserves of the aid surge (and full sterilization) can contain real exchange rate appreciation pressures, but also at the cost of affecting negatively both private consumption and investment.

Our micro-founded model allows us to calculate the welfare associated with these different sterilization and reserve accumulation policies and use it as a selection criterion. Following Galí (2008), we define welfare in this economy as the present value of a second order approximation of the representative household's utility U_t around its steady state $\bar{U}$, and expressed it as a fraction of steady-state consumption $\bar{c}$.[17] Hence welfare corresponds to

$$\sum_{t=0}^{\infty} \beta^t \left(\frac{U_t - \bar{U}}{\bar{U}_c \bar{c}} \right),$$

where U_t is instantaneous utility in (4) and $\bar{U}_c$ corresponds to the marginal utility of consumption at the steady state.

To make the welfare analysis more exhaustive, we consider a continuum of sterilization policies that correspond to a convex combination of the two cases analyzed above—full sterilization and no sterilization. We can index these policies with the sterilization parameter $\zeta \in [0, 1]$ to describe general open-market operations as

$$b_t^{cb} - \frac{b_{t-1}^{cb}}{\mathfrak{n}\pi_t} = \zeta \left[\frac{m_{t-1}}{\mathfrak{n}\pi_t} (\mathfrak{g} - 1) - s_t \left(R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*} \right) \right] + (1 - \zeta) \left[\frac{b_{t-1}^{cb}}{\mathfrak{n}\pi_t} (\mathfrak{g} - 1) \right].$$

[17] Note that since our model is *non-stochastic*, the spirit of our analysis differs from that of the recent optimal policy analysis of the new-Keynesian literature. This literature studies optimal fiscal and monetary policies in the context of *stochastic* models in which the volatility of the shocks plays a crucial role (see for instance Schmitt-Grohé and Uribe, 2007, among others). Here we abtract from these issues that are investigated in a similar setup in Moldovan et al. (2014).

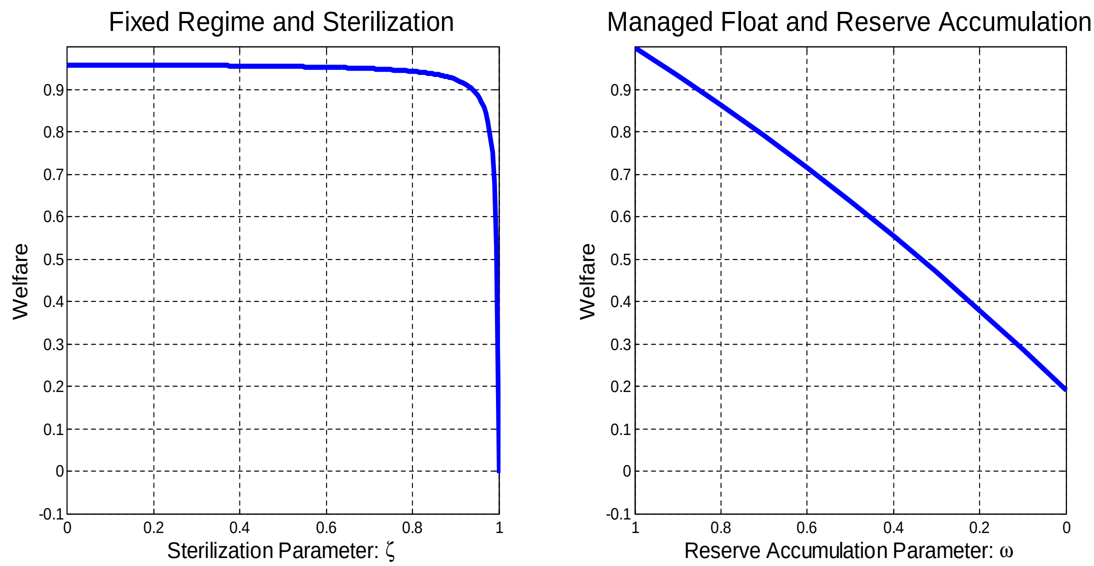

Figure 5: Welfare analysis. Welfare corresponds to the present value of a second order approximation of the representative household's utility around its steady state, expressing it as a fraction of steady-state consumption.

Then when $\zeta = 0$, we recover (51), which corresponds to the case of no sterilization. On the other hand, if $\zeta = 1$ we obtain (50) reflecting full sterilization. Similarly, under a flexible exchange rate regime, it is possible to calculate the welfare associated with a continuum of reserve accumulation policies $\omega_s \in [0, 1]$ with $\omega_s = 0$ (no reserve accumulation) and $\omega_s = 1$ (full accumulation), as the extreme cases.

The left-hand side of Figure 5 presents the results of this welfare analysis for a fixed regime for different sterilization policies. It shows that no sterilization appears to be a dominant policy: for the given calibration, the welfare associated with no sterilization ($\zeta = 0$) is much greater than that of full sterilization ($\zeta = 1$). This is not surprising, since our previous impulse response analysis revealed the significant private consumption crowding out under full sterilization. However, note that although welfare is maximized in the absence of sterilization, there seems to be a threshold for the sterilization parameter ($\zeta \approx 0.8$) beyond which welfare significantly declines. That, is beyond that threshold, sterilization policies become effective in controlling the growth rate of reserve money, but at the cost of generating much higher real interest rates and, therefore, significant reductions in private consumption, especially in the first years. Moreover, since households no longer have the aid-related money liquidity to buy foreign currency, the endogenous reserve accumulation ends up being much larger than for policies below that threshold. This further restricts the consumption for traded goods and contributes to the decline of aggregate consumption.

The right-hand side of Figure 5 shows the welfare analysis for a flexible regime for different reserve accumulation policies, which we refer to as a managed float regime.[18] Welfare is maximized under no reserve accumulation ($\omega = 1$)—i.e., the case of a *fully* flexible exchange rate regime—which clearly dominates the other policies, including full reserve accumulation ($\omega = 0$). As before, this is just a consequence of the fact that not absorbing aid (accumulating reserves) may have a negative effect on private consumption, especially in the short to medium run. In other words, with full absorption (no reserve accumulation), the positive impact of aid on consumption is maximized.

The welfare analysis also confirms the equivalence between a fixed exchange rate regime and a managed float, along the dimensions of sterilization and reserve accumulation policies. As explained above, the equivalence should be clear in the extreme cases of (i) full sterilization for a fixed and (ii) full reserve accumulation and sterilization for a float. In other words, a managed float regime should behave as a fixed regime, insofar as in these cases both regimes involve accumulating reserves and full sterilization. The main difference is that in our model the managed float regime involves accumulating aid in reserves as an exogenous policy by the central bank, while in the fixed regime it is an endogenous decision driven by a nominal exchange rate target. Perhaps more surprising is the equivalence between the a fully flexible regime and the fixed regime with no sterilization. The *real* macroeconomic effects are very similar, which explains the equivalence of the welfare results, but the transmission mechanism is different. In the flexible regime, the real appreciation associated with aid is driven by the nominal exchange rate appreciation, while in the fixed regime, it is caused by inflation.

F. Discussion

The previous results have yielded a number of insights that merit further discussion. The first insight, which is known in academic circles but is sometimes overlooked in the policy debate is that, under a peg, movements in inflation become an essential component of macroeconomic adjustment. In the case of an aid surge, allowing the aid to finance much needed imports (including to help implement welcome increases in private investment) requires an equilibrium real appreciation, and inflation is the flip side of such an outcome. In addition, in the presence of nominal rigidities, the increase in inflation is distortionary because it must be accompanied by an artificial expansion of the economy which would not have taken place if prices were fully flexible. This adds to the drama of the aid surge, because it would indicate that the economy is overheating, and that something must be done about it, while the opposite is true. More generally, the "real" nature of inflationary movements can be difficult to acknowledge by the central bank, because it runs counter to the consensus view on the role of such institutions in modern economies, which is to ensure stable inflation and keep aggregate demand pressures in check. Understanding the nature of inflation in these regimes is therefore essential to allow the aid to fulfill its role.

The second insight is that important challenges emerge when the central bank, out of concern for inflationary pressures or the potential loss of competitiveness, sterilizes any endogenous accumulation of reserves, in a fixed regime, or any exogenous accumulation of reserves, in a flexible (managed)

[18] Note that here we assume full sterilization.

regime. While it succeeds in curbing inflation or containing real appreciation pressures, it is at the sizeable real cost of a fall in private investment and private consumption. With a fixed regime, these large real effects may arise in part from the inability to recognize the increase in inflation for what it is. More generally they reflect the fact that by curbing the inflationary pressure, the central bank is effectively undoing the aid surge to the point where the aid ends parked in an account in New York or London (as part of the central bank's reserve holdings) rather than financing much needed local projects. In this case the fiscal expansion that follows the increase in aid is domestically as opposed to externally financed. This insight underscores the crucial importance of the central bank in effectively determining the impact of the aid surge.

A third and related insight is that sterilization policies in pegs have real effects that go beyond the presence of nominal rigidities. Because these policies can influence the actual accumulation of reserves, they affect real outcomes over the medium term, ranging from movements in private consumption and investment to movements in the real exchange rate. Just like for the case of movements in inflation, the real nature of sterilization in pegs is fundamentally different from the view of open market operations in closed economies or open economies with flexible exchange rates. The latter have a real effect only to the extent that nominal rigidities are present, which implies that the effects of monetary policy die out after a few quarters.[19] Whenever possible, we have stressed the term "central bank policy" as opposed to "monetary policy" to emphasize the real nature of these decisions. In our view, this "realness" adds some nuance to the concept of central bank independence, because in this particular case such independence can result in suboptimal policies.

We now discuss some important caveats. In our model simulations, it was preferable to fully absorb the aid. But there are cases where some accumulation of aid in reserves may be desirable. With managed floats, Berg et al. (2010b) show that under pessimistic assumptions—i.e., public investment is very inefficient and there are large learning-by-doing externalities in the traded sector capturing Dutch disease effects—accumulating some of the aid in reserves may be welfare enhancing.[20] Simulations under a fixed exchange rate regime but with the same pessimistic assumptions yield the same results about the desirability of reserve accumulation (not shown). A second caveat is that in our model we abstract from other policy instruments—e.g., direct price controls or export subsidies— that may also help offset inflation and real appreciation pressures, beyond sterilization and reserve accumulation policies. Furthermore from the government and central bank perspective, there are other important considerations when deciding for fully sterilizing aid surges, such as the desirability of facing dramatically higher interest rates in thin money markets while dealing with large stock of short-term domestic debt.[21] Finally, our welfare analysis has not considered the implications of macroeconomic volatility which may affect the comparison and equivalences between fixed and flexible exchange rate

[19] See Christiano, Eichenbaum and Evans (1999, 2005) for empirical evidence on, and theoretical foundations of, these assertions.

[20] Berg et al (2010b) show that much of the challenge comes from trying to spend the aid in the first place. In this case, it is better to limit the amount of spending so that government savings coincide with the accumulation of reserves. This avoids having to crowd out the private sector in order to limit the negative effect on productivity.

[21] Our model generates a significant increase in real interest rates under full sterilization. However, the increase in real interest rates would be even more dramatic if the model included hand-to-mouth consumers, which lower the aggregate interest-elasticity of the demand for bonds and can help mimic market thinness. This type of consumer is analyzed in Berg et al (2010a, 2010b), and we do not include them in this model for simplicity.

regimes.

V. Conclusions

We have shown how, under limited capital mobility, the combination of different exchange rate regimes with sterilization and reserve accumulation policies by the central bank, in response to an aid surge, actually shapes the macroeconomic effects of aid in a fundamental way. We have discussed the trade-offs and welfare consequences of these policies highlighting some similarities, in terms of real macroconomic effects, between fixed exchange rate regimes and flexible regimes (managed floats).

Results from the paper raise various questions that have not been covered here. The importance of equilibrium movements in inflation suggests that the optimal design of policy, in countries that have fixed exchange rate regimes but limited capital mobility (and thus some degree of monetary policy autonomy), may lead to a radical departure from the consensus view on optimal monetary policy that is found in the traditional new–Keynesian literature.[22] This is because the objective of stabilizing aggregate demand needs to be measured against the need for equilibrium movements in the real exchange rate. Second, downward nominal rigidities, e.g., in wages, may qualify some of our findings about the desirability of sizeable but temporary real appreciations, because such appreciations could end up threatening the sustainability of the peg. We leave these questions for future work.

Appendix

This Appendix provides a self-contained and detailed description of the model presented in the main text. In particular, it elaborates on different aspects of the model and presents the first-order conditions of the optimization problems by the households and firms, as well as the definition of the equilibrium analyzed and simulated in the paper.

A. The Model in Detail

Our framework is a simplified version of the model presented in Berg et al. (2010b). It consists of a standard two-sector model of a small open economy embellished with sticky prices, public investment inefficiencies, learning-by-doing externalities and, most importantly, policy reaction functions that determine the degree of exchange rate commitment, international reserve accumulation, and sterilization. For simplicity in the analysis and exposition, in the main text we turn off the learning-by-doing externalities and assume that public investment is fully efficient.

The country produces a non-traded good y_t^N (which is a composite good) and a traded good y_t^T using private capital k, labor l, and government-supplied infrastructure q. Households participate in

[22] See Galí (2008).

both domestic and foreign asset markets, with participation in the latter subject to portfolio adjustment costs. These costs capture the degree of international capital mobility, and their calibration allows to study a range of options, from de facto closed to a fully open capital account.

We separate policy decisions: the central bank is in charge of exchange rate and monetary policy (including international reserves accumulation and open-market operations), while the fiscal authority, which is the direct recipient of aid, decides how much of this aid to spend. All quantity variables except labor are de-trended by the labor productivity level $\mathcal{T}_t$, which grows at a constant factor $\mathfrak{n}$—the exogenous long-run gross growth rate of the economy, so that $\mathcal{T}_t = \mathfrak{n}\mathcal{T}_{t-1}$.

We assume that the law of one price holds for the traded good. Therefore $P_t^T = S_t P_t^{T*}$, where P_t^T is the price of traded goods, S_t corresponds to the nominal exchange rate, and P_t^{T*} is the foreign price of traded goods. By denoting the domestic (foreign) Consumer Price Index (CPI) as P_t (P_t^*), we can express the CPI-based real exchange rate as $s_t = \frac{S_t P_t^*}{P_t}$ and the relative price of non-traded goods as $p_t^N = \frac{P_t^N}{Pt}$. We also define real gross domestic product (GDP) as:

$$y_t = \bar{p}^N y_t^N + \bar{s} y_t^T, \tag{15}$$

i.e., the sum of the production of the non-traded good, y_t^N, and the traded good, y_t^T, valued at their steady-state relative prices $\bar{p}^N$ and $\bar{s}$.

We proceed to lay out the model in stages, starting with the specification of price-setting and production decisions.

A.1. Firms

The Non-Traded Good Sector: Firms in the non-traded sector face monopolistic competition and sticky prices. Each monopolist produces a variety i of the non-traded good. The monopolist is subject to a demand constraint of the Dixit-Stiglitz type:

$$y_{it}^N = \left(\frac{p_{it}^N}{p_t^N}\right)^{-\theta} y_t^N, \tag{16}$$

where y_t^N is the overall demand for the good and p_{it}^N is the price (relative to the CPI index) set for variety i. As in Rotemberg (1982), the monopolist faces price adjustment costs, but we also allow for indexation to past values of inflation. These costs are given by $\mathcal{G}_{it} \equiv \frac{\xi}{2}\left[\left(\frac{p_{it}^N}{p_{it-1}^N \pi_{t-1}^N}\right) - 1\right]^2 p_t^N y_t^N$, where π_t^N is the non-traded goods inflation with the steady-state value represented by $\bar{\pi}^N$.

Production is given by

$$y_{it}^N = z^N \left[\left(k_{it-1}^N\right)^{\phi} \left(q_{t-1}\right)^{1-\phi}\right]^{1-\alpha} \left(l_{it}^N\right)^{\alpha}, \tag{17}$$

where z^N is a constant productivity parameter, l_{it}^N is the amount of labor employed, k_{it-1}^N is private capital, which is firm-specific, and q_{t-1} is public capital. The coefficient α indicates the production share of labor, while ϕ denotes the share of private capital in total capital used in production. Private capital is accumulated via investment x_{it}^N as described by

$$\mathfrak{n}k_{it}^N = (1-\delta)k_{it-1}^N + \left(1-\mathcal{F}_{it}^N\right)x_{it}^N, \tag{18}$$

where x_{it}^N is a composite good, δ is the depreciation rate, and $\mathcal{F}_{it}^N \equiv \frac{\kappa}{2}\left(\frac{x_{it}^N}{x_{it-1}^N}-1\right)^2$ are adjustment costs as in Christiano et al. (2005).

The maximization problem of the monopolist corresponds to choosing the price level p_{it}^N, the amount of labor l_{it}^N, capital k_{it-1}^N, and investment x_{it}^N to maximize the discounted profits

$$\sum_{t=0}^{\infty} J_t \left\{(1-\varpi)\left[p_{it}^N y_{it}^N - \mathcal{G}_{it}\right] - w_t^N l_{it}^N - x_{it}^N + \varpi(p_t^N y_t^N - \mathcal{G}_t)\right\},$$

subject to equations (16)-(18), where the price adjustment costs $\mathcal{G}_{it}$ correspond to $\mathcal{G}_t$ when $p_{it}^N = p_t^N$.[23]

Note that there is a tax distortion ϖ that reduces the value of firms' sales net of price adjustment costs for any given level of production. This distortion is offset in the aggregate, as the amount $\varpi(p_t^N y_t^N - \mathcal{G}_t)$ is rebated to each firm, but it affects firms' incentives to hire labor and invest in new capital. The distortion is meant to capture a broad set of institutional features that keep poor countries from investing at the high rates that might otherwise be justified by the very low stocks of private capital. In this way, we match the observed low investment shares in low-income countries.

In a symmetric equilibrium (dropping the sub-indices), the first order conditions of the representative monopolist in the non-traded sector are equations (16)-(17) and:

$$\beta\left\{\frac{u_{c_{t+1}}}{u_{c_t}}\left((1-\delta)\lambda_{t+1}^N + \frac{\phi(1-\alpha)}{\alpha}w_{t+1}^N\frac{l_{t+1}^N}{k_t^N}\right)\right\} = \mathfrak{n}\lambda_t^N, \tag{19}$$

$$\frac{1}{\lambda_t^N} = 1 - \mathcal{F}^N\left(\frac{x_t^N}{x_{t-1}^N}\right) - \kappa\frac{x_t^N}{x_{t-1}^N}\left(\frac{x_t^N}{x_{t-1}^N}-1\right) + \beta\kappa\left[\frac{u_{c_{t+1}}}{u_{c_t}}\frac{\lambda_{t+1}^N}{\lambda_t^N}\left(\frac{x_{t+1}^N}{x_t^N}-1\right)\left(\frac{x_{t+1}^N}{x_t^N}\right)^2\right], \tag{20}$$

and

$$\Pi_t^N = \beta\left[\left(\frac{u_{c_{t+1}}}{u_{c_t}}\right)\left(\frac{p_{t+1}^N}{p_t^N}\right)\left(\frac{y_{t+1}^N}{y_t^N}\right)\Pi_{t+1}^N\right] + \frac{\theta-1}{\xi}\left[\frac{\theta}{(\theta-1)(1-\varpi)\alpha}\left(\frac{w_t^N l_t^N}{p_t^N y_t^N}\right)-1\right], \tag{21}$$

where β is the consumers' subjective discount factor, λ_t^N is related to Tobin's Q, and $\Pi_t^N \equiv \frac{\pi_t^N}{\pi_{t-1}^N}\left(\frac{\pi_t^N}{\pi_{t-1}^N}-1\right)$.

The Traded Good Sector: The traded sector features perfect competition and flexible prices. The representative firm i is endowed with a similar technology to that of the non-traded sector:

$$y_{it}^T = z_t^T\left[\left(k_{it-1}^T\right)^{\phi}\left(q_{t-1}\right)^{1-\phi}\right]^{1-\alpha}\left(l_{it}^T\right)^{\alpha}, \tag{22}$$

[23] The discount factor J_t of the profits is stochastic and related to the households' marginal utility of consumption, as we described below, since they own the firms.

and also accumulates capital k_{it}^T following

$$\mathfrak{n}k_{it}^T = (1-\delta)k_{it-1}^T + \left(1-\mathcal{F}_{it}^T\right)x_{it}^T, \tag{23}$$

where x_{it}^T is investment and $\mathcal{F}_{it}^T \equiv \frac{\kappa}{2}\left(\frac{x_{it}^T}{x_{it-1}^T}-1\right)^2$ are adjustment costs.

The firm picks the amount of capital k_{it}^T, labor l_{it}^T and investment x_{it}^T in order to maximize the discounted profits

$$\sum_{t=0}^{\infty} J_t\left[(1-\varpi)s_t y_{it}^T - w_t^T l_{it}^T - x_{it}^T + \varpi s_t y_t^T\right],$$

subject to equations (22) and (23). As in the non-traded sector, sales in this sector are also subject to the distortion ϖ.

The general model allows for Dutch disease effects. To capture them, we assume that the productivity in the traded sector depends on the history of the deviations of the previous sectoral outputs from the steady state, as described by

$$\frac{z_t^T}{\bar{z}^T} = \left(\frac{z_{t-1}^T}{\bar{z}^T}\right)^{\rho_z}\left(\frac{y_{t-1}^T}{\bar{y}^T}\right)^{\mathfrak{v}}, \tag{24}$$

where $\bar{z}^T$ is the steady-state value of the productivity in the traded sector, and $\rho_z \in (0,1)$ and $\mathfrak{v} > 0$. This specification is a variation of the one in Matsuyama (1992) and Krugman (1987), among others. It implies that a decline in the traded sector will impose an economic cost through lost total-factor productivity (TFP) in this sector.[24] Although there are no permanent effects of learning by doing on output or productivity, deviations of traded sector output from trend do imply persistent productivity effects.[25] For simplicity in the main text, we turn off the learning-by-doing effects by setting $\mathfrak{v} = 0$.

In a symmetric equilibrium (dropping the sub-indices), the optimizing conditions for the firm in the traded sector correspond to (22), (23), and

$$l_t^T = \left(\frac{s_t\alpha(1-\varpi)z_t^T}{w_t^T}\right)^{\frac{1}{1-\alpha}}\left(k_{t-1}^T\right)^{\phi}\left(q_{t-1}\right)^{1-\phi}, \tag{25}$$

$$\beta\left\{\frac{u_{c_{t+1}}}{u_{c_t}}\left((1-\delta)\lambda_{t+1}^T + \phi(1-\alpha)(1-\varpi)s_{t+1}\frac{y_{t+1}^T}{k_t^T}\right)\right\} = \mathfrak{n}\lambda_t^T, \tag{26}$$

and

$$\frac{1}{\lambda_t^T} = 1 - \mathcal{F}^T\left(\frac{x_{it}^T}{x_{it-1}^T}\right) - \kappa\frac{x_t^T}{x_{t-1}^T}\left(\frac{x_t^T}{x_{t-1}^T}-1\right) + \beta\kappa\left[\frac{u_{c_{t+1}}}{u_{c_t}}\frac{\lambda_{t+1}^T}{\lambda_t^T}\left(\frac{x_{t+1}^T}{x_t^T}-1\right)\left(\frac{x_{t+1}^T}{x_t^T}\right)^2\right]. \tag{27}$$

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[24] Rodrik (2008) models LBD as one of two broadly equivalent—for our purposes—reasons why real appreciation could lower productivity growth, the other being that the traded sector is intensive in public goods such as strong contracting institutions that are scarce in many low-income countries.

[25] Frequently, the real appreciation and shrinkage of the traded sector are interpreted as evidence of Dutch disease effects. However both effects may not constitute a "disease", as they are an indispensable part of the transmission mechanism to shift resources from the traded to the non-traded sector in order to meet higher government demand for non-traded goods.

A.2. Households

Consumers must decide how to allocate consumption expenditures among different goods. Consumption of the traded good and the non-traded good, denoted by c_t^T and c_t^N, respectively, are combined into a CES basket

$$c_t = \left[\varphi^{\frac{1}{\chi}}\left(c_t^N\right)^{\frac{\chi-1}{\chi}} + (1-\varphi)^{\frac{1}{\chi}}\left(c_t^T\right)^{\frac{\chi-1}{\chi}}\right]^{\frac{\chi}{\chi-1}}, \tag{28}$$

with the associated CPI $P_t = \left[\varphi\left(P_t^N\right)^{1-\chi} + (1-\varphi)(P_t^T)^{1-\chi}\right]^{\frac{1}{1-\chi}}$, where χ denotes the intratemporal elasticity of substitution, and φ is the degree of home bias in consumption.[26] This CES aggregator implies the following demand functions for traded and non-traded goods:

$$c_t^N = \varphi\left(p_t^N\right)^{-\chi} c_t \qquad \text{and} \qquad c_t^T = (1-\varphi) s_t{}^{-\chi} c_t. \tag{29}$$

The non-traded good is in turn a composite good with a continuum of varieties indexed by $i \in [0,1]$ satisfying $c_t^N = \left[\int_0^1 \left(c_{it}^N\right)^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}}$, with θ measuring the elasticity of substitution of these varieties. The demand for variety i is given by:

$$c_{it}^N = \left(\frac{p_{it}^N}{p_t^N}\right)^{-\theta} c_t^N, \tag{30}$$

where $p_{it}^N \equiv \frac{P_{it}^N}{P_t}$ and $P_t^N = \left[\int_0^1 \left(P_{it}^N\right)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$.

The representative consumer maximizes her life-time utility:

$$\sum_{t=0}^{\infty} \beta^t \left[u(c_t, m_t) - \frac{\varkappa}{1+\psi}(l_t)^{1+\psi}\right], \tag{31}$$

with

$$u(c_t, m_t) \equiv \log\left\{\left[\vartheta(c_t)^{\frac{\eta-1}{\eta}} + (1-\vartheta)(m_t)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}\right\}, \tag{32}$$

where m_t are the holdings of real money balances and l_t is the amount of labor supplied to firms. The parameter $\beta \in (0,1)$ corresponds to the subjective discount factor, $\vartheta \in (0,1)$ is the share of consumption in the utility $u(.)$, $\eta > 0$ measures the elasticity of substitution between c_t and m_t, $\varkappa$ is a scale parameter, and $\psi > 0$ is the inverse of the labor supply elasticity.

Labor mobility is limited across sectors and intersectoral wage differentials are possible. Supplied labor is defined as in Bouakez et al. (2009):

$$l_t = \left[\mathfrak{d}^{-\frac{1}{\varrho}}\left(l_t^N\right)^{\frac{1+\varrho}{\varrho}} + (1-\mathfrak{d})^{-\frac{1}{\varrho}}\left(l_t^T\right)^{\frac{1+\varrho}{\varrho}}\right]^{\frac{\varrho}{1+\varrho}}, \tag{33}$$

[26] We assume investment in both the traded and non–traded sector has the same composite structure and same shares as aggregate consumption.

where $\mathfrak{d} \in (0,1)$ is the share of labor supplied to the non-traded sector, l_t^N, in total employment, and $\varrho > 0$ is the elasticity of substitution between labor services provided to the two sectors. The index of real wages associated with the aggregator (33) corresponds to:

$$w_t = \left[\mathfrak{d}\left(w_t^N\right)^{1+\varrho} + (1-\mathfrak{d})\left(w_t^T\right)^{1+\varrho}\right]^{\frac{1}{1+\varrho}}. \tag{34}$$

The budget constraint of the representative agent, deflated by the domestic CPI and expressed in stationary terms, is given by:

$$c_t + m_t + b_t^c + s_t b_t^* + s_t \mathcal{P}_t = (1-\tau) w_t l_t + \frac{m_{t-1}}{\mathfrak{n}\pi_t} + i_{t-1}\frac{b_{t-1}^c}{\mathfrak{n}\pi_t} + s_t i_{t-1}^* \frac{b_{t-1}^*}{\mathfrak{n}\pi^*} + \Omega_t, \tag{35}$$

where b_t^c is the consumer's real holdings of domestic bonds issued by the government, which pay a gross nominal interest rate i_t and b_t^* denotes his real holdings of foreign assets that pay i_t^* and are subject to portfolio adjustment costs $\mathcal{P}_t$. Total labor income satisfies $w_t l_t = w_t^N l_t^N + w_t^T l_t^T$ with w_t^k denoting the real wage in sector $k = N, T$. Moreover, $\pi_t = \frac{P_t}{P_{t-1}}$ denotes gross domestic inflation, while π^* is foreign inflation, which is assumed to be constant; Ω_t denotes real profits from domestic firms; and τ is an income tax rate set by the government.

The portfolio adjustment costs are given by $\mathcal{P}_t \equiv \frac{\upsilon}{2}(b_t^* - \bar{b}^*)^2$, where $\bar{b}^*$ is the steady-state value of real foreign assets. These costs serve two purposes. First, they ensure stationarity of b_t^*.[27] Second, they allow us to model *limited* international capital mobility. When $\upsilon \to +\infty$, the capital account is practically closed; whereas when $0 < \upsilon << \infty$, it is partially open.

The problem of the representative consumer reduces to maximizing (31) with respect to consumption, real money balances, labor supply in both sectors, and domestic and foreign assets, subject to the constraint (35) and a transversality condition associated with all asset holdings. The first order conditions of the problem correspond to (35) and

$$u_{c_t} = \beta\left(\frac{u_{c_{t+1}} i_t}{\mathfrak{n}\pi_{t+1}}\right) \qquad \text{with} \qquad u_{c_t} \equiv \left[\vartheta\left(c_t\right)^{\frac{\eta-1}{\eta}} + (1-\vartheta)\left(m_t\right)^{\frac{\eta-1}{\eta}}\right]^{-1} \vartheta\left(c_t\right)^{-\frac{1}{\eta}}, \tag{36}$$

$$u_{m_t} = \left[\vartheta\left(c_t\right)^{\frac{\eta-1}{\eta}} + (1-\vartheta)\left(m_t\right)^{\frac{\eta-1}{\eta}}\right]^{-1}(1-\vartheta)\left(m_t\right)^{-\frac{1}{\eta}} = u_{c_t}\left(\frac{i_t - 1}{i_t}\right), \tag{37}$$

$$u_{c_t}\left[1 + \upsilon(b_t^* - \bar{b}^*)\right] = \beta\left[u_{c_{t+1}}\left(\frac{i_t^*}{\mathfrak{n}\pi^*}\right)\left(\frac{s_{t+1}}{s_t}\right)\right], \tag{38}$$

$$u_{l t} = \varkappa(l_t)^{\psi} = u_{c_t} w_t (1-\tau), \tag{39}$$

$$l_t^N = \mathfrak{d}\left(\frac{w_t^N}{w_t}\right)^{\varrho} l_t, \tag{40}$$

and

$$l_t^T = (1-\mathfrak{d})\left(\frac{w_t^T}{w_t}\right)^{\varrho} l_t. \tag{41}$$

[27] See Schmitt-Grohé and Uribe (2003) for alternative methods to ensure stationarity of net foreign assets.

A.3. The Government

Fiscal Policy: The government is the direct recipient of foreign aid A_t^*, which follows the process

$$A_t^* = \bar{A}^* + \rho_A (A_{t-1}^* - \bar{A}^*) + \epsilon_t^A, \tag{42}$$

where $\bar{A}^*$ is the steady state level of aid, ϵ_t^A corresponds to an exogenous increase in aid at time t, and $\rho_A \in (0,1)$ is the degree of persistence of the increase in aid.

Government consumption g_t is a CES basket, similar to the private agent but with different weights:

$$g_t = \left[\nu^{\frac{1}{\chi}} \left(g_t^N\right)^{\frac{\chi-1}{\chi}} + (1-\nu)^{\frac{1}{\chi}} \left(g_t^T\right)^{\frac{\chi-1}{\chi}} \right]^{\frac{\chi}{\chi-1}}, \tag{43}$$

with an associated relative price index p_t^g.

The government is subject to a period–by–period budget constraint (in real terms) of the type

$$p_t^g g_t = \tau w_t l_t + s_t A_t^* + \left(b_t - \frac{b_{t-1}}{\mathfrak{n}\pi_t} \right) - \frac{(i_{t-1}-1) b_{t-1}^c}{\mathfrak{n}\pi_t}. \tag{44}$$

The government can finance its spending $p_t^g g_t$ by taxing labor income $\tau w_t l_t$, using the domestic currency value of aid proceeds, or issuing domestic debt net of amortization. It must however pay interest on the share of government debt held by the private sector (b_t^c). We assume the stock of total government debt is constant and is held by either the private sector of the central bank (b_t^{cb}), with their relative shares varying through open market operations by the central bank.[28] So $b_t = b = b_t^c + b_t^{cb}$.

The previous budget constraint implies that spending will always adjust to satisfy the constraint (44). In addition, spending can be used for public consumption or investment purposes. For simplicity, public investment is a constant share of government spending:

$$x_t^g = \mu g_t, \tag{45}$$

with $\mu \in [0,1]$. It serves to accumulate public capital q_t following

$$\mathfrak{n} q_t = (1-\delta_g) q_{t-1} + \varepsilon x_t^g, \tag{46}$$

where δ_g is the depreciation rate of public capital, and $\varepsilon \in [0,1]$ measures the efficiency of public investment. Following Pritchett (2000), the efficiency parameter ε captures the idea that *less* than one dollar of public capital may be created for each public dollar spent on investment, because of waste and corruption, an absence of market pressures to ensure that all projects have the highest possible rate of return, or simply misclassification of current spending (e.g. salary payments to civil servants).[29] For simplicity in the analysis of the main text, we assume full efficiency, so we set $\varepsilon = 1$.

[28] Berg et al (2010) allow the government to adjust the rate at which it spends the aid, by introducing government deposits at the central bank d_t^g as an additional variable. They study the rate of spending as an additional policy decision. As our emphasis is on central bank policy, we simplify the model and focus on the case where aid is spent as it accrues.

[29] See also Agenor (2010), for the implications of inefficiencies in public investment for both demand and supply sides.

A.4. The Central Bank

We want to study the implications of different exchange rate regimes for the macroeconomic effects of aid surges. We will first consider the case of a flexible exchange rate regime and use it as a benchmark to understand the effects of having a fixed regime. Then, under a fixed regime, we will analyze the consequences of different sterilization policies.

To organize the discussion, it is helpful to start with the central bank balance sheet in first (real) differences:

$$m_t - \frac{m_{t-1}}{\mathfrak{n}\pi_t} = b_t^{cb} - \frac{b_t^{cb}}{\mathfrak{n}\pi_t} + s_t\left(R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*}\right). \tag{47}$$

That is, real changes in money supply, $m_t - \frac{m_{t-1}}{\mathfrak{n}\pi_t}$, depend on open-market operations, $b_t^{cb} - \frac{b_t^{cb}}{\mathfrak{n}\pi_t}$, and changes in international reserves, $s_t\left(R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*}\right)$. We proceed to describe how the components of this equation are determined. Note that, although the central bank accumulates reserves, the public sector does not derive any revenue from accumulating these assets. In particular, reserves do not enter the government's budget constraint directly. This reflects our assumption that reserves do not earn any interest.

Reserve Accumulation Policies: We capture different specifications of exchange regimes (flexible versus fixed) by assuming that the central bank implements the following rule for the accumulation of international reserves:

$$R_t^* - \bar{R}^* = \rho_{R^*}\left(R_{t-1}^* - \bar{R}^*\right)(1-\omega)\left(A_t^* - \bar{A}^*\right) - \omega_s(\pi_t^S - \bar{\pi}^S), \tag{48}$$

where π_t^S is the nominal depreciation of the currency, and $\bar{R}^*$ and $\bar{\pi}^S$ are the steady-state levels (targets) of reserves and nominal depreciation. The parameter $\omega_s \geq 0$ measures the degree of commitment to a nominal depreciation target. For $\omega_s = 0$, the rule replicates a flexible exchange rate regime, while for $\omega_s >> 0$, the rule captures a fixed regime. Under a flexible exchange rate regime, the central bank can still accumulate reserves in response to *changes* in the volume of aid. In this case the regime becomes a managed float. The coefficient $\omega \in [0,1]$ measures the fraction of additional aid dollars sold on the market to the private sector by the central bank, i.e., the degree of absorption of aid by the private sector. Under a fixed regime, on the other hand, reserves accumulation is driven by the central bank's commitment to hitting the targeted nominal depreciation $\bar{\pi}^S$.[30] This, of course, implies that aid absorption by the private sector, under a fixed regime, becomes endogenously determined, as we discuss below.

Monetary and Sterilization Policies: We allow for two alternative money growth rules: either full or zero sterilization. To model full sterilization, we assume that open-market operations (changes in b_t^{cb}) adjust such that nominal reserve money always grows at the rate $\mathfrak{g}$—i.e., $\frac{M_t}{M_{t-1}} = \mathfrak{g}$—implying

[30] To be precise, our fixed exchange rate regime is a crawling peg unless $\bar{\pi}^S = 1$.

that[31]

$$m_t = \mathfrak{g}\frac{m_{t-1}}{\mathfrak{n}\pi_t}. \tag{49}$$

This captures in general the fact that many low-income countries still target money, at least *de jure.* More specifically, full sterilization requires that open-market operations follow:

$$b_t^{cb} - \frac{b_{t-1}^{cb}}{\mathfrak{n}\pi_t} = \frac{m_{t-1}}{\mathfrak{n}\pi_t}(\mathfrak{g}-1) - s_t\left(R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*}\right). \tag{50}$$

Then if aid is accumulated in international reserves, either in the case of a flexible exchange rate regime or under a fixed regime, open-market operations would increase—the stock of government debt held by the central bank would decrease—in order to fully sterilize the direct monetary injection that would follow from higher aid inflows.

In the alternative specification, central bank purchases of nominal government bonds grow at constant rate $\mathfrak{g}$,:

$$b_t^{cb} - \frac{b_{t-1}^{cb}}{\mathfrak{n}\pi_t} = \frac{b_{t-1}^{cb}}{\mathfrak{n}\pi_t}(\mathfrak{g}-1). \tag{51}$$

At steady state, this process ensures that nominal money supply grows at the gross rate $\mathfrak{g}$, which pins down the steady-state level of inflation, just like in the previous specification. Outside of the steady state, however, this rule does not ensure a constant growth rate for nominal money. In this case, the money growth rate will increase when aid is accumulated as international reserves.

A.5. The Good Market Equilibrium Conditions

We focus on a symmetric equilibrium, so we can drop the sub-indices that distinguish among firms in the non-traded productive sector. Here we state explicitly the market clearing conditions for non-traded and traded goods, but bear in mind that similar equilibrium conditions hold for bonds, labor, and money, respectively.

The equilibrium in the non-traded goods market is described by:

$$y_t^N = \left(p_t^N\right)^{-\chi} D_t^N, \tag{52}$$

where $D_t^N = \varphi\left(c_t + x_t^N + x_t^T + \mathcal{G}_t\right) + \nu\left(p_t^g\right)^{\chi} g_t$; while the market-clearing condition for traded goods can be derived by combining the equilibrium condition (52) and the budget constraints for all agents, including consumers, the government, and the central bank. Then

$$A_t^* = \underbrace{c_t^T + g_t^T + x_t^{aT} + \mathcal{P}_t - y_t^T - \frac{(i_{t-1}^*-1)b_{t-1}^*}{\mathfrak{n}\pi^*}}_{\text{CAD}} + \underbrace{b_t^* - \frac{b_{t-1}^*}{\mathfrak{n}\pi^*}}_{\text{KAS}} + \underbrace{R_t^* - \frac{R_{t-1}^*}{\mathfrak{n}\pi^*}}_{\text{RA}}, \tag{53}$$

where x_t^{aT} corresponds to the traded components of the investments in the traded and non-traded sectors defined as

$$x_t^{aT} = x_t^{NT} + x_t^{TT}, \quad \text{with} \quad x_t^{NT} = (1-\varphi)(s_t)^{-\chi} x_t^N \qquad \text{and} \qquad x_t^{TT} = (1-\varphi)(s_t)^{-\chi} x_t^T. \tag{54}$$

[31] In Berg et al. (2010), we also allow for the money growth rule to depend on inflation.

Equation (53) makes clear the possible uses of aid: it can finance a higher current account deficit net of aid (CAD), a capital account surplus (KAS), or an accumulation of reserves (RA).

Finally, by the definitions of the CPI, the government price index, the nominal depreciation rate, and the inflation of non-traded goods we have

$$1 = \left[\varphi \left(p_t^N\right)^{1-\chi} + (1-\varphi)(s_t)^{1-\chi}\right]^{\frac{1}{1-\chi}}, \tag{55}$$

$$p_t^g = \left[\nu \left(p_t^N\right)^{1-\chi} + (1-\nu)(s_t)^{1-\chi}\right]^{\frac{1}{1-\chi}} \tag{56}$$

$$\pi_t^S = \frac{s_t}{s_{t-1}} \frac{\pi_t}{\pi^*}, \tag{57}$$

and

$$\pi_t^N = \frac{p_t^N}{p_{t-1}^N} \pi_t. \tag{58}$$

A.6. Definition of Equilibrium

The simulations of the paper conform with the following definition of equilibrium.

Definition 1 *Given* $\{m_{-1}, b_{-1}, b^*_{-1}, m_{-1}, k^N_{-1}, k^T_{-1}, z^T_{-1}, q_{-1}, A^*_{-1}, R^*_{-1}, b^*_{-1}, \bar{b}^*, \tau, \bar{z}^T\}$, *the external variables* $\{i^*_t, \pi^*, \bar{A}^*\}$, *the target and policies* $\{\tau, \varpi, \iota_N, \bar{\pi}, \bar{\pi}^S, \bar{b}, \bar{R}^*\}$ *and the exogenous increase in aid* $\{\epsilon^A_t\}^\infty_{t=0}$, *a symmetric equilibrium is a set of sequences* $\{c_t, c^N_t, c^T_t, l_t, l^N_t, l^T_t, m_t, b_t, b^*_t, A^*_t, g_t, g^N_t, g^T_t, q_t, x^g_t, d^g_t, b_t, R^*_t, b^{cb}_t, b^*_t, k^N_t, l^N_t, y^N_t, x^N_t, k^T_t, z^T_t, l^T_t, y^T_t, x^T_t, x^{NT}_t, x^{TT}_t, y_t, \lambda^N_t, \lambda^T_t, w^N_t, w^T_t, w_t, \pi^N_t, \pi^S_t, \pi_t, p^g_t, p^N_t, i_t, s_t\}^\infty_{t=0}$ *satisfying (i) the price indices and definitions (15), and (55)-(58); (ii) the processes (24) and (42); (iii) the optimal conditions for firms (17)-(23), (25)-(27), and (54); (iv) the optimal conditions for consumers (29), (34), and (36)-(41); (v) the government rules and constraint (43)-(46),* $b_t = \bar{b}$*; (vi) the central bank rules and constraint (47)-(50); and (vii) the aggregation and equilibrium market conditions for labor, non-traded goods (52), traded goods (53), money and assets.*

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