ISSN 1749-8279

World Economy & Finance
Research Programme
Working Paper Series

WEF 0037

Aid volatility, monetary policy rules and the capital account in African economies

Christopher Adam
University of Oxford

Stephen O'Connell
Swarthmore College

Edward Buffie
Indiana University

June 2008

World Economy & Finance Research Programme
▪ Birkbeck, University of London ▪ Malet Street ▪ London ▪ WC1E 7HX ▪

Aid volatility, monetary policy rules and the capital account in African economies*

Christopher Adam**
University of Oxford, UK.

Stephen O'Connell
Swarthmore College, USA.

Edward Buffie
Indiana University, USA

June 2008

Abstract

We examine the properties of simple quantity-based monetary policy rules of the kind widely used in low-income African economies. Using a DSGE model and focusing our attention on responses to positive aid shocks, we suggest that policy rules involving substantial reserve accumulation in the face of aid surges serve to ease macroeconomic adjustment to shocks, particularly when a portion of aid is used to support fiscal adjustment. These rules are robust to assumptions about the degree of integration of the domestic public debt market with world capital markets. Although an open capital account facilitates smoother adjustment to temporary aid surges when an aid inflow is fully spent, it exacerbates the adjustment problem when aid is accompanied by fiscal adjustment and hence reinforces the case for a managed float in such circumstances.

Keywords: Monetary policy, Africa, Aid volatility, foreign capital flows, stochastic simulation models.

Email: christopher.adam@economics.ox.ac.uk

* An abridged version of this paper appears in Gill Hammond, Ravi Kanbur and Eswar Prasad (eds) *New Monetary Policy Frameworks for Emerging Markets: Coping with the Challenges of Financial Globalization* (Edward Elgar and Bank of England, 2008)

** Christopher Adam acknowledges the support of Economic and Social Research Council (ESRC) World Economy and Finance Programme (RES-156-25-0001 *Managing Macroeconomic Risks in Developing Countries: Policies and Institutions*).

1. Introduction

The conduct of monetary policy in Africa has undergone significant changes in the last decade. Shifts in the macroeconomic orthodoxy in favour of tighter fiscal control and the emergence of low and stable inflation as a central policy objective of governments across the continent have been reinforced by greater institutional independence of central banks and a shift away from administrative controls in the foreign exchange and financial markets. Together, these have afforded central banks a degree of protection against excessive fiscal pressures and provided them with the instruments with which to pursue their inflation targets. The removal of exchange controls has reduced exchange rate policy to choices regarding the degree of flexibility of a unified exchange rate, while the shift away from interest-rate controls and directed credit has facilitated a move from direct to indirect instruments for controlling overall liquidity, albeit in the context of relatively thin and oligopolistic asset markets.

These institutional changes have occurred against a changing macroeconomic environment across the continent. Throughout the early years of this century many African central bankers have been confronted by the challenge of managing rapidly rising primary export prices which, for those countries that have implemented successful adjustment programmes, have often been accompanied by surges in official aid flows. At the same time, and in response to these same developments, strong foreign capital inflows have become a feature of the landscape. These inflows have consisted mainly of medium-term FDI flows to natural resource sectors but a significant proportion represents short-run portfolio investments in local-currency public debt instruments. In Zambia, for example, foreign investors currently hold around 20% of the stock of domestic government bonds (IMF, 2007a) while in December 2006 over 80 percent of the Government of Ghana 5-year domestic currency bond was taken up by foreign investors (IMF, 2007b). Similar developments are occurring elsewhere across the continent.

With these factors generating substantial upward pressure on nominal and real exchange rates, and given concerns about the possible consequences for external competitiveness, central bankers have been increasingly drawn into attempts to prevent the appreciation of the real exchange rate which, in turn, raises questions about the degree to which intervention should be sterilized and hence the trade-off between exchange rate and interest rate volatility.[1] Central bankers across the continent are actively seeking feasible monetary rules that provide guidance on how to navigate these concerns about the exchange rate without yielding on hard-won inflation gains. In particular, they are

[1] A second concern is that volatile external flows, particularly aid flows, threaten fiscal destabilization as aid inflows induce difficult-to-reverse public spending commitments, raising the risk that the fiscal authorities will fall back on deficit financing when aid inflows recede. (See Buffie *et al*, 2008).

attempting to determine how aggressively they should seek to manage the path of the nominal exchange rate, if at all; whether there is a role for reserves to smooth the spending response to aid inflows; and whether aid-related liquidity growth should be sterilized through bond sales.

By the end of 2007 only two African countries had sought to resolve these issues by committing themselves to fully-fledged inflation targeting. South Africa adopted inflation targeting in 2000 and in May 2007 the Bank of Ghana followed suit by announcing the creation of a similar framework.[2] Elsewhere, however, although many countries are actively considering moves in the same direction, the vast majority maintain what Stone (2003) has labeled 'inflation targeting lite' regimes, typically utilizing a money-based anchor for inflation.

The distinctions between full-fledged and 'lite' regimes are important. The hallmarks of strict inflation targeting are a public commitment to inflation as a nominal anchor, in preference to the exchange rate or some monetary aggregate, and an explicit prioritization of inflation over competing objectives of central bank policy, including output and exchange rate stability. By contrast, 'inflation targeting lite' regimes typically announce an inflation target but may retain exchange rate stability and financial stability among their objectives, often reconciled through an IMF-supported financial programming framework (see Porter and Yao, 2005).

Operationally, countries that practice strict inflation targeting almost uniformly employ a short-term interest rate as the primary policy instrument. For this approach to be effective there must be a reliable transmission mechanism from short-term interest rates to expected inflation. Interest rates do not play as central a role in theories of the transmission mechanism in most African economies, consistent perhaps with the rudimentary nature of the financial sector. Instead monetary equilibrium plays the key role and remains at the core of most programs of monetary management in sub-Saharan Africa. For a given value of expected inflation, the path of velocity is assumed to be fixed, rather than dependent on a nominal interest rate, so that the path of the price level is then determined endogenously, to equalize the policy-determined path of the nominal money supply with the path of real money demand.

Although the choice of operational target often differs sharply between inflation-targeting central banks and those based more loosely on financial programming, it does not constitute an important analytical difference. First of all, unavailability of a policy interest rate does not rule out the setting of available policy instruments to target expected

[2] In May 2007, the Bank of Ghana announced a formal target of 7%-8% per annum for a core inflation target which excludes energy and utility prices.

inflation to whatever desired degree of transparency and exclusion of other objectives. Second, even when a policy interest rate is available, the transmission from monetary aggregates to aggregate demand may well be more reliable. Finally, even where a policy interest rate does afford reasonably sensitive control over aggregate demand, a given path for that rate can in principle be accomplished either directly, by controlling the interest rate, or indirectly, by controlling the supply of central bank balances.

The more fundamental difference between these regimes has to do with their choice of nominal anchor and the degree to which they prioritize price stability over other objectives of monetary policy. It is these differences which shape the research programme discussed in this paper. This research -- discussed in Buffie *et al* (2004), O'Connell *et al* (2007) and Adam *et al* (2008) – is fundamentally concerned with integrating these institutional characteristics of African economies into coherent macroeconomic models with the ultimate objective of building a bridge between the policy frameworks currently in use in most of sub-Saharan Africa and the inflation-targeting frameworks that form the analytical core of monetary policy among emerging-market and industrial countries.

This work is ongoing and to date we have framed the policy question rather narrowly in terms of the conduct of monetary policy in the face of volatile but persistent positive shocks to net aid inflows, such as experienced by a number of countries in sub-Saharan Africa since the turn of the century. Although it readily extends to the analysis of other shocks and sources of volatility including in particular commodity price shocks, we retain the narrow focus on aid shocks in this paper.[3]

Our analysis to date suggests that efficient management of aid inflows requires a degree of foreign exchange intervention, particularly in circumstances where aid is used partly to substitute for domestic deficit financing and where domestic prices are sticky in a downwards direction. However, these results are derived for an environment where countries' whose integration with global capital markets is rudimentary. Even though many African countries have formally removed controls on capital account transactions, access to global capital markets has tended to run predominantly through official aid channels and processes of dollarization and currency substitution. One consequence of this is that domestic real interest rates can deviate substantially from world interest-parity conditions for extended periods of time.

[3] The short-run management of aid surges has become a central policy issue amongst donors and the international financial institutions, particularly when set against the background of commitments on the part of some donors to scale up aid flows to some of the world's lowest-income countries. As a result the question of efficient macroeconomic management of aid surges has been the subject of much recent work by IMF staff including, Gupta *et al* (2006), Prati and Tressel (2006), Berg *et al*(2007) and Peiris and Saxegaard (2007).

We discuss these core results in some detail in this paper. However, as we have noted above, *de jure* capital account openness has become *de facto* openness as foreign investors have responded to the compression of risk margins by seeking out ever more exotic markets including the most under-developed African markets. To reflect these recent developments, we modify our basic closed capital account model to allow for capital market integration, albeit limited by considerations of sovereign risk. We show that although an open capital account facilitates smoother adjustment to temporary aid surges when an aid inflow is fully spent, volatility is magnified and the adjustment problems identified in our earlier work are likely to be exacerbated when aid inflows are accompanied by fiscal adjustment. Given this, the case for a managed float in such circumstances is strengthened. The central policy implications in Adam *et al* (2008) appear robust.

The remainder of the paper is organized as follows. In Section 2 we briefly set the scene and discuss the basic structure of the model. Section 3 then turns directly to the simulations and a discussion of the results. We start with a recapitulation of the principal results reported in Adam *et al* (2008) before turning to the main new contribution of this paper which is to examine the robustness of our earlier results to the emergence of significant foreign participation in domestic public debt markets. Section 4 concludes.

2. The Model

2.1 Some background considerations

We develop a dynamic, stochastic general-equilibrium model (DSGE) whose design is inspired by the structure of low-income African countries, the shocks that preoccupy African central bankers, and the institutional environments they operate within. As a result, the model stands in contrast to the contemporary literature on monetary policy in emerging-market economies. In particular, reflecting the nature of the transmission mechanism, there is no policy interest rate in our model. Instead, central banks deploy balance sheet instruments – foreign exchange reserves, base money and bonds.

In this respect, our model shares more with the earlier literature on monetary management in industrial countries (for example, Branson and Henderson 1985) than with contemporary approaches. However, as Woodford (2003) shows, there exists an isomorphism between a now-conventional AS-IS-IR model (where IR denotes the interest rate rule) and the earlier AS-IS-LM style of model.[4] Thus the choice of model is

[4] This is achieved by including the first-order condition for money (i.e. the money demand equation), which adds one equation and one variable (money) to the model.

a matter of taste but typically will turn on a practical matter of institutions (i.e. whether a policy interest rate exists) and, for example, whether velocity is particularly volatile, so that the link from money to inflation is less reliable than the link from the policy rate to inflation.

This simple equivalence is easily derived for a closed economy. To move to an open economy, an equation for exchange rate determination can be added, possibly by assuming UIP as per Svensson (2003) or imperfect asset substitution (as per Ball, 1999 or Cespedes *et al,* 2003). These extensions typically entail adding a single equation but *two* new variables, the exchange rate and reserves. Overwhelmingly, however, the developed country literature conveniently sidesteps the more subtle issue of the added policy instrument, reserves, by assuming that the authorities pursue a pure float (which implies the change in the instrument, reserves, is zero throughout).

While this may be an appropriate simplification for full-fledged inflation targeting – even though many would argue that virtually every countries engages in some intervention, if only for 'technical reasons'– it is patently not a good approximation of reality in developing countries in general (see for example Edwards, 2007), and for those of sub-Saharan Africa in particular where the authorities often reach for exchange rate intervention as the first instrument of choice. It is for this reason we include in our model explicit rules for foreign exchange intervention, which represent our first main point of departure from the literature.

A second and related point is that in our model fiscal policy is not innocuous. With only very recent exceptions (e.g., Benigno and Woodford, 2007), analytical treatments of inflation targeting tend to assume non-distortionary transfers, so that seigniorage requirements do not complicate the management of monetary policy. In our model, by contrast, the management of seigniorage through the interaction of fiscal policy plays directly on the private sector's portfolio behaviour which in turn shapes the dynamic adjustment to aid (and other) external shocks.

2.2 Model specification

This model and its calibration are described in Appendix I and discussed in more detail in Adam *et al* (2008). Central to the model is a characterization of households' portfolio choices and the financing options facing government which reflects the 'imperfectly open' capital account structures pervasive in much of Sub-Saharan Africa. Formally, we work with a simple optimizing two-sector dependent economy model with currency substitution in which both domestic and foreign currencies delivery liquidity services. The representative private agent consumes traded imports and non-traded final goods and accumulates financial wealth in the form of three assets: domestic currency, foreign currency and government bonds.[5] There are no banks in the model, so that money is base money and foreign currency balances are held in non-interest-bearing forms.

The private agent can accumulate or decumulate foreign currency either via transactions with the central bank or through the current account, depending on the exchange rate regime. The private sector's relative demand for domestic and foreign currencies depends on the liquidity services delivered by the assets and on their opportunity costs relative to bonds, i_t and $i_t - {}_t x_{t+1}$ respectively, where i_t denotes the domestic nominal interest rate and ${}_t x_{t+1}$ the expected rate of nominal depreciation. The sensitivity of relative currency demand to these opportunity costs depends on both the elasticity of currency substitution and the elasticity of intertemporal substitution in consumption (see Appendix equations A10 and A11). The higher the degree of substitutability between currencies, for a given value of the inter-temporal elasticity of substitution, the larger the desired portfolio reallocation and therefore the greater the pressures on the nominal exchange rate in response to shocks. A higher value of the inter-temporal elasticity of substitution, other things equal, tends to produce greater volatility in consumption and the current account and less volatility in the real interest rate. The settings adopted in this paper correspond to mid-range values from the limited empirical evidence on these parameters. When combined with initial steady state values of inflation and the nominal interest rates, they imply a steady state inflation elasticity of the demand for money of around 0.5 (see Table A1a).[6]

In Adam *et al* (2008) we assume that, aside from the currency substitution channel, neither the private nor public sector has direct access to world capital markets. Hence domestic government debt is effectively non-tradable and domestic interest rates are not tied down by interest parity conditions. In this paper we nest this as a special case in a more general model which allows for the possibility of foreign portfolio investment in African domestic bond markets (although we continue to assume that the government does not issue foreign currency debt instruments). We therefore assume the economy faces an upward-sloping foreign supply of funds schedule whose elasticity is determined by the premium over uncovered interest parity demanded by foreign investors to compensate for sovereign risk. The foreign investor is assumed to hold a home bond whose real yield, denominated in units of the tradable good, is given by $R_t^* = (1 + r_t^*)$.

---

[5] In the current version of the model these are treated as index-linked. This is consistent with environments where debt maturities are extremely short and the stock is turned over rapidly. In many African economies the longest maturities actively traded were 91 day bills. We have, however, also simulated the model under the assumption that government issues nominal bonds. This alters the behaviour of the model but does not change the fundamental characteristics of our results.

[6] The sensitivity of our central results to variations in these elasticities is discussed in Adam *et al* (2008) and O'Connell *et al* (2007).

This yield is assumed independent of developments in the local economy. The foreign supply of funds is defined implicitly by the condition

$$R_t = R_t^* \left(\frac{e_{t+1}}{e_t} \right)^{-\gamma} \phi \left(\frac{p_t b_t^f}{y_t} \right). \tag{1}$$

where e_{t+1} denotes the expected real exchange rate, γ the non-tradable share in the CPI, and $p_t b_t^f / y_t$ the value of domestic debt, in units of GDP, held by foreign investors. The term $\phi(p_t b_t^f / y_t)$ corresponds to the risk premium so that ϕ determines the slope of the supply schedule. As $\phi \to \infty$ the schedule becomes vertical and the model converges on the 'closed' capital account used in Adam *et al* (2008). At the other extreme, as $\phi \to 0$ the supply schedule becomes horizontal at the UIP interest rate, corresponding to the case of perfect asset substitutability.

The supply side of the model is simple, reflecting our short run focus. The economy produces exported and non-tradable goods using sector-specific capital, an intermediate import (oil) and labour, which is intersectorally mobile. The aggregate capital stock is fixed and there is no investment. Non-traded goods prices are sticky so that the output of non-traded goods is demand-determined in the short run. In this case, macroeconomic adjustment can then take place off the production frontier, via booms or recessions in the non-traded goods sector.

The model is completed by defining a stochastic process for the external shocks. In this case we limit the sources of external volatility to stochastic shocks in the net aid inflow.[7] The aid shock, which follows a stationary AR(1) process around a steady-state mean value, is scaled to an equivalent of 2 percent of GDP and is characterized by an autoregressive parameter of 0.50.

Policy Rules

We now turn to the macroeconomic policy choices of interest in the analysis of aid shocks. On the fiscal side, our focus is on the financing implications of fiscal policy, and in particular on the consequences of deficit reduction or delayed expenditure out of aid. Given the focus of the paper, we assume a high degree of fiscal flexibility which provides for a credible imposition of solvency on a continuing basis.

[7] This simple one-shock structure is nested within a higher dimension structure in which we allow for the stochastic determination of commodity export prices, non-tradable output (via rainfall volatility) and intermediate input prices ('oil shocks'). Given the specific focus on managing aid shocks we suppress these other sources of volatility in this paper.

Tax rates are held constant throughout so that aid shocks constitute the only source of revenue volatility. Fiscal behaviour is then governed by the level of spending out of aid.[8] Specifically, a portion δ of aid may be devoted to *deficit reduction*. Hence for a given aid surge, denoted $(a_t - \overline{a})$, where $\overline{a}$ denotes the steady-state level of aid, an amount $\delta(a_t - \overline{a})$ is used to substitute for domestic deficit financing and $(1-\delta)(a_t - \overline{a})$ is spent: in the simulations reported below, we assume $\delta = 0$ or $\delta = 0.25$.

Variations in government revenues arising from aid inflows are transferred directly to household by means of variation in transfers, net of changes in the cost of providing a fixed volume of non-tradable government expenditure arising from changes in the real exchange rate. It is possible, however to allow for aid surges to be met by changes in the volume of either tradable or non-tradable government expenditure. We explore this option in O'Connell *et al* (2007).

The instruments of monetary policy are transactions in foreign exchange and government securities with the private sector.[9] To characterize reserve management, we begin with the simplest reaction function that accommodates alternative degrees of commitment to a fixed rate of crawl: $\Delta z_t = -\alpha_1 (x_t - \overline{x}),$ for $\alpha_1 \geq 0$.To this we add a fixed long-run reserve target $\overline{z},$ in order to preserve the stationary structure of the analysis; and – possibly – a time-varying reserve target that is tied to the pattern of fiscal spending out of aid. Reserve policy is therefore given by

$$\frac{\Delta z_t}{\overline{z}} = -\alpha_1 \frac{x_t - \overline{x}}{\overline{x}} - \alpha_2 \frac{z_{t-1} - \overline{z}}{\overline{z}} + \alpha_3 \frac{(a_t - \overline{a}) - \gamma \cdot (d_t - \overline{d})}{\overline{z}} \qquad (2)$$

where $(d_t - \overline{d})$ denotes the deviation of government spending net of taxes from its steady state level, $\alpha_1 \geq 0,\ \alpha_2 > 0,\ \alpha_3 \in \{0,1\},$ and $0 \leq \gamma \leq 1$. Here $\overline{x}$ is the steady-state rate of depreciation, which is tied down by the long-run inflation rate, $\overline{z}$ is the steady-state level of reserves, and $\overline{d}$ the steady-state level of net expenditure. The parameter α_1 governs the degree of commitment to the steady-state rate of crawl. As $\alpha_1 \to \infty$ the regime approaches a predetermined *crawl* in which $x_t = \overline{x}$ on a continuous basis. Lower values of α_1 represent looser commitments to the reference rate of crawl, and for $\alpha_1 = 0$ the exchange rate floats: central bank intervention, if any, is independent of movements in

[8] In principal, given this planned level of spending out of aid, the fiscal authorities may choose also to smooth the path of spending relative to that of the aid inflow. Smoothing rules are discussed in Adam *et al* (2008).

[9] With no banking system in model, there is no role for reserve requirements or deposit placement policies in the central bank's toolkit.

the nominal exchange rate.[10] In the floating case, all foreign exchange available to the economy is immediately priced in a competitive foreign exchange market and either added to private foreign currency holdings or absorbed through an increased current account deficit.

We refer to the combination of $\alpha_1 = 0$ and $\alpha_3 = 0$ as a *pure float*. The final term in (2), however, allows the central bank to tie foreign exchange sales directly to the path of aid-induced government spending. A policy of $\alpha_1 = 0$, $\alpha_3 = 1$ and $\gamma = 1$ corresponds to what we call a *buffer plus float*. This approach is simple and intuitive: the central bank sells aid dollars in the precise amount required to finance aid-induced spending as it occurs, but floats with respect to all other shocks.[11] In a *buffer plus float*, any aid that is not spent in the current period is retained as reserves. Of course, if $\delta = \mu = 0$ so that aid is always spent immediately, there is no operational difference between a *buffer plus float* and a *pure float*. In the presence of deficit-reduction or expenditure-smoothing components, however, a *buffer plus float* involves a period of potentially substantial reserve accumulation during an aid boom.

Foreign exchange operations are unwound over time, at a rate determined by α_2. Since private foreign currency holdings return to a steady-state level over time, the long-run reserve target implies that aid is ultimately fully absorbed in current account deficits, regardless of the time pattern of aid-induced public spending and the other parameters of the monetary policy reaction functions. In the simulations reported below, we assume a relatively slow rate of adjustment, setting $\alpha_2 = 0.05$ throughout.

The instruments of monetary policy are completed by the rules governing bond operations. A conventional bond reaction function would define bond operations to offset the net impact of domestic credit creation or foreign exchange intervention on the monetary base. In the context of managing liquidity in the face of aid shocks, however, policy discussions often centre on a ‘burden sharing’ approach to managing the liquidity generated out of aid-induced spending. To reflect this, we gear bond operations directly and solely to spending out of aid and actual foreign exchange intervention (rather than to reserve accumulation) to define a bond reaction function of the form

---

[10] Equation (2) can be adapted to accommodate a real rather than a nominal exchange rate target by replacing the exchange rate term $(x_t - \overline{x})$ with $(e_t - \overline{e})$, where *e* denotes the real exchange rate. We do not examine this option here, although this case is examined in some detail in Adam *et al* (2008).

[11] Note that the import component of aid-induced spending (zero in our runs) is self-sterilizing. It generates no increase in the monetary base because government deposits decline (and net domestic credit rises) as reserves decline.

$$p_t \Delta b_t = \beta_1 (1-\gamma)(d_t - \overline{d}) - \beta_2 (b_{t-1} - \overline{b}). \qquad (3)$$

In this rule, $\beta_2 > 0$ allows for a gradual return of bond holdings to a long-run level.[12] It is useful to consider (2) and (3) together. In a *pure float* or *buffer plus float*, where $\gamma = 1$ in the reserve equation (2), the liquidity effect of aid-induced spending is fully offset through the sale of aid dollars. At the other extreme, with $\gamma = 0$ and $\alpha_3 = \beta_1 = 1$, the authorities retain the aid inflow as reserves and sterilize the full aid-spending induced liquidity injection through open market operations. Between these two polar extremes, the same liquidity injection could be absorbed through any combination of foreign exchange and bond sales. For example, in a case we examine below, Berg *et al* (2007) advocate a '50-50' approach that allocates half of the task of liquidity management to foreign exchange sales and half to bond sales. In terms of the reaction functions, this entails $\alpha_3 = 1$ and $\gamma = 0.50$.

3. Results

We start by briefly recapitulating the central results from our earlier work (Adam *et al,* 2008) in which we focus on the properties of three monetary policy rules under different assumptions about the fiscal response to aid inflows and where government bonds are held exclusively by domestic residents. The first two rules are the polar cases of a *pure float* (i.e. a money anchor) and an *exchange rate crawl.* In the former case, official foreign exchange reserves are held constant and the growth of the money supply is determined exclusively by the actions of the fiscal authorities. In the latter, the monetary authorities target the nominal exchange rate at the steady-state rate of depreciation, with changes in the money supply arising from intervention potentially being sterilized through bond purchases or sales.[13] The third case, the *reserve buffer plus float,* entails initially accumulating aid inflows as official foreign exchange reserves and then sterilizing the full domestic currency counterpart of aid-financed non-import spending through foreign exchange sales as it occurs. This rule thus sets a time-varying reserve target corresponding to the unspent component of aid, and allows the exchange rate to float freely once this reserve target is satisfied.

In section 3.1 we examine the properties of these rules in circumstances where, initially, the aid inflow is spent as it is received. We then examine their performance when a portion of the aid inflow is used to substitute for domestic deficit financing. In Section

[12] Ensuring that bonds held by the private sector return to their steady-state level means in turn that interest payments and the fiscal deficit are unchanged in the long run. This is required by consistency with the long-run inflation target.

[13] The steady state rate of crawl is determined by the steady-state rate of inflation required to satisfy the government budget constraint.

3.2 we re-examine these rules in the presence of an open capital account. Finally, in Section 3.3, we explore the characteristics of 'burden sharing' rules that seek to allocate responsibility for liquidity sterilization between foreign exchange intervention and bond sterilization, under both closed and open capital accounts. Throughout this analysis we eschew any formal welfare comparison, preferring at this stage to focus on the positive characteristics of the rules.

3.1. Aid shocks with a closed capital account

Table 1 reports the simulated impulse response functions (IRFs) of the key behavioural variables of the model in response to a positive aid shock equivalent to 2% of GDP (around a steady state mean value of 10% of GDP). The final column reports the theoretical standard deviations of the endogenous variables given the stochastic aid process.[14]

When the fiscal authorities spend all the aid inflow as it is received, domestic financing is fully and continuously insulated. In this case, full spending implies there is no distinction between a *pure float* and a *buffer plus float*. Both, however, entail a different path for the nominal exchange rate and aggregate prices compared to the *crawl*, at least in the short run. The aid inflow induces a mild real exchange rate appreciation consistent with a pro-cyclical spending boom but while an initial inflationary spike is required under the crawl, the initial adjustment is mildly deflationary under a float as the nominal exchange rate appreciates. In neither case, however, are the effects large; macroeconomic adjustment is largely benign. While the crawl delivers marginally less volatility for both inflation and the real exchange rate, and marginally more current account volatility, the differences between these polar approaches to exchange rate policy are second-order, at least for the parameters of the policy rules considered here.

These similarities disappear when aid is used to provide an element of fiscal stabilization. When aid substitutes for seigniorage the monetary authorities are confronted with the explicit challenge of how to manage a first-order alteration to the path of domestic financing. Now, the *buffer plus float* rule is no longer equivalent to a pure float. The *pure float* implies that the contraction in the fiscal deficit after net budgetary aid is fully met by a contraction in the government's seigniorage requirement for a given stock of domestic debt. As shown in Table 2 (Panel 1), the consequences are dramatic: the nominal exchange rate appreciates by more than 13% on impact (compared to an appreciation of around 2% in the corresponding no-deficit reduction case reported in Table 1), and the real rate appreciates by 8% (again compared to 3%). These powerful price effects induce a contraction in non-tradable output of 0.4% on impact compared to

[14] The simulations are generated by the Dynare-Matlab routines (Julliard, 1996) using a first-order Taylor approximation to the non-linear model around the non-stochastic steady state.

an *increase* of around the same size in Table 1. The reason for this outturn is that the reduction in expected inflation as a result of the fiscal adjustment shifts the private sector's asset portfolio decisively in favour of domestic money: given the contraction in the supply of money and the fact that the authorities are not intervening in the foreign exchange market, this requires the nominal exchange rate to overshoot in the short run to restore portfolio equilibrium. Since the nominal appreciation is much larger than the real appreciation required to absorb the aid inflow, non-tradable prices must fall sharply entailing a sharp recession in the non-tradable goods sector if prices are sticky.

Against this counterfactual, strategies that align the absorption of aid more closely to spending and hence smooth the path for seigniorage can substantially close off this source of macroeconomic volatility. Both the *crawl* (Panel 2) and a *buffer plus float* (Panel 3) do rather well in these circumstances. In both cases, but particularly under the crawl, the disruptive volatility in inflation and the real exchange rate are greatly reduced. The sharp deflationary impact under the pure float is substantially eliminated, with prices falling by 3.5% under the *buffer plus float* and virtually not at all under the *crawl,* compared to a 9% fall under the *pure float.* By the same token, the initial real exchange rate appreciation is pegged back to around 1.9% under the *crawl* and 4% under the *buffer plus float* compared to 8% under a *pure float* and the strong recessionary pressures on non-traded output are completely avoided.

These latter rules entail substantial reserve accumulation, and although the patterns of accumulation are broadly similar under either rule, as indeed are the real outcomes, the two approaches are not the same. Moreover, the superior performance of the crawl observed here is reinforced if the model is re-calibrated to reflect a pre-stabilization situation in which inflation is initially higher and the fiscal authorities are more likely to direct a proportion of aid towards deficit reduction: in such a setting an aggressive crawl is significantly more effective than the *buffer plus float* strategy.

The reason the *crawl* contributes to a much smoother adjustment path is that it aligns movements in the nominal exchange rate much more closely to the modest real exchange rate adjustment required to absorb the aid inflow, while the (unsterilized) liquidity injection arising from reserve accumulation forestalls the contraction in the domestic money supply observed under the float. Instead, the increased demand for liquidity as a result of the decline in the seigniorage requirement is accommodated without requiring a sharp price adjustment so that the economy responds to the aid inflow with virtually stable prices. Domestic output is hardly affected, and total private spending follows a smoother path. While the *buffer plus float* strategy goes some way to delivering this same outcome it does so less efficiently since it involves reserve accumulation with respect to the unspent portion of aid only – thereby serving to efficiently match the *supply* of domestic money – but does not fully accommodate changes in the *demand* for domestic money arising from the fall in expected inflation. In the simulations reported in Table 2, for example, the *buffer plus float* entails rather more up-front intervention than the *crawl* but rather less over the remainder of the simulation. As the inflation elasticity of the demand for money rises, this distinction becomes more marked and the *buffer plus float* does less well in aligning the demand and supply of domestic liquidity compared to the float.

3.3 Aid shocks with an open capital account

These simulations suggest that when deficit-reduction considerations are important, active foreign exchange intervention with little or no sterilization of increases in the monetary base serves to accommodate changed in the increased demand for money associated with declining inflation and delivers a more attractive way of smoothing macroeconomic volatility than relying on a pure float. These results assume, however, that domestic asset markets are fully insulated from the rest of the world. In the next section we consider whether these results remain pertinent as the capital account is liberalized *de facto.*

Tables 3 and 4 illustrate the impact of incorporating foreign participation in the domestic public debt market. Drawing on the recent experience of countries such as Zambia and Ghana we assume that foreign investors hold 15 percent of debt in the initial steady state (equivalent to 1% of GDP). We allow for a modest elasticity with respect to the country risk premium by setting $\phi = 0.15$. There are, to the best of our knowledge, no reliable estimates of this parameter, but preliminary sensitivity analysis with our model suggest that the qualitative characteristics of our results are monotonic in ϕ.

In the case where all aid is spent as it is received, integration with world capital markets via foreign bond holders allows for smoother aggregate adjustment to the aid shock than was previously the case. The results are sufficiently similar under a *float / buffer plus float* and the *crawl* in this case that it suffices to report only the results for the *pure float.* Relative to the closed capital account case, adjustment entails significantly more muted movements in domestic nominal and relative prices, while the short run boom in aggregate consumption and non-traded output is substantially eliminated. These smoother paths for consumption and production are facilitated by larger current account adjustments. With an open capital account, the private sector's consumption is less pro-cyclical as it can now smooth more efficiently over the temporary aid flow by indirectly accumulating net foreign assets via the bond market.[15] In the limiting case shown in panel 2 of Table 3, where we allow $\phi \to 0$, so that the economy's financial terms of trade

[15] In terms of the model, and given that total bonds are fixed in supply, the private sector accumulates claims on government which in turn amortizes an equivalent volume of bonds held by the foreign investor.

are invariant to the shock, the economy follows a textbook adjustment to a temporary income shock (recalling that the data-generating process for the aid shock is known to the private sector). The real interest rate does not move and consumption adjusts rapidly *and permanently* to the annuity value of the increase to aggregate wealth represented by the temporary aid shock.[16]

The results in Table 3 give the impression that greater capital account openness creates an important additional degree of freedom for efficient adjustment to external shocks and that this necessarily smooths the adjustment path for the economy. As the results in Table 4 suggest, however, this is false when some fraction of the aid inflow is used for deficit reduction purposes: if anything, the open capital account raises the stakes. In this case the open capital account exacerbates the adjustment problem under the *float* and accentuates the wedge between the *float* on the one hand and the *crawl* and *buffer plus crawl* on the other. This is seen most clearly if we focus on the costs of the real exchange rate appreciation for the non-traded sector. Previously, the limited capacity of the private sector to acquire foreign assets ensured that aggregate consumption was quite strongly pro-cyclical, and this in turn limited the contractionary effects of real exchange rate appreciation on the non-traded sector. With a more open capital account, however, the private sector is better placed to smooth aggregate consumption with the result that aggregate demand effects provide less support to the non-traded sector, exposing it to a much sharper contraction than before.

By contrast, the properties of the *crawl* and *buffer plus float* strategies, in which reserve accumulation serves to avoid nominal and real exchange rate overshooting, change relatively little when we allow for foreign participation in domestic debt markets. As such, the relative benefits from pursing these strategies over the *pure float*, in terms of facilitating a smooth macroeconomic adjustment to deficit-reducing aid shocks, are further enhanced in the presence of a more open capital account. The central insights from our earlier work are preserved and even reinforced when the capital account is open n open capital account: when aid is used to substitute for seigniorage the incipient portfolio adjustment by the private sector in response to changes in expected inflation will dominate macroeconomic dynamics and ensure that efficient adjustment to temporary aid surges entails a fairly heavy degree of unsterilized foreign exchange intervention, either under an explicit exchange rate crawl or through the operation of a *buffer plus float* rule. This result is not surprising. The fundamental factor underpinning the volatility observed when the domestic government debt market is closed is the domestic private sector's incipient portfolio adjustment, between domestic and foreign

[16] The one-period aid shock is equivalent to 2% of GDP and has an autoregressive parameter of 0.5 implying a present value the aid shock is equivalent to 4% of GDP which implies an annuity value of 0.3636 percent of GDP at the steady-state real interest rate of 10%.

currency. Opening the domestic debt market serves to anchor the real return on debt, which may have important implications for interest sensitive expenditure in the public and private sectors, but given that bonds do not generate liquidity services (or, in an alternative set-up, satisfy cash in advance constraints) the open capital account by itself does not eliminate the domestic agent's portfolio problem.

3.3. Burden-sharing and bond sterilization

The discussion so far has focused on monetary policy from the perspective of alternative degrees of commitment to a floating exchange rate. In doing so, we have seen how the *crawl* and *buffer plus float* each end up allocating 100 percent of the burden of liquidity control to foreign exchange sales. Macroeconomic adjustment is smooth, suggesting that there is no obvious case for shifting any of the burden to bond operations. In practice, however, central banks in Africa often feel compelled to adhere to strict monetary targets and match intervention with active bond sterilization. This is particularly so in the context of the IMF-supported financial programmes, most of which are predicated on the assumption of a constant velocity of circulation over the short to medium term. Table 5 illustrates the case where the domestic currency value of aid spending is exactly matched by sales of foreign exchange and government securities in the share $[\gamma, 1-\gamma]$. In the case of 'full bond sterilization', $\gamma = 0$ and for the '50:50' rule $\gamma = 0.5$.

In either case, these sterilization rules are decisively dominated by the *buffer plus float* and *crawl* which rely on foreign exchange sales alone to manage domestic liquidity growth for aid-funded spending. Panels 1 and 2 of Table 5 illustrate the case in which aid is fully spent – so that seigniorage requirements are stationary. In this case, bond sterilization, whether partial or full, merely imparts a substantial dose of conventional 'unpleasant arithmetic', with higher domestic debt service costs contributing to persistent domestic inflation over the horizon and a steady depreciation in the nominal exchange rate. Moreover, as the memorandum items to Table 5 indicate, the real interest rate (*RIR*) and the budget deficit (*def*) under *bond sterilization* are both substantially higher than under the comparable *buffer plus float* run reported in Table 1.

Opening the capital account does little to alter this picture. As the comparison of Panels 2 and 3 indicates, the adjustment path for the economy is virtually unchanged beyond the change in the composition of debt holdings arising from the sterilization rule. The path for the real interest rate is pegged slightly tighter to the foreign bond rate (adjusted for the expected real exchange rate appreciation), debt service costs are consequently marginally lower across the response horizon and the paths for inflation and the real exchange rate very slightly smoother. But overall, these differences are nugatory. Moreover, the results do not change substantially as the elasticity of the foreign bond supply increases: even with a perfectly open capital account the same outcomes prevail for this particular shock and response. The reason is that the sterilization rule in operation here -- where the bond issue is conditioned directly and exclusively on the fiscal response to the aid shock – is invariant to the evolution of the intermediate target such as reserve money or indeed to the evolution of inflation. As such, the chosen volume of sterilization is independent of capital market conditions so that the fiscal burden of sterilization varies only in terms of the variations in the real interest rate which, as noted changes relatively little with changes in the elasticity of foreign bond supply. Indeed, as the results presented in Table 5 show, this particular rule does not do a particularly good job in controlling inflation. To fully understand the consequences of capital account liberalization on the properties of sterilization rules, including the implications for the offset between bond sterilization and the path of reserves, requires an examination of a wider range of settings for the intervention and bond reaction functions, a task beyond the scope of this paper.

4. Conclusions and next steps

We argued at the beginning of this paper that central bankers in Africa face substantial problems in managing aid surges. In practice, many appear to have adopted strategies involving substantial intervention and reserve accumulation in response to aid surges, accompanied in many cases by fairly aggressive bond sterilization. Our simulations suggest that when currency substitution is active, this pattern is consistent with an efficient monetary policy response to an aid surge, and particularly so when a portion of the aid will be used for inflation stabilization. Conditional on these portfolio effects, however, there is essentially no role for bond sterilization during an aid surge, at least when the capital account is closed. Moreover, we find that the relative properties of the alternative rules are robust to relaxing the assumption that the domestic bond market is entirely closed to external influences. We show that while foreign participation in the domestic bond market allows for more efficient adjustment when aid flows are fully spent, this does not carry over to the case in which aid alters the trajectory for domestic deficit financing. In the latter case, foreign bondholders exacerbate the short-run tradeoffs facing the monetary authority and strengthen the appeal of temporary reserve accumulation.

Monetary policy has a complex mandate in Sub-Saharan Africa, where conventional objectives of macroeconomic stability coexist with an interest in facilitating the development of financial markets. While we have emphasized the appeal of temporary reserve accumulation in the face of an aid surge, there is a sharp divergence between how this is accomplished under a crawl and a buffer plus float. In a crawl, the monetary authority targets the exchange rate, while in a buffer plus float intervention coincides with aid-financed spending in a version of reserve-money targeting. The two approaches have widely divergent implications for how the exchange rate responds to other shocks, and therefore for the patterns of volatility facing portfolio holders (and their assumptions regarding the nominal anchor). Our current DSGE treats the parameters of portfolio behavior as exogenous to these variations in monetary policy behavior. We are therefore ignoring any impact of alternative rules on the trajectory of financial market development. This is an important area for further work.

Table 1: Impulse Response Functions to Stochastic Aid Shock

All aid is spent as received

Closed Capital Account

Aid Shock (% GDP)

Variable	**0**	**1**	**2**	**3**	**4**	**5**	**15**	**Stdev**
a	2.000	1.000	0.500	0.250	0.125	0.063	0.000	2.320
Panel 1: Pure Float [= buffer plus float]								
NER	-2.217	-1.092	-0.800	-0.484	-0.285	-0.168	-0.001	2.698
RER	2.941	3.346	2.985	2.351	1.730	1.222	0.019	6.598
I	-0.659	-2.804	-2.388	-1.670	-1.117	-0.736	-0.010	4.500
RIR	-1.680	-1.172	-0.685	-0.389	-0.222	-0.128	-0.001	2.246
IN	-0.599	-0.869	-0.999	-0.833	-0.626	-0.448	-0.007	1.980
ca	0.770	0.088	-0.128	-0.172	-0.155	-0.122	-0.002	0.817
C	1.725	1.076	0.623	0.359	0.208	0.123	0.001	2.202
DN	0.550	0.182	-0.005	-0.070	-0.080	-0.068	-0.001	0.587
Panel 2: Crawl								
NER	0.203	-0.169	-0.179	-0.134	-0.093	-0.065	-0.022	0.447
RER	1.989	2.574	2.391	1.932	1.448	1.036	0.020	5.134
I	1.427	-1.476	-1.544	-1.212	-0.866	-0.597	-0.032	3.093
RIR	-1.494	-1.123	-0.715	-0.429	-0.251	-0.146	-0.001	2.110
IN	1.297	0.152	-0.280	-0.386	-0.359	-0.291	-0.027	1.492
ca	0.880	0.142	-0.102	-0.156	-0.143	-0.113	-0.003	0.914
C	1.690	1.112	0.678	0.402	0.236	0.139	0.002	2.226
DN	0.634	0.283	0.085	-0.004	-0.036	-0.040	-0.001	0.696

Notes:
See Appendix Tables A1 and A1b for description of variables.
An increase in NER represents a depreciation; an increase in RER an appreciation.

Table 2: Impulse Response Functions to Stochastic Aid Shock

25% of aid inflow devoted to domestic deficit reduction

Closed Capital Account

Aid Shock (% GDP)

Variable	0	1	2	3	4	5	15	Stdev
a	2.000	1.000	0.500	0.250	0.125	0.063	0.000	2.320
Panel 1: Pure Float.								
NER	-13.352	-1.304	-1.001	-0.602	-0.348	-0.201	-0.002	13.253
RER	7.747	5.750	4.246	3.029	2.101	1.428	0.020	11.656
I	-10.000	-2.941	-2.675	-1.865	-1.235	-0.806	-0.010	11.097
RIR	-0.271	-0.604	-0.424	-0.264	-0.161	-0.099	-0.001	0.879
IN	-9.091	-2.402	-1.828	-1.271	-0.858	-0.571	-0.008	9.731
ca	0.837	0.085	-0.142	-0.186	-0.166	-0.130	-0.002	0.885
C	0.768	0.663	0.430	0.266	0.164	0.101	0.001	1.180
DN	-0.439	-0.279	-0.236	-0.189	-0.141	-0.101	-0.002	0.654
dZ	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Panel 2: Crawl								
NER	-0.862	-0.541	-0.368	-0.253	-0.184	-0.145	-0.093	1.592
RER	1.889	2.269	2.035	1.612	1.195	0.851	0.029	4.457
I	0.194	-1.702	-1.465	-1.102	-0.793	-0.566	-0.108	3.056
RIR	-1.216	-0.835	-0.517	-0.307	-0.180	-0.106	-0.001	1.636
IN	0.176	-0.331	-0.497	-0.485	-0.414	-0.335	-0.097	1.523
ca	1.113	0.334	0.034	-0.066	-0.085	-0.077	-0.005	1.155
C	1.285	0.816	0.493	0.293	0.175	0.105	0.004	1.666
DN	0.442	0.167	0.030	-0.025	-0.040	-0.038	-0.001	0.472
dZ	0.470	0.271	0.164	0.093	0.051	0.027	-0.003	0.587
Panel 3: Buffer plus float								
NER	-5.687	-1.574	-1.513	-1.264	-1.074	-0.943	-0.487	6.907
RER	3.951	3.560	2.961	2.289	1.695	1.229	0.120	7.220
I	-3.865	-3.141	-3.025	-2.403	-1.890	-1.520	-0.547	7.664
R	-1.066	-0.907	-0.551	-0.317	-0.183	-0.106	-0.002	1.585
IN	-3.514	-1.790	-1.843	-1.633	-1.400	-1.200	-0.495	5.845
ca	0.919	0.183	-0.067	-0.136	-0.137	-0.116	-0.015	0.957
C	1.279	0.867	0.517	0.304	0.181	0.111	0.007	1.701
DN	0.220	0.055	-0.056	-0.091	-0.089	-0.075	-0.009	0.290
dZ	0.500	0.225	0.089	0.022	-0.011	-0.026	-0.026	0.572

Notes:
See Table 1.

Table 3: Impulse Response Functions to Stochastic Aid Shock

All aid spent as received

Open Capital Account

Aid Shock (% GDP)

Variable	**0**	**1**	**2**	**3**	**4**	**5**	**15**	**Stdev**
a	2.000	1.000	0.500	0.250	0.125	0.063	0.000	2.320

Panel 1: Pure Float
[Imperfect Capital Mobility phi=0.15]

NER	-1.329	-0.124	-0.085	-0.060	-0.045	-0.036	-0.009	1.320
RER	1.959	2.277	2.297	2.178	2.002	1.810	0.550	6.607
I	-0.277	-0.338	-0.372	-0.363	-0.337	-0.306	-0.093	1.077
RIR	-0.358	-0.264	-0.204	-0.165	-0.137	-0.117	-0.033	0.612
IN	-0.252	0.051	-0.074	-0.126	-0.142	-0.141	-0.048	0.486
ca	1.365	0.528	0.125	-0.060	-0.139	-0.166	-0.065	1.528
C	0.812	0.674	0.572	0.494	0.430	0.377	0.110	1.668
DN	0.198	0.096	0.042	0.016	0.003	-0.003	-0.003	0.226
bp	1.140	1.581	1.684	1.632	1.516	1.377	0.421	4.842
bf	-1.140	-1.581	-1.684	-1.632	-1.516	-1.377	-0.421	4.842
dz	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Panel 2: Pure Float
[Perfect Capital Mobility phi=0.001]

NER	-1.060	-0.044	-0.009	0.005	0.010	0.013	0.014	1.056
RER	1.258	1.425	1.492	1.518	1.527	1.529	1.502	19.888
I	-0.405	-0.050	-0.013	0.002	0.008	0.010	0.012	0.431
R	-0.094	-0.039	-0.017	-0.008	-0.004	-0.003	-0.002	0.105
IN	-0.368	0.048	0.027	0.019	0.015	0.014	0.012	0.397
ca	1.665	0.830	0.411	0.202	0.098	0.045	-0.006	1.931
C	0.389	0.353	0.337	0.331	0.328	0.326	0.319	4.236
DN	0.061	0.025	0.010	0.004	0.002	0.001	0.000	0.067
bp	1.595	2.397	2.797	2.995	3.091	3.136	3.123	41.242
bf	-1.595	-2.397	-2.797	-2.995	-3.091	-3.136	-3.123	41.242
dz	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: See Table 1.

Table 4: Impulse Response Functions to Stochastic Aid Shock

25% of aid inflow devoted to domestic deficit reduction

Open Capital Account

Aid Shock (% GDP)

Variable	0	1	2	3	4	5	15	Stdev
a	2.000	1.000	0.500	0.250	0.125	0.063	0.000	2.320

Panel 1: Pure Float
[Imperfect Capital Mobility phi=0.15]

NER	-12.469	-0.409	-0.241	-0.145	-0.091	-0.060	-0.009	12.211
RER	6.735	4.674	3.527	2.828	2.360	2.018	0.561	10.946
I	-9.641	-0.653	-0.557	-0.472	-0.404	-0.349	-0.097	9.567
RIR	0.949	0.366	0.100	-0.019	-0.068	-0.085	-0.034	1.040
IN	-8.765	-1.542	-0.872	-0.529	-0.348	-0.248	-0.050	8.876
ca	1.436	0.534	0.122	-0.068	-0.148	-0.175	-0.067	1.597
C	-0.149	0.217	0.358	0.396	0.389	0.363	0.112	1.138
DN	-0.789	-0.388	-0.195	-0.102	-0.056	-0.033	-0.004	0.914
bp	1.118	1.608	1.726	1.675	1.555	1.411	0.423	4.932
bf	-1.118	-1.608	-1.726	-1.675	-1.555	-1.411	-0.423	4.932
dz	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Panel 2: Crawl
[Imperfect Capital Mobility phi=0.15]

NER	-1.101	-0.425	-0.253	-0.169	-0.128	-0.107	-0.084	1.576
RER	1.436	1.794	1.819	1.712	1.560	1.400	0.421	5.112
I	-0.342	-0.632	-0.497	-0.416	-0.363	-0.324	-0.156	1.718
RIR	-0.347	-0.213	-0.150	-0.118	-0.099	-0.086	-0.025	0.512
IN	-0.311	-0.228	-0.239	-0.228	-0.212	-0.195	-0.114	1.234
ca	1.509	0.642	0.213	0.011	-0.079	-0.114	-0.052	1.679
C	0.643	0.509	0.427	0.369	0.323	0.285	0.085	1.273
DN	0.169	0.064	0.020	0.003	-0.004	-0.006	-0.002	0.181
bp	0.908	1.204	1.268	1.224	1.134	1.028	0.308	3.636
bf	-0.908	-1.204	-1.268	-1.224	-1.134	-1.028	-0.308	3.636
dz	0.601	0.202	0.098	0.047	0.022	0.010	-0.003	0.643

Panel 3: Buffer plus float
[Imperfect Capital Mobility phi=0.15]

NER	-4.901	-0.727	-0.865	-0.888	-0.867	-0.832	-0.493	5.817
RER	3.084	2.622	2.352	2.135	1.935	1.746	0.582	7.123
I	-3.526	-0.982	-1.205	-1.245	-1.213	-1.155	-0.619	5.550
R	0.089	-0.082	-0.125	-0.126	-0.114	-0.101	-0.029	0.337
IN	-3.205	-0.981	-1.013	-1.007	-0.977	-0.936	-0.530	4.831
ca	1.444	0.568	0.153	-0.041	-0.125	-0.156	-0.069	1.613
C	0.473	0.508	0.476	0.428	0.379	0.335	0.102	1.320
DN	-0.091	-0.024	-0.012	-0.013	-0.016	-0.018	-0.011	0.114
bp	1.003	1.397	1.481	1.429	1.322	1.199	0.373	4.241
bf	-1.003	-1.397	-1.481	-1.429	-1.322	-1.199	-0.373	4.241
dz	0.500	0.225	0.089	0.022	-0.011	-0.026	-0.026	0.572

Notes: See Table 1.

Table 5: Impulse Response Functions to Stochastic Aid Shock

Float with Partial Bond sterilization

	Aid Shock (% GDP)							
Variable	**0**	**1**	**2**	**3**	**4**	**5**	**15**	**Stdev**
a	2.000	1.000	0.500	0.250	0.125	0.063	0.000	2.320

Panel 1: All aid spent as received

Full Bond Sterilization: closed capital account

NER	31.481	6.441	7.633	7.413	7.017	6.628	3.906	40.698
RER	-12.953	-7.205	-4.336	-2.520	-1.316	-0.525	0.649	16.227
I	26.792	9.351	10.741	9.771	8.749	7.925	4.244	41.208
RIR	-1.102	0.554	0.471	0.274	0.141	0.062	-0.034	1.320
IN	24.357	9.603	9.211	8.412	7.679	7.063	3.893	37.447
ca	3.128	1.812	0.920	0.397	0.098	-0.070	-0.210	3.926
C	0.201	-0.224	-0.010	0.171	0.277	0.332	0.269	1.472
DN	1.477	0.653	0.455	0.353	0.278	0.222	0.066	1.820
db	2.000	0.900	0.355	0.087	-0.042	-0.103	-0.103	2.288
db	2.000	0.900	0.355	0.087	-0.042	-0.103	-0.103	2.288
dbf	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dz	2.000	0.900	0.355	0.087	-0.042	-0.103	-0.103	2.288
def	2.054	1.714	1.182	0.823	0.603	0.467	0.170	3.350

Panel 2: All aid spent as received

50:50 bond and foreign exchange sterilization: closed capital account

NER	14.632	2.674	3.417	3.464	3.366	3.230	1.952	19.230
RER	-5.006	-1.929	-0.676	-0.084	0.207	0.349	0.334	5.670
I	13.067	3.274	4.177	4.051	3.816	3.594	2.117	19.207
RIR	-1.391	-0.309	-0.107	-0.058	-0.040	-0.033	-0.017	1.417
IN	11.879	4.367	4.106	3.789	3.526	3.308	1.943	17.973
ca	1.949	0.950	0.396	0.112	-0.028	-0.096	-0.106	2.279
C	0.963	0.426	0.306	0.265	0.243	0.227	0.135	1.381
DN	1.014	0.418	0.225	0.141	0.099	0.077	0.032	1.151
db	1.000	0.450	0.178	0.044	-0.021	-0.051	-0.051	1.144
dbp	1.000	0.450	0.178	0.044	-0.021	-0.051	-0.051	1.144
dbf	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dz	1.000	0.450	0.178	0.044	-0.021	-0.051	-0.051	1.144
def	2.021	1.208	0.707	0.434	0.290	0.213	0.084	2.591

Panel 3: All aid spent as received

50:50 bond and foreign exchange sterilization: imperfectly open capital account

NER	14.428	2.467	3.181	3.363	3.336	3.227	1.957	18.988
RER	-4.825	-1.763	-0.570	-0.095	0.103	0.194	0.322	5.427
I	12.952	2.755	3.557	3.753	3.711	3.580	2.139	18.871
R	-1.647	-0.603	-0.213	-0.071	-0.022	-0.007	-0.011	1.757
IN	11.774	4.151	3.837	3.624	3.445	3.277	1.955	17.749
ca	1.831	0.880	0.374	0.123	-0.002	-0.063	-0.097	2.135
C	1.150	0.514	0.281	0.199	0.172	0.163	0.134	1.483
DN	1.087	0.444	0.201	0.110	0.075	0.061	0.033	1.211
db	1.000	0.450	0.178	0.044	-0.021	-0.051	0.001	1.144
bp	0.774	0.387	0.210	0.105	0.039	-0.001	-0.001	6.321
bf	0.226	0.097	-0.032	-0.062	-0.060	-0.051	0.002	0.802
dz	1.000	0.450	0.178	0.044	-0.021	-0.051	-0.051	1.144
def	2.237	1.087	0.528	0.255	0.120	0.053	-0.016	2.571

Memo: Impulse Response and std. dev for real interest rate deficit under pure float

RIR	-1.680	-1.172	-0.685	-0.389	-0.222	-0.128	-0.001	2.246
def	1.855	0.836	0.353	0.134	0.040	0.002	-0.001	2.067

Notes:
See Table 1.

Appendix I: The baseline simulation model

This appendix outlines the basic structure of the core simulation model. The full set of calibration parameters is reported in Table A1a and the variables to be tracked in the simulations in Table A1b.

A1. Household preferences

The representative household maximizes an expected utility function of the form

$$\mathbf{E}_t \sum_{s=t}^{\infty} \beta^{s-t} \left(\frac{C_s^{1-\tau^{-1}}}{1-\tau^{-1}} + \frac{h L_s^{1-\tau^{-1}}}{1-\tau^{-1}} \right) \tag{A1}$$

where τ is the inter-temporal elasticity of substitution; $\beta \equiv (1+\rho)^{-1}$ the discount factor $\mathbf{E}$ the expectations operator. C and L are CES functions of the underlying goods and currencies:

$$C_t \equiv \left(k_N C_{Nt}^{\frac{\alpha-1}{\alpha}} + k_I c_{It}^{\frac{\alpha-1}{\alpha}} \right)^{\frac{\alpha}{\alpha-1}} \tag{A2}$$

$$L_t \equiv \left\{ k_M \left(\frac{M_t}{P_t} \right)^{\frac{\sigma-1}{\sigma}} + k_F \left(\frac{E_t f_t}{P_t} \right)^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}} \tag{A3}$$

and h is a scaling parameter calibrated by the data.

Household budget constraint

Nominal household financial wealth, W, acquired in period t is given by

$$W_t = M_t + P_t b_t^P + E_t f_t \tag{A4}$$

where M and f denote end-of-period stocks of domestic and foreign currency balances, E the nominal exchange rate and P is an exact consumption-based price index.[17]. Domestic debt, represented by CPI-indexed bonds, is defined

$$b_t = b_t^p + b_t^f \tag{A5}$$

---

[17] Given the CES structure for the consumption aggregate, $P_t = \left(k_N^{\alpha} P_{Nt}^{1-\alpha} + k_I^{\alpha} P_{It}^{1-\alpha} \right)^{\frac{1}{1-\alpha}}$.

where b_t^P is held by the domestic household and b_t^f by the foreign investor. Nominal financial wealth of the domestic agent is represented via the overall budget constraint by

$$W_t = M_{t-1} + R_{t-1} P_t b_{t-1}^p + E_t f_{t-1} + Y_t - TR_t - P_t C_t \tag{A6}$$

where Y_t denotes income from production, $P_t C_t = (P_{Nt} C_{Nt} + P_{It} c_{It})$ is nominal consumption expenditure and TR_t taxes net of transfers. The real interest rate is pre-determined so that $R_{t-1} = 1 + r_{t-1}$ is the real interest factor applicable to bonds carried over from period *t*–1.

The model is analysed in terms of the imported good. PPP holds for traded goods. By normalizing the foreign price of importables to 1, and lower-case letters denote stocks or flows measured in terms of imported goods. Define $\Pi_t = 1 + \pi_t = P_t / P_{t-1}$ and $X_t = 1 + x_t = E_t / E_{t-1}$ as the inflation and exchange rate factors, $e_t \equiv P_{Nt} / E_t$ as the real exchange rate, the real return on bonds in terms of importables as $R_{It} = 1 + r_{It} = R_{t-1} \Pi_t / X_t$, and $p_t \equiv \dfrac{P_t}{E_t} = \left(k_N^\alpha e_t^{1-\alpha} + k_I^\alpha\right)^{\frac{1}{1-\alpha}}$.

Dividing (A6) by the nominal exchange rate E_t we obtain

$$w_t = m_t + p_t b_t^P + f_t = X_t^{-1} m_{t-1} + R_{It} p_{t-1} b_{t-1}^P + f_{t-1} + y_t - tr_t - p_t C_t \tag{A7}$$

which can be re-written as

$$\Delta w_t = r_{It} w_{t-1} - \frac{i_t}{1 + x_t} m_{t-1} - \frac{i_t - x_t}{1 + x_t} f_{t-1} + y_t - tr_t - p_t C_t. \tag{A8}$$

First Order Conditions

The first order conditions consist of, along with the standard transversality condition, the consumption Euler equation

$$C_t^{-\tau^{-1}} = \beta E_t \left[\frac{R_{I,t+1} p_t}{p_{t+1}} C_{t+1}^{-\tau^{-1}} \right] = \beta R_t E_t C_{t+1}^{-\tau^{-1}} \tag{A9}$$

and the domestic and foreign currency demand conditions

$$\left(\frac{m_t}{p_t}\right)^{-\frac{1}{\sigma}} = \left(\frac{1}{hk_M}\right) L_t^{\left(\frac{\sigma-\tau}{\sigma\tau}\right)} \beta E_t \left[\frac{i_{t+1}}{1+\pi_{t+1}} C_{t+1}^{-\tau^{-1}}\right] \tag{A10}$$

and

$$\left(\frac{f_t}{p_t}\right)^{-\frac{1}{\sigma}} = \left(\frac{1}{hk_F}\right) L_t^{\left(\frac{\sigma-\tau}{\sigma\tau}\right)} \beta E_t \left[\frac{i_{t+1} - x_{t+1}}{1+\pi_{t+1}} C_{t+1}^{-\tau^{-1}}\right]. \tag{A11}$$

A2. Aggregate supply

For fixed capital endowments, aggregate domestic output is

$$\bar{Q} = \left[\delta Q_N^{(1+\eta)/\eta} + (1-\delta) Q_X^{(1+\eta)/\eta}\right]^{\eta/(1+\eta)} \tag{A12}$$

where η is the long-run elasticity of transformation between tradable and non-tradable output. Full-employment GDP is given as:

$$y = e\left(1 - \omega_N\left(\frac{p^O}{e}\right)\right) Q_N + p_X\left(1 - \omega_X\left(\frac{p^O}{p_X}\right)\right) Q_X \tag{A13}$$

where p^X denotes the (stochastic) world price of tradables, p^O denotes the world oil price (where oil is the only intermediate input in production) and ω_N and ω_X are input-output coefficients for the non-tradable and tradable sectors respectively.

Non-tradable prices

Prices of tradables are fully flexible. By contrast, Calvo-pricing prevails in the non-tradable goods market. The price level chosen by adjusting firms in period *t* satisfies

$$\log P_{Nt}^A = [1-(1-\lambda)\Gamma] \log P_{Nt}^* + (1-\lambda)\Gamma E_t \log P_{N,t+1}^A \tag{A14}$$

where $\log P_{N,t+k}^*$ is the target (log) price in *t+k,* and Γ the discount factor. Since a proportion λ of (the large number of) firms ends up changing prices in period *t*, the aggregate price level for non-traded goods satisfies

$$\log P_{Nt} = \lambda \log P_{Nt}^A + (1-\lambda) \log P_{N,t-1} \tag{A15}$$

Optimal price for non-traded goods is a function of the aggregate price level and the gap between the output of non-traded goods and their supply at full employment.

$$\log P_{Nt}^{*} = \log P_{Nt} + \zeta \cdot \left[\frac{C_{Nt}(e, C_t) + G_{Nt} - \varphi_{Nt} Q_N(e_{Xt})}{\varphi_{Nt} Q_N(e_{Xt})} \right]. \qquad \text{(A16)}$$

These three equations yield the sector-specific Phillips Curve

$$\log P_{Nt} - \log P_{N,t-1} = \Gamma E_t[\log P_{N,t+1} - \log P_{Nt}] + \psi \cdot \left[\frac{C_{Nt}(e_t, C_t) + G_{Nt} - \varphi_{Nt} Q_N(e_{Xt})}{\varphi_{Nt} Q_N(e_{Xt})} \right] \qquad \text{(A17)}$$

where $\psi \equiv \frac{\zeta\lambda}{1-\lambda}[1-(1-\lambda)\Gamma] > 0$. High values of ψ imply greater price flexibility, and as $\psi \to \infty$ equation (A17) approaches the flexible-price market-clearing condition in the non-traded goods market, $\varphi_{Nt} Q_N(e_{Xt}) = C_{Nt}(e_t, C_t) + G_{Nt}$. To ensure that the Natural Rate Hypothesis holds, we impose $\Gamma = 1$.

A3. The public sector

The central bank's balance sheet, in nominal terms is given as:

$$\Delta M_t = E_t \Delta z_t + P_t \Delta b_t^C \qquad \text{(A18)}$$

Assuming the central bank transfers its operating surplus to government (i.e. interest on govt securities are remitted to government)

$$P_t(\Delta b_t^P + \Delta b_t^f + \Delta b_t^C) = P_{Nt} G_{Nt} + E_t g_{It} + P_t r_{t-1}(b_{t-1}^P + b_{t-1}^f) - TR_t - E_t a_t \qquad \text{(A19)}$$

where G_{Nt} and g_{It} denote quantities of government consumption of non-tradables and tradables, respectively, and *a* denotes net aid inflows, measured in the world price of imports. The consolidated public sector budget constraint in terms of importables becomes

$$\Delta m_t + p_t(\Delta b_t^p + \Delta b_t^f) - \Delta z_t = d_t - a_t - \frac{x_t}{1+x_t} m_{t-1} \qquad \text{(A20)}$$

where, letting $g_t = e_t G_{Nt} + g_{It}$, $d_t \equiv g_t - t_t + p_t r_{t-1}(b_{t-1}^p + b_{t-1}^f)$ is the fiscal deficit before aid. Public sector behaviour is described in section A5.

A4. Balance of payments

The foreign investor's bond supply is defined implicitly by the arbitrage condition

$$R_t = R_t^* \left(\frac{e_{t+1}}{e_t}\right)^{-\gamma} \phi\left(\frac{p_t b_t^f}{y_t}\right) \qquad \text{(A21)}$$

where the parameter $\phi > 0$ denotes the slope of the foreign bond supply schedule. Combined with the household sector's flow budget constraint this yields the current account identity:

$$\Delta f_t + \Delta z_t - p_t \Delta b_t^f = y_t - g_t - p_t C_t - p_t r_{t-1} b_{t-1}^f + a_t \qquad \text{(A22)}$$

A5. External Shocks and policy rules

External shocks are assumed to follow a first-order VAR of the form

$$v_t = \alpha_1 v_{t-1} + \varepsilon_{vt}, \qquad E_t \varepsilon_{vt} \varepsilon'_{vt} = \sigma_a^2. \qquad \text{(A23)}$$

In the current version the vector v consists only of aid (see main text).

Fiscal policy is controlled according to

$$d_t - \overline{d} = (1-\delta)(a_t - \overline{a}) \qquad \text{(A24)}$$

where δ denotes the portion of the aid inflow devoted to deficit reduction

Monetary policy is defined in terms of simple linear rules for reserve intervention and bond sterilization.

Reserve management and intervention

Intervention options are defined by

$$\frac{\Delta z_t}{\overline{z}} = -\alpha_1 \frac{x_t - \overline{x}}{\overline{x}} - \alpha_2 \frac{z_{t-1} - \overline{z}}{\overline{z}} + \alpha_3 \frac{(a_t - \overline{a}) - \gamma \cdot (d_t - \overline{d})}{\overline{z}} \qquad \text{(A25)}$$

where $\alpha_1 \geq 0$, $\alpha_2 > 0$, $\alpha_3 \in \{0,1\}$, and $0 \leq \gamma \leq 1$. Here $\overline{x}$ is the steady-state rate of depreciation, which is tied down by the long-run inflation rate, and $\overline{z}$ is the steady-state level of reserves (see text for discussion).

Bond operations are directly linked to the domestic liquidity expansion produced by aid.

$$p_t \Delta b_t = \beta_1 (1-\gamma)(d_t - \overline{d}) - \beta_2 (b_{t-1} - \overline{b}). \qquad \text{(A26)}$$

Table A1a. *Calibration values*

Parameter	*calibration values*
Intertemporal elasticity, τ	0.50
Currency substitution elasticity, σ	2.00
Elasticity of production substitution, *nu*	0.10
Foreign currency holdings, percent of GDP (*f*)	0.12
Domestic currency holdings, percent of GDP (*m*)	0.08
Government securities, percent of GDP (*b)*	0.09
o/w domestic (foreign) percent GDP	0.08 (0.01)
Net official reserves, percent of GDP (*z*)	0.04
Inflation rate, π (percent)	0.10
Government spending; percent of GDP (*s*)	0.25
Aid (aid shock), both percent of GDP (*a*)	0.10 (0.02)
Deficit reduction share *dr* (δ)	0.25
Foreign bond supply: imperfect (perfect) capital mobility (ϕ)	0.15 (0.001)
Implied values:	
Nominal interest rate (*i*)	0.210
Steady-state inflation elasticity of money demand	0.53

Table A1b. ***Definition and Scaling of Variables in Simulation Runs***

Variable	*Definition*	*Scaling of IRs and Standard Deviations*
`In`	Inflation rate = π	percentage points
`NER`	Nominal exchange rate	"
`RER`	Real exchange rate for imports $= EP_I / P_N$	"
`RIR`	Real interest rate	"
`I`	Nominal interest rate	"
`Ca`	Current account surplus including grants	percentage points of GDP
`DN`	Output of non-traded goods	"
`C`	Private consumption	"
`def`	Budget deficit before aid	"
`dz`	Reserve accumulation	"
`db`	Bond sales	"
`dbp (dpf)`	Bond accumulation by domestic (foreign) bond holders.	"

.

References

Adam, Christopher and Stephen O'Connell (2006) "Monetary Policy and Aid Management in Sub-Saharan Africa" mimeo, Africa Department, IMF.

Adam, Christopher, Stephen O'Connell, Edward Buffie and Catherine Pattillo (2008) "Monetary Policy Rules for Managing Aid Surges in Africa" *Review of Development Economics* (forthcoming).

Benigno, Pierpaolo and Michael Woodford (2007), "Optimal Inflation Targeting Under Alternative Fiscal Regimes," in Mishkin, Frederic and Klaus Schmidt-Hebbel (eds) *Monetary Policy under Inflation Targeting* , Central Bank of Chile, Santiago, Chile..

Berg, Andrew, Shekhar Aiyar, Mumtaz Hussein, Shaun Roache, Tokhir Mirzoev and Amber Mahone (2007) "The Macroeconomics of Scaling Up Aid: Lessons from Recent Experience" *IMF Occasional Paper* 235

Branson, William and Dale Henderson (1985) "The Specification and Influence of Asset Markets" in Robert Jones and Peter Kenen (eds) *Handbook of International Economics, Vol II* Elsevier, North Holland.

Brownbridge, Martin, and Emmanuel Tumusiime-Mutebile, (2006), "Aid and Fiscal Deficits: Lessons from Uganda on the Implications for Macroeconomic Management and Fiscal Sustainability" *Development Policy Review,* Vol. 25(2),pp. 193-213.

Buffie, Edward, Christopher Adam, Stephen O'Connell, and Catherine Pattillo, (2004), "Exchange Rate Policy and the Management of Official and Private Capital Inflows in Africa," *Staff Papers,* International Monetary Fund, Vol. 51 (Special Issue), pp.126-160.

Buffie, Edward Stephen O'Connell, Christopher Adam, and Catherine Pattillo, (2008), "Aid Reversals, Credibility and Macroeconomic Policy" in Gill Hammond, Ravi Kanbur and Eswar Prasad (eds) *New Monetary Policy Frameworks for Emerging Markets: Coping with the Challenges of Financial Globalization* (Edward Elgar and Bank of England, 2008)

Caputo, Rodrigo, Felipe Liendo and Juan Pablo Medina (2007) "New Keynesian Models for Chile in Inflation-Targeting Period" in Mishkin, Frederic and Klaus Schmidt-

Hebbel (eds) *Monetary Policy under Inflation Targeting* , Central Bank of Chile, Santiago, Chile.

Calvo, Guillermo A., (1983), "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics,* Vol. 12, pp. 383-98.

Calvo, Guillermo. A., Carmen. Reinhart, and Carlos. Vegh, (1995), "Targeting the Real Exchange Rate: Theory and Evidence," *Journal of Development Economics,*Vol.47, pp.97-133.

Cespedes, Luis Felipe, Roberto Chang and Andres Velasco (2003) "IS-LM-BP in the Pampas" *IMF Staff Papers*, Vol 50, 2003.

Edwards, Sebastian (2007) "The Relationship between Exchange Rates and Inflation Targeting Revisited" in Mishkin, Frederic and Klaus Schmidt-Hebbel (eds) *Monetary Policy under Inflation Targeting* , Central Bank of Chile, Santiago, Chile.

Gupta, Sanjeev, Robert Powell, and Yongzheng Yang, 2006, *Macroeconomic Challenges of Scaling Up Aid to Africa: A Checklist for Practitioners* (Washington: International Monetary Fund).

IMF (2007a) "Zambia: 5th and 6th Reviews of Poverty Reduction and Growth Facility" *IMF Country Report* CR 07/209.

IMF (2007b) "Ghana: Selected Issues and Statistical Appendix" *IMF Country Report* CR 07/208.

Juilliard, Michel (1996), "Dynare: A Program for the Resolution and Simulation of Dynamic Models With Forward Variables Through the Use of a Relaxation Algorithm," *CEPREMAP Working Paper* 9602.

O'Connell, Stephen A., Christopher S. Adam, Edward Buffie, and Catherine Patilllo (2007) "Managing External Volatility: Central Bank Options in Low-Income Countries, in *Monetary Policy in Emerging Market and Other Developing Countries* ed Nicoletta Batini (New York: Nova Science Books and Journals).

Peiris, Shanakar and Magnus Saxegaard (forthcoming) "Monetary policy rules in Sub-Saharan Africa: lessons from a dynamic stochastic general equilibrium model applied to Mozambique *IMF Working Paper* .

Porter, Nathan and james Yudong Yao (2005), "'Inflation Targeting Lite' in Small Open Economies: The Case of Mauritius," *IMF Working Paper* WP/05/172, August.

Prati, Alessandro and Tierry Tressel (2006) "Aid Volatility and Dutch Disease: Is there a role for monetary policy?" *IMF Working Paper* 06/145.

Stone, Mark R (2003), "Inflation Targeting Lite", *IMF Working Paper* WP/03/12, January.

Tan, Kang-Young and David Vines (2007) "Woodford Goes to Africa" *mimeo*.

Woodford, Michael (2003), *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton: Princeton University Press.