Riding the Wave: Monetary Responses to Aid Surges in Low-Income Countries*

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Abstract

We focus on the management of highly persistent shocks to aid flows, including PRSP-related increases in net flows, in the presence of currency substitution by the domestic private sector. Such shocks have beneficent long-run effects, but when currency substitution is high they can produce dramatic macroeconomic management problems in the short run. What is the appropriate mix of money and exchange rate targeting in such cases, and the role of temporary sterilization? We analyze these and related issues in an intertemporal optimizing model that allows a portion of aid to be devoted to reducing the government's seigniorage requirement. Our results argue that a managed float, with little or no sterilization of increases in the monetary base, is the most attractive approach.

KEYWORDS: Aid, Sterilization, Currency Substitution, Seigniorage, Africa.

1 Introduction

Since the early 1990s, African central banks have struggled to find the appropriate mix of money and exchange rate targeting when faced with highly persistent shocks to aid inflows (including PRSP- and HIPC-related increases in net flows).[1] In many episodes, higher aid flows have attracted equally large inflows of private capital.[2] The combined surge of official and private capital flows is beneficial in the long run but confronts policy makers with dramatic monetary management problems in the short run. Thus "fear of floating" (Calvo and Reinhart, 2000) initially spurs the central bank to intervene in the foreign exchange market. But reserve accumulation then expands the monetary base, generating fears of inflation and "overheating." Bond sales may be used to sterilize the liquidity injection, but this leads to large increases in real interest rates.

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In the end, policy makers have to make a difficult decision: what combination of changes in inflation, nominal and real exchange rates, and real interest rates should be used to absorb the aid shock?[3]

The natural place to look for answers is in the vast literature on capital flows to emerging market economies, which has wrestled with many of the problems that concern Africa's central banks. But while the capital inflows literature is large, it contains little in the way of clean, precise results. This is not surprising. A full and rigorous treatment of the issues associated with capital inflows requires the analysis of multiple scenarios in multiple models (fixed vs. flexible exchange rates and passive vs. active monetary policy, for a start). Researchers in the field have steered well clear of this task, relying instead on general theoretical principles to evaluate the likely effects of capital inflows and alternative policy remedies.

Conjecture informed by theory can generate useful insights. There is a limit, however, to what it can achieve. Despite all that has been written, the existing literature has not moved beyond a check list of things to think about. Controversy persists therefore regarding the efficacy of bond sterilization, the appeal of alternative approaches to absorbing domestic liquidity, and the relevance of underlying concerns about "overheating."[4] The lack of firm conclusions has *inter alia* prevented the literature from settling on a coherent bottom line for policy. Calvo, Leiderman, and Reinhart (1994), for example, recommend countering the undesireable effects of capital inflows through a combination of sterilization, fiscal adjustment, greater exchange rate flexibility, and (perhaps) higher reserve requirements. This may be the right policy response, but it is hard to escape the impression that it is a concession to ignorance, that the unspoken rationale is more or less: "We don't have a good handle on the repercussions of different policy measures, so do a bit of everything and hope for the best."

The message we take away from this critique is that it is time to get on with the job of analyzing capital inflows with the aid of fully articulated macromodels. Accordingly, the present paper solves an *array* of models designed to shed light on the tradeoffs associated with alternative policies for managing large capital inflows. Since we have the African context in mind, the initiating inflows are official rather than private; the officially pronounced nominal anchor is money rather than the exchange rate; and the economies in question are low-income rather than emerging-market economies, with correspondingly less developed financial markets. These features give the analysis an African twist, but the central issues are the same as in the capital inflows literature.

The rest of the paper is organized into ten sections. Following Buffie (2003), sections 2 and 3 develop the core structure of an optimizing two-sector currency substitution model in which aid accrues directly to the public sector. The government spends most but not all of the aid; consistent with the data for Sub-Saharan Africa, we assume that 25% of the extra aid is devoted to reducing the government's seigniorage requirement.[5] Hence inflation decreases in the long run.

In sections 4-7 we solve the model for the polar cases of a pure float and a crawling peg. We allow prices to be flexible or sticky and calibrate the model(s) to the data for Ghana, a high-inflation economy slated to receive substantial debt relief in the next three years.[6] It turns out that neither of the polar exchange rate regimes delivers satisfactory results. A pure float keeps short-run inflationary pressures in check at the cost of extreme instability in the real exchange rate and severe contraction in the nontradables sector (assuming prices are not highly flexible in the downward direction). Under a crawling peg, on the other hand, the path of the real exchange rate is stable but not the price level — higher aid spending and private capital flows trigger a tremendous upfront spike in the CPI. Thus policy makers have to choose their poison; a commitment to fix or float entails the sacrifice of at least one important macroeconomic target.

Seeking a better menu of choices, we examine two alternative strategies in sections 8 and 9: (i) temporary sterilization of capital inflows in a crawling peg and (ii) a managed float that targets the long-run equilibrium real exchange rate. In the Ghanaian economy, sterilization has limited appeal. Temporary, *very large* bond sales can reduce the initial pricel level spike by 40-70%; but the spike that remains is large in absolute terms (P jumps 1-5%), and the real interest rate may increase 10-20 percentage points in the short run. By contrast, a managed float allows large official and private capital inflows to be absorbed without adverse side effects on inflation, stability of the real exchange rate, the real interest rate or real output. In practice, it may not be easy to quantify the policy rule that guides the perfect managed float. But this is not a serious problem. Our results indicate that for a wide range of parameter values the central bank should lean heavily against nominal appreciation: roughly speaking, the right managed float is 60-80% of the way toward the crawling peg end of the continuum.

Section 10 investigates the robustness of the results to the time profile of aid flows (gradual vs. sudden increases) and a different specification of sticky prices (one that reflects inertial inflation). The final section recapitulates and discusses promising directions for future research.

2 The Core Structure of the Model

We work with a simple currency substitution model of a small open economy that produces a nontraded good and a composite traded good. Real output is fixed in both sectors and the world price of the traded good equals unity. The private sector divides its wealth between domestic currency, foreign currency, and government bonds. Notational conventions are as follows: P_n and γ denote the relative price of the nontraded good and its share in aggregate consumption; Q_i is output in sector i; b is the nominal stock of bonds deflated by the price level; and m, F, and E are real money balances, the stock of foreign currency, and aggregate real expenditure measured in dollars (i.e., units of the traded good).

Before turning to the equations, two remarks are in order about the general specification of the model. First, the assumption that the foreign asset does not earn interest is innocous. What *is* critical, especially in the section on sterilization, is that the foreign asset and dometic bonds are not perfect substitutes; hence the domestic interest rate is not tied down by the interest parity condition. Second, when aid spending shifts out the demand curve in the nontradables sector, the real exchange rate would appreciate less if the supply curve were not vertical. This does not substantively alter the results. The only change in the solutions is that the compensated elasticity of demand, whenever it appears, is replaced by the sum of the demand elasticity and the general equilibrium elasticity of nontradables supply.

Prices

P_n adjusts to clear the goods market in the nontradables sector. This requires

$$D_n(P_n, E) = Q_n, \tag{1}$$

where $D(\cdot)$ is the Marshallian demand function for the nontraded good.

The overall price level P is a geometric weighted average of the prices of the traded and nontraded goods. Since the nominal exchange rate e sets the domestic price of the traded good,[7]

$$P = eP_n^\gamma. \tag{2}$$

The Private Agent's Optimization Problem

All economic decisions in the private sector are controlled by a representative agent who possesses an instantaneous utility function of the form $V(P_n, E) + \phi(mP_n^{-\gamma}, FP_n^{-\gamma})$. $V(\cdot)$ is a standard indirect utility function that measures utility from goods consumption, while $\phi(\cdot)$ reflects liquidity services generated by holdings of domestic and foreign currency. The private agent chooses m, b, F, and E to maximize

$$U = \int_0^\infty [V(P_n, E) + \phi(mP_n^{-\gamma}, FP_n^{-\gamma})]e^{-\rho t}dt, \tag{3}$$

subject to the wealth constraint

$$A = m + P_n^\gamma b + F \tag{4}$$

and the budget constraint

$$\dot{A} = P_nQ_n + Q_T + P_n^\gamma g + rP_n^\gamma b + (\pi - \chi)P_n^\gamma b - \chi m - E, \tag{5}$$

where ρ is the time preference rate; g is real lump-sum transfers; $\chi = \dot{e}/e$ is the rate of currency depreciation; r is the real interest rate; and $\pi = \dot{P}/P$ is the inflation rate. $P_n^\gamma = P/e$ multiplies g and b because wealth is measured in dollars but transfers and bonds are indexed to the price level. For the same reason, the artificial capital gains term $(\pi - \chi)P_n^\gamma b$ appears in the budget constraint (5).

Let ω be the multiplier attached to the constraint in (5). The necessary conditions for an optimum then consist of

$$V_E = \omega, \tag{6}$$
$$\phi_1/\omega P_n^\gamma = r + \pi, \tag{7}$$
$$\phi_2/\omega P_n^\gamma = r + \pi - \chi, \tag{8}$$

and the co-state equation

$$\dot{\omega} = \omega(\rho + \chi - r - \pi). \tag{9}$$

Equations (6)-(8) state that the marginal utility of consumption equals the shadow price of wealth and that the marginal rate of substitution between consumption and m or F equals the income foregone from holding that type of money. The co-state equation (9) may look less familiar, but it is nothing more than a standard Euler equation. Differentiate (6) with respect to time and substitute for $\dot{\omega}$. Under the assumption of homothetic preferences, this gives[8]

$$\frac{\dot{E}}{E} = \frac{\tau(\eta+\gamma)}{\eta}(r-\rho), \tag{10}$$

where $\tau \equiv -V_E/V_{EE}E$ is the intertemporal elasticity of substitution and η is the compensated own-price elasticity of demand.

The Public Sector Budget Constraint

Money is injected into the economy whenever the central bank accumulates foreign exchange reserves Z or runs the printing press to finance the fiscal deficit of the central government. For now, we ignore bond sales and open market operations. The *consolidated* public sector budget constraint is thus

$$\dot{m} = P_n^{\gamma}(g + rb) + \dot{Z} - X - \chi m, \tag{11}$$

where X is sale of aid dollars net of government imports and interest payments on the public sector foreign debt net.[9]

Net Foreign Asset Accumulation and the Balance of Payments

One last equation completes the core structure of the model. Summing the private and public sector budget constraints produces the accounting identity that foreign asset accumulation equals national saving or the current account surplus:

$$\dot{F} + \dot{Z} = P_n Q_n + Q_T + X - E. \tag{12}$$

3 The Steady-State Outcome

The long-run equilibrium is independent of the exchange rate regime. It is not yet necessary therefore to specify whether the central bank operates a crawling peg, a clean float, or some type of managed float.

Across steady states, $\dot{m} = \dot{F} = \dot{Z} = \dot{E} = 0$. Imposing these conditions leads to $r = \rho$, $\chi = \pi$, and

$$\phi_1 = V_E P_n^{\gamma}(\rho + \pi), \tag{13}$$

$$\phi_2 = V_E P_n^{\gamma}\rho, \tag{14}$$

$$E = P_n Q_n + Q_T + X, \tag{15}$$

$$\pi m = P_n^{\gamma}(g + \rho b) - X. \tag{16}$$

In the long run, private spending rises by the full amount of the aid inflow and revenue from the inflation tax covers the fiscal deficit after grants. (Hereafter we use the shorter term fiscal deficit and omit "after grants.") Note also, from (13) and (14), that lower inflation attracts capital inflows only if domestic and foreign currency are Edgeworth substitutes (i.e., $\phi_{21} < 0$).

When more aid flows in, the government increases real transfers to the private sector by $d(P_n^{\gamma} g) = \psi dX$ and earmarks the rest of the extra revenue for reduction of the fiscal deficit. To obtain concrete results and prepare the model for calibration, we postulate nested CES-CRRA functions for $V(\cdot)$ and $\phi(\cdot)$:

$$\begin{aligned} V(P_n, E) &= \frac{E^{1-1/\tau}\left(k_o + k_1 P_n^{1-\beta}\right)^{(1-1/\tau)/(\beta-1)}}{1-1/\tau}, \\ \phi(\bar{m}, \bar{F}) &= h\frac{\left\{\left[k_2\bar{m}^{(\sigma-1)/\sigma} + k_3\bar{F}^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)}\right\}^{1-1/\tau}}{1-1/\tau}, \end{aligned}$$

where h and $k_o - k_4$ are constants, β is the elasticity of substitution between traded and nontraded consumer goods, σ is the elasticity of substitution between domestic and foreign currency, $\bar{m} \equiv mP_n^{-\gamma}$, and $\bar{F} \equiv FP_n^{-\gamma}$. For this utility function,

$$dE = \frac{dX}{1-\gamma k}, \tag{17}$$

$$\frac{dP_n}{P_n} = \frac{dX}{\eta E}, \tag{18}$$

$$d\pi = -\frac{\pi\mu - \rho s\gamma k + (1-\psi)(1-\gamma k)}{(1-\gamma k)\mu(1-\epsilon)}\frac{dX}{E}, \tag{19}$$

$$\frac{dm}{m} = \left[\frac{1}{1-\gamma k} + \frac{\epsilon}{\pi\mu(1-\epsilon)}\left(\frac{\pi\mu - \rho s\gamma k}{1-\gamma k} + 1 - \psi\right)\right]\frac{dX}{E}, \tag{20}$$

$$\frac{dF}{F} = -\left[\frac{(\sigma-\tau)\theta_m}{i\mu(1-\epsilon)}\left(\frac{\pi\mu - \rho s\gamma k}{1-\gamma k} + 1 - \psi\right) - \frac{1}{1-\gamma k}\right]\frac{dX}{E}, \tag{21}$$

where

$$\begin{aligned} \theta_m &= \frac{im}{im + \rho F} \\ \theta_f &= \frac{\rho F}{im + \rho F} = 1 - \theta_m \end{aligned}$$

are the shares of liquidity services provided by domestic and foreign currency; $\mu \equiv m/E$; $k \equiv (\eta+\gamma)^{-1}$; $s \equiv P_n^{\gamma}b/E$; $i = \rho + \pi$ is the nominal interest rate; and $\epsilon = (\tau\theta_m + \sigma\theta_f)\pi/i$ is the elasticity of money demand with respect to inflation. In the ensuing analysis we assume $\epsilon < 1$ and $\sigma > \tau$. Neither assumption is particularly restrictive. The first keeps the economy away from the slippery, downward-sloping portion of the seigniorage Laffer curve.[10] The second implies that lower inflation reduces the demand for foreign currency. Although theory does not guarantee this result, there is not much doubt that it is easier to substitute between the two currencies than to substitute intertemporally in consumption; hence some flight capital comes home when inflation declines.

Aid spending drives up the relative price of the nontraded good, but it is not clear what happens to currency demands or inflation. The problem is that, despite policy makers' intentions, the fiscal deficit might increase. Return to (16) for a moment. The direct effect on the deficit $[-(1-\psi)dX]$ is favorable.

But aid also drives up the relative price of the nontraded good, which increases the size of the internal debt measured in dollars. The overall impact on the fiscal deficit D is thus

$$dD = (\psi - 1 + s\rho\gamma/\eta)dX \gtrless 0.$$

We assume $\psi < 1 - \rho s\gamma/\eta$ so that the seigniorage requirement does, in fact, decline. This ensures that inflation falls and that the real money supply increases. Private capital flows could go either way since lower inflation and higher consumption spending exert conflicting effects on the demand for foreign currency. Normally, however, the currency substitution effect dominates the outcome. Observe in (21) that $i\mu(1-\epsilon)/\theta_m = (i\mu + \rho F/E)(1-\epsilon)$ is the ratio of liquidity services to national income, scaled down by $1-\epsilon$. The reciprocal of this, which multiplies $\sigma - \tau$, is a huge number. Private capital flows out therefore only when domestic and foreign currency are extremely weak substitutes.[11]

4 Flexible Exchange Rates

On paper, flexible exchange rates and strict targeting of the money supply are the norm in SSA. But the commitment to money-based stabilization and market-determined exchange rates is far from absolute, especially in periods of adjustment to large external shocks. Many countries have responded to large aid inflows by shifting to managed floats and partly accomodating monetary policy.

The decision about how much to manage the exchange rate is a decision about how much to move in the direction of a fixed exchange rate. Most of the information relevant to this decision is contained in the outcomes at the endpoints of the policy spectrum. Accordingly, we start by investigating the transition path associated with a pure float. Section 5 analyzes the polar opposite case of a crawling peg.

4.1 Analytical Results

In a pure float the central bank never intervenes in the foreign exchange market. With $\dot{Z} = 0$, the Euler equation

$$\dot{E} = \frac{\tau(\eta+\gamma)}{\eta} E(r-\rho), \tag{10}$$

and

$$\begin{aligned} \dot{m} &= P_n^{\gamma}(g + rb) - X - \chi m & (11') \\ \dot{F} &= P_n Q_n + Q_T + X - E & (12') \end{aligned}$$

comprise a 3x3 dynamic system in which F is predetermined and m and E are jump variables. To solve the system, we need to figure out how r and χ vary with m, F, and E. [Equation (1) already relates P_n to E.] Working toward this end, note from (1), (2) and (10) that

$$\dot{P}/P = \pi = \chi + \frac{\gamma\tau}{\eta}(r-\rho). \tag{22}$$

Equations (7), (8), and (22) can be solved for π, χ, and r. The solutions for r and χ are

$$dr = \frac{\rho\eta}{\tau\sigma(\eta+\gamma\tau)}[(\tau-\sigma)\theta_m\hat{m} - (\tau\theta_m + \sigma\theta_f)\hat{F} + \sigma\hat{E}], \tag{23}$$

$$d\chi = -\left[\frac{\rho}{\sigma} + \frac{\pi(\tau\theta_f + \sigma\theta_m)}{\tau\sigma}\right]\hat{m} + \left[\frac{\rho}{\sigma} + \frac{\pi(\tau-\sigma)\theta_f}{\tau\sigma}\right]\hat{F} + \frac{\pi}{\tau}\hat{E}, \tag{24}$$

The requisite machinery is now in place. Linearizing (10), (11′), and (12′) around the steady state (m^*, F^*, E^*) produces

$$\begin{bmatrix} \dot{m} \\ \dot{F} \\ \dot{E} \end{bmatrix} = \begin{bmatrix} c_1 & -c_2 & c_3 \\ 0 & 0 & \gamma k - 1 \\ c_4 & -c_5 & c_6 \end{bmatrix} \begin{bmatrix} m - m^* \\ F - F^* \\ E - E^* \end{bmatrix}, \tag{25}$$

where

$$\begin{aligned}
v &= \rho\eta/\tau\sigma(\eta+\gamma\tau) \\
c_1 &= \frac{sv(\tau-\sigma)\theta_m}{\mu} + \frac{\rho}{\sigma} + \frac{\pi(\tau\theta_f + \sigma\theta_m)}{\tau\sigma} - \pi, \\
c_2 &= \frac{P_n^\gamma bv(\tau\theta_m + \sigma\theta_F)}{F} + \frac{m}{F}\left[\frac{\rho}{\sigma} + \frac{\pi(\tau-\sigma)\theta_f}{\tau\sigma}\right], \\
c_3 &= s\left(\frac{\gamma}{\eta+\gamma} + \sigma v\right) - \frac{\pi\mu}{\tau}, \\
c_4 &= \frac{\tau(\tau-\sigma)\theta_m v(\eta+\gamma)}{\mu\eta}, \\
c_5 &= \frac{\tau(\tau\theta_m + \sigma\theta_F)v(\eta+\gamma)}{\eta F/E} \\
c_6 &= \tau\sigma v(\eta+\gamma)/\eta.
\end{aligned}$$

The system is saddlepoint stable.[12] On the unique path that converges to the stationary equilibrium,

$$m(t) - m_o = m^* - m_o - \frac{R_1}{R_2}(F^* - F_o)e^{\lambda_3 t}, \tag{26}$$

$$F(t) - F_o = (F^* - F_o)(1 - e^{\lambda_3 t}), \tag{27}$$

$$E(t) - E_o = E^* - E_o - \frac{F^* - F_o}{R_2}e^{\lambda_3 t}, \tag{28}$$

where

$$\begin{aligned}
R_1 &= \frac{\lambda_3 - c_6 + c_5 R_2}{c_4} \gtrless 0, \\
R_2 &= \frac{\gamma k - 1}{\lambda_3} > 0,
\end{aligned}$$

and λ_3 is the system's negative eigenvalue.

Across steady states, the demand for foreign currency decreases along with inflation (assuming σ is not unusually small). In a floating rate system, the private sector cannot reduce its collective holdings of foreign currency by trading dollars for domestic currency in the foreign exchange market. The desire to hold less foreign currency leads instead to appreciation of the nominal exchange rate, a windfall gain in wealth ($m \uparrow$ on impact), and lower saving. This pins down several results: at t = 0 expenditure increases *more* than aid ($E(0) > E^*$), the current account worsens, and the real exchange rate ($1/P_n$) *overshoots* its steady-state level [$P_n(0) > P_n^*$]. Furthermore, since $\dot{E}, \dot{F} < 0$, $\forall t$, the real interest rate is lower

$$r(t) = \rho - \lambda_3 \frac{1 - \gamma k}{\tau} \frac{F^* - F_o}{ER_2} e^{\lambda_3 t} < \rho$$

and current account (CA) deficits persist throughout the adjustment process

$$CA(t) = \dot{F}(t) = -\lambda_3 (F^* - F_o) e^{\lambda_3 t} < 0.$$

The spending boom that accompanies aid might seem to be a source of trouble for the price level in the short run. But this is not the case. When the private sector attempts to sell foreign currency at $t = 0$ the nominal exchange rate appreciates enough to fully neutralize the inflationary pressures of higher consumption spending. In the appendix we demonstrate that the price level decreases on impact and that inflation is continously lower on the transition path to the new steady state.

4.2 Numerical Results: How Big Are the Effects?

To calibrate the model we chose units so that $P_{no} = E_o = 1$ and set

$$\begin{aligned} m_o &= .10, \quad b_o = .20, \quad \pi_o = .25, \quad \gamma_o = .50, \quad X_o = .10, \\ \beta &= .50, \quad \sigma = .75 - 3, \quad \rho = .08, \quad \tau = .25 - .50, \quad F_o = .15. \end{aligned}$$

The numbers assigned to m_o, π_o, b_o, γ_o, and X_o are rough averages of the values observed in Ghana in the period 2000-2003. With respect to the other choices:

- *Elasticity of substitution in consumption between traded and nontraded consumer goods* (β). Fixing β at .50 implies that the compensated elasticity of demand for the nontraded good is .25 initially. This agrees with the finding in empirical studies that compensated elasticities of demand tend to be small at high levels of aggregation.[13]

- *Elasticity of substitution between domestic and foreign currency* (σ). There are no reliable estimates of σ for Ghana or any other country in Africa. For Latin America the numbers range from 1.5 to 7 (Ramirez-Rojas, 1985; Marquez, 1987; Giovannini and Turtleboom, 1994; Kamin and Ericcson, 1993). Not trusting the high-end estimates (7??), we decided to let σ vary from .75 to 3.

- *Time preference rate* (ρ). Across steady states, the real interest rate is fixed by the time preference rate. The value assigned to ρ (8%) is slightly less than the average real rate paid by short-term treasury bills since 1992 (8.25% according to IMF 2003, p.66).

- *Elasticity of intertemporal substitution* (τ). Most estimates for LDCs place τ between .20 and .50. (See Agenor and Montiel, 1999, Table 12.1.) We settled therefore on .25 and .50 as the low and high values for the intertemporal elasticity of substitution.[14] Occasionally, we also report results for the intermediate case of $\tau = .35$.

- *Ratio of foreign currency to national income* (F_o). Foreign currency deposits in the domestic banking sector are 60% of reserve money in Ghana. This suggests $F_o = .06$, but the true value is higher because a good deal of foreign currency is held outside of the domestic banking system. We arbitrarily set F_o at .15. This is in line with dollarization ratios in other parts of the Third World.[15]

- *Share of aid inflow set aside for deficit reduction* (ψ). A value of .75 for ψ is consistent with African data for the 1990s and with the the stated intent of the Ghanian government to use part of the saving in debt service in upcoming years to reduce the fiscal deficit.[16]

All of the simulations assume that aid inflows increase by 3% of national income (the projected increase for 2002-2006). Since the aid shock is large, linearization error is a potential problem. To address this concern, we solved for the transition path using a variant of the procedure recommended by Novales et al.(1999).[17]

4.2.1 Steady-State Outcome

Table 1 reports the results for five different runs. In every case, the long-run effects of the aid shock are significant. The value for ψ implies that the fiscal deficit decreases by .75% of GDP. This reduces the steady-state inflation rate from 25% to 11-15%. Cumulative private capital inflows range from $-.1\%$ to10% of national income, while the real exchange rate appreciates 11%.

4.2.2 The Transition Path

What happens on the way to the long-run equilibrium depends mainly on the currency substitution parameter σ. For $\sigma = .75$ private capital inflows are small and the economy moves quickly to the vicinity of the new steady state. But when $\sigma = 2-3$ the ride is a bit wild. Consumption spending strongly overshoots its steady-state level; as a result, the real exchange rate appreciates 20-24% in the short run and the current account deficit, *inclusive of aid*, jumps to 2.3-3.7% of national income. There are also pronounced fluctuations in π and r in the runs where $\tau = .25$. The real interest rate decreases 1.5 percentage points in the first year; it rises steadily thereafter but is still 1-1.2 percentage points lower at $t = 3$. Because of the temporary decrease in the real interest rate, the fiscal deficit and inflation also overshoot their steady-state levels.

Caveat

Unfortunately, the results in Table 1 presume far too much flexibility of nominal prices. Consider how the economy adjusts in the short run. According to our model, the nominal exchange rate appreciates 22-48% at $t = 0$ to forestall incipient capital inflows (F is predetermined). Since the real exchange rate appreciates "only" 12-24%, the nominal price in the nontradables sector has to immediately fall 11-35% to keep demand equal to supply. This strains belief to say the least. But if nominal price adjustment is incomplete the economy slides into a recession — probably a deep recession given the magnitude of nominal appreciation at $t = 0$. We return to this point later in section 6.

5 A Crawling Peg

Under a crawling peg, the money supply adjusts endogenously through the capital account to satisfy money demand. But while domestic currency can be swapped for foreign currency at the central bank, the total dollar value of currency holdings is predetermined. Thus $J \equiv m + F$ is the state variable in the dynamic system defined by (10)-(12). To bring J into view, add (11) and (12). This gives

$$\dot{J} = P_n^{\gamma}(g + rb) + P_n Q_n + Q_T - E - \chi m. \tag{29}$$

For simplicity, suppose the government lowers the rate of currency depreciation χ to its new steady-state level immediately at $t = 0$. The inputs needed to solve (10) and (29) are then limited to the reduced forms that show how r and m vary with J and E on the transition path. These are buried in (7) and (8). After substituting for π from (22) and replacing F with $J - m$, the first-order conditions yield[18]

$$dm = \frac{\sigma\pi\mu}{\Delta} dE + \frac{m}{F\Delta}[\tau\rho + \pi\theta_f(\tau - \sigma)]dJ, \tag{30}$$

$$dr = \frac{\rho i \eta}{\Delta F(\eta + \tau\gamma)} \left(\frac{J}{E} dE - dJ \right), \tag{31}$$

where

$$\Delta = \tau[\theta_f i + \theta_m \rho(2 + \rho\theta_m / i\theta_f)] + \sigma\theta_m \pi^2 / i.$$

Routine algebra now delivers

$$\begin{bmatrix} \dot{J} \\ \dot{E} \end{bmatrix} = \begin{bmatrix} -n_{16} & n_{17} \\ -n_{18} & n_{18} \end{bmatrix} \begin{bmatrix} J - J^* \\ E - E^* \end{bmatrix}, \tag{32}$$

where

$$n_{16} = \frac{P_n^{\gamma} b \rho i \eta}{\Delta F(\eta + \tau\gamma)} + \frac{\pi m}{F\Delta}[\tau\rho + \pi\theta_f(\tau - \sigma)]$$

$$n_{17} = \frac{\gamma(1 + \rho s)}{\eta + \gamma} + \frac{sJ\rho i \eta}{\Delta F(\eta + \tau\gamma)} - \frac{\pi^2 \sigma\mu}{\Delta} - 1,$$

$$n_{18} = \frac{\tau\rho i(\eta + \gamma)}{\Delta(\eta + \tau\gamma)}.$$

Under the weak restriction $\eta > \rho s \gamma$, the steady state is a saddle point and the solutions for J and E read[19]

$$J(t) - J_o = (J^* - J_o)(1 - e^{\lambda_2 t}), \tag{33}$$

$$E(t) - E_o = E^* - E_o - (J^* - J_o)R_3 e^{\lambda_2 t}, \tag{34}$$

where λ_2 is the system's negative eigenvalue and

$$R_3 = \frac{n_{18}}{n_{18}(J/E) - \lambda_2(F/E)} > 0.$$

To locate the position of J^*, add the solutions for m^* and F^* in (20) and (21):

$$J^* - J_o = \frac{J}{E}(E^* - E_o) - \frac{m}{i\rho}[\tau\rho + \pi\theta_f(\tau - \sigma)](\pi^* - \pi_o). \tag{35}$$

Higher spending increases total currency demand proportionately, but the impact of lower inflation depends on initial conditions (π_o, θ_f) and the relative magnitudes of the substitution parameters σ and τ.

5.1 Analytical Results

Most of the qualitative results hinge on the degree of substitutability between domestic and foreign currency. If

$$\sigma > \tau(1 + \rho/\pi\theta_f) + \frac{i\rho(1-\epsilon)(\eta+\gamma)}{\pi\theta_f \underbrace{[\pi\mu(\eta+\gamma) - \rho s\gamma + \eta(1-\psi)]}_{\text{Positive for } \psi < 1 - \rho s\gamma/\eta}} \frac{J}{E}, \tag{36}$$

currency substitution allows the private agent to enjoy more liquidity services while spending down part of his wealth. The paths for expenditure, the real exchange rate, the current account, and the real interest rate are then qualitatively the same as the paths in a pure float. The item missing from the list is the impact effect on the price level. Since the nominal exchange rate is predetermined, the big increase in spending at $t = 0$ triggers large jumps in the nominal price of the nontraded good and the CPI.

The dynamics are quite different when the condition in (36) does not hold: expenditure and the real exchange rate undershoot their steady-state levels, the real interest rate rises, and the current account registers surpluses instead of deficits. Moreover, expenditure may *decrease* initially, causing the real exchange rate to depreciate and the price level to jump downward at $t = 0$. The result is odd but it cannot be ruled out by plausible parameter values.

5.2 Numerical Results and Comparisons With a Pure Float

How does switching from a pure float to a crawling peg affect the paths of key macroeconomic variables? We should be able to say a lot about this *without* taking a stand on the condition in (36). In a pure float, spot appreciation of the nominal exchange rate at $t = 0$ confers a large wealth gain on the private sector ($m + F \uparrow$ on impact) while also exerting strong downward pressure on the price level. No similar effects operate in a crawling peg. Thus intuition argues that in comparisons of the two systems a crawling peg buys greater stability of the real exchange rate and smaller current account deficits (or possibly current account surpluses) at the price of higher inflation and higher real interest rates. But if these results are obvious they are not easy to prove. The problem is that the negative eigenvalue governing the saddle path in the flexible rate system is the root of a cubic equation. The solutions in (26)-(28) are not, therefore, as simple as they look — the expression for λ_3 takes up several pages.

The condition in (36) does not hold for the two runs where $\sigma = .75$ or the run where $\tau = .50$ and $\sigma = 2$ (see Table 2). In these runs, the real interest rate rises, the current account improves, and inflation and the real exchange rate undershoot, approaching their steady-state levels from above. In the other two cases, the qualitative properties of the transition path are the same (apart from the initial jump in the price level) as in a float. Under a crawling peg, however, inflation and the real interest rate decrease less, the real exchange rate appreciates less, and the current account deficit is smaller.

Two other results merit comment. First, the increase in the real interest rate is small. For $\sigma = .75$, the rate jumps initially to 9.4-9.6%, but by the end of the first year r falls back below 9%. Second, inflationary pressures are confined to the spike in the price level at $t = 0$. Although the spike is large (P jumps 3-9%),[20] the path of the CPI drops below the pre-aid path within 4-7 months and the inflation rate for the first year decreases from 25% to 16-20%. (The number in parentheses in the cell for $t = 1$ is the cumulative percentage increase in the price level over the first year — the real world definition of inflation.)[21]

6 Sticky Prices

There is some unfinished business connected with the analysis of PBS aid in a pure float. Turn back to Table 1. The numbers look nice but they rely on extreme downward price flexibility to preserve full employment when the nominal exchange rate appreciates 22-48% in the short run. We conjectured that real output would decrease sharply if, instead, nominal prices were sticky downward. This needs to be confirmed before drawing any conclusions about the efficacy of managing aid flows in flexible vs. fixed exchange rate systems.

We introduce sticky prices à la Calvo and Vegh (1993). The price of the traded good is set by the exchange rate but firms in the nontradables sector adjust prices only when they receive a random "price-change signal." Firms that receive a signal choose a new price by forecasting the future paths of the price level and excess demand.[22] Price adjustment is thus forward-looking. Calvo (1983) shows that when the price-change signal obeys a Poisson process

$$\dot{P}_n = (\pi_n - \chi)P_n \qquad (37)$$

$$\dot{\pi}_n = -\delta[D_n(P_n, E) - \bar{Q}_n], \quad \delta > 0, \qquad (38)$$

where $\bar{Q}_n$ denotes notional output (i.e., the level of output associated with a normal capacity utilization rate). Equation (37) follows from the fact that, at any given point in time, the nominal price of the nontraded good is fixed by past price quotations. (More precisely, at any time t the set of firms that adjust their prices is of measure zero.) Equation (38) is a higher-order Phillips Curve. It says that the *change* in π_n, the inflation rate in the nontradable sector, is a decreasing function of excess demand. The parameter δ is larger the shorter the length of the average price quote.

Sticky prices add two variables to the dynamic systems analyzed earlier. In a pure float, both π_n and P_n are jump variables.[23] Under a crawling peg, π_n is a jump variable but P_n is predetermined. Nontradables output is demand determined in both exchange rate regimes.

6.1 A Pure Float

The row for Q_n in Table 3 tracks the path of $[Q_n(t) - Q_{no}]/Q_{no}$, the percentage difference between nontradables output at time t and its pre-aid level.[24] Although the compensated elasticity of demand is only .25, substitution toward traded goods — induced by appreciation of the nominal exchange rate — easily dominates the expansionary income effect of higher aid flows. Consequently, Q_n declines in every case. When $\sigma = 2 - 3$, the recession in the nontradables sector is protracted and severe as large private capital inflows force the nominal exchange rate to appreciate 21-33% at $t = 0$. For $\sigma = .75$, capital inflows and nominal appreciation are comparatively modest; nevertheless, Q_n falls 2.5-5.5% on impact and is .7-1.6% lower at $t = 1$.

Recession is not the only problem policy makers face. The real exchange rate overshoots its steady-state level much more than in the flexprice model, especially in the runs for $\sigma = 2-3$. Moreover, the impact on the real interest rate changes dramatically. When prices are flexible, the real interest rate decreases temporarily from 8% to 6.4-7.6%. With sticky prices, the rate jumps to 14-26% in the first year. This is a natural byproduct of the transitory recession: r is higher on the transition path because aggregate consumption spending rises over time as demand and output recover in the nontradables sector.

The adverse impact on the real interest rate is important, for it implies that the simulation results underestimate the real output losses from floating. Our model assumes constant output in the tradables sector. But if a higher return on treasury bills increases the cost of working capital or depresses investment spending, then tradables production will contract and the demand curve in the nontradables sector will shift further to the left. In a more elaborate model that captured these linkages, the recession would be deeper and more persistent than in Table 3.

6.2 A Crawling Peg

The results for a crawling peg in Table 4 are what policy makers dream about. Inflation decreases smoothly without an initial spike in the price level. The current account records a small surplus (an imperceptible deficit for $\sigma = 3$) and the real exchange rate moves toward its long-run equilibrium value in a gradual, orderly manner. For a couple of years, the economy also enjoys higher output and lower real interest rates. What makes everything work is that the budget-support component of aid effectively finances a perfectly credible exchange-rate-based stabilization. The small ERBS component (1/4 of the total aid package) ensures that inflation decreases monotonically even though real spending rises 3.3-6.5% in the short run.

Does this mean that a crawling peg with fully accommodating monetary policy solves all macroeconomic problems in the case of PBS aid? Probably not. Few macroeconomists have trouble with the notion that prices are sticky downward. But are prices sticky upward as well? For reasons that are hard to justify, we suspect that price adjustment is asymmetric in Sub-Saharan Africa and that the flexprice specification is correct for many branches of the nontradables sector (e.g., the informal sector) when nominal price increases are required to clear the market. The pure flexprice model of sections 2-5 may exaggerate the initial upward jump in the CPI, but the sticky-price model is overly optimistic in assuming the problem away. Doubtless the truth lies somewhere inbetween.

7 Policy Implications

The long-run equilibrium inflation rate declines when aid serves in part to reduce the fiscal deficit. So far so good. But expectations of lower inflation elicit large private capital inflows. This complicates macroeconomic management because staying out of the foreign exchange market is not a genuine option: central banks that rely on a pure float passively acquiese to (i) stupendous appreciation of the nominal exchange rate, (ii) lower employment in both the tradables and nontradables sectors (assuming wages and prices are not exceptionally flexible downward), (iii) overshooting of the real exchange rate, and (iv) large current account deficits. A crawling peg eliminates the threat of a harsh recession and secures greater stability of the real exchange rate but leaves the government with the problem of negotiating an initial big spike in the CPI.

Summing up, neither a crawling peg nor a pure float produces fully acceptable results. We move on therefore to the analysis of alternative policy strategies. In section 8 the central bank temporarily sterilizes capital inflows; in section 9 it operates a dirty float, intervening in the foreign exchange market to prevent extreme fluctuations in the nominal exchange rate.

8 Temporary Sterilization

The price level jumps when aid flows increase and the central bank maintains a crawling peg. Since inflation decreases rapidly after the initial spike in the CPI, temporary sterilization comes to mind as a strategy for smoothing the paths of money growth and the price level. To fix ideas, suppose the government sells a large block of bonds at $t = 0$ and then redeems the debt in future periods. That is

$$b(t) = b_o + [b(0) - b_o]e^{-\alpha t}. \tag{39}$$

where initial bond sales are $b(0) - b_o$ and the parameter α determines how fast the debt is paid off.

Temporary sterilization alters only one equation in the model. The public sector budget constraint is now

$$\dot{m} + P_n^\gamma \dot{b} = P_n^\gamma (g + rb) + X + \dot{Z} - \chi m, \tag{11$'$}$$

so (29) changes to

$$\dot{J} = P_n^\gamma (g + rb) + P_n^\gamma \alpha(b - b_o) + P_n Q_n + Q_T - E - \chi m. \tag{29$'$}$$

Proceeding as before yields

$$\begin{aligned} J(t) - J_o &= J^* - J_o + h_2 e^{\lambda_2 t} + [b(0) - b_o]R_4 e^{-\alpha t}, & (40)\\ E(t) - E_o &= E^* - E_o + h_2 R_3 e^{\lambda_2 t} + [b(0) - b_o]R_5 e^{-\alpha t}, & (41)\end{aligned}$$

where

$$\begin{aligned} R_4 &= (\alpha + \rho)(n_{18}J/F + \alpha)/H,\\ R_5 &= (\alpha + \rho)n_{18}E/FH,\\ H &= \alpha^2 + \alpha(n_{18}J/F - n_{16}) + \frac{n_{18}}{F}(n_{17}E - n_{16}J).\end{aligned}$$

At $t = 0$, J jumps downward by the same amount as b jumps upward. Thus

$$h_2 = J_o - J^* - [b(0) - b_o](1 + R_4)$$

Tables 5 and 6 show the outcome when bond sales at $t = 0$ are 8% of GDP and 80% of the newly issued debt is redeemed over ten years ($\alpha = .161$).[25] A quick scan of the results reveals plusses and minuses. On the plus side, temporary sterilization is helpful in smoothing the path of the price level. The inflation rate drops to 13-18% at $t = 0$ and then declines monotonically toward its steady-state level. This is accomplished with a much smaller prefatory spike in the CPI (0-5.6% vs. 3-9% in Table 2). Compared to the no-sterilization case, inflation is one percentage point lower in the first year and slightly higher in subsequent years. Preferences decide which path is superior, but we suspect most policy makers would opt for the smoother path proffered by temporary sterilization.

The drawbacks of the policy concern the impact on the real interest rate and the size of the initial bond sale. In the runs for $\tau = .50$ the real interest rate fluctuates between 11 and 21 percent in the first year. This is worrisome enough, but when $\tau = .25 - .35$ the rate vaults to 18-43% and takes two full years to fall back to 9-11%. It is also disturbing that the modest reduction in price volatility requires so much debt to be sold so quickly. The assumption in (39) that all bond sales occur at $t = 0$ is an artificial simplification. A fair interpretation of the policy rule, however, is that open market operations increase the internal debt by 7–8% of GDP in the span of 6-9 months. This is probably the outer limit of what is feasible in the Ghanian bond market, yet the price level spike still exceeds 2% in five of the eight cases.

It is easy to understand in light of these results why most African governments have employed a mix of sterilization and foreign exchange sales to counteract the short-run inflationary pressures created by high aid flows. The problem with relying on sterilization alone is that bond sales push up the real interest rate and thereby attract the capital inflows they are trying to neutralize.[26] Observe in Tables 5 and 6 that high real interest rates are associated with *massive* overshooting of private capital inflows and large offset coefficients.[27] This makes life difficult for the central bank. Sterilization works by reducing liquidity and raising the real interest rate to a level that induces the private agent to curtail expenditure (relative to the no-sterilization path). At the margin, the withdrawal of one dollar of domestic currency from circulation reduces liquidity services by i dollars (33 cents worth in Table 5). When the private agent exchanges foreign for domestic currency at the central bank, π dollars of the cut in liquidity services is restored, leaving a net loss of r dollars. This is only 24% of the decrease in liquidity services achieved from selling bonds for domestic currency [$r/i = \rho/(\rho + \pi) = .24$ for differential changes]. The central bank is not powerless, but capital flows severely constrain its ability to manage the path of liquidity.

9 A Managed Float

> " . . . the question of the apropriate exchange rate regime for African countries remains open. None of these countries has a 'pure' floating

exchange rate, opting instead for the common intermediate case of a 'managed' float . . . " (Leape, 1999, pp.126-127)

The preceding results may explain why most countries prefer managed floats to either a pure float or a crawling peg. Policy is too passive in a pure float: while inflation decreases strongly, the nominal exchange rate is allowed to appreciate to the point where output contracts in the nontradables sector. A crawling peg errs in the opposite direction, imperiling a different target: when the government commits to a fixed path for the exchange rate it throws away the policy instrument that is most effective in combatting the short-run inflationary pressures created by higher aid spending and accompanying private capital inflows. Nor does more active monetary policy resolve the targets-instruments problem. A crawling peg combined with temporary sterilization reduces the initial price spike; but, as we have just seen, this often produces very high real interest rates and may require bond sales on a scale that is not feasible.

A managed float gives policy makers the freedom to find the middle ground between too much and too little intervention. The right amount of intervention depends, of course, on the weights attached to the targets for output, inflation, the real exchange rate, and the real interest rate. Rather than derive a complicated intervention rule by optimizing over a quadratic objective function that incorporates all of these targets, we assume the central bank sells/buys foreign currency whenever the real exchange rate ($1/P_n$) is above/below its long-run equilibrium level:

$$\dot{Z} = \Omega \frac{P_n - P_n^*}{P_n}, \quad \Omega > 0. \tag{42}$$

Equation (42) relates the *flow* accumulation of reserves to deviations of the real exchange rate from its target value. In addition, Z may jump at $t = 0$. The initial purchase of reserves and Ω are chosen jointly to ensure that the existing nominal price of the nontraded good clears the market at $t = 0$. The intervention strategy, in other words, is to let the exchange rate appreciate enough to reduce inflation but not so much as to drive the nontradables sector into a recession. Other targets do not influence the intervention rule; it turns out, however, that the rule postulated here also greatly reduces volatility of the real exchange rate and the real interest rate.

Table 7 shows the outcome when the initial stock of reserves is 5% of GNP. At long last, we have something that can be pronounced an unqualified success. In contrast to the polar exchange rate regimes, the managed float reduces inflation immediately without any adverse side-effects on output, the current account balance, or the real exchange rate. The one minor blemish in the results is that the real interest rate initially jumps to 10% in the run for ($\tau = .50, \sigma = .75$).

The upshot of all this is that the optimal exchange rate regime lies close to the crawling peg end of the policy spectrum. To quantify the meaning of "close," consider the paths of the exchange rate and reserves associated with the policy rule in Table 7. Appreciation of the nominal exchange rate at $t = 0$ is 7-17% vs. 22-48% in a pure float. Cumulative reserve purchases are 52-88% as large as in a crawling peg, with the figure exceeding 75% when $\sigma = 2 - 3$. (The figure in parentheses in the row for Z is the stock of reserves in a crawling peg.)[28]

10 Other Scenarios

In this section we examine the sensitivity of the results to alternative specifications of aid flows and sticky prices.

10.1 Gradual Aid Flows

The right type of managed float avoids both a spike in the price level and excessive appreciation of the nominal and real exchange rate. It is, however, a complicated, imperfect solution to the macroeconomic problems associated with a sudden aid bonanza: a lot of information and a fair bit of technical expertise is needed to calculate the parameters of the policy rule in equation (42). An alternative, easier-to-implement strategy is to defer some aid to the future. If capital inflows and spending increase gradually along with aid, then macroeconomic stability may be compatible with a crawling peg or a pure float — with continued operation of a simple, transparent exchange rate regime.

Pursuing this idea, suppose aid rises toward its permanent level $\bar{X}$ at the rate

$$\dot{X} = c[\bar{X} - X(t)], \quad c > 0. \tag{43}$$

Delayed gratification should not be punished. The present value increase in aid is the same therefore as in the case where X increases instantaneously from X_o to X^*. This implies

$$\bar{X} = X_o + \frac{c + \tilde{r}}{c}(X^* - X_o), \tag{44}$$

where $\tilde{r}$ is the world market interest rate.

In Tables 8 and 9, $\tilde{r}$ is 5% and the extra aid is phased-in slowly over a period of five years. Disappointingly, the results are similar to those in Tables 2 and 3. This reflects the logic of Ricardian Equivalence. Since the private agent anticipates higher aid flows and lower fiscal deficits in the near future, the paths for real expenditure, private capital flows, and other key macro variables are about the same as when aid increases instantaneously. The one exception is the significantly better path for nontradables output in the run for ($\tau = .25, \sigma = .75$) in Table 9. In all other cases, the improvement in the transition path is inconsequential. The spike in the price level is still very large in a crawling peg, and sharp contraction in the nontradables sector, temporarily high real interest rates, and overshooting of the real exchange rate are still severe problems when the currency floats. In short, gradualism helps, but not enough to matter.

10.2 Inertial Inflation

In the specification of sticky prices developed by Calvo (1983), the price level is sticky but not the inflation rate. This detail is critical. The quick response of inflation is the reason an abrupt reduction in the rate of crawl works well in the Calvo model. Earlier we expressed doubts about the notion that prices are sticky upward. In this section we wish to make the additional point that different sticky-price models give different results. The strong, uniformly positive results in the Calvo model do *not* carry over to models in which sticky prices stem from inertial inflation.

There are a variety of ways to model inertial inflation. For illustrative purposes, we adopt the specification in Calvo and Vegh (1994). In their formulation,

$$\pi_n = \omega + \alpha[D_n(P_n, E) - \bar{Q}_n], \quad (45)$$

$$\dot{\omega} = \Lambda(\pi_n - \omega), \quad (46)$$

where ω, the rate of nominal wage growth, is predetermined. Equation (45) says that firms in the nontradables sector react to excess demand by raising prices faster than wages. The rationale for (46) is less clear; presumably workers aim for wage increases that track price growth at the firms that employ them.

Consider again what happens when aid increases and the government immediately reduces the rate of crawl χ to its new steady-state level. After staring at equations (45) and (46) for thirty seconds, it should be transparent that the path to the new steady state will involve alternating cycles of expansion and contraction. In the short run, nontradables output *and* π_n increase. But the initial expansionary phase *must* be followed by a contractionary phase if π_n is to trek downward in the direction of χ. Because π_n increases initially, the contractionary phase is often prolonged and deep. Tables 10 and 11 report results for $\Lambda = 1$ and $\alpha = 2, 5$. Although price adjustment is fast and inflation is not highly inertial, the expansionary phase is exceedingly brief and the subsequent recession lasts 2-6 years. In the runs where $\alpha = 2$, the real exchange rate also overshoots its long-run level by a considerable amount.

We should acknowledge that some of our other results change if the Calvo-Vegh specification mirrors reality. In particular, while a managed float continues to dominate a crawling peg and a pure float (compare Table 12 and Table 11),[29] it does not cure all macroeconomic problems: since wage and price inflation in the nontradables sector decrease only when firms operate with excess capacity, a recession is inevitable regardless of how the exchange rate is managed. This conclusion probably does not apply to all types of aid. Intuition suggests, for example, that spending aid money to increase supply might reduce inertial inflation without subjecting the economy to a recession. There is no pain-free solution, however, when aid affects only aggregate demand.

11 Concluding Remarks

The dynamic response to persistent official capital flows is linked to the degree of budget support they provide and the strength of private portfolio substitution. When these take even ordinary values, portfolio adjustments dominate the short-run dynamics and produce some distinctly unpleasant tradeoffs. A pure float, in particular, performs very poorly. Portfolio pressures produce a nominal appreciation that is an order of magnitude larger than the required real appreciation, and unless the prices of nontraded goods are perfectly flexible, the real exchange rate overshoots and substitution effects drive the economy into a deep recession. A crawling peg does better, but allows a short-run spike in inflation; bond sterilization can prevent the inflation spike, but only at the cost of a rapidly rising interest burden. In our preferred “managed float” scenario, the central bank uses unsterilized foreign exchange intervention to target the modest real appreciation needed to absorb the aid inflow. Real interest rates then stay low and macroeconomic adjustment is rapid. Our analysis suggests that African central banks have been correct to intervene substantially in the face of recent increases in aid, and to discount the argument that rapid domestic liquidity expansion necessarily calls for a combination of bond sterilization and cleaner floating.

We close with some thoughts about two extensions of the analysis that would test the robustness of our conclusions in a broader policy context.[30] The first concerns aid flows that support public investment. We have equated aid with transfer payments to the "poor" (i.e., the representative private agent). It is also desireable to investigate the repercussions of aid that finances rehabilitation of social and physical infrastructure. This type of aid brings many new effects into play. If productive capacity increases proportionately in the tradables and nontradables sectors, then appreciation of the real exchange rate will be strictly temporary. Furthermore, if private capital and infrastructure are complements, aid may produce large multiplier effects and a nontrivial increase in tax revenue in the long run.[31] The complications that arose here from private capital inflows augmenting aid flows would then materialize in the case where all aid is spent. Related to this, we conjecture that productive aid — aid that has a strong positive impact on permanent income and the equilibrium private capital stock — will elicit immediate, large increases in private consumption and investment. In the short run, therefore, it might prove very difficult to contain inflationary pressures. This pushes the "optimal" managed float more in the direction of the middle ground between a fixed exchange rate and a pure float. How much more is not clear absent careful analysis. For what it is worth, our prior is that the macroeconomic tradeoffs associated with aid and the right policy intervention *are* sensitive to the type of aid.

The second extension acknowledges that African central banks have to worry about more than just aid shocks when deciding on the appropriate exchange rate regime. We are currently working on a stationary, discrete-time version of our model in which aid shocks compete with other important shocks for policymakers' attention and some portion of aid may in fact represent a response to other shocks (e.g., to the terms of trade). We look for desirable intervention and sterilization rules, given a plausible loss function and given the observed joint distribution of shocks and aid. This approach links the analysis in the current paper with the growing literature on monetary policy rules in the open economy (e.g., Svensson, 2000). The conclusions we have emphasized here — including the merits of managed floating and the limited role for bond sterilization — seem likely to survive if the environment is dominated by autonomous and reasonably persistent changes in aid. What remains to be seen is whether these conclusions constitute a serious challenge, under more general circumstances, to rules that incorporate greater exchange rate flexibility and/or more aggressive bond operations.

Appendix

It is easy to confirm that in a pure float the price level decreases on impact and the inflation rate is continuously lower. Recall that the nominal money supply is predetermined. Thus

$$\begin{aligned}\frac{e(0)-e_o}{e_o} &= -\frac{m(0)-m_o}{m_o}\\ &= -\frac{m^*-m_o}{m_o}+\frac{R_1(F^*-F_o)}{R_2 m_o}.\end{aligned}$$

After substituting for m^*-m_o and F^*-F_o, this becomes

$$\frac{e(0)-e_o}{e_o}=-\left\{\frac{R_2\sigma}{(\sigma-\tau)\theta_m(1-\gamma k)}+\frac{\lambda_3-c_6}{c_4}\frac{F}{m}\underbrace{\left[\frac{(\sigma-\tau)\theta_m K}{i\mu(1-\epsilon)}-\frac{1}{1-\gamma k}\right]}_{\text{Positive for } F^*<F_o}\right\}\frac{dX}{ER_2}<0, \tag{A1}$$

where

$$K=\frac{\pi\mu-\rho s\gamma k}{1-\gamma k}+1-\psi>0.$$

The solution for the jump in the price level is obtained from (1), (2), (28), and (A1):

$$\begin{aligned}\frac{P(0)-P_o}{P_o} &= \frac{e(0)-e_o}{e_o}+\gamma k\frac{E(0)-E_o}{E_o}\\ \Longrightarrow \frac{P(0)-P_o}{P_o} &= -\left\{\frac{R_2}{1-\gamma k}\underbrace{\left[\frac{\sigma}{(\sigma-\tau)\theta_m}-\gamma k\right]}_{\text{Positive for } \sigma>\tau}+\frac{F}{E}\underbrace{\left[\frac{(\sigma-\tau)\theta_m K}{i\mu(1-\epsilon)}-\frac{1}{1-\gamma k}\right]}_{\text{Positive for } F^*>F_o}\right.\\ &\quad\left.\times\left[\frac{\lambda_3}{c_4\mu}+\underbrace{\frac{\sigma}{(\sigma-\tau)\theta_m}-\gamma k}_{\text{Positive for } \sigma>\tau}\right]\right\}\frac{dX}{ER_2}<0. \qquad \text{(A2)}\end{aligned}$$

Finally, equation (22) and the first-order conditions (7) and (8) yield

$$\frac{k_2}{k_3}\left(\frac{m}{F}\right)^{-1/\sigma}=\frac{\eta(r+\pi)}{r(\eta+\gamma\tau)-\rho\gamma\tau}. \tag{A3}$$

m/F rises and r falls, so π must decrease at $t=0$. This guarantees continuously lower inflation on the transition path to the new steady state. (After jumping at $t=0$, the path of π is continuous, with $\dot{\pi}=h(F^*-F_o)$. For $h>0$, $\dot{\pi}<0$. When $h<0$, $\dot{\pi}>0$, implying that π approaches its steady-state level from below.)

NOTES

1. The Poverty Reduction Strategy Paper (PRSP), articulates a country's medium-term macroeconomic and public expenditure program. In the majority of countries the PRSP anticipates increased public expenditures financed in part by sustained increases in net aid flows, including from debt relief payments arising from the Highly Indebted Poor Countries (HIPC) initiative.

2. A growing literature emphasizes the importance of capital flows in sub-Saharan Africa. See, for example, Asea and Reinhart (1996), Bhindra et al (1999), Collier et al (2002), and Fedderke and Liu (2002). Empirical work by, amongst others, Fielding (1994), Adam (1999), Henstridge (1999) and Nachega (2001) finds significant currency-substitution effects on the demand for domestic monetary aggregates.

3. Dissatisfaction with the policy choices is evident in Ouanes, Nyawata and Jonassen (2001) radical suggestion (p.21) that aid inflows should not exceed a country's "sterilization capacity."

4. Calvo, Leiderman and Reinhart (1994) argue that it is best to absorb capital inflows through a float on the grounds that appreciation of the nominal exchange rate reconciles appreciation of the real rate with with lower inflation. Schadler et al. (1993) and Fernandez-Arias and Montiel (1996) worry, however, that floating may result not only in extreme volatility of the nominal exchange rate but also in greater appreciation of the real rate. Assessments of sterilization are equally diverse and inconclusive. Calvo (1991) and Calvo, Leiderman and Reinhart hold that sterilization is self-defeating: the higher real interest rates that accompany bond sales worsen inflationary pressures by increasing the fiscal deficit; moreover, higher interest rates attract additional capital inflows, necessitating further bond sales, etc. Echoing this position, Schadler et al. first assert that "sterilization is discredited as a response to capital inflows" (p.3), but then acknowledge that "sterilization is often effective in insulating an economy for short periods of time from some of the unwanted effects of surges in inflows" (p.30). This latter view is close to that of Lopez-Mejia (1999), Khan and Reinhart (1995), Held and Szalachman (1998), and Fernandez-Arias and Montiel (1996), who contend that sterilization is effective in the short run but hard to sustain because of rising fiscal costs.

5. In our working paper (Buffie et al., 2003) we use data from Gupta et al (2002), covering a sample of 39 low-income countries from 1991 to 2000, to assess the contribution of aid (grants plus net loan disbursements) to the fiscal deficit and the domestic financing requirement. In sub-Saharan Africa between 1999 and 2001, 21 cents of the aid dollar substituted, on average, for domestic financing. The ex post budget financing component rises to nearly 30 percent in sub-Saharan Africa in the second half of the 1990s.

6. Ghana has been struggling off and on for twenty years to find the right policy response to large aid inflows. See Younger (1992) for an account of the 1987-1994 period.

7. For small changes, γ can be treated as a constant. In the numerical simulations, γ varies endogenously with P_n. (We do not assume Cobb-Douglas preferences.)

8. We have omitted some intermediate steps. The first is

$$\left(\frac{V_{EP}}{V_{EE}D_n} - \tau\right)\gamma\frac{\dot{P}_n}{P_n} + \frac{\dot{E}}{E} = \tau(r - \rho),$$

where $V_{EP} \equiv \partial V_E/\partial P_n$. [Note from (2) that $\pi - \chi = \gamma \dot{P}_n/P_n$.] To get rid of the awkward V_{ij} terms, recall Roy's identity $D_n = -V_P(P_n, E)/V_E(P_n, E)$. For homothetic preferences, $V_{EP}/V_{EE}D_n = \tau - 1$.We also have from (1) that $dP_n/P_n = kdE/E$. Substituting for $\dot{P}_n/P_n$ and for $V_{EP}/V_{EE}D_n$ produces equation (10) in the text.

9. For simplicity, we ignore interest payments on reserves. This ensures that the long-run impact of aid on real income and the fiscal deficit is independent of the exchange rate regime.

10. When $\epsilon > 1$, long-run comparative statics results are perverse and the equilibrium path is indeterminate.

11. To illustrate, suppose $\tau = \eta = .25$, $\gamma = .50$, $\pi = .15$, $\rho = \mu = F/E = .10$, $s = .15$, $\psi = .75$, and that aid increases by 2% of national income. Holdings of foreign currency then decrease as long as σ exceeds .565. And for $\sigma = 1.5$, a value at the low end of empirical estimates, cumulative private inflows are big — 2% of national income.

12. Saddlepoint stability requires $c_2c_4 - c_1c_5 < 0$, which holds for $\epsilon < 1$.

13. See Lluch et al. (1977, chapter 3), Deaton and Muellbauer (1980, p.71), Blundell (1988, p.35), and Blundell, Pashardes, and Weber (1993, Table 3b, p.581).

14. .25-.50 is the range defined by the lower- and upper-bound estimates of τ for Ghana in Ogaki, Ostry, and Reinhart (1996).

15. See Kamin and Ericsson (1993), Savastano (1996), and Balino, Bennett, and Borensztein (1999).

16. The Ghanaian government dedicates 20% of HIPC debt relief to deficit reduction (IMF 2004, p.31). Empirical estimates for Ghana place ψ at .23, right on the regression line for Africa. (See note 5.)

17. The paths for inflation, the real interest rate, the current account balance, etc. were generated by substituting the linearized solutions for the variables in the core dynamic system into the static nonlinear model. This "semi-Novales" procedure retains more of the nonlinear structure of the model and thereby reduces linearization error. In the full Novales procedure, the linearized solution for the core dynamic system is used only to impose stability conditions on the relationship between the paths of the state variables and the paths of the jump variables. The solution paths for all endogenous variables (r, π, etc.) and for the state variables are computed from the original nonlinear model. We computed fifteen solutions

using both the semi-Novales and full Novales procedures. The results were very close in every case (often differences did not appear until the third or fourth decimal place). Since the semi-Novales procedure is faster and easier to program, we used it to generate the solutions.

18. Since they will shortly be used in linearizing (10) and (29), the solutions in (30) and (31) are evaluated at the stationary equilibrium.

19. The steady state is a saddle point iff

$$n_{17} - n_{16}J/E < 0,$$

or

$$\gamma\rho s - \eta - (\eta+\gamma)\frac{\mu}{\Delta}\left[\frac{J}{F}\tau(\rho+\pi\theta_f) + \sigma\pi(1-\underbrace{\theta_f J/F}_{<1})\right] < 0.$$

The second and third terms in the stability condition are negative. The first term is positive, however, because the feedback effects between changes in expenditure, the real exchange rate, and the real interest payments on the internal debt are mutually reinforcing. This is a nuisance, not a serious problem. Instability is a threat only if η is unusually small and variations in the real exchange rate unrealistically large. Even in the extreme case where $\gamma = .80$ and real interest payments on the internal debt are 10% of national income, $\eta > .10$ ensures stability.

20. Aid is funneled to the private sector through lump-sum transfers. Since $\gamma_o = .50$, approximately half of the extra aid money is spent on nontraded goods. If aid financed some project that involved a larger component of nontradables spending, the initial increase in the price level would be greater. When all aid is spent on nontraded goods, for example, the upward jump in P at $t = 0$ is about twice as large as in Table 2.

21. Due to continuous-time compounding, the increase in the price level over the calendar year is greater than 10% when $\dot{P}/P = \pi = .10$ (i.e., $e^{.25} - 1 = .284$). The figure reported for inflation in the first year is the constant level of inflation that produces the same increase in the price level at $t = 1$ as in the model.

22. Forecasts are mathematically correct and weighted by the probability the price quote wil be in force at time t.

23. To solve the floating rate model, real money balances measured in units of the nontraded good has to be introduced as a state variable.

24. We assume fast price adjustment: $\delta = 5$ in Tables 3 and 4.

25. Paying off the debt more quickly results in higher real interest rates.

26. This drawback of sterilization is emphasized by Schadler et al. (1993) and Calvo, Leiderman and Reinhart (1994).

27. Interestingly, numerous empirical estimates find offset coefficients close to those in Table 6. See Agenor and Montiel (1999, p.204).

28. Note that in the case where $\tau = .50$ and $\sigma = .75$ reserve purchases at $t = 0$ are greater than in a crawling peg. This makes an odd impression. Shouldn't a managed float involve less, not more, intervention than a crawling peg? Ceteris paribus, the answer is yes. But other things are not equal in Tables 2 and 7. For $\tau = .50$ and $\sigma = .75$, inflation and the rate of currency depreciation χ decrease more in the short run when the government operates a managed float instead of a crawling peg. ($\chi = .093$ at $t = 0$. In a crawling peg, χ is constant at the steady-state inflation rate, .131.) This leads to larger capital inflows and greater reserve accumulation in the short run even though appreciation of the nominal exchange rate bears some of the burden of adjustment.

29. We have not presented results for a pure float and inertial inflation. They are too awful to contemplate.

30. For a couple of reasons, we do not consider the assumption that aid is permanent to be especially limiting. First, empirical measures of aid generally show strong persistence in African countries. Even after removing a linear trend, for example, the variance of variables like real aid per capita or the aid-to-GNP ratio tends to be dominated by low-frequency components. [Thus while Bulir and Annan (2001) emphasize the volatility of aid, their analysis applies to the short-run "cycle" — i.e., the component that remains after using the Hodrick-Prescott filter to remove a slow-moving nonlinear "trend." The trend itself shows very substantial persistence, even when applied to linearly detrended aid series.] Second, intutition suggests that temporary aid inflows will produce results qualitatively similar to but quantitatively weaker than in the case of permanent aid flows. (The present model applies, of course, if the government converts temporary aid into permanent aid by spending only its annuity value.)

31. Theory suggests that the crowding-in effect on private investment could be quite strong. See Buffie (1995).

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Table 1: Transition path in a pure float.

	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
	τ = .25 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.140	.142	.144	.145	.145	.145	.146
r	.076	.077	.078	.079	.079	.079	.08
RER	.88	.88	.89	.89	.89	.89	.89
CA	-.003	-.002	-.001	0	0	0	0
	τ = .50 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.131	.131	.131	.131	.131	.131	.131
r	.08	.08	.08	.08	.08	.08	.08
RER	.89	.89	.89	.89	.89	.89	.89
CA	0	0	0	0	0	0	0
	τ = .25 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.079	.093	.103	.110	.115	.118	.125
r	.064	.066	.069	.071	.074	.076	.08
RER	.81	.83	.85	.87	.87	.88	.89
CA	-.023	-.015	-.010	-.007	-.004	-.003	0
	τ = .50 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.083	.093	.097	.100	.102	.103	.105
r	.075	.074	.075	.076	.077	.078	.08
RER	.80	.83	.85	.86	.87	.88	.89
CA	-.024	-.016	-.011	-.007	-.005	-.003	0
	τ = .25 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.041	.064	.081	.093	.100	.105	.114
r	.069	.066	.066	.068	.071	.074	.08
RER	.76	.80	.83	.85	.87	.87	.89
CA	-.037	-.024	-.016	-.010	-.007	-.004	0

Table 2: Transition Path in a Crawling Peg.[1]

	$\tau = .25$ and $\sigma = .75$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.152 (.048)	.150 (.198)	.148	.148	.147	.147	.146
r	.094	.088	.085	.083	.082	.081	.08
RER	.91	.90	.90	.90	.89	.89	.89
CA	.006	.004	.003	.001	.001	.001	0
	$\tau = .50$ and $\sigma = .75$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.143 (.032)	.139 (.173)	.136	.135	.134	.133	.131
r	.096	.089	.086	.083	.082	.081	.08
RER	.94	.92	.91	.90	.90	.90	.89
CA	.013	.009	.006	.004	.003	.002	0
	$\tau = .25$ and $\sigma = 2$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.120 (.073)	.122 (.191)	.123	.123	.124	.124	.125
r	.074	.076	.077	.078	.079	.079	.08
RER	.87	.88	.88	.89	.89	.89	.89
CA	-.005	-.003	-.002	-.001	-.001	-.001	0
	$\tau = .50$ and $\sigma = 2$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.108 (.055)	.107 (.161)	.106	.106	.106	.106	.105
r	.083	.082	.081	.081	.080	.080	.08
RER	.90	.90	.89	.89	.89	.89	.89
CA	.003	.002	.001	.001	.001	0	0
	$\tau = .25$ and $\sigma = 3$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.102 (.090)	.106 (.190)	.109	.111	.112	.113	.114
r	.070	.072	.074	.076	.077	.078	.08
RER	.85	.86	.87	.88	.88	.89	.89
CA	-.012	-.007	-.005	-.003	-.002	-.001	0

[1] The numbers in parentheses in the cells for t = 0 and t = 1 are, respectively, the percentage increase in the price level at t = 0 and the inflation rate in the first year inclusive of the initial price level jump.

Table 3: Transition path in a pure float when nontradables prices are sticky.

	τ = .25 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.144	.143	.145	.145	.146	.146	.146
r	.143	.093	.083	.080	.080	.080	.08
RER	.83	.87	.88	.89	.89	.89	.89
CA	-.005	-.002	-.001	-.001	0	0	0
Q_n	-.025	-.007	-.002	-.001	0	0	0
	τ = .50 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.095	.120	.128	.131	.131	.131	.131
r	.180	.104	.086	.082	.080	.080	.08
RER	.80	.86	.88	.89	.89	.89	.89
CA	.001	0	0	0	0	0	0
Q_n	-.055	-.016	-.004	-.001	0	0	0
	τ = .25 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.075	.092	.105	.112	.116	.119	.125
r	.197	.101	.081	.077	.076	.077	.08
RER	.73	.80	.84	.86	.87	.88	.89
CA	-.025	-.016	-.010	-.007	-.004	-.003	0
Q_n	-.045	-.017	-.008	-.004	-.002	-.001	0
	τ = .50 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.006	.067	.090	.098	.101	.103	.105
r	.261	.119	.087	.080	.078	.078	.08
RER	.68	.78	.83	.86	.87	.88	.89
CA	-.021	-.016	-.011	-.007	-.005	-.003	0
Q_n	-.087	-.030	-.011	-.004	-.002	-.001	0
	τ = .25 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.030	.061	.083	.095	.102	.106	.114
r	.236	.111	.083	.076	.075	.076	.08
RER	.67	.76	.81	.84	.86	.87	.89
CA	-.039	.025	-.016	-.010	-.006	-.004	0
Q_n	-.054	-.023	-.011	-.006	-.004	-.002	0

Table 4: Transition path in a crawling peg when nontradables prices are sticky.

	τ = .25 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.190	.165	.155	.150	.148	.147	.146
r	.043	.071	.079	.081	.081	.081	.08
RER	1	.94	.91	.90	.90	.89	.89
CA	.011	.007	.004	.002	.001	.001	0
Q_n	.036	.013	.005	.002	.001	.001	0
	τ = .50 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.171	.148	.140	.136	.134	.133	.131
r	.064	.082	.085	.084	.083	.082	.08
RER	1	.94	.92	.91	.90	.90	.89
CA	.013	.009	.006	.004	.003	.002	0
Q_n	.033	.011	.004	.002	.001	.001	0
	τ = .25 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.183	.146	.132	.127	.125	.125	.125
r	.003	.050	.069	.076	.078	.079	.08
RER	1	.94	.90	.89	.89	.89	.89
CA	.003	.001	0	0	0	0	0
Q_n	.053	.018	.006	.002	.001	0	0
	τ = .50 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.158	.124	.113	.109	.107	.106	.105
r	.027	.066	.077	.080	.081	.081	.08
RER	1	.93	.91	.90	.90	.89	.89
CA	.004	.004	.003	.002	.001	.001	0
Q_n	.051	.015	.005	.002	.001	0	0
	τ = .25 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.181	.136	.120	.115	.114	.113	.114
r	-.015	.041	.064	.073	.077	.078	.08
RER	1	.92	.89	.89	.89	.89	.89
CA	-.002	-.003	-.002	-.002	-.001	0	0
Q_n	.065	.021	.007	.002	.001	0	0

Table 5: Transition path in a crawling peg with temporary sterilization.[1]

	τ = .25 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.181 (.015)	.166 (.188)	.157	.152	.149	.147	.146
r	.427	.171	.113	.094	.086	.082	.08
RER	.97	.92	.89	.88	.87	.87	.89
CA	.022	.008	.001	-.003	-.004	-.005	0
	τ = .35 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.178 (.008)	.162 (.177)	.153	.147	.144	.142	.141
r	.290	.145	.106	.092	.085	.082	.08
RER	.99	.93	.90	.89	.88	.87	.89
CA	.026	.011	.003	-.001	-.004	-.005	0
	τ = .50 and σ = .75[2]						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.169 (0)	.154	.145	.139	.136	.133	.131
r	.210	.127	.100	.090	.085	.082	.08
RER	1	.94	.91	.89	.88	.88	.89
CA	.029	.014	.006	.001	-.002	-.004	0
	τ = .25 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.145 (.042)	.136 (.181)	.131	.128	.126	.125	.125
r	.235	.126	.097	.087	.082	.080	.08
RER	.92	.90	.88	.87	.87	.87	.89
CA	.009	.001	-.003	-.005	-.006	-.006	0
	τ = .35 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.141 (.034)	.131 (.169)	.125	.121	.119	.118	.117
r	.197	.119	.096	.087	.083	.081	.08
RER	.94	.90	.89	.88	.87	.87	.89
CA	.013	.004	-.001	-.004	-.005	-.006	0
	τ = .50 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.134 (.021)	.122 (.149)	.115	.111	.108	.106	.105
r	.173	.114	.094	.086	.083	.081	.08
RER	.96	.92	.89	.88	.88	.87	.89
CA	.018	.008	.001	-.002	-.004	-.005	0

Sterilization Table (continued)							
	τ = .25 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.130 (.056)	.122 (.180)	.118	.115	.114	.113	.114
r	.182	.109	.090	.083	.080	.079	.08
RER	.90	.88	.87	.87	.86	.87	.89
CA	.003	-.003	-.006	-.007	-.007	-.007	0
	τ = .35 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.127 (.047)	.117 (.168)	.112	.108	.107	.106	.106
r	.167	.108	.090	.083	.081	.079	.08
RER	.91	.89	.87	.87	.87	.87	.89
CA	.007	-.001	-.004	-.006	-.007	-.007	0

[1] The numbers in parentheses in the cells for t = 0 and t = 1 are, respectively, the percentage increase in the price level at t = 0 and the inflation rate in the first year inclusive of the initial price level jump.

[2] Bond sales at t = 0 are 7.8% of initial GDP.

Table 6: The path of capital flows and the offset coefficient when the central bank engages in temporary sterilization.

	Path of F (F_o = .15)[1]				
τ	t = 0	t = 1	t = 2	Long Run	σ
.25	.066 (.126)	.095 (.132)	.116 (.136)	.143	.75
.35	.069 (.124)	.097 (.132)	.118 (.137)	.146	
.50	.071 (.121)	.100 (.131)	.120 (.138)	.151	
.25	.028 (.102)	.048 (.096)	.065 (.092)	.125	2
.35	.029 (.091)	.048 (.089)	.064 (.087)	.084	
.50	.029 (.077)	.046 (.079)	.061 (.080)	.083	
.25	.013 (.088)	.027 (.074)	.039 (.064)	.049	3
.35	.013 (.124)	.025 (.063)	.035 (.057)	.047	

	Offset Coefficient[2]			
τ	σ = .75	σ = 2	σ = 3	
.25	.75	.93	.94	
.35	.69	.77	.76	
.50	.64	.60	-	

[1] The number in parentheses is the value of F when there is no temporary sterilization.

[2] The offset coefficient is calculated as $[F(0)_{ns} - F(0)]/[b(0) - b_o]$, where F(0) and $F(0)_{ns}$ are the post-jump values of foreign currency holdings at t = 0 with and without sterilization.

Table 7: Transition path in a managed float.[1]

	τ = .25 and σ = .75 (Ω = .50)						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.133	.139	.142	.144	.145	.145	.146
r	.086	.083	.082	.081	.080	.082	.08
RER	.90	.89	.89	.89	.89	.89	.89
CA	.002	.001	.001	0	0	0	0
Z	.068 (.074)	.065	.062	.063	.061	.061	.061 (.071)
	τ = .50 and σ = .75 (Ω = .15)						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.105	.118	.124	.127	.129	.130	.131
r	.100	.089	.085	.083	.081	.081	.08
RER	.93	.91	.90	.90	.89	.89	.89
CA	.011	.006	.004	.002	.001	.001	0
Z	.084 (.080)	.079	.076	.074	.073	.072	.071 (.083)
	τ = .25 and σ = 2 (Ω = .15)						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.125	.125	.125	.125	.125	.125	.125
r	.071	.073	.075	.076	.077	.078	.08
RER	.86	.87	.88	.88	.88	.89	.89
CA	-.009	-.006	-.004	-.002	-.002	-.001	0
Z	.078 (.098)	.083	.085	.087	.088	.089	.091 (.102)
	τ = .50 and σ = 2 (Ω = 1)						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.113	.109	.107	.106	.106	.106	.105
r	.079	.079	.080	.080	.080	.080	.08
RER	.89	.89	.89	.89	.89	.89	.89
CA	-.001	-.001	0	0	0	0	0
Z	.107 (.123)	.111	.113	.114	.114	.115	.115 (.124)
	τ = .25 and σ = 3 (Ω = .15)						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.105	.109	.111	.112	.113	.113	.114
r	.071	.071	.072	.074	.076	.077	.08
RER	.83	.85	.87	.87	.88	.88	.89
CA	-.017	-.011	-.007	-.004	-.003	-.002	0
Z	.086 (.113)	.094	.100	.103	.105	.106	.109 (.122)

[1] The row for Z shows the path of reserves. Z equals .05 initially. The number in parentheses in the cells for t = 0 and Long Run is the level of reserves in a crawling peg.

Table 8: Transition in a crawling peg when aid increases gradually.[1]

	τ = .25 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.141 (.034)	.143 (.175)	.143	.142	.141	.140	.146
r	.089	.094	.093	.091	.088	.086	.08
RER	.94	.93	.92	.91	.90	.89	.89
CA	-.016	-.007	-.002	0	.001	.001	0
	τ = .50 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.132 (.017)	.132 (.149)	.130	.129	.127	.126	.131
r	.094	.093	.090	.088	.086	.084	.08
RER	.97	.95	.93	.92	.91	.90	.89
CA	-.008	-.001	.002	.003	.003	.003	0
	τ = .25 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.109 (.060)	.115 (.170)	.117	.118	.118	.118	.125
r	.071	.078	.082	.084	.084	.084	.08
RER	.89	.90	.90	.90	.89	.89	.89
CA	-.027	-.014	-.007	-.003	-.001	0	0
	τ = .50 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.098 (.040)	.101 (.139)	.101	.101	.10	.10	.105
r	.081	.084	.084	.085	.084	.083	.08
RER	.93	.92	.91	.91	.90	.89	.89
CA	-.019	-.008	-.003	0	.001	.001	0
	τ = .25 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.091 (.076)	.100 (.170)	.105	.106	.107	.107	.114
r	.069	.072	.077	.081	.082	.082	.08
RER	.87	.88	.89	.89	.89	.89	.89
CA	-.034	-.018	-.009	-.004	-.002	-.001	0

[1] The numbers in parentheses in the cells for t = 0 and t = 1 are, respectively, the percentage increase in the price level at t = 0 and the inflation rate in the first year inclusive of the initial price level jump.

Table 9: Transition Path in a pure float when nontradables prices are sticky and aid increases gradually.

	τ = .25 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.178	.159	.150	.145	.142	.140	.146
r	.128	.088	.080	.078	.078	.079	.08
RER	.85	.87	.88	.88	.88	.88	.89
CA	-.033	-.021	-.013	-.008	-.005	-.004	0
Q_n	-.010	0	.002	.002	.001	.001	0
	τ = .50 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.127	.132	.131	.129	.126	.125	.131
r	.161	.099	.084	.081	.080	.080	.08
RER	.82	.87	.88	.88	.88	.88	.89
CA	-.029	-.019	-.012	-.008	-.005	-.003	0
Q_n	-.039	-.009	-.001	.001	.001	.001	0
	τ = .25 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.102	.103	.107	.110	.111	.113	.125
r	.183	.096	.078	.075	.075	.076	.08
RER	.74	.80	.83	.85	.86	.87	.89
CA	-.053	-.035	-.026	-.015	-.010	-.006	0
Q_n	-.034	-.012	-.004	-.002	-.001	-.001	0
	τ = .50 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.029	.074	.090	.095	.096	.096	.105
r	.24	.114	.086	.079	.078	.078	.08
RER	.68	.78	.82	.85	.86	.87	.89
CA	-.051	-.035	-.023	-.015	-.010	-.007	0
Q_n	-.075	-.025	-.008	-.003	-.001	-.001	0
	τ = .25 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.053	.071	.085	.093	.098	.101	.114
r	.222	.106	.081	.075	.074	.075	.08
RER	.67	.76	.81	.83	.85	.86	.89
CA	-.067	-.044	-.028	-.018	-.012	-.007	0
Q_n	-.045	-.019	-.009	-.005	-.003	-.002	0

Table 10: Transition path in a crawling peg when sticky prices stem from inertial inflation ($\Lambda = 1$, $\alpha = 2$).

	$\tau = .25$ and $\sigma = .75$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.210	.192	.168	.147	.134	.130	.146
r	.019	.050	.081	.103	.111	.107	.08
RER	1	.89	.84	.82	.83	.87	.89
CA	.017	.008	.002	-.001	-.003	-.002	0
Q_n	.025	-.017	-.035	-.036	-.027	-.014	0
	$\tau = .50$ and $\sigma = .75$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.204	.176	.147	.126	.116	.117	.131
r	.029	.060	.086	.101	.103	.098	.08
RER	1	.88	.84	.83	.85	.88	.89
CA	.016	.012	.007	.003	.001	0	0
Q_n	.026	-.027	-.044	-.040	-.024	-.007	0
	$\tau = .25$ and $\sigma = 2$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.207	.182	.151	.123	.105	.100	.125
r	-.023	.018	.065	.102	.118	.115	.08
RER	1	.87	.80	.79	.81	.85	.89
CA	.010	.003	-.003	-.005	-.005	-.004	0
Q_n	.039	-.020	-.044	-.046	-.034	-.017	0
	$\tau = .50$ and $\sigma = 2$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.199	.163	.124	.095	.082	.083	.105
r	-.016	.034	.077	.102	.109	.102	.08
RER	1	.86	.80	.80	.83	.87	.89
CA	.008	.007	.003	0	-.001	-.002	0
Q_n	.043	-.033	-.057	-.051	-.031	-.008	0
	$\tau = .25$ and $\sigma = 3$						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.206	.178	.143	.111	.090	.085	.114
r	-.042	.002	.057	.102	.122	.119	.08
RER	1	.85	.79	.78	.80	.84	.89
CA	.005	0	-.005	-.007	-.007	-.005	0
Q_n	.043	-.033	-.057	-.051	-.031	-.008	0

Table 11: Transition path in a crawling peg when sticky prices stem from inertial inflation ($\Lambda = 1$, $\alpha = 5$).

	τ = .25 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.233	.182	.148	.135	.138	.143	.146
r	-.003	.067	.102	.105	.094	.084	.08
RER	1	.88	.86	.87	.89	.90	.89
CA	.015	.006	.001	0	0	.001	0
Q_n	.028	-.015	-.021	-.013	-.003	.002	0
	τ = .50 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.223	.159	.127	.123	.128	.132	.131
r	.007	.079	.102	.098	.088	.082	.08
RER	1	.89	.87	.89	.90	.90	.89
CA	.015	.010	.006	.003	.002	.001	0
Q_n	.029	-.022	-.022	-.009	-.001	.001	0
	τ = .25 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.242	.170	.121	.105	.110	.120	.125
r	-.057	.037	.095	.107	.096	.083	.08
RER	1	.85	.83	.85	.88	.90	.89
CA	.008	-.001	-.004	-.003	-.001	0	0
Q_n	.044	-.020	-.028	-.016	-.003	.004	0
	τ = .50 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.235	.139	.095	.090	.098	.105	.105
r	-.051	.060	.100	.099	.088	.080	.08
RER	1	.86	.85	.87	.89	.90	.89
CA	.007	.005	.002	.001	0	0	0
Q_n	.046	-.029	-.029	-.012	0	.003	0
	τ = .25 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.249	.165	.109	.090	.096	.108	.114
r	-.084	.023	.092	.108	.096	.082	.08
RER	1	.84	.81	.84	.88	.90	.89
CA	.003	-.004	-.006	-.005	-.002	-.001	0
Q_n	.054	-.022	-.032	-.018	-.003	.005	0

Table 12: Transition path in a managed float when sticky prices stem from inertial inflation ($\Lambda = 1$, $\alpha = 5$).[1]

	τ = .25 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.169	.173	.163	.157	.153	.151	.146
r	-.024	.065	.066	.068	.070	.072	.08
RER	.92	.89	.89	.89	.89	.89	.89
CA	.009	.007	.003	.002	.001	0	0
Q_n	0	-.015	-.008	-.004	-.002	-.001	0
	τ = .50 and σ = .75						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.169	.163	.150	.143	.139	.137	.131
r	0	.070	.72	.074	.075	.076	.08
RER	.93	.89	.89	.89	.89	.89	.89
CA	.010	.008	.004	.002	.001	.001	0
Q_n	0	-.018	-.010	-.006	-.003	-.002	0
	τ = .25 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.168	.167	.152	.144	.139	.136	.125
r	-.046	.061	.060	.061	.062	.064	.08
RER	.93	.89	.89	.89	.89	.89	.89
CA	.010	.007	.003	.002	.001	0	0
Q_n	0	-.017	-.010	-.005	-.003	-.002	0
	τ = .50 and σ = 2						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.176	.155	.138	.128	.122	.118	.105
r	-.020	.060	.064	.065	.068	.060	.08
RER	.93	.88	.88	.89	.89	.89	.89
CA	.010	.008	.004	.002	.001	.001	0
Q_n	0	-.020	-.012	-.007	-.004	-.003	0
	τ = .25 and σ = 3						
	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	Long Run
π	.167	.161	.145	.136	.130	.126	.114
r	-.053	.055	.056	.057	.059	.062	.08
RER	.92	.88	.88	.89	.89	.89	.89
CA	.009	.007	.003	.002	.001	0	0
Q_n	0	-.018	-.010	-.006	-.004	-.002	0

[1] $\Omega = 3$ and reserve purchases at t = 0 are 50% of reserve purchases in a crawling peg.