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Riding the wave: Monetary responses to aid surges in low-income countries

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A B S T R A C T

We focus on the management of highly persistent shocks to aid 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 show that a managed float, with little or no sterilization of increases in the monetary base, supports the smooth absorption of the increased aid without incurring higher inflation, higher real interest rates or over-shooting of the real exchange rate.

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. In many episodes, higher aid flows have attracted equally large inflows of private capital.[1] The combined surge of official and private capital flows is beneficial in the long run but confronts policy makers

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[1] A growing literature emphasizes the importance of capital flows in sub-Saharan Africa. See Asea and Reinhart (1996), Bhindra et al. (1999), Nachega (2001), Collier et al. (2002), Fedderke and Liu (2002), and Mohanty and Turner (2006).

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with dramatic monetary management problems in the short run. Case studies (Berg et al., 2007; Foster and Killick, 2006) recount a cycle of confusion and frequent policy shifts. Typically the policy cycle starts with the central bank buying up large quantities of aid dollars in an effort to stabilize the exchange rate. The rapid increase in the monetary base and the boom in aid spending, however, create fears of higher inflation. Striving to reassert monetary discipline, the authorities sterilize capital inflows with bond sales only to see real interest rates and the cost of internal debt service rise sharply. So policy shifts again. To reduce interest rates without losing control of the money supply, the central bank suspends bond sales and withdraws from the foreign exchange market. But this leads back to square one and concerns about excessive appreciation of the currency. In short, policy makers need help in answering one difficult question: What combination of changes in inflation, nominal and real exchange rates, and real interest rates should be used to absorb a persistent aid surge?[2]

The natural place to look for advice 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." The lack of firm conclusions has *inter alia* prevented the literature from settling on a coherent bottom line for policy. Calvo et al. (1994), for example, recommend countering the undesirable 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 a dynamic general equilibrium model for an *array* of policy scenarios that delineate the tradeoffs associated with alternative strategies for managing large capital inflows. Having the African context in mind, we calibrate the model(s) to data from Ghana, a country that recently experienced a surge in official capital flows through debt forgiveness.

For the most part, the analysis is positive. Our principal objective is to characterize how different policy packages affect the paths of key macroeconomic variables. The results could be fed into a social welfare function, but this seems superfluous. It is clear from the case studies cited above that the goal of economic policy is to absorb the extra aid without suffering any discomfort from higher inflation, higher real interest rates, lower output, or overshooting of the real exchange rate. Accordingly, when judging outcomes, we employ a loose minimax criterion: "Successful" policies avoid all tradeoffs; they produce better results for some target variables without asking the government to tolerate worse results for others.

The main body of the paper is organized into four sections. Section 2 develops the core structure of an optimizing two-sector currency substitution model in which aid accrues directly to the public sector. Twenty-five percent of the aid inflow is used to lower the fiscal deficit. Although deficit

[2] See the discussion of Uganda and Tanzania's experiences with aid inflows in Buffie et al. (2004). Dissatisfaction with the policy choices is evident in Ouanes et al. (2001) radical suggestion (p. 21) that aid inflows should not exceed a country's "sterilization capacity."

reduction purchases lower inflation in the long run, management of the transition path is complicated by large private capital inflows and by demand pressures from higher aid spending.

In Sections 3 and 4 we solve the model for the polar cases of a pure float and a crawling peg. It turns out that neither of the polar exchange rate regimes avoids difficult tradeoffs. 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.

Seeking a wider menu of choices, we examine two alternative strategies in Section 5: (i) temporary sterilization of capital inflows in a crawling peg and (ii) a managed float that targets the long-run equilibrium real exchange rate. Sterilization has limited appeal. Temporary, *very large* bond sales can reduce the initial price level spike by 40–70%; but the spike that remains is large in absolute terms (the price level, P jumps 2–6%), 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 "manage" means to lean heavily against nominal appreciation, moving the float 60–80% of the way toward the crawling peg end of the continuum.

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 M, foreign currency F, and government bonds B. Bonds are indexed to the price level P, so $B = Pb$, where $b \equiv B/P$. Other notational conventions are as follows: C_i and Q_i are consumption and output in sector i; e is the nominal exchange rate; and P_n and E are the relative price of the nontraded good and aggregate real expenditure measured in dollars (i.e., units of the traded good).

Preferences and the private agent's optimization problem:

All economic decisions in the private sector are controlled by a representative agent who derives utility from consumption of traded and nontraded goods and from the liquidity services generated by holdings of domestic and foreign currency. To obtain concrete results, we assume preferences take the form

$$U = \int_0^\infty \left[\frac{C(C_n, C_T)^{1-1/\tau}}{1-1/\tau} + h\frac{\phi(M/P, eF/P)^{1-1/\tau}}{1-1/\tau}\right] \mathrm{e}^{-\rho t}\,\mathrm{d}t, \tag{1}$$

where

$$C(C_n, C_T) = [k_0 C_T^{(\beta-1)/\beta} + k_1 C_n^{(\beta-1)/\beta}]^{\beta/(\beta-1)},$$
$$\phi(M/P, eF/P) = [k_2(M/P)^{(\sigma-1)/\sigma} + k_3(eF/P)^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)},$$

are linearly homogeneous CES aggregator functions; h and $k_0 - k_3$ are constants; ρ is the pure time preference rate; τ is the intertemporal elasticity of substitution; β is the elasticity of substitution between traded and nontraded consumer goods; and σ is the elasticity of substitution between domestic and foreign currency.

The private agent solves his optimization problem in two stages. In the first stage, C_n and C_T are chosen to maximize $C(C_n, C_T)$ subject to the constraint $P_n C_n + C_T = E$. The optimal choices $\bar{C}_n$ and $\bar{C}_T$ are subsumed in the indirect utility function

$$V(P_n, E) = C[\bar{C}_n(P_n, E), \bar{C}_T(P_n, E)] = E/c(P_n),$$

where

$$c(P_n) = (k_0^\beta + k_1^\beta P_n^{1-\beta})^{1/(1-\beta)}.$$

As a byproduct of optimization, we get the solution for the exact consumer price index:[3]

$$P = ec(P_n). \tag{2}$$

For future use, note also that

$$\pi = \chi + \gamma \dot{P}_n / P_n, \tag{3}$$

where $\pi = \dot{P}/P$ is the inflation rate; $\chi = \dot{e}/e$ is the rate of currency depreciation; and $\gamma = k_1^\beta P_n^{1-\beta}/[k_0^\beta + k_1^\beta P_n^{1-\beta}]$ is the consumption share of the nontraded good.[4]

In the second stage of optimization, the private agent chooses asset holdings and expenditure to maximize

$$U = \int_0^\infty \left\{ \frac{[E/c(P_n)]^{1-1/\tau}}{1-1/\tau} + h \frac{\phi(M/P, eF/P)^{1-1/\tau}}{1-1/\tau} \right\} e^{-\rho t}\, dt, \tag{1'}$$

subject to the budget constraint

$$\frac{\dot{M}}{e} + \frac{P}{e}\dot{b} + \dot{F} = P_n Q_n + Q_T + \frac{P}{e} g + \frac{P}{e} rb - E, \tag{4}$$

where g is real lump-sum transfers and r is the real interest rate. Let the traded good serve as the numeraire and define $m \equiv M/e$ and $A \equiv m + (P/e)b + F$ to be real money balances and real wealth measured in dollars. Since

$$\dot{M}/e = \dot{m} + \chi m,$$
$$\dot{A} = \dot{m} + \frac{P}{e}\dot{b} + \frac{P}{e} b(\pi - \chi) + \dot{F},$$

and[5]

$$\phi(M/P, eF/P) = \phi(m, F)/c(P_n),$$

the agent's optimization problem can then be written as

$$\underset{\{m,F,E\}}{Max}\ U = \int_0^\infty \left[\frac{E^{1-1/\tau}}{1-1/\tau} + h \frac{\phi(m,F)^{1-1/\tau}}{1-1/\tau} \right] c(P_n)^{(1-\tau)/\tau} e^{-\rho t}\, dt, \tag{1''}$$

subject to

$$\dot{A} = P_n Q_n + Q_T + cg + (r + \pi - \chi)(\underbrace{A - m - F}_{(P/e)b}) - E - \chi m. \tag{4'}$$

$c(P_n) = P/e$ multiplies g because the traded good is the numeraire but transfers are indexed to the price level. For the same reason, $\pi - \chi$ multiplies $A - m - F$.

On an optimal path,

$$\dot{E}/E - \gamma \dot{P}_n/P_n = \tau(r - \rho), \tag{5}$$
$$h\phi(m,F)^{-1/\tau}\phi_m(m,F) = E^{-1/\tau}(r + \pi), \tag{6}$$
$$h\phi(m,F)^{-1/\tau}\phi_F(m,F) = E^{-1/\tau}(r + \pi - \chi). \tag{7}$$

These conditions hold no surprises. Equation (5) is nothing more than a standard Euler equation (the term on the left side is the percentage change in aggregate real consumption), while (6) and (7) state

[3] It is more common to write the price index as $P = (k_0^\beta e^{1-\beta} + k_1^\beta \tilde{P}_n^{1-\beta})^{1/(1-\beta)}$, where $\tilde{P}_n$ is the nominal price of the nontraded good. This is the same expression as in Equation (2).

[4] It easy to confirm that $\gamma = P_n C_n / E$. See Equation (9) that follows in the text.

[5] We exploit here linear homogeneity of ϕ and the fact that $P/e = c(P_n)$.

the marginal rate of substitution between consumption and m or F equals the income foregone from holding that type of money.

The nontradables sector:

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

$$C_n = Q_n, \tag{8}$$

where C_n is retrieved from the indirect utility function by invoking Roy's Identity

$$C_n = -\frac{\partial V/\partial P_n}{\partial V/\partial E} = E\frac{k_1^{\beta}P_n^{-\beta}}{k_0^{\beta} + k_1^{\beta}P_n^{1-\beta}}. \tag{9}$$

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

$$\dot{m} = c(P_n)(g + rb) + \dot{Z} - X - \chi m, \tag{10}$$

where X is the sale of aid dollars net of government imports.[6] In the ensuing analysis, a fraction ψ of new aid pays for transfers to the "poor" (i.e., the representative agent); the rest is used for general budget support.

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:

$$\dot{F} + \dot{Z} = P_nQ_n + Q_T + X - E. \tag{11}$$

2.1. The steady-state outcome

The long-run equilibrium is independent of the exchange rate regime. The results in this section apply equally therefore to a crawling peg, a clean float, or some type of managed float.

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

$$h\phi(m,F)^{-1/\tau}\phi_m(m,F) = E^{-1/\tau}(\rho + \pi), \tag{6$'$}$$

$$h\phi(m,F)^{-1/\tau}\phi_F(m,F) = E^{-1/\tau}\rho, \tag{7$'$}$$

$$\pi m = c(P_n)(g + \rho b) - X, \tag{10$'$}$$

$$E = P_nQ_n + Q_T + X. \tag{11$'$}$$

Equations (10′) and (11′) state that aid allows consumption to exceed national income and that revenue from the inflation tax equals the fiscal deficit after grants. (Hereafter we use the shorter term fiscal deficit and omit "after grants.") The other two equations are the steady-state versions of the first-order conditions for domestic and foreign currency. This group of equations and the nontradables market-clearing condition in (8) can be solved for P_n, E, π, m and F as a function of X. From (8) and (11′) we get the obvious results that aid increases consumption and the relative price of the nontraded good:

$$\mathrm{d}E = (1 + \gamma/\eta)\,\mathrm{d}X > 0, \tag{12}$$

$$\mathrm{d}P_n/P_n = \mathrm{d}X/\eta E > 0, \tag{13}$$

where $\eta = \beta(1 - \gamma)$ is the compensated own-price elasticity of demand.

[6] 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.

The impact on the fiscal deficit is more complicated as it involves both direct and indirect effects. Recall that the government spends a fraction ψ of extra aid on poverty reduction. Thus the direct effect on the deficit is favorable: Real transfer payments net of aid decrease by $\mathrm{d}(cg) - \mathrm{d}X = (\psi - 1)\,\mathrm{d}X$. But aid also drives up the relative price of the nontraded good, which increases the internal debt measured in dollars by the amount $(c'P_n/c)cb\,\mathrm{d}P_n/P_n = \gamma cb\,\mathrm{d}X/(\eta E)$. The overall impact on the deficit D is therefore

$$\mathrm{d}D = (\psi - 1 + \gamma s\rho/\eta)\,\mathrm{d}X \gtrless 0, \tag{14}$$

where $s \equiv cb/E$, the ratio of the internal debt to national income inclusive of aid and $E = P_nQ_n + Q_T + X$ at a steady state. We assume $\psi < 1 - \rho s\gamma/\eta$ so that, in keeping with policy makers' intentions, the seigniorage requirement declines.[7]

With the solutions for P_n, E and D in hand, it is now easy to determine how inflation and asset demands change. Equations (6′), (7′) and (10) yield

$$\mathrm{d}\pi = \frac{\mathrm{d}D}{m(1-\varepsilon)} - \frac{\pi}{E(1-\varepsilon)}\,\mathrm{d}E, \tag{15}$$

$$\mathrm{d}F = \frac{(\sigma-\tau)\theta_m F}{i}\,\mathrm{d}\pi + \frac{F}{E}\,\mathrm{d}E, \tag{16}$$

where $i = \rho + \pi$ is the nominal interest rate; θ_j is the share of liquidity services provided by currency j; and $\varepsilon = (\tau\theta_m + \sigma\theta_f)\pi/i$ is the elasticity of money demand with respect to inflation. We assume $\varepsilon < 1$ 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. (When $\varepsilon > 1$, long-run comparative statics results are perverse and the equilibrium path is indeterminate.) The second implies that lower inflation reduces the demand for foreign currency and elicits the return of flight capital. 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.

When more aid flows in, the fiscal deficit declines at the same time that higher consumption raises the demand for domestic and foreign currency. The reduction in the fiscal deficit 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: F decreases provided σ is not unusually small.

This ends the formal notation-intensive part of the paper. Most of the space in the next three sections is devoted to intuitive, non-technical explanations of how aid affects the economy's equilibrium path. Additional equations appear only insofar as they are needed to state important results or describe extensions of the core model. Analysis of additional cases and all of the algebra involved in solving for the steady-state outcome, deriving key conditions, and characterizing the dynamic systems associated with different policy regimes may be found in the long version of the paper available at http://mypage.iu.edu/~ebuffie.[8]

3. Polar exchange rate regimes

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. Since most of the information relevant to this decision is contained in the outcomes at the endpoints of the policy spectrum, we start by investigating the transition path associated with a pure float. Section 3.2 analyzes the polar opposite case of a crawling peg.

[7] This condition holds comfortably when we calibrate the model to the data in Section 3.1.

[8] The long version presents additional results for sterilization in a crawling peg and investigates the robustness of the conclusions to the time profile of aid (gradual vs. sudden increases) and the specification of sticky prices (inertial inflation vs. Calvo-pricing). For an analysis of the outcome when all aid is spent, see Buffie et al. (2004).

3.1. Flexible exchange rates

The Euler equation (5) is part of the dynamic system in every exchange rate regime. To get this equation in the right form, solve (8) and (9) for P_n:

$$\frac{dP_n}{P_n} = \frac{dE}{(\eta+\gamma)E}. \tag{17}$$

Interpret the differentials as time derivatives and substitute for $\dot{P}_n/P_n$ in (5). This delivers

$$\dot{E} = \frac{\tau(\eta+\gamma)}{\eta}E(r-\rho). \tag{18}$$

In a pure float the central bank never intervenes in the foreign exchange market. With $\dot{Z}=0$, the Euler equation (18) and

$$\dot{m} = c(P_n)(g+rb) - X - \chi m \tag{10'}$$

$$\dot{F} = P_n Q_n + Q_T + X - E \tag{11''}$$

comprise a 3×3 dynamic system in which F is predetermined and m and E are jump variables. To solve the system we need to figure out how the equilibrium values of P_n, r and χ vary with m, F and E on the transition path. Equation (17) already relates P_n to E. For r and χ, it is natural to combine information in the asset demand equations with the path for the equilibrium inflation rate. Note from (3), (17), and (18) that

$$\pi = \chi + \frac{\gamma\tau}{\eta}(r-\rho). \tag{19}$$

Equations (6), (7) and (19) can be solved for π, χ and r as a function of m, F and E. Substituting the reduced-form solutions $r(m,F,E)$, $\chi(m,F,E)$ and $P_n(E)$ into (18), (10″) and (11″) then gives a *self-contained* system of three differential equations in m, F and E. As usual, the stationary equilibrium is a saddle point; consequently, the path of F, the only state variable in the system, drives the paths of the jump variables, m and E.

Fig. 1 provides a bird's eye view of the transition path. Since P_n depends only on E and aid is constant after its initial jump, the $\dot{F}=0$ schedule is horizontal at the steady-state level of expenditure E^*. At points above the schedule, expenditure exceeds income, the current account shows a deficit, and the stock of foreign currency is decreasing. Conversely, when $E<E^*$, the current account registers a surplus and F is increasing. The KK and MM schedules show how E and m vary with F on the convergent saddle path. (To repeat, F is the driving variable in the system.) KK slopes upward as saving depends positively on the gap between F and its desired level. The slope of MM is indeterminate, but for the range of values covered by the numerical simulations the schedule is positively sloped as in Fig. 1. Finally, the NN schedule tracks the path of P_n, mirroring the solution in (17).

After aid increases, the stationary equilibrium shifts from ABC to GHJ. Anticipating lower inflation, the private agent tries to exchange foreign for domestic currency at $t=0$. In a floating rate system, however, 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 and lower saving. To understand why saving declines, consider the special case where $F_0=F^*$ and points J and G are vertically above points A and C. In this case, the economy jumps immediately to the new steady state, with a downward jump in the price level raising m to m^*. (All of the adjustment occurs through P because M is predetermined.) Since actual wealth equals desired wealth, the private agent is content to consume at the new level of permanent income. Now carry out the same thought experiment with $F_0>F^*$. The price level still adjusts to supply the desired quantity of real money balances at $t=0$. But since $F_0>F^*$, the private agent wishes to consume more than E^*; the wealth effects associated with adjustment in the exchange rate and the price level create both the desire and the means to temporarily consume in excess of permanent income. Thus 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 [$P_n(0)>P_n^*$]. Observe also

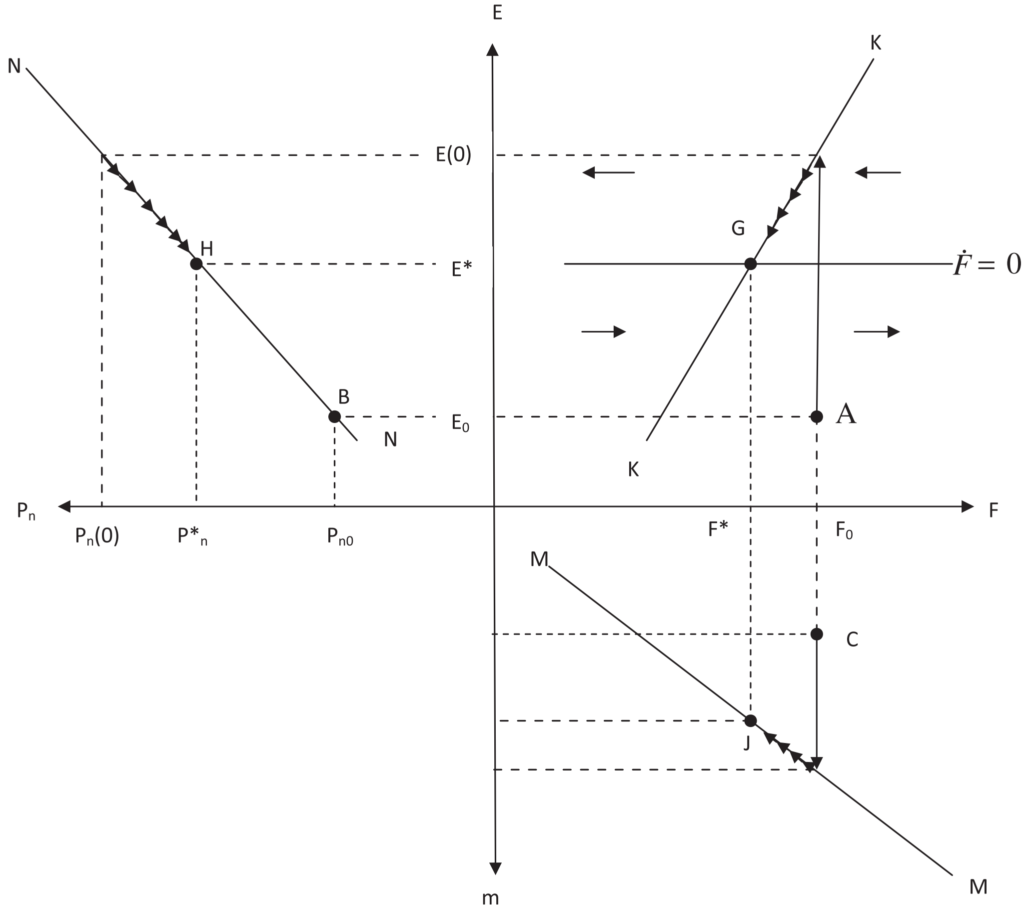

Fig. 1. Transition path in a pure float.

that capital inflows are associated with lower real interest rates [$\dot{E} < 0$ in the Euler equation (18)] and that current account (CA) deficits persist throughout the adjustment process ($\dot{F} < 0$, $\forall t$).

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. Higher demand for domestic real money balances, spending of foreign currency wealth, and the consumption boom all stem from the perception that the fiscal deficit and inflation will be lower in the future. Even a temporary increase in inflation is inconsistent therefore with a perfect foresight equilibrium.[9]

3.1.1. *Numerical results: How big are the effects?*

We calibrate the model to Ghana, using the parameter values listed in Table 1. m_0, π_0, b_0, γ_0 and X_0 are close to the values seen in Ghana in 2003. Data for Ghana also informs our choices (albeit more loosely) for ρ, ψ and F_0. The values for the deep parameters β, σ and τ, however, are guesses based on econometric estimates for other LDCs.

All of the simulations assume that aid inflows increase by 3% of national income.[10] To minimize linearization error, we solved for the transition path using a variant of the procedure recommended byNovales et al. (1999).[11]

[9] See the long paper for a formal proof that the price level decreases on impact and that inflation is continuously lower on the transition path to the new steady state.

[10] HIPC debt relief was projected to reduce debt service from 14.1% of export earnings in 2003 to 4.4% for the period 2004–2013. The reduction is equivalent to 3.1% of 2003 GDP.

[11] 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 procedure retains more of the nonlinear structure of the model and thereby reduces linearization error.

Table 1
Calibration of the model

Parameter/variable	Assigned value	Source and commentary[a]
Reserve money (m)	10% of GDP[b]	Ghana 2003: 10.2%
Inflation (π)	25%	Ghana 2003: 23.6 % for Dec.– Dec.; 26.7% = period average
Stock of internal debt (b)	20% of GDP	Ghana 2003: 18.3% of GDP
Consumption share of nontraded good (γ)	50%	Ghana 2003: 50.8% weight in CPI[c]
Aid (X)	10% of GDP	Ghana 2003: 9.44% (World Development Indicators)[d]
Time preference rate (ρ)	8%	Close to the average real interest rate paid of 8.25% paid by short-term treasury bills since 1992 (IMF, 2003)
Foreign currency (F)	15% of GDP	Guess based on the ratio of foreign currency deposits to reserve money in Ghana and figures for dollarization in other LDCs
Share of aid inflow set aside for deficit reduction ($1-\psi$)	.25	Estimates in Buffie et al. (2004) and the commitment of Ghanaian policy makers to dedicate 20% of HIPC debt relief to deficit reduction
Elasticity of substitution between traded and nontraded consumer goods (β)	.50	Estimates of demand systems with 5– 10 goods[e]
Elasticity of substitution between domestic and foreign currency (σ)	.75, 2, 3	Guess based on estimates for Latin America[f]
Intertemporal elasticity of substitution (τ)	.25	Estimates for other LDCs (Agenor and Montiel, 1999, Table 12.1)

[a] Data for Ghana are from IMF Country Reports 05/286 and 05/292.
[b] Average of beginning and end-of-year money stock divided by nominal GDP.
[c] Half the weight of food plus the weights for rent, fuel and power, medical care and health, transport and communication, and recreation. The guesstimate that half of food consumption is nontradable is based on the findings in Adam and Bevan (2002).
[d] Net official development assistance less the estimate of government imports reported in the IMF's Ghana Statistical Appendix 2005.
[e] See Lluch et al. (1977, chapter 3), Deaton and Muellbauer (1980, p. 71), and Blundell (1988).
[f] See Ramirez-Rojas (1985) and Giovannini and Turtleboom (1994).

Steady-state outcome:

Fig. 2 reports the results for $\sigma = .75$, 2 and 3. The real exchange rate is $1/P_n$ and the current account deficit (inclusive of aid) is measured as a percentage of national income (GDP + aid), with positive values signifying a deficit.

In each run, 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 .7% to 10% of national income, while the real exchange rate appreciates 11%.

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 $(1/P_n)$ appreciates 19–24% 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. The real interest rate decreases 1.5 percentage points in the first year; it rises thereafter but is still 1–1.3 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.

3.2. 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

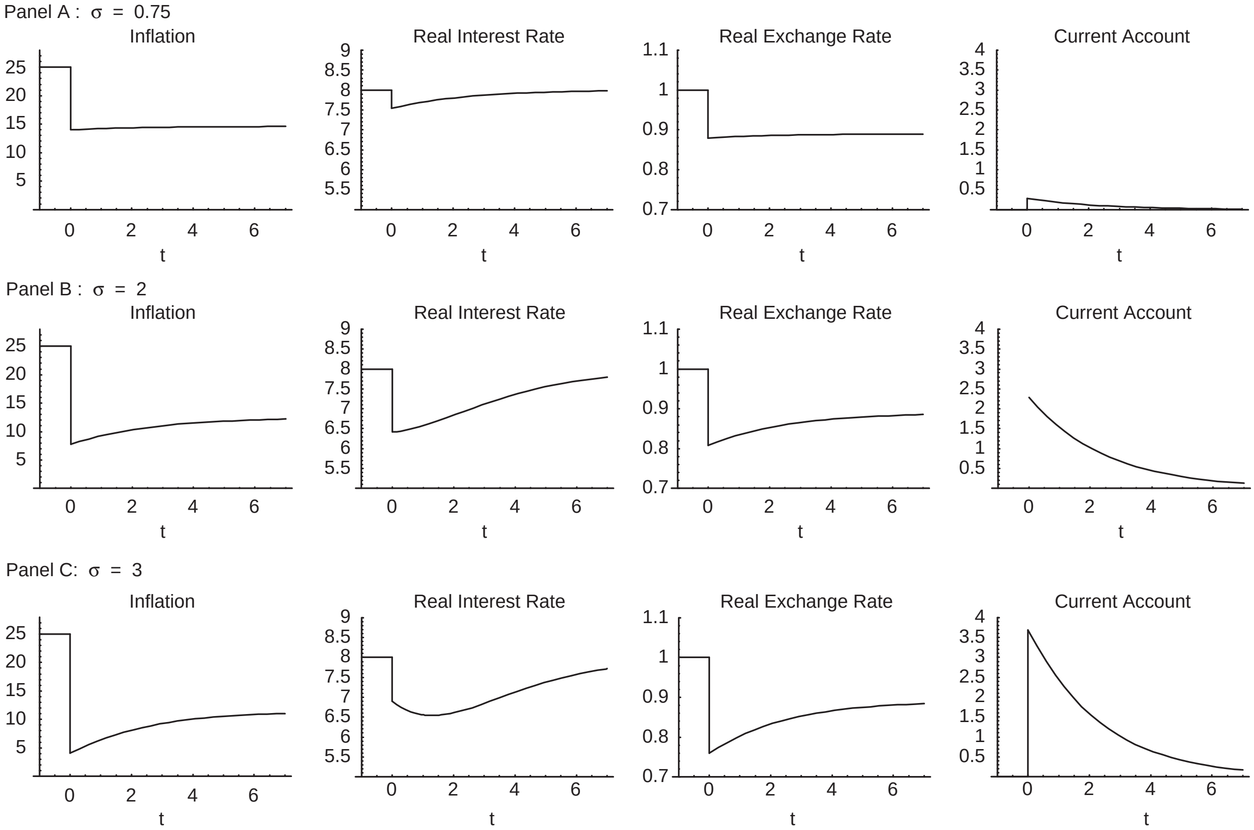

Fig. 2. Transition path under a pure float.

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), (11) and (18). To bring J into view, add (10) and (11). This gives

$$\dot{J} = c(P_n)(g + rb) + P_n Q_n + Q_T - E - \chi m. \tag{20}$$

We assume the government lowers the rate of currency depreciation χ to its new steady-state level immediately at $t = 0$. The inputs needed to solve (18) and (20) are thus limited to (17) and the reduced forms that show how r and m vary with J and E on the transition path. The latter are buried in the first-order conditions (6) and (7). After substituting for π from (19) and replacing F with $J - m$, we have

$$h\phi(m, J - m)^{-1/\tau}\phi_m(m, J - m) = E^{-1/\tau}[r(1 + \gamma\tau/\eta) + \chi - \rho\gamma\tau/\eta], \tag{6''}$$

$$h\phi(m, J - m)^{-1/\tau}\phi_F(m, J - m) = E^{-1/\tau}[r(1 + \gamma\tau/\eta) - \rho\gamma\tau/\eta], \tag{7''}$$

Equations (6″) and (7″) deliver the reduced-form solutions $r(J, E)$ and $m(J, E)$. When these are substituted into (18) and (20), the system is ready for linearization (everything on the right side depends on J and/or E). The solution is portrayed in Fig. 3. The SS schedules in the first quadrant are potential saddle paths, while the NN schedule in the second quadrant again tracks the path of P_n.

Fig. 3 looks much like Fig. 1, except J replaces F on the horizontal axis. This difference is critical. In the case of a pure float we know that $F^* < F_0$ and hence that real spending overshoots its steady-state level. Under a crawling peg the transition path is less well defined because J^* may be either larger or smaller than J_0. The steady-state solutions for m and F yield (see the long paper)

$$J^* < J_0 \quad \text{iff} \quad \sigma > \tau(1 + \rho/\pi\theta_f) + \frac{i\rho(1 - \varepsilon)(\eta + \gamma)}{\pi\theta_f \underbrace{[\pi\mu(\eta + \gamma) - \rho s\gamma + \eta(1 - \psi)]}_{\text{Positive for } \psi < 1 - \rho s\gamma/\eta}} \frac{J}{E}, \tag{21}$$

where $\mu \equiv m/E$ and θ_f is the share of liquidity services provided by foreign currency holdings. Although this condition is complicated, it admits of a straightforward intuitive explanation. Spending is higher and inflation lower at the new steady state. Both factors increase the private agent's

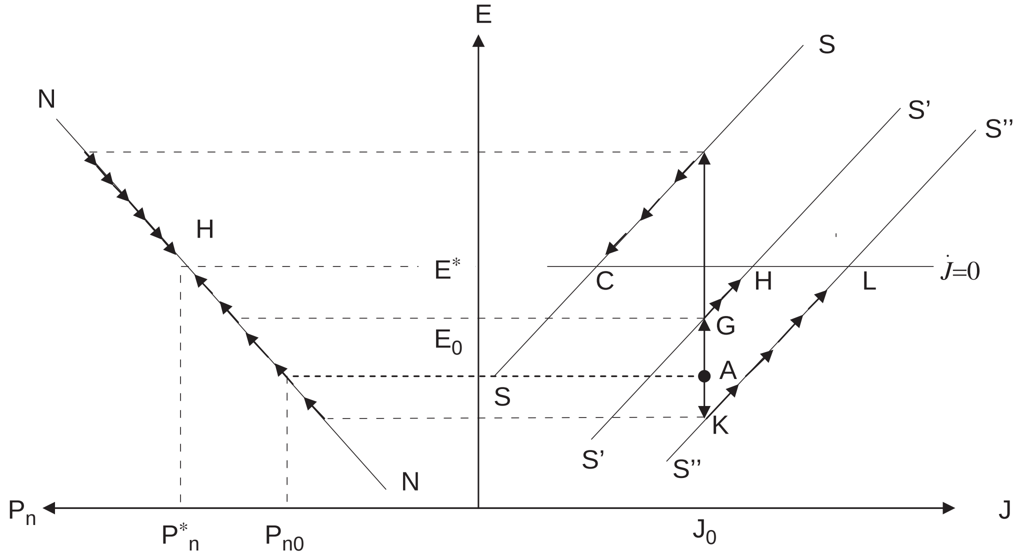

Fig. 3. Alternative transition paths under a crawling peg.

demand for liquidity services. An increase in liquidity services, however, does not necessarily require an increase in total currency holdings. Note from the first-order conditions (6′) and (7′) that a straight swap of foreign for domestic currency increases the supply of liquidity services by π. Consequently, when inflation is high and currency substitution easy (σ large), the private agent may increase consumption of liquidity services by holding much more domestic currency but less total money. The precise condition for this to happen is stated in Equation (21). If σ satisfies the inequality, currency substitution then allows the private agent to enjoy more liquidity services while spending down part of his wealth. The steady-state equilibrium shifts from A to C and the paths for expenditure, the real exchange rate, the current account, and the real interest rate are 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 (21) does not hold: on path AGH 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 (path AKL), 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.

3.2.1. 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 (21). In a pure float, spot appreciation of the nominal exchange is large enough to reduce the price level even though spending, motivated by the positive gap between F_0 and F^*, rises more than aid (75–120% more for $\sigma = 2-3$). By contrast, when the central bank operates a crawling peg (i) the exchange rate does not adjust at $t = 0$ to blunt initial inflationary pressures and (ii) spending depends on the gap between J_0 and J^*, which is ambiguous in sign and *smaller* than $F_0 - F^*$. Thus intuition argues that in comparisons of the two systems a crawling peg buys smaller current account deficits (or possibly current account surpluses) and greater stability of the nominal and real exchange rate at the price of higher inflation in the short run.

The condition in (21) does not hold for $\sigma = .75$ in Fig. 4. In this run, 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 *much* less, and the current account deficit is smaller.

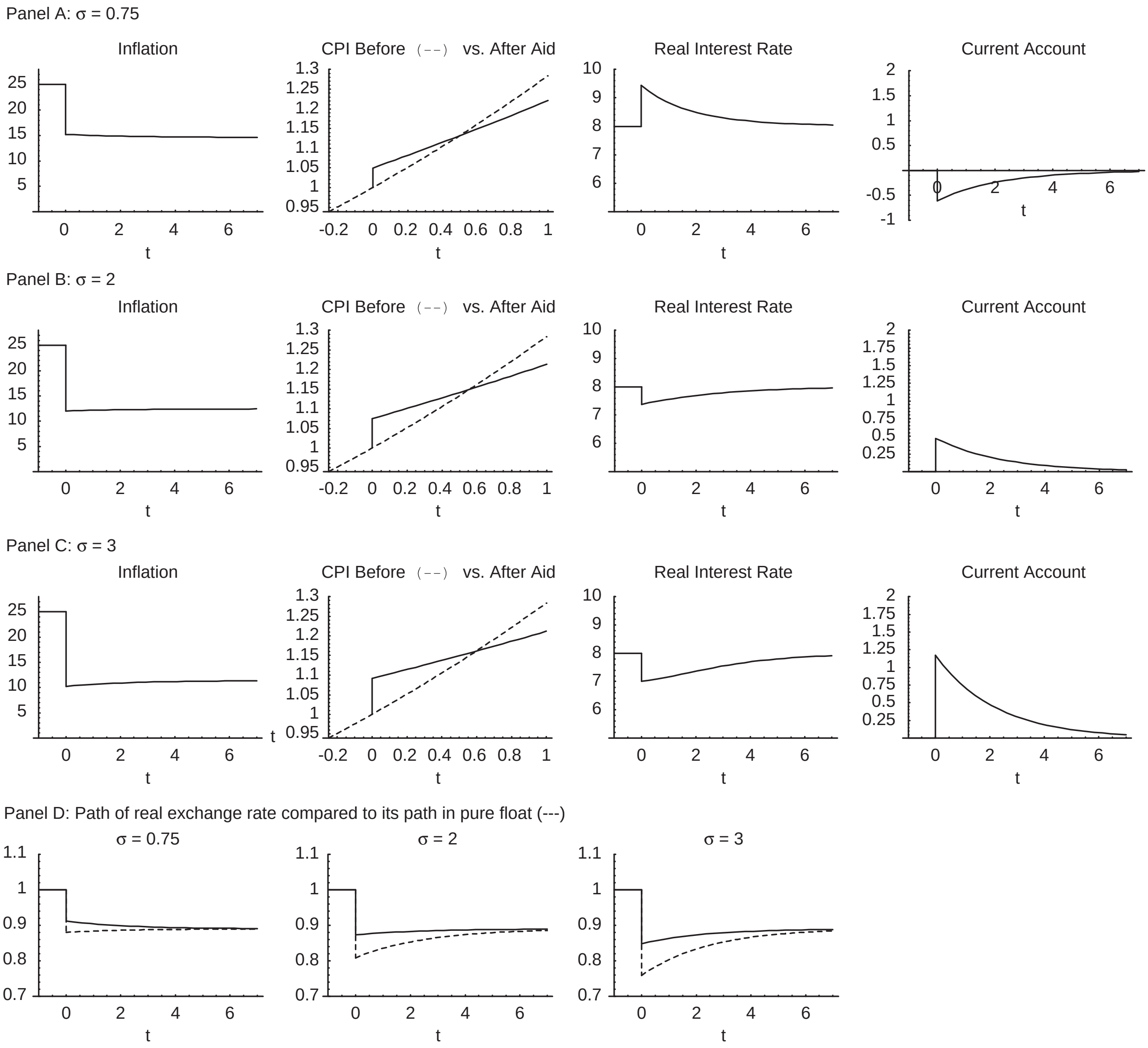

Fig. 4. Transition path in a crawling peg.

Two other results should be mentioned. First, in the run for $\sigma = .75$, the increase in the real interest rate is small: r jumps initially to 9.4%, but by the end of the first year it 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 5–9%), the path of the CPI drops below the pre-aid path within 6–7 months and the inflation rate for the first year (measured as the cumulative percentage increase in the price level) decreases from 25% to 19–20%.[12]

4. Sticky prices

There is some unfinished business connected with the analysis of aid in a pure float. Turn back to Fig. 2. The numbers look nice but they rely on extreme downward price flexibility to preserve full

[12] Due to continuous-time compounding, the increase in the price level over the calendar year is greater than 10% when $\dot{P}/P = \pi = .25$ (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.

employment. According to the model, the nominal exchange rate appreciates 22–46% 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 11–29% to keep demand equal to supply. This strains belief to say the least. We conjecture 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 (1983). The exchange rate still sets the price of the traded good, but in the nontradables sector,

$$\dot{P}_n = (\pi_n - \chi)P_n \tag{22}$$

$$\dot{\pi}_n = -\delta[D_n(P_n, E) - \bar{Q}_n], \quad \delta > 0, \tag{23}$$

where $\bar{Q}_n$ denotes notional output (i.e., the level of output associated with a normal capacity utilization rate) and 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. 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.

4.1. A pure float

The plot for Q_n in Fig. 5 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.[13] 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 27–33% at $t=0$. For $\sigma = .75$, capital inflows and nominal appreciation are comparatively modest; nevertheless, Q_n falls 2.5% on impact.[14]

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 14–24% 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 [see the Euler equation (18)] 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 Fig. 5.

4.2. A crawling peg

The results for a crawling peg (not shown) are what policy makers dream about. Inflation decreases smoothly without an initial spike in the price level. The current account (not shown) records a small surplus 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

13 We assume fast price adjustment: $\delta = 5$ in Fig. 5. The path for the current account is not shown because it differs little from the path in the flex-price case.

14 The severity of the recession is sensitive to the intertemporal elasticity of substitution. When $\tau = .50$, the decrease in Q_n at $t=0$ is 5.5% for $\sigma = .75$, 8.7% for $\sigma = 2$, and 9.5% for $\sigma = 3$. Recovery is fairly rapid, but Q_n is still 1.6–4% lower at $t=1$.

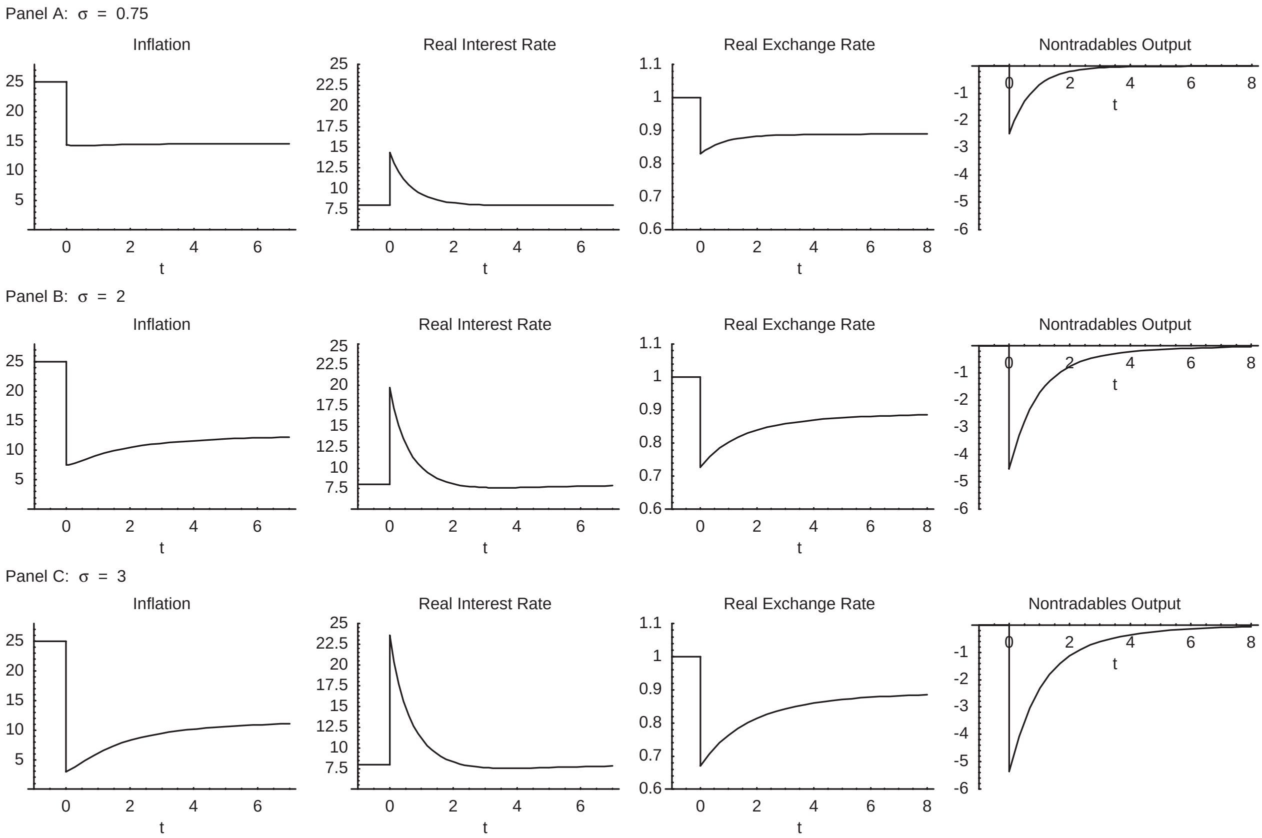

Fig. 5. Transition path in a pure float when nontradables prices are sticky.

interest rates. What makes everything work is that the budget-support component of aid effectively finances a perfectly credible exchange-rate-based stabilization (ERBS). The small ERBS component ($\frac{1}{4}$ of the total aid package) ensures that inflation decreases monotonically even though real spending rises 4–6.5% in the short run.

Does this mean that a crawling peg with fully accommodating monetary policy solves all macroeconomic problems? 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 2–3 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 in between.

5. Alternative policies

Since neither a crawling peg nor a pure float produces fully acceptable results, we move on to the analysis of alternative policy strategies. In Section 5.1 the central bank temporarily sterilizes capital inflows; in Section 5.2 it operates a dirty float, intervening in the foreign exchange market to prevent extreme fluctuations in the nominal exchange rate.

5.1. Temporary sterilization

The price level jumps when aid flows increase and the central bank maintains a crawling peg. Inflation decreases rapidly, however, after the initial spike in the CPI; temporary sterilization comes to mind therefore 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, viz.:

$$\dot{b} = -\alpha[b(t) - b_0], \tag{24}$$

$$\Longrightarrow b(t) = b_0 + [b(0) - b_0]e^{-\alpha t}. \tag{25}$$

Initial bond sales are $b(0) - b_0$ and the parameter α determines how fast the debt is paid off. The steady state is unchanged—b eventually returns to b_0.

Fig. 6 shows the outcome when bond sales at $t = 0$ are 8% of GDP and 80% of the newly issued debt is redeemed over ten years ($\alpha = .161$).[15] 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 (1.5–5.6% vs. 5–9% in Fig. 4). 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 $\sigma = 2-3$ the real interest rate fluctuates between 11% and 24% in the first year. This is worrisome enough, but when $\sigma = .75$ the rate vaults to 43% and takes two full years to fall back to 11%. It is also disturbing that the modest reduction in price volatility requires so much debt to be sold so quickly. The assumption in (25) 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 4% in the cases where $\sigma = 2-3$.

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. (The offset coefficient ranges from .75 to .94.) 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 ofdomestic currency from circulation reduces liquidity services by i dollars (33 cents worth in Fig. 6). 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.

5.2. A managed float

> "... the question of the appropriate 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. In a pure float, inflation decreases strongly, the nominal exchange rate is allowed to appreciate to the point where output contracts in the nontradables sector. A crawling peg imperils 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

[15] Paying off the debt more quickly results in higher real interest rates.

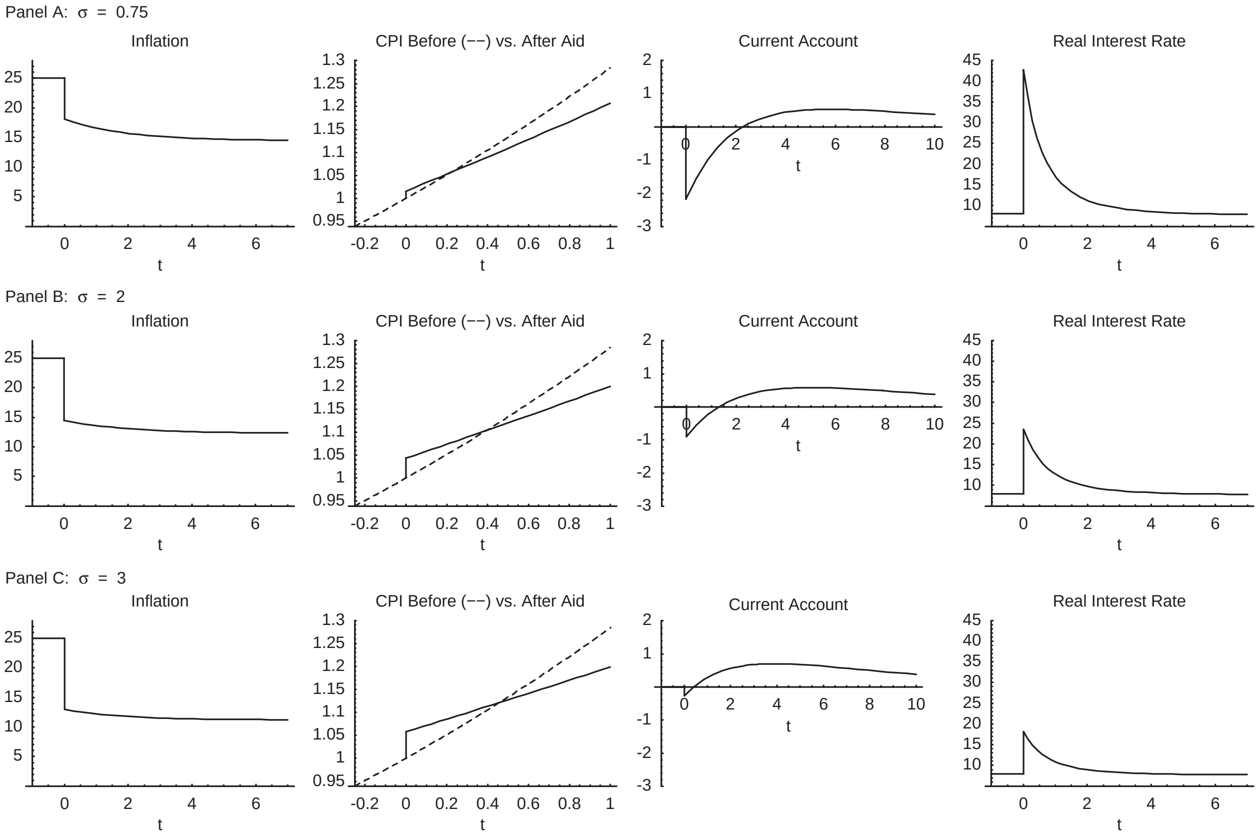

Fig. 6. Transition path in a crawling peg with temporary sterilization.

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 explore the middle ground between zero intervention and full 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:

$$\dot{Z} = \Omega \frac{P_n - P_n^*}{P_n}, \quad \Omega > 0. \tag{26}$$

Equation (26) 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.

Fig. 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. To quantify the underlying policy rule, we compared the paths of the exchange rate and reserves in the managed float with the path of the exchange rate in a pure float and the path of reserves in a crawling peg. Both comparisons point to

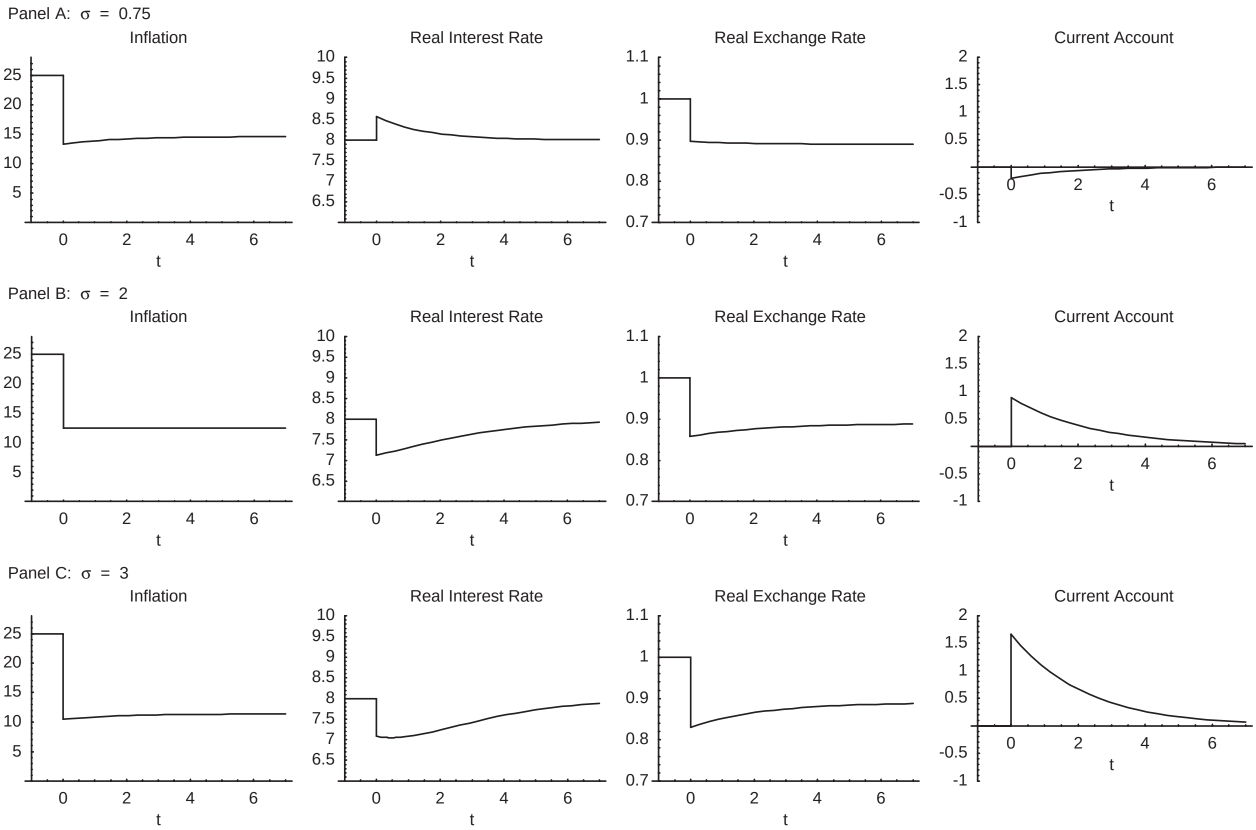

Fig. 7. Transition path in a managed float.

substantial intervention. Appreciation of the nominal exchange rate at $t = 0$ is 10–17% vs. 22–46% 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 "optimal" exchange rate, in other words, is about 3/4 of the way toward the crawling peg end of the spectrum.

6. Concluding remarks

In this paper we have examined numerous policy responses to a permanent surge in aid. Consistent with the evidence for Sub-Saharan Africa, we assumed that 75% of the extra aid was spent and the remainder used for budget support. The reduction in the fiscal deficit ensures that inflation decreases in the long run. Macroeconomic management of the transition path is complicated, however, by large private capital inflows. 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, and (iii) overshooting of the real exchange rate. A crawling peg eliminates the threat of a harsh recession and secures greater stability of the real exchange rate but allows an initial big spike in the CPI. Bond sales can reduce the spike in the CPI, but only at the cost of extremely high real interest rates. These tradeoffs can be avoided in a managed float that targets 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.

At a technical level, the theoretical framework developed here is notable for its flexibility. In a series of related papers, we have adapted the framework to analyze a wide variety of monetary policy issues. Buffie et al. (2007) introduce private sector concerns' about the impact of an aid surge on fiscal stability. When donors intend to supply a lasting increase in aid but cannot commit to do so, portfolio behavior again plays a key role in the dynamic response to aid. We show that successful management of inflation expectations requires a combination of near-term fiscal restraint and reserve accumulation. O'Connell et al. (2007) develop a stationary stochastic version of the analysis in order to place aid flows in a broader context of shocks confronting the monetary authority. Stationary but persistent aid shocks create similar tradeoffs to those studied in this paper, while the impact of commodity price volatility on the appropriate degree of exchange rate flexibility depends on the fiscal impact of export revenues and on the degree of insurance provided by aid. Finally, Adam et al. (2007) look for simple operational rules that separate the management of aid shocks from the broader question of exchange rate commitments. Tying foreign exchange intervention to the domestic liquidity generated by aid-induced spending produces time paths for reserves and depreciation close to those generated by a crawling peg, while leaving the central bank free to float with respect to non-aid shocks.

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