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# Capital inflows, external shocks, and the real exchange rate

Pierre-Richard Agénor*

*Research Department, International Monetary Fund, 700 19th St. NW, Washington, DC 20431, USA*

**Abstract**

This paper examines the effects of a fall in world interest rates on capital flows and the real exchange rate in an optimizing framework with imperfect capital markets. A permanent fall leads to a steady-state reduction in net foreign assets and a real depreciation, regardless of whether the country is initially a net creditor or net debtor. On impact, the real exchange rate appreciates in the net debtor case, but may either appreciate or depreciate in the net creditor case. The dynamics associated with a temporary shock depend not only on its duration but also on the initial asset position. © 1998 Elsevier Science Ltd. All rights reserved.

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## 1. Introduction

The role of domestic and external variables in explaining the surge in capital inflows to developing countries in the early 1990s has attracted much attention among economists and policymakers. Several recent studies have concluded that, although improved performance and long-term economic prospects (associated notably with price stabilization, trade and financial liberalization, privatization, and debt-reduction operations under the Brady Plan) appear to have affected capital

* E-mail: pagenor@imf.org


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inflows in some countries, movements in world interest rates appear to have played a major role. Frankel and Okongwu (1996), for instance, in a study of the determinants of portfolio capital flows in seven Latin American and East Asian countries over the period 1987–1994, concluded that low interest rates prevailing in the United States in the early 1990s had the most significant effect on capital flows.[1] The reduction in US interest rates, in addition to reducing the opportunity cost of investing abroad, helped to lower the perceived default risk and to improve the creditworthiness of large indebted countries, as measured by the sharp increase in secondary debt prices and secondary prices for loans to these countries (Fernández-Arias, 1996).

The long-term benefits of capital inflows are well recognized. Foreign direct investment flows for instance have positive effects on productivity and the efficiency of domestic resource utilization (through transfers of technology and other intangible assets), thereby raising economic growth. But the magnitude of the inflows recorded by some developing countries in recent years and the fears that they could be subject to abrupt reversal have raised serious concerns among policymakers. It has been argued that large inflows create difficulties in containing monetary and credit expansion, and may have adverse effects on inflation, the external current account, and the real exchange rate. Indeed, several of the main recipient countries in Asia and Latin America have experienced an increase in domestic inflation and a significant real exchange rate appreciation. This phenomenon was more pronounced in Latin America than in Asia,[2] as a result of various factors.[3] The deterioration in competitiveness has raised questions about the credibility and sustainability of fixed exchange rate regimes in a number of countries.

However, blaming capital inflows for the real appreciation experienced by some countries neglects two important (and related) considerations. The first is that even in circumstances in which changes in world interest rates provide an ‘impulse’ effect on capital inflows, feedback effects on capital movements tend to occur through changes in domestic rates of return — which are determined, together with the real exchange rate itself, by macroeconomic equilibrium conditions. Accounting for these interactions is essential to understand the dynamics associated with external shocks. The second (and somewhat obvious) consideration is

[1]As pointed out by Fernández-Arias and Montiel (1996), however, very few studies have attempted to capture the role of structural changes in industrial-country financial markets, which have eased access to foreign funds for developing-country borrowers.

[2]Among Latin American countries, the real appreciation was particularly marked in Argentina, Brazil, Colombia, Ecuador, Mexico and Uruguay. It was significantly less dramatic in Chile. See Agénor and Hoffmaister (1998), Corbo and Hernández (1996), Gavin et al. (1995) and Steiner (1995).

[3]Chief among them are the more common reliance on fixed exchange rates in Latin America (which provide no ‘cushion’ when residual inflation is high); the different composition of inflows (foreign direct investment flows have accounted for a larger share of inflows to Asian countries); the allocation of these flows (with a more pronounced tendency to allocate flows to investment in Asia, as opposed to consumption of home goods); and the better ability of Asian countries to sterilize capital inflows and control the money supply. See Calvo et al. (1996).

that a proper distinction between the short- and long-term dynamics of capital flows, asset accumulation, and the real exchange rate is required to assess the effects of macroeconomic shocks to world interest rates. Impact movements in domestic interest rates and the real exchange rate will typically lead to subsequent portfolio reallocations and shifts in production or consumption patterns, which tend to generate correcting movements in relative prices.

This paper provides a formal framework that integrates both types of considerations in an optimizing model of a small open economy. A key feature of the model is the assumption that domestic private borrowers face an upward-sloping supply curve of funds on world capital markets, and internalize the effect of capital market imperfections in making their portfolio decisions. This leads to a setting in which capital is imperfectly mobile internationally — a feature of the model that is well-supported by the evidence for developing countries (Agénor and Montiel, 1996). By allowing domestic interest rates to be determined through the equilibrium condition of the money market instead of foreign interest rates (as implied by uncovered interest rate parity under perfect capital mobility), feedback effects on capital inflows induced by changes in overall domestic macroeconomic conditions can be better analyzed.

Section 2 presents the model, and Section 3 derives its dynamic structure. Section 4 analyzes the short- and long-run effects of permanent and temporary reductions in world interest rates on capital flows, domestic interest rates, asset accumulation, and the real exchange rate, under the assumption that the country considered is initially a net creditor. Section 5 considers the case of a net debtor. Finally, Section 6 summarizes the main results of the analysis and discusses some possible extensions.

## 2. The model

Consider a small open economy in which perfect foresight prevails and four types of agents operate: households, producers, the government, and the central bank. The nominal exchange rate $E$ is depreciated by the central bank at a constant rate, $\varepsilon$. The economy produces two goods: a home good which is used only for final domestic consumption, and a traded good, the price of which is fixed on world markets. The capital stock in each sector is fixed within the time-frame of the analysis. Labor is homogeneous and perfectly mobile across sectors.

### *2.1. Households*

Households supply labor inelastically, consume both traded and nontraded goods, and hold three categories of financial assets in their portfolios: domestic money (which bears no interest), domestic government bonds and foreign bonds. Domestic and foreign bonds are intrinsically perfect substitutes, but the existence of market imperfections (which are such that the interest rate faced by the representative household on world capital markets is inversely related to private holdings of foreign bonds) limits the degree of capital mobility. Foreigners do not hold domestic assets.

Consumption decisions follow a two-step process: households first determine the optimal level of total consumption, and then allocate that amount between consumption of the two goods. In the first stage of the decision process, the representative household is assumed to maximize its discounted lifetime utility given by[4]

$$\int_0^\infty [u(c) + v(m)]e^{-\rho t}\mathrm{d}t, \qquad \rho > 0 \tag{1}$$

where $\rho$ denotes the rate of time preference (assumed constant), $c$ an index of total consumption expenditure, and $m$ real money balances, measured in terms of the price of the consumption basket, $P$. The instantaneous utility functions $u()$ and $v()$ are increasing, strictly concave functions.

Real wealth of the representative household $a$ is defined as

$$a = m + b + b^*, \tag{2}$$

where $b$ denotes real holdings of government bonds, and $b^*$ real holdings of foreign bonds, both measured in terms of the price of the consumption basket. Specifically, $b^* \equiv EB^*/P$, where $B^*$ represents holdings of foreign bonds measured in foreign-currency terms. The flow budget constraint is given by

$$\dot{a} = q + ib - c - \tau + (i^* - \theta)b^* - \pi a + \varepsilon b^*, \tag{3}$$

where $q$ denotes net factor income (derived below), $\tau$ the real value of lump-sum taxes, $i$ the domestic nominal interest rate, and $\pi$ the overall inflation rate. The total rate of return on foreign bonds $i^* - \theta$ consists of an exogenous, 'base' (or risk-free) interest rate $i^*$ and an endogenous discount (or negative premium) $\theta$. The term $-\pi a$ accounts for capital losses on total wealth resulting from inflation, whereas the term $\varepsilon b^*$ represents capital gains on the stock of foreign bonds resulting from exchange rate depreciation. As a result of capital market imperfections, the endogenous component of the rate of return on foreign bonds is positively related to private holdings of foreign assets. Specifically, the linear approximation $\theta = \theta(B^*,\cdot) \simeq \theta_{B^*}B^*$, where $\theta_{B^*} > 0$, is used.[5] Thus, the effective, household-specific world interest rate falls the more private agents lend ($B^* > 0$)

[4] Except otherwise indicated, partial derivatives are denoted by corresponding subscripts, whereas the total derivative of a function of a single argument is denoted by a prime. A sign over a variable refers to the sign of the corresponding partial derivative, and $\dot{x} \equiv \mathrm{d}x/\mathrm{d}t$. Time subscripts are omitted for simplicity.

[5] In general, the function $\theta(B^*,\cdot)$ may depend on various other factors, which are ignored for simplicity. The fact that $\theta(B^*,\cdot)$ may be a convex function of $B^*$ — a source of multiple equilibria — is not discussed either.

and rises the more they borrow ($B^* < 0$). The latter effect may be interpreted as resulting from the existence of default risk.[6]

In the first stage of the consumption decision process, households treat $\pi$, $\varepsilon$, $q$, $i$, $i^*$ and $\tau$ as given, internalize the effect of their portfolio decisions on $\theta$, and maximize Eq. (1) subject to Eqs. (2) and (3) by choosing a sequence $\{c,m,b,B^*\}_{t=0}^{\infty}$. Let $r = i - \pi$ denote the domestic real rate of interest. The optimality conditions are given by:

$$v'(m)/u'(c) = i, \;\Rightarrow\; m = m\left(\overset{+}{c}, \overset{-}{i}\right) \tag{4}$$

$$i = i^* - \theta + \varepsilon - B^*\theta_{B^*}, \tag{5}$$

$$\dot{c}/c = \sigma(r - \rho) \tag{6}$$

together with the transversality condition $\lim_{t\to\infty}(e^{-\rho t}a) = 0$. The parameter $\sigma \equiv -u'/u''c$ is the intertemporal elasticity of substitution.

Eqs. (4) and (6) are familiar results. Eq. (4) equates the marginal rate of substitution between consumption and real money balances to the opportunity cost of holding money, the domestic nominal interest rate. It determines the demand for money as a positive function of the level of transactions — as measured by total consumption expenditure — and a negative function of the nominal interest rate. Eq. (6) shows that total consumption rises or falls depending on whether the domestic real interest rate exceeds or falls below the rate of time preference.

Eq. (5) is an arbitrage condition, which equates the rates of return on domestic and foreign interest-bearing assets under imperfect world capital markets. To understand its derivation, suppose that agents are net creditors ($B^* > 0$) and consider first the case in which households face no risk discount on world capital markets ($\theta = 0$). In that case, clearly, optimality requires $i = i^* + \varepsilon$. Suppose, for instance, that $i > i^* + \varepsilon$; agents would not hold foreign assets at all, and would actually borrow unlimited amounts of funds on world capital markets — reaping a net profit by buying government bonds. This would, however, bid up the price of government bonds and lower the domestic interest rate until agents are indifferent between domestic and foreign bonds. On the contrary, with $i < i^* + \varepsilon$, households would hold no domestic bonds in their portfolios. Equilibrium with a positive level of domestic bonds therefore requires that the parity condition $i = i^* + \varepsilon$ hold continuously.

Suppose now, as assumed above, that $\theta$ rises with the household's level of foreign assets, so that the marginal rate of return on foreign bonds falls with a

[6] This interpretation is similar to that offered in models emphasizing the effect of country risk on the country-specific world interest rate, as discussed for instance in Fisher (1996), Montiel (1996), or Pitchford (1989). There are, however, two critical differences here, which are discussed at length by Agénor (1997). The first is that there is no sovereign risk (only individual risk), so that the premium depends only on private holdings of foreign assets — rather than the economy's stock of foreign assets. Second, as shown below, private agents internalize the effect of their borrowing decisions on $\theta$.

marginal increase in $B^*$. Equilibrium (with positive levels of both categories of assets) requires, as before, that the rates of return on domestic and foreign bonds be equalized. However, the marginal rate of return on foreign bonds is no longer equal to $i^* + \varepsilon$ but is now given by $i^* - \theta + \varepsilon$ minus the loss in interest income on the existing stock of assets induced by the marginal increase in the risk discount, itself resulting from the marginal increase in lending on world capital markets, $-B^*\theta_{B^*}$. A similar reasoning shows that Eq. (5) must also hold if households are net debtors ($B^* < 0$), with the term on the left-hand side of that equation measuring now the marginal cost of foreign borrowing.

With a linear approximation to $\theta$, Eq. (5) can be written as

$$B^* = (i^* + \varepsilon - i)/\gamma, \tag{7}$$

where $\gamma = 2\theta_{B^*} > 0$. Eq. (7) indicates that holdings of foreign bonds (measured in foreign-currency terms) depend positively on the difference between the domestic interest rate and the rate of return on foreign assets — calculated as the sum of the risk-free interest rate and the devaluation rate.[7] When $\gamma \to 0$, Eq. (7) yields the uncovered interest parity condition $i = i^* + \varepsilon$.[8]

In the second stage of the consumption decision process, the representative household maximizes a homogeneous sub-utility function $\upsilon(c_N, c_T)$, subject to the budget constraint $P_N c_N + Ec_T = Pc$, where $P_N$ denotes the price of the home good, $c_N$ purchases of nontraded goods, and $c_T$ expenditure on traded goods. The solution to this program yields the familiar result according to which the representative household sets the marginal rate of substitution between home and traded goods equal to their relative price $z \equiv E / P_N$, that is, the real exchange rate. Assuming that the sub-utility function is Cobb–Douglas yields

$$c_N = \delta z^{1-\delta} c, \qquad c_T = (1 - \delta) z^{-\delta} c \tag{8}$$

where $0 < \delta < 1$ denotes the share of total spending falling on home goods. The appropriate definition of the consumer price index $P$ is thus

$$P = P_N^{\delta} E^{1-\delta}, \tag{9}$$

[7]An early paper by Turnovsky (1985) provides a specification of households' portfolio decisions that leads to a result analytically similar to Eq. (7). An asset demand equation functionally equivalent to Eq. (7) can also be obtained by assuming that limits on the speed of capital movements result from the existence of a 'Tobin' tax (at the rate, say, $\iota$) on the level of foreign assets — as, for instance, in Reinhart (1991) — so that the term in $B^*$ in Eq. (3) would be $(i^* + \varepsilon - \iota)B^*$. Assuming that the tax rate $\iota$ is proportional to actual holdings of foreign assets ($\iota \simeq \gamma B^*$) would yield Eq. (7). Evidence regarding the existence of such taxes is, however, limited (see Spahn, 1995).

[8]An alternative approach would be to assume, as done by Sutherland (1996), that world capital markets are perfect but that holdings of foreign bonds are subject to convex costs of adjustment (such as fees associated with financial transactions). However, this specification leads only to a short-run relationship between the interest rate differential and changes in holdings of foreign assets.

so that the inflation rate is

$$\pi = \varepsilon - \delta \dot{z}/z. \tag{10}$$

### 2.2. Supply side

Technology for the production of traded and nontraded goods is characterized by decreasing returns to labor:

$$q_h = F(n_h), \qquad F_h' > 0, \qquad F_h'' < 0 \qquad h = N,T$$

where $q_h$ denotes output of good $h$, and $n_h$ the quantity of labor employed in sector $h$. From the first-order condition for profit maximization, the labor demand functions can be derived as

$$n_T^d = n_T^d(w_T), \qquad n_N^d = n_N^d(zw_T), \qquad n_T^{d'}, n_N^{d'} < 0, \tag{11}$$

where $w_T$ is the product wage in the traded goods sector. Nominal wages are perfectly flexible. $w_T$ is thus determined by the equilibrium condition of the labor market:

$$n_T^d(w_T) + n_N^d(zw_T) = n,$$

where $n$ denotes the supply of labor. This equation implies that the equilibrium real wage (measured in terms of traded goods) is negatively related to the real exchange rate, $w_T = w_T(z)$, with $|w_T'| < 1$. Substituting this result in Eq. (11), and noting that $\mathrm{d}(zw_T)/\mathrm{d}z > 0$, yields the sectoral supply equations:

$$q_h^s = q_h(z), \qquad q_N' < 0, \qquad q_T' > 0. \tag{12}$$

### 2.3. Government and the central bank

There are no commercial banks in the economy. In addition to depreciating the nominal exchange rate at a constant rate, the function of the central bank is to provide, at any given moment in time and at the prevailing exchange rate, costless conversion of domestic currency holdings into foreign currency. Because there is no credit, the real money stock is equal to

$$m = z^{\delta} R^*, \tag{13}$$

where $R^*$ is the central bank's stock of net foreign assets, measured in foreign currency terms. Real profits of the central bank consist of interest on its holdings of foreign assets $i^* z^{\delta} R^*$, and capital gains on reserves, $\varepsilon z^{\delta} R^*$. All profits are transferred to the government.

In addition to transfers from the central bank, the government levies lump-sum taxes on households. It consumes both home and traded goods. It finances its budget deficit by issuing bonds. The budget constraint of the government is thus

$$\pi m + \dot{b} = z^{\delta}(g_T + g_N/z) + rb - \tau - z^{\delta}(i^* + \varepsilon - \pi)R^*, \tag{14}$$

where $g_T$ and $g_N$ denote government spending on traded and nontraded goods, respectively. Eq. (14) indicates that government spending on goods plus net interest payments on the domestic debt, minus lump-sum taxes and interest income on reserves, must be financed by the inflation tax or issuance of bonds.

### 2.4. Market-clearing conditions

To close the model requires specifying the equilibrium conditions for the home goods market and the money market. The equilibrium condition for the home goods market is given by

$$q_N^s = \delta z^{1-\delta} c + g_N. \tag{15}$$

For a given level of $m$, Eq. (4) can be solved for the market-clearing interest rate:

$$i = i\left(\overset{+}{c}, \overset{-}{m}\right), \tag{16}$$

which shows that the nominal interest rate depends positively on consumption and negatively on real money balances.

## 3. Dynamic structure

Before examining the macroeconomic effects of a fall in the world interest rate, it is convenient to re-write the model in a more condensed form in order to characterize its dynamic structure. To begin with, suppose that the government foregoes the issuance of bonds to finance its deficit and instead varies lump-sum taxes so as to balance the budget. Setting the constant level of government bonds to zero, Eq. (14) yields

$$\tau = z^{\delta}(g_T + g_N/z) - z^{\delta}(i^* + \varepsilon)R^*. \tag{17}$$

Real factor income $q$ (measured in terms of cost-of-living units) is given by $z^{\delta}(q_T + q_N/z)$. Substituting this result together with Eqs. (13), (15) and (17) in Eq. (3) yields

$$\dot{R}^* + \dot{B}^* = i^*(R^* + B^*) - \theta B^* + q_T^s - c_T - g_T, \tag{18}$$

which represents the consolidated budget constraint of the economy.[9]

Substituting Eqs. (8) and (12) in Eq. (18) yields

$$\dot{R}^* + \dot{B}^* = i^*(R^* + B^*) - \theta B^* + q_T^s(z) - (1-\delta)z^{-\delta}c - g_T. \tag{19}$$

From Eq. (12) and (15), the real exchange rate consistent with equilibrium in the market for home goods is obtained as

$$z = z(\bar{c};\bar{g}_N). \tag{20}$$

Eqs. (6), (7), (10), (13), (16) and (20) describe the evolution of the economy along any perfect foresight equilibrium path. These equations can be summarized as follows:

$$B^* = [i^* + \varepsilon - i(c,m)]/\gamma \tag{21}$$

$$\dot{c}/c = \sigma[i(c,m) - \varepsilon + \delta\dot{z}/z - \rho], \tag{22}$$

$$z = z(c;g_N), \tag{23}$$

$$\dot{R}^* + \dot{B}^* = i^*(R^* + B^*) - \theta B^* + q_T^s(z) - (1-\delta)z^{-\delta} - g_T, \tag{24}$$

$$m = z^{\delta}R^*, \tag{25}$$

with Eq. (17) determining residually lump-sum taxes.

The dynamic form of the model can be further reduced to a system involving two variables: total private consumption $c$ (which may jump in response to new information) and total holdings of foreign bonds measured in foreign currency terms, $F = R^* + B^*$, which can change only gradually. To begin with, note that from Eq. (25),

$$m = z^{\delta}(R^* + B^* - B^*) = z^{\delta}(F - B^*), \tag{26}$$

or using Eq. (21):

$$m = z^{\delta}\{F - [i^* + \varepsilon - i(c,m)]/\gamma\}. \tag{27}$$

Substituting Eq. (23) in Eq. (27) yields

$$m = z(c;g_N)^{\delta}\{\gamma F - (i^* + \varepsilon) + i_c c\}/(\gamma - i_m), \tag{28}$$

[9] Integrating Eq. (18) yields the economy's intertemporal budget constraint

$$R_0^* + B_0^* = \int_0^{\infty} [c_T + g_T + \theta B^* - q_T^s]e^{-\int_0^t i_h^* dh}\mathrm{d}t + \lim_{t\to\infty}(R^* + B^*)e^{-\int_0^t i_h^*\mathrm{d}h}.$$

The economy cannot run up an indefinite debt or credit abroad, so the second term in the above expression must be zero. Thus, the current level of foreign assets must be equal to the discounted stream of the excess of domestic absorption of traded goods (adjusted for the loss in interest income due to capital market imperfections) over future production of these goods.

so that

$$m = m\left(\overset{?}{c},\overset{+}{F};i^* \overset{-}{+} \varepsilon,\overset{-}{g_N}\right), \tag{29}$$

where $m_c = (\gamma\delta z_c\tilde{R}^* + i_c)/(\gamma - i_m)$, where a '$\sim$' is used to denote initial steady-state values.[10] If the initial level of official foreign assets $\tilde{R}^*$ is not too large — or equivalently if the positive valuation effect associated with a real exchange rate depreciation is not too large — $m_c > 0$.

Substituting Eq. (29) in Eq. (22) yields

$$\dot{c}/c = \sigma\{i[c,m(c,F;i^* + \varepsilon,g_N)] - \varepsilon + \delta\dot{z}/z - \rho\}. \tag{30}$$

Assuming that changes in $g_N$ occur only in discrete fashion, Eq. (23) implies that $\dot{z} = z_c\dot{c}$, with $z_c < 0$. Substituting this result in Eq. (30) yields[11]

$$\dot{c} = G\left(\overset{+}{c},\overset{-}{F};\overset{+}{i^*},\overset{+}{g_N}\right). \tag{31}$$

Substituting Eq. (29) into Eq. (21) yields

$$B^* = \left\{i^* + \varepsilon - i_c c - i_m m\left(c,F;i^* - \tilde{\theta} + \varepsilon,g_N\right)\right\}(\gamma - i_m),$$

so that[12]

$$B^* = \Lambda\left(\overset{-}{c},\overset{+}{F};i^* \overset{+}{+} \varepsilon,\overset{+}{g_N}\right). \tag{32}$$

Using Eq. (32), Eq. (24) can be written as

$$\dot{F} = \Psi\left(\overset{?}{c},\overset{?}{F};\overset{-}{g_N};\overset{?}{i^*},\overset{-}{g_T}\right), \tag{33}$$

[10] In linearizing the model, all derivatives are calculated at an initial steady-state value of $z$ equal to unity.

[11] As shown formally in the Appendix, $G_c > 0$ regardless of whether $m_c$ is positive or negative.

[12] It can be verified that

$$i_c + i_m m_c = i_c + i_m \frac{\gamma\delta z_c\tilde{R}^* + i_c}{\gamma - i_m} > 0,$$

which ensures that $\Lambda_c < 0$. We also have

$$1 + i_m m_{i^*} + \varepsilon = 1 + \frac{i_m}{\gamma - i_m} > 0,$$

ensuring that $\Lambda_{i^* + \varepsilon} > 0$.

where $\Psi_{g_T} = -1$ and

$$\Psi_F = i^* - \left(\tilde{\theta} + \tilde{B}^*\theta_{B^*}\right)\Lambda_F,$$

$$\Psi_c = z_c[q_T^{s\prime} + \delta(1-\delta)\tilde{c}] - (1-\delta) - (\tilde{\theta} + \tilde{B}^*\theta DB^*)\Lambda_c,$$

$$\Psi_{i^*} = \tilde{F} - \left(\tilde{\theta} + \tilde{B}^*\theta_{B^*}\right)\Lambda_{i^*}.$$

The sign of $\Psi_{i^*}$ depends on the initial level of assets $\tilde{F}$, whereas the sign of $\Psi_c$ and $\Psi_F$ depends (in addition to $\tilde{B}^*$) on the sensitivity of $\theta$ to the household's stock of foreign bonds. If $\tilde{F} < 0$, then $\Psi_{i^*}$ is unambiguously negative. In what follows, it will be assumed that $\tilde{F}$, if positive, is sufficiently large to ensure that $\Psi_{i^*} > 0$, and that the elasticity of the risk discount function is not too large (or, equivalently, that $\tilde{\theta} + \tilde{B}^*\theta_{B^*}$ is sufficiently small) to ensure that $\Psi_c < 0$ and $\Psi_F > 0$.

Eqs. (31) and (33) form a dynamic system in consumption and private wealth measured in foreign currency terms, which can be linearized around the steady state to give

$$\begin{bmatrix} \dot{c} \\ \dot{F} \end{bmatrix} = \begin{bmatrix} G_c & G_F \\ \Psi_c & \Psi_F \end{bmatrix} \begin{bmatrix} c - \tilde{c} \\ F - \tilde{F} \end{bmatrix}. \tag{34}$$

$c$ is a jump variable, whereas $F$ is a predetermined variable which evolves continuously from its initial level $F_0$. Saddlepath stability requires therefore one unstable (positive) root. To ensure that this condition holds, the determinant of the matrix of coefficients in Eq. (34) must be negative: $G_c\Psi_F - G_F\Psi_c < 0$. This condition is interpreted graphically below.

To understand the short-run dynamics of the model, it is important to note that although total foreign assets evolve only gradually over time, both official reserves and the private stock of foreign bonds may shift discretely in response to changes in domestic or foreign interest rates. Discrete changes in private holdings of foreign bonds must nevertheless be accompanied by an offsetting movement (at the given official exchange rate) in the stock of foreign reserves held by the central bank, in order to leave the overall stock of foreign assets $F$ constant on impact.[13]

The steady-state solution is obtained by setting $\dot{c} = \dot{F} = 0$. From Eq. (10), the steady-state inflation rate and the rate of inflation in nontradable prices are thus equal to the devaluation rate ($\tilde{\pi} = \pi_N = \varepsilon$). From Eq. (6), the real interest rate is

[13] Offsetting movements between holdings of domestic money and foreign assets occur because the central bank in the present setting does not engage in sterilized intervention. This assumption is supported by recent evidence, which suggests that attempts to sterilize the effects of capital inflows have not been very effective and may have in fact exacerbated the problem — by driving domestic interest rates up and thus stimulating further inflows. See Calvo et al. (1996), Corbo and Hernández (1996) and Frankel and Okongwu (1996).

equal to the rate of time preference ($\tilde{r} = \tilde{i} - \varepsilon = \rho$). Substituting this result in Eq. (21) yields

$$\tilde{B}^* = (i^* - \rho)/\gamma, \tag{35}$$

which indicates that the steady-state stock of foreign bonds is positive as long as $i^* > \rho$. This condition can be interpreted as indicating that if the rate of time preference of domestic consumers is sufficiently low relative to the exogenous component of the cost of foreign borrowing (that is, if domestic agents value the future sufficiently), domestic agents will tend to be net creditors in the long run.

From Eq. (4) long-run real money balances are given by

$$\tilde{m} = m(\tilde{c}, \rho + \varepsilon). \tag{36}$$

The steady-state equilibrium of the model is depicted in Fig. 1. The *NN* curve in the north-west quadrant depicts combinations of consumption and the real exchange rate that are consistent with equilibrium in the market for nontraded goods. The locus $[\dot{F} = 0]$ gives the combinations of $c$ and $F$ for which holdings of foreign assets (measured in foreign-currency terms) remain constant, whereas the locus $[\dot{c} = 0]$ depicts the combinations of $c$ and $F$ for which the real exchange rate does not change over time. Points above the $[\dot{F} = 0]$ curve correspond to situations of current account deficits, whereas points below the curve represent surpluses. Points located to the right of the $[\dot{c} = 0]$ curve represent situations where the domestic real interest rate is lower than the rate of time preference, consumption is falling, and the real exchange rate is depreciating to eliminate excess supply of nontraded goods. Conversely, points located to the left of the $[\dot{c} = 0]$ curve represent situations of excess demand of home goods and an appreciating real

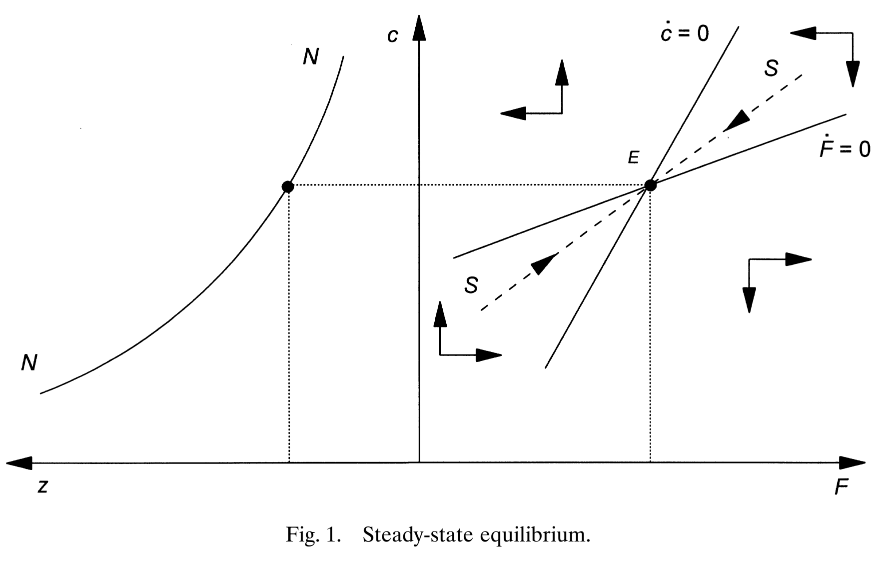


Fig. 1. Steady-state equilibrium.

exchange rate. Saddlepath stability requires that the $[\dot{c} = 0]$ curve be steeper than the $[\dot{F} = 0]$ curve. The saddlepath $SS$ has a positive slope (as shown in Appendix A) and defines the only convergent path to the steady-state equilibrium, which is obtained at point $E$.

## 4. Reduction in the world interest rate

As indicated earlier, several recent studies have attributed the surge in capital inflows to developing countries in the early 1990s to a significant reduction in interest rates in industrial countries. In what follows the macroeconomic effects of both permanent and temporary reductions in the safe world interest rate are examined in the framework described in the previous sections. We focus in this section on the case in which the country considered is a net creditor in the initial steady state ($\tilde{F} > 0$) and examine in the next section the case of a net debtor.

### 4.1. Permanent shock

Consider first the case of an unanticipated, permanent reduction in $i^*$. The macroeconomic effects of this shock are illustrated in Figs. 2 and 3. As shown in both figures (and as formally derived in Appendix A), the long-run effects are a reduction in private consumption, a depreciation of the real exchange rate, and a reduction in total holdings of foreign assets. As can be inferred directly from Eq. (35), private holdings of foreign bonds (measured in domestic currency terms) fall; and because the nominal interest rate is constant at $\rho + \varepsilon$, real money balances — and thus official reserves, because the real exchange rate depreciates — fall also [see Eq. (36)].

Intuitively, a permanent reduction in the rate of return on foreign assets reduces holdings of that category of assets, which results in lower interest income and a deterioration in the services account of the balance of payments.[14] Because the current account balance is in equilibrium in the long run, there must be a lower deficit in the trade balance. Lower private holdings of foreign assets is, of course, a reduction in the economy's wealth and consumption of both home and traded goods (at the initial structure of relative prices) must fall. The lower demand for nontraded goods leads to a depreciation of the real exchange rate and an increase in output of traded goods (the intratemporal substitution effect). The fall in consumption of traded goods and the expansion of output of tradables bring about the required improvement in the trade balance.

[14] Recall that a change in the risk-free world interest rate has, in general, an ambiguous effect on interest income on net foreign assets — and thus the services account. A reduction in $i^*$ reduces private holdings of foreign bonds, which has two effects. On the one hand, it reduces (at the initial level of official reserves $\tilde{R}^*$) income on the economy's stock of foreign bonds; on the other, it lowers the discount-related component $\theta\tilde{B}^*$, which tends to increase net interest income. As indicated earlier, it is assumed that the former effect dominates, so that the services account deteriorates.

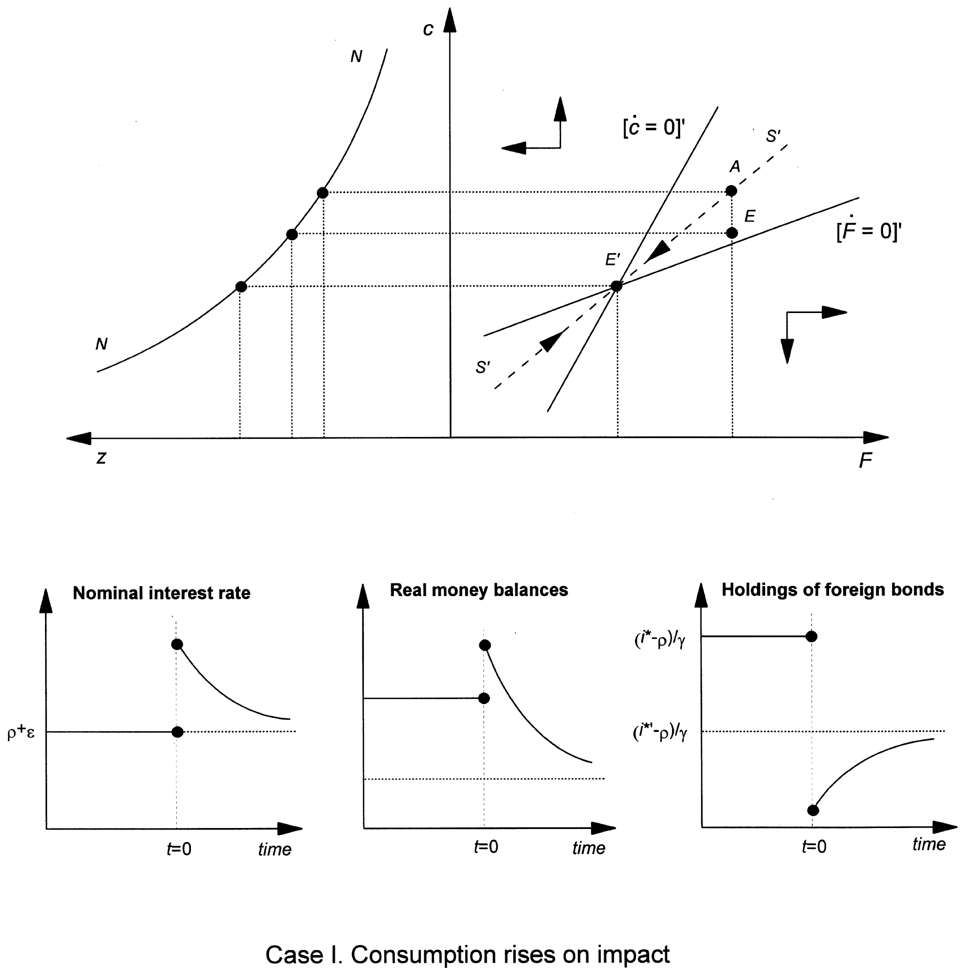


Fig. 2. Permanent reduction in the world interest rate (net creditor country). Case 1: consumption rises on impact.

Because the steady-state stock of foreign assets falls, the transition (given the permanent nature of the shock and the monotonic nature of the adjustment path) must involve a sequence of current account deficits. However, as illustrated in Figs. 2 and 3, on impact consumption may either rise or fall, and the real exchange rate may either appreciate or depreciate (see Appendix A). The immediate effect of a reduction in the rate of return on foreign assets is a reduction in the private demand for foreign bonds, a fall in interest income for the economy as a whole (because overall holdings of foreign assets cannot change on impact), and an increase in the demand for domestic currency holdings.[15] This instantaneous

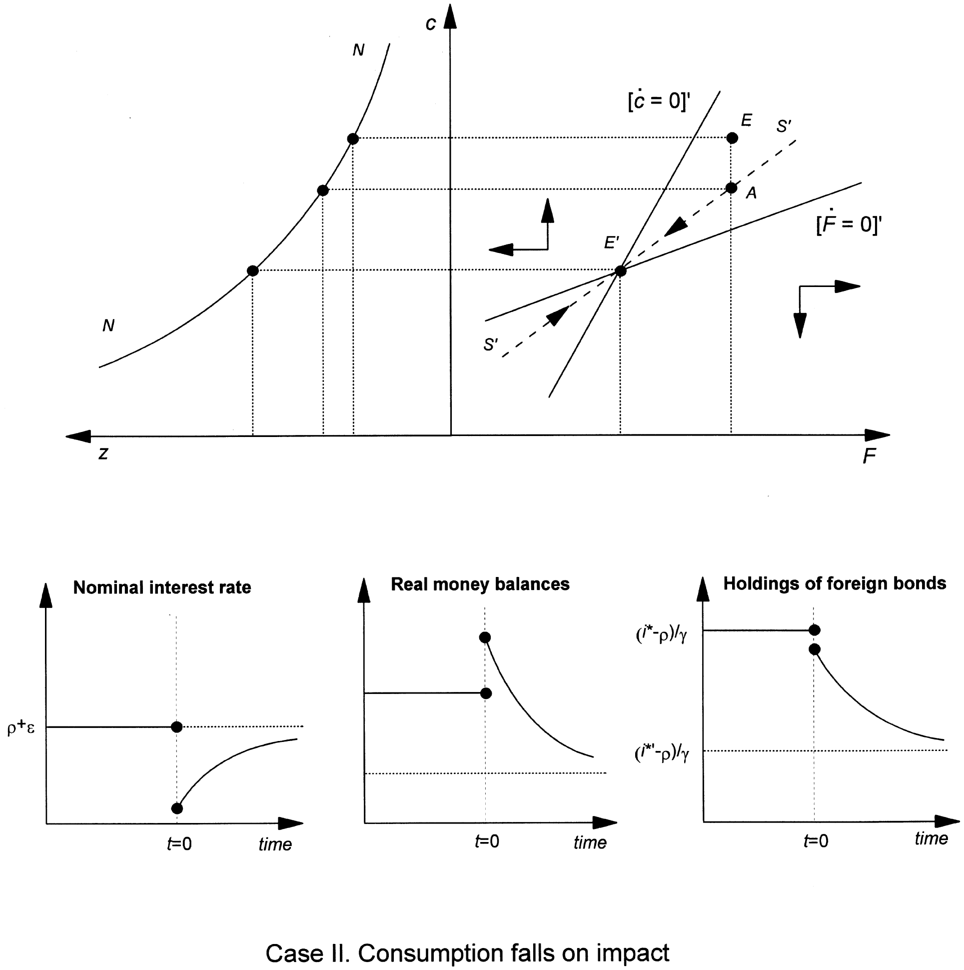


Fig. 3. Permanent reduction in the world interest rate (net creditor country). Case 2: consumption falls on impact.

portfolio shift takes place through an inflow of capital (a discrete reduction in private holdings of foreign bonds) and an offsetting movement in central bank holdings of foreign assets, which leads (under unsterilized intervention) to a discrete increase in the real money stock. However, whether domestic interest rates

[15]Again, it is assumed that the impact effect of a reduction in the risk-free world interest rate, although ambiguous in general — since it reduces at the same time income on the economy's initial stock of foreign assets and the discount-related component of income on private holdings of foreign bonds — is a deterioration of the services account.

rise or fall to maintain equilibrium in the money market cannot be ascertained a priori, because aggregate consumption may rise or fall on impact.[16]

This ambiguity emerges as a result of conflicting wealth and intertemporal effects on private consumption. On the one hand, the current and expected future reduction in interest income (induced by the reduction in the world interest rate and the level of financial wealth) tends to reduce immediately (at the initial level of the real exchange rate) private expenditure and increase saving. On the other, a reduction in $i^*$ encourages agents to save less (and consume more) today, because the rate of return on foreign assets has fallen (intertemporal effect). Because the initial effect on private consumption is ambiguous, the real exchange rate may either appreciate or depreciate on impact.

Fig. 2 illustrates the case in which consumption rises on impact (so that the degree of intertemporal substitution is sufficiently high), and the real exchange rate appreciates.[17] Consumption of both goods also increases.[18] The trade balance (which, in the initial equilibrium, is characterized by a deficit equal in absolute value to interest income on net foreign assets) tends therefore to deteriorate. The real appreciation leads to a reduction in output of traded goods, which compounds the effect of the increase in consumption on the trade deficit.[19] Because the net effect (as argued earlier) on interest income received on the economy's stock of assets is also negative, the economy generates a current account deficit on impact. Graphically, consumption jumps upward from point $E$ to point $A$. As shown in Appendix A, real money balances unambiguously increase whereas private holdings of foreign bonds — assuming that valuation effects are not too large — fall. The increase in the domestic money stock (induced by the discrete portfolio adjustment) tends to lower the domestic interest rate on impact, but the increase in consumption tends to raise it. The net effect, as shown in Appendix A, is in general ambiguous but is assumed to be positive in Fig. 2 — a result which obtains if the degree of intertemporal substitution is sufficiently high. The increase in domestic interest rates, of course, reinforces the effect of a reduction in the world interest rate on the demand for foreign bonds, and further stimulates capital inflows.

During the transition period, the economy moves down along $S'S'$ towards $E'$.

[16] The ambiguous impact effect of a reduction in the world interest rate on consumption and the real exchange rate was derived by Khan and Montiel (1987) in a nonoptimizing model with perfect capital mobility, and more recently by Montiel (1996).

[17] Graphically, as shown in Figs. 2 and 3, the case where consumption rises (falls) on impact corresponds to the case where the vertical shift in the $[\dot{c} = 0]$ curve is larger (smaller), in absolute value, than that of the $[\dot{F} = 0]$ curve, implying that the new saddlepath $S'S'$ lies above (below) the original path $SS$, which passes through the initial steady state equilibrium at point $E$.

[18] From Eq. (8) and Eq. (15), private consumption of nontraded goods must increase since the real appreciation has a positive effect on output of nontradables. From Eq. (8), both the real appreciation and the increase in aggregate consumption lead to an increase in expenditure on traded goods.

[19] The intertemporal budget constraint derived from Eq. (18) must hold at any point in time; thus, any reduction in $i^*$ must be accompanied either by a continuous sequence of trade deficits (as is the case here), or by an initial improvement in the trade balance followed by a sequence of deficits (as is the case below).

The adjustment process is characterized by a continuous reduction in the stock of foreign assets (associated with current account deficits), a fall in consumption, and a depreciation of the real exchange rate. The expansion in output of traded goods (resulting from the real depreciation) tends to reverse over time the adverse effect of the initial appreciation on the trade balance. However, because interest payments continue to fall with the reduction in the stock of assets, improvements in the trade balance are not large enough to prevent the current account from remaining in deficit until the new steady state is reached. Because the devaluation rate does not change, the nominal interest rate must fall in order to return to its initial value $(\rho + \varepsilon)$ and ensure equality between the real interest rate and the rate of time preference. And because the domestic interest rate falls, holdings of foreign assets by the private sector tend to increase during the transition, thereby leading to capital outflows and lower reserve accumulation by the central bank. The domestic money stock is thus falling during the transition, which equivalently means that the positive effect on the demand for real money balances induced by the gradual reduction in domestic interest rates is outweighed by the negative effect stemming from the reduction in total consumption [Eq. (4)]. The new long-run equilibrium, as indicated earlier, is characterized by lower holdings of foreign assets, lower holdings of foreign bonds and real money balances, lower consumption, a more depreciated real exchange rate, and an improvement in the trade balance. Inflation falls initially, and returns gradually to its equilibrium value given by the devaluation rate.

Fig. 3 illustrates the case in which consumption falls on impact (so that the wealth effect dominates the intertemporal effect) and the real exchange rate depreciates. Although the reduction in private expenditure and the expansion in output of traded goods (resulting from the real depreciation) lead on impact to an improvement in the trade balance, the reduction in interest income is large enough to generate a current account deficit. Graphically, private consumption jumps downward from point $E$ to point $A$. As shown in Appendix A, the net effect on the domestic interest rate is now unambiguously negative, because consumption falls. This tends to increase the demand for foreign bonds. However, because both the world interest rate and the domestic interest rate fall, whether the net effect on real money balances and the demand for foreign bonds is positive or negative cannot be determined a priori. Thus, the economy may experience either capital inflows or capital outflows. Fig. 3 illustrates the case in which holdings of foreign bonds fall and the economy experiences capital inflows on impact — implying that the reduction in the world interest rate is larger than the induced reduction in the domestic interest rate. Real money balances rise, regardless of the importance of the valuation effect. During the transition period, as before, the economy moves down along $S'S'$ towards $E'$. Despite the reduction in private expenditure, the depreciation of the real exchange rate (which stimulates output of traded goods), and thus the improvement in the trade balance, the fall in net interest income ensures that the current account remains in deficit. The domestic interest rate rises gradually toward its initial level, stimulating further capital inflows. With consumption falling and domestic interest rates increasing, real money balances tend again to fall over time.

### 4.2. Temporary shock

Consider now the case in which the reduction in the safe world interest rate $i^*$ is temporary.[20] Specifically, we examine the case in which the world interest rate falls at $t = 0$ but returns to its initial value at $t = T$. The short-run dynamics in this case are illustrated in Fig. 4.

Consider first the case in which the duration of the shock $T$ is sufficiently long. The upper panel illustrates the case in which consumption rises on impact and the real exchange appreciates. Because the shock is known to be temporary, the optimal 'smoothing response' is such that consumption rises initially by less than it would if the shock was known to be permanent. After the initial upward jump, consumption begins to fall (reaching point $C$ on the original saddlepath $SS$ at $T$ and the real exchange rate depreciates. Net foreign assets fall during the first phase of the transition. However, the depreciation that occurs during the first phase stimulates output and dampens consumption of traded goods to such an extent that the economy at some point during the transition period begins to accumulate foreign assets. Formally, this occurs at the point where the path of the system crosses the $[\dot{F} = 0]$ curve corresponding to the long-run equilibrium point $E'$, that is, at point $B$. After that point, the current account moves into surplus, net foreign assets begin to increase, consumption continues to fall and the real exchange rate continues to depreciate — until reaching the saddlepath corresponding to the original equilibrium position, $SS$, exactly at $T$ (point $C$). Consumption starts increasing, the real exchange rate starts appreciating, and the current account remains in surplus, until the economy returns to its original equilibrium position at point $E$.

The case in which aggregate consumption falls initially is illustrated in the lower panel of Fig. 4. Consumption falls to a point such as $A$ on impact, and the real exchange rate depreciates. Consumption continues to fall until it reaches point $B$ (which is located on the $[\dot{c} = 0]$ curve corresponding to the equilibrium point $E'$) and begins to increase until it reaches at $T$ the saddlepath leading back to the original equilibrium position (point $C$). The real exchange rate depreciates during the first phase of the transition, and appreciates afterwards. Throughout the transition, and despite the initial reduction in income and the phase of real depreciation, the current account remains in deficit, because the expected future real appreciation is sufficiently powerful to raise consumption today. After $T$, as in the previous case, consumption rises, the real exchange rate appreciates, and the current account moves into surplus, taking the economy back to its original steady state.

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[20] Dornbusch (1983) provides an early analysis of a temporary reduction in the world interest rate on the time profile of consumption in an intertemporal framework. One conclusion of his analysis is that the presence of a home goods sector dampens the effects of changes in the world interest rate.

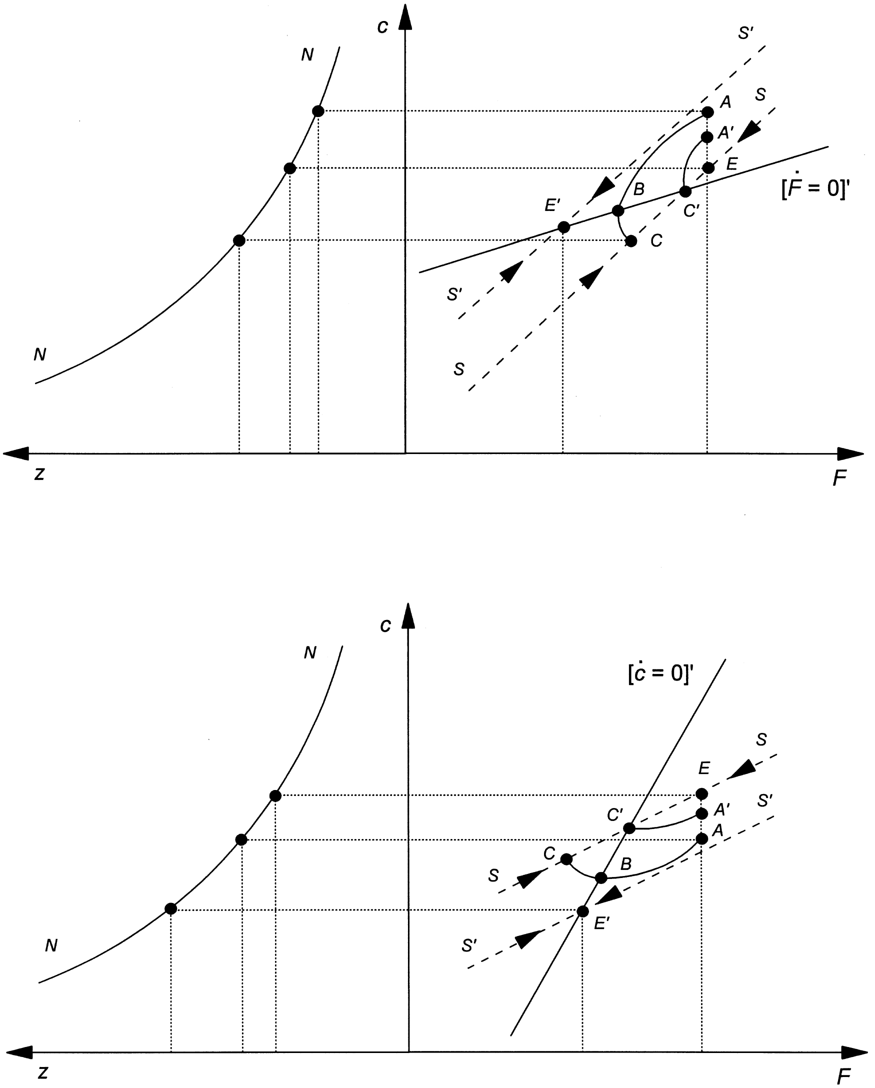


Fig. 4. Temporary reduction in the world interest rate (net creditor country).

Consider now the case in which $T$ is relatively short. As illustrated in the upper panel of Fig. 4, the adjustment process may not be characterized by a period of falling consumption and improving current account (as illustrated by the segment $BC$). In fact, there exists a value $T = T^*$ for which, following the initial increase in private spending (from point $E$ to point $A'$, say), the economy will evolve along the segment $A'C'$. Point $C'$ is located at the intersection of the original saddlepath $SS$ and the new $[\dot{F} = 0]$ curve, and is reached exactly at period $T^*$. Thus, for any value of $T < T^*$, the current account will remain in deficit (and the economy's stock of net foreign assets will fall) throughout the duration of the shock. Similarly, as shown in the lower panel of Fig. 4, there exists a value $T^*$ of $T$ which is such that consumption will not increase during the second phase of the adjustment process — as implied by the path $EABC$. The threshold value $T^*$ is again determined by the condition that, following the downward jump from point $E$ to, say, $A'$, the economy reach point $C'$ at $T^*$, located at the intersection of the original saddlepath and the new $[\dot{c} = 0]$ curve.

## 5. The net debtor case

Consider now the case in which the country is initially a net debtor country ($\tilde{F} < 0$), so that $\Psi_{i*}$ in Eq. (33) is unambiguously negative.[21] As formally established in Appendix A, the long-run effects of a permanent reduction in the world interest rate are again a reduction in consumption, a depreciation of the real exchange rate, and a reduction in total holdings of foreign assets — that is, an increase in foreign debt. The initial effect of the reduction in the cost of borrowing on world capital markets, as can be inferred from Eq. (35), is an increase in private foreign indebtedness, which results in higher interest payments and a deterioration of the services account. To maintain external balance in the long run, the initial trade surplus (which is just equal, in absolute terms, to the initial deficit in the services account) must increase. Consumption must therefore fall. This leads to a depreciation of the real exchange rate, which in turn stimulates output of traded goods and further improves the trade balance. Because the nominal interest rate remains constant at $\rho + \varepsilon$, real money balances — and thus official reserves in foreign-currency terms — fall also [see Eq. (36)]. With foreign borrowing by private agents increasing, and net foreign assets held by the central bank falling, the economy's external debt unambiguously rises.

In contrast to the case in which the economy is initially a net creditor, the impact effects of a permanent reduction in the world interest rate on private spending and relative prices can be signed unambiguously. Consumption increases, and the real exchange rate appreciates. The reason why the ambiguity obtained previously disappears is that now the wealth and intertemporal effects operate in the same direction: the reduction in $i^*$ not only encourages agents to save less (and consume more) today, but it also lowers the debt burden and generates a positive wealth effect. Although the trade balance and the services account move in opposite direction (the former deteriorates, whereas the latter improves), the net effect is a current account deficit on impact.

The upper panel of Fig. 5 illustrates the dynamic path associated with a

[21] Since the counterpart to the money stock consists only of official reserves in the case considered here, it is assumed that the net debtor position results from private agents being net borrowers ($\tilde{B}^* < 0$). Clearly, the initial stock of official reserves cannot be too large if total external debt is required to be positive in the initial steady state. The exact condition on $\tilde{R}^*$ is given in Appendix A.

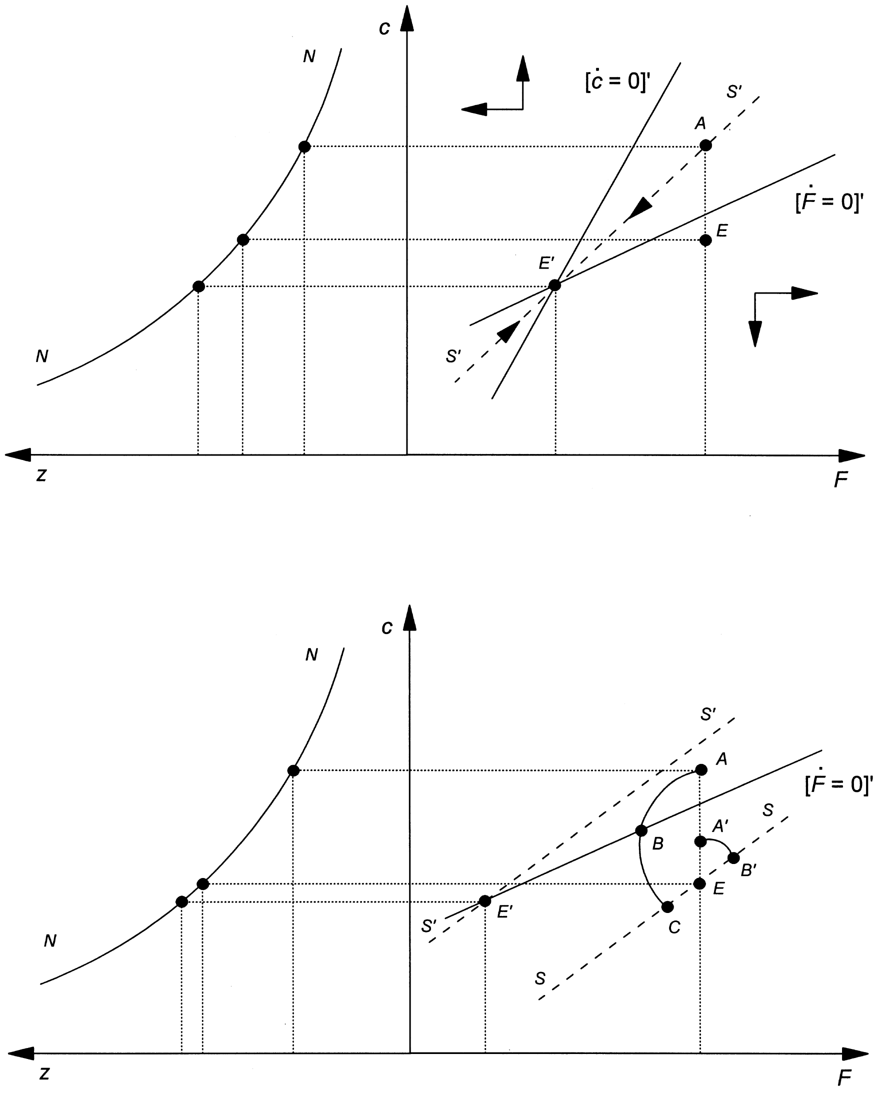


Fig. 5. Permanent and temporary reduction in the world interest rate (net debtor country).

permanent shock. As shown in the figure, both curves $[\dot{c} = 0]$ and $[\dot{F} = 0]$ shift to the left, but the former shifts algebraically by more than the latter. Consumption jumps upward from point $E$ to point $A$. Because of the permanent nature of the shock and the monotonic nature of the adjustment process, the current account remains in deficit throughout the transition period, with consumption falling towards its new, lower steady-state level, and the real exchange rate depreciating — with both effects contributing to a gradual reversal of the initial reduction in the trade surplus.

The lower panel of Fig. 5 illustrates the dynamics of a temporary shock. If the period of time $T$ during which the world interest rate falls is sufficiently large, the path followed by consumption, the real exchange rate, and the current account will be similar to what was obtained earlier in the case of a net creditor, under the assumption that consumption rises and the real exchange rate appreciates on impact (path $EABC$). By contrast, if the length of time during which the world interest rate falls is sufficiently short, a temporary reduction in $i^*$ can be accompanied by an initial phase of depreciation and a current account surplus (the path labeled $EA'B'$). Intuitively, if the duration of the shock is sufficiently long, agents have an incentive to substitute intertemporally and increase consumption; the negative effect on the trade balance in that case outweighs the positive effect on the services account, so that the current account moves into deficit. By contrast, if the reduction in the world interest rate is expected to be short-lived, agents will not adjust their consumption path by much; the improvement in the services account will therefore outweigh the deterioration in the trade balance, and the current account will move into surplus.

## 6. Summary and conclusions

This paper has used an intertemporal optimizing framework to examine the macroeconomic effects of permanent and temporary reductions in world interest rates. An essential feature of the model is the focus on individual (as opposed to country) risk, captured through the assumption that domestic private borrowers face an upward-sloping supply curve of funds on world capital markets. In contrast to most studies in that area, private agents are assumed to internalize the effect of capital market imperfections in making their portfolio decisions. This formulation leads to a setting in which capital is imperfectly mobile internationally.

The analysis showed that a permanent reduction in the world interest rate leads to a steady-state reduction in the economy's net stock of foreign assets and a depreciation of the real exchange rate if the economy is initially a net creditor. The reduction in the world interest rate leads to a fall in holdings of foreign assets and reduced interest income in the steady state. To ensure long-run equilibrium of the current account, the economy must reduce its trade deficit. This, in turn, requires a reduction in private consumption, with the lower demand for nontraded goods leading to a depreciation of the real exchange rate. The real depreciation raises output of traded goods, and reinforces the effect of the reduction in consumption on the trade balance. On impact, the real exchange rate may either appreciate or depreciate. The source of indeterminacy was shown to be associated with the existence of offsetting wealth and intertemporal effects on consumption. On the one hand, the reduction in the world interest rate lowers (current and expected) income, which tends to reduce private spending today; on the other hand, it lowers the cost of borrowing, which tends to raise consumption today.

If the economy is initially a net debtor, the long-run effects are qualitatively similar to those described above: consumption falls, the real exchange rate depreciates, and external debt increases. On impact, however, the ambiguity obtained previously disappears: a reduction in the world interest rate always increases private consumption and appreciates the real exchange rate. The reason is that now, wealth and intertemporal effects operate in the same direction: a reduction in the cost of foreign borrowing not only encourages agents to save less today, but it also lowers the external debt burden — thereby generating a positive wealth effect.

The analysis showed as well a temporary reduction in the world interest rate depends not only on the duration of the shock, but also on the initial asset position of the economy. If the economy is initially a net debtor, for instance, the reduction in the world interest rate is likely to be characterized by an initial phase of depreciation followed by a real appreciation, after an initial step appreciation. The current account will either remain in surplus throughout the entire period during which the world interest rate falls, or may move into surplus before the shock is reversed, after deteriorating during an initial phase.

The thrust of the analysis is thus that caution should be exercised before viewing 'autonomous' capital inflows (or, more precisely, capital movements induced by shocks to external variables) as the main culprit for real exchange rate appreciation and a deterioration of the current account. Ad hoc models in which intertemporal considerations are excluded and in which capital inflows are modeled as having a large direct effect on the demand for nontraded goods and the real exchange rate can be misleading. Our analysis suggests that whether a persistent real appreciation is observed depends crucially on the initial level of debt, and on the permanent or temporary nature of the shock.

## Acknowledgements

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## Appendix A

The partial derivatives appearing in Eq. (31) are given by

$$G_F = \gamma i_m (1/\sigma\tilde{c} - \delta z_c)^{-1}/(\gamma - i_m) < 0,$$

$$G_{i^*} = -i_m (1/\sigma\tilde{c} - \delta z_c)^{-1}/(\gamma - i_m) > 0,$$

$$G_c = (1/\sigma\tilde{c} - \delta z_c)^{-1}\left\{i_c\left(1 + \frac{i_m}{\gamma - i_m}\right) + \gamma\delta\tilde{R}^* i_m z_c\right\} > 0,$$

$$G_{g_N} = \delta\gamma i_m z_{g_N}(1/\sigma\tilde{c} - \delta z_c)^{-1}/(\gamma - i_m) > 0,$$

where the term in brackets in the definition of $G_c$ is negative, regardless of whether $m_c$ is positive or negative.

The solution to the system described by Eq. (34) is given by

$$F = \tilde{F} + \left(F_0 - \tilde{F}\right)e^{\nu t}, \tag{A1}$$

$$c = \tilde{c} + \kappa(F - \tilde{F}), \tag{A2}$$

where $\kappa = G_F/(\nu - G_c) = (\nu - \Psi_F)/\Psi_c > 0$, and $\nu$ denotes the negative root of the system. Eq. (A2) is the equation of the saddlepath $SS$, and shows that consumption falls (rises) — and the real exchange rate depreciates (appreciates) — along the saddlepath when the current account is in deficit (surplus).

It can be established that, with $\tilde{F} > 0$:

$$\mathrm{d}\tilde{c}/\mathrm{d}i^* = (\Psi_{i^*}G_F - \Psi_F G_{i^*})/\Omega > 0, \tag{A3}$$

$$\mathrm{d}\tilde{F}/\mathrm{d}i^* = (\Psi_c G_{i^*} - \Psi_{i^*}G_c)/\Omega > 0, \tag{A4}$$

where $\Omega = G_c\Psi_F - G_F\Psi_c < 0$ to ensure saddlepath stability and (as discussed in the text) $\Psi_{i^*} > 0$. These equations show that a reduction in the world interest rate lowers both consumption and the stock of net foreign assets. From the equilibrium condition of the market for nontraded goods,

$$\mathrm{d}\tilde{z}/\mathrm{d}i^* = z_c \mathrm{d}\tilde{c}/\mathrm{d}i^* < 0,$$

which shows that the real exchange rate depreciates.

To determine the impact effects of a reduction in $i^*$, note that from Eqs. (A1) and (A2), and because $\mathrm{d}F_0/\mathrm{d}i^* = 0$:

$$\mathrm{d}c_0/\mathrm{d}i^* = \mathrm{d}\tilde{c}/\mathrm{d}i^* - \kappa\left(\mathrm{d}\tilde{F}/\mathrm{d}i^*\right)\gtrless 0,$$

because $\mathrm{d}\tilde{c}/\mathrm{d}i^*$, $\mathrm{d}\tilde{F}/\mathrm{d}i^* > 0$. It therefore follows, from the equilibrium condition of the market for nontraded goods, that $\mathrm{d}z_0/\mathrm{d}i^*$ is also ambiguous. If, for instance, $\mathrm{d}c_0/\mathrm{d}i^* < 0$ (rise in consumption and thus real appreciation), then from Eq. (12) output of nontraded (traded) goods must rise (fall) on impact. Eq. (A3) and Eq. (A4) yield

$$\mathrm{d}c_0/\mathrm{d}i^* = -\nu G_{i^*}/\Omega + \Psi_{i^*}(G_F + \kappa G_c)/\Omega,$$

or equivalently, because $G_F + \kappa G_c = \kappa\nu$:

$$\mathrm{d}c_0/\mathrm{d}i^* = -\nu(G_{i^*} - \kappa\Psi_{i^*})/\Omega, \tag{A5}$$

so that in the benchmark case where $\Psi_{i^*} = 0$, consumption rises on impact ($\mathrm{d}c_0/\mathrm{d}i^* < 0$) and the real exchange rate appreciates ($\mathrm{d}z_0/\mathrm{d}i^* > 0$).

From Eqs. (15) and (25):

$$\begin{aligned}\mathrm{d}i_0/\mathrm{d}i^* &= i_c(\mathrm{d}c_0/\mathrm{d}i^*) + i_m(\mathrm{d}m_0/\mathrm{d}i^*)\\ &= (i_c + i_m m_c)(\mathrm{d}c_0/\mathrm{d}i^*) + i_m m_{i^*} \gtrless 0,\end{aligned} \tag{A6}$$

where $i_c + i_m m_c = \gamma(i_c + i_m \delta z_c \tilde{F})/(\gamma - i_m) > 0$ and $i_m m_{i^*} = -i_m/(\gamma - i_m) > 0$. Eq. (A6) indicates that the domestic nominal interest rate must fall on impact if consumption falls on impact ($\mathrm{d}c_0/\mathrm{d}i^* > 0$). If consumption rises on impact, however, the movement in domestic interest rates is ambiguous. If the degree of intertemporal substitution is sufficiently low, the domestic interest rate will increase on impact.

Eq. (29) implies:

$$\mathrm{d}m_0/\mathrm{d}i^* = m_c \mathrm{d}c_0/\mathrm{d}i^* + m_{i^*}, \tag{A7}$$

and, from Eq. (21):

$$\mathrm{d}b_0^*/\mathrm{d}i^* = \gamma^{-1}(1 - \mathrm{d}i_0/\mathrm{d}i^*), \tag{A8}$$

so that the impact effects on private holdings of foreign bonds and the real money stock are also indeterminate. Because $\mathrm{d}F_0/\mathrm{d}i^* = 0$, $\mathrm{d}B_0^*/\mathrm{d}i^* = -\mathrm{d}R_0/\mathrm{d}i^*$. Movements in the domestic-currency value of the real money stock and real holdings of foreign assets are thus linked by

$$\mathrm{d}b_0^*/\mathrm{d}i^* = -\mathrm{d}m_0/\mathrm{d}i^* + \delta\tilde{F}(\mathrm{d}z_0/\mathrm{d}i^*). \tag{A9}$$

From Eq. (29), it can be seen that (if initial holdings of foreign assets are not too large) $m_c$ is positive. Thus, from Eq. (A7), if consumption rises on impact ($\mathrm{d}c_0/\mathrm{d}i^* < 0$), real money balances will unambiguously increase and private holdings of foreign bonds (again, assuming that the initial level of foreign assets is not too large) will fall.[22]

With a temporary shock, the general solution of the system Eq. (34) can be written as for $0 \leq t \leq T$:

$$F = \tilde{F}_{t \leq T} + C_1 e^{\nu_1 t} + C_2 e^{\nu_2 t}, \tag{A10}$$

[22] In the benchmark case where $\tilde{F} = 0$, Eq. (A6), Eq. (A8), and Eq. (A9) yield

$$\mathrm{d}b_0^*/\mathrm{d}i^* = \{1 - i_c(\mathrm{d}c_0/\mathrm{d}i^*)\}/(\gamma - i_m),$$

so that $\mathrm{d}b_0^*/\mathrm{d}i^* > 0$ — the economy experiences a capital inflow — if consumption rises on impact ($\mathrm{d}c_0/\mathrm{d}i^* < 0$). Thus, from Eq. (A8) $|\mathrm{d}i_0/\mathrm{d}i^*| < 1$. If $i_0$ falls on impact ($\mathrm{d}i_0/\mathrm{d}i^* > 0$), it cannot fall by as much as the reduction in the world interest rate.

$$c = \tilde{c}_{t \le T} + \frac{G_F}{(\nu_1 - G_c)} C_1 e^{\nu_1 t} + \frac{G_F}{(\nu_2 - G_c)} C_2 e^{\nu_2 t}, \tag{A11}$$

for $t \ge T$:

$$F = \tilde{F}_0 + C_1' e^{\nu_1 t} + C_2' e^{\nu_2 t}, \tag{A12}$$

$$c = \tilde{c}_0 + \frac{G_F}{(\nu_1 - G_c)} C_1' e^{\nu_1 t} + \frac{G_F}{(\nu_2 - G_c)} C_2' e^{\nu_2 t}, \tag{A13}$$

where $\nu_1(= \nu)$ denotes the negative root and $\nu_2$ the positive root of the system. The four arbitrary constants $C_1, C_2, C_1', C_2'$ are determined under the assumptions that (a) $C_2' = 0$ (for the transversality condition to hold); (b) $F$ evolves continuously from its initial given value $\tilde{F}_0 = F_0$, so that $F_0 = \tilde{F}_{t \le T} + C_1 + C_2$; and (c) the time paths for $c$ and $F$ are continuous for $t > 0$. In particular, at time $t = T$, the solutions for Eqs. (A10), (A12) and Eqs. (A11), (A13) must coincide, yielding two more equations which, together with the above condition on $F_0$, uniquely determine the solution for $C_1$, $C_2$, and $C_1'$. The solutions are given by: for $0 \le t \le T$:

$$F = \tilde{F}_{t \le T} - \frac{\left(F_0 - \tilde{F}_{t \le T}\right) e^{\nu_1 t}}{G_c(\nu_2 - \nu_1)} \Delta + \frac{\nu_1(\nu_2 - G_c)\left(F_0 - \tilde{F}_{t \le T}\right) e^{\nu_2(t-T)}}{G_c(\nu_2 - \nu_1)},$$

$$c = \tilde{c}_{t \le T} - \frac{G_F\left(F_0 - \tilde{F}_{t \le T}\right) e^{\nu_1 t}}{G_c(\nu_2 - \nu_1)(\nu_1 - G_c)} \Delta + \frac{\nu_1 G_F\left(F_0 - \tilde{F}_{t \le T}\right) e^{\nu_2(t-T)}}{G_c(\nu_2 - \nu_1)},$$

and for $t \ge T$:

$$F = F_0 - \frac{\left(F_0 - \tilde{F}_{t \le T}\right) e^{\nu_1 t}}{G_c(\nu_2 - \nu_1)} \{\Delta - \nu_2(\nu_1 - G_c) e^{-\nu_1 T}\},$$

$$c = \tilde{c}_0 + \frac{G_F}{\nu_1 - G_c}(F - F_0),$$

where $\Delta = -G_c(\nu_2 - \nu_1) + \nu_1(\nu_2 - G_c) e^{-\nu_2 T}$.

Consider now the case in which the country is initially a net debtor ($\tilde{F} < 0$, so that $\Psi_{i^*}$ is unambiguously negative), because private agents are net borrowers ($\tilde{B}^* < 0$). Let $\tilde{D}$ denote net external debt, $-\tilde{B}^* - \tilde{R}^*$. Then, using Eq. (35)

$$\tilde{D} = (\rho - i^*)/\gamma - \tilde{R}^*.$$

Clearly, for $\tilde{D}$ to be positive, it must be that $\tilde{R}^* < (\rho - i^*)/\gamma$, which in turn implies that $\tilde{R}^* < \rho/\gamma$. This condition, given that $G_D = -G_F$, can be used to establish from Eq. (A3) that $\mathrm{d}\tilde{c}/\mathrm{d}i^* > 0$, so that consumption falls. To show that Eq. (A4) also implies that $\mathrm{d}\tilde{D}/\mathrm{d}i^* < 0$, note that, at the initial level of the real exchange rate:

$$\mathrm{d}\tilde{D}/\mathrm{d}i^* = -\mathrm{d}\tilde{B}^*/\mathrm{d}i^* - \mathrm{d}\tilde{R}^*/\mathrm{d}i^* = -\gamma^{-1} - m_c(\mathrm{d}\tilde{c}/\mathrm{d}i^*) < 0.$$

Because the real exchange rate depreciates ($\mathrm{d}\tilde{z}/\mathrm{d}i^* < 0$), this result holds at any level of $z$.[23] Finally, Eq. (A5) implies that with $\Psi_i^* < 0$ consumption rises on impact ($\mathrm{d}c_0/\mathrm{d}i^* < 0$), from which it can be established that the real exchange rate appreciates.

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[23] Note also that now, $G_c$ is ambiguous in sign. If $G_c$ remains positive, the same stability condition derived above in the net creditor case must hold. If $G_c < 0$, the saddlepath condition always holds, and the effect of a reduction in $i^*$ on the level of foreign debt can be established directly from Eq. (A4) — with the result being again $\mathrm{d}\tilde{D}/\mathrm{d}i^* < 0$.

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