THE EXCHANGE RATE-INVESTMENT NEXUS AND EXCHANGE RATE INSTABILITY: ANOTHER REASON FOR 'FEAR OF FLOATING'

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January 2009

Abstract: We show that expansionary monetary policy causes exchange rate overshooting due to the secondary repercussion comes through the reaction of firms to changed asset prices and the firms' decisions to invest in real capital. This overshooting effect adds to any overshooting that occurs through the traditional Dornbusch (1976) channel, since our model with its market clearing in the short run excludes any Dornbusch overshooting. The model sheds further light on the volatility of real and nominal exchange rates. It suggests that changes in corporate sector profitability may affect exchange rates through international portfolio diversification in corporate securities, and it offers an additional reason for 'fear of floating'.

Key Words: exchange rates, open economy macroeconomics, monetary policy, exchange rate overshooting

JEL Classification: F31, F32

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1. Introduction

In this paper, we investigate theoretically whether and how exchange rate induced changes in the level of investment cause a reverse effect on the exchange rate. Our approach creates a monetary surprise – as in the Dornbusch (1976) exchange rate overshooting model -- allowing the new exchange rate to affect the level of investment, and investigates the effect of this change in investment on the exchange rate.

Several empirical studies find an inverse relationship between the demand for investment goods and the level of the exchange rate (defined as the domestic currency price of one unit of foreign currency). Among OECD countries, Nucci and Pozzolo (2001), using an OECD data set, find exchange rate depreciations exert negative effects on the level of investment operating through the cost channel**.** Ginn (2006) finds much the same in Canadian data.[1] Goldberg (1993) and Campa and Goldberg (1995) find an inverse relationship in 1980s US data – a time when US manufacturing industry experienced "import exposure" in capital goods.[2] Landon and Smith (2005) also support the finding of an adverse effect of currency depreciation on levels of investment. In a large data set of OECD countries, they demonstrate that exchange rate depreciation associates with increases in the price of investment goods – a more marked effect in industries that employ larger proportions of imported capital. For emerging market economies, Mayes (2004) reports impulse response functions for Estonia, Latvia, and Lithuania for the effect of an exchange rate shock on the level of investment. In all three cases, though, Estonia exhibits

[1] In her empirical modeling, Ginn (2006) assumes that 'actors' view changes in the exchange value of the Canadian dollar as permanent changes. Our theoretical modeling below makes the same assumption.

[2] An empirical literature also exists that finds an inverse relationship between exchange rate volatility and the level of investment – see, *inter alia*, Servén (2003) and Campa and Goldberg (1995).

a stronger effect, unanticipated exchange rate depreciation causes a persistent fall in the level of investment.[3] And in a Latin American data set, Goldberg (1997) also finds an inverse relationship between exchange rate depreciations and the level of investment.

Krugman and Taylor (1978) authored a seminal paper on understanding the reasons for adverse economic effects stemming from currency devaluation in 'emerging markets.' Their arguments emerge from a Keynesian macroeconomic model with distortions caused by slow responses in real quantities to changes in relative prices. They show, among other things, that if capitalists exhibit lower consumption propensities than workers, as currency devaluation favors profits, devaluation provokes economic recession. Taylor (1983) further developed structuralist models in which inter-sectoral factor immobility, or, factor price rigidity, or, limited substitutability exists between domestic sourced and imported capital good inputs (or, combinations of these), showing that devaluation causes economic recession. More recently, thinking on the negative effects of devaluation in developing countries migrated from macroeconomic and structural modeling to consider possible adverse balance sheet effects of devaluation.[4] When emerging market banks or non-banks turn to international markets to raise capital, as did much of East Asia in the 1990s, and Latin America two decades earlier, they most often cannot borrow in their own currency due to a lack of well developed domestic capital markets – something dubbed 'original sin' by Eichengreen and Hausmann (1999). Moreover, these countries lack foreign currency hedging facilities - again for want of domestic capital markets in which the foreign counterparties providing hedging facilities could invest. The upshot, when domestic banks and non-banks hold assets denominated in domestic currency and

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[3] The depreciation actually meant higher foreign prices as all three countries operated currency boards during the data period.

[4] For a recent survey, see Frankel (2005).

liabilities in foreign currency, devaluation of the domestic currency can devastate their balance sheets, solvency, and level of lending and investment. Lamfalussy (2000) catalogues the devastating economic contractions suffered in East Asia in 1998 following the financial crisis that began the previous year. Moreover, he also refers to the 'lost decade' suffered by most of Latin America following the Mexican financial crisis of 1983.

We will show that when a change in the level of investment feeds back onto the exchange rate, the time path of the exchange rate overshoots, adding to the typical Dornbusch (1976) effect. Our model excludes Dornbusch overshooting, since we do not introduce price stickiness in the short run. In this respect, the time series of exchange rates exhibits more volatility than in Dornbusch's famous paper. We, therefore, view this paper as relating to "fear of floating" in emerging markets and other economies - as documented by Calvo and Reinhart (2000), and the widespread adoption of managed exchange rates by these countries. Our theoretical work also relates to McKinnon (2005) who points out that in several emerging East Asian market economies, countries with either habitual balance of payments deficits or surpluses choose to manage their exchange rates because foreign liabilities or assets are largely denominated in foreign currencies, and that abrupt exchange rate movements could destroy domestic company balance sheets.

In the interest of clarity and tractability, we make certain simplifying assumptions in addition to those usually made in the exchange rate literature. First, we assume that physical capital is endogenous through just two time periods, the short- and the long-runs. In this two-period framework, we avoid, and assume away, the complication of discounted values. Second, we assume that capital fully depreciates over a single time period, which makes the outstanding capital stock in the long run (second period in our analysis) equal to investment in the short run (first period). Finally, while rendering the stock of physical capital endogenous provides the novelty of this paper, our most important results stand even when we make the assumption that the rates of interest on domestic government bonds and corporate bonds remain equal at all times. That is, we assume perfect substitutability between these bonds.

The rest of the paper unfolds as follows. Section 2 describes our model. Section 3 illustrates how exchange rate volatility behaves sequentially following a monetary innovation. Section 4 concludes. The Appendix describes some important mathematical derivations that do not appear in the main text.

2. The Model

Consider a small open economy producing three goods -- traded and non-traded consumption goods, and a traded capital good (*T, N*, and *K*, respectively). The household sector's wealth consists of money (*M*), domestic government and private bonds (B^h and B^K , respectively), and foreign government bonds (*F*).[5] Private bonds finance physical capital investment. Since firms produce capital goods, we first consider the demand for and supply of capital as a good. Then we discuss the demand for and supply of capital as an asset.

2.1. Demand for and Supply of Physical Capital

Assume that firms make investment decisions and that all capital fully depreciates each period. Thus, the capital stock equals investment.[6] The demand for physical capital emerges from the profit maximization decisions of firms.[7] Once firms know their demand for capital, they float

[5] Like other open economy macroeconomic models, we assume that the household sector holds foreign government bonds (*F*), which equal a portion of the total exogenously given quantity *F**, and that foreigners do not hold domestic (government or private) bonds (Branson and Henderson 1985).

[6] This assumption keeps some rather complex analysis as simple as possible. The analysis does not change if the depreciation rate falls below 100 percent. For the analysis to proceed, the depreciation rate must exceed zero so that, in equilibrium, firms exhibit positive investment (equal to the depreciated capital).

[7] See, for example, Frenkel and Rodriguez (1975), Dornbusch (1975), and Sachs (1981).

corporate bonds to finance this demand. We assume that the rate of interest at which firms borrow equals that of the domestic government bond (r), implying that government bonds perfectly substitute for private bonds supplied by firms.[8]

The price of the non-traded good (P_N) clears that market and, given the assumption of a small open economy, the prices of the traded consumption (P_T) and traded capital (P_K) goods equal prices, adjusting for the exchange rate, in the rest of the world. That is,

(1) $$P_T = E \cdot P_T^* \text{ and } P_K = E \cdot P_K^*,$$

where E equals the nominal exchange rate (domestic currency price of a unit of foreign exchange), and P_T^* and P_K^* equal exogenously given prices of the traded consumption and capital goods measured in foreign currency. For given values of r, P_N, E, and P_i^* ($i = T, K$), the demand for capital emerges from profit maximization.

Production of good i ($i = T, N,$ and K) responds positively to the amount of capital used as follows:

(2) $$y^i = y^i(\overset{+}{k^i}),$$

where y^i equals the real production of the i-th sector's good and the plus sign over the capital stock here and in future equations indicates the sign of the marginal effect (i.e., y_K^i equals the marginal physical product of capital in sector i). Firms in sector i maximize profit (Π_i) defined as follows:

$$\Pi_i = P_i \cdot y^i(k^i) - (1+r) \cdot E \cdot P_K^* \cdot k^i > 0,$$

where P_i equals the price of the good in sector i, and $(1+r) \cdot E \cdot P_K^*$ equals the rental price (user

[8] Generally, we employ upper- and lower-case letters for nominal and real values, respectively. Interest rates prove an exception.

cost) of capital.[9] From the first-order marginal-productivity conditions, the demands for capital in the different sectors emerge as follows:

(3) $$y_K^T = (1+r)\cdot\left[P_K \big/ P_T\right] = (1+r)\cdot\left[P_K^* \big/ P_T^*\right] \quad \Rightarrow \quad k^T = k^T\left(\overset{-}{r}, \overset{-}{P_K^*} \big/ P_T^*\right);$$

(4) $$y_K^N = (1+r)\cdot\left[P_K \big/ P_N\right] = (1+r)\cdot\left[E\cdot P_K^* \big/ P_N\right] \quad \Rightarrow \quad k^N = k^N\left(\overset{-}{r}, E\cdot \overset{-}{P_K^*} \big/ P_N\right);\ \text{and}$$

(5) $$y_K^K = (1+r)\cdot\left[P_K \big/ P_K\right] = (1+r) \quad \Rightarrow \quad k^K = k^K(\overset{-}{r}).$$

Firms in different sectors demand capital until the marginal product of capital equals the rental price (user cost) of capital divided by the price of the good produced in that sector. The demand for capital in the non-traded sector (equation 4) depends on the interest rate and the ratio of the nominal exchange rate times the price of traded capital goods to the price on non-traded goods. In the traded goods sectors, however, because world markets determine the prices of traded goods (equation 1), changes in the exchange rate do not affect the demand for capital in these sectors. That is, in equation (3), the demand for capital in the traded consumption good sector depends on the interest rate and the ratio of the foreign prices of traded capital to traded goods, that is, $\left(P_K^* \big/ P_T^*\right)$. In the capital good sector (equation 5), the demand for capital depends only on the interest rate (plus the depreciation rate), as the price of capital cancels. Note that the effect of changes in the rate of interest (and other determinants) on the demand for capital depends on the elasticities of demand for the capital good in different sectors.

Firms make their investment decisions based on expectations of prices and the exchange

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[9] Remember that the depreciation rate equals one so that the rental price (user cost) of capital equals $(\delta + r)\cdot E\cdot P_K^*$ = $(1+r)\cdot E\cdot P_K^*$, where δ equals the depreciation rate.

rate. To keep the model dynamics simple, we assume that agents have static expectations.[10] That is,

$$P^e_{N,t+1} = P_{N,t},$$

where $P^e_{N,t+1}$ equals the expected price and $P_{N,t}$ equals the actual price of the non-traded consumption good in period *t*. A similar specification characterizes other prices and the exchange rate.

The total demand for capital in the economy, which equals investment with a 100-percent depreciation rate (i.e., k = real investment), equals the sum of the total demands by different sectors. That is,

(6) $$k = k^T + k^N + k^K = k\left(\overset{-}{r}, \overset{-}{P^*_K} / P^*_T, \overset{-}{E \cdot P^*_K} / P_N\right).$$

The total demand for capital, thus, responds positively to the prices of traded and non-traded consumption goods and negatively to the interest rate, the exchange rate, and the price of the capital good. The supply of capital emerges after inserting k^K from equation (5) into the production function of the capital goods sector (equation 2), giving

(7) $$y^K = y^K(\overset{-}{r}).$$

Given the supply of capital, and the determinants of the demand for capital, we can now illustrate the market for capital, which shows how the exchange rate determines the quantity demanded and whether the economy imports or exports capital. The price of capital is $E \cdot P^*_K$. That is, given the small country assumption, the price of capital changes as a result of changes in

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[10] This assumption accords with that of Ginn (2006), where all exchange rate changes are permanent, in her empirical estimations of the exchange rate investment relationship. That is, the exchange rate follows a random walk.

the exchange rate, assuming a fixed foreign currency price of capital. Note, also, that the supply of capital depends only on the interest rate (plus the depreciation rate). Figure 1 illustrates market equilibrium where investment equals the demand for capital each period, since the depreciation rate equals one. A higher exchange rate raises the domestic price of capital and lowers the quantity of capital demanded, implying a movement along the demand for capital. For a given exchange rate, a lower interest rate leads to, on the one hand, a higher demand for capital and, on the other hand, higher supply, as shown in Figure 1 by the rightward shifts of the capital demand and supply curves. The increase in demand exceeds the increase in supply, capturing a capacity constraint in the capital goods industry (Witte 1963).

2.2 Goods-Market Equilibrium and the Current Account

The supplies of traded and non-traded goods come from substituting the demands for capital into equation (2). The demands for traded and non-traded goods depend on the real exchange rate and total income, where we assume that traded and non-traded goods substitute for each other.[11] Thus, the supplies and demands in the different sectors are given as follows:

(8) $$c^T = c^T\left(\overset{-}{q}, \overset{-}{Y/P_N}\right);$$

(9) $$y^T = y^T\left(\overset{-}{r}, \overset{+}{P_K^*/P_T^*}\right);$$

(10) $$c^N = c^N\left(\overset{+}{q}, \overset{+}{Y/P_N}\right);$$

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[11] The demands for traded and non-traded goods come from household utility maximization. We deflate nominal variables by the price of non-traded goods, which plays a key role in most of our subsequent analysis. See the Appendix for details.

(11) $$y^N = y^N\left(\bar{r}, \overline{E \cdot P_K^*} / P_N\right);$$

(6) $$k = k^T + k^N + k^K = k\left(\bar{r}, \overline{P_K^*} / P_T^*, \overline{E \cdot P_K^*} / P_N\right); \text{ and}$$

(7) $$y^K = y^K(\bar{r}),$$

where c^T and c^N equal the real demands for traded and non-traded consumption goods, $q = \left[E \cdot P_T^* / P_N\right]$ equals the real exchange rate, and Y / P_N equals total real income in terms of non-traded goods, that is, nominal income divided by the price on non-traded goods. We define total nominal income below.[12]

The demand for the traded consumption good [equation (8)] depends negatively on the real exchange rate (q) and positively on real income $\left(Y / P_N\right)$. Similarly, output supplied in the traded consumption sector [equation (9)] responds negatively to the interest rate (r) and the price of the capital good in foreign currency (P_K^*), and positively to the price of the traded consumption good (P_T^*). The demand for the non-traded good [equation (10)] relates positively to both the real exchange rate and real income. The supply of the non-traded good [equation

[12] Derivation of the real exchange rate as $q = \left[E \cdot P_T^* / P_N\right]$ is as follows. By definition, the real exchange rate measures the 'home' country's price level relative to that of the foreign country, measured in the home country's currency. Thus, $q = \left(E \cdot P^* / P\right)$. Now, measure the home country's price level as $P = P_N^\alpha E^{1-\alpha}$, which assumes that the foreign county's price level, $P_T^* = 1$, α equals the share of traded goods in the home county's price index, and E measures P_T. By substitution, $q = \left(E \cdot 1 / P_N^\alpha E^{1-\alpha}\right)$; or $q = \left(E^\alpha / P_N^\alpha\right)$; or $q = \left(P_T / P_N\right)$. But given perfect substitutability between home and foreign traded goods, $P_T = E \cdot P_T^*$.

(11)] adjusts negatively to the interest rate, the nominal exchange rate (*E*), and the price of the capital good in foreign currency, and positively to the price of the non-traded good (P_N). We repeat the demand for and supply of the capital good [equations (6) and (7)], the determinants of which are discussed above. The price of the non-traded consumption good (P_N) clears the non-traded-goods market (i.e., $y^N = c^N$). The world prices of the traded consumption and capital goods (P_T^* and P_K^*) clear the world markets and, thus, the exchange rate determines the domestic prices of these goods as in equation (1). We discuss the determination of the exchange rate below.

Total income (*Y*) is defined as follows:

(12) $$Y = Y^N + Y^T + Y^K + (r^* + \Delta e^e) \cdot E \cdot F, \text{ and } Y^i = P_i y^i,\ i = N,\ T, \text{ and } K,$$

where $(r^* + \Delta e^e)$ equals the domestic currency interest earnings from foreign assets, Δe^e equals the expected rate of change in the exchange rate, $\Delta e^e = \left[(E_{t+1}^e - E_t) / E_t \right]$, and E_{t+1}^e equals the expected exchange rate in period *t+1* at time *t*. Thus, we can write total real income in terms of the non-traded goods as follows:

(12a) $$Y / P_N = y^N + q \cdot y^T + \left(E \cdot P_K^* / P_N \right) \cdot y^K + (r^* + \Delta e^e) \cdot \left(E / P_N \right) \cdot F$$

Total saving *S* equals disposable income less consumption ($P_T c^T + P_N c^N$) or

(13) $$S = (P_T y^T - P_T c^T) + P_K y^K + (r^* + \Delta e^e) \cdot E \cdot F,$$

where $y^N = c^N$, and consumption of the traded consumption good depends positively on real income (equation 8).

From national income accounting identities in a small country whose traded goods perfectly substitute for those abroad, the current account (*CA*) equals the difference between household saving and investment. That is,

(14) $$CA = S - I = (P_T y^T - P_T c^T) + (P_K y^K - P_K k) + (r^* + \Delta e^e) \cdot E \cdot F = \Delta F,$$

where *ΔF* equals the capital outflow, or the increase in (net) foreign assets held. Nominal investment (*I*) equals $P_K k$, where the depreciation rate equals 100-percent. In other words, the current account equals the negative of the capital and financial account, defined as the change in (net) foreign assets held by the household during the period. Viewed differently, the current account (equation 14) measures the difference between the nominal supplies and nominal demands for traded goods and capital plus interest earnings of foreign bonds.

In Figure 2, the left-hand quadrant shows the demand for the two traded goods (the sum of consumption and capital goods) as a negative function of the exchange rate. See equations (6) and (8) and Figure 2.[13] The total supply (the sum of the supplies of these two goods) remains fixed, for a given interest rate (plus the depreciation rate) and world prices of the traded and capital goods.[14] See equations (7) and (9) and Figure 2. The explanation for the right hand side of Figure 2 is discussed in the next section. Initially, we assume that the current account balances. Thus, the trade balance equals the negative of the interest earning on foreign bonds. As a result, supply exceeds demand at the equilibrium nominal exchange rate by the interest earnings on foreign bonds.

2.3 Asset-Market Equilibrium

Households' total nominal wealth *(W)* consists of money *(M),* domestic government bonds *(B^h),*

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[13] To aggregate the traded consumption and capital goods into one demand curve requires expressing the two demands in nominal terms. As a result, we introduce the nominal exchange rate as a common multiplier in both demands. We divide the nominal demands by the nominal exchange rate, expressing the demand in terms of foreign currency. Doing so generates the negatively sloped function of the exchange rate. Note that since the foreign prices are fixed, the domestic prices of traded consumption and capital only adjust as the nominal exchange rate adjusts. Nominal foreign currency values are expressed as $Y^{*i} = P_i^* y^i$. See the Appendix for more details.

[14] For consistency, we also express the supply in terms of foreign currency. That is, both nominal supplies expressed in domestic currency include the nominal exchange rate as a multiplier. See the Appendix for more details.

domestic private bonds (B^K), and foreign bonds in domestic currency units ($E \cdot F$),. That is,

(15) $$W = M + B + E \cdot F = M + B^h + B^K + E \cdot F \,.$$

Note that the domestic private bonds finance the capital stock (*K*). Thus, the wealth constraint conforms to the standard in macroeconomic models, where wealth includes domestic money, domestic bonds, (net) foreign bonds, and the capital stock (B^K).

The central bank's balance sheet is given as follows:

(16) $$M = B^c + R,$$

where *R* equals the foreign currency reserves held by the central bank (which with our assumption of a flexible exchange rate equals a constant) and B^c equals the domestic government bonds held by the central bank. Note that $B^G = B^c + B^h$ defines the total outstanding government bonds in the economy and reflects the accumulation of past budget policies.[15]

The supplies of *M* and B^h enter exogenously ($\overline{M}$ and $\overline{B^h}$, respectively), while the evolution of *F* (the amount of foreign bonds held by domestic residents) adjusts endogenously by equation (14). Once a firm knows its demand for capital, it finances this capital by floating bonds. The nominal amount of bonds (B^K) equals investment, that is, $B^K = E \cdot P_K^* \cdot k$. As mentioned above, we assume that private bonds and government bonds perfectly substitute for each other, so that firms borrow at the same rate of interest as that paid on government bonds. Moreover, given our assumption that capital depreciates entirely each production period, we use one-period bonds to finance the capital stock each period.

The demand for different assets depends on the domestic rate of return (*r*), the expected rate of return on foreign bonds ($r^* + \Delta e^e$), and the total wealth (*W*) as follows:

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[15] We do not discuss the government budget constraint because we analyze the effects of monetary policy only and not that of fiscal policy.

(17) $$M = m(\overset{-}{r}, \overset{-}{r^* + \Delta e^e}) \cdot W;$$

(18) $$B = B^h + B^K = b(\overset{+}{r}, \overset{-}{r^* + \Delta e^e}) \cdot W; \quad and$$

(19) $$E \cdot F = f(\overset{-}{r}, \overset{+}{r^* + \Delta e^e}) \cdot W.$$

Following Tobin (1969), we assume that the effect of a change in the rate of return of an asset on itself exceeds that on other assets. That is,

$$b_r > -f_r, \;\; b_r > -m_r, \;\; f_{r^*+\Delta e^e} > -b_{r^*+\Delta e^e}, \;\; and \;\; f_{r^*+\Delta e^e} > -m_{r^*+\Delta e^e}.$$

For a given money supply, the rate of return (r) and the exchange rate (E) that give equilibrium in the money market come from the following equation:

(20) $$(m_r \cdot W) \cdot dr + (m \cdot F) \cdot dE = 0 \;\Rightarrow\; \left.\frac{dE}{dr}\right|_{dM=0} = -\frac{m_r \cdot W}{m \cdot F} > 0.$$

A depreciation of the exchange rate (i.e., increase in E) increases the demand for money, since wealth in domestic currency rises, but given a fixed supply of money, equilibrium only restores itself, as the interest rate rises and the demand for money falls. This gives the positively sloped M_0 curve in the right-hand quadrant of Figure 2. Similarly, for given supply of domestic bonds (both government and private) and foreign assets, the rate of return (r) and the exchange rate (E) that give equilibrium in the domestic bonds and foreign assets market are shown by the following equations:

(21) $$(b_r \cdot W) \cdot dr + (b \cdot F) \cdot dE = 0 \;\Rightarrow\; \left.\frac{dE}{dr}\right|_{dB=0} = -\frac{b_r \cdot W}{b \cdot F} < 0; \text{ and}$$

(22) $$(f_r \cdot W) \cdot dr - (1-f) \cdot F \cdot dE = 0 \;\Rightarrow\; \left.\frac{dE}{dr}\right|_{dF=0} = \frac{f_r \cdot W}{(1-f) \cdot F} < 0.$$

The B_0 curve in Figure 2 slopes negatively [equation (21)] because a depreciation of the exchange rate (i.e., an increase in E) increases the demand for bonds, and equilibrium restores itself when the demand equals the supply of bonds by decreasing the interest rate (*r*). Only two independent equations exist to determine two independent variables that give asset-market equilibrium [the wealth constraint, equation (15), makes equilibrium in the third market redundant]. Nonetheless, the F_0 curve (not shown in Figure 2) also slopes negatively in the (r, E) space [equation (22)]. Note that $-{dE}/{dr}\big|_{dB=0} > -{dE}/{dr}\big|_{dF=0}$, since $b_r > -f_r \quad and \quad (1-f) > b.$[16]

Asset-market equilibrium occurs when the demands for money and bonds equal their respective supplies. Thus, the interest rate and exchange rate that produce asset-market equilibrium emerge from solving the following two implicit equations:

(23) $$\overline{M} - m(\overset{-}{r}, r^* \overset{-}{+} \Delta e^e) \cdot W = 0; \text{ and}$$

(24) $$\overline{B^h} + \overline{B^K} - b(\overset{+}{r}, r^* \overset{-}{+} \Delta e^e) \cdot W = 0.$$

Figure 2 illustrates the equilibrium at the intersection of the B_0 and M_0 curves. The F_0 curve also runs through this intersection with a negative slope, but flatter than the B_0 curve, since $b_r > -f_r$ and $(1-f) > b$.

2.4 Short-Run and Long-Run Exchange Rate Determination

In the short-run, the exchange rate first clears the asset markets and then, following that, affects the balance of payments where changes in foreign assets (*F*) offset the current account imbalance. The introduction of physical capital, as mentioned earlier, causes adjustments in both the asset and goods markets, which we restrict to the long run because of capital’s gestation period. Changes in firms' investment decisions, responding to changes in the exchange rate and

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[16] Remember that the wealth constraint implies that $m + b + f = 1$. Thus, $(1 - f) = m + b$. So, $(1 - f) > b$, since $m > 0$.

the interest rate, lead to changes in the supply of private bonds. Investment decisions of firms also affect the supply-side of the goods market. This effect, along with the demand for the traded capital goods affects the current-account and long-run equilibrium exchange rate and interest rate. In sum, we assume that the asset markets and then the goods market adjust before the production of capital (i.e., the investment decision) responds to the monetary policy change. After a gestation period, when the supply of capital adjusts, a second round of asset market and finally goods market adjustments occur.

To analyze the effects of an exogenous monetary expansion in the economy, we distinguish between the short-run and the long-run adjustment periods. In both periods, asset-market and goods-market (current-account) adjustments occur. In the short-run, the initial adjustments in the economy occur, while in the long-run, the investment decisions of firms and their effects in the economy emerge.

Adjustment processes after a monetary shock to our system of equations with endogenous capital reflects the following sequence:

Short-Run Asset-Market Adjustment. This period considers the instantaneous effects of a monetary disturbance in the asset market. It also examines the changes in the demands for different assets, and the adjustment to the asset-market short-run equilibrium, leading to the beginning-of-period exchange rate and interest rate adjustments.

Short-Run Current-Account Adjustment. This period studies the effects of asset-price changes on the demand side of the goods market. Specifically, it examines the effects of price changes on income, saving, consumption, and the current account. Capital flows resulting from changes in the current-account balance determine the end-of-the-period exchange rate and interest rate adjustments.

Long-Run Asset-Market Adjustment. In the long run, firms make adjustments to their capital stocks, given the new exchange rate and interest rate that emerges from the short-run adjustments. We explore the effects of these investment decisions on the asset market and beginning-of-period exchange rate and the interest rate adjustments.

Long-Run Goods-Market (Current-Account) Adjustment. Finally, we consider the effects of investment decisions on the current account, capital flows, and end-of-period interest rate and exchange rate adjustments. Investment decisions affect both the supply side and the demand side of the traded-goods sector and, as such, affect the current account. In the long run, the economy moves to the equilibrium exchange rate and interest rate that together give current-account balance.

Given this set-up, we examine the effects of an increase in the money supply through open market operations. To emphasize our strategy, we assume that the asset market and then the goods market adjusts before the production of capital (i.e., the investment decision) responds to the monetary policy change, Then when the supply of physical capital changes, this generates a second round of asset market and, finally, goods market adjustments.

3. Effects of Increases in the Money Supply by Open Market Operations

The initial equilibrium appears in Figure 2 with the B_0 and M_0 curves in the asset market and Y_0 and D_0 in the traded goods sector.[17] The equilibrium exchange rate and interest rate equal E_0 and r_0, respectively, and the current-account and trade-account balances. That is, no capital flows occur. In addition, the trade balance is in deficit and equal to the earned on foreign band holdings. When the central bank increases the money supply through an open market purchase of

[17] Remember that we express the demand and supply curves in foreign currency and combine the traded consumption and capital markets into one market. As a preview, this market traces the adjustment in the current account and the determination of the nominal exchange rate.

bonds, government bonds held by the household (B^h) decrease and the money supply (M) increases. This causes the following sequence of events in the economy, which follows our schema enumerated in the last section.

3.1 Short-Run Asset-Market Adjustment

When the money supply increases through open market operations, equilibrium in the money market restores itself by either decreasing the interest rate or increasing the exchange rate (i.e., lowering expected exchange rate depreciation), both of which increase the demand for money. Similarly, when the supply of bonds decreases, equilibrium in this market restores itself by decreasing the demand for bonds with either a decrease in the interest rate or a decrease in the exchange rate (i.e., raising expected exchange rate depreciation). Also, note that in the short run, the supply of capital (i.e., Y^K) and the supply of private bonds (i.e., B^h) do not change, since the investment decision only emerges by assumption in the long run.

The effects these changes exert on the equilibrium exchange rate and interest rate emerge by using the implicit function rule on equations (23) and (24) and Cramer's rule. The total effect of open market operations on the interest rate and the exchange rate equals the following:

(25) $$\left.\frac{\partial r}{\partial M}\right|_{dM=-dB^h,dB^K=dF=0} = \frac{(b+m)\cdot F}{D} < 0; \text{ and}$$

(26) $$\left.\frac{\partial E}{\partial M}\right|_{dM=-dB^h,dB^K=dF=0} = -\frac{(b_r+m_r)\cdot W}{D} > 0, \text{ because } b_r > -m_r,$$

where $D = (b\cdot m_r - m\cdot b_r)F\cdot W < 0,$ since $m_r < 0$ and $b_r > 0.$

Figure 2 illustrates the new equilibrium at the intersection of the M_1 and B_1 curves after shifting from M_0 and B_0.[18] The increase in the supply of money creates an excess supply, putting downward pressure on the interest rate for a given nominal exchange rate. Similarly, the reduction in the supply of domestic bonds creates an excess demand, pushing the interest rate down for a given nominal exchange rate. A lower interest rate, however, leads to a higher demand for foreign bonds, creating an excess demand and putting downward pressure on the exchange rate.[19] Thus, the short-run effect of an open market operation (derived from asset-market equilibrium) produces a higher (depreciated) exchange rate (E_1) and a lower interest rate (r_1) than the initial values. The real exchange rate $\left(q = \left[E \cdot P_T^* / P_N\right]\right)$ increases by the same proportion as that of the nominal exchange rate, since possible changes in the price on non-traded goods (P_N) occurs in the short-run current account (goods market) adjustment.

3.2 Short-Run Goods-Market (Current-Account) Adjustment

Here, the effects of changes in the exchange rate and the interest rate reflect adjustments on the demand side of the traded-goods (traded consumption and capital) market. Since supply depends only on the capital stock, which adjusts in the long run, output remains fixed during short-run goods-market (current-account) adjustment. The adjustment in the non-traded goods sector, however, provides important information for determining short-run adjustment in the goods market.

Equilibrium in the non-traded goods market requires that demand equals supply. In addition, since capital does not adjust until the long run, the supply of non-traded goods equals a

[18] Why does the M curve shift more horizontally than the B curve? Given the magnitude of the open market operation, to reestablish equilibrium in the money and bond markets, respectively, requires a larger horizontal shift in the M curve than in the B curve, since $b_r > -m_r$.

[19] Given no adjustment in the current account in this period, the supply of foreign bonds available domestically remains fixed.

constant in the short run. The increase (depreciation) in the nominal exchange rate causes both the real exchange rate and nominal income to rise. To re-establish equilibrium with the increase in the demand for non-traded goods, the price of non-traded goods must increase. In addition, the increase in the price of non-traded goods must cause the real exchange rate and real income to fall sufficiently so that the reduction in demand for non-traded goods exactly offset the increase in demand caused by the increase in the nominal exchange rate. That is, the rise in the price of non-traded goods must exactly offset the rise in the nominal exchange rate from E_0 to E_2, and return the real exchange rate and real income to their initial values.[20]

Bringing the previous discussion together, real supplies remain unchanged because capital only adjusts in the long run. On the demand side, the ratio of the nominal exchange rate to the price on non-traded goods and, thus, the real exchange rate and real income do not change.[21] Consequently, the current account adjusts as follows:

$$(27) \qquad dCA = \left[CA/E \right] dE \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \text{ and } CA \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0.$$

Since we assume for simplicity that the current account initially balances, the current account remains in balance during the short-run goods market adjustment period.

In summary, the expansionary monetary policy leaves at the end of the short run a lower interest rate, a higher nominal exchange rate, an unchanged real exchange rate and real income, and a trade deficit, offset by income from the interest earned on foreigner bonds. Consequently, the DD curve in Figure 2 must shift vertically at each quantity by the increase in the nominal exchange rate, since short-run equilibrium requires the ratio of the nominal exchange rate to the

[20] See the Appendix for more details.

[21] The interest rate falls, stimulating the demand for capital (investment). But, capital adjustments, including the interest rates effect on capital demand, occur in the long run.

price on non-traded goods to remain unchanged. Further, if we introduced some form of sticky prices in this model, such as in Dornbusch (1976), then we could generate the Dornbusch overshooting result. But, our model is a market-clearing model. Thus, we observe monetary neutrality in that the monetary policy change only generates changes in nominal values.

3.3 Long-Run Asset-Market Adjustment

Given the new interest rate, firms make their investment decisions. Note that the lower interest rate increases investment in all sectors (though with different intensities, depending on the respective elasticities of capital demand). The movement in the nominal exchange rate does not cause any adjustment in investment in the non-traded goods sector because the rise in the price of non-traded goods leaves the real exchange rate unchanged. See equation (6).

As mentioned earlier, the increase in the demand for capital goods affects both the goods and asset markets. In the long-run asset-market adjustment period, however, for tractability we abstract from goods market adjustment, considered next, and only entertain the asset-market equilibrium and the determination of the exchange rate and the interest rate. To invest in capital, firms float new bonds (equal to the nominal value of investment). Thus, the increase in investment increases the supply of domestic bonds, lowering their price and increasing the interest rate.[22] Figures 3a and 3b illustrate the effects of an increase in the private bond supply on the interest rate and the exchange rate. Larger bond supply increases wealth and the demand for both money and bonds. The supply of bonds rises more than the demand for bonds, because of the adding-up constraint for asset demands. The excess demand for money and the excess supply of bonds requires a higher interest rate, for a given exchange rate, to achieve market equilibrium. Thus, the B and M curves experience rightward shifts from B_2 to B_3 and M_2 to M_3. The

[22] Remember that we employ one-period bonds, since capital completely depreciates each production period.

changes in the interest rate and the equilibrium nominal exchange rate due to increased private bond supply emerges from applying the implicit function rule on equations (23) and (24) and Cramer's rule. The total effects of an increase in the supply of private bonds equal the following:

(28) $$\left.\frac{\partial r}{\partial B^K}\right|_{dM=dB^h=dF=0} = -\frac{m \cdot F}{D} > 0; \text{ and}$$

(29) $$\left.\frac{\partial E}{\partial B^K}\right|_{dM=dB^h=dF=0} = \frac{[(1-b)\cdot m_r + m \cdot b_r]\cdot W}{D} = ?,$$

where the effect of an increase in private bond supply on the nominal exchange rate does not possesses a determinant sign. Two opposing effects operate on the exchange rate. First, increases in the bond supply raise nominal wealth (*W*), thereby strengthening the demand for all assets including foreign bonds. This puts downward pressure on the exchange rate. Second, the higher interest rate decreases the demand for foreign bonds and appreciates the currency. Depending on which of these effects dominates, the exchange rate in the long-run asset-market equilibrium may rise (depreciate) or fall (appreciate). We illustrate an example of each of these cases in Figures 3a and 3b, respectively.

The discussion of the long-run current-account adjustment begins with the observation that the interest rate falls during the short-run asset-market adjustment.[23] Thus, firms plan to accumulate capital in the long run and will issue private bonds to finance their acquisition of more capital. The long-run asset-market adjustment shows that the interest rate rises, because firms expand the supply of private bonds to finance the acquisition of a larger capital stock and raise the interest rate in the process. The rise in the interest rate, however, cannot reverse the fall of the interest rate generated during the short-run asset-market adjustment. Otherwise, firms will

[23] The short-run current-account adjustment leaves the interest rate unchanged because of our assumption of static expectations about the exchange rate.

not plan to accumulate capital. That is, although the interest rate will rise because of the long-run asset-market adjustment, it will not surpass its initial starting point.

3.4 Long-Run Goods-Market (Current-Account) Adjustment

Higher capital investment affects the current account in two ways. On the one hand, an increase in the demand for capital goods, which occurs in all sectors, worsens the current-account deficit. We already considered this shift in the demand for traded goods during the short-run adjustment in the goods market in Figure 2 from DD_0 to DD_1. On the other hand, more investment leads to an increase in output supplied by firms that improves the current account. In Figures 3a and 3b, this appears as a leftward shift in the supply curve from SS_0 to SS_1. We will discuss demand side shifts shortly.

A key to understanding the long-run adjustment in the goods market involves how adjustment occurs in the non-traded goods market, just as we saw for short-run goods market adjustment. That is, the non-traded goods market must clear. But, in the long run, both the demand for and supply of non-traded goods adjust. Market equilibrium implies that

$$c^N = c^N\left(\overset{+}{q}, \overset{+}{Y/P_N}\right) = y^N\left(\overset{-}{r}, \overset{-}{E \cdot P_K^*/P_N}\right) \tag{30}$$

The change in the interest rate affects the supply of non-traded goods directly and the demand for traded goods indirectly through real income. That is, based on changes in the interest rate only, a lower interest rate increases the supplies in each sector, thus increasing real income. The ratio of the nominal exchange rate to the price of non-traded goods and the real exchange rate, on the other hand, rise or fall depending on whether the supply-side effect exceeds or falls short of the demand side effect (see the Appendix for details).

Combining all of these effects will allow us to determine whether the current account improves or worsens. Taking the total differential of the current account equation (14) with respect to the interest rate, the nominal exchange rate, and the nominal exchange rate over the price of non-traded goods yields the following result (See the Appendix for details):

(31)
$$dCA = \left[P_T \cdot y_r^T + P_K \cdot y_r^K - P_T \cdot c_{Y/P_N}^T \cdot \left\{ y_r^N + q \cdot y_r^T + \left({E \cdot P_K^*}/{P_N} \right) \cdot y_r^K \right\} \right] dr + \left({CA}/{E} \right) dE$$
$$- \left[P_T \cdot c_q^T \cdot \left(P_T^* \cdot y^T + P_K^* \cdot y^K + (r^* + \Delta e^e) \cdot F \right) + P_K \cdot k_{\left(E/P_N \right)} \right] d\left({E}/{P_N} \right).$$

We know that the interest rate falls, but that the ratio of the nominal exchange rate to the price of non-traded goods can increase or decrease. Moreover, the term in brackets modifying *dr* does not possess a determinant sign. Since we enter the long run with a current account balance, the coefficient of dE equals zero.[24] Finally, the term modifying the second term involving $d\left(E/P_N \right)$ exceeds zero.

Thus, we can identify two cases: the current account improves or worsens. The exchange rate provides the equilibrating factor in the long-run current-account adjustment process. Given the two cases of a higher (depreciated) and lower (appreciated) nominal exchange rate that come from the long-run asset-market adjustment, we can consider four cases – higher exchange rate with a current-account surplus or deficit and a lower exchange rate with a current-account deficit or surplus. We now discuss two of those cases in turn – higher exchange rate and a current-account surplus and a lower exchange rate and a current-account deficit.[25]

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[24] The term $\left(CA/E \right) \cdot dE$ reflects a scale effect as the nominal exchange rate changes. Since the demand for and supply of traded goods are expressed in foreign currency, the shifts in these curves reflect all other terms in equation (31), except $\left(CA/E \right) \cdot dE$.

[25] We will discuss the other two cases in footnotes.

The adjustments in the current account reflect shifts in the supplies and demands for traded consumption and capital (See Figures 3a and 3b). If the current account goes into surplus (deficit), then the supply shift exceeds (falls short of) the demand shift.

Case I: (Figure 3a). We assume in Figure 3a that the current account ends the long-run asset-market adjustment in surplus (i.e., $CA > 0$) and that the nominal exchange rate rises (depreciates). In addition, the demand curve shifts to DD_2, which is a smaller earlier mentioned shift in the supply curve to SS_1. This accommodates the development of a current account surplus. The current-account surplus leads to accumulation of foreign assets. As foreign assets accumulate, the M_3 curve moves to M_4, B_3 moves to B_4, and asset-market equilibrium occurs at a lower exchange rate (E_4). The effects of the accumulation of (net) foreign assets on the interest rate and the nominal exchange rate appear in equations (28) and (29).

Once again, the adjustment in the non-traded good market plays a critical role. Since the interest rate does not adjust further in the long run goods market period, the ratio of the nominal exchange rate to the price of non-traded goods must remain constant, implying that the nominal exchange rate and the price of non-traded goods moves up or down proportionally with each other. In so doing, the real exchange rate, real income, and $\left(E \cdot P_K^* / P_N \right)$ do not change and the non-traded goods market remains in equilibrium. Thus, the adjustment in the nominal exchange rate occurs without further shifts in the supply of and demand for traded consumption and capital in Figure 3a.

Long-run equilibrium emerges when the nominal exchange rate appreciates enough to give current-account balance.[26] The only adjustment occurs through the interest earned on foreign assets, which fall sufficiently to balance the current account. In other words, no further shifts in the supply of and demand for traded consumption and capital occur.

Case II (Figure 3b). We assume in Figure 3b that along with a lower (appreciated) nominal exchange rate, the current account ends the long-run asset-market adjustment in deficit (i.e., $CA < 0$). Here, the shift in the demand for traded consumption and capital to DD_2 exceeds the shift in the supply curve to SS_1 to accommodate the current account deficit in Figure 3b. A current-account deficit translates into selling foreign bonds. A fall in foreign bonds held by domestic residents decreases nominal wealth, shifting the M_3 curve moves to M_4 and B_3 moves to B_4 in Figure 3b. The effects of the accumulation of (net) foreign assets on the interest rate and the nominal exchange rate appear in equations (28) and (29).

Long-run equilibrium emerges when the exchange rate depreciates enough to give current-account balance.[27] Once again, all adjustment occurs through the increase in the domestic currency value of interest earnings on foreign bonds. That is, since the interest rate does not adjust in the long-run goods market adjustment, equilibrium in the non-traded goods market requires that the ratio of the nominal exchange rate to the price on non-traded goods remains constant. That is, no further shifts in the supply of and demand for traded consumption and capital occurs.

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[26] If the current account initially experienced a deficit at the beginning of the long-run current-account adjustment, then the country would loss (net) foreign assets and the nominal exchange rate would depreciate until the current account balanced.

[27] If the current account initially experienced a surplus at the beginning of the long-run current-account adjustment, then the country would gain (net) foreign assets and the nominal exchange rate would appreciate until the current account balanced.

3.5 Summary

Introducing capital into an open economy macroeconomic model, thus, makes the effects of monetary policy on different variables more volatile (see Figures 2, 3a, and 3b). Open market operations occur at the beginning of the period and the figures illustrate the short-run adjustments (i.e., Figure 2) and the long-run adjustments (i.e., Figures 3a and 3b) induced by the change in capital investment by firms.

Consider, first, Figures 2 and 3a. In Figure 2, the short-run adjustment in the exchange rate leads to depreciation (i.e., E rises from E_0 to E_1). No further adjustment in the nominal exchange rate occurs in the short-run goods-market adjustment as the current account does not go into deficit or surplus. The long-run adjustment captured in Figure 3a (i.e., Case I) experiences overshooting.[28] That is, the exchange rate depreciates (i.e., E rises from E_1 to E_2) in response to the long-run asset-market adjustment, since we assume in Case I that the wealth effect of the increase in bond supply on the exchange rate dominates the interest rate effect. But this initial long-run depreciation gets offset somewhat by an appreciation (i.e., E falls from E_2 to E_3) in response to the long-run current-account adjustment.

Now, consider Figures 2 and 3b. The short-run adjustment process follows the arguments of the previous paragraph with a depreciating exchange rate. The long-run adjustment captured in Figure 3b (i.e., Case II) also experiences overshooting of the exchange rate.[29] That is, the exchange rate appreciates (i.e., E falls from E_1 to E_2) in response to the long-run asset-market

[28] Overshooting occurs only if the initial situation entering the long-run current-account adjustment exhibits a current-account surplus. If, instead, the economy experiences a current-account deficit, then the exchange rate continues to depreciate during the final long-run current-account adjustment.

[29] Overshooting occurs only if the initial situation entering the long-run current-account adjustment exhibits a current-account deficit. If, instead, the economy experiences a current-account surplus, then the exchange rate continues to appreciate during the final long-run current-account adjustment.

adjustment, since we assume in Case II that the interest rate effect on the exchange rate dominates the wealth effect. This initial long-run appreciation is partially offset by depreciation (i.e., E rises from E_2 to E_3) in response to the long-run current-account adjustment.

In sum, an open market purchase by the central bank causes a short-run and a long-run depreciation of the exchange rate in Case I. The long-run depreciation associates with overshooting of the exchange rate. In Case II, however, an open market purchase causes a short-run depreciation, but a long-run appreciation with overshooting, where the long-run appreciation reduces, but does not reverse, the short-run depreciation. For the cases not considered in these sections, the long-run adjustment in the exchange rate extends and reinforces the short-run movement.

4. Conclusions

The exchange rate model developed in this paper attempts to depict the interaction between exchange rates and firms' investment decisions. Tobin (1969) introduced the idea of Tobin's *q,* which expresses a representative firm's rate of investment as a function of the ratio of its share price to the price an extra unit of physical capital. A fall in q reduces the level of new investment. Currency depreciation, by raising the price of capital goods, reduces profitability in the business sector, and in reducing share prices (calculated as the discounted value of profits), lowers Tobin's q, and so the rate of investment. We show that this decrease in investment, stemming from currency depreciation, has a 'reverse', or, secondary, effect on the exchange rate. This secondary effect ultimately drives the nominal and real exchange rates and the current account to long-run equilibriums that differ from those in exchange rate overshooting models that ignore this secondary effect.[30] The inclusion of capital as a traded good along with its financing decision (i.e., the floating private bonds) reveal an additional channel for exchange rate movements, one more reason for the fear of floating observed in emerging markets.

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[30] Nor, to the best of our knowledge, do the new open economy models of, for example, Obstfeld and Rogoff (1996), examine this reverse investment effect on the exchange rate and the balance of payments

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Figure 1: Demand and Supply of Physical Capital

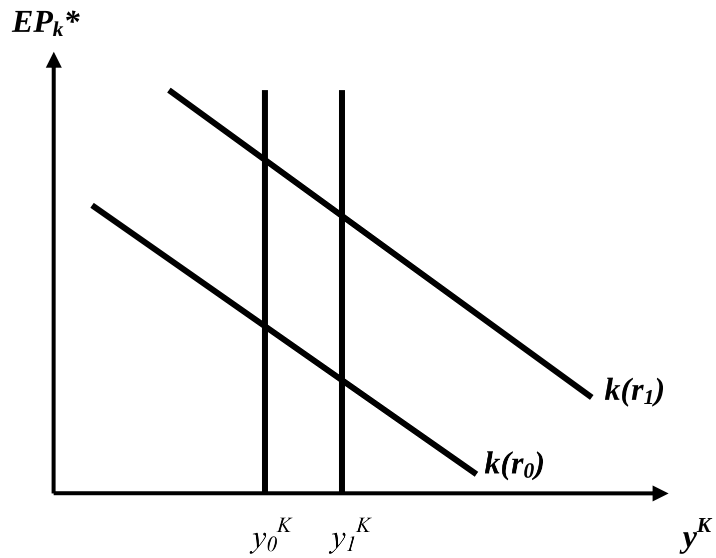


Figure 2: Short-Run Adjustments

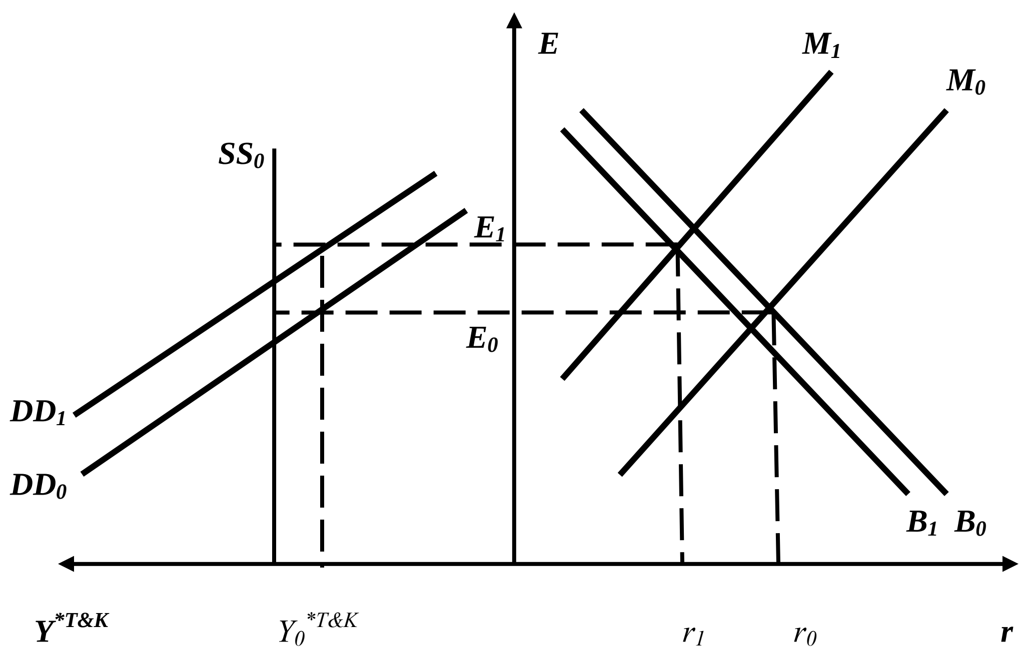


Figure 3a: *Long-Run Adjustments: Exchange Rate Depreciation in the Asset-Market Equilibrium and Improvement in the Current Account*

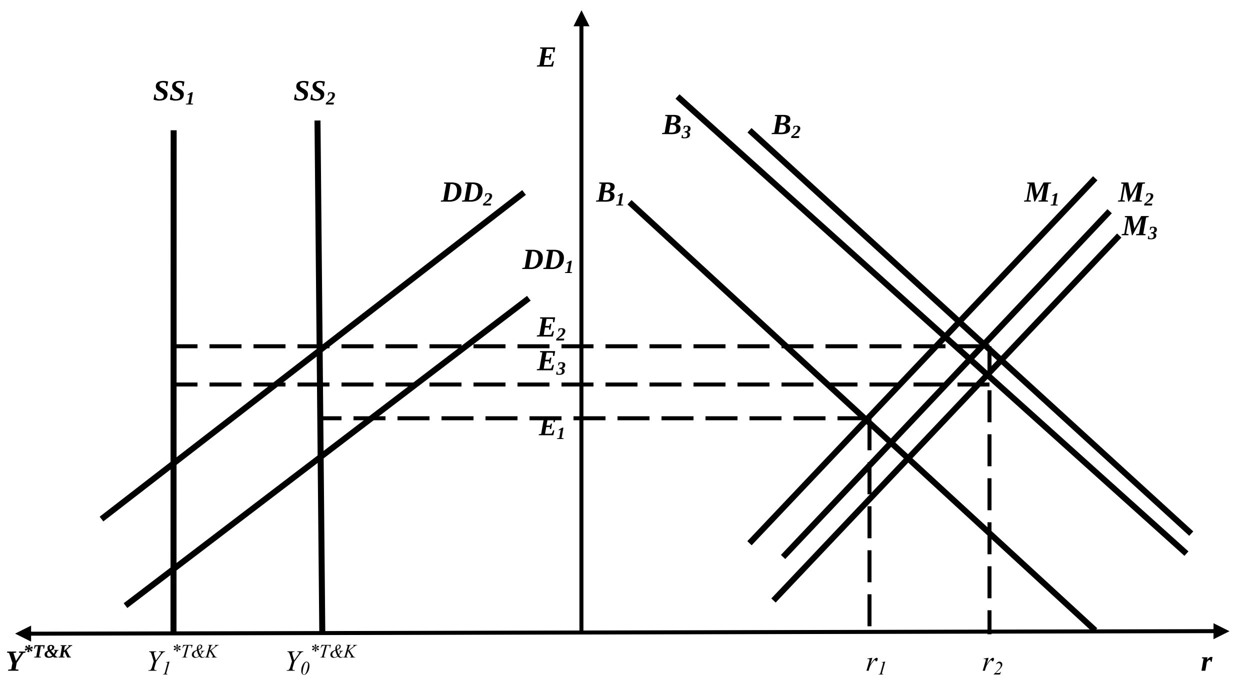
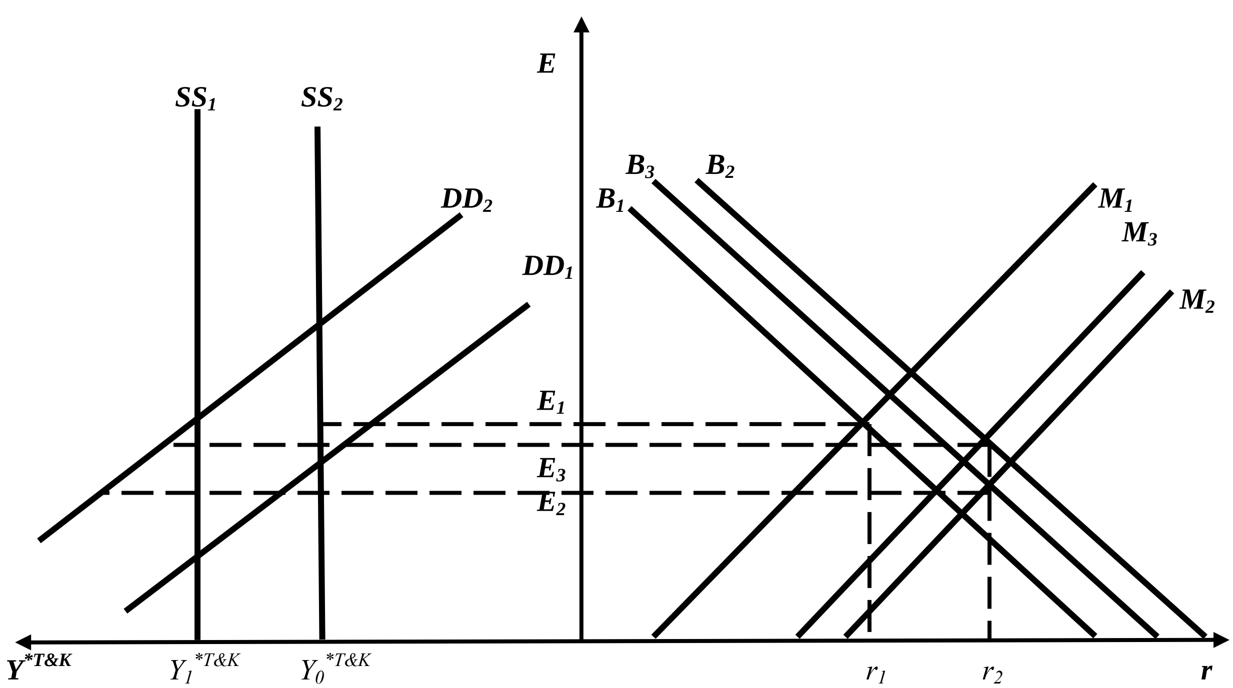


Figure 3b: *Long-run Adjustments: Exchange Rate Appreciation in the Asset-Market Equilibrium and Worsening of the Current Account*



Appendix: Mathematical Derivations

We repeat the relevant equations for our analysis in this appendix as follows:

(2) $y^i = y^i(\overset{+}{K^i}),$ where $i = T, N,$ and $K;$

(3) $$y_K^T = (1+r)\cdot\left[P_K / P_T\right] = (1+r)\cdot\left[P_K^* / P_T^*\right] \quad \Rightarrow \quad k^T = k^T\left(\overset{-}{r}, \overset{-}{P_K^* / P_T^*}\right);$$

(4) $$y_K^N = (1+r)\cdot\left[P_K / P_N\right] = (1+r)\cdot\left[E\cdot P_K^* / P_N\right] \quad \Rightarrow \quad k^N = k^N\left(\overset{-}{r}, \overset{-}{E\cdot P_K^* / P_N}\right);$$

(5) $$y_K^K = (1+r)\cdot\left[P_K / P_K\right] = (1+r) \quad \Rightarrow \quad k^K = k^K(\overset{-}{r});$$

(6) $$k = k^N + k^T + k^K = k\left(\overset{-}{r}, \overset{-}{P_K^* / P_T^*}, \overset{-}{E\cdot P_K^* / P_N}\right);$$

(7) $$y^K = y^K(\overset{-}{r});$$

(8) $$c^T = c^T\left(\overset{-}{q}, \overset{+}{Y / P_N}\right);$$

(9) $$y^T = y^T\left(\overset{-}{r}, \overset{+}{P_K^* / P_T^*}\right);$$

(10) $$c^N = c^N\left(\overset{+}{q}, \overset{+}{Y / P_N}\right);$$

(11) $$y^N = y^N\left(\overset{-}{r}, \overset{-}{E\cdot P_K^* / P_N}\right);$$

(12) $Y = Y^N + Y^T + Y^K + (r^* + \Delta e^e)\cdot E\cdot F$ and $Y^i = P_i y^i,\ i =, N, T,$ and $K;$

(12a) $$Y/P_N = y^N + q \cdot y^T + \left(E \cdot P_K^* / P_N \right) \cdot y^K + (r^* + \Delta e^e) \cdot \left(E/P_N \right) \cdot F$$

(13) $$S = (P_T y^T - P_T c^T) + P_K y^K + (r^* + \Delta e^e) \cdot E \cdot F;$$

(14) $$CA = S - I = (P_T y^T - P_T c^T) + (P_K Y^K - P_K k) + (r^* + \Delta e^e) \cdot E \cdot F = \Delta F;$$

(15) $$W = M + B + E \cdot F = M + B^h + B^K + E \cdot F;$$

(17) $$M = m(\overset{-}{r}, r^* \overset{-}{+} \Delta e^e) \cdot W;$$

(18) $$B = B^h + B^K = b(\overset{+}{r}, r^* \overset{-}{+} \Delta e^e) \cdot W; \text{ and}$$

(19) $$E \cdot F = f(\overset{-}{r}, r^* \overset{+}{+} \Delta e^e) \cdot W.$$

The modeling in the text involves four stages, corresponding to (i) short-run asset-market equilibrium, (ii) short-run goods-market equilibrium, (iii) long-run asset-market equilibrium, and (iv) long-run goods-market equilibrium. The distinction between the short and long runs occurs because investment and capital accumulation only occur in the long run. Moreover, since we specify for simplicity that the production functions only depend on capital, we impose the condition that supplies of output in the various sectors remain fixed in the short run.

A.1 Deriving the Demands for Traded and Non-Traded Consumption Goods

Since our model does not explicitly involve intertemporal decisions, we specify an aggregate utility function that depends on traded and non-traded consumption goods plus nominal saving. The representative consumer maximizes this utility function subject to the income constraint. This gives the following optimization problem:

$$\max_{\{c^T, c^N, s\}} U = U(c^T, c^N, s)$$

(A-1) subject to $Y = E \cdot P_T^* \cdot c^T + P_N \cdot c^N + S$ or

$$\left(Y/P_N \right) = q \cdot c^T + c^N + s,$$

where $q = \left({E \cdot P_T^*}/{P_N} \right)$ and $s = \left({S}/{P_N} \right)$. That is, we express the budget constraint in real terms, deflating by the price of non-traded goods.

The demands for traded and non-traded consumption and nominal saving derive from the first order conditions to this optimization. The implicit form of the demands will depend on the exogenous variables as follows:

$$c^T = c^T\left(\overset{-}{q}, \overset{+}{Y/P_N} \right);$$

(A-2) $$c^N = c^N\left(\overset{+}{q}, \overset{+}{Y/P_N} \right); \text{ and}$$

$$s = s\left(\overset{?}{q}, \overset{+}{Y/P_N} \right).$$

But, from the budget constraint, we can rewrite the saving demand as follows:

(A-3) $$S = P_N \cdot s = s\left(\overset{?}{q}, \overset{+}{Y/P_N} \right) = Y - E \cdot P_T^* \cdot c^T\left(\overset{-}{q}, \overset{+}{Y/P_N} \right) - P_N \cdot c^N\left(\overset{+}{q}, \overset{+}{Y/P_N} \right).$$

Now, substituting from equation (12) gives the following:

(A-4) $$S = Y^T - E \cdot P_T^* \cdot c^T\left(\overset{-}{q}, \overset{+}{Y/P_N} \right) + Y^K + (r^* + \Delta e^e) \cdot E \cdot F,$$

since the non-traded goods market clears and cancels from (A-4). Equation (A-4) equals equation (13) above, where we make some substitutions.

A.2 Deriving the Graphs: Aggregate Demand and Aggregate Supply

The aggregate demand curve in Figure 2 come from equations (6) and (8) where as the aggregate supply curve comes from equations (7) and (9). Note that the aggregate demand and aggregate supply curves only determine the output of the traded goods sectors – goods and capital. It excludes the demand for and supply of non-traded goods, which come from equations (10) and

(11). We assume that the price of non-traded goods adjusts to clear the non-traded-goods market in the short run.

Aggregate demand (*DD*) for traded goods and capital is given by the following equation:

(A-5) $$DD = P_T^* c^T \left(\overset{-}{q}, \overset{+}{Y / P_N} \right) + P_K^* k \left(\overset{-}{r}, \overset{-}{P_K^* / P_T^*}, \overset{-}{E \cdot P_K^* / P_N} \right).$$

As we noted in the text, we measure this demand in foreign currency. That is, we divide the total demand in domestic currency by the nominal exchange rate. Since the prices of both traded consumption and capital are determined in world markets, the domestic prices equal the world prices times the nominal exchange rate. That is, the nominal exchange rate merely acts as a multiplicative factor on both components. And since we graph the demand as a function of the nominal exchange rate, we obtain the typical negatively sloped demand once we convert the demand into foreign currency.

Taking the total derivative of equation (A-5) with respect to the nominal exchange rate (*E*) and the demand for traded consumption goods and capital, holding the interest rate, real income constant, and the price on non-traded goods constant, gives the following result for the derivative of the demand for traded consumption goods and capital with respect to the nominal exchange rate:

(A-6) $$\frac{dDD}{dE} = P_T^* \cdot c_q \cdot \left(P_T^* / P_N \right) + P_K^* \cdot k_{E \cdot P_K^* / P_N} \cdot \left(P_K^* / P_N \right) < 0.$$

In other words, the slope of the *DD* curve is unambiguously negative.

Aggregate supply (*SS*) for traded goods and capital is given by the following equation:

(A-7) $$SS = P_T^* y^T \left(\overset{-}{r}, \overset{-}{P_K^* / P_T^*} \right) + P_K^* y^K (\overset{-}{r}) = Y^{*T} + Y^{*K} = Y^{*T\&K} .$$

The supply of output in the traded and capital goods sectors depends on the production functions in equation (2), which we express in foreign currency to match the specification of *DD*. We then substitute for capital from the solutions in equations (3) and (5) to obtain the results in equation (A-7). But, as noted above, capital does not adjust in the short run and the output equals a constant, as seen in the vertical aggregate supply curve depicted in Figure 2. The price of the non-traded good adjusts to equate the demand for and supply of non-traded goods in the short run (not shown).

A.3 Deriving the Graphs: Asset-Market Equilibrium Curves

We substitute the definition of wealth, equation (15), into the three asset market equilibriums, equations (17), (18), and (19), to give the following:

(A-8) $$M = m(\overset{-}{r}, r^* \overset{-}{+} \Delta e^e)[M + B^h + B^K + E \cdot F];$$

(A-9) $$B = B^h + B^K = b(\overset{+}{r}, r^* \overset{-}{+} \Delta e^e)[M + B^h + B^K + E \cdot F];\text{ and}$$

(A-10) $$E \cdot F = f(\overset{-}{r}, r^* \overset{+}{+} \Delta e^e)[M + B^h + B^K + E \cdot F].$$

Taking the total differential of these three equations with respect to the nominal exchange rate (*E*) and the interest rate (*r*), holding all other variables constant, yields the following:

(A-11) $$m_r \cdot dr + mF \cdot dE = 0;$$

(A-12) $$b_r \cdot dr + bF \cdot dE = 0;\text{ and}$$

(A-13) $$F \cdot dE = f_r \cdot dr + fF \cdot dE.$$

The outcomes for the derivative of the nominal exchange rate with respect to the interest rate equal the following:

(A-14) $$\left.\frac{dE}{dr}\right|_{dM = dB^h = dB^K = dF = 0} = -\frac{m_r W}{mF} > 0;$$

(A-15) $$\left.\frac{dE}{dr}\right|_{dM=dB^h=dB^K=dF=0} = -\frac{b_r W}{bF} < 0; \text{ and}$$

(A-16) $$\left.\frac{dE}{dr}\right|_{dM=dB^h=dB^K=dF=0} = \frac{f_r W}{(1-f)F} < 0.$$

The money-market equilibrium curve slopes upward where as both the domestic and foreign bond-market equilibrium curves slope downward, as seen in Figure 2. The foreign bond-market equilibrium curve is not shown in Figure 2, but intersects the same point as the money and domestic bond-market equilibrium curves, because of Walras Law, but with a larger absolute slope than the domestic bond-market equilibrium curve, because $b_r > -f_r$ and $(1-f) > b$.

A.4 Short-Run Asset-Market Adjustment

Suppose that the monetary authorities increase the money supply through open market operations. Thus, the central bank buys domestic bonds, removing them from the supply side of the market, and purchases the bonds with money, increasing the supply of money. During short-run asset market adjustment, only the interest rate and the nominal exchange rate adjust with domestic and foreign price levels fixed.

Totally differentiating equations (17) and (18) and using equation (15) produces the following result:

(A-17)
$$dM = m_r W \cdot dr + mF \cdot dE \text{ and}$$
$$dB^h = b_r W \cdot dr + bF \cdot dE, \text{ where } dB^h = -dM.$$

Putting the system of equations into matrix form produces the following:

(A-18) $$[D]\begin{bmatrix} dr \\ dE \end{bmatrix} = \begin{bmatrix} m_r W & mF \\ b_r W & bF \end{bmatrix}\begin{bmatrix} dr \\ dE \end{bmatrix} = \begin{bmatrix} dM \\ -dM \end{bmatrix}, \text{ where } |\mathrm{D}| = (bm_r - mb_r)\cdot FW < 0.$$

Applying Cramer's rule to this system of equations produces the following solutions:

(A-19) $$\left.\frac{\partial r}{\partial M}\right|_{dM=-dB^h, dB^K=dF=0} = \frac{(b+m)\cdot F}{D} < 0; \text{ and}$$

(A-20) $$\left.\frac{\partial E}{\partial M}\right|_{dM=-dB^h, dB^K=dF=0} = -\frac{(b_r+m_r)\cdot W}{D} > 0, \text{ because } b_r > -m_r,$$

Thus, expansionary monetary policy causes the money-market equilibrium curve to shift to the left and the domestic bond-market equilibrium curve to shift to the right, as seen in Figure 2. Moreover, the shift in the money-market equilibrium curve proves larger than in the domestic bond-market equilibrium curve, since the nominal exchange rate rises. That is, examining equations (A-17), holding the nominal exchange rate unchanged (i.e., $dE = 0$), and solving for the change in the interest rate (i.e., dr) for an open market purchase, we see that the interest rate must fall more for the money-market equilibrium curve shift, since $b_r > -m_r$.

A.5 Short-Run Goods-Market (Current-Account) Adjustment

Once again, we note that since the production functions depend only on the capital stock and that capital stock adjustments confine themselves to the long run, the supply of output in each market remains unchanged in the short run. The expansionary monetary policy leads to a rise in the nominal exchange rate and a fall in the interest rate. A higher nominal exchange rate also implies a higher real exchange rate before considering any adjustment in the price of non-traded goods. But, the adjustment in the non-traded goods sector provides important information for determining short-run adjustment in the goods market.

Equilibrium in the non-traded goods market requires that demand equals supply. In addition, since capital does not adjust until the long run, the supply of non-traded goods equals a constant in the short run. Thus, market clearing requires the following:

(A-21)
$$c^N = c^N\left(\overset{+}{q}, \overset{+}{Y/P_N}\right) = y^N,$$
$$\text{where } Y/P_N = q \cdot y^T + y^N + \left(E \cdot P_K^* / P_N\right) \cdot y^K + (r^* + \Delta e^e) \cdot \left(E/P_N\right) \cdot F.$$

Note that the definition of real income in terms of the non-traded good's price implies that it does not change as long as the nominal exchange rate to the price of non-traded goods does not change. Now, the increase (depreciation) in the nominal exchange rate causes both the real exchange rate and nominal income rise. To re-establish equilibrium with the increase in the demand for non-traded goods, the price of non-traded goods must increase. In addition, the increase in the price of non-traded goods must cause the real exchange rate and real income to fall sufficiently so that the reduction in demand for non-traded goods exactly offset the increase in demand caused by the increase in the nominal exchange rate. That is, the rise in the price of non-traded goods must exactly offset the rise in the nominal exchange rate from E_0 to E_2, and return the real exchange rate and real income to their initial values.

Taking the total differential of equation (A-21) with respect to E/P_N produces the following:

(A-22)
$$\frac{\partial c^N}{\partial q} \cdot P_T^* \cdot d\left(E/P_N\right) + \frac{\partial c^N}{\partial \left(Y/P_N\right)} \cdot \left[P_T^* \cdot y^T + P_K^* \cdot y^K + (r^* + \Delta e^e) \cdot F\right] \cdot d\left(E/P_N\right) = 0.$$
$$\Rightarrow d\left(E/P_N\right) = 0,$$

since the partial derivatives of non-traded consumption demand with respect to the real exchange rate and real income are both positive. In the derivation of this result, we used the observation that

(A-23)
$$d\left(Y/P_N\right) = \left[P_T^* \cdot y^T + P_K^* \cdot y^K + (r^* + \Delta e^e) \cdot F\right] \cdot d\left(E/P_N\right)$$

Real supplies remain unchanged because capital only adjusts in the long run. Real demands also remain unchanged, but because the ratio of the nominal exchange rate to the price on non-traded goods and, thus, the real exchange rate do not change. Consequently, the rising nominal exchange rate produces the following effect on the current account (i.e., equation 14):

(A-24) $$dCA = \left[CA/E \right] dE \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0 \text{ and } CA \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 0.$$

since the current account (*CA*) contains the nominal exchange rate multiplicatively in each term. That is, if the current account initially exhibited a surplus (deficit), then the rising nominal exchange rate will make the surplus (deficit) larger. In addition, a rising exchange rate will not affect the current account, if it initially balanced. In this paper, we assume that initially the current account balances. Thus, the current account remains in balance during the short-run goods-market adjustment.

A.6 Long-Run Asset-Market Adjustment

The end result of the short-run adjustments in the asset market and goods market (current account) produces a lower interest rate and a higher nominal exchange rate. In addition, the real exchange rate, real income and the ratio of the nominal exchange rate to the price on non-traded goods do not change. The lower interest rate increases investment in the long run.

Focusing only on the asset-market adjustment, firms finance higher investment by issuing domestic bonds (B^h), affecting both the money and bond market equilibriums. Taking the total differential of the money and bond market equilibrium conditions with respect to the interest rate, the nominal exchange rate, and the supply of domestic bonds yields the following result:

(A-25)

$$0 = m_r W \cdot dr + m \cdot dB^K + mF \cdot dE \text{ and}$$

$$dB^K = b_r W \cdot dr + b \cdot dB^K + bF \cdot dE.$$

Putting the system of equations into matrix form produces the following:

(A-26)
$$[D]\begin{bmatrix} dr \\ dE \end{bmatrix} = \begin{bmatrix} m_r W & mF \\ b_r W & bF \end{bmatrix}\begin{bmatrix} dr \\ dE \end{bmatrix} = \begin{bmatrix} -m \cdot dB^K \\ (1-b) \cdot dB^K \end{bmatrix}.$$

Applying Cramer's rule to this system of equations produces the following solutions:

(A-27)
$$\left.\frac{\partial r}{\partial B^K}\right|_{dM=dB^h=dF=0} = -\frac{m \cdot F}{D} > 0; \text{ and}$$

(A-28)
$$\left.\frac{\partial E}{\partial B^K}\right|_{dM=dB^h=dF=0} = \frac{[(1-b)\cdot m_r + m \cdot b_r)\cdot W}{D} = ?, \text{ since } (1-b) > m \text{ and } -m_r < b_r.$$

An increase in the supply of bonds causes the interest rate to rise, but produces an indeterminate movement in the nominal exchange rate. This adjustment in the asset market in the long run occurs because of the short-run decrease in the interest rate. Thus, the actual investment process attenuates the short-run decrease in the interest rate, but cannot completely reverse it. The indeterminate effect on the nominal exchange rate arises because higher wealth increases the demand for all assets, including the demand for foreign bonds and tending to downward pressure on the nominal exchange rate. At the same time, a higher interest rate decreases the demand for foreign bonds, putting upward pressure on the nominal exchange rate.

A.7 Long-Run Goods-Market (Current-Account) Adjustment

The fall in the interest rate in the short run stimulates long-run adjustment. As a reminder, the interest rate falls in the short-run asset market adjustment, but does not change in the short-run goods-market (current-account) adjustment, because of our assumption of static exchange rate expectations. The long-run adjustment captures the increases in the supply of and demand for capital. The long-run asset market adjustment implies that the interest rate rises as capital adjusts.

But, the rise in the interest rate cannot offset the short-run decrease. Otherwise, no reason would exist for the capital demand and supply to rise in the first place.

A key to understanding the long-run adjustment in the goods market involves how adjustment occurs in the non-traded goods market, just as we saw for short-run goods market adjustment. Once again, the non-traded goods market must clear. But, in the long run, both the demand for and supply of non-traded goods adjust. Market equilibrium implies that

(A-29) $$c^N = c^N\left(\overset{+}{q}, \overset{+}{Y/P_N}\right) = y^N\left(\overset{-}{r}, \overset{-}{E\cdot P_K^*/P_N}\right)$$

Taking the total differential of the equilibrium condition in equation (A-29) with respect to the interest rate, the real exchange rate, and real income produces the following result:

(A-30) $$\begin{aligned} & c_q^N \cdot P_T^* \cdot d\left(E/P_N\right) + c_{Y/P_N}^N\left[y_r^N + q\cdot y_r^T + \left(E\cdot P_K^*/P_N\right)\cdot y_r^K\right]\cdot dr \\ & c_{Y/P_N}^N \cdot \left[P_T^*\cdot y^T + P_K^*\cdot y^K + (r^* + \Delta e^e)\cdot F\right]\cdot d\left(E/P_N\right) = \\ & \qquad y_r^N \cdot dr + y_{\left(E\cdot P_K^*/P_N\right)}^N \cdot P_K^* \cdot d\left(E/P_N\right). \end{aligned}$$

In this derivation, we use the observation that

(A-31) $$\begin{aligned} d\left(Y/P_N\right) = & \left[y_r^N + q\cdot y_r^T + \left(E\cdot P_K^*/P_N\right)\cdot y_r^K\right]\cdot dr \\ & + \left[P_T^*\cdot y^T + P_K^*\cdot y^K + (r^* + \Delta e^e)\cdot F\right]\cdot d\left(E/P_N\right). \end{aligned}$$

Solving for the effect of the interest rate on real income and, thus, the real exchange rate produces the following outcome:

(A-32) $$\frac{d\left(E/P_N\right)}{dr} = \frac{y_r^N - c_{\left(Y/P_N\right)}^N\cdot\left[y_r^N + q\cdot y_r^T + \left(E\cdot P_K^*/P_N\right)\cdot y_r^K\right]}{c_q^N\cdot P_T^* + c_{\left(Y/P_N\right)}^N\cdot\left[P_T^*\cdot y^T + P_K^*\cdot y^K + (r^* + \Delta e^e)\cdot F\right] - y_{\left(E\cdot P_K^*/P_N\right)}^N\cdot P_K^*} = ?$$

That is, the change in the interest rate affects the supply of non-traded goods directly and the demand for traded goods indirectly through real income. The ratio of the nominal exchange rate to the price of non-traded goods and the real exchange rate rise or fall depending on whether the supply-side effect exceeds or falls short of the demand side effect (i.e., the two terms in the numerator of the effect).

Combining all of these effects will allow us to determine whether the current account improves or worsens. Taking the total differential of the current account equation (14) with respect to the interest rate and the nominal exchange rate yields the following result:

(A-33)
$$\begin{aligned} dCA = & \left[P_T \cdot y_r^T + P_K \cdot y_r^K - P_T \cdot c_{Y/P_N}^T \cdot \left\{ y_r^N + q \cdot y_r^T + \left({E \cdot P_K^*}/{P_N} \right) \cdot y_r^K \right\} \right] dr + \left({CA}/{E} \right) dE \\ & - \left[P_T \cdot c_q^T \cdot \left(P_T^* \cdot y^T + P_K^* \cdot y^K + (r^* + \Delta e^e) \cdot F \right) + P_K \cdot k_{\left(E/P_N \right)} \right] d\left({E}/{P_N} \right). \end{aligned}$$

We know that the interest rate falls, but that the ratio of the nominal exchange rate to the price of non-traded goods can increase or decrease. Moreover, the term in brackets modifying *dr* does not possess a determinant sign. Since we enter the long run with a current account balance, the coefficients of dE equals zero. Finally, the bracket modifying the second term involving $d\left(E/P_N \right)$ exceeds zero.

We distinguish between two cases in this paper: the current account improves with a higher (depreciated) exchange rate or worsens with a lower (appreciated) exchange rate.

<u>Case I: Higher Nominal Exchange Rate and Current-Account Surplus.</u> The current-account surplus increases the purchases foreign bonds, which causes adjustments in the asset markets as follows.

Taking the total differential of the money-market and bond-market equilibrium conditions produces the following result:

(A-34)
$$mE \cdot dF = m_r W \cdot dr + mF \cdot dE \text{ and}$$
$$bE \cdot dF = b_r W \cdot dr + bF \cdot dE.$$

Putting the system of equations into matrix form produces the following:

(A-35)
$$[D]\begin{bmatrix} dr \\ dE \end{bmatrix} = \begin{bmatrix} m_r W & mF \\ b_r W & bF \end{bmatrix}\begin{bmatrix} dr \\ dE \end{bmatrix} = \begin{bmatrix} -mE \cdot dF \\ -bE \cdot dF \end{bmatrix}.$$

Applying Cramer's rule to this system of equations produces the following solutions:

(A-336)
$$\left.\frac{\partial r}{\partial F}\right|_{dM = dB^h = dB^K = 0} = \frac{(mbEF - mbEF)}{D} = 0; \text{ and}$$

(A-37)
$$\left.\frac{\partial E}{\partial F}\right|_{dM = dB^h = dB^K = 0} = \frac{(mb_r - bm_r) \cdot EW}{D} = \frac{(mb_r - bm_r) \cdot EW}{(bm_r - mb_r) \cdot FW} = -\frac{E}{F} < 0.$$

The effect on the interest rate, as before, equals zero, because we assume static expectations for the expected future exchange rate. Since foreign assets accumulate in this case, the nominal exchange rate falls.[31]

For both Case I and Case II (below), the adjustment in the non-=traded good market proves critical. That is, equilibrium in the non-traded goods market is given in equation (A-26) repeated for convenience:

(A-29)
$$c^N = c^N\left(\overset{+}{q}, \overset{+}{Y/P_N}\right) = y^N\left(\overset{-}{r}, \overset{-}{E \cdot P_K^* / P_N}\right).$$

Since the interest rate does not change in the long-run goods-market adjustment, equilibrium in the non-traded goods market requires that the nominal exchange rate and the price of non-traded

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[31] If the current account initially experienced a deficit at the beginning of the long-run current-account adjustment, then the country would loss (net) foreign assets and the nominal exchange rate would depreciate until the current account balanced.

goods move proportionally with each other so that their ratio, $\left(E/P_N\right)$,does not change. Consequently, we experience no shifts in the supply of or demand for traded consumption goods and capital in this period. The same conclusion holds for Case II, to which we now turn.

Case II: Lower Nominal Exchange Rate and Current-Account Deficit. The current-account deficit decreases the purchases foreign bonds, which causes adjustments in the asset markets as follows.

Taking the total differential of the money-market and bond-market equilibrium conditions produces the following result:

(A-38)
$$mE \cdot dF = m_r W \cdot dr + mF \cdot dE \text{ and}$$
$$bE \cdot dF = b_r W \cdot dr + bF \cdot dE.$$

Putting the system of equations into matrix form produces the following:

(A-39)
$$\left[D\right]\begin{bmatrix} dr \\ dE \end{bmatrix} = \begin{bmatrix} m_r W & mF \\ b_r W & bF \end{bmatrix}\begin{bmatrix} dr \\ dE \end{bmatrix} = \begin{bmatrix} -mE \cdot dF \\ -bE \cdot dF \end{bmatrix}.$$

Applying Cramer's rule to this system of equations produces the following solutions:

(A-40)
$$\left.\frac{\partial r}{\partial F}\right|_{dM=dB^h=dB^K=0} = \frac{(mbEF - mbEF)}{D} = 0; \text{ and}$$

(A-41)
$$\left.\frac{\partial E}{\partial F}\right|_{dM=dB^h=dB^K=0} = \frac{(mb_r - bm_r)\cdot EW}{D} = \frac{(mb_r - bm_r)\cdot EW}{(bm_r - mb_r)\cdot FW} = -\frac{E}{F} < 0.$$

The effect on the interest rate, as before, equals zero, because we assume static expectations for the expected future exchange rate. Since foreign assets decrease in this case, the nominal exchange rate rises.[32]

[32] If the current account initially experienced a surplus at the beginning of the long-run current-account adjustment, then the country would gain (net) foreign assets and the nominal exchange rate would appreciate until the current account balanced.