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Abstract

We develop an open economy macroeconomic model with real capital accumulation and microeconomic foundations. We show that expansionary monetary policy causes exchange rate overshooting, not once, but potentially twice; the secondary repercussion comes through the reaction of firms to changed asset prices and the firms decisions to invest in real capital. The model sheds further light on the volatility of real and nominal exchange rates, and it suggests that changes in corporate sector profitability may affect exchange rates through international portfolio diversification in corporate securities.

Journal of Economic Literature Classification: F31, F32

Keywords: physical capital, open economy macroeconomic, monetary policy, exchange rate

Monetary Policy, Exchange Rate Overshooting, and Endogenous Physical Capital

Abstract: We develop an open economy macroeconomic model with real capital accumulation and microeconomic foundations. We show that expansionary monetary policy causes exchange rate overshooting, not once, but potentially twice; the secondary repercussion comes through the reaction of firms to changed asset prices and the firms' decisions to invest in real capital. The model sheds further light on the volatility of real and nominal exchange rates, and it suggests that changes in corporate sector profitability may affect exchange rates through international portfolio diversification in corporate securities.

1. Introduction

Even though capital goods constitute a large percentage of total trade and empirical studies show that investment affects the long-term current-account balance,[1] few open economy macroeconomic models incorporate investment in physical capital (Krueger, 1983). Rather, these models typically postulate a fixed capital stock, and consider only financial assets in the portfolios of households (e.g., Allen and Kenen 1980, Branson 1978, Dornbusch and Fischer 1980, Dornbusch 1975, chapter 5, Genberg and Kierzkowski 1979, Isard 1977, Kouri 1976, and Rodriguez 1980).[2] A similar state of affairs holds for empirical tests of open economy macroeconomic models (e.g., Hooper and Morton 1983 and Frankel 1983).

The omission of investment in open economy macroeconomic models that consider the current account poses a theoretical problem, since the current account equals the (ex-post) difference between saving and investment. By fixing investment, fluctuations in the current

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[1] In a sample of 82 countries, capital imports represented about 30 percent of total imports (Serven, 1995). Dar and Amirkhalkhali (1991) and Sachs (1981, 1983) show the effects of investment on the current account.

[2] Some current-account models incorporate investment in physical capital, but these models do not consider asset markets (e.g., Kouri, 1978, Sachs, 1981, and Ruffin, 1979). Some monetary models also consider capital, but the exchange rate is not an asset price as in open economy macroeconomic models (e.g., Connolly and Taylor, 1976, and Frenkel and Rodriguez, 1975).

account correspond only to adjustments in national saving. Those few models that do incorporate capital do not consider an array of assets. For example, Dornbusch (1975, chapter 6) includes the capital stock in an open economy macroeconomic model, but does not consider domestic (private or government) bonds. Furthermore, capital, a non-traded good in his model, does not affect the current account directly. In our model, however, physical capital enters as a traded good and, as such, affects the current account.

Our paper relates to the behavior of Tobin's q in the context of an open economy. Tobin's q expresses a representative firm's rate of investment as depending on the ratio of its share price to the price an extra unit of capital (an extra "machine") (Tobin, 1969). A q greater than one stimulates new investment. Currency depreciation raises profitability in the business sector, and in raising share prices (calculated as the discounted value of profits), raises Tobin's q, and so the rate of investment. We show that this increase in investment, stemming from currency depreciation, causes 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 equilibriums that differ from those in earlier open economy macroeconomic models. Those models ignore the reverse investment effect of currency depreciation caused by monetary expansion in a sticky price open economy. 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. The inclusion of capital as a traded good along with its financing decision (i.e., floating private bonds) provides additional reasons for exchange rate movements, increasing volatility

Endogenous physical capital in an open economy macroeconomic model introduces a richer mix of connections between the financing of firms, and the production of, supply of, and

demand for physical capital. Such investment directly links the asset and goods markets, and this emphasis differs from that found in other open economy macroeconomic models. As Allen and Kenen (1978) and Hallwood and MacDonald (2000) note, the goods market only indirectly links to the asset market through the exchange rate; no direct link exists. We also show, and emphasize, how endogenous physical capital affects the current, and the capital and financial accounts of the balance of payments.

To emphasize our point, endogenous physical capital permits innovations in monetary policy to affect the time-path of equilibrium exchange rates through new avenues. Thus, by including a previously over-looked dynamic specification, our analytical results may partly explain the poor empirical performance of earlier open economy macroeconomic models.

In the interest of clarity and tractability, we make certain simplifying assumptions in addition to those usually made in the open economy literature. First, physical capital is endogenous through just two time periods, the short and 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 equal to the current period's investment. Third, 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 and corporate bonds remain equal at all times. That is, we assume perfect substitutability between these bonds. To simplify the analytics of our discussion, we assume static exchange rate expectations. Finally, our model relies exclusively on demand and supply and market analysis.

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;

and the final section draws conclusions.

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*).[3] 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.

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.[4] The demand for physical capital emerges from the profit maximization decisions of firms as in, *inter alia*, Frenkel and Rodriguez (1975), Dornbusch (1975), and Sachs (1981). Once firms know their demand for capital, they float 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.

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 capital (P_K) goods equal

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[3] 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).

[4] 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).

prices, adjusting for the exchange rate, in the rest of the world. That is,

(1) $$P_T = E \cdot P_T^* \quad and \quad P_K = E \cdot P_K^*,$$

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 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 cost) of capital.[5] From the first-order marginal-productivity conditions, the demands for capital in the different sectors emerge as follows:

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

[5] 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.

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

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

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 its own price, the price of the capital good in the foreign currency, and the exchange rate (*E*). 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 world prices of its good and that of the capital good (P_T^* and P_K^*, respectively). 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 rate. To keep the model dynamics simple, we assume that agents have static expectations. That is,

$$P_{N,t+1}^e = P_{N,t},$$

where $P_{N,t+1}^e$ 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, where exchange rate expectations provide a crucial part of our model.[6]

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

(6) $$K = K^K + K^T + K^K = k(\overset{-}{r}, \overset{-}{P_K^*}, \overset{+}{P_T^*}, \overset{-}{E}, \overset{+}{P_N}).$$

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. Note, however, that the exchange rate affects the non-traded sector only, giving $|k_r| > |k_E|$ in the aggregate. 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 equals $E \cdot P_K^*$. That is, given the small country assumption, the price of capital changes as a result of

[6] Open economy macroeconomic models assume both perfect foresight and static expectations (e.g., Dornbusch 1975 and Hallwood and MacDonald 2000, respectively). Ample evidence began accumulating in the early-1980s that portfolio managers moved from fundamental analysis to technical analysis, since the fundamental models seriously under-predicted dollar appreciation (e.g., Frankel and Froot 1986, 1990b). Moreover, since the pioneering paper by Meese and Rogoff (1983), many researchers attempt to overturn the finding that the simple random walk proves the best predictor of the exchange rate. A wide consensus now exists in international finance – illustrated by Frankel and Rose (1995) and Rogoff (1999) – that analysts cannot forecast exchange rates. If true, then the expected change in the exchange rate equals zero, supporting the adoption of static expectations. Nonetheless, throughout our analysis, the qualitative results do not change, if we adopt a process of expectations formation that exhibits inelastic exchange rate expectations (i.e., a mean reversion process for the exchange rate). Note that static expectations imply unitary elastic exchange rate expectations. Frankel and Froot (1987) find support for inelastic exchange rate expectations using survey data from a sample of central bankers, private bankers, corporate treasurers, and economists. In another paper, Frankel and Froot (1990a), also using survey data, find extrapolative (elastic) exchange rate expectations at short horizons, whereas mean reversion (inelastic expectations) set in at longer horizons. In sum, our analytical analysis focuses on the longer time horizon where inelastic exchange rate expectations hold.

changes in the exchange rate, assuming a fixed foreign 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. 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 movement 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).

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.[7] Thus, the supplies and demands in the different sectors are given as follows:

(8) $$C^T = c^T(\overset{-}{q}, \overset{+}{Y});$$

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

(10) $$C^N = c^N(\overset{+}{q}, \overset{+}{Y});$$

(11) $$Y^N = y^N(\overset{-}{r}, \overset{+}{P_N^*}, \overset{-}{P_K^*}, \overset{-}{E});$$

(6) $$K = K^K + K^T + K^K = k(\overset{-}{r}, \overset{-}{P_K^*}, \overset{+}{P_T^*}, \overset{-}{E}, \overset{+}{P_N});$$ and

[7] The demands for traded and non-traded goods come from household utility maximization.

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

where $q = \left[E \cdot P_T^* \big/ P_N \right]$ equals the real exchange rate, and Y equals total income as defined below.

Equation (8) says that the demand for the traded consumption good depends negatively on the real exchange rate (q) and positively on income (Y). Similarly, equation (9) shows that output supplied in the traded consumption sector 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)] responds positively to both the real exchange rate and income. The supply of the non-traded good [equation (11)] depends negatively on the interest rate, the nominal exchange rate (E), and the price of the capital good in foreign currency, and positively on the price of the non-traded good (P_N). Equations (6) and (7) repeat the demand for and supply of the capital good, the determinants of which are discussed above. The price of the non-traded consumption good P_N proximately clears the non-traded-goods market (i.e., $Y^N = C^N$), and the prices of the traded consumption and capital goods clear the world markets, given the exchange rate. We discuss the determination of the exchange rate below.

Total income (Y) is defined as follows:

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

where $(r^* + \Delta e^e)$ equals the domestic currency interest earnings from foreign assets, Δe^e equals the expected rate of depreciation in the exchange rate, $\Delta e^e = \left[(E_{t+1}^e - E_t) \big/ E_t \right]$, and E_{t+1}^e equals the

expected exchange rate in period *t+1* at time *t*.[8] Total saving *S* equals disposable income less consumption $(C^T + C^N)$ or

(13) $$S = (Y^T - C^T) + Y^K + (r^* + \Delta e^e) \cdot E \cdot F,$$

where $Y^N = C^N$, and consumption of the traded consumption good depends positively on 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) $$CA = S - I = (Y^N - C^N) + (Y^T - C^T) + (Y^K - I) + (r^* + \Delta e^e) \cdot E \cdot F = \Delta F,$$

where ΔF equals the capital outflow, or the increase in (net) foreign assets held. 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. 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. 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. See equations (7) and (9) and Figure 2.

Asset-Market Equilibrium

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[8] We include the expected rate of depreciation of the exchange rate in the return on foreign assets. But static expectations will make this contribution to income zero. If another expectations formulation process exists, then depreciation in the exchange rate (i.e., *E* rises) causes the current account to improve through adjustments in the demands for traded and capital goods and the increasing nominal value of (net) foreign assets in domestic currency units (i.e., $E \cdot F$). The depreciation of the exchange rate produces deterioration in the current account through reduced expected rate of depreciation of the domestic currency (i.e., inelastic exchange rate expectations). The former effects dominate the latter effect, if a depreciating exchange rate improves the current account, which we assume.

Households' total nominal wealth *(W)* consists of money *(M)*, domestic government bonds *(* B^h *)*, 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 equals the summation of bonds issued to finance prior deficits.[9] That is,

$$B^G = \sum_{i=t-1}^{-\infty} (G - T)_i ,$$

where G and T equals government outlays and revenue.

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) is determined 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, $B^K = E \cdot P_K^* \cdot K$.

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

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.

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:

(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,

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

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

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.[10] This gives the positively sloped M_0 curve in the right-hand quadrant of Figure 2. Similarly, for given supply of domestic bonds

[10] Adopting an expectations formation different from static expectations, whereby a depreciation of the spot exchange rate reduces the expected rate of depreciation, does not alter the results in equation (20) or in equations (21), (22), (26), (27), (31), and (32) that follow. This assertion holds as long as exchange rate expectations prove inelastic. In fact, this assertion still holds for elastic exchange rate expectations as long as the effect through

(both government and private)[11] and foreign assets, the rate of return (*r*) and the exchange rate (*E*) that give equilibrium in the domestic bonds and foreign assets market come from the are shown by the following equations:

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

(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 $-\left.dE/dr\right|_{dB=0} > -\left.dE/dr\right|_{dF=0}$, since $b_r > -f_r \quad and \quad (1-f) > b.$[12]

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

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exchange rate expectations proves relatively small. See footnote 6 for further discussion on exchange rate expectations.

[11] Holding the supply of private bonds constant means the supply of capital equals a constant as well.

[12] Remember that the wealth constraint implies that *m + b + f = 1*. Thus, *(1 – f) = m + b*. So, *(1 – f) > b*, since *m > 0*. With other than static expectations (see footnote 10), the F_0 curve still possesses a negative slope.

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

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* $(1-f) > b.$

Short-Run and Long-Run Exchange Rate Determination

Broadly speaking, the short-run exchange rate clears the asset market while the current-account balance, by changing foreign held assets (*F*), determines the long-run exchange rate. The introduction of physical capital, as mentioned earlier, causes adjustments in both the asset and goods markets. Changes in firms' investment decisions lead to changes in the supply of private bonds, where instantaneous adjustments determine the short-run exchange rate and the interest rate. 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. 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 determination of the short-run exchange rate and interest rate.

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 equilibrium exchange rate and interest rate.

Long-Run Asset-Market Adjustment: Here, the period considers the effects of monetary policy on the private sector. In this period, firms make adjustments to their capital stocks, given the new exchange rate and interest rate. We explore the effects of these investment decisions on the asset market and the determination of the equilibrium values of the exchange rate and the interest rate.

Long-Run Goods-Market (Current-Account) Adjustment: This period studies the effects of investment decisions on the current account, capital flows, and the determination of the final interest rate and exchange rate. Investment decisions affect both the supply side and the demand side of the traded-goods sector and, as such, affect the current account. The economy moves to the equilibrium exchange rate and interest rate that together give current-account balance. Final (long-run) equilibrium occurs when no further wealth accumulates, no changes in net-investment occur, saving equals investment, and the current-account balances.

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. The equilibrium exchange rate and interest rate equal E_0 and r_0, respectively, and the current-account balances. That is, no capital flows occur. When the central bank increases the money supply through an open market purchase of 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.

Short-Run Asset-Market Adjustments

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

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

where $$D = b\cdot m_r \cdot F\cdot W - b_r \cdot m\cdot F\cdot W < 0.$$

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.[13] 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.[14] 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. Note that 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.

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 goods market. The initial effect of a higher nominal exchange rate increases

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[13] 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 $b_r > -m_r$.

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

the real exchange rate that decreases the quantity demanded of the traded consumption good. This, with a fixed supply, improves the current account as follows:

(27) $$dCA = \left[-c_q^T \cdot P_T^* \big/ P_N + r^* \cdot F \right] dE > 0; \quad c_q^T < 0,$$

where c_q^T equals the partial derivative of the traded consumption good with respect to the real exchange rate. A decrease in consumption of the traded good increases saving [see equation (13)] that can cause either increased investment in physical capital or accumulation of foreign assets. Since investment decisions only occur in the long run (discussed later), all increased saving during this period leads to the accumulation of foreign assets. This manifests itself in the deficit in the capital and financial account (equal to the current-account surplus). Thus, the current account equals the excess of saving over the current level of investment.

The current-account surplus puts downward pressure on the exchange rate and, as such, it appreciates (i.e., *E* decreases). This appears in the asset market as an increase in foreign assets and thereby in nominal wealth, leading to the rightward movement of the *M* curve (to M_2) and the leftward movement of the *B* curve (to B_2) in Figure 2. More specifically, the effects of the increase in foreign assets 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 the increase in foreign assets on the interest rate and the exchange rate equals the following:

(28) $$\left. \frac{\partial r}{\partial F} \right|_{dM = dB^h = 0} = 0; \quad and$$ [15]

[15] The effect on the interest rate equals zero, because we assume static expectations for the expected future exchange rate. With other expectations models (see footnote 10), a rise in the spot exchange rate will alter the expected rate of depreciation of the exchange rate and generate a non-zero change in the interest rate from a change in (net) foreign assets. Moreover, depending on the elasticities of the money and bond demands with respect to the expected rate of

(29) $$\left.\frac{\partial E}{\partial F}\right|_{dM=dB^h=0} = \frac{(m \cdot b_r - b \cdot m_r) \cdot E}{D} < 0.$$

The end-of-the-period equilibrium exchange rate (E_2) falls below the initial short-run level (E_1).[16] As foreign assets (*F*) accumulate, income increases [see equation (12)] and consumption of the traded consumption good increases, moving the current account toward balance. The increase in consumption appears as the movement of the demand for traded goods leftwards (from D_0 to D_1) in Figure 2. Note that in short-run current-account equilibrium when (net) foreign assets no longer change, the economy runs a trade-account deficit, financed by the interest earnings from foreign assets.

In the non-traded-goods sector, a higher short-run asset-market equilibrium nominal exchange rate and a larger income increase the demand for goods produced in this sector, increasing the price of non-traded goods. This, along with a falling nominal exchange rate in the current-account adjustment period (from E_1 to E_2), decreases the real exchange rate. Because the price of the non-traded goods increases and the nominal exchange rate decreases in this period, the real exchange rate decreases proportionally more than the nominal rate.

Long-Run Asset-Market Adjustment

Given the new interest rate and exchange rate, firms make their investment decisions. Note that these variables affect investment in the various sectors differently. For example, while a lower interest rate increases investment in all sectors (though with different intensities, depending on the respective elasticities of capital demand), a higher exchange rate (E_2 as compared to E_0)

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depreciation of the exchange rate, the interest rate can rise or fall. Thus, our finding of no change in the interest rate provides a good baseline for analysis.

[16] But, the exchange rate still exceeds E_0.

lowers investment in the non-traded sector only. In this sector, an increase in the exchange rate works in the opposite direction to the decrease in the interest rate. Depending on which effect is stronger, the non-traded sector invests/disinvests. Overall investment in the economy depends on the relative capital intensities of the different sectors. Assuming that investment in the traded and capital goods sectors dominates that in the non-traded sector (if negative), the overall investment in the economy increases.

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, we only consider 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). This increases the supply of domestic bonds, lowering their price and increasing the interest rate. 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. 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 from M_2 to M_3. The 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:

(30) $$\left.\frac{\partial r}{\partial B^K}\right|_{dM=dE=0} = -\frac{m \cdot F}{D} > 0; \quad and$$

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

where the effect of an increase in private bond supply on the nominal exchange rate does not possesses a determinant sign. Again, asset-market equilibrium determines the interest rate and exchange rate. The effect of an increase in the supply of bonds on the interest rate proves positive, while the effect on the exchange rate proves ambiguous. 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 dominate, 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.[17] 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 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.

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

Long-Run 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 occurs in different sectors, and this worsens the current-account deficit. This appears in Figures 3a and 3b as leftward shifts in the demand curve for traded goods from D_1 to D_2. 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 Y_0 to Y_1. The total effect of investment on the current account, thus, depends on these two effects as follows:

$$dCA = (y_r^T + y_r^K)dr - \left[k_r \cdot dr + \left(k_E + c_q^T \cdot \left\{ P_T^* / P_N \right\} - r^* \cdot F \right) dE \right]; \tag{32}$$

$$y_r^T < 0, y_r^K < 0, k_r < 0, k_E < 0, c_q^T \cdot \left\{ P_T^* / P_N \right\} < 0, \quad and \left| k_r \right| > \left| k_E \right|.$$

The relative size of the demand for capital goods and the corresponding effect on the current account depends on the demand elasticities of capital in different sectors. Two cases can be distinguished: 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.[18]

Case I: (Figure 3a): A higher (depreciated) nominal exchange rate dampens the demand-side

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

effect of higher investment by reducing the demand for capital goods in the non-traded sector. We assume in Figure 3a that the current account ends the long-run asset-market adjustment in surplus (i.e., $CA > 0$). A higher nominal exchange rate also increases the real exchange rate, thereby decreasing the demand for the traded consumption good, improving the current account (as shown by equation 32), and increasing household saving. Some of this increased saving finances higher investment and the rest buys foreign bonds, represented by the current-account surplus. That is, the current-account surplus leads to accumulation of foreign assets. As foreign assets accumulate, the M_3 curve moves to M_4 and 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). More foreign assets also increase total income and consumption that appears as a movement of the demand curve from D_2 to D_3 in Figure 3a.

Long-run equilibrium emerges when the exchange rate appreciates enough to give current-account balance.[19] Note that compared to the initial situation, investment rises so that in long-run equilibrium, saving rises above its level at the beginning of the period. The (long-run) nominal exchange rate still remains higher than at the beginning of the long-run asset-market period adjustment (E_4 compared to E_2).

In the non-traded goods sector, higher income and a higher equilibrium nominal exchange rate raises the demand for, and the price of, the non-traded goods. A lower interest rate affects the supply positively, while a higher exchange rate affects it negatively. The total effect

[19] 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.

depends on the relative elasticities. We assume that the increase in the demand for non-traded goods exceeds the change in supply so that the price of the non-traded good increases. This observation, along with a falling exchange rate in the current-account adjustment period, reduces the real exchange rate proportionately more than the nominal rate.

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., $CA < 0$). An appreciated exchange rate induces effects that worsen the current account. On the one hand, the appreciated exchange rate increases the demand for capital goods in the non-traded sector and also increases the demand for traded consumption goods (relative to non-traded consumption goods). 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). More foreign assets also increase total income and consumption that appears as a movement of the demand curve from D_2 to D_3 in Figure 3b.

Long-run equilibrium emerges when the exchange rate depreciates enough to give current-account balance.[20] As long as residents hold foreign bonds, this will occur with a trade deficit financed by foreign interest earnings. Investment exceeds the initial situation, implying higher (ex-post) saving. Note, however, that the composition of saving (and wealth) differs from Case I. Now, foreign bonds held by residents fall below the initial situation.

[20] 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.

In the non-traded-goods sector, higher output (resulting from higher investment) and lower demand (due to a lower exchange rate) lowers the price of the traded goods. During the current-account adjustment period, when the nominal exchange rate adjusts upwards, increases the real exchange rate proportionally more than the nominal rate.

Summary

Introducing capital into a 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 possesses overshooting. That is, the exchange rate depreciates (i.e., E rises from E_0 to E_1) initially in response to the short-run asset-market adjustment. But, the initial depreciation gets offset somewhat by an appreciation (i.e., E falls from E_1 to E_2) in response to the short-run current-account adjustment due to the current-account surplus. The long-run adjustment captured in Figure 3a (i.e., Case I) experiences a second round of overshooting.[21] That is, the exchange rate depreciates (i.e., E rises from E_2 to E_3) 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_3 to E_4) in response to the long-run

[21] 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.

current-account adjustment.

Now, consider Figures 2 and 3b. The short-run adjustment process follows the arguments of the previous paragraph with an overshooting exchange rate. The long-run adjustment captured in Figure 3b (i.e., Case II) also experiences overshooting of the exchange rate.[22] That is, the exchange rate appreciates (i.e., E falls from E_2 to E_3) in response to the long-run asset-market 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 a depreciation (i.e., E rises from E_3 to E_4) 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. Both depreciations are associated with overshooting of the exchange rate. In Case II, however, an open market purchase causes a short-run depreciation with overshooting, but a long-run appreciation with overshooting, where the long-run appreciation reduces, but not reverses, the short-run depreciation.

4. Conclusion

We develop an open economy macroeconomic model where capital fills the role of an asset and a good produced and demanded by firms. The asset role reflects the need of firms to finance capital production with private bonds. We examine the effects of a monetary disturbance. Consideration of capital leads to adjustments in the economy that generate after-shocks in both asset and goods markets. Admittedly, when endogenous physical capital enters an open economy macroeconomic model, the model becomes more complicated, but, as we have shown, it does

[22] 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.

remain tractable and plausible results emerge from our analysis, given sufficient simplifying assumptions.

Nor is the insertion of endogenous physical capital an idle exercise. Extant open economy macroeconomic models ignore the interplay that may well exist between changes in private-sector investment and the equilibrium exchange rate. This omission would not matter except that extant open economy macroeconomic exchange rate models possess a poor track record, even 'within sample', of tracking the exchange rate over time. Thus, at the very least, this paper represents an exercise in persuasion -- encouraging exchange-rate econometricians to include proxies for domestic investment in their estimating equations. As MacDonald (1999) argues, extant exchange rate models do not incorporate sufficient dynamics. Our paper offers one previously over-looked dynamic channel.

Finally, we offer a couple of conjectures that flow naturally from our findings. Following the insight of Dooley and Isard (1982), we can solve the open economy macroeconomic model for a risk premium. In particular, they show, *inter alia*, that an increase in the outstanding stock of home country domestic bonds increases the risk premium and causes further currency depreciation. But that discussion considers only changes in stocks of *government* bonds. Although our paper assumes that home country government and corporate bonds perfectly substitute for each other, our model does suggest that researchers should give attention to *corporate* bonds (and, for that matter, other private sector securities including stocks and shares). Thus, we show that following a monetary expansion and consequent currency depreciation, profitability in the traded goods sector increases. We expect, *ceteris paribus*, that the latter will reduce any risk premium on home country corporate securities and, therefore, strengthen -- relative to what it would have been -- the domestic currency on foreign exchanges. Furthermore,

emphasizing the role of private-sector profitability in the exchange rate adjustment process proves in keeping with the recent phenomenon of international portfolio diversification across other countries' corporate securities. These conjectures, however, represent an agenda for future research.

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Figure 1: Demand and Supply of Physical Capital

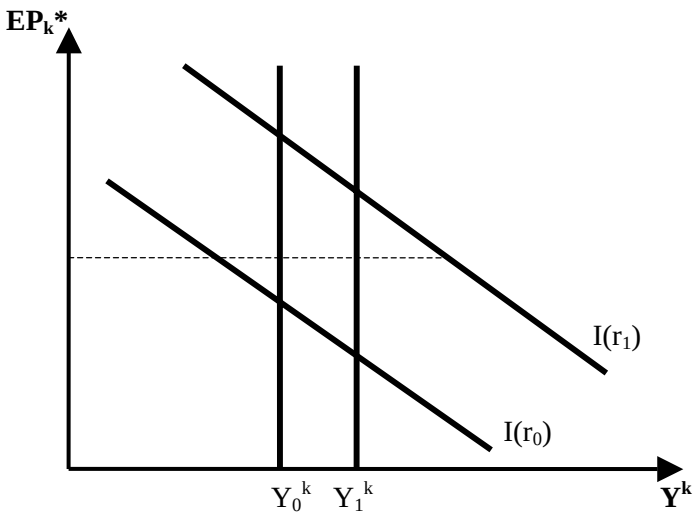

Figure 2: Short-Run Adjustments

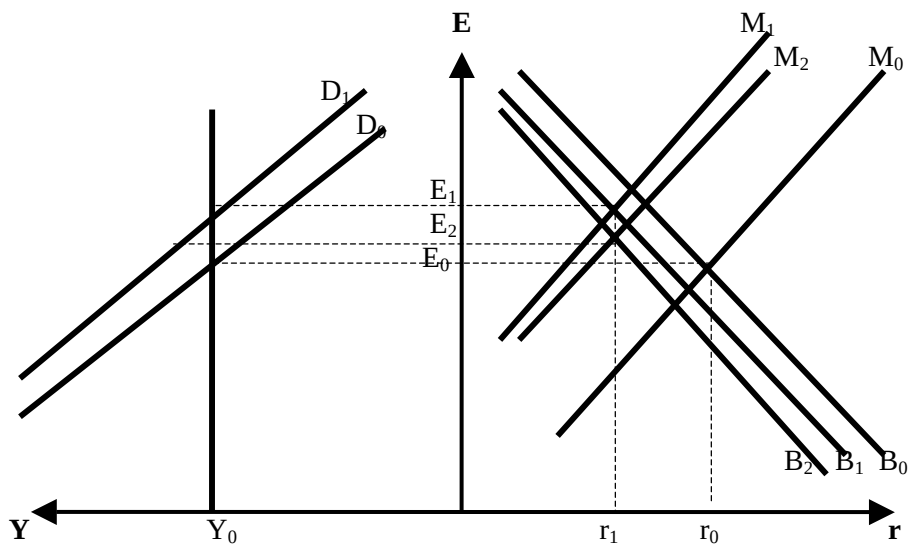

Figure 3a: Long-Run Adjustments: Exchange Rate Depreciation in the Asset-Market Equilibrium and Improvement in the Current Account

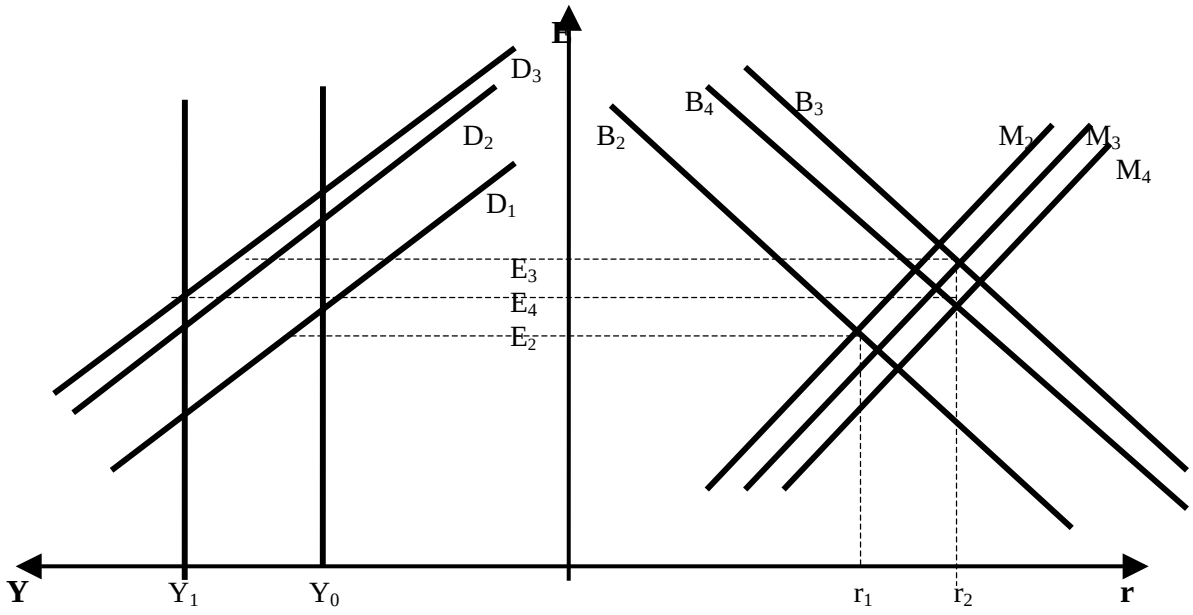
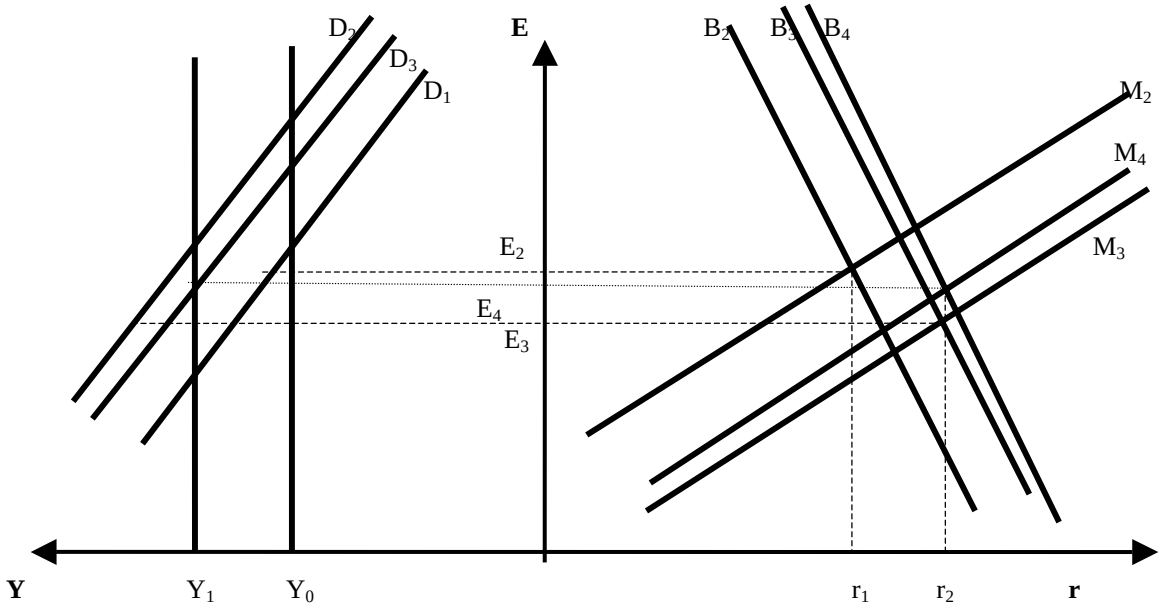
Figure 3b: Long-run Adjustments: Exchange Rate Appreciation in the Asset-Market Equilibrium and Worsening of the Current Account