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Monetary Policy in a Portfolio Balance Model with Endogenous Physical Capital

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Abstract
We develop a portfolio balance model with real capital accumulation. The introduction of real capital as an asset as well as a good produced and demanded by firms enriches extant portfolio balance models of exchange rate determination. We show that expansionary monetary policy causes exchange rate overshooting, not once, but 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 portfolio diversification in corporate securities.

Journal of Economic Literature Classification: F31, F32
1. Introduction


The omission of investment in models that consider the current account poses a theoretical problem, since the current account is defined as the (ex-post) difference between saving and investment. By considering investment as fixed, fluctuations in the current 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 a portfolio balance model, but does not consider domestic (private or government) bonds. Furthermore, capital, a nontraded good in his model, does not affect the current account directly. In our model, however, physical capital is a traded good and, as such, affects the current account.

The current account does have an important role to play in existing portfolio balance models. That is, changes in the current account affect income and wealth that, in turn, affect consumption, money demand, the equilibrium exchange rate, domestic bond prices, and, given the usual risk aversion assumption, domestic wealthholders' preferences between holding domestic and foreign government bonds. But what the extant portfolio balance literature fails to consider is any effect of changes in asset prices, including the exchange rate, on the level of domestic real corporate investment and the size of the capital stock. And, of course, there is no consideration of feedbacks from changes in the level of corporate investment to asset prices and the current account. Furthermore, as we note in our conclusion, because they ignore the effect of changes in the real exchange rate

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1 In a sample of 82 countries, capital imports represented about 30 percent of total imports (Serven, 1995). Dar and Amirkhalkali (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 portfolio balance models (e.g., Connolly and Taylor, 1976, and Frenkel and Rodriguez, 1975).
on the level of private sector profits and corporate investment, extant portfolio balance models may incorrectly perceive the effect of an increase in a country's money supply, and consequent corporate sector profitability, on currency risk premia.

Since we think that feedbacks from changes in the level of investment to asset prices and the current account are important in a properly specified model, we extend a representative portfolio balance model, that of Hallwood and MacDonald (1994, chapter 10), by adding endogenous physical capital. Endogenous physical capital in a portfolio balance model differs from financial assets because it is produced, supplied, and demanded by firms. Such investment directly links the asset and goods markets, and this is a different emphasis than is found in other portfolio balance models for, as Allen and Kenen (1978) and Hallwood and MacDonald (1994) note, the goods market is only indirectly linked to the asset market through the exchange rate; no direct link exists. We also show, and emphasize, how endogenous physical capital affects both the current and capital accounts of the balance of payments.

The most important implication of endogenous physical capital is that innovations in monetary policy have longer-lasting and even more volatile effects on the time-path of equilibrium exchange rates than they do in existing portfolio balance models. Thus, by pointing to a previously over-looked dynamic specification, our analytical results may help to explain the poor empirical performance of earlier portfolio balance models for, as Meese and Rogoff (1983) note, in out of sample exchange rate predictions, portfolio balance models are unable to beat a random walk.

In the interest of clarity, we make certain simplifying assumptions in addition to those usually made in the portfolio balance model literature. First, physical capital is rendered endogenous in the context of just two time periods, periods t and t+1. The advantage of this is to avoid the complication of using discounted values. Second, we assume that capital fully depreciates over the course of a single time period, which defines the outstanding capital stock to equal the current period's level of investment. The advantage of this is again one of simplification. Third, while the novelty of this paper is to render endogenous the stock of physical capital, we think that our most important results stand even making the assumption that the rates of interest on domestic government and corporate bonds are at all times equal. That is, we assume that these bonds are perfect substitutes.

The rest of the paper is organized as follows: section 2 describes our model; section 3 illustrates how exchange rate volatility is engendered following a monetary innovation; and the final section draws conclusions.
2. The Model

Consider a small open economy producing three goods -- traded and nontraded consumption goods, and a traded capital good \((T, N, \text{ and } K, \text{ respectively})\). The household sector's wealth consists of money \((M)\), domestic government and private bonds \((B^h \text{ and } B^k, \text{ respectively})\), and foreign government bonds \((F)\).\(^3\) Private bonds finance investment in capital. Since capital goods are produced by firms, 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 in the asset market.

**Demand for and Supply of Capital**

Assume that firms make investment decisions and that all capital fully depreciates within the 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 and bonds supplied by firms are perfect substitutes.

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

\[
P_T = EP^*_T, \text{ and } P_K = EP^*_K,
\]

where \(E\) is the nominal exchange rate defined as the domestic currency price of a unit of foreign exchange, and \(P^*_T\) and \(P^*_K\) are exogenously given prices of the traded consumption and capital goods in foreign currency. For given expected values of \(r, P_N, E,\) and \(P^*_i (i = T, K)\), the demand for capital emerges from profit maximization as shown below. The nature of expectations appears in due course.

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

\[
Y^i = y^i (K), \quad y^i_K > 0,
\]

where \(y^i_K\) is the marginal physical product of capital in sector \(i\). Firms in sector \(i\) maximize profit \((\Pi_i)\) defined as follows:

\(^3\) Like other portfolio balance models, we assume that the household sector holds foreign government bonds \((F)\), which is a portion of the total exogenously given quantity \(F^*\), and that foreigners do not hold domestic (government or private) bonds (see 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 is less than 100 percent. For the analysis to proceed, the depreciation rate must be positive so that, in equilibrium, firms have positive investment (equal to depreciated capital).
\[ \Pi_i = P_i y^i (K^i) - (1+r)EP^* K^i > 0, \]

where \( P_i \) is the price of the good in sector \( i \), and \((1+r)EP^* \) is the rental rate on capital. From the first-order conditions, the demands for capital in the different sectors are derived as follows:

\[ y^T_K = (1+r)P_K/P_T = (1+r)P^*_K/P^*_T \rightarrow K^T = k^T (r, P^*_K, P^*_T); \]
\[ y^N_K = (1+r)P_K/P_N = (1+r)EP^*_K/P_N \rightarrow K^N = k^N (r, P^*_K, P_N, E); \]
\[ y^K_K = (1+r)P_K/P_K = 1+r \rightarrow K^K = k^K (r). \]

Firms in different sectors demand capital until the marginal product of capital equals the rental price of capital divided by the price of the good produced in that sector. All firms finance their investment by selling bonds; and, as such, the interest rate \((r)\) enters the demand for capital function in each sector. The demand for capital in the nontraded 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 the prices of traded goods are determined in world markets (equation 1), changes in the exchange rate do not affect the demand for capital in these sectors. This is shown by equation (3), where the demand for capital in the traded consumption good sector depends on the world prices of its good and that of the capital good \((P^*_T \text{ and } P^*_K, \text{ respectively})\).

In the capital good sector (equation 5), the demand for capital depends only on the rate of interest, 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.\(^5\) That is,

\[ P_{N,t+1} = P_{N,t}, \]

where \( P_{N,t+1} \) is the expected price and \( P_{N,t} \) is the actual price of the nontraded consumption good in period \( t \). A similar specification characterizes other prices and the exchange rate.

The total demand for capital in the economy \((K=I)\) equals the sum of the total demands by different sectors. That is,

\[ K = K^K + K^T + K^N = k (r, P^*_K, P^*_T, E, P_N), \]

\[ k_r < 0, k_{P^*_K} < 0, k_{P^*_T} > 0, k_E < 0, \text{ and } k_{P^*_N} > 0. \]

---

\(^5\) Portfolio balance models assume both perfect foresight and static expectations (e.g., Dornbusch, 1975 and Hallwood and MacDonald, 1994, respectively). The assumption of perfect foresight makes the model more complicated without necessarily adding much to the analysis.
The total demand for capital, thus, responds positively to the prices of traded and nontraded 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 nontraded 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

\[
Y^K = y^K (r), \quad y^K_r < 0.
\]

Given the supply of capital, and the determinants of the demand for capital, the exchange rate determines the quantity demanded and whether the economy imports or exports capital. This is shown, following Witte (1963), in Figure 1. 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, more supply, as shown in Figure 1 by the rightward movement of the capital demand and supply curves.

**Goods Market Equilibrium and the Current Account**

The supply and demand in the different sectors are given as follows:

\[
\begin{align*}
Y^T &= y^T (r, P^*_T, P^*_K), \quad y^T_r < 0, y^T_{P_T} > 0, y^T_{P_K} < 0; \\
Y^N &= y^N (r, P^*_K, P_N, E), \quad y^N_r < 0, y^N_{P^*_N} > 0, y^N_{P_K} < 0, y^T_E < 0; \\
C^T &= c^T (q, Y), \quad c^T_q < 0, c^T_w > 0; \\
C^N &= c^N (q, Y), \quad c^N_q > 0, c^N_w > 0; \\
K &= k (r, P^*_K, P^*_T, E, P_N); \quad \text{and} \\
Y^K &= y^K (r);
\end{align*}
\]

where \(q = EP^*/P_N\) is the real exchange rate, and \(Y\) is the total income (defined later).

Given expected values of prices, of the interest rate, and of the exchange rate, output supplied by the different sectors is fixed. Equation (8) 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 \((P^*_T)\). Similarly, equation (9) says that the supply of the nontraded good is a negative function of the interest rate, the nominal exchange rate, and the price of the capital good in foreign currency and a positive function of the price of the nontraded good. Equation (10) illustrates that the demand for the traded consumption good is a negative function of the real exchange rate and a positive function of income. The demand for the nontraded good (equation 11) is a positive function of both the real exchange rate and income. Equations (6) and (7) are the demand for and supply of the capital good, the determinants of which have been discussed earlier. As mentioned before, the price of the nontraded consumption good \(P_N\) clears the market (i.e., \(Y_N = C_N\)), and that of the traded
consumption and capital goods is determined by equation (1). The determination of the exchange rate $E$ is discussed later.

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

$$Y = Y^N + Y^T + Y^K + rEF,$$

where $rEF$ is the domestic currency interest earnings from foreign assets. Total saving $S$ equals disposable income less consumption ($C^T + C^N$) or

$$S = (Y^T - C^T) + Y^K + rEF,$$

where $Y_N = C_N$. Consumption of the traded consumption good is a positive function of income (equation 11).

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

$$CA = S - I = (Y^N - C^N) + (Y^T - C^T) + (Y^K - I) + rEF = -\Delta F,$$

where $(\Delta F)$ is the capital outflow, or the increase in foreign held assets. The current account is the negative of the capital account, defined as the change in the 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. The total supply (the sum of the supplies of these two goods) is, for given expected interest rates and world prices of the traded and capital goods, fixed. This is seen in equations (7) and (8) and in Figure 2.

**Asset Market Equilibrium**

Households' total nominal wealth ($W$) consists of money ($M$), domestic government bonds held by the household sector ($B^h$), foreign bonds ($EF$), and domestic private bonds ($B^K$). That is,

$$W = M + EF + B = M + EF + B^h + B^K.$$

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

$$M = B^c + R,$$

where $R$ is the foreign currency reserves held by the central bank (which with our assumption of a flexible exchange rate is held constant) and $B^c$ is the domestic government bonds held by the central bank. Note that $B^G = B^c + B^h$ is the total outstanding government bonds in the economy, and equals the summation of bonds issued to finance deficits of the previous periods.\(^6\) That is,

---

\(^6\) We do not discuss the government budget constraint because we analyze the effects of monetary policy only and not that of fiscal policy.
\[ B^G = \sum_{i=t}^{\infty} (G - T) \]

where \( G \) and \( T \) are government expenditure and tax revenue.

While the supplies of \( M \) and \( B^H \) are exogenously given, the evolution of \( F \) (the amount of foreign bonds held by the 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, \( B^K = EP^*K \). As mentioned earlier, we assume that private bonds and government bonds are perfect substitutes, so that firms borrow at the same rate of interest as that paid on government bonds.

The demand for different assets is a function of 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:

\[ M = m(r, r^* + \Delta e^e)W, \quad m_r < 0, m_{r^*+\Delta e} < 0; \]

\[ B = B^H + B^K = b(r, r^* + \Delta e^e)W, \quad b_r > 0, b_{r^*+\Delta e} < 0; \]

\[ EF = f((r, r^* + \Delta e^e)W, \quad f_r < 0, f_{r^*+\Delta e} > 0; \]

where \( \Delta e^e \) is the expected rate of change in the exchange rate,

\[ \Delta e^e = (E_{t+1}^e/E_t) = (E_{t+1}^e/E_t) - 1, \]

and \( E_{t+1}^e \) is the expected exchange rate at period \( t \) for the period \( t+1 \).

Given these relationships, the effects of exchange rate changes on different assets emerge as follows:

\[ m_E > 0, b_E > 0, \text{ and } f_E < 0. \]

Depreciation of the exchange rate (for given expectations \( E_{t+1}^e \)) lowers the expected rate of return on foreign bonds, reducing the demand, and increasing that of domestic bonds and money. Following Hallwood and MacDonald (1994), we assume that the effect of a change in the rate of return of an asset on itself is greater than other assets (that is, \( b_r > f_r, b_{r^*+\Delta e} > b_{r^*+\Delta e}, \text{ and } f_{r^*+\Delta e} > m_{r^*+\Delta e} \)).

For a given money supply, the rate of return \( r \) and the exchange rate \( E \) that give equilibrium in the money market are related as follows:

\[ m_r dr + m_E dE = 0 \quad \rightarrow \quad dE/dr \bigg|_{dM=0} = -m_r/m_E > 0. \]

Depreciation of the exchange rate increases the demand for money, but given a fixed supply of money, equilibrium can only be restored if the interest rate rises and the demand for money falls. This gives the positively sloped \( M_0 \) curve in 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:

\[
(22) \quad b_r dr + b_E dE = 0 \quad \rightarrow \quad \frac{dE}{dr}{|_{db=0}} = -\frac{b_r}{b_E} < 0; \text{ and }
\]

\[
(23) \quad f_r dr + f_E dE = 0 \quad \rightarrow \quad \frac{dE}{dr}{|_{dF=0}} = -\frac{f_r}{f_E} < 0.
\]

The \(B_0\) curve in Figure 2 is negatively sloped because an increase is the exchange rate increases the demand for bonds, and equilibrium is restored if the demand equals the supply of bonds by decreasing the interest rate \((r)\). Note that \(\frac{dE}{dr}{|_{db=0}} > \frac{dE}{dr}{|_{dF=0}}\) (as \(b_r > -f_r\) and \(f_E > -b_E\)).

Asset market equilibrium occurs when the demands for the different assets equal their respective supplies. There are, however, only two independent equations to determine two independent variables that give asset market equilibrium (the wealth constraint, equation 17, makes equilibrium in the third market redundant). Thus, the interest rate and exchange rate that give asset market equilibrium emerge from solving the following two implicit equations:

\[
(24) \quad \frac{M}{\text{Error! Switch argument not specified.}} = m(r, r^* + \Delta e^*)W = 0, \text{ and }
\]

\[
(25) \quad \frac{B}{\text{Error! Switch argument not specified.}} = b(r, r^* + \Delta e^*)W = 0.
\]

This is shown by the intersection of the \(B_0\) and \(M_0\) curves in Figure 2.

**Exchange Rate Determination in the Short-Run and the Long-Run**

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 an increase/decrease of 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 capital goods (which is a traded good) affects the current account and long-run equilibrium exchange rate and interest rate.

To analyze the effects of an exogenous disturbance in the economy, we distinguish between the short-run and the long-run adjustment periods. In both periods, asset market and current account adjustments occur. In the short-run, the initial adjustments in the economy are analyzed, while in the long-run, the investment decisions of firms and their effects in the economy are analyzed.

Adjustment processes after shocks to our system of equations with endogenous capital are distinguished as follows:
(i) **Short-Run Asset Market Adjustments:** The instantaneous effects of a disturbance in the asset market are analyzed. The changes in the demands for different assets are examined, and the adjustment to the asset market equilibrium leading to the determination of the short-run exchange rate and interest rate are analyzed.

(ii) **Short-Run Current Account Adjustments:** In this period, the effects of asset price changes on the demand side of the goods market are studied. Specifically, the effects of price changes on income, saving, consumption, and the current account are examined. The end-of-the-period equilibrium exchange rate and interest rate are determined by capital flows resulting from changes in the current account balance.

(iii) **Long-Run Asset Market Adjustments:** Here, the effects of monetary policy on the private sector are considered. 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.

(iv) **Long-Run Current Account Adjustments:** In this period, the effects of investment decisions on the current account, capital flows, and the determination of the final interest rate and exchange rate are determined. Investment decisions affect both the supply side and the demand side of the traded goods sector and, as such, affect the current account. The movement of the economy to the equilibrium exchange rate and interest rate that together give current account balance is studied. Final (long-run) equilibrium is a state where no wealth is accumulating, with no changes in net-investment, saving equals investment, and the current account balances.

Given this set-up, an increase in the money supply by open market operations is considered next.

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 are $E_0$ and $r_0$, respectively, and the current account balances. When the central bank increases the money supply by 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.

(i) **Short-Run Asset Market Adjustments:** When the money supply increases by open market operations, equilibrium in the money market is restored 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 is restored by decreasing the demand for bonds by decreasing either the interest rate or the exchange rate.

The effects these changes have on the equilibrium exchange rate and interest rate emerge by using the implicit function rule on equations (24)-(25) and Cramer's rule. The results are as follows:

\( \frac{\delta r}{\delta M} = \frac{(1-m)b_E + m_b(1-m)}{D_1} < 0; \)
\( \frac{\delta E}{\delta M} = \frac{-m_b + b_r(1-m)}{D_1} > 0; \)
\( \frac{\delta r}{\delta B} = \frac{m_r(1-b) + b_r m}{D_1} > 0; \)
\( \frac{\delta E}{\delta B} = \frac{m_r(1-b) + b_r m}{D_1} > 0; \)

where \( D_1 = m_r b_E - b_r m_E < 0 \) since \( b_r > -m_r \), and \( (1-b) > m \) and the sign of \( \frac{\delta E}{\delta B} \) can be either positive or negative.

The total effect of open market operations on the interest rate and the exchange rate adds the effects of the increase in money supply and the decrease in the bond supply as follows:

\( \frac{\delta r}{\delta M} - \frac{\delta r}{\delta B} = \frac{(b_E + m_E)}{D_1} < 0, \) and
\( \frac{\delta E}{\delta M} - \frac{\delta E}{\delta B} = -\frac{(m_r + b_r)}{D_1} > 0. \)

This is the leftward movement of \( M_0 \) to \( M_1 \) and \( B_0 \) to \( B_1 \) seen in Figure 2, with the new equilibrium represented by the intersection of the \( M_1 \) and \( B_1 \) curves in Figure 2. Reduction in the supply of domestic bonds creates an excess demand, pushing the interest rate down. A lower interest rate, however, leads to a higher demand for foreign bonds, putting downward pressure on the exchange rate. Thus, the short-run effect of an open market operation (derived from asset market equilibrium) gives a higher (depreciated) exchange rate \((E_1)\) and a lower interest rate \((r_1)\) than the initial values. Note that the real exchange rate \((q = E^P/P_N)\) increases by the same proportion as that of the nominal exchange rate.

(ii) Short-Run Current Account Adjustment: Here, the effects of changes in the exchange rate and the interest rate are studied on the demand side of the goods market. The initial effect of a higher exchange rate is an increase in 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:

\( dCA = -c^T_q \text{ Error! Switch argument not specified.} P^* / P_N dE > 0, \)
\( c^T_q \text{ Error! Switch argument not specified.} < 0, \)

where \( c^T_q \text{ Error! Switch argument not specified.} \) is 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 either cause increased

\(^7\) Note that with no adjustment in the current account in this period, the supply of foreign bonds available domestically is fixed.
investment in physical capital or the accumulation of foreign assets. Since investment decisions are made in the long run (discussed later), however, all increased saving during this period leads to the accumulation of foreign assets. This manifests itself in the deficit in the capital 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 is shown 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. These results are given as follows:

\begin{align*}
(31) \quad dr/dF \bigg|_{dM=0} &= -mE/m_r > 0; \quad \text{and} \\
(32) \quad dr/dF \bigg|_{dB=0} &= -bE/b_r < 0.
\end{align*}

The end-of-the-period equilibrium exchange rate ($E_2$) is lower than the initial short-run level ($E_1$).\(^8\) 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 equilibrium, the economy runs a trade-account deficit, financed by the interest earnings from foreign assets.

In the nontraded sector, a higher short-run asset market equilibrium nominal exchange rate and a larger income increase the demand for goods produced in the sector, increasing the price of nontraded 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 nontraded good increases and the nominal exchange rate decreases in this period, the decrease in the real exchange rate is proportionally more than the nominal rate.

\begin{itemize}
  \item[(iii)] 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 $E_0$) lowers investment in the nontraded 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
\end{itemize}

\(^8\) Note that the interest rate may also change in this period. This new interest rate, however, will be lower than the initial rate $r_0$, and not shown in the Figure as we are interested in exchange rate volatility.
effect is stronger, the nontraded 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 nontraded 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, the
asset market equilibrium and the determination of the exchange rate and the interest rate
are explored. 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. The effects of an increase in the private bond supply on the
interest rate and the exchange rate is shown by a rightward shift in the B curves to B3 in
Figure 3. Higher wealth increases the demand for both money holdings and foreign bonds.
The change in the equilibrium exchange rate and interest rate due to increased private bond
supply is derived by using implicit function rule. The result is as follows:

\[ \frac{\delta r}{\delta B} = \frac{\{(1-b)m_r + mb_E\}}{D_1} > 0, \quad \text{and} \quad \frac{\delta E}{\delta B} = \frac{\{m_r(1-b) + mb_r\}}{D_1}, \]

where \( D_1 \) was defined earlier and \( \delta E/\delta B \) can be either positive or negative. Again, asset
market equilibrium determines the short-run interest rate and exchange rate. Note that
while the effect of an increase in the supply of bonds on the interest rate is positive, the
effect on the exchange rate is ambiguous. Two opposing effects act on the exchange rate.
First, increases in 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 go up or down. These cases are shown
in Figures 3a and 3b, respectively.

(iv) 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:

\[ dCA = (y_T^r + y_K^r)dr - (k_r dr + k_E dE), \]
\(y^T_r < 0, y^K_r < 0, k_E < 0, k_r < 0, \) and \(|k_r| > |k_E|\).

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: first, the current account improves and second, the current accounts worsens. An important factor determining the current account balance is the exchange rate (determined in the asset market equilibrium period). We now discuss these cases in turn.

**Case I:** A higher (depreciated) exchange rate dampens the demand-side effect of higher investment by reducing the demand for capital goods in the nontraded sector, so that \((y^T_r + y^K_r) dr - k_r dE > k_r dr\) and the current account improves (i.e., \(CA > 0\)). A higher nominal exchange rate also increases the real rate, thereby decreasing the demand for traded consumption good, improving the current account (as shown by equation 32), and increasing household saving. Some of this increased saving goes to finance higher investment and the rest buys foreign bonds, which is represented by the current account surplus. The current account surplus leads to accumulation of foreign assets. Once again, as foreign assets accumulate, the \(M_3\) curve moves to \(M_4\) and \(B_3\) moves to \(B_4\), and asset market equilibrium is established with a lower exchange rate (\(E_4\)). More foreign assets also increase total income and consumption. This 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 has appreciated enough to give current account balance. Note that compared to the initial situation, investment is higher so that in long-run equilibrium saving is higher than at the beginning of the period. The (long-run) exchange rate (\(E_4\) compared to \(E_2\)) is also higher than the long-run asset market equilibrium period rate.

In the nontraded goods sector, increased income and a higher asset market equilibrium nominal exchange rate raises the demand for, and the price of, the nontraded goods. A lower interest rate affects the supply positively, while a higher exchange rate affects it negatively. The total effect depends on the relative elasticities. It is, however, safe to assume that the increase in the demand for nontraded goods is greater than the change in supply (because both wealth and the exchange rate affect demand directly, while the interest rate and the exchange rate affect the supply in opposite directions) so that the price of the nontraded good increases. This, 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:** 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 nontraded sector and also increases the demand for traded consumption goods (relative to nontraded consumption goods). A worsening current account translates into selling foreign bonds. A fall in foreign bonds held by residents decreases nominal wealth shifting the M curve leftwards (from $M_3$ to $M_4$) and the B curve rightwards (from $B_3$ to $B_4$) in Figure 3b. The worsening current account is cushioned as fewer foreign assets dampen total income and consumption and appear as rightward movement of the D curve (from $D_2$ to $D_3$).

Long-run equilibrium emerges when the exchange rate adjusts enough to give current account balance. As long as residents hold foreign bonds, this will occur with a trade deficit financed by foreign interest earnings. Investment is higher than initial situation, implying (ex-post) saving to be higher. Note, however, that composition of saving (and wealth) is different than what we had in case I. Now, foreign bonds held by residents are lower than the initial situation.

In the nontraded-goods sector, higher output (resulting from higher investment) and lower demand (due to lower asset market equilibrium 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.

4. **Conclusion**

Admittedly when endogenous physical capital enters a portfolio balance model, the model becomes more complicated, but, as we have shown, it does remain tractable and plausible results were derived. Nor is the insertion of endogenous physical capital an idle exercise. This is because extant portfolio balance models, which many international economists would regard as being on the cutting edge of analytical exchange rate modeling, ignore the interplay that may well exist between changes in private sector investment and the equilibrium exchange rate. This would not matter except that extant portfolio balance exchange rate models are known to have a poor track record, even 'within sample', of tracking the exchange rate over time. Thus, at the very least, this paper should be regarded as an exercise in persuasion -- encouraging exchange rate econometricians to include proxies for domestic investment in their estimating equations.

We have developed a portfolio balance model where capital is considered both as an asset and as a good produced and demanded by firms. The effects of a monetary disturbance were then examined. Consideration of capital leads to adjustments in the
economy that generate after-shocks in both asset and goods markets. These effects make the variables more volatile (see Figures 2, 3a, and 3b). In these figures, open market operations take place at the beginning of the period and the figures illustrate the short-run adjustment (i.e., Figure 2) and long-run adjustment (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 is 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 captures in Figure 3a (i.e., case I) experiences a second round of overshooting. 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 is offset somewhat by an appreciation (i.e., $E$ falls from $E_3$ to $E_4$) 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 an overshooting exchange rate. The long-run adjustment captured in Figure 3b (i.e., case II) also experiences overshooting of the exchange rate. 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 offset somewhat 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.

Finally, note that, following the insight of Dooley and Isard (1982), the portfolio balance model can be solved 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 is in terms of changes in stocks of *government* bonds. Although we have assumed in this paper that home country government and corporate bonds are perfect substitutes, our model does
suggest that attention should be paid to corporate bonds (and, for that matter, other private sector securities including stocks and shares). Thus, we have shown that following a monetary expansion and consequent currency depreciation, profitability in the traded goods sector increases. We expect, ceteris paribus, that the latter will tend to reduce any risk premium on home country corporate securities and, therefore, to strengthen -- relative to what it would have been -- the domestic currency on the foreign exchanges. Furthermore, we think that emphasizing the role of private-sector profitability in the exchange rate adjustment process is in keeping with the recent phenomenon of international portfolio diversification across other countries' corporate securities.

References


Figure 1: Demand and Supply of 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