

CHAPTER IV

STRUCTURAL MODELS OF EXCHANGE RATE DETERMINATION

In this chapter we will attempt to explain the behavior of exchange rates by analyzing the behavior of supply and demand in the foreign exchange rate market. Recall that in Chapter I, we emphasized that exchange rates are just prices that are determined by supply and demand considerations.

An imbalance in any market is corrected by an adjustment in price and/or quantity. In currency markets, excess demand or excess supply will be corrected by a change in exchange rates. We will present two different models that explicitly incorporate different views of the market for exchange rates: the balance of payment approach and the monetarist approach. The balance of payment approach treats exchange rates as determined in flow markets, while the asset approach treats exchange rates as any other asset price.

I. Balance of Payments (BOP) Approach

Under the BOP approach, the domestic price of a foreign currency is determined just like the price of any commodity, i.e., by the intersection of the market demand and supply curves for that foreign currency. The BOP approach models the demand and supply for foreign exchange as determined by the *flows* of currency created by international transactions. According to the BOP theory of exchange rates, the supply and demand for a currency arise from the flows related to the BOP, that is, trade in goods and services, portfolio investment, and direct investment. Equilibrium exchange rates are determined when the BOP is in equilibrium. Exchange rates will move in response to a BOP imbalance and, therefore, will restore the equilibrium to the BOP.

We should note that PPP implicitly incorporated, through trade, demand and supply factors in the determination of exchange rates. For example, under PPP, if prices abroad are lower than at home, then domestic demand for foreign goods will increase and then the foreign currency will appreciate. The BOP approach can be seen as encompassing the PPP approach.

1.A. The BOP

The BOP tracks all financial flows crossing the borders of a country during a given period. For example, an import creates a negative financial inflow (positive financial outflow) for the country, whereas an export creates a positive financial inflow (negative financial outflow). The convention is to treat all financial inflows as a credit to the balance of payments. A BOP is not an income statement or a balance sheet but rather a cash balance of the country relative to the rest of the world. As long as the country is not bankrupt, the balance of all financial flows must be equilibrated, like any cash balance. In other words, the final balance must be zero.

Example IV.1: Consider a country whose only international transaction in the year 1999 consists of a USD 10 million import. This operation creates a negative USD 10 million inflow to the country. The importer could liquidate foreign assets worth USD 10 million to pay for this transaction. This operation creates a positive

USD 10 million inflow to the country. Thus, the net balance will be zero. Of course, the importer could instead borrow USD 10 million abroad, creating a positive USD 10 million inflow to the country. ¶

The BOP is usually divided in three parts: the current account (CA), the capital and financial account (KA), and the official reserve account. That is,

$$\text{BOP} = \text{CA} + \text{KA} + \text{OR} = 0.$$

The current account (CA), or *balance of trade*, includes the balance of goods and services, income received or paid on existing investment, and unrequited transfers. Exports and income received from foreign countries appear as credits to the balance.

The capital and financial account (KA) includes all short-term and long-term capital transactions. The KA includes direct investment, portfolio investment and other capital flows (especially short-term capital), and net errors and omissions. Direct investment is the net amount of direct purchases of companies or real estate made by a resident abroad and by foreigners at home. The purchase of a foreign company by a resident is treated as a debit, as it corresponds to a financial outflow. The capital account covers all transactions that involve the receipt of payment of capital transfers and acquisition/disposal of non-produced, non-financial assets. The financial account covers all transaction associated with changes of ownership in the foreign financial assets and liabilities of an economy. Such changes include the creation and liquidation of claims on, or by, the rest of the world.

In the definition of KA we excluded transactions made by the central bank, which are assigned to the official reserve account (OR). The OR reflects net changes in the government's international reserve. For example, when the Federal Reserve Bank sells foreign currencies, it will receive USD in exchange. This inflow of USD is treated as a credit to the BOP. The OR has two components: one that reflects the change of the Fed's holdings of foreign assets, and a second one that reflects the change in the net borrowing position of the Fed from foreign central banks.

There is also an item that reflects omitted and badly recorded transactions. This item is called Statistical Discrepancy (SD). The origin of this item arises since the BOP has to add up to zero. It is very common, however, to find that CA+KA+OR is different from zero. There are many reasons to justify this inequality. Recording of payments and receipts arising from international transactions are done at different times and places, sometimes using different methods. The recording of some services and some financial transactions might not be reported with accuracy.

The overall balance, or *overall settlement balance*, is equal to:

$$\text{CA} + \text{KA} + \text{SD},$$

which by construction should be equal to -OR. That is, the overall balance of payment is significant because it indicates a country's imbalance that should be accommodated with the government's official reserve transactions. The overall balance might be a good indicator of the pressure that a country's currency faces for depreciation or appreciation.

Example IV.2: The following table presents a summary of the U.S. BOP accounts for the year 2002 (in USD billions).

	Credits	Debits
Current Account (CA)		
Exports (X)	1,229.649	
Imports (M)		1,651.657
Unilateral transfers (UT)		58.853
Balance on CA (X+M+UT)		-480.861
Capital and Financial Account (KA)		
Capital Account Net		-1.285
Financial Account		
U.S.-owned assets abroad (net change) (USOA)		175.304
Foreign-owned assets in the U.S. (net change) (FOA)	706,983	
Balance on Financial Account (USOA+FOA)		531.679
Balance on KA (Capital + Financial Account)		530.394
Statistical discrepancy (SD)		-45.852
Overall balance (CA+KA+SD)		3.681
Official Reserve (OR)		
Balance on OR		-3.681

1.B The Balance of Trade as a Determinant of Exchange Rates

The BOP theory views exchange rates as determined in flow markets. Recall that we want to determine equilibrium exchange rates. The balance of trade approach simplifies the BOP approach. In this context, exchange rates will move to eliminate international trade imbalances. To simplify the theory, assume that the KA and OR are equal to zero. In this case, the BOP is equal to the CA. The current account is determined by the difference between exports (X) and imports (M). Both exports and imports are a function of the real exchange rate (R_t), domestic income (Y_d) and foreign income (Y_f). Therefore,

$$CA = X - M = f(R_t, Y_d, Y_f).$$

In general, at higher real exchange rates we should expect more exports and fewer imports, and higher current account surpluses; while at lower real exchange rates, the opposite should occur.

According to the balance of trade approach, the exchange rate moves in the required direction to compensate a trade imbalance. For example, suppose the trade balance is in equilibrium –i.e., $CA=0$. An increase in domestic income leads to an increase in demand for imports and therefore to a trade deficit ($CA<0$). Then, we should expect the exchange rate to depreciate to correct this imbalance. Using a similar argument, we should also expect a depreciation of the domestic currency, following an increase in domestic prices, a decrease in foreign prices, or a decrease in foreign income.

Example IV.3: The drop in oil prices after the Gulf War led to a Venezuelan trade balance deficit; the value of the oil that Venezuela exported suddenly dropped, without a corresponding reduction in imports. This deficit forced the Venezuelan government to borrow abroad to offset the imbalance; it also led to a depreciation of the bolivar. This devaluation helped to equilibrate the CA. ¶

The balance of trade approach needs the estimation of trade elasticities with respect to changes in exchange rates. These elasticities are needed to measure the response of imports and exports to a change in exchange rates. To calculate the elasticities we need to distinguish between short-run elasticities and long-run elasticities. For example, because of contracts, in the short-run imports and exports are quite inelastic (insensitive) to changes in exchange rates. Then, contrary to what the balance of trade approach predicts, in the short-run, a devaluation might increase the CA imbalance. Over time, however, we should expect this CA imbalance to be reversed. This over-time phenomenon of the CA is called the J-curve.

During the past twenty years, it has become quite clear that exchange rates did not work in the simple way considered by the balance of trade approach. There have been many situations when countries with trade surpluses have depreciating currencies, while countries with trade deficits have appreciating currencies.

1.C The Absorption Approach to the Balance of Trade

The absorption approach to the balance of trade (CA) studies how domestic spending on domestic goods changes relative to domestic output. That is, the CA is viewed as the difference between what the economy produces and what it consumes, or absorbs, for domestic purposes.

Using basic macroeconomic identities, in equilibrium, we can write

$$Y = C + I + G - T + (X - M),$$

where C is consumption, I is private investment, G is government spending and T is national taxes. Absorption, A, is defined as the sum of C+I+G.

If total output, Y, exceeds absorption, A, then the nation will export more to the rest of the world and the current account will increase. On the other hand, if absorption exceeds domestic output, the current account will fall. The absorption approach can analyze the effect of a devaluation on the trade balance. For example, if a government devalues its currency, a devaluation would tend to increase net exports and, then, domestic output only if the economy is not at the full employment level. If the economy is at the full employment level a devaluation will only result in inflationary pressures.

Rearranging terms in the previous equation,

$$CA = S - [I + (G - T)],$$

where S is after-tax private savings.

Now, we can analyze how to reduce a CA deficit. To increase the CA, one of the following must happen:

- (1) S should be increased, for a given level of I and (G-T).
- (2) I must fall, for a given level of S and (G-T).
- (3) The government deficit G-T must fall, for a given level of S and I.

Example IV.4: As a country, Japan has a high savings rate relative to the rest of the world. Many argue that this is the reason behind the persistent Japanese CA surpluses. One of the usual proposed solutions to reduce the persistent Japanese CA surplus is to increase the size of the Japanese government spending. ¶

The absorption approach helps us to understand the balance of trade. But this theory will only work as a theory of the BOP in a world without capital flows.

1.D The Monetary Approach to the BOP

So far, we have ignored financial flows. The BOP analysis becomes more complex when the capital account is taken into consideration. When the official reserve account (OR) is small, the KA provides the other side of the CA. That is,

$$KA = -CA.$$

A CA surplus equals a KA deficit. For example, in 1979, Kuwait was earning much more on its oil exports than it was spending on imports. Since it was earning more than it was spending, it was accumulating foreign IOUs, or financial assets, in the form of bank deposits in New York and other financial centers. By looking at the KA, we can see that when the CA is in a deficit, then the country is either accumulating debt or else running down its current stock of foreign assets. If the CA is in surplus, then the country is either repaying debt or building up its stock of foreign assets.

◆ **Liquidity in, Liquidity out**

If a country is running a current account deficit, this country is actually taking liquidity out of the international system. A country with a current account deficit is a net borrower of funds from the international financial system. During the year previous to the Thai bhat's crisis, 1996, the developing countries borrowed USD 200 billion from the international financial system. After the bhat's crisis of July 1997, the developing economies found it difficult to borrow from the international financial system. That meant there was more liquidity to buy developed world financial securities, for example, U.S. Treasury bonds. ◆

The monetary approach to the BOP incorporates international financial flows to the model. The monetary approach views any BOP disequilibrium as a monetary disequilibrium, which is manifested through the capital account.

Under fixed exchange rates, the intuition of the monetary approach to the BOP is very simple: if the central bank is supplying more money than what domestic residents demand, the excess supply will be eliminated through capital outflows. Given the excess supply of money, domestic prices increase. Foreign goods become relatively cheaper. Since the exchange rates are fixed, the excess money supply leaves the country as capital outflows until domestic prices get to the level of the rest of the world. At that point, equilibrium is achieved again. On the other hand, when there is an excess money demand in the domestic country, the country will receive an inflow of capital. That is, under fixed exchange rates, international capital flows adjust monetary disequilibria.

Under flexible exchange rates, the adjustment mechanism is different. Recall that the KA includes financial transactions associated with international trade as well as flows associated with portfolio shifts involving the purchase of foreign stocks, bank deposits, and bonds. The KA is assumed to depend on the interest rate differential. Since investors only care about returns denominated in their home currency, the KA also depends on S_t . Thus,

$$KA = f(i_d - i_f, S_t).$$

To see how the above equation works, suppose the BOP is in equilibrium. Assume that domestic interest rates increase relative to foreign interest rates, that is, $i_d - i_f$ increases. Foreign and domestic investors will attempt to substitute foreign denominated assets by domestic denominated assets, which in turn might lead to a capital inflow. Demand for domestic currency increases and therefore the domestic currency appreciates. This appreciation will bring the BOP back to equilibrium, since foreign assets and goods become cheaper than domestic assets and goods. That is, under flexible exchange rates, changes in the level of exchange rates adjust monetary disequilibria.

1.E BOP Approach: Implications

In section 1.B, we ignored financial flows when we analyzed the BOP. We stated that, according to the balance of trade approach, a CA deficit (surplus) tends to be corrected with a depreciation (appreciation) of the exchange rate. Now, once we consider the KA, this depreciation (appreciation) might not occur since foreigners might be willing to lend (borrow) to finance the CA imbalance. This financing will produce a KA surplus (deficit) and the exchange rate depreciation (appreciation) might not occur.

Example IV.5: Current Account imbalances and exchange rate movements.

In the early 1980s, the U.S. ran large current account deficits, and yet the USD remained strong in foreign exchange markets. This was possible because foreigners kept accumulating USD denominated assets given the current exchange rate.

On the other hand, since the early 1980s, Japan has had huge current account surpluses. As mentioned before, Japan has a relatively high savings rate. Japan may run a current account surplus without any change in the real yen exchange rate, as long as the Japanese continue to accumulate foreign assets. ¶

In the long-run, however, the BOP approach has more precise predictions. Foreigners will not be able to finance CA imbalances forever. For example, continuous CA deficits in the long-run will create KA outflows, since the foreign investment used to finance the CA deficit will generate profits and interest payments. Thus, according to the BOP, long-run equilibrium implies a CA equal to zero. Then, the exchange rate, in the long-run, would move to balance the CA.

II. Asset Approach

The flows approach was very popular until the late 1960s. During the 1970s, several economists started to challenge the view that the short-term behavior of exchange rates is determined by the flows associated with international trade. Instead, economists began to think of currencies as any other asset. Under this view, exchange rates are asset prices that adjust to equilibrate international trade in financial assets. Exchange rates are relative prices between two currencies and these relative prices are determined by the desire of residents to hold domestic and foreign financial assets. Like other asset prices, exchange rates are determined by expectations about the future. Therefore, past or present trade flows cannot influence exchange rates to the extent that they have already been expected. This approach, which treats currencies as assets, is appropriately called the *asset approach*.

2.A Monetary Approach

The asset approach assumes a high degree of capital mobility between assets denominated in different currencies. The difficult part of this approach is to specify the domestic and foreign assets to be included in the portfolio of a domestic resident. Since exchange rates are relative prices between two currencies, a simple model is to consider domestic money and foreign money. This simple asset model is called the *monetary approach* model.

2.A.1 A Simple Monetary Approach Model

The traditional monetary approach is a long-run theory that assumes that prices are flexible. Through Purchasing Power Parity (PPP), the monetary approach is able to relate the factors that affect prices with exchange rates. The determination of prices is based on the Quantitative Theory of Money (QTM). Recall that the QTM says that

$$M_S V = P Y,$$

where V is the velocity of money, P is the price level, Y is real output and M_S is the supply for money, which in equilibrium is equal to the demand for money. This equation assumes that prices are fully flexible, that is if the money supply, M_S , decreases or increases then prices will adjust instantaneously. Solving for P , we obtain

$$P = (M_S V)/Y.$$

The monetary approach model needs an equation that relates the QMT to exchange rates. We already know a theory that relates domestic and foreign prices to exchange rates: PPP. Using the subscripts d and f to denote domestic and foreign quantities, and after simple substitutions, the spot rate is determined by:

$$S_t = (V_d/V_f) \times (Y_f/Y_d) \times (M_{Sd}/M_{Sf}). \quad (\text{IV.1})$$

Equation (IV.1) assumes not only fully flexible prices, but also that PPP holds continuously. Assuming V is constant in the short-run and after some algebra, we obtain:

$$s_{t+T} = y_{f,T} - y_{d,T} + m_{Sd,T} - m_{Sf,T},$$

where small letters represent percent changes (growth rates) in the underlying variables.

2.A.2 A More Sophisticated Monetary Approach Model

The previous monetary model was very simple. Implicitly, we have not paid any attention to money demand. We have only looked at money supply and assumed that monetary variables are exogenous variables. However, in equilibrium, monetary variables are jointly determined by supply and demand. We can complicate the monetary approach model by introducing the demand for real-money holdings, L_D . In equilibrium L_D equal to M_S/P , that is,

$$M_S/P = L_D.$$

Now, let us model L_D as a function of income, Y , and interest rates, i . For example,

$$L_D = k Y^a e^{b i},$$

where k represents the inverse of velocity of money, V .

After some substitutions and using PPP, we obtain:

$$\ln(S_T) = a[\ln(Y_{f,T}) - \ln(Y_{d,T})] + b(i_{f,T} - i_{d,T}) + [\ln(k_f) - \ln(k_s)] + [\ln(M_{Sd,T}) - \ln(M_{Sf,T})].$$

Again, like in the IFE model, interest rate differentials play a role in the determination of exchange rates. In the monetary approach, interest rate differentials play a role through the impact on the demand for money. The same can be said about income growth rate differentials, they influence exchange rates through the demand for money.

We can also note that expectations about future exchange rates enter into the monetary approach model. Recall the interest rate differentials provides information about the expected change in exchange rates, $\{E(S_{t+T})/S_t - 1\}$. That is, the exchange rate today depends on expectations about the expected next period exchange rate. Through several substitutions, it is easy to see that the exchange rate today depends on the expected path of future exchange rates.

2.A.3 Monetary Approach: Sticky Prices

One popular variation of the monetary model takes into account that PPP is not a good short-run theory and proposes, in the short-run, *sticky prices*. This sticky prices monetary model incorporates the fact that exchange rates are a lot more volatile than prices of goods and services.

Since prices do not react instantaneously to “*shocks*” –say, a monetary shock –, financial prices do. In this case, the exchange rate *overreacts* –i.e., it depreciates more than it should in non-sticky prices world- to bring prices and quantities immediately to equilibrium.

In the long-run, prices will adjust and the exchange rate will appreciate accordingly. This is called *overshooting*. This is a popular model to explain the behavior of S_t after financial crisis.

2.A.4 Monetary Approach: Implications

The monetary approach presented in this section has very precise implications. It predicts that the spot rate behaves like any other speculative asset price; the value of the spot rate changes whenever relevant information is released. For example, for the simple monetarist model, relevant information includes changes in the domestic and foreign money markets and changes in domestic and foreign output. As with any other assets, expectations about the future value of the relevant variables play a major role on the determination of exchange rates.

Example IV.6: Suppose the money supply in the U.S. market increases unexpectedly by 2% and all the other variables remain constant. According to the monetary approach, an increase in the money supply of 2% leads to an increase of 2% in S_t (a depreciation of the USD).

Now, suppose that investors expect the U.S. Federal Reserve to quickly increase U.S. interest rates to offset this increase in the money supply, then the USD might appreciate instead of depreciate. ¶

III. Structural Models: Evidence

Many studies have found very weak evidence to support structural models. As we will see below, a seminal paper by Richard Meese and Kenneth Rogoff, published in the Journal of International Economics in 1983, found structural models to be very poor forecasting models. The failure of structural models to forecast exchange rates was very surprising. Many researchers tried to explain this failure. Many economists suggested that structural models were misspecified, because of the so-called *structural change problem*. When economic models are used, in general, they assume that the parameters are constant. Changes in the structure of the economy, however, can cause the parameters to also change. For example, consider the monetarist model:

$$\ln(S_T) = a[\ln(Y_{f,T}) - \ln(Y_{d,T})] + b(i_{f,T} - i_{d,T}) + [\ln(k_f) - \ln(k_s)] + [\ln(M_{sd,T}) - \ln(M_{sf,T})].$$

The parameters a and b might change if the structure of the economy changes. For example, a new Chairman of the U.S. Federal Reserve may have an effect on the coefficient b and, then, exchange rates may become more sensitive to interest rate differentials.

From a different perspective, other studies based on news have found some support for structural model variables to explain exchange rates. These studies analyze the movement of exchange rates around news announcements. These event studies find:

- News about greater than expected U.S. current account deficits tends to depreciate the USD, as predicted by the BOP approach.
- News about unexpected U.S. economic growth tends to appreciate the USD, as predicted by the monetary approach.
- News about positive money supply surprises tends to appreciate the USD. This is consistent with the monetary approach if agents expect the U.S. Federal Reserve to quickly change interest rates to offset the increase in money supply.
- News about unexpected increases (decreases) of interest rate differentials tends to depreciate (appreciate) the domestic currency, as predicted by the monetary approach.

That is, even though regression-based structural models tend to perform very poorly, the variables used in structural models have power to explain the movement of exchange rates.

◆ **Applied Corner: Trade deficit unexpectedly widens, USD falls**

On September 21, 1999, the U.S. Commerce Department released the new trade figures for the month of July. According to the news release, the U.S. trade deficit surged to a record \$25.18 billion in July on swelling imports, as trade gaps with Western Europe, China, Japan and Canada rose to new highs.

The deficit was much wider than the \$23.8 billion gap forecast by Wall Street analysts, and compared with a \$24.60 billion deficit in June.

After the report was released, the dollar fell against the Japanese yen, dragging U.S. bond prices lower, and helped pressure U.S. stock prices. ◆

IV. The Martingale-Random Walk Model

So far, the different theories in this chapter and in the previous chapter have failed to explain the behavior of exchange rates, especially in the short-run. Many economists find the failure of the different exchange rate theories as another proof that financial markets are efficient markets.

4.A Efficient Markets

Many financial economists characterize the behavior of exchange rates markets (for major currencies) and other financial markets as *efficient* (see Review Chapter). In efficient markets, prices fully incorporate all available information. A process compatible with efficient asset prices is a

martingale. We will say that the random variable X_t follows a martingale, relative to the information set Ψ_t , if:

$$E[X_{t+T}|\Psi_t] = X_t.$$

In the case of exchange rates, a martingale implies that all information about future spot rates is incorporated in S_t . All other information included in Ψ_t is irrelevant to forecast future spot rates. That is, future spot rates are not dependent on their own histories. This is consistent with the notion that the foreign exchange market is a "fair game" (i.e., there are no exploitable trends). The martingale model states that the best predictor for the future spot rate at date T is today's spot rate. This implies

$$E_t[S_{t+T} - S_t] = 0,$$

where E_t is the expectation operator with respect to the information set available at time t, Ψ_t .

◆ Technical Details: Random Walk and Martingales

Earlier work on financial assets used the *random walk* model. The difference between a random walk and a martingale is very technical. A random walk model is a special case of the martingale model. The random walk model assumes that price changes are independently and identically distributed. The martingale model only requires that price changes are uncorrelated. Technically speaking, when a random walk is specified, we need to consider not only the equilibrium expected value, but also the entire distribution. ◆

4.B Martingale-Random Walk Model: Implications

This is a very powerful theory: at time t, the expected change in spot rates at time T is zero. We can think of the probabilities of an appreciation or a depreciation as both equal to 50%. On average, it is impossible to predict future spot rates using past information. Thus, the Martingale-random walk model has a testable implication: changes in exchange rates are serially uncorrelated, and, then, they appear random. That is, firms should not spend any resources forecasting exchange rates based on past history.

Martingale-random walk forecasters seem ignorant. When asked about future levels of exchange rates, martingale-random walkers best answer is: "I don't know." This ignorance, however, has hedging implications. Since future exchange rates are unknown, risk-averse firms should always hedge their open currency positions.

4.C Martingale-Random Walk Model: Evidence

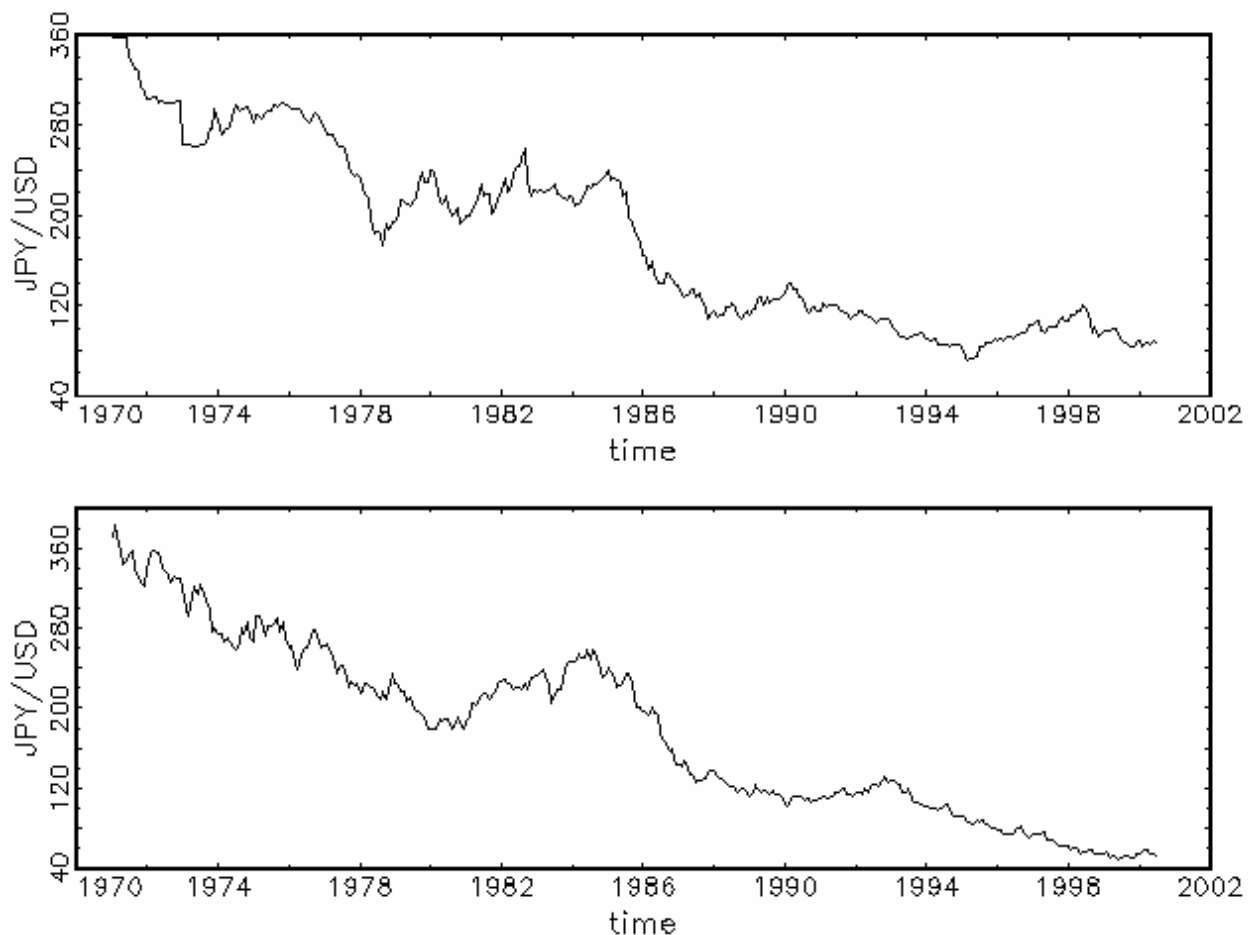
Meese and Rogoff (1983) tested the out-of-sample short-term forecasting performance of different models. They considered structural models, like the monetarist model, the expectations hypothesis, time series models (see Appendix A.IV), and the random walk model. Meese and Rogoff used monthly observations for the DEM/USD, USD/JPY, USD/GBP, and a trade-weighted USD

exchange rate. They found that the random walk model performed, at least, as well as any other model.

The findings of Meese and Rogoff have been replicated for other currencies and other time periods. For example, Frankel and Rose (1995), published in the *Handbook of International Economics*, review the empirical literature on floating nominal exchange rates. They find that a driftless random walk characterizes exchange rates better than standard models based on observable macroeconomic fundamentals. As implied by the random walk, Frankel and Rose find that exchange rates are very difficult to forecast as short- to medium-term horizons. More recently, Cheung, Chinn and Pascual (2005) checked the Meese and Rogoff's results with 20 more years of data. They found, again, that the random walk model produces the best forecasts.

In Figure IV.1 the monthly JPY/USD exchange rate from January 1971 to September 2000 is plotted on one panel. In the other panel a simulated random walk series -with the same mean and variance as the JPY/USD- is plotted. It is very difficult to distinguish one from the other. This informal, visual, evidence also supports the random walk hypothesis.

FIGURE IV.1
A Random Walk? Monthly USD/JPY exchange rate



4.D Simple Tests of the Martingale-Random Walk Model

It is important to test the martingale-random walk hypothesis. For instance, if an exchange rate follows a random walk, a firm should not spend any resources to forecast that exchange rate. Most popular tests are based on testing if exchange rate changes, s_t , are autocorrelated. Some of these tests are based on the sample autocorrelation, which is defined by:

$$\rho_k = \text{Cov}(s_t, s_{t-k}) / \text{Var}(s_t).$$

The standard error (SE) of the sample autocorrelations is given by $(1/T)^{1/2}$, where T is the sample size.

The t-test, t_k , is given by: $t_k = \rho_k / \text{SE}$. You may recall that t_k follows a standard Normal distribution.

Rule of Thumb for the t-statistic

If $|t_k| > 2$, then there is significant autocorrelation at the lag K.

The Q(K) test, proposed by Ljung and Box in a paper published in Biometrika, in 1978, is given by:

$$Q(K) = T(T+2) \sum_{k=1}^m \rho_k^2 / (T-K).$$

The Q(K) test follows a Chi-squared distribution. It is designed to test the significance of the first K autocorrelation coefficients. If $Q(K) > \chi^2_{k,\alpha}$, then the first K autocorrelations are jointly significant at the α significance level (α is usually set equal to 10%, 5% or 1%). The χ^2_{12} value can be taken from a Chi-squared distribution table in any statistical book.

Example IV.7: Testing for non-zero autocorrelations.

1.- Monthly JPY/USD first three autocorrelations for December 1973-December 1989 (T=203).

$$\rho_1: .014 \quad (t_1 = .014/.072 = .194)$$

$$\rho_2: .041 \quad (t_2 = .041/.072 = .569)$$

$$\rho_3: .081 \quad (t_3 = .081/.072 = 1.125)$$

$$\text{SE} = (1/203)^{1/2} = 072.$$

$$Q(12) = 13.9 \quad (\chi^2_{12,.05} = 21.0).$$

Interpretation: All the t_k statistics are less than 2. Therefore, all autocorrelations are not individually significantly different from zero. The Q(12) statistic is less than 21.0, thus, we can also reject the joint significance of the first twelve autocorrelations. The χ^2_{12} value can be taken from a Chi-squared distribution table in any statistical book.

2.- Daily JPY/USD first three autocorrelations for Jan 3, 1985 to August 30, 1989 (T=1189).

$$\rho_1: .075 \quad (t_1 = .075/.029 = 2.59)$$

$$\rho_2: .020 \quad (t_1 = .020/.029 = 0.70)$$

$$\rho_3: .102 \quad (t_1 = .075/.029 = 3.52)$$

$$\text{SE} = .029.$$

$$Q(10) = 21.8 \quad (\chi^2_{10,.05} = 18.3).$$

Interpretation: Now, only t_2 is less than 2. Therefore, the first and third autocorrelations are individually significantly different from zero. The $Q(10)$ statistic is larger than 18.3, thus, we cannot reject the joint significance of the first ten autocorrelations. ¶

For low frequency data (for example, monthly rates), the random walk model seems to provide a good description of currency markets. However, for high frequency data (for example, daily rates), the random walk model might not be appropriate, since there is evidence for serial correlation.

Rule of Thumb for Selection of K (number of lags)

When testing for autocorrelation with the $Q(K)$ statistic, the choice of K is arbitrary. For quarterly data, K is usually set equal to 4 (a year). For monthly data, K is set equal to 12 (a year); for weekly data, K is set equal to 4 (a month), 12 (a quarter) or 52 (a year); and for daily data, K is set equal to multiples of 5 (a week).

V. Looking Ahead

The economic models that we have presented do not enjoy a strong support from the data. Moreover, the Martingale-Random walk model seems to do, at least, as good a job as any other model. We noted that news about macroeconomic events gives some support for the structural models, especially the asset approach models. Macroeconomic news, however, reflects unexpected surprises. Therefore, the news is not incorporated in the prices. Unexpected events are driving the short-run behavior of exchange rates. That is, exchange rate short-run behavior seems to be very difficult to predict. Forecasting short-run exchange rates should be a very difficult task.

Interesting readings:

Parts of Chapter IV were based on the following books:

International Financial Markets, by J. Orlin Grabbe, published by McGraw-Hill.

International Financial Markets and The Firm, by Piet Sercu and Raman Uppal, published by South Western.

International Investments, by Bruno Solnik, published by Addison Wesley.

Handbook of International Economics, G. Grossman and K. Rogoff (eds.). North Holland, Amsterdam, 1995.

Exercises:

- 1.- You hear a trader say "in this bright future, you can't forget your past." Does this statement apply to the foreign exchange market?
- 2.- Reconsider the daily JPY/USD autocorrelations calculated in Example IV.7. Calculate the t-statistics for the first three autocorrelations. Are they significantly different than zero?
- 3.- San Marcos had a government deficit of USD 32 billion in 1999. In addition, private investment exceeded private after-tax saving by USD 18 billion. What can you say about San Marcos's current account? If, relative to GNP, a country has a high proportion of after-tax savings, an average proportion of investment expenditures, and an average government deficit, will the country tend to have current account deficits or surpluses?
- 4.- Suppose Brazil residents tastes change. Now, Brazilians favor the Brazilian goods more than before. What would be the effect of this change in tastes on the exchange rate BRR/USD?
- 5.- Go back to Section 2.B. Derive equation (IV.1). (Hint use the QTM equation, i.e., $M v = P Y$, and PPP.)
- 6.- Consider the asset approach. Explain the effect of an increase in the U.S. inflation rate on the USD/EUR. What happens to the USD/EUR exchange rate if real output in the U.S. grows at a faster pace than real output in Europe?
- 7.- Compare the Random Walk theory with the Expectations Hypothesis theory. What can you say about the hedging strategies that both theories imply?
- 8.- Contrast the different effect on short-term exchange rates of an increase in domestic real output under the BOP Approach and the Monetary Approach.
- 9.- Suppose that you use the following monetarist model to generate equilibrium exchange rates:

$$s_{t+T} = \alpha + \beta_1 (y_{f,T} - y_{d,T}) + \beta_2 (m_{sd,T} - m_{sf,T}) + \varepsilon_t.$$

Your estimated coefficients are: $\alpha=.005$, $\beta_1=.95$, $\beta_2=-.72$. This quarter the income growth differential between Chile and the U.S. is 2%, while the money growth differential is -4.50%. This quarter the exchange rate is $S_t=484$ CLP/USD (CLP: Chilean Peso) and last quarter the exchange rate was $S_{t-1}=481$ CLP/USD. What is the equilibrium exchange rate generated by your model? According to your model, is the USD overvalued or undervalued?