

Overview of Forecasting Models

Seminar on High Frequency Finance

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1 Introduction

The break-down of the Bretton-Woods system of fixed exchange rates led to a boom in the theoretical and applied work on free-floating exchange rates. But almost three decades later, we are still faced with the problem of how to explain and forecast the behavior of free-floating exchange rates. Forecasting exchange rates is an important task, especially for international operating companies for whom the exchange rate is part of the decision making process, but it is no less important for governments in order to determine optimal government policies and, last but not least, exchange rate forecasts are important in order to earn money from speculation.¹

Economic theory suggests that exchange rates are not independent of macroeconomic factors such as prices, income, money supply, etc. Monetary International Trade theory has developed several models for this relationship, such as e.g. purchasing power parity, or monetary exchange rate models.

However, most studies find weak linkages between exchange rates and fundamental economic variables. Estimates of exchange rate equations do not fit the data very well and the out-of-sample predictions are often not better than a random walk. This holds especially in the short run.

This paper surveys the most important theoretical exchange-rate models and their empirical performance.

In Section 2 efficient markets are discussed. Section 3 states how forecasts can be evaluated. An overview of the basic concepts of purchasing power parity and interest rate parity and their empirical evidence is given in section 4. In section 5, the most important monetary models that dominate the literature are presented, which are the flexible price monetary model, the sticky price monetary model (Dornbusch 1976) and the real interest rate differential model (Dornbusch 1976 and Frankel 1979). Basically, these models relate the log exchange rate to fundamental variables of two countries such as

¹Gerlow and Irwin 1991 p.133

money supply, interest rates, etc. Section 6 gives a few possible explanations for the failure of the models to determine and forecast the exchange rate. Finally, section 7 concludes.

2 Efficient Markets

Originally, the concept of efficient markets was developed for asset prices. But as we will see in section 5.1, the exchange rate can also be represented in the form of an asset price. Hence, the concept of efficiency applies also to the foreign exchange market.

Fama (1970) defines a market to be efficient, if prices in a market contain all available information. If the market processes new information immediately, price changes can only be caused by the arrival of new information. But future information cannot be predicted and thus price changes cannot be predicted.

Equivalently, if the foreign exchange market is efficient, the current spot rate has to reflect all currently available information and expectations about the future exchange rate should all be incorporated in the forward rate.² Hence the forward rate should be an unbiased predictor for the expected exchange rate. Empirical tests of forward rate unbiasedness are overwhelmingly rejected in the literature.³ Despite these rejections it is not clear, if this is evidence for market inefficiency or if the results are due to other facts, e.g. the existence of a risk premium, as is discussed below.

We distinguish three forms of market efficiency. Weak-form efficiency excludes the possibility to earn a superior return based on an information set that contains past prices and returns. The semi-strong form states that investors cannot make a superior profit using information that is publicly available. The third form of market efficiency is the strong form which states that the information set contains all information, including private information.

²see e.g. Frenkel 1981, p.668

³for an overview see e.g. MacDonald and Marsh 1999, p.12

Hence in such a market insider trading is not profitable.⁴

However, in order to determine superior profits, an equilibrium level of expected returns has to be specified first. But how should this be specified? If investors are risk-averse, they demand a risk premium. Then, according to EMH, it is not possible to earn a risk-adjusted superior return from speculation based on an information-set. The possibility of earning a superior return is not an indication for the inefficiency of a market, as we have to adjust for the risk that someone has to bear in order to make this profit.⁵ One possibility to model the relationship between risk and return is the Capital Asset Pricing Model.

The empirical testing of market efficiency is not easy, since it jointly tests if the equilibrium expected return is specified correctly and if investors process new information immediately. A rejection of the test cannot be assigned to one or the other assumption. In contrast, if studies can not reject the hypothesis of market efficiency, this might be due to a wrong specification of the equilibrium return. Then, with respect to the real equilibrium, the market is not efficient.⁶

Originally, EMH was derived under the assumption that investors act rationally. But the growing literature on behavioral finance states that investors are not rational. They trade on irrelevant information ("noise traders"), they do not diversify, they hold losing stocks and sell the winners (this is called the "disposition effect"). This is no problem if their trades are uncorrelated so that they cancel out each other; then their trades do not affect equilibrium prices. But it is more likely that investors are biased in the same direction, which implies that their trades are correlated and do not cancel out. In this case rational investors in the market will arbitrage out their influence and the price will still be the equilibrium price.⁷ Hence markets can still be efficient in the presence of irrational investors.

⁴see e.g. Shleifer 2000, p.5

⁵see e.g. Shleifer 2000, p.5

⁶Levich 1979, p.247

⁷Shleifer 2000, pp.10-14

Information costs lead to another difficulty in testing the EMH. If prices do not fully reflect all available information, investors have an incentive to buy information which is not yet included in the prices. If the information were already present in the prices, no one would spend money to get information. If everyone has the same possibilities to buy information, in equilibrium the higher profit that can be realized has to be equal to the price that has to be paid to get the information, hence marginal revenue from more information has to be equal to the marginal cost one has to bear to get the information.⁸

Another concept of efficiency is "speculative efficiency", a term that was coined by Bilson (1981, quoted after Boothe and Glassman (1987)). This means the absence of unexploited speculative profits. To test this hypothesis one needs to formulate a trading strategy and calculate its profitability in simulated trading. Such strategy might be filter rules which imply buying if the exchange rate rises by x percent and selling if it goes down x percent, which showed to be profitable in the early 1970's.⁹

3 Evaluation of Forecasts

When making forecasts we have to deal with the question what a good forecast is and how forecasts can be compared to one another.

Meese and Rogoff (1983a) evaluate their forecasts using three statistical concepts, namely by Mean Error (ME)

$$\sum_{s=0}^{N_k-1} \frac{F(t+s+k) - A(t+s+k)}{N_k} \quad (1)$$

Root Mean Squared Error (RMSE)

$$\sqrt{\sum_{s=0}^{N_k-1} \frac{[F(t+s+k) - A(t+s+k)]^2}{N_k}} \quad (2)$$

and Mean Absolute Error (MAE)

$$\sum_{s=0}^{N_k-1} \frac{|F(t+s+k) - A(t+s+k)|}{N_k} \quad (3)$$

⁸Baillie and McMahon 1998, p.50

⁹Boothe and Glassman 1987, p.67

$A(t)$ denotes the actual value, $F(t)$ is the forecast value. k is the forecast step (which is 1, 3, 6, and 12 months in the paper of Meese and Rogoff (1983a)) and N_k is the number of forecasts per period.

Using these statistical criteria to evaluate the forecast implicitly assumes that they are optimal for the subsequent use of the forecast in a decision framework. This is not necessarily the case, as it would imply that the economic problem is characterized by a function which is symmetric over gains and losses,¹⁰ as only the size of the forecast error is important. As these criteria do not consider the influence of the forecasting error on the resulting profits and losses they might not be optimal. The direction of the forecast error is quite important, especially in financial transactions when it is important to know whether to buy or to sell. So forecasts that do well according to the statistical criteria can be unprofitable as they fail to give advice in which direction to go. Boothe and Glassman (1987) proposed a different measure for the performance of a forecast which is based on profitability. First they generate a forecast and compare this to the current forward rate. If the forecast of the exchange rate is bigger than the forward rate, a forward contract is bought. If the realized future spot rate is bigger than the forward rate, the forward purchase was profitable and unprofitable if the future spot rate is less than the forward rate. The profit / loss from each forward contract is

$$\text{profit / loss} = [S_{t+1} - F_t] z_t \quad (4)$$

where S_{t+1} is the future spot rate, F_t is the forward rate and $z_t = 1$ if a forward contract was bought and $z_t = -1$ if a forward contract was sold.¹¹

Merton (1981) proposes a different evaluation of price forecasts. He assumes that a forecast has only positive value if it changes the investors expectations about the future. A rational investor has expectations about the distribution of future returns. If these expectations are not altered by means of the forecast, all information contained in the forecast were already present in the market and thus the forecast has no positive value.

¹⁰Gerlow and Irwin 1991, p.134

¹¹Boothe and Glassman 1987, p.69

4 Basic Theoretical Concepts

This section gives an overview of the basic concepts of absolute and relative Purchasing Power Parity and Covered and Uncovered Interest Rate Parity. These concepts are not only themselves a theory how the exchange rate is determined, but are also the basis for the Monetary Models which will be presented in section 5.

4.1 Purchasing Power Parity

4.1.1 Theory

Purchasing Power Parity (PPP) is a fundamental theory to determine floating exchange-rates.¹² In its simplest form it states that the nominal exchange rate is determined by the relative price-levels of two countries. Absolute PPP is based on the law of one price, which states that identical goods should have the same price expressed in the same currency:

$$P_i = S_t P_i^* \quad (5)$$

where S_t is the exchange rate, defined as the home-currency price of foreign currency, P_i is the price for good i in the home country and P_i^* is the price for good i in the foreign country.

If the law of one price does not only apply to a single good but also to all n goods in a certain consumer price index, we have absolute PPP, with $P = \sum_{i=1}^n P_i$:

$$P = S_t P^* \quad (6)$$

In the absence of transaction costs immediate arbitrage holds this equation constant at every point in time, no matter what disturbances occur in an economy.

But which consumer price index should be considered? The problem is that

¹²see for example MacDonald 1988, p.23

there is no index for a standardized basket of goods, rather those indices are different across countries, and the weights in the basket are not the same. Another problem is that indices are always relative to a certain year, which differs across countries.¹³

Given these measurement problems, it seems that the weaker concept of relative PPP would be more appropriate. Relative PPP states that the alteration of the exchange rate is equal to the differential between the growth rates of prices in the home and the foreign country. Formally, it can be derived by writing equation (6) in logs, so that $p = s_t + p^*$, where lowercase letters denote logs. Differentiating we get relative purchasing power parity $ds = dp - dp^*$, which can be rewritten in the following way

$$\frac{S_{t+k}}{S_t} = \left(\frac{1 + \pi_t}{1 + \pi_t^*} \right)^k \quad (7)$$

where $\pi(\pi^*)$ is the inflation rate in the home (foreign) country. The equation predicts that the country with the higher inflation rate will face a currency devaluation in order to compensate for the higher prices. If the inflation rate in the home country is relatively bigger, S_t will rise, as the home currency loses in value. If relative purchasing power parity holds, this equation determines the value of the spot rate S_t in k years.

Another problem is that the indices do not only contain internationally traded goods, but also non-traded goods, such as services. This can lead to problems in the calculation of PPP when countries have different productivities,¹⁴ which can be caused by economic growth, for example.¹⁵ Arising differences in the productivities of traded-goods between countries change prices, especially relative prices of traded and non-traded goods. Balassa and Samuelson found in 1994, that rich countries have higher price levels than poor countries. The reason for this is that rich countries are relatively more productive in the production of internationally traded goods.¹⁶

This can happen, since the exchange rate equates only the prices of traded

¹³Rogoff, 1996, p.650

¹⁴This problem is called the Balassa-Samuelson hypothesis

¹⁵MacDonald 1988, p.25

¹⁶Rogoff 1996, p.658

goods (in the absence of transportation costs). Now assume for example, that productivity in the sector of traded goods rises in one country. Prices are fixed in the short run, hence they will stay constant. Labor is remunerated according to marginal productivity, hence wages in this sector rise. As labor is a mobile factor, this will induce higher wages in the sector of non-traded goods, without having the gain of higher productivity. Prices will now have to rise in this sector to cover the higher costs. This implies that services are now relatively more expensive in that country. As services enter the price index, but do not have influence on the exchange rate, the currency of the country with higher productivity seems overvalued.¹⁷

Further, transaction costs, tariffs and non-tariff barriers prevent the prices of different countries from being equal, so that the law of one price does not hold. Their existence creates a band in which it is not profitable to arbitrage away deviations from PPP.

4.1.2 Empirical Evidence

As there are so many obstacles for the law of one price to hold, it is no wonder to see that purchasing power parity is rejected,¹⁸ at least in some studies. One reason for this might be the stickiness of prices in the short run. If this was the only reason, PPP would be expected to hold over one or two years as wages and prices adjust to shocks.¹⁹ However, deviations from PPP "appear to damp out at a rate of roughly 15% per year",²⁰ so the speed of convergence is very slow.

Frenkel (1978) tested PPP for the time period from 1921-1925 for the dollar-pound, franc-dollar and franc-pound rates, using the following regression equations:

$$\text{absolute PPP: } s_t = \alpha + \beta p_t - \beta^* p_t^* \quad (8)$$

$$\text{relative PPP: } \Delta s_t = \alpha + \beta \Delta p_t - \beta^* \Delta p_t^* \quad (9)$$

¹⁷Balassa 1964,p.586

¹⁸Rogoff 1996, p.654

¹⁹Rogoff 1996, p.654

²⁰Rogoff 1996, p.647

PPP holds if $\alpha = 0$ and $\beta = \beta^* = 1$. Frenkel (1978) found evidence of both versions of PPP, except for the dollar-pound rate.²¹ However, the finding that PPP, which is a long run concept, is supposed to hold during a time horizon that covers only 4 years seems strange, especially if one considers that deviations from PPP have a half-life of three to five years.²² Frenkel (1981) came to different results using data from 1973-1979 for the dollar-pound, dollar-franc, dollar-DM, pound-DM and franc-DM, rate. The estimate for the first two rates was not significant, and was significantly different from 1 for the dollar-DM rate. However, PPP could not be rejected for the last two rates.²³ Frenkel puts this down to three reasons: First, transportation costs are much smaller between neighboring countries than between a European country and the US. Second, changes in commercial policy and nontariff barriers were more stable within Europe than between Europe and the US, and his final reason is that due to the snake agreement and later the European Monetary System exchange rates within Europe were more stable.²⁴

PPP can also be tested with the help of the real exchange rate, which is the nominal rate weighted by the relative price levels: $Q_t = S_t P/P^*$. If PPP holds, this rate should be constant²⁵ and independent of the nominal exchange rate. However, as we saw before, because of transaction costs etc. the exchange rate will deviate from its PPP-determined value. Hence it is tested if the real exchange rate is mean-reverting, implying that disturbances are offset in the long run.

Abuaf and Jorion (1990) claim that the real exchange rate is very well captured by an AR(1) process with a coefficient slightly below 1.²⁶ Hence the real exchange rate does not follow a random walk, so that Purchasing Power Parity holds in the long run. The nominal exchange rate, in contrast, is well approximated by a unit-root process in their study; that means that price

²¹Frenkel 1978, pp. 178/179

²²Rogoff 1996, p.648

²³Frenkel 1981, p.695

²⁴Frenkel 1981, p.695

²⁵for absolute PPP $Q_t = 1$

²⁶They used exchange rates from 1973-1987 for ten industrialized countries for their research

levels are the reason for long run stability.²⁷

Lothian and Taylor (1996) use time series for the real French franc-sterling exchange rate for the time period from 1805-1990 and the real dollar-sterling exchange rates for time period from 1791-1990. They use the augmented Dickey-Fuller and the Philipps-Peron test to test for unit roots. They reject the unit root for both time series which implies that PPP holds in the long run.²⁸

Cuddington and Lian (2000) use the same data but use more lags for the augmented Dickey-Fuller test. They confirm the no unit root result for the French franc-sterling rate, but cannot reject the unit root for the dollar-sterling time series.²⁹ A possible explanation may be that the geographic distance between the UK and the USA imply higher transportation and communication costs and state that the law of one price holds more closely for countries within the same geographic regions.³⁰

Glen (1992) also finds that real exchange rates are not a random walk. But he only finds evidence of mean reversion at time horizons longer than 32 months, using data from 1973 to 1988 for the rates of nine currencies against the US-dollar.³²

MacDonald and Marsh (1994, quoted by MacDonald and Marsh 1999) have a look at how PPP performs out-of-sample. They use a dynamic error correction model for the following exchange rates for the period from 1974 to 1989: UK pound-US dollar, German mark-US dollar, UK pound-German mark, Italian lira-German mark, and French franc-German mark. Comparing their forecasts for the horizons of 1, 3, 6, 12 and 24 months against the random walk, they found that relative PPP does not outperform the random walk at the 1 month horizon, according to the statistical criteria discussed in section 3. However, as the forecast horizon is increased, PPP models do better than

²⁷Abuaf and Jorion, 1990, p.173

²⁸Lothian and Taylor 1996, p.503

²⁹Cuddington and Lian 2000, p.754

³⁰Cuddington and Lian 2000, p.756

³¹MacDonald and Marsh 1999, p.58

³²Glen 1992, p.164

the random walk.³³ MacDonald and Marsh (1994) also note, that results are different, depending on what price index is taken. For the pound-dollar rate for example, the random walk is only outperformed using a consumer price index, whereas for the pound mark rate the random walk can only be outperformed using the whole-sale price index.

Overall, empirical results do not give a clear picture if relative and absolute PPP hold or not. Some studies are in favor of PPP, some reject it. Though there seems to be evidence, that deviations diminish in the long run. Further, PPP is more likely to hold for countries that are geographically close together, which can be explained by the existence of transaction costs. These costs can be thought of as a band around PPP in which the exchange rate can move freely without affecting prices, outside the band the exchange rate converges quickly. This would imply a non-linear adjustment process.³⁴

4.2 Interest Rate Parity

4.2.1 Theory

Interest Rate Parity determines the exchange rate by means of interest rates in the different countries. Two forms of interest rate parity are distinguished: covered and uncovered, where both theories assume perfect substitutable assets and perfect capital mobility, as was already presumed for the PPP models.

Covered Interest Rate Parity (CIP) states that investing one unit of currency which pays an interest rate of $i\%$ per period or investing one unit of currency in the foreign country which pays $i^*\%$ per period must yield the same profit. To do this the investor first has to convert one unit of home currency into the foreign currency at a price of S units of home currency per unit of foreign currency. At the end of the period the investor will have $1/S_t(1 + i^*)$ units of foreign currency. Then he needs to convert this back. He can do this

³³MacDonald and Marsh 1999, pp.56-59

³⁴Rogoff 1999, p.F658

by using the forward exchange market and change back his earnings at the forward rate F_t . The absence of arbitrage opportunities requires that both possibilities yield the same return:

$$1 + i_t = \frac{1}{S_t}(1 + i_t^*)F_t \quad (10)$$

taking logs and using that $\log(1 + x) \approx x$ for small x , covered interest rate parity can be approximated as

$$f_t - s_t = i_t - i_t^* \quad (11)$$

If now $i_t < i_t^*$ people will invest their money in the foreign country in order to earn the higher interest rate. As demand for the foreign currency rises, the spot rate S_t will rise. Investors sell the foreign currency forward, so that the forward price of the home currency will rise and F_t goes down.

Uncovered Interest Rate Parity (UIP) relates the relative interest rates to the expected change in the exchange rate. UIP results from CIP by assuming that markets are efficient so that the forward rate is an unbiased predictor for the future spot rate:³⁵

$$\left(\frac{1 + i_t}{1 + i_t^*}\right)^k = \frac{1}{S_t}E_t[S_{t+k}] \quad (12)$$

Using equation (12) for just one period and taking logs the equation can be rewritten as

$$E_t[s_{t+1}] - s_t = i_t - i_t^* \quad (13)$$

The expected change in the log exchange rate is equal to the interest rate difference. If for example UK interest rates are higher than interest rates in the US, UIP holds if the log exchange rate of pound against dollars is expected to depreciate.

In contrast to CIP, this is not a riskless arbitrage opportunity as the ex-post future spot and what we expect it to be may differ.

³⁵see e.g. MacDonald and Marsh 1999, p.10, or Baillie and McMahon 1989, p.152

4.2.2 Empirical Evidence

From the theoretical point of view CIP must hold, for if it would not, an investor could yield an arbitrage profit without incurring additional risks.

Frenkel and Levich (1975) test CIP by testing if deviations from CIP are significantly different from zero. They found that there are deviations from CIP, but that they can be traced back to the existence of transaction costs. These transaction costs can be thought of as kind of band around the equilibrium within which covered arbitrage is not profitable. This implies that unexploited profit opportunities do not exist.³⁶ They state that the few deviations for which transaction costs can not account could be due to different tax treatments, government controls or political risk, or a time differential between observing a profitable opportunity and executing the arbitrage strategy.³⁷ Several other studies, too, found that there are no profitable deviations from CIP.

Fratianni and Wakeman (1982) for example found no arbitrage profits for the Eurocurrency market during the time span from 1967 to 1980. Using OLS regressions of equation (11) they, too, found that transaction costs account for deviations.³⁸

Cosander and Laing (1981) test the following equation³⁹

$$\frac{F_t - S_t}{S_t} = a + b \frac{(i_t - i_t^*)}{1 + i_t^*} \quad (14)$$

and found for a time span from 1962-1978 for SFr/\$, DM/\$ and \$/£ that the constant a is not significantly different from zero and that the coefficient b is close to one, this also being consistent with a band around CIP due to transaction costs.⁴⁰

Taylor (1989) analyzes the dollar-pound rate around events which are known to have introduced turbulences into the foreign exchange market. He also

³⁶Frenkel and Levich 1975, p.337

³⁷Frenkel and Levich 1975, p.337

³⁸Fratianni and Wakeman 1982, pp. 320/321

³⁹this equation can be derived by rearranging equation (10) and subtracting one from each side.

⁴⁰Cosander and Laing 1981, p.190

analyzed one calm period to check his results. He could not find deviations from CIP during the calm period, but found small exploitable arbitrage opportunities during the turbulent periods, especially for longer maturities.⁴¹

Frenkel (1981) tests Uncovered Interest Rate Parity (UIP) by regressing the spot rate onto the forward rate

$$s_{t+1} = a + bf_t + \nu_{t+1} \quad (15)$$

for the dollar prices of the French franc, the German mark and the pound sterling for the time period 1973-1979. He finds that his results are consistent with UIP. However, there is criticism about his approach, as for example Meese and Singleton (1982) point out, that tests of f_t being an unbiased predictor of the future spot rate, should use stationary series of s_t and f_t as asymptotic theory is not applicable otherwise.⁴² Using data for Germany, Canada and Switzerland from 1976 to 1981 they found that the log forward rate, f_t , is not stationary.⁴³, hence Frenkel's approach is possibly not valid.

To avoid the unit-root problem Cumby and Obstfeld (1984) subtract the spot rate from each side of the equation to get a difference stationary time series and test whether $a = 0$ and $b = 1$ for the following equation:⁴⁴

$$s_{t+1} - s_t = a + b(f_t - s_t) \quad (16)$$

They use data from 1976-1981 for the US dollar prices of the pound sterling, the German mark, the Swiss franc, the Canadian dollar and the Japanese Yen. In their results UIP is rejected.⁴⁵

In other studies the first step in order to test UIP is an assumptions about the formation of expectations. Cumby and Obstfeld (1981) assume rational expectations, so that

$$s_{t+1} = E_t[s_{t+1}] + \eta_t \quad (17)$$

Substituting this expression into equation (13) yields

$$s_{t+1} - s_t - i_t + i_t^* = \nu_t. \quad (18)$$

⁴¹Taylor 1989, p.389

⁴²Meese and Singleton 1982, p.1033

⁴³Meese and Singleton 1982, p.1032

⁴⁴Cumby and Obstfeld 1984, p.137

⁴⁵Cumby and Obstfeld 1984, p.139

All variables on the left side are observable ex post, hence UIP can be tested by testing if ν_t is really white noise.⁴⁶ If investors are risk-averse, ν_t is not only the expectation error, but also includes a risk premium that accounts for divergences from the assumption of the interest rate differential being equal to the expected rate of depreciation.⁴⁷ They tested this for the time span from 1974-1980 for US\$ prices of Canadian \$, French franc, German mark, Swiss franc, pound sterling and Dutch guilders with the result the UIP is rejected except for the pound sterling-dollar rate. They found that the deviations from UIP are highly correlated. This implies that the error term does not only contain expectation errors, hence this can be seen as evidence of the existence of a risk premium.⁴⁸

There are a number of studies about uncovered interest rate parity and all of them rejected UIP very strongly.⁴⁹ The most common argument of the rejection is the assumption of the forward rate being equal to the expected spot rate and therefore the non-existence of a risk premium. But in UIP a risk premium might be required as investors have open positions in foreign currency which bare risk that cannot be diversified.⁵⁰ Another reason might be reflected by the assumption of rational expectations, which might not be fulfilled.⁵¹

5 Monetary Models

Although most monetary approaches rely on PPP on the long run, the view of the exchange rate in these models is quite different. The exchange rate in these models is the relative price of two assets instead of two commodities as in PPP.⁵² In this monetary view the exchange rate is viewed as freely moving to equilibrate the international demand for and supply of stocks of

⁴⁶Cumby and Obstfeld 1981, p.698

⁴⁷The risk premium in the foreign exchange market is defined as $f_t - E_t[s_{t+1}]$

⁴⁸Cumby and Obstfeld 1981, p.701

⁴⁹see e.g. Cumby and Obstfeld 1984, p.135 or Gerhards 1994, p.118

⁵⁰MacDonald and Marsh 1999, p.13

⁵¹Hallwood and MacDonald 2000 pp.40/41

⁵²MacDonald and Marsh 1999, p.79

money. Capital is assumed to be perfectly mobile internationally. Assets in the home and the foreign country are perfect substitutes, which means that investors are indifferent about in which country to invest. Also, this implies that uncovered interest rate parity holds continually as under this assumption there is no risk-premium⁵³.

The monetary approach is one part of the asset approach to exchange rate modelling. The other part are portfolio balance models which assume that securities are not perfect substitutes. These models are not going to be dealt with here.

The difference among the monetary models presented here, will depend on whether prices are assumed to be flexible in the short run or not.

5.1 Monetary Model with flexible prices

This model assumes that all goods prices are fully flexible.⁵⁴ Further a stable money demand function and purchasing power parity is assumed. However, domestic money is demanded only by domestic residents and foreign money only by foreign residents. Further, money supplies and real incomes are determined exogenously.

In this model, the exchange rate adjusts, so that the price level equilibrates demand and supply of money, hence, the money market is in equilibrium.⁵⁵

The demand for money depends positively on income and negatively on the level of the nominal interest rate. The real money demand functions are given by

$$m_t - p_t = \alpha y_t - \beta i_t \quad (19)$$

$$m_t^* - p_t^* = \alpha^* y_t^* - \beta^* i_t^* \quad (20)$$

where all variables, except interest rates, are expressed in logs and the asterisks denote variables of the foreign country. Subtracting equation (20)

⁵³MacDonald and Marsh 1999, p.13

⁵⁴which entails that the aggregate supply curve is vertical

⁵⁵Frenkel 1976, p.207

from equation (19), solving for relative prices and assuming that the income elasticity, α , and the interest elasticity of the money demand functions, β , in the home and in the foreign country are the same yields

$$(p_t - p_t^*) = (m_t - m_t^*) - \alpha(y_t - y_t^*) + \beta(i_t - i_t^*) \quad (21)$$

Using the log form of absolute purchasing power parity

$$s_t = p_t - p_t^* \quad (22)$$

to replace the relative prices leads to the reduced form of the monetary exchange rate model with flexible prices⁵⁶

$$s_t = (m_t - m_t^*) - \alpha(y_t - y_t^*) + \beta(i_t - i_t^*) \quad (23)$$

We can see from equation (23) that the exchange rate depends positively on the money supply of the home country and negatively on the money supply of the foreign country. Hence an increase in the domestic money supply leads to a devaluating home currency, whereas increases in the foreign money supply appreciate the home currency. A rise in domestic output leads to an appreciation of the home currency through the mechanism of money demand and purchasing power parity. A higher interest rate differential⁵⁷ will increase s_t (i.e. the domestic currency will depreciate) because a higher interest rate will decrease the amount of money demanded making the domestic currency relatively abundant.

In this model the nominal interest rate differential is interpreted in terms of relative expected inflation rates. This follows from the assumptions of perfect asset substitutability and perfect capital mobility, which imply that real interest rates must be equal across countries, in equilibrium.⁵⁸ More formally, this can be seen by means of the Fisher effect, which states that $(1 + i_t)/(1 + \pi_t^e) = (1 + r_t)$, where π_t^e is the expected inflation rate and r_t is the real interest rate. If the real interest rate is equal in both countries, we can derive an equation that relates nominal interest rates in both countries

⁵⁶see e.g. MacDonald and Marsh 1999, p.81

⁵⁷this means that i_t rises relative to i_t^*

⁵⁸Basically, this assumption links PPP to IRP

to the inflation rate of both countries

$$\frac{(1 + i_t)}{(1 + i_t^*)} = \frac{(1 + \pi_t)}{(1 + \pi_t^*)} \quad (24)$$

Hence, increases in the money supply will depreciate the domestic currency, without affecting the real interest rate. The nominal interest rate increases, however, reflecting changes in the price level. On the other hand, an increase in real income will appreciate the domestic currency due to the increased (transactions) demand for money, which makes domestic money relatively scarce.

Equation (23) can be rewritten by making use of the uncovered interest rate condition

$$s_t = (m_t - m_t^*) - \alpha(y_t - y_t^*) + \beta E_t[s_{t+1} - s_t] \quad (25)$$

By solving this equation forward in time, taking expectations and replacing for $E_t[s_{t+1}]$, the spot rate turns out to be the expected discounted sum of the future market fundamentals:^{59 60}

$$s_t = \frac{1}{1 + \beta} \sum_{i=0}^{\infty} \left(\frac{\beta}{1 + \beta} \right)^i E_t[(m - m^*)_{t+i} - \alpha(y - y^*)_{t+i}] \quad (26)$$

Expected changes in future fundamental values, will have an impact on the current spot rate, even if the current fundamental values have not changed. Hence changes in the spot rate result from news about future fundamentals. Thus, changes in the spot rate can be predicted if the economic fundamentals are predictable.⁶¹ Equation (26) is a common characterization of asset prices. As stock prices can be understood as the present value of all future dividends, the current spot price can be thought of as being the expected discounted sum of future market fundamentals.⁶²

This equation is also able to explain the observation that exchange rates are more volatile than the fundamental values explaining the exchange rate,⁶³ if the covariances between money supply and income are positive.⁶⁴

⁵⁹Taylor 1995, p.22

⁶⁰this equation is derived in the Appendix

⁶¹Meese 1990, p.122

⁶²Meese 1990, p.122

⁶³Meese 1990, p.118

⁶⁴Meese 1990, p.123

5.2 Sticky Price Model

The assumption of short run equilibrium in the goods market was relaxed by Dornbusch (1976). In this model, goods market prices are sticky in the short run and adjust to a new equilibrium with a lag, due to e.g. costs of adjustment or lack of complete information. Thus, this model distinguishes between the long run and the short run equilibrium. In contrast, financial markets are assumed to react immediately, meaning that prices adjust instantly in this market. The different adjustment speeds of the goods and financial markets leads to an initial overshooting of the exchange rate. PPP is still assumed to hold in the long run, so that the long-run effects of, say, an increase in the money supply, will be identical to those predicted in the flexible price model.

Formally, the model consists of the following equations:

$$m_t - p_t = \phi y_t - \lambda i_t \quad (27)$$

$$d_t = u + \delta(s_t - p_t) + \gamma y_t - \sigma i_t \quad (28)$$

$$\Delta p = \pi(d_t - y_t) \quad (29)$$

$$E_t[s_{t+1}] - s_t = i_t - i_t^* \quad (30)$$

$$E_t[s_{t+1}] - s_t = \theta(\bar{s} - s_t) \quad (31)$$

Equation (27) is the log demand for real money which depends on income, y , and interest rates, i . In equilibrium real money demand will be equal to real money supply. The second equation is the log aggregate demand function for goods, which depends on income, interest and the real exchange rate, which is represented by $(s_t - p_t)$ as the foreign price level was set equal to unity so that $p^* = 0$. The sticky adjustment of goods prices is presented in equation (29). It states, that price changes are a function of demand over full-employment output (excess demand). In this model capital is perfectly mobile, hence uncovered interest rate parity holds, which is represented in equation (30). Finally, equation (31) refers to the expectation formation, where \bar{s} denotes the log of the long run exchange rate and the coefficient of adjustment, θ , is taken as exogenous.

Equations (28) and (29) define the goods market equilibrium:

$$\Delta p = \pi(u + \delta(s_t - p_t) + (\gamma - 1)y_t - \sigma i_t) \quad (32)$$

Similarly, using equations (27), (30) and (31) yields the money market equilibrium:

$$m_t - p_t = \phi y_t - \lambda i_t^* - \lambda \theta (\bar{s} - s_t). \quad (33)$$

On the long run, when $s_t = \bar{s}$ and $p_t = \bar{p}$ this equation yields the following equation for the long run equilibrium price level

$$\bar{p} = m_t - \phi y_t + \lambda i_t^* \quad (34)$$

Replacing m_t in equation (33) by equation (34), and solving for s_t , we get a relation between the exchange rate and the price level.

$$s_t = \frac{1}{\lambda \theta} (\bar{p} - p_t) + \bar{s} \quad (35)$$

This function determines the current exchange rate as a function of current prices, given the long run value for p and s . As the money market will always clear, this equation will always be fulfilled.

An equation for the long run equilibrium exchange rate can be obtained by setting $\Delta p = 0$ in equation (32) as in equilibrium prices don't change any more. Setting the variables s_t and p_t equal to their long run values \bar{s} and \bar{p} , replacing i_t by i_t^* , which holds in the long run, and solving for the equilibrium exchange rate yields

$$\bar{s} = \bar{p} + \left(\frac{1}{\delta} \right) (\sigma i_t^* + (1 - \gamma)y_t - u) \quad (36)$$

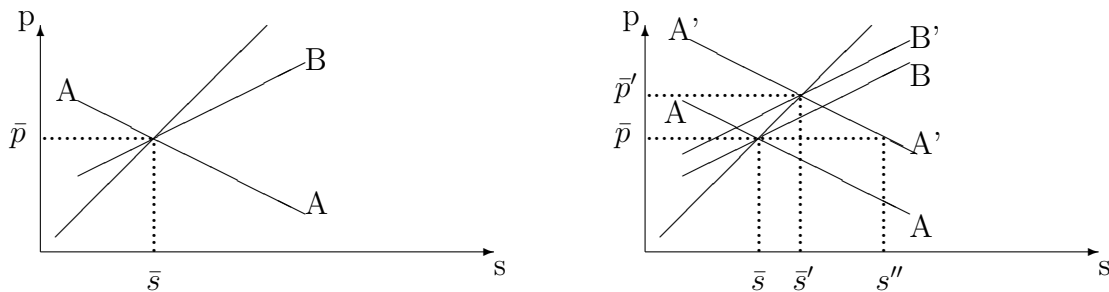
Replacing \bar{p} in equation (36) by equation (34) yields

$$\bar{s} = m_t - \frac{1}{\delta} (u + (\phi \delta + \gamma - 1)y_t - (\lambda \delta + \sigma)i_t^*) \quad (37)$$

In the long run prices are at their equilibrium level and won't change any more so that $\Delta p = 0$. Substituting for the interest rate from equation (27) and setting $\Delta p = 0$ in equation (32) yields the following equation which implies long run equilibrium in the money market as well as in the goods market

$$p_t = \frac{\delta \lambda}{(\delta \lambda + \sigma)} s_t + \frac{\sigma}{(\delta \lambda + \sigma)} m_t + \left[\frac{\lambda}{(\delta \lambda + \sigma)} \right] \left[u - y_t + \gamma y_t + \frac{\phi \sigma}{\lambda} y_t \right] \quad (38)$$

Now assume an increase in the nominal amount of money. The resulting effects can be illustrated graphically in Figure 1, where schedule AA represents equation (35), and schedule BB equation (38). Prices are sticky in the short run. Instead, adjustment is brought about by an instantaneous adjustment of the interest rate and the exchange rate. This means that the money market clears any time, implying that we are continuously on the AA schedule



1a) equilibrium in the money and goods market

1b) An increase in the money supply shifts both curves outwards.

Figure 1a depicts the initial equilibrium with the exchange rate being at the equilibrium level \bar{s} . If the money supply rises, the new long run equilibrium exchange rate \bar{s}' and the new equilibrium price level \bar{p}' will have risen proportionately to the increase in the money supply (see equations (34) and (37)), moving up a 45° line through the old equilibrium point which determined \bar{s} and \bar{p} . But prices will only adjust slowly (see equation (29)). To ensure money market equilibrium, interest rates decline. According to equation (30), this implies an expected depreciation of the exchange rate. The lower interest rate as well as the expected depreciation of the exchange rate cause a capital outflow of the country, resulting in a depreciation of the exchange rate. In short run equilibrium, uncovered interest rate parity holds again, i.e. the expected rate of depreciation is equal to the interest differential. The new exchange rate is denoted as s'' in Figure 1b. The exchange rate overshoots the new equilibrium long run rate \bar{s}' . How much the exchange rate overshoots the new equilibrium, depends on the coefficients for the expectation, θ , and

the interest elasticity, λ .⁶⁵

At the new short-run equilibrium, interest rates are low, inducing an excess demand for goods (see equation (28)) and the exchange rate is high, resulting in relatively low prices of domestic goods, which also leads to an excess demand for domestic goods. Hence, prices will rise, resulting in a declining real money supply so that interest rates will rise. This leads to a capital flow into the country, so the exchange rate will appreciate until it has reached its new long run equilibrium \bar{s} .⁶⁶

5.3 Real Interest Rate Differential Model

This model, suggested by Frankel (1979) constitutes an extension of the Dornbusch model which allows inflation to occur in the long run, and highlights the importance of the real interest rate in the determination of the real exchange rate. PPP is still assumed to hold in the long run, thus a long run equilibrium version of equation (22) would be:

$$\bar{s} = \bar{p} - \bar{p}^* \quad (39)$$

Next, the expectation formation is considered. Again, it is assumed that there is a gap between the long run equilibrium exchange rate \bar{s} and the current exchange rate s_t . Frankel (1979, p.611) extends Dornbusch's (1976) expectation formation equation (31) by the current rate of expected long run inflation differential between two countries, denoted by $\pi_t - \pi_t^*$, so that

$$E_t[s_{t+1}] - s_t = \theta(\bar{s} - s_t) + \pi_t - \pi_t^* \quad (40)$$

In the long run, when the exchange rate will be at its equilibrium level so that $s_t = \bar{s}$, the expected exchange rate alteration is equal to the long run inflation differential $\pi_t - \pi_t^*$.

The short run exchange rate can be obtained by combining equations (30) and (40)

$$s_t = \bar{s} - \frac{1}{\theta}[(i_t - \pi_t) - (i_t^* - \pi_t^*)] \quad (41)$$

⁶⁵Dornbusch 1976, p.1169

⁶⁶Dornbusch 1976, p.1171

Hence, the current exchange rate is equal to its long run equilibrium level, if the real interest rates between two countries are the same. If the real interest rate in the home country is bigger than in the foreign country, the exchange rate is below its long run level, and hence will rise.

The money demand equations for both countries are modelled as in the flexible price model. Taking the difference between equations (19) and (20) and solving for the spot rate:

$$m_t - m_t^* = p_t - p_t^* + \alpha(y_t - y_t^*) - \beta(i_t - i_t^*) \quad (42)$$

In the long run, when $s_t = \bar{s}$, the interest rate differential between both countries is equal to the inflation differential: $(i - i^*) = (\pi_t - \pi_t^*)$. Inserting this and equation (39) into equation (42) yields

$$\bar{s} = m_t - m_t^* - \alpha(y_t - y_t^*) + \beta(\pi_t - \pi_t^*) \quad (43)$$

Again the (long run) exchange rate is determined by the relative supply and demand for the two currencies. In equilibrium a fall in the domestic supply of money, an increase in domestic income or a fall in the expected rate of inflation in the home country raises the demand for money and lowers the exchange rate.

Now substitute equation (43) into equation (41). Letting $1/\theta = \phi$ and $(1/\theta + \beta) = \varphi$ we get an equation for the exchange rate

$$s_t = m_t - m_t^* - \alpha(y_t - y_t^*) + \phi(i_t - i_t^*) + \varphi(\pi_t - \pi_t^*) \quad (44)$$

Note that with $\varphi = 0$ we get the flexible price monetary model

5.4 Empirical Evidence

In order to test the monetary models researchers usually make use of the following regression equation⁶⁷

$$s_t = \alpha_0 + \alpha_1(m_t - m_t^*) + \alpha_2(y_t - y_t^*) + \alpha_3(i_t - i_t^*) + \alpha_4(\pi_t - \pi_t^*) + \epsilon_t \quad (45)$$

⁶⁷see e.g. Meese and Rogoff 1983 p.5

The interest rate and inflation rate differential are an approximation for the expected alteration of the exchange rate. α_1 is supposed to be positive, whereas in most studies it is assumed that the exchange rate is homogeneous of degree one in the money supply, which implies that $\alpha_1=1$. For α_2 a negative value is expected, α_3 is expected to be positive. α_4 equals zero for the flexible price monetary model and is positive for the Dornbusch-Frankel model.

One of the first tests of the flexible price monetary model was conducted by Frenkel (1976) over the hyperinflation period in Germany from 1920-1923 for the German mark-US dollar rate, finding considerable support for the model.

The flexible price monetary model also fits reasonably well during the 1970s and 1980s. Also the real interest rate differential model performs very well for the period from 1974-1978, which was tested by Frankel (1979).

Research beyond 1978 does not yield satisfying results. Coefficients are reported to either having wrong signs or being insignificant. This holds for all presented monetary models.⁶⁸

One reason for this poor performance might be omitted variables. Frankel (1982 quoted by MacDonald 1988) includes wealth of the foreign and the home country into the money demand function which is defined as the sum of government debt and cumulated current account surpluses. He finds reasonably good results for the German mark-US dollar rate, which is due to the fact that Germany had a current account surplus during that time. Other problems which may be reasons for this poor performance are discussed below.

In an out-of-sample examination Meese and Rogoff (1983a) found that more sophisticated models could not beat a simple random walk in forecasting the exchange rate on the basis of RMSE and MAE. They examined the exchange rate of the US-dollar to the pound sterling, the German mark and to the Japanese yen during the time span from 1973 to 1981.

⁶⁸for an overview see e.g. Gerhards 1994, pp.120-122

In a further paper, Meese and Rogoff (1983b) impose coefficient constraints and find for the same sample that this model can outperform the random walk at forecast horizons which are longer than one year.⁶⁹

Chinn and Meese (1995) use data from 1973 to 1990 for the Canadian dollar, the German mark, the Japanese yen, and the pound sterling relative to the US dollar. They confirm the findings of Meese and Rogoff that structural models cannot explain exchange rate behavior better than a simple random walk in the short run. They also find that adding dynamic structure by using an error correction model, yields better results than the random walk at horizons longer than two years for the German mark and the Japanese yen, relative to the US dollar. They propose that the reasons for the poor performance are simultaneity problems, improper modelling of expectation formation, a failure of accounting for nonlinearities and parameter instabilities.⁷⁰

Boothe and Glassman (1985) use data from 1976 - 1984 for Canadian dollar/US dollar and German mark/US dollar rates to make forecasts over 1, 2, 6 and 12 months. Using the root mean squared error as criterion for evaluating the forecast, they confirm the results of Meese and Rogoff that structural models perform badly. They used different versions of the real-interest rate differential model. In the first version, the coefficients of domestic and foreign variables were constrained to be equal (which results in equation (44)); coefficients were unconstrained in the second version. Further, they used two dynamic models; one with one lag of all variables, and an error-correction model. For making forecasts, they used the actual future values of the explanatory variables, which has the advantage that errors due to wrong expectation formation can be ruled out but has the disadvantage that the forecasts are no more based on information available to agents at the time of forecasting.⁷¹

When using the profitability in forward market speculation as evaluation criterion, results are quite different. For the Canadian dollar the structural

⁶⁹Meese and Rogoff 1983b, p.91

⁷⁰Chinn and Meese 1995, p.162

⁷¹Boothe and Glassman 1985, p.68

models perform better than the random walk, hence the structural models perform well in predicting the direction of the forward rate for the Canadian dollar, but not the size of the exchange rate change,⁷² whereas for the German mark the random walk still performs best, no matter which evaluation method is chosen.

They found that the forecast errors grow the more the forecast horizon is extended. This is not surprising for the time series models,⁷³ but it is for the structural models, as these models should perform better in the long run.⁷⁴ Observing this lack of improvement in structural models as the forecast horizon is extended, Boothe and Glassman (1985) suggest that there is no long-run equilibrium relationship between the exchange rate and the economic fundamentals included in the models.⁷⁵ This result also suggests that different models may apply to different countries.

Boughton (1987) also gets to a similar result using data from 1973-1984 for the US-\$, Japanese Yen and German mark exchange rates. He states that the fundamental variables explain only a small portion of exchange rate changes, which implies that exchange rate movements are responses to unforeseen disturbances.⁷⁶

In contrast, MacDonald and Taylor (1994) find significant cointegration between exchange rates, domestic and foreign money supply, output and long-term interest rates, using the pound sterling/US dollar rate from 1974 to 1988. Hence their conclusion is that there really is a relationship between the exchange rate and the fundamental variables, but that the monetary models cannot account for the complex short run dynamics.⁷⁷

⁷²Boothe and Glassman 1985, p.72

⁷³for the random walk for example the best predictor for tomorrow is the value of today.

The more the forecast horizon is increased, the higher the volatility of the forecast

⁷⁴Boothe and Glassman 1985, p.69

⁷⁵Boothe and Glassman 1985, p.73

⁷⁶Boughton 1987, p.55

⁷⁷MacDonald and Taylor 1994, p.288

6 Possible Explanations and Solutions

The results reported in the literature suggest that the monetary approach to exchange rate determination does not provide a satisfactory description of how the data is generated.

However, there are a lot of reasons for the poor performance of the monetary models. Most authors have ignored possible simultaneity-biases. Further, residuals are autocorrelated for almost all estimates. This suggests a misspecification of the monetary models which might be either due to omitted variables or a missing dynamic structure.⁷⁸

Recent developments in econometric methodology and techniques suggest new ways of approaching the data which may lead to improved results.

First of all, the poor performance of the monetary models to forecast the exchange rate may be due to the building blocks of the theories. As we saw before, uncovered interest rate parity is rejected in empirical tests. Further we saw before that Purchasing Power Parity does not hold, especially not in the short run as assumed in the flexible price model.

Further, equation (42) is not stable and has break points during the period 1973-1981.⁷⁹

Another possible explanation for the bad performance is that nonlinearities are not considered. If the exchange rate is indeed determined by macroeconomic fundamentals, linear exchange rate models will not perform well if they depend nonlinearly on exogenous macroeconomic fundamentals.⁸⁰ Meese and Rose (1990) do not find support for nonlinearities in fixed exchange rates using nonparametric estimators.

In 1991 Meese and Rose found that incorporating nonlinearities into existing structural models of floating exchange rate determination does not improve

⁷⁸MacDonald 1988, p.153

⁷⁹Meese and Rogoff 1983b, p.96

⁸⁰Meese and Rose 1990, p.192

the ability to understand how exchange rates are determined.⁸¹ They did not find nonlinear transformations of the fundamentals which could strengthen the relationship between the fundamentals and the exchange rate.⁸² In addition they find, that the exchange rate and the fundamentals are unit-root processes but that the models are not cointegrated for any exchange rate. For their results they used a sample period from 1974-1987 for exchange rates of the US-dollar against the Canadian dollar, German mark, Japanese yen and pound sterling.

Previously estimated models lack dynamic structure, in the sense that the use of lagged variables is almost absent. The use of error correction mechanisms (Hendry, Pagan and Sargan, 1984), for example, could improve the estimation results for these models, allowing for a more flexible dynamic structure. This is true to some extent as the already presented results of Chinn and Meese (1995) suggest.

Missing lags might also cause problems considering the money demand function. Woo (1985) states that the money demand function has to include a lagged money term in order to model partial adjustments in money holding.⁸³ Specifying a money demand function which additionally contains lagged money supplies and lagged price levels,⁸⁴ he finds that for 1980-1981 the dollar-mark exchange rate forecast relying on this specification of the money demand function performs better than the random walk, according to the RMSE and MAE for all forecast horizons (which were 2, 3, 4, 6 and 12 months).⁸⁵

Somanath (1986) introduces a lagged adjustment of the form that the exchange rate equation (45) also depends on the lagged exchange rate.⁸⁶ He confirms Meese and Rogoffs result for the time period they examined (which was 1973-1981), but finds that for the time-period from 1982-1983 the flexi-

⁸¹Meese and Rose 1991, p.604

⁸²Meese and Rose 1991, pp.614/615

⁸³Woo 1985, p.2

⁸⁴Woo 1985, p.3

⁸⁵Woo 1985, p.12

⁸⁶Somanath 1986, p.198

ble price monetary model and the real interest rate differential model, which were also used by Meese and Rogoff (1983a), outperformed the random walk, according to the RMSE and MAE. He also finds that the lagged versions do even better than those without lags.⁸⁷

Schinasi and Swamy (1989) also find that adding a lagged dependent variable improves the performance of the flexible price monetary model and of the real interest rate differential model for the dollar-yen, dollar-German mark and dollar-pound rates, and also for the Hooper Morton model⁸⁸ for the first two rates, but not for the dollar-pound rate.⁹⁰ Further, they claim that coefficients change over time. A reason for this may be that information is used differently over different time horizons or in different political regimes. They state that the rolling regression that Meese and Rogoff (1983a) applied to estimate the fixed coefficients is not an appropriate way of accounting for time-varying coefficients.⁹¹ They find that the inclusion of parameters which are allowed to vary over time into the monetary models, leads to estimates that outperform the random walk.

One important, but long neglected issue is that of the long memory of the series. Nelson and Plosser (1982) have found that most macroeconomic series are non stationary. Also, Meese and Singleton (1982), *inter alia*, have detected that exchange rates display non stationarity. If the series are difference stationary then standard asymptotic results do not hold and the OLS estimation may produce spurious results (Granger and Newbold, 1974), unless the OLS residuals are stationary. This was handled in the past by taking first differences, or using the Cochrane-Orcutt estimation method. The Cochrane-Orcutt procedure has been shown to be asymptotically equivalent to taking first differences by Blough (1992, quoted by Hamilton, 1994). If non stationarity is removed by taking first differences, then the standard

⁸⁷Somanath 1986, p.215

⁸⁸The Hooper-Morton model is an extension of the real interest rate differential model. The equilibrium exchange rate in this model is defined as the rate that equilibrates the current account in the long run.⁸⁹ The equation for the exchange rate is extended by the differential between cumulated trade balance of two countries.

⁹⁰Schinasi and Swamy 1989 p.386

⁹¹Schinasi and Swamy 1989, p.378

asymptotic results do hold, but important long-run information will be lost. Indeed, there is a special class of models for which the relation among the involved series will be misspecified if first differences are taken.

Another largely ignored issue is that of exogeneity. The assumed exogeneity of the right hand side variables in the specification of the monetary models could be questioned. In the case of exchange rate modelling, it can be argued that the money supply, for example, is affected by the spot rate if the Central Bank intervenes precisely in response to movements in the spot rate. Further, central banks do not determine the money supply exogenously, but depending on the short-term interest rates. Although, from an econometric point of view this problem could be dealt with using instrumental variable estimation, but finding a suitable instrument is not easy.⁹² Similarly, real income may be affected by the exchange rate, as has been argued in relation to the 'strong dollar' of the early 1980's.

7 Conclusion

Several concepts were presented which are supposed to give an understanding of how exchange rates are determined. These were the basic theoretical concepts of purchasing power parity and interest rate parity, and monetary models, namely the flexible price monetary model, the sticky price monetary model and the real interest rate differential model.

However, these models do not perform as well as one would guess from an economic point of view.

Although there is some evidence that shocks to purchasing power parity tend to diminish in the long run, the question remains why the convergence is so slow. One should assume that deviations are arbitrated out immediately, but as Rogoff (1996) mentions, the half-life of shocks is in between three to four years. This long time period can be explained by large frictions in the goods

⁹²Rogoff 1999, p.F657

markets, such as transportation costs, etc. The existence of transportation costs may also be the reason for the observation that purchasing power parity is more likely to hold for countries that are geographically close together.

Covered interest rate parity can clearly not be rejected empirically. If this concept would not hold, immediate risk-less arbitrage-profits would be possible. Things look different for uncovered interest rate parity. This concept is resoundingly rejected, which is most likely due to the forward rate not being an unbiased predictor for the spot rate and to expectation formations that are not rational.

Ever since the seminal paper of Meese and Rogoff (1983a) which came to the devastating result that monetary models can not outperform a random walk, researchers have tried to modify the models and use more sophisticated econometric techniques in order to overcome these poor results.

But still, results reported in the literature suggest that these models do not provide a satisfactory basis for determining or forecasting the exchange rate. This may be due to a large variety of problems that arise when estimating monetary models, such as for example omitted variables, incorrect functional forms, or a lack of dynamic specification.

However, results are difficult to compare as they change depending on the exchange rate considered, the time horizon examined and the econometric technique applied.

Do these poor results imply that monetary models have no relevance? The models have shown to be quite useful in explaining the behavior of exchange rates during times of high inflation. Also, the models can make forecast to some extent. Relative purchasing power for example predicts that the currency of a country with relatively higher inflation will depreciate. Similarly, uncovered interest rate parity states that the currency of the country with relatively higher interest rates will depreciate. Further, monetary models can make predictions about the direction in which the exchange rate should move during times of a monetary expansion or contraction.

8 Appendix

Let $(m_t - m_t^*) - \alpha(y_t - y_t^*)$ be denoted by the function H_t . Equation (25) can then be rewritten as

$$s_t = H_t + \beta E_t[s_{t+1}] - \beta s_t \quad (46)$$

Solving for s_t yields

$$s_t = \frac{1}{1+\beta} H_t + \frac{\beta}{1+\beta} E_t[s_{t+1}] \quad (47)$$

Solving this equation forward one period and taking expectations conditioned on the information set in t yields

$$E_t[s_{t+1}] = \frac{1}{1+\beta} E_t[H_{t+1}] + \frac{\beta}{1+\beta} E_t[s_{t+2}] \quad (48)$$

Inserting (48) into (47) yields

$$s_t = \frac{1}{1+\beta} H_t + \frac{\beta}{1+\beta} \left(\frac{1}{1+\beta} E_t[H_{t+1}] + \frac{\beta}{1+\beta} E_t[s_{t+2}] \right) \quad (49)$$

$$= \frac{1}{1+\beta} H_t + \frac{1}{1+\beta} \frac{\beta}{(1+\beta)} E_t[H_{t+1}] + \left(\frac{\beta}{1+\beta} \right)^2 E_t[s_{t+2}] \quad (50)$$

Solving (47) forward two periods and taking expectations conditional on the information set in t and inserting this into equation ((50)) yields

$$s_t = \frac{1}{1+\beta} \left(H_t + \frac{\beta}{(1+\beta)} E_t[H_{t+1}] + \left(\frac{\beta}{1+\beta} \right)^2 E_t[H_{t+2}] \right) + \left(\frac{\beta}{1+\beta} \right)^3 E_t[s_{t+3}] \quad (51)$$

Doing this for ∞ periods yields equation (26)

$$s_t = \frac{1}{1+\beta} \sum_{i=0}^{\infty} \left(\frac{\beta}{1+\beta} \right)^i E_t[H_{t+i}] \quad (52)$$

as $\left(\frac{\beta}{1+\beta} \right)^j E_t[s_{t+j}] \rightarrow 0$ for $j \rightarrow \infty$, since $0 < \beta < 1$.

9 Literature

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