Exchange-Rate Determination:
Is there a role for macroeconomic fundamentals?

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by

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1 INTRODUCTION

The collapse of the fixed exchange-rate system of Bretton Woods at the beginning of the 1970s has marked the start of the modern research on exchange-rate determination. In the 1970s and early 1980s the asset market approach dominated the literature on exchange-rate determination. According to this view financial markets determine the exchange rate in the short run, whereas in the medium and long run goods markets play a role as well to the extent that economic fundamentals determine the exchange rate. These models have been tested by estimating semi-reduced form relations using monthly or quarterly data. Meese and Rogoff (1983a) use a popular form of the asset market approach, namely the monetary model, and show that the out-of-sample performance of these models is rather bad: for many time horizons the forecasts of the random walk model outperform those of the monetary models. The conclusion drawn is that economic fundamentals do not play a role in exchange-rate determination. These results have led many researchers to switch to testing exchange rates on high frequency data: daily and weekly figures (see De Vries (1994) for a review). This literature does not relate the exchange rate to fundamentals but concentrates on the time series properties of exchange-rate returns. Recently this branch of research has been extended by the microstructure approach which emphasizes institutional aspects and actual behaviour of market participants. It examines aspects like: volume of transactions, heterogeneity of traders, the bid-ask spread, and asymmetric information (see e.g. Frankel et al. (1996)
Although during the second half of the 1980s and the first of the 1990s an increasing number of researchers focused on the distribution of high frequency exchange-rate returns, others remained interested in the question whether macroeconomic variables are able to explain exchange-rate movements for low frequency data. Five approaches have been used for improving the quality of the medium-term models. First, the data set used for estimating the models was extended. These extensions include: more data on the recent period of floating exchange rates, more currencies, data from the pre-Bretton Woods period and disaggregated data. Secondly, new econometric techniques were applied. In particular methods based on co-integration were used for estimating the models. An interesting feature of this technique is that it makes a clear distinction between the long-run equilibrium and the short-run dynamics. Thirdly, some authors take the balance of payments identity as a starting point, arguing that it represents the equilibrium in the foreign-exchange market. Behavioural relations for components of the balance of payments are then estimated and substituted into the balance of payments identity. The exchange rate is derived from the resulting relation. Fourthly, the relation between the exchange rate and its fundamentals may differ between exchange-rate regimes. According to the basic target-zone model (Krugman (1988)), expected exchange market interventions in the future turn the linear relation between the exchange rate and its fundamentals into a S-shaped curve. Finally, attention has been paid to the role of expectation formation in exchange-rate determination. In some studies heterogeneous expectations are introduced: some agents base their expectations on fundamentals, while others - the so-called chartists - do not make use of
economic theory when forming expectations. One may argue that these models build a bridge between the micro and macro approach to exchange-rate determination. The five approaches to model improvements are not mutually exclusive. For instance, extended data sets and co-integration techniques can be applied for estimating various models.

The quality of the models can be judged by three criteria, viz.: the within-sample fit of the model, the out-of-sample forecasting performance and the existence of a long-run relation corresponding with the theory. Since Meese and Rogoff's seminal paper of 1983 the benchmark for exchange-rate models has been the performance of the random walk in forecasting the exchange rate. Recently some papers - such as De Arcangelis and Gandolfo (1996), Mark (1995) and MacDonald and Marsh (1994) - claim that, especially for longer lead times, models based on macroeconomic variables outperform the random walk; "Economic theory, correctly used, is useful." (De Arcangelis and Gandolfo (1996)). These papers might indicate a reversal of Meese and Rogoff's verdict, in that they at least partly vindicate the macro approach to exchange-rate determination.

The aim of the present paper is to review and assess the recent trends in the literature on the macroeconomic approach to exchange-rate determination. We focus on the question whether the recent optimism with respect to the relevance of macroeconomic variables in explaining the exchange rate is well founded. Aspects of the microstructure approach are considered when they form part of a macroeconomic model. The discussion is organized along the lines of the theoretical approaches. The novelties in datasets and estimation techniques are dealt with in passing.

The set up of the paper is as follows. In the next section empirical research on the validity of the purchasing power parity (PPP) is reviewed. The asset-market...
approach consists of the monetary approach and the portfolio-balance approach. An empirical investigation of the latter requires information on the domestic and foreign investors' holdings of domestic and foreign assets. This information is not available. Except for the indirect test on the existence of a risk premium (see note 2), there are only a few studies on the portfolio-balance approach, which were published in the 1980s. We therefore restrict the discussion of the asset-market approach to the developments in testing the monetary approach (Section 3). In some studies the balance of payments identity is interpreted as an equilibrium condition of the foreign exchange market and used for deriving an exchange-rate relation. Section 4 deals with this literature. In the Sections 2-4 it is implicitly assumed that the exchange rates are freely floating. The target-zone literature argues that the existence of an (implicit or explicit) target zone can change the relation between the fundamentals and the exchange rate. This argument is discussed in Section 5. Section 6 is dedicated to studies that incorporate the behaviour of chartists in a macroeconomic model of exchange-rate determination. Finally, Section 7 draws some conclusions on the perspectives for the macroeconomic approach to exchange-rate determination.

2 PURCHASING POWER PARITY

The purchasing power parity (PPP) is an old, if not the oldest, theory on exchange-rate determination. The basic idea is that goods market arbitrage equalizes cross border prices (expressed in the same currency) of many goods, so that there will be a high
correlation between aggregate price levels. PPP-theory has two versions: the absolute and the relative version. The absolute version states that the parity holds for price levels:

\[ S = \frac{P}{P'} \]

(1)

where \( S \) is the spot rate and \( P \) (\( P' \)) is the domestic (foreign) aggregate price level. According to the relative version of the PPP-theory the percentage change of the exchange rate equals the difference in inflation rates between the two countries:

\[ \Delta s = \Delta p - \Delta p' \]

(2)

where small letters indicate natural logarithms and \( \Delta \) is the difference operator.

The "law-of-one-price" (LOP) forms an essential building block of the PPP-theory. It states that relation (1) holds for every good. The LOP-hypothesis has been tested for internationally traded goods (see e.g. Isard (1977) and Giovannini (1988)). Isard studies prices of goods such as industrial chemicals, paper and glass works. He found large deviations from the law-of-one-price. To a significant extent the deviations simply reflect nominal exchange-rate movements. Giovannini investigates monthly domestic and export prices of relatively narrowly defined sectors, such as ball bearings and screws producers in Japan. He finds that deviations from the LOP are due to exchange-rate surprises, price staggering and ex ante price discrimination.

Some recent studies (Engel and Rogers (1995) and Jenkins (1996)) include non traded goods into the analysis. Both studies investigate disaggregated price data in the
United States and Canada. The disaggregation is at two levels: location (prices from different cities in the two countries) and types of goods (e.g. local transport, health care, men's wear). These data are used to investigate whether the distance between two cities or the fact that the cities are located in different countries influence the level (Jenkins) or variance (Engel and Roger) of their relative prices. Both the distance and the border appear to contribute significantly to the failure of the LOP. An estimate of Engel and Rogers' study is that crossing the border is equivalent to 1780 miles of distance between cities. The studies show that despite the relative openness of the U.S.-Canadian border, the markets are still segmented.

Given the failure of the law of one price, it comes at no surprise that many studies analyzing monthly, quarterly and annual aggregate price indices reject the purchasing power parity as a short-run relation. Frankel (1990) argues that the failure of empirical studies to find evidence in favour of the purchasing power parity is due to the low speed of adjustment towards PPP. Larger data sets are needed in order to improve the power of the tests. The data sets can be extended in two ways: (a) the years previous to the current period of floating exchange rates are included or (b) various currencies are considered, applying panel-data techniques.

Both approaches appear to be fruitful. Becketti, Hakkio and Joines (1995) test the PPP-hypothesis using monthly data on bilateral real exchange rates between the United States and five countries from the 1920s to 1988. Their results strongly favour mean stationarity over models that permit a long-run trend in real exchange rates. Thus PPP appears to be a reasonable characterization of the long-run behaviour of national price levels and exchange rates. A drawback of this approach is that the period covers
different institutional environments. Institutional changes cause structural breaks in the data-generating process. For the post World-War II period Mussa (1986) shows that the variability of the real exchange rate is much higher under floating exchange rates than under fixed exchange rates. This conclusion holds when exchange rates of almost all currencies are fixed (Bretton Woods period, for example) or floating (after 1973), and when a bilateral exchange rate is floating (fixed) while the majority of other currencies are fixed (floating). The Canadian dollar versus U.S. dollar in 1951 through early 1962 is an example of a floating currency in a world of pegged currencies. The Belgian franc versus Luxembourg franc rate is an example of a fixed bilateral exchange rate while others are floating. These results suggest that one should be cautious with the use of data from fixed and floating exchange-rate regimes in one dataset. Grilli and Kaminsky (1991) question the relevance of Mussa's finding with regard to the role of the exchange-rate regime for pre-World War II periods. They analyse the pound/dollar rate from January 1885 to December 1986 and find that the behaviour of the real exchange rate varies substantially across historical periods. However, the large differences in the volatility of real exchange rates between fixed and floating regimes are present only in the post-WWII period. Although Grilli and Kaminsky criticize Mussa, they confirm his conclusion in the sense that "great care should be exercised in interpreting empirical regularities of the real exchange-rate behavior because they are likely to be specific to a particular sample period and, therefore, cannot be generalized" (p. 192). Thus, both studies prefer the efficient use of data from the recent period of floating exchange rates.

Studies that make efficient use of data of various exchange rates during the recent period of floating exchange rates can be divided in three categories. The first
group consists of studies which compare the OLS-estimates of PPP for each country individually with estimates obtained by means of a simultaneous estimation technique, such as 3 Stage Least Squares (Hakkio (1984)) or Zellner's Seemingly Unrelated Regressions (MacDonald (1988b)). The simultaneous estimation techniques take into account the contemporaneous correlation of deviations from PPP. These studies find that the estimates for the individual countries are very uncertain, thus yielding no clear conclusions. The use of the simultaneous techniques improves the estimates' precision considerably and the results are in favour of the existence of PPP in the long run. In the regression the long-run aspect of PPP is dealt with by including the one-period lag of the exchange rate and the price ratio. In Hakkio (1984) the autocorrelation coefficient was very often not significantly different from one. This might indicate that deviations from PPP follow a random walk. This implies that there is no tendency for PPP to hold in the long run.

The two other groups of studies explicitly deal with the long-run aspect of PPP by applying unit root tests on the real exchange rate (MacDonald (1996) and Wu(1996)) or by taking averages of annual data (Flood and Taylor (1996)). MacDonald (1996) finds very little evidence of rejection of the a unit root in the case the tests are applied on individual real exchange rates of OECD-countries. Applying panel unit root tests rejects the existence of a unit root in the real exchange rates. This result is independent from the price measure (wholesale prices or consumer prices) used. Flood and Taylor (1996) use a paneldata for twenty two countries during the period 1973-1992 for examining the simple purchasing power parity relation (2), which in regression form can be written as:
\[ \Delta s_{it} = \beta (\Delta p_{it} - \Delta \bar{p}) + \epsilon_{it} \]  

(3)

where \( s_{it} \) is country \( i \)'s exchange rate against the US dollar, \( p_{it} \) (\( \bar{p} \)) is the price level in country \( i \) respectively the US and \( \epsilon_{it} \) is an independently distributed disturbance term.

Using annual data for estimating this relation for bilateral exchange rates against the US dollar leads to very poor results (\( R^2 \) is approximately zero). Simply pooling the observations does not improve the regression results. A pooled regression of five-year-average changes explains over 40 percent of the pooled variation in the exchange rate. This fit improves to approximately 70 percent if ten-year-average changes are used. These results clearly show that a simple fundamental model, such as the relative PPP is a good description of exchange rate changes at horizons of five years or longer. Hence, deviations from PPP tend to dampen out, but only slowly. A similar result is found by many other authors.

Hitherto it has been assumed that the equilibrium value of the real exchange rate is constant. Real factors can, however, change this long-run value and hence account for long-run deviations from PPP. Three modifications to the long-run PPP have been put forward in the literature.

The first deviation from PPP is the following empirical regularity: when expressed in terms of a single currency, countries’ price levels are positively related to the level of real income per capita. The Balassa-Samuelson theory explains this regularity by postulating that the labour forces in the tradable sector of poor countries are less productive than those of rich countries, but that international productivity differences in nontradables are negligible. Assume that prices of traded goods are more
or less the same. Then the lower labour productivity in tradables industry in poor countries implies lower wages there than abroad and so lower price levels of nontrada-
bles. The empirical evidence of the Balassa-Samuelson effect is mixed. It seems to work for the yen-dollar rate but not for the other industrial countries (Rogoff 1996, p. 662). A result which is reaffirmed in Mark and Choi (1996), where productivity differentials are found to improve the forecasting performance of the US yen-dollar rate and the Canadian dollar-US dollar rate. Productivity differentials do not improve the forecasts of other main currencies.

Another explanation for long-run deviations from PPP is that the real exchange-rate changes are due to sustained imbalances of the current account. These imbalances lead to a change in the international distribution of wealth. Since spending patterns differ across countries, a redistribution will give rise to changes in the long-run real exchange rate. The portfolio-balance approach emphasizes the influence of cumulated current account balances on the net-interest payments. Big current account deficits give rise to increased interest payments which will have to be paid for by a surplus on the trade balance, which at its turn has to be generated by a depreciated real exchange rate. Hence, the causation of the relation between the exchange rate and current account can be both ways.

Finally, the level of government spending adjusts the purchasing power parity. Relative to private spending, government spending tends to fall more heavily on non-
traded goods. Hence an increase in government spending depreciates the real exchange-
rate more than an equivalent rise in private spending. One can question whether this demand effect can be permanent. With free capital movements the real exchange rate
will be determined by differences in productivity and other supply side shocks. Mark and Choi (1996) find that the inclusion of government spending in the regression improves the forecasts of the bilateral rate between the Japanese yen and the US dollar and the Canadian dollar and the US dollar.7

3 TESTING THE MONETARY MODEL

Since the mid-1970s, the asset market approach is the dominant view on exchange-rate determination. The majority of papers that test a version of this approach use the semi-or quasi-reduced form for estimating the relation between the exchange rate and other macroeconomic variables. This procedure can be illustrated by means of a simple version of the asset market approach, namely the flexible price monetary model. The two-country version of this model consists of:

\[ m_t - p_t = \alpha_y y_t - \alpha_i i_t \]  
(4)

\[ m^*_t - p^*_t = \beta_y y^*_t - \beta_i i^*_t \]  
(5)

\[ i_t = i^*_t + E_t (\Delta s_{t,y}) \]  
(6)

\[ p_t = s_t + p^*_t \]  
(7)
where Greek letters are positive parameters. $E$ is the expectations operator: $E_t (\Delta s_{t+1})$ denotes the expectations of the change of the log of the exchange rate from time $t$ to $t+1$ founded by individuals at time $t$, and $y$ is exogenous aggregate supply of domestic goods. Equation (4) describes the equilibrium in the domestic money market, whereas relation (5) represents the foreign money market. Relation (6) is the uncovered interest parity and (7) the purchasing power parity. The latter represents the flexible price assumption.

The exchange-rate equation is derived from these four equations and is:

$$s_t = (m_t - m_t^* - \alpha_1 y_t + \beta_1 y_t^* + (\alpha_2 - \beta_2)\bar{y}_t + \alpha_2 E_t s_t) / (1 + \alpha_j) \quad (8)$$

In many articles exchange-rate relations like (8) are labelled the exchange-rate model's reduced-form equation. Strictly speaking, these relations are not reduced-form equations because some of the explanatory variables may not be predetermined. In a regime of freely floating exchange rates the domestic and foreign money stock will be exogenous, but then the foreign interest rate and the expected exchange rate will be influenced by the current spot rate. On the other hand, in a system with managed exchange rates the domestic and foreign money stocks vary with the unsterilized part of foreign exchange-market interventions, which are influenced by the level of the exchange rate. Consequently, under various exchange-rate regimes the exchange rate and some of its explanatory variables are simultaneously determined (see for example Frankel, 1981, pp. 1076-1077, and Hacche and Townend, 1983, p. 139). Authors who are aware of this simultaneity therefore refer to these exchange-rate relations as semi- or quasi-reduced
form equations (see e.g. Meese and Rogoff, 1983a, p. 5, and Gylfason and Helliwell, 1983, p. 823).

The asset market approach satisfactorily explains exchange-rate movements for some time periods: the interwar period and the first years of the floating exchange-rate period (the years 1973 - 1978).9 Rather good within-sample results were reported. Meese and Rogoff (1983a), however, show that for the period 1973 - 1981 the out-of-sample forecast performance of various versions of the monetary model is very bad. For many horizons, the random walk performs better than the estimated single-equation models. In a companying paper Meese and Rogoff (1983b) argue that this result cannot be ascribed to a bias resulting from the fact that various variables are simultaneously determined.

Many studies have been published that bring forward an explanation for the bad forecasting performance of the monetary model and that suggest changes in the specification or estimation procedure, so that the out-of-sample fit is improved. Assume that \( \alpha_1 = \beta_1 \) and \( \alpha_2 = \beta_2 \) in relations (4) and (5). Then the rational expectations solution of the flexible price monetary model is

\[
s_t = (m_t - m^* + \sum_{j=1}^{n} [(\alpha_2/(1 + \alpha_2)) E_t (m_{t+j} - m^*_{t+j})] \\
- \alpha_1 (y_t + \sum_{j=1}^{n} [(\alpha_2/(1 + \alpha_2)) E_t (y_{t+j} - y^*_{t+j})] ) / (1 + \alpha_2)
\]

In this relation the current spot rate is determined by currently expected values of the future exogenous variables. Finn (1986) postulates that the data-generating process of
these variables is autoregressive. The estimated coefficients of the rational expectations model are more closely to their theoretically expected value than those of the standard monetary model. The forecasting performance of the rational expectations model is approximately the same as that of the random walk.

Some studies (Wolff (1987 and 1989) and Schinasi and Swamy (1989)) estimate semi-reduced-form relations of the monetary approach with time-varying coefficients to allow for structural changes in the data-generating process. For example, structural changes in the money demand function resulting from financial liberalization and innovation. Schinasi and Swamy (1989) and Wolff (1987) find that various variants of the monetary approach with time varying coefficients can outperform forecasts of a random walk model. These studies do not investigate whether the monetary models significantly outperform the random walk. Wolff (1989) shows that this improvement is significantly better at forecast-horizons of two years and up but not so for shorter horizons. In the forecast experiments reported above the exogenous variables were equal to their actual values. In practice however a forecaster doesn't have the actual values of the exogenous variables at his disposal but has to use forecasts. A true ex-ante forecasting experiment was performed in Wolff (1989), where exchange-rate forecasts are based only on information which was available to agents at the time the forecast was made. This experiment reveals that for horizons up to one year the monetary approach models did better than the random walk model, even on an ex-ante basis. The ex-ante forecasts are less accurate for the longer horizons (maybe due to the inferior quality of the forecasts of the exogenous variables).

In the flexible price monetary model - relations (4) to (7) - the asset markets are
assumed to clear instantaneously clearing. This assumption has been criticized by Woo (1985) who suggests a partial adjustment specification in the money demand functions and estimates the resulting reduced form by two rational expectations techniques. The parameter estimates are reasonable and the out-of-sample forecasts outperform the random walk. Recent studies once again stress the importance of the dynamics for explaining exchange rates. Now co-integration techniques are used to distinguish between short-run dynamics and long-run relations. If there exists a long-run relationship between some variables then these variables are co-integrated. An error-correction specification models the gradual movement of a variable to its long-term relation and the short-run dynamics. Basically there are two ways in which this type of models can be estimated: single equation methods and multivariate full information approaches. The two-step method of Engle and Granger (1987) is the best-known example of a single-equation method, it estimates the long-run relation in the first step. The second step consists of estimating the adjustment process conditional upon the long-run relation estimated in the first step. The full-information methods estimate the short-run and long-run relations simultaneously (see e.g. Johansen (1988) and Johansen and Juselius (1992 and 1994)). The Engle and Granger two-step method has two disadvantages which do not pertain to the full-information method. Firstly, the estimation of the long-run relation independently from the short-run influences introduces the possibility of misspecification (short-run influences are not dealt with when estimating the long-run relation). Secondly, Engel and Granger's method requires that one of the variables is selected as the endogenous variable.

The Engle-Granger single-equation procedure has been applied in Boothe and
Glassman (1987) and Meese (1986). Both studies do not find evidence of co-integration between the exchange rate and variables suggested by the monetary model. So the monetary approach does not hold even as a long-run relation. These results might be caused by the above mentioned disadvantages of the Engle and Granger method. MacDonald and Taylor (1991 and 1993) therefore propose to use the full-information technique developed by Johansen. Applying this method to three exchange rates (sterling, Deutsche mark and yen against the dollar), MacDonald and Taylor (1991) find evidence in favour of the existence of co-integration between these exchange rates and the variables suggested by the monetary approach. According to MacDonald and Taylor (1993) there also exists a long-run relation between the Deutsche mark - dollar rate and the variables suggested by the monetary approach. An error-correction model is estimated and used for calculating forecasts which appear to be superior to those generated by the random walk model. Moosa (1994) uses the same procedure as MacDonald and Taylor for a version of the monetary model which makes an explicit distinction between traded and non-traded goods: PPP is assumed to hold only for traded goods. This amended monetary approach model also appears to be a good candidate for a long-run relation of the exchange rate.

As has been stated in the Introduction, since Meese and Rogoff (1983a) the forecasting performance of the semi-reduced form models has been used as the testing device of exchange-rate models. In a number of recent papers Mark and his co-authors investigate the long-horizon predictability of formulas that contain the economic fundamentals suggested by the monetary approach (Mark (1995)), PPP augmented with productivity differentials, real interest rate differentials and per capita income differenti-
als (Mark and Choi (1996)) or by PPP, the monetary model and the uncovered interest parity (Chen and Mark (1996)). The general conclusions from these studies is that economic fundamentals can significantly predict exchange rates at long horizons. The fundamentals of the monetary model appear to be the most robust predictors of the long-run changes in nominal exchange rates (Chen and Mark (1996)). Short-horizon changes in exchange rates tend to be dominated by noise, which is averaged out over time, thus revealing systematic exchange-rate-movements that are determined by economic fundamentals. Chen and Mark (1996) also investigate whether the same conclusions would have been drawn if the standard with-in sample criteria for evaluating models would have been used. They conclude that except for the Japanese yen, the two criteria (in-sample fit and out-of-sample prediction) lead to the same conclusions. These results are noteworthy because since 1983 it has been thought that the nominal exchange rates are unpredictable. Further research is needed in order to investigate the robustness of these results.\textsuperscript{12}

Although Mark and his co-authors find that economic fundamentals can significantly improve the long-horizon predictions of exchange rates, they explicitly state that these predictions cannot form a test for a particular exchange-rate model.\textsuperscript{13} Berben (1996) carries this argument somewhat further and explicitly proves the unsuitability of the forecast performance as a test of an exchange-rate model. He first investigates whether the individual structural-form relations of the standard monetary model (relations (4), (5) and (7)) hold and finds that there are long-run relations for the German and American money demand. Probably due to the relatively short length of the sample, PPP fails to hold for the Deutsche mark - dollar rate. So not all assumptions of
the simple monetary model are met. However, tests on the number of co-integrating relations in the semi-reduced-form relation suggests that there is at least one long-run relation. Forecasts derived from the semi-reduced form relation outperform the random walk model at long horizons. So Berben (1996) finds that the forecast performance of the monetary model may be good, although one of the constituent assumptions (PPP) is invalid. This sheds a new light on the practice in exchange-rate modelling to judge exchange-rate models by means of their ability to outperform the forecasts of the random walk. The common practice since Meese and Rogoff (1983a) of using the forecast as a test on exchange-rate models seems to be incorrect. Forecasts that are better than those of a random walk only suggest that macroeconomic variables are relevant for exchange-rate determination. They are not valid tests of a particular exchange-rate model. To test a model use should be made of the structural-form relations.

4 THE BALANCE-OF-PAYMENTS IDENTITY AND EXCHANGE-RATE DETERMINATION

Some authors interpret the balance-of-payments identity as the equilibrium condition of the foreign exchange market. It does not imply, according to the adherents of this approach, that they advocate the traditional flow approach to exchange-rate determination. The balance of payments identity can be used as a framework that encompasses many of the previously mentioned models of exchange-rate determination. Two
approaches can be distinguished, the explicit and the implicit method. The first approach substitutes behavioural relations into the balance-of-payments identity and derives an equation of the exchange rate. Thereafter, this exchange-rate relation is estimated. The second approach first estimates behavioural equations for various components of the balance-of-payments identity. These estimated relations are substituted into the balance-of-payments identity and the equilibrium value of the exchange rate is derived.\textsuperscript{14}

MacDonald and Marsh (1994) use the explicit method to generate a framework that encompasses many of the explanations described in Section 2 for the deviations from the purchasing power parity. Under floating exchange rates the balance of payments identity is:

\[ CA - \Delta NFA = 0 \tag{10} \]

where \( CA \) is the balance on the current account and \( NFA \) is the stock of net foreign assets. The current account is made up of the trade balance \((TB)\) and the balance of net investment income, \( i^{*}\cdot NFA \), where \( i^{*} \) is the foreign interest rate:

\[ CA = TB + i^{*}\cdot NFA \tag{11} \]

Assume that the following behavioral relations hold:

\[ TB = \alpha (s + p^{*} - p) + \beta Z \tag{12} \]
\[ \Delta NFA = -\mu(t - i^* - \Delta s^e) \] (13)

where, in addition to variables previously defined, \( Z \) is a vector of exogenous influences on net exports, \( \alpha, \beta \) and \( \mu \) are positive coefficients, and the superscript \( e \) denotes an expectation.

On substituting (11), (12) and (13) in (10) and solving for the exchange rate we obtain:

\[ s = p - p^* - (\beta/\alpha) \cdot Z - (i^*/\alpha) \cdot NFA - (\mu/\alpha) \cdot (i - i^* - \Delta s^e) \] (14)

The last three terms in relation (14) capture deviations from PPP. These terms and the theories of real exchange-rate determination presented above are related in the following way. Across-country differences in productivity (Balassa-Samuelson theory) and changes in the level of government spending are candidates for inclusion in the vector of exogenous variables \( Z \). The term \( (i^*/\alpha) \cdot NFA \) refers to influence of current account imbalances on net interest payments. The last term in equation (14), which is the risk premium\(^{15} \), has not been considered before.

MacDonald and Marsh apply the framework captured in relation (14) to the Deutsche mark-US dollar, Japanese yen-US dollar, and British pound-US dollar rate in the period of January 1974 up to December 1992. The data up to September 1989 are used for estimating the model while the remaining observations are used for forecast experiments. Interpreting equation (14) as a long-run relation for the exchange rate and making some additional assumptions that simplify (14)\(^{16} \) to the regression equation:
\[ s = p - p^* - \left( \frac{\mu}{\alpha} \right) (i - \hat{i}) + c + \epsilon \]  \tag{15}

where \( c \) is a constant term and \( \epsilon \) an independently distributed disturbance. The full information maximum likelihood method of Johansen is used for estimating co-integrating relationships. For Germany, the long-run relation appears to consist of PPP augmented with the interest differential (equation (15)), whereas for the UK and Japan in the long-run relation the coefficients on the interest terms are not of equal size. These long-run relations are used for estimating error-correction models. Comparing the forecasts of the error-correction models with the forecasts generated by the random walk model reveals that the model outperforms the random walk at horizons of about three months and onward.

The implicit method for deriving the exchange rate from the balance of payments identity is applied in De Arcangelis and Gandolfo (1996), De Jong (1991), and Gandolfo et al. (1990a and 1990b). These four studies use quarterly data for estimating a macroeconomic model of the Dutch (De Jong) or Italian economy (Gandolfo and his co-authors). These models contain behavioural relations of international trade and international capital flows. De Jong (1991) investigates the Dutch guilder-US dollar rate and finds a satisfactory in-sample fit, but does not make forecasts of the exchange rate. Gandolfo and his co-authors investigate the Italian lire-US dollar rate and compare the forecasts of their model with those of the random walk. These forecasts outperform the random walk for lead times of three months and longer. The predictive performance of the model relative to the random walk improves with the lengthening of the time horizon (Gandolfo et al. (1990b)). The model is superior to the random walk when the
prediction of turning points is used as a yard stick (De Arcangelis and Gandolfo (1996)).

5 THE TARGET ZONE MODEL

In the previous sections we have assumed that the central banks do not intervene in the foreign exchange markets. In practice, authorities of many countries try to stabilize the value of their currency against a single currency or a basket of other currencies (or indicators). The best known example is the Exchange Rate Mechanism (ERM) of the European Monetary System (EMS). A common feature of many of these arrangements is that the authorities announce a central rate and a band around this central rate, within which the exchange rate is allowed to move. Up to the end of the 1980s no study existed which investigated whether these target zones have any influence on the behaviour of the exchange rates within the band. The publication of Krugman's NBER paper on the target zone model (Krugman, 1988) changed the scene dramatically. In that paper Krugman argues that the mere existence of an exchange-rate band changes the functional form between the exchange rate and its fundamentals from a linear relation into a S-shaped curve. In this section we describe his arguments and investigate whether it is likely that the S-shaped curve appears in empirical work.

In his paper Krugman starts with the flexible price monetary approach model with rational expectations. He assumes a small open economy described by relations (4), (6) and (7). This model is used for deriving a relation of the exchange rate.
\[ s_t = \left( m_t - p_t - \alpha_1 y_t + \alpha_2 E_t s_{t+1} \right) / (1 + \alpha) \]  

(16)

For simplicity, assume that the foreign price level is the numeraire, so that its logarithm is zero and that the foreign interest rate is zero. The rational expectations solution of the simplified version of (16) is:

\[ s_t = \left( m_t + \sum_{j=1}^{w} \left( \frac{\alpha_j}{(1 + \alpha)} \right)^j E_t m_{t+j} \right) \]

\[ - \alpha_1 (y_t + \sum_{j=1}^{w} \left( \frac{\alpha_j}{(1 + \alpha)} \right)^j E_t y_{t+j}) / (1 + \alpha) \]  

(17)

Hence, the current value of the exchange rate depends on the present and expected future values of money supply and national income, the so-called fundamentals (compare equation (9)). Money supply is exogenous under flexible exchange rates. Under a target zone arrangement, however, money supply becomes endogenous because the monetary authorities are obliged to intervene in the foreign exchange market.

Assume that at the bands the monetary authorities intervene with infinitesimal small amounts, so that the exchange rate just stays within the band. If the private agents regard this arrangement to be credible, then at every point within the band they foresee the interventions, which will take place in case the exchange rate hits one of the boundaries. As a result, if the probability that the exchange rate will hit the upper boundary (depreciating currency) is greater (less) than the chance that it will hit the lower boundary (appreciating currency), the expected future money supply will be lower (higher) than the one under flexible exchange rates. Hence, in the upper (lower) half
the band the exchange rate is lower (higher) than it would have been had there been floating exchange rate. The expectation of future interventions stabilizes the exchange rate within the band; the "honeymoon" effect of target zones. The relation between the exchange rate and its fundamentals becomes S-shaped.

This non-linear relation between the fundamentals and the exchange rate is illustrated in Figure 1, where the 45-degrees line represents the floating exchange-rate regime and the solid line the relation under a target zone arrangement.

For deriving these characteristics of Krugman's model, three assumptions are crucial, namely: foreign exchange interventions are on the boundaries only, the band is fully credible and expectations are forward looking. Interventions at the edges of the band are known as infra-marginal interventions. Intra-marginal interventions occur within the exchange-rate bands rather than at the edges. These interventions are "leaning-against-the-wind", that is, they aim at returning the exchange rate to the target value in the middle of the band. As a result the exchange rate is stabilized and the relation between the fundamentals and the exchange rate becomes flatter than under a regime of floating exchange rates (compare the curves MM and FF in figure 2). Under a target zone regime there will still be a honeymoon effect (curve TT in Figure 2). This stabilizing effect is much smaller than under a regime with inframarginal interventions.
only (compare Figure 1 with Figure 2). The reason is that the probability that the exchange rate will hit the band is smaller under a regime with intra-marginal interventions.

Especially after the Basle-Nyborg agreement of September 1987 intra-marginal interventions have become increasingly important. These interventions might explain the finding in De Jong (1993) that the model is essentially linear for the Dutch guilder / Deutsche mark rate (see also lines MM and TT in Figure 2). Beetsma (1995) reaffirms the importance of the correct assumption of the intervention policy. In Beetsma (1995) a Monte Carlo analysis is used to compare the original Krugman model with a model where interventions also take place inside the band. The last model appears to be a more appropriate description of the Deutsche mark exchange rates against many other currencies during the period January 1987 - August 1992.

The case that the band is not fully credible is presented in Bertola and Cabellero (1992). They introduce the possibility that at the boundary the central bank will not defend the existing band, but will decide to adjust the central rate and the corresponding band. In this case the relation between the exchange rate and its fundamentals is a weighted average of that under a credible target zone and that under floating exchange rates. Hence, the curve in Figure 1 representing this regime will lie between the 45-degrees line and the solid curve. Mizrach (1992) compares the empirical fit of target zone models with and without a probability of a realignment and the random walk
model. The target zone models are: the original Krugman model, a model with constant realignment probability and a model with time varying propensity of a realignment. The last model appears to sharply dominate the other models. Once again the Monte Carlo experiments in Beetsma (1995) reaffirm this result. A target zone model with the possibility of realignments forms a better representation of the characteristics of the exchange rates than the original Krugman model.

Related to the previous criticism is that which questions the assumption of fully rational (forward looking) expectations, which generates the "honey moon" effect. Under fully rational expectations economic agents know the true model so that they do not learn. In reality very often private agents do not know the exact intervention policy of the authorities. They have to learn whether the central banks will use intra-marginal interventions and/or whether they will defend the band when the exchange rate hits one of the boundaries. As a consequence of this learning the relation between the exchange rate and the fundamentals will be less like a S-shape than in the basic model. Garretsen et al. (1996) incorporate Bayesian learning into a standard target zone model. They apply this modified model to the widening of the French ERM bands in 1993. During this period the forecast errors of professional forecasters were large; many expected that the French would loosen their monetary policy. This expectation didn't materialize. It appears that the model with Bayesian learning forms a good description of this period. Klein and Lewis (1993) apply a similar model to the Deutsche mark-dollar and yen-dollar for the period from the Louvre Accord to the stock market crash in 1987. Their results suggest that the market's perceptions of the target zone shifted significantly during this period.
To sum up, the feature of the basic target-zone model that there will be a S-shaped relation between the exchange rate and its fundamentals can only be derived under very strict assumptions. These assumptions are: there are only intra-marginal interventions, the band is fully credible and expectations are forward looking. The relation between the exchange rate and its fundamentals approaches that of a regime of free floating exchange rates, when one or more of these assumptions are not met.\(^1\) The empirical literature on target zone models reaffirms the impression that the exchange-rate regime has no significant influence on the relation between the exchange rate and macroeconomic variables: the S-shaped relation proves to be difficult to detect (see e.g. Diebold and Nason 1990, Flood, Rose and Mathieson, 1991, and Lindberg and Söderlind, 1994). Hence, to a great extent macroeconomic variables determine the exchange-rate movements under a target-zone regime in the same way as they do under freely floating exchange rates. As a consequence, the results presented in the previous sections are also relevant for exchange-rate regimes which contain exchange-rate bands.

6 CHARTISTS AND FUNDAMENTALISTS

Hitherto if we payed attention to the role of expectations we assumed that expectations were formed rationally. Empirical research by means of survey data reveals, however, that expectations are not formed rationally (Frankel and Froot (1987), Ito (1990) and Tagaki (1990)) and that very often they are not based on fundamentals either. Allen and Taylor (1990), for example, found that the dealers in the London foreign-exchange
market use charts or technical analysis for forecasting over short time horizons. "At the shortest time horizons, intra-day to one week, approximately 90% of the respondents use some form of chartist input in forming their exchange rate expectations, with 60% judging charts to be at least as important as fundamentals. ... at the longest forecast horizons, one year or longer, the skew towards fundamentals is most pronounced, with nearly 30% of respondents relying on pure fundamentals and 85% judging fundamentals to be more important than charts" (Allen and Taylor, 1990, p. 50).

The theoretical analysis of exchange-rate behaviour under uncertainty proves the rationality of basing the expectations on non-fundamental factors. In De Grauwe (1996, Ch. 9) every period a risk-averse speculator has to decide whether he will make a new forecast at a fixed cost. For small changes in the fundamentals it is not worthwhile to invest in a new forecast based on economic fundamentals. He has to use a decision rule to pick an exchange rate as the expected rate. A possible rule is to stick to the present value of the exchange rate. Another rule is to follow the opinion of others, "herd behaviour" (see Kirman (1995). A reason for following others is that the actions of individuals reveal something about the information they possess; maybe others have private information on the future values of fundamentals. Another reason to follow others is that they are more successful so that imitation might appear to be profitable. Finally a reason to follow others is simply that their opinion influences the exchange rate (Keynes' beauty contest, Keynes (1936), p. 156).

This empirical evidence and theoretical arguments on the relevance of both economic theory and some form of technical analysis for the formation of exchange-rate expectations, have inspired some authors to include into their analysis these two types
of expectation formation. In a number of publications De Grauwe and his co-authors (Grauwe de and Dewachter (1993), and Grauwe de, Dewachter and Embrechts (1993) extend the Dornbusch model with two classes of speculators. The first are chartists (noise traders, technical analysts), who use the past of the exchange rates to detect patterns and extrapolate these into the future. The second group of speculators consists of fundamentalists. They compute the equilibrium value of the exchange rate as given by the model, and expect that the exchange rate will move into the direction of this equilibrium. The expected exchange rate is a weighted average of the two types of expectations, where the weight of the fundamentalists increases if the actual exchange rate moves away from the equilibrium rate. The model is not used for empirical tests, but theoretically plausible values are assigned to the model's parameters, whereafter time paths of the exchange rate are simulated. These simulated time series exhibit some features of the actual time series, namely unit roots and a forward exchange rate which is a biased predictor of future spot rates. The behaviour of the exchange rate becomes chaotic in situations where the chartists dominate, then the relation between economic fundamentals and the exchange rate is very variable and the forecasting performance of semi-reduced form relations is worse than that of the random walk.

Frankel and Froot have published a number of papers (Frankel and Froot (1986 and 1988)) in which the exchange rate is determined by the expected exchange rate and other contemporaneous determinants, such as the supply of foreign assets. An increase of the supply of foreign assets will appreciate the domestic currency. The expectations are determined by three classes of actors: fundamentalists, chartists and portfolio managers. The portfolio managers are the agents who actually buy and sell and form
their expectations as weighted average of the predictions of the other two types of agents. The portfolio managers update the weights over time in a Bayesian way, according to whether fundamentalists or chartists have recently been doing a better job in forecasting the exchange rate. The chartists are assumed to expect that the exchange rate will not change. The fundamentalists know the long-run equilibrium value of the exchange rate and assume that this will remain constant. Suppose that the exchange rate equals its long-run equilibrium value, so that the expectations are fully determined by the fundamentalists. Frankel and Froot (1988, pp. 85 and 86) show that for reasonable values of the parameters this equilibrium will be unstable. So if there is any unanticipated shock then the chartists are gaining prominence and the exchange rate moves away from its long-run equilibrium. This process will continue until the portfolio managers' expectations are entirely determined by the expectations of the chartists. Since they expect no change, the exchange rate will stay at this level. This equilibrium is fully rational in the sense that the portfolio managers do not expect any change of the exchange rate and the exchange rate indeed doesn't move. Hence, the model is able to explain why an exchange rate can differ from its long-equilibrium level for a long period. The stock of net foreign assets is assumed to be the fundamental variable that brings the exchange rate back to its equilibrium value. Assume that a currency has been appreciated above its long-run value. This will result in current account deficits and thus in a reduction of net foreign assets, which leads to a depreciating currency. Since the fundamentalists expected a depreciation this materializes, the weight of the fundamentalists in the expectations increases until in the long-run equilibrium this weight is one.

Both the model of the De Grauwe et al. and that of Frankel and Froot have
drawbacks. A disadvantage of the former is that the weight of the fundamentalists increases as the exchange rate is further away from the long-run equilibrium. This feature does not correspond with some computations that indicate that during the rise of the dollar in the first half of the 1980s the weight of the fundamentalists decreases, and was very low in 1985, when the dollar was at its highest level (see Frankel and Froot (1988), pp. 67 and 68). A disadvantage of the model put forward by Frankel and Froot is that it is a set-up to explain the long-lasting appreciation and fast depreciation of the US dollar during 1980-1987. It is unclear why the stock of net foreign asset is the trigger that changes the expectations from chartists to fundamentalists. Which factors determine the critical level of this stock? The model is unable to explain why after 1987 the dollar has appreciated during several periods, whereas the current account of the US still shows a deficit. A more general model is needed, capable of explaining more events in the foreign exchange market and introducing an endogenous mechanism that triggers the switch from chartists to fundamentalists.

7 CONCLUDING REMARKS

With a view towards assessing the relevance of macroeconomic variables for exchange-rate determination, this paper reviews recent trends in exchange-rate modelling. It appears that various studies are able to find a long-run relation between the exchange rate and economic fundamentals suggested by the purchasing power parity theory and the monetary approach. These results are more favourable than those presented in
studies published in the 1980s with regard to the relevance of macroeconomic variables for exchange rates. They can be ascribed to the use of co-integration techniques and of extended datasets. The co-integration techniques developed in the 1980s have considerably improved the ability to estimate long-run relations.

Following Meese and Rogoff (1983a) the out-of-sample forecasting performance is used as a benchmark in exchange-rate modelling. Some recent studies extend the monetary model with short term dynamics and use the resulting semi-reduced-form relation for deriving forecasts. These experiments reveal that the resulting equation generates forecasts that, at longer time horizons, are better than forecasts provided by the random walk model. Hence, according to these tests macroeconomic variables are relevant for improving the forecastability of exchange rates. These tests do not, however, validate particular macroeconomic models of exchange-rate determination. As Berben (1996) clearly shows, crucial parts of the monetary approach can be incorrect whereas the model based on this approach still delivers good forecasts. Hence more work has to be done on testing the validity of these models.

Both the modification of the basic target-zone model and the empirical evidence of these models suggest that the relation between the exchange rate and its fundamentals is not significantly influenced by the type of the exchange-rate regime (floating or a target zone). The short-run behaviour of exchange rates contains too much noise to be explained by macroeconomic factors. In this respect a merger of the macroeconomic approach with some aspects of the microeconomic approach of exchange-rate determination might be fruitful.
Footnotes

* The author acknowledges the comments on previous versions of this paper by Roel Beetsma, Simon Kuipers, an anonymous referee and members of the Department of Applied Economics, University of Nijmegen. The usual disclaimer applies.

1. Reviews of this literature can be found in Jones and Kenen (1985), De Jong (1991, Ch. 2), MacDonald (1988a), MacDonald and Taylor (1992) and Visser (1989).

2. The distinction between the short-run (intra-daily, daily and weekly) and medium-run (monthly and quarterly) exchange-rate dynamics can be based on the distribution of exchange rate returns. At high frequencies the distribution has excessive mass in the tails (leptokurtosis) and has strong serial dependence of volatility (heteroskedasticity). As a consequence of the heteroskedasticity there is a strong clustering of small and large exchange-rate fluctuations in the short-run data. The distribution of the monthly and quarterly data, however, converges to the Gaussian white noise (see Kaehler and Marnet (1993, Section 2)).

3. In this article we restrict ourselves to the literature on the determination of spot exchange rates. Hence, no attention is paid to other phenomena in international finance in which macroeconomic variables may play a role. Examples are: (a) the role of "news", where the independent variable is the difference between the actual and expected spot rate and (b) the macroeconomic influences on risk premia.
4. See for example, Boughton (1987).

5. Similar results are reported in Lothian and Taylor (1996).

6. Frankel and Rose (1996) re-examine deviations from PPP using a panel of 150 countries and 45 annual post-Word War II observations. They find that the variation in the cross-section data is greater than that of the time series. As a consequence the estimates derived from cross-section regressions are more stable and show a higher significance than those obtained from time series regressions.

7. Note, however, that Mark and Choi find the best results when monetary variables are considered. This suggests that money is not neutral and that hysteric effects are present.

8. Note that some authors refer to these single equation models as "structural models". With this term they want to distinguish these models from the pure time series models which explain the exchange rate's current value only from past observations of its own time series. From an econometric point of view the term "structural models" is deceptive, because these equations are not the model's structural form.


10. Woo labels the estimation techniques as the "exogenous" and the "endogenous" technique for estimating rational expectations models. A description of these techniques
can be found in Sargent (1978) and Woo (1985).


12. Some preliminary estimations by R.-P. Berben at the Department of Applied Economics of the University of Nijmegen indicate that for other periods than those used by Mark, the out-of-sample predictions are less accurate.

13. See e.g. Mark (1995, p. 204) and the following quote from Mark and Choi (1996, p. 5) "We emphasize that the main thrust of the paper is to establish and to explore the relation between current valued fundamentals and future changes in the log real exchange rate. We draw on some popular models of exchange-rate determination to guide our choice of these fundamentals, but tests of any particular theory are beyond the scope of the paper".

14. The difference between the two approaches corresponds with that implicit and explicit method for explaining the interest rate (see Den Butter (1986) and De Jong (1991)).

15. The risk premium can result from: (a) imperfect substitutability of domestic and foreign assets, (b) capital controls, and (c) imperfect domestic and foreign capital markets.

17. Krugman uses a continuous time model and applies stochastic calculus in order to derive the explicit form of the solutions under a target zone.

18. See, for example Gärtner (1993, pp. 125-127) for a derivation.

19. Oppers (1993) applies the target zone model to the bimetallic system in France in the 19th century. Under the bimetallic system the changes from one metallic to the other were in a well defined area of the relative price of gold in terms of silver (a currency band). This area was determined by technical factors such as melting costs and transport costs. In fact this mechanism closely corresponds with the assumption in the original Krugman model of infinitesimal small interventions at the bands and full credibility of the arrangement. Accordingly, Oppers finds that the historical data of the bimetallic system correspond very closely with those derived from the original target zone model.

20. Note that these expectations are not fully rational in the sense that the fundamentalists do not take into account the reactions of the chartists, and the speed by which the exchange rate is expected to move into the direction of the equilibrium rate is not equal to the actual speed.

21. Note that the fundamentalists are not rational. They do not know the model, but only the exchange rate's equilibrium value.
22. Note that in contrast to the model of De Grauwe et al. the weight of the fundamentalists is small when the exchange rate is far from its long-run equilibrium level.
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Abstract

This paper reviews recent trends in exchange rate modelling with a view towards assessing new claims that macroeconomic variables are useful for explaining exchange rates. The application of co-integration techniques and the use of larger datasets have led to more empirical evidence in favour of both the Purchasing Power Parity and the monetary approach to exchange rate determination as long-run relationships. Various studies show that the forecasts based on variables suggested by the monetary approach outperform the random walk. It is questionable, however, whether the tests used validate the monetary approach of exchange rate determination or just show that macroeconomic variables have a role to play. Extensions of the basic target-zone model and empirical evidence reveal that the relation between economic fundamentals and exchange rates is much less influenced by the target-zone arrangement than Krugman originally suggested. A merger of the macroeconomic approach with microeconomic factors may be a fruitful direction for explaining short-run behaviour.