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# Balance of payments flows and exchange rate prediction in Japan\*

Nikolas A. Müller-Plantenberg<sup>†</sup>

## Abstract

Monetary models of exchange rates tend to focus on inflation differentials to explain exchange rate movements. This paper assesses the ability of currency flows to predict exchange rate changes. The focus is on Japan. Currency flows are assumed to depend on the level of the current account and on the international investment position, where the latter is used as a proxy for international debt repayments. A state space model is used to predict simultaneously the exchange rate and its determinants. Using rolling regressions and out-of-sample predictions, it is shown that a model featuring currency flows can predict the direction of exchange rate movements better than a random walk (with or without drift). However, as happens with standard macroeconomic models, the model is not able to outperform a random walk in terms of the mean square prediction error criterion.

JEL classification: F31, F32, F34, F37, C22, C53

Keywords: balance of payments flows, international investment position, exchange rate prediction, out-of-sample prediction, random walk

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# 1 Introduction

A major empirical advance in exchange rate economics has recently come about with the emergence in the 1990s of the microstructure approach to exchange rate determination (Lyons 2001, Evans & Lyons 2002, Vitale 2007). The central finding of this approach is that order flow in the foreign exchange market—that is, the difference between seller- and buyer-initiated currency trades—is a good predictor of exchange rate changes. The establishment of a robust empirical relationship is in stark contrast to the macroeconomic literature which over decades has not been able to explain the movements of exchange rates satisfactorily, at least in the short and medium run. Meese & Rogoff (1983*a,b*) showed early after the breakdown of the Bretton Woods system that standard macroeconomic exchange rate models of the time were not able to outperform a naive random walk model of the exchange rate in an out-of-sample forecasting contest. Their findings have recently been confirmed by Cheung et al. (2005) who considered a set of modern exchange rate models and similarly could not find a model that would do significantly better in predicting exchange rates than a random walk (see also Alquist & Chinn 2008).

This paper examines the exchange rate performance of Japan, the country with the largest external surpluses during recent decades. The ultimate goal of this paper is to make useful exchange rate predictions based on data on inflation rates and balance of payments movements. The paper is based on the hypothesis that exchange rate movements are significantly influenced by the relative demands of different currencies in the foreign exchange market and thus ultimately by the balance of payments transactions determining those demands. The basic premise of the paper is thus not very different from the assumption that order flow determines exchange rate movements, as suggested by the microstructure approach. However, it represents a major departure from traditional macroeconomic exchange rate models which have by and large ignored the flow perspective (the only exception being the old-fashioned flow market model of the exchange rate, see Robinson 1937, Machlup 1939, 1940).

Macroeconomic models of exchange rates commonly focus on differences in inflation levels to explain nominal exchange rate movements. The monetary model for instance holds that fluctuations in money supply and output are important determinants of inflation differentials and thus of exchange rate changes. The theory works particularly well in times of high inflation rates or when exchange rate movements over long time spans are considered. However, it has a hard time predicting exchange rates when money supply and output fluctuations are modest, as has ultimately been the case in many countries.

This paper analyses a model of exchange rate pressure, in which exchange rate movements depend on balance of payments flows in addition to inflation differentials. As a

result of the liberalization of international trade and finance, balance of payments flows have grown substantially in magnitude over recent decades. Moreover, there is ample empirical evidence showing that balance of payments flows have a strong impact on currency demands and exchange rates.

To facilitate the prediction of the nominal exchange rate, this paper constructs a state space model in which different exchange rate determinants are modelled individually and are then combined to yield an exchange rate estimate. To test whether the model is able to forecast exchange rates, the model is estimated reiteratively for a rolling subset of observations and its out-of-sample forecasts are compared to those of a naive random walk model. The comparison is carried out on the basis of two different criteria: the mean square prediction error and the direction of change criterion.

The paper is organized as follows. Section 2 proposes a simple theoretical model that links nominal exchange rate movements to price movements as well as to currency flows produced by balance of payments transactions. Section 3 presents time series evidence that demonstrates the strong correlation between the movements of the Japanese balance of payments and exchange rate, respectively. Section 4 develops a multivariate state space model that can be used to predict the movements of the Japanese exchange rate, based on the univariate prediction of each of its determinants. Section 5 presents the exchange rate predictions of the proposed model and compares them to those of a simple random walk model. Section 6 provides conclusions.

## 2 A model of exchange rate prediction

In this paper, the nominal and real exchange rates are defined in indirect terms; that is, the nominal exchange rate is the price of the domestic currency in terms of the foreign currency and the real exchange rate is given by the ratio of the domestic and foreign price levels where both price levels are expressed in terms of the same currency. It follows from the definition of the real exchange rate that the nominal exchange rate can be stated as the ratio of the purchasing power of the domestic currency,  $1/P_t$ , versus that of the foreign currency,  $1/P_t^*$ , multiplied by the real exchange rate,  $Q_t$ . In logarithmic terms, the nominal exchange rate is therefore given by the following:

$$s_t = p_t^* - p_t + q_t. \quad (1)$$

Macroeconomic models of exchange rate determination often take equation (1) as their starting-point. The basic monetary model for example assumes that foreign and domestic price levels are determined by the equilibrium in the money market, with the consequence that prices, and thus the exchange rate, are primarily driven by variables such as foreign

and domestic money supplies and outputs (at least in the long run). The real exchange rate, on the other hand, is given less of a role, and often purchasing power parity is assumed to hold, implying that  $q(t) = 0$ .

However, over the years inflation rates have come down to single-digits levels in most countries. As a consequence, low international inflation differentials seem unable to account for the often large movements of nominal exchange rates. In contrast, cross-border commercial and financial transactions have increased and with them the movements of different currencies between countries. It is thus reasonable to assume that nominal exchange rate changes are influenced by international currency flows (Müller-Plantenberg 2010):

$$\Delta s_t = \bar{\pi}_t - \xi c_t + \Delta \bar{q}_t, \quad (2)$$

where  $\bar{\pi}_t$  is the difference between foreign inflation,  $\pi_t^*$ , and domestic inflation,  $\pi_t$ ,  $c_t$  is the net flow of payments made to foreigners, or minus the country's cash flow (with the usual definition of cash flow as the excess of cash revenues over cash outlays in a given period of time) and  $\Delta \bar{q}_t$  is the change of the real exchange rate that is not explained by the exchange rate pressure originating from international payment flows; finally,  $\xi$  is a positive parameter.

It is important to note that a country's cash flow, or minus the value of  $c_t$ , is equal to that country's current account plus the value of all the non-cash items of its financial account. However, cross-border cash payments are recorded in the "other investment" balance of the financial account, which also includes a number of non-cash items (such as trade credits and bank loans). In other words, the financial account does not distinguish clearly between cash and non-cash transactions. In general, it is therefore impossible to read a country's cash flow directly off the published balance of payments statistics. The solution adopted in this paper is to use the current account as a proxy for payment flows associated with a country's commercial flows (net of adaptive capital flows). In addition, the international investment position is used as a proxy for payment flows associated with the country's foreign debt repayments.

### 3 Time-series evidence from Japan

To motivate the econometric modelling in the later sections of this paper, it is useful to examine the empirical evidence. In fact, a glance at the relevant time series gives interesting hints at which variables have been important determinants of the yen in the past and which have not.

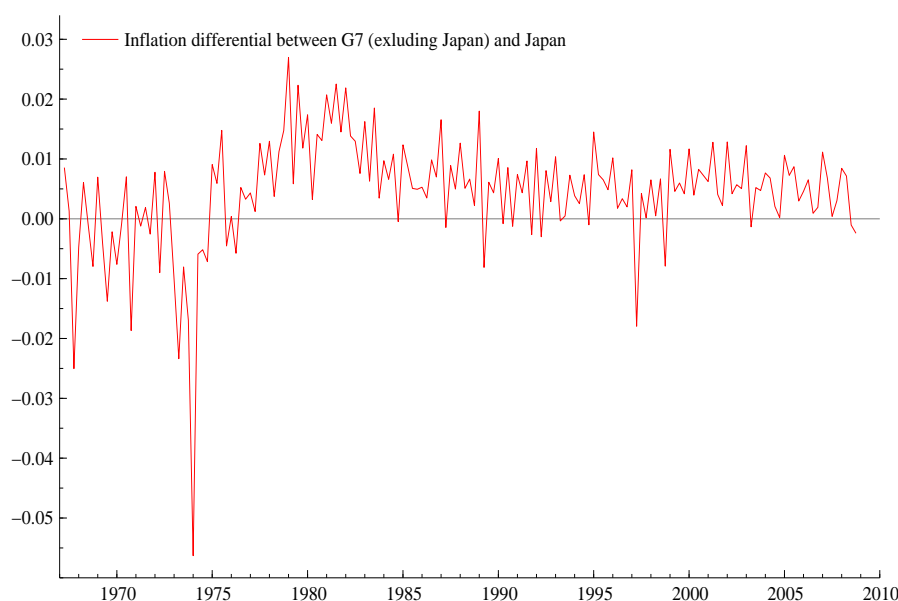


Figure 1: **Inflation differential between G7 and Japan.** Difference between the average quarterly inflation rate in the G7 countries Canada, France, Germany, Italy, the United Kingdom and the United States and the quarterly inflation rate in Japan, period from 1967Q2 to 2008Q4. *Source: Main Economic Indicators (OECD).*

To start with, consider the inflation differential between Japan and the rest of the world. Figure 3 plots the time series of the difference between the average quarterly inflation rate of Canada, France, Germany, Italy, the United Kingdom and the United States on the one hand (that is, the G7 excluding Japan) and the quarterly inflation rate of Japan on the other. The figure shows that Japanese inflation exceeded inflation in other G7 countries up until the first oil crisis in 1973–1974 but has stayed consistently below foreign inflation during the 1980s, 1990s and 2000s. In principle, the data suggest that the yen’s nominal exchange rate should have depreciated during the 1970s and appreciated from the late 1970s onwards. Yet in reality, figure 2 (which plots Japan’s effective nominal exchange rate alongside its current account) shows that there has instead been a consistent tendency of the Japanese exchange rate to appreciate, reaching back at least to the early 1970s. Between 1970 and 1978 for instance the yen’s value did not—as the high inflation in Japan would let one think—fall but rose instead by two thirds.

However, it is not only the trend of Japan’s currency that is difficult to explain on the basis of Japan’s foreign-versus-domestic inflation differential. Besides the yen’s long-term tendency to appreciate, figure 2 shows that the Japanese exchange rate went through five “long swings” during the last four decades, consisting of pronounced appreciations during a number of years and almost as strong depreciations in the following years. Given that the inflation differential has shown very little variability over time, it is difficult to

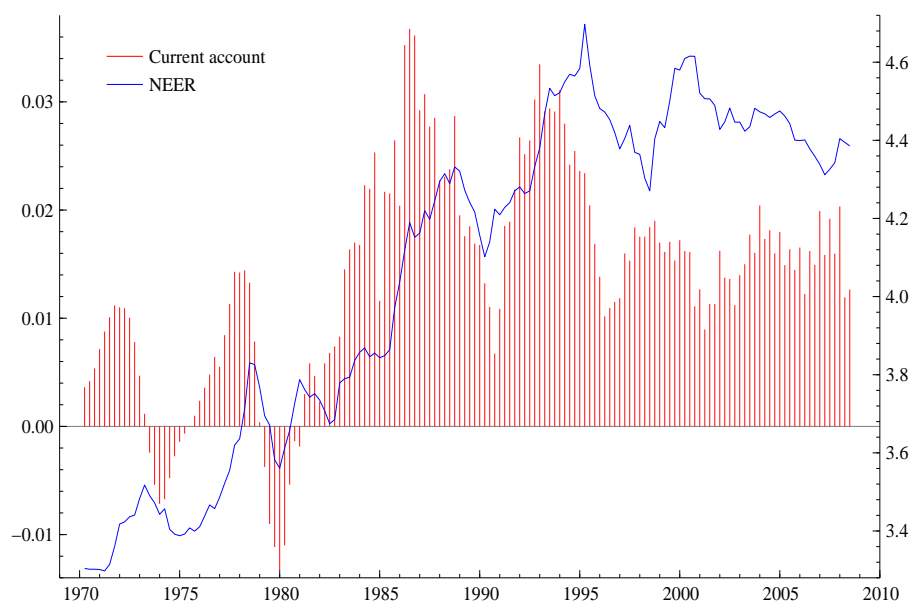


Figure 2: **Japanese current account and exchange rate.** Japanese current account (left scale, as a percentage of world trade) and nominal effective exchange rate (right scale, in logarithms), period from 1970Q2 to 2008Q3. *Source: International Financial Statistics (IMF) and Main Economic Indicators (OECD).*

conceive how monetary conditions could have contributed to this pattern of the yen to repeatedly rise and fall.

Just as the temperature of the water pouring out of a tap is determined not just by the temperatures of the hot and cold waters being mixed but also by the relative strengths of the hot and cold water flows, the nominal exchange rate should not be regarded as being driven solely by the purchasing powers of the currencies being exchanged but also by the demands and supplies of those currencies in the foreign exchange market. The net demand of the currency of a country is determined by the country's cash flow and can, as a first approximation, be measured by the country's current account. In the case of Japan, figure 2 shows that there has indeed been a strong empirical link between the Japanese current account and exchange rate that can be traced from the early 1970s until the early 2000s. Quite strikingly, the years during which the yen appreciated most strongly—that is, the years 1972, 1977, 1986, 1993 and 1999—are precisely the years in which the current account was booming. Neither does it seem to be coincidence that the yen's value fell most sharply during the years when Japanese exports were at their respective lows—namely in 1973–1974, 1979, 1989, 1995–1996 and 2000–2001. (It is true that the empirical relationship holds less well in the very recent years but it should be kept in mind that capital flows from and to Japan have grown enormously in size and volatility since the 1990s.)

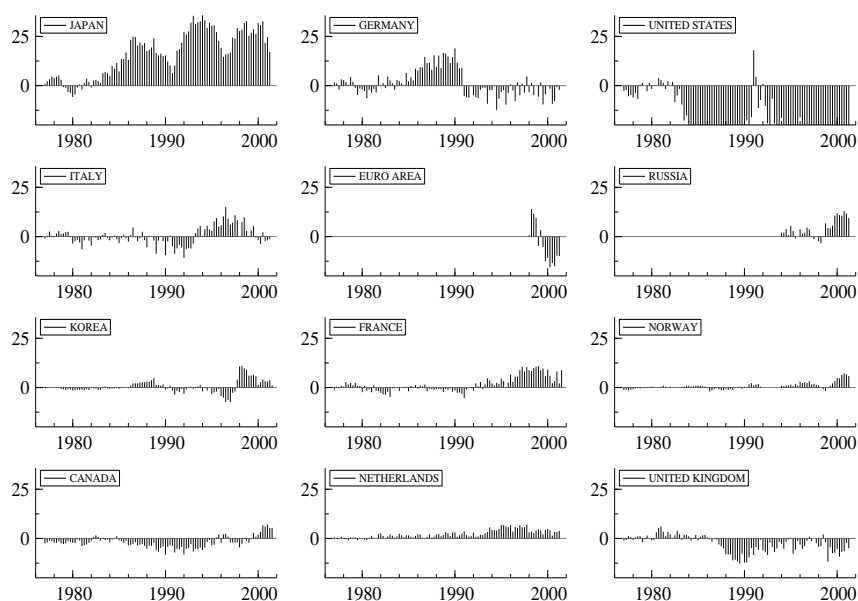


Figure 3: **Large current account surpluses.** Current account balances of countries with large current account surpluses (in billions of US dollar). Countries are selected and ordered according to the highest current account balance they have achieved in any single quarter in the period from 1977Q1 to 2001Q3. *Source: International Financial Statistics (IMF).*

Japan is a particularly good example for the economic relationship described here since it is the country that, as figure 3 demonstrates, until very recently achieved the by far largest current account surpluses in the world. However, the strong sensitivity of the exchange rate to external imbalances can be evidenced for the other countries displayed in figure 3, too. The rising strength of the German mark during the 1980s for example went hand in hand with Germany's remarkable export boom during that decade. Likewise, the US dollar experienced two prolonged depreciations—one starting in 1985 and the other in 2002—that can both be linked to the enormous current account deficits the country saw itself confronted with in the 1980s and early 2000s, respectively. Italy, France and the United Kingdom all saw their worst deficits on current account in the early 1990s, just before being caught up in the EMS crisis of 1992–1993. The euro's fall in the first years after its inauguration in 1999 looks less surprising when one considers the large combined external deficit the euro area entered into during that period. Finally, the currency crisis in Korea in 1997 and that in Russia in 1998 have both been linked by observers to the unusually strong current accounts deficits of those countries in the years preceding their crises.

Nonetheless it would be wrong to assume that Japan's cash flow, and thus its exchange rate, has merely been driven by its balance on current account. After all, international payments to and from Japan are affected not just by the country's commercial but also



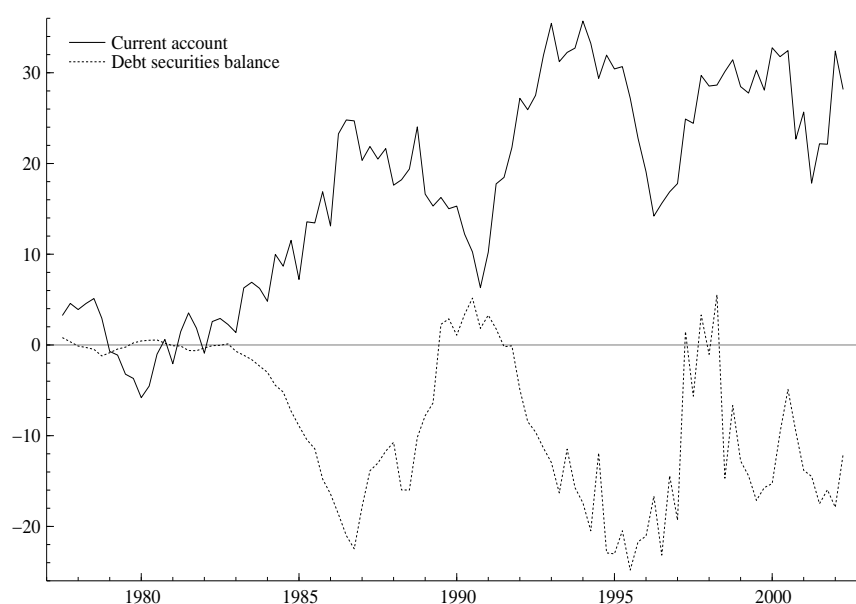


Figure 4: **Current account and lending in Japan.** Japanese current account (left scale) and debt balance (right scale, with reversed sign), in billions of US dollar, period from 1977Q3 to 2002Q2. *Source: International Financial Statistics (IMF).*

by its financial transactions. To understand how the financial account matters for the money flows to and from Japan, it is instructive to examine the time series evidence in figure 4 which plots Japan's current account alongside its net outflow of debt securities (by its value the most significant item in Japan's financial account). Since the opening of its financial account in the mid-1980s, Japan has been investing huge amounts of money in debt securities abroad, for instance by buying large amounts of US Treasuries. Quite remarkably, over many years those investments represented a relatively stable fraction of the country's export revenues. Indeed, the impression one takes away when looking at figure 4 is that Japan's lending to foreigners closely mirrored its export performance (rather than being driven by independent factors).

The finding that in Japan the current account was driving the financial account, rather than vice versa, is important here since it suggests that payment flows associated with current account transactions, though partly offset by financial transactions, were still the main driving force behind the Japanese exchange rate. Moreover, a surplus on current account, even if it is neutralized by debt purchases abroad, still appreciates the domestic currency since foreigners will eventually have to repay their debt. Therefore when capital flows are adaptive, rather than autonomous, the effect of current account movements on the exchange rate persists, except that it may be spread out over a longer horizon (Müller-Plantenberg 2006, 2010). Based on these considerations, this paper will use the Japanese current account as a proxy for the payments flows associated with the country's com-

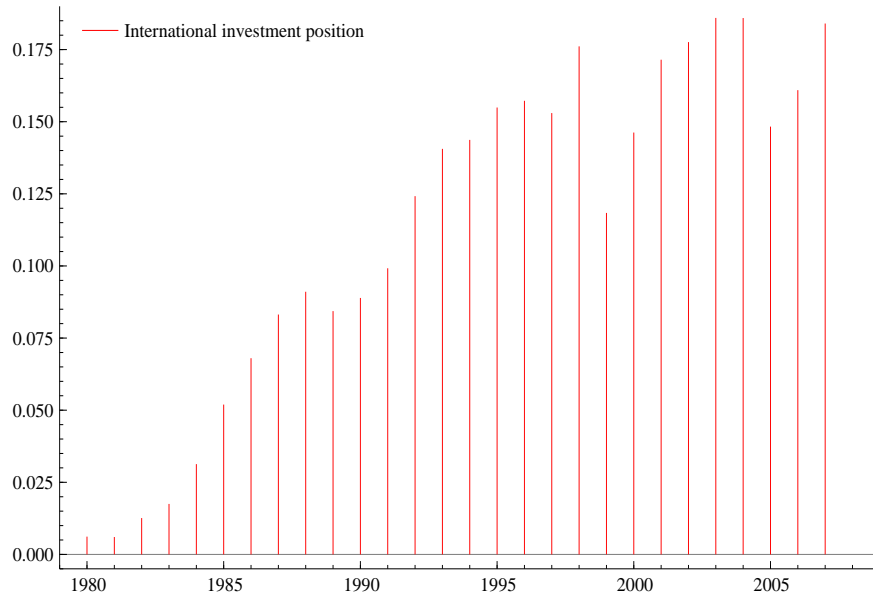


Figure 5: **Japan's international investment position.** Japan's international investment position (as a percentage of world trade), period from 1980 to 2007. *Source: International Financial Statistics (IMF).*

mercial flows (net of adaptive capital flows). In addition, since the net debt held by the Japanese abroad is closely linked to Japan's international investment position, the latter variable, which is displayed in figure 5, is used as an proxy for the net flow of debt repayments Japan receives year after year. Both variables together thus serve to approximate Japan's cash flow vis-à-vis the rest of the world.

## 4 A state space model of exchange rate prediction

### 4.1 Exchange rate determinants

In this paper, the prediction of exchange rates is carried out using a state space model that is based on equation (2). According to equation (2), there are three basic determinants of nominal exchange rate changes: the inflation differential,  $\bar{\pi}_t$ , international cash flow,  $c_t$ , and the real exchange rate movements that are unrelated to international cash flow,  $\Delta\bar{q}_t$ .

Given that international cash flow is not directly observable (see section 2), we use two economic variables to proxy for it, the current account and the international investment position, thus raising the total number of exchange rate determinants to four. As was explained in the previous section, the current account,  $z_t$ , is used because it is a good proxy for international cash flow associated with commercial transactions (net of accommodating capital flows); the international investment position, on the other hand, serves as a

proxy for international cash flow associated with foreign debt repayments which account for an ever larger share of cross-border payments.

To predict future exchange rate movements, it is necessary to predict the movements of the underlying determinants. This is done here by incorporating in the general state space framework individual forecasting models for each of the four exchange rate determinants. More specifically, the most appropriate univariate state space model for each of the exchange rate determinants is chosen from the following set of models: the local level model, the random walk plus drift model, the smooth trend model and the locally linear trend model. Note that these models are all special cases of the locally linear trend (or random walk plus drift plus noise) model, which is defined as follows:

$$\begin{aligned}
\mu_{t+1} &= \mu_t + \beta_t + \eta_t, & \eta_t &\sim \text{NID}(0, \sigma_\eta^2), \\
\beta_{t+1} &= \beta_t + \zeta_t, & \zeta_t &\sim \text{NID}(0, \sigma_\zeta^2), \\
y_t &= \mu_t + \varepsilon_t, & \varepsilon_t &\sim \text{NID}(0, \sigma_\varepsilon^2),
\end{aligned} \tag{3}$$

for  $t = 1, \dots, n$ , where  $\mu_t$  is the unobserved level at time  $t$ ,  $\eta_t$  the level disturbance,  $\beta_t$  the unobserved slope,  $\zeta_t$  the slope disturbance,  $y_t$  the measurement, or observation, of the series in question and  $\varepsilon_t$  the observation disturbance, or irregular component. The local level model is obtained by fixing the slope,  $\beta_t$ , at zero (stochastic level, no slope), the random walk plus drift model by fixing only the slope disturbance,  $\zeta_t$ , at zero (stochastic level and deterministic slope), the smooth trend model by fixing only the level disturbance,  $\eta_t$ , at zero (deterministic level and stochastic slope) and the locally linear trend model by allowing the variances of both the level and slope disturbances,  $\sigma_\eta^2$  and  $\sigma_\zeta^2$ , to be positive (stochastic level and slope).

From this set of state space models, the model with the lowest Akaike information criterion (AIC) is chosen to model each of the exchange rate determinants (see Commandeur & Koopman 2007).

## 4.2 Model of exchange rate prediction

To predict future exchange rates, a multivariate state space model is set up, which combines the nominal exchange rate equation, equation (2), with the individual models of the four exchange rate determinants. The details of the fully specified composite model are shown in section 5, once the appropriate state space models of the exchange rate determinants are identified.

Note that a deliberate choice is made here to model and forecast exchange rate determinants by means of a purely econometric methodology rather than by means of a macroeconomic model. While it may be tempting to model the evolution of exchange rate

determinants theoretically, there are important reasons why a purely empirical approach will produce more reliable forecasts. First, macroeconomic models are never strictly true or correct and thus it may be difficult to ascertain whether a poor predictive performance is due to bad theoretical modelling or to the genuine unpredictability of a time series. More importantly, however, each of the four exchange rate determinants tend to be influenced by a large number of economic factors, whose importance may moreover vary over time.

Take the current account as an example. The factors that push the current account into one direction or the other can be categorized into those that are internal to the economy in question and those that are external. Examples of internal factors are changes in a country's real exchange rate and international competitiveness, movements of domestic output and interest rates driving saving and investment decisions, changes in the prices of the country's exports, fiscal imbalances, structural reforms stimulating foreign investment, liberalization measures removing restrictions on foreign trade and finance, currency crises or natural disasters. Examples of external factors include changes in world output and interest rates, fluctuations of import prices (particularly the price of oil), shifts in the availability of foreign finance, portfolio adjustments by international investors, contagion effects associated with economic crises abroad, and so on. There is reason to believe that time series models, which focus on the dynamic properties of the current account, do a better job in terms of forecasting than highly-parameterized macroeconomic models that generally tend to consider only a small subset of all relevant variables.

Another question is whether the four exchange rate determinants cited above should be modelled and forecast individually or whether some kind of multivariate approach should be used instead. In this paper, an individual modelling approach is chosen for statistical as well as theoretical reasons. From a statistical perspective, individual modelling is preferable as it guarantees a much more parsimonious parameterization. Theoretically, it is argued that the exchange rate fundamentals that are analysed here, say inflation differentials and current account imbalances, carry little economic feedback and can thus be modelled and projected into the future in isolation.

### **4.3 Evaluation of forecasting ability**

The forecasting performance of the composite exchange rate model will be assessed in section 5 by means of a comparison of the model's out-of-sample predictions with those of a random walk with and without drift. Assessed is both the ability of the model to produce a smaller mean square prediction error (MSPE) and its ability to forecast the direction of future exchange rate movements better than a random walk.

Table 1: Selection of appropriate state space model for the inflation differential.

Model	Seasonal dummies	AIC	Final choice
Local level model	no	1.56098	•
Random walk plus drift model	no	1.72181	
Smooth trend model	no	3.3154	
Locally linear trend model	no	3.3232	
Local level model	yes	2.89242	
Random walk plus drift model	yes	2.60562	
Smooth trend model	yes	2.87396	
Locally linear trend model	yes	3.02764	

## 5 Empirical results

This section presents the empirical results. First, the appropriate models for the four exchange rate determinants are identified. Second, the composite state space model that is used to model and forecast the nominal exchange rate is specified. Finally, the forecasting potential of the composite model is compared to that of a random walk.

### 5.1 Exchange rate determinants

#### 5.1.1 Inflation differential

Table 1 presents the goodness of fit of the four alternative models for the inflation differential. To allow for seasonality, the models are analysed both without and with seasonal dummies. Based on the AIC, which measures the tradeoff between the precision and complexity of a given model, the local level model performs best and is thus chosen to represent the inflation differential.

#### 5.1.2 Current account

Table 2 shows the empirical fit of the four alternative models of the current account. Seasonality is again allowed for, raising the number of considered models to eight. It is found that the smooth trend model without seasonal dummies has the lowest AIC and the model is thus chosen to describe the movements of the current account.

#### 5.1.3 International investment position

Table 3 presents the AIC values for the different models used to describe the behaviour of the international investment position. Seasonality is not considered here since the data

Table 2: Selection of appropriate state space model for the current account.

Model	Seasonal dummies	AIC	Final choice
Local level model	no	1.56996	
Random walk plus drift model	no	1.46190	
Smooth trend model	no	1.02949	•
Locally linear trend model	no	3.59052	
Local level model	yes	2.24255	
Random walk plus drift model	yes	1.92835	
Smooth trend model	yes	2.80617	
Locally linear trend model	yes	3.61926	

Table 3: Selection of appropriate state space model for the international investment position.

Model	AIC	Final choice
Local level model	2.67641	
Random walk plus drift model	2.94309	
Smooth trend model	1.82187	•
Locally linear trend model	3.26825	

is only available on an annual basis. It turns out that the smooth trend model is again providing optimal fit in terms of the AIC. This model is thus chosen to model and forecast the international investment position.

#### 5.1.4 Real exchange rate

The fourth of our exchange rate determinants is the change of the real exchange rate that is not explained by the exchange rate pressure originating from international payment flows, see equation (2). The smooth trend model is used to model and forecast this variable. Note that due to the absence of data for this variable, the decision is based on a discretionary choice rather than on a comparison of the AIC values of different models. An argument in favour of the smooth trend model is that it is parsimonious and avoids to over-adjust to temporary deviations of a variable from its trend and thus generally provides good forecasts.

## 5.2 Model of exchange rate prediction

### 5.2.1 The multivariate state space model

Given the sub-models for the four exchange rate determinants, it is now possible to set up a composite state space model to describe the movements of the nominal exchange rate. The state equation of the composite model describes the transition of the state variables from one period to the next:

$$\begin{bmatrix} \mu_{s,t+1} \\ \mu_{\bar{\pi},t+1} \\ \mu_{z,t+1} \\ \beta_{z,t+1} \\ \mu_{b,t+1} \\ \beta_{b,t+1} \\ \mu_{\bar{q},t+1} \\ \beta_{\bar{q},t+1} \end{bmatrix} = \begin{bmatrix} 1 & 1 & \xi & 0 & -\gamma\xi & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \mu_{s,t} \\ \mu_{\bar{\pi},t} \\ \mu_{z,t} \\ \beta_{z,t} \\ \mu_{b,t} \\ \beta_{b,t} \\ \mu_{\bar{q},t} \\ \beta_{\bar{q},t} \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \eta_{\bar{\pi},t} \\ \zeta_{z,t} \\ \zeta_{b,t} \\ \zeta_{\bar{q},t} \end{bmatrix} \quad (4)$$

Note that the first line in equation (4) is equivalent to equation (2), except that the nominal exchange rate is now measured in levels. The measurement equation of the composite model shows how the observed variables are obtained from the state variables:

$$\begin{bmatrix} s_t \\ \bar{\pi}_t \\ z_t \\ b_t \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \mu_{s,t} \\ \mu_{\bar{\pi},t} \\ \mu_{z,t} \\ \beta_{z,t} \\ \mu_{b,t} \\ \beta_{b,t} \\ \mu_{\bar{q},t} \\ \beta_{\bar{q},t} \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{s,t} \\ \varepsilon_{\bar{\pi},t} \\ \varepsilon_{z,t} \\ \varepsilon_{b,t} \end{bmatrix} \quad (5)$$

The multivariate model in equations (4) and (5) is now estimated and used to forecast the exchange rate and its determinants into the future.

### 5.2.2 Estimation using simulated annealing

Due to the possibility of local maxima and of ridges and plateaus in the likelihood surface of the composite model in equations (4) and (5), it is practically impossible to estimate the model's parameters using conventional optimization routines such as the Broyden-Fletcher-Goldfarb-Shanno method, Newton's method or the Nelder-Mead sim-

plex method. However, it was found that optimization is still feasible taking recourse to an optimization procedure known as simulated annealing.

Simulated annealing is a global optimization method that distinguishes between different local optima. Starting from an initial point, the algorithm takes a step and the function is evaluated. When maximizing a function, any uphill step is accepted and the process repeats from this new point. A downhill step may be accepted, enabling the algorithm to escape from local optima. This downhill decision is based on the Metropolis criterion. As the optimization process proceeds, the length of the steps declines and the algorithm closes in on the global optimum. Since the algorithm makes very few assumptions regarding the function to be optimized, it is very robust with respect to non-quadratic and even discontinuous surfaces. The rate of convergence and the degree of robustness can be adjusted by the user.

In this paper, all computations were carried out using Ox version 3.20 (Doornik 2007), and the MaxSA package written by Charles Bos was used to apply simulated annealing to the estimation problem posed by equations (4) and (5). The MaxSA package provides an implementation in Ox of the simulated annealing algorithm for optimizing non-smooth functions with possibly multiple local maxima. The implementation follows exactly the implementation of Goffe et al. (1994), who provide programmes in Fortran and Gauss.

Besides having a much greater potential to identify global, rather than local, optima, the simulated annealing algorithm has the advantage over conventional optimization routines that it avoids the multiple restarts usually required by the latter. The sole drawback is that the algorithm may have to go through a fairly large number of iterations to arrive at the final result. For the problem analysed here, it was found that several hundred thousand iterations were needed to reach the optimum for a given sample. The rolling regression performed in this paper thus required a few million iterations, amounting to a computing time on a modern PC of slightly more than a day (with one hundred out-of-sample observations).

### **5.2.3 Data**

The analysis used quarterly data on the nominal exchange rate, the inflation differential and the current account of Japan and yearly data on its international investment position. The sample of the exchange rate runs from 1966Q1 to 2008Q4, that of the inflation differential from 1967Q2 to 2008Q4, that of the current account from 1977Q1 to 2008Q2 and that of the international investment position from 1980 to 2007. All variables except the inflation differential are taken from the International Financial Statistics of the IMF. The inflation differential was defined as the difference between the average of the inflation rates of the G7 countries excluding Japan (that is, of Canada, France, Germany,



Italy, the United Kingdom and the United States) minus the inflation rate of Japan. The inflation rates were calculated from the consumer price indices of the respective countries which were obtained from the Main Economic Indicators of the OECD (with base year 2000). Note finally that the current account and the international investment position are measured as a percentage of world trade, the latter variable being taken from the OECD's International Trade Statistics.

### **5.3 Evaluation of forecasting ability**

To evaluate the forecast accuracy of the composite state space model in equations (4) and (5), the mean square prediction error (MSPE) of the state space model is compared to that of a random walk model, where the latter model is estimated first without and then with drift. Inference is based on a formal test of the null hypothesis of no difference in prediction accuracy of the two models being compared in each case. The test builds on the Diebold-Mariano statistic (Diebold & Mariano 1995) which is defined as the ratio between the sample mean loss differential and an estimate of its standard error. The Diebold-Mariano statistic is asymptotically distributed as a standard normal. The loss differential is defined as the difference between the squared forecast error of the state space model and that of the random walk (respectively without and with drift). A consistent estimate of the standard deviation can be constructed from a weighted sum of the available sample autocovariances of the loss differential vector.

The MSPE criterion is a standard measure for evaluating the forecasting performance of competing time series models and is essentially based on statistical motivations. A problem with this criterion (and with the related mean absolute error criterion) is that it may not be important from an economic standpoint (Cheung et al. 2005). A measure that is arguably more relevant for profitability and economic purposes and that is moreover related to tests for market timing ability is the direction of change criterion (Boothe & Glassman 1987, Cumby & Modest 1987, Gerlow & Irwin 1991, Leitch & Tanner 1991, 1995). For these reasons, it seems sensible to use this criterion in addition to the MSPE criterion to evaluate the forecasting performance of the exchange rate model analysed here.

The direction of change statistic is computed as the number of correct predictions of the direction of change over the total number of predictions. A value above 50% indicates a better forecasting performance than a naive random walk model (without drift) which predicts the exchange rate has an equal chance to go up or down; conversely a value below 50% indicates a worse forecasting performance. Again, Diebold & Mariano (1995) provide a test statistic for the null of no forecasting performance of the composite state

Table 4: Comparison of the forecasting performance of the composite state space model and the random walk model based on the Diebold-Mariano statistic testing the null hypothesis that the difference of the mean squared errors of the models being compared is zero (p-values in parentheses).

Horizon	Comparison with random walk	
	without drift	with drift
1	0.0014703 (0.00144)	0.0014696 (0.00099)
2	0.010370 (0.00003)	0.010339 (0.00003)
4	0.077567 (0.00000)	0.077162 (0.00000)

space model. The statistic follows a binomial distribution and its studentized version is asymptotically distributed as a standard normal.

### 5.3.1 Mean square prediction error

Table 4 shows the outcome of the comparison of the MSPE of the composite state space model with that of the random walk model. Note that the normalized loss differential is positive, no matter which horizon one looks at (one, two or four quarters) or whether a random walk with or without drift is considered as competing model. This means that the state space model in equations (4) and (5) offers less prediction accuracy in terms of the MSPE than a random walk. Moreover, the p-values displayed in table 4 indicate that the null hypothesis of no difference in the forecasting performance of the competing models can be rejected at the 1% significance level whatever forecasting horizon is considered. The results thus indicate that the random walk model (with or without drift) is superior to the state space model as long as the forecast comparison is based on the MSPE criterion.

### 5.3.2 Direction of change criterion

It is well known that professional forecasts tend to add little to the forecasts generated by the simplest of models (see references in Leitch & Tanner 1991). Using conventional error criteria, economic forecast evaluations usually conclude that the professional forecasts are little better than the no-change or ARIMA type forecast. This observation is not confined to the prediction of exchange rates but applies to economic forecasts in general (Leitch & Tanner 1995). Yet caution should be used when interpreting this finding since the conventional error criteria may not capture why forecasts are made or how they are used. This is why this paper uses forecast directional accuracy as an alternative evaluation criterion. In the author's view, this criterion should indeed be the preferred one when

Table 5: Forecasting performance of the composite state space model and the random walk model with drift in terms of the direction of change criterion (p-values in parentheses).

Horizon	State space model of exchange rate	Random walk model with drift
1	0.55556 (0.11381)	0.51515 (0.34394)
2	0.60606 (0.01326)	0.51515 (0.34394)
4	0.58763 (0.03353)	0.56701 (0.07741)

taking into account that, unlike the MSPE criterion, it is highly correlated with profits in an exchange rate setting.

Table 5 summarizes the forecasting performance of the composite state space model based on the direction of change criterion. Quite strikingly, the model presented in equations (4) and (5) outperforms the naive random walk model (without drift) no matter whether the forecast horizon is one, two or four quarters. This result is significant at the 5% significance level when a medium or long-term forecast horizon is considered (two and four quarters, respectively).

For comparison, table 5 also provides information on the ability of the random walk model with drift to predict the direction of future exchange rate movements correctly. Evidently, the random walk model with drift always predicts exchange rate movements in the same direction. Given that the exchange rate in Japan has shown an overall appreciating trend, it is not surprising that the random walk with drift model anticipates future upward movements of the yen correctly in the majority of periods. However, table 5 also reveals that this model is significantly superior to the no-change model only at a four-quarter forecast horizon and only at the 10% significance level. In sum therefore, the random walk plus drift model is only of limited usefulness when it comes to forecasting the direction of future exchange rate movements and performs significantly worse than the state space model of equations (4) and (5) in this respect.

## 6 Conclusions

The idea that flows of demand and supply in the foreign exchange market determine exchange rates is an old one and is shared by market participants and financial analysts alike. Perhaps surprisingly, the theory has received little attention in macroeconomic exchange rate modelling. Nevertheless, it squares extremely well with the microstructure

approach to exchange rate determination which has recently established a strong empirical link between FX order flow and exchange rate changes.

This paper builds on the flow market model of the exchange rate and assesses the ability of currency flows to predict exchange rate changes. The country under consideration is Japan, the country with the by far largest external surpluses during recent decades. Currency flows are assumed to depend on the level of the current account and on the international investment position, where the latter variable is used as a proxy for international debt repayments. A multivariate state space model is used to predict simultaneously the exchange rate and its determinants. Using rolling regressions and out-of-sample predictions, it is shown that a model featuring currency flows can predict the direction of exchange rate movements better than a random walk (with or without drift). However, as happens with standard macroeconomic models, the model is not able to outperform a random walk in terms of the mean square prediction error criterion.

The partial empirical success of the present study provides incentives for further research. First of all, it would be desirable to apply exchange rate models based on currency flows to a wider set of countries and to test their forecasting performance. In particular, it would be interesting to see whether models like the one studied here are able to predict exchange rate crises. The fact that the majority of those crises are preceded by large and persistent current account deficits and a rapidly increasing external debt indicates that the current account and the international investment position may be useful indicators of exchange market pressure in crisis situations, too.

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