# Forecasting exchange rates of major currencies with long maturity forward rates

Zsolt Darvas[a,*] , Zoltán Schepp[b]

[a]Corvinus University of Budapest, Fővám tér 8, Budapest 1093, Hungary and Argenta Zrt, Budapest, Hungary

[b]University of Pécs, Rákóczi út 80, Pécs 7622, Hungary

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**Abstract**

This paper presents unprecedented forecasting results with a new model. Our error correction model assuming that long-maturity forward rates are stationary outperforms the random walk in out-of-sample forecasting at forecasting horizons mostly above one year, for US dollar exchange rates against nine industrial countries' currencies, using the 1990-2006 period for evaluating out-of-sample forecasts. The improvement in forecast accuracy of our models is economically significant for most of the exchange rate series and statistically significant according to a bootstrap test. Our results are robust to the specification of the error correction model and to the underlying data frequency.

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* Corresponding author. Corvinus University of Budapest, Fővám tér 8, Budapest 1093, Hungary. Tel: +36-1-482-5279; fax: +36-1-482-5029; E-mail address: zsolt.darvas@uni-corvinus.hu (Z. Darvas).

## 1. Introduction

Quarter of a century ago Meese and Rogoff (1983) put a hallmark on exchange rate forecasting, which was followed by a widespread skepticism about the forecasting ability of standard fundamental based exchange rate models. By conducting an extensive review of the literature Sarno and Taylor (2002) made the observation that "*a model that forecasts well for one exchange rate and time period will tend to perform badly when applied to another exchange rate and/or time period*" (p. 137), which could well describe the view of many authors in the literature. In a recent paper studying many exchange rate models Cheung, Chinn and Pascual (2005) found a similar conclusion. Engel and West (2005) offered an explanation: the exchange rate could be arbitrary close to a random walk if the fundamentals have a unit root and the factor for discounting future fundamentals is close to one. These findings render any attempt to forecast exchange rates dubious.

There are also some papers challenging the skeptic view. For example, Clarida and Taylor (1997) set out an 'agnostic' theoretical framework for explaining why spot and short maturity forward rates should be cointegrated even when foreign exchange rate markets are not efficient and put forward a simple test for the framework based on the cointegrating space. Their forecasting model beat the random walk for US dollar rates of the German mark, Japanese yen and British pound using the July 1990–December 1993 period for evaluating the out-of-sample forecasts. Clarida et al (2003) replicated these findings –among others– for the 1996–1998 forecast evaluation period.

Our paper also claims to beat the random walk. The model we use is related to that of Clarida and Taylor (1997) but is based on a new concept that has not been used before: it relies on the empirical finding that long maturity forward rates of major currencies are stationary (Darvas and Schepp, 2007). The forecasting result we present is also without precedent. Using a 17-year long period for evaluating the out-of-sample forecasts (1990-2006) our model outperforms the random walk in out-of-sample forecasting at forecasting horizons mostly above one year, for US dollar exchange rates against currencies of the widest available group of industrial countries: Germany, United Kingdom, Japan, Canada, Switzerland, Australia, New Zealand, Norway and Sweden. These nine US dollar exchange rates constitute approximately 75 percent of world foreign exchange rate market turnover according to BIS (2005, Table B4, p. 10). The improvement in forecast accuracy is statistically significant[1] and also economically significant for most of the exchange rate series studied. For example, in the case of the German mark/US dollar rate, which has always been the most traded exchange rate, the RMSPE (root mean squared prediction error) point estimates are 30-40 percent smaller at the three-year and four-year forecasting horizons than that of the random walk. Our results are robust to the three possible model specifications we adopt and to whether monthly or weekly data is used. Furthermore, for some of the exchange rate series we also found significant within year predictability.[2]

To our knowledge, none of the few papers reporting exchange rate predictability used such a long period for evaluating out-of-sample forecasts (other papers generally used evaluation periods between three and ten years), none of them studied nine exchange rate series (the number usually varied between two and five), and they generally did not receive so universal results across their fewer exchange rate series studied and shorter evaluation periods as we found for the nine exchange rate series and long evaluation period. Furthermore, replication of our results is very easy. The number of parameters to be estimated of our three possible model specifications varies between two and eight and no specification search is needed. In contrast,

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[1] Following Mark (1995), Kilian (1999), McCracken and Sapp (2005), and the findings and suggestion of Clark and West (2006, 2007), we evaluated our forecast with a bootstrap test.

[2] Our forecasting results are not in conflict with the findings of Engel and West (2005), because our key driving variable, the long maturity forward rate, is stationary.

many models of the literature require the estimation of a large number of parameters and/or a time-consuming process of model selection.[3]

Our models are rather simple (log)linear models. Clarida et al (2003), for example, was among the first to show the superiority of non-linear models over some linear models (including the simple martingale difference hypothesis) in out-of-sample forecasting. Kilian and Taylor (2003) also adopt a non-linear specification but an in-sample forecast test. They argue that the power of statistical tests of the random walk model will be especially low for recursive out-of-sample forecasts tests when the true process follows a smooth transition autoregression (Teräsvirta, 1994). However, our recursive out-of-sample forecasting results with linear models are so overwhelming in out-of-sample tests that we do not search for possible non-linear alternatives, nor we perform an in-sample test.

Regarding the use of long maturity bond yields, our work is related to papers of MacDonald and Marsh (1997) and Boudoukh et al (2005), though both the motivation and the models used are rather different from those of our paper, and the empirical findings also differ. MacDonald and Marsh (1997), who studied US dollar rates of the German mark, British pound, and the Japanese yen, incorporated long maturity bond yields into the purchasing power parity relationship and estimated a simultaneous vector error correction model. They found that their dynamic out-of-sample forecasts from three months to one year ahead outperformed the random walk using the October 1989 – December 1992 forecast evaluation period. Boudoukh et al (2005), who studied US dollar rates of the German mark and British pound, related forward interest rate differentials to future changes in the exchange

[3] We note that the critique formulated for favorable forecasting results based on the monetary model of Mark (1995) by Faust et al (2003), that is, results depend on the data vintage used to construct the explanatory variables, does not apply to our model. The only explanatory variable we use is the forward exchange rate calculated from the spot exchange rate and the interest rate, which are available in real time and not revised.

rate with the coefficient imposed to unity (as implied by the uncovered interest rate parity hypothesis and the expectation hypothesis of the term structure). They found that the forward interest rate differentials predicted future annual exchange rate movements better than spot interest rate differentials[4] and also slightly outperformed the random walk in the 1980–2003 period, although this latter result was generally not significant.

The rest of the paper is organized as follows. Section 2 describes our models and the bootstrap test we use. Section 3 introduces the data (more details are given in the appendix) and performs some preliminary data analysis. Section 4 presents our out-of-sample forecasting results. Section 5 provides some thoughts on the interpretation of our findings. Finally, Section 6 presents a brief summary.

## 2. Error correction models and the bootstrap test

The main benchmark in exchange rate forecasting exercises is the driftless random walk (Frankel and Rose, 2001), which we also use as the benchmark to compare the models. The driftless random walk benchmark is nested in all models; consequently, model comparisons should properly handle this property as we shall discuss.

### *2.1. Models*

Our emphasis will be on our new models assuming that long maturity forward rates are stationary, but we also compare the results of the driftless random walk to the drifting random walk[5] (following the suggestions of Engel, 1994 and Kilian, 1999), the simple estimated autoregression and the forward rate itself. We use the simple autoregression as an alternative

[4] For example, their result suggests that the change in the exchange rate from today to one year ahead could be better forecasted using past forward interest rate differentials (i.e. the one-year forward interest rate differential quoted two years before for two years ahead) than spot or forward one-year interest rate differentials quoted today.

[5] Obviously, the drift parameter should be estimated the same recursive way as the parameters of other models.

model, because our models assume a stationary autoregressive representation for the long maturity forward rate and hence it could be intriguing to see the outcome of a simple estimated autoregression for the spot exchange rate. We also use the forward rate itself as a predictor, because our models use the long maturity forward rate as the driving variable, and the hypothesis of long horizon uncovered interest rate parity (UIP) received more support recently (Chinn and Meredith, 2005).[6] We do not estimate various models incorporating other variables than the spot and forward exchange rates in order to conserve space on the one hand, and because Cheung, Chinn and Pascual (2005) have recently shown that results for many of these models are not robust on the other.

On the basis of covered interest rate parity forward exchange rates can be calculated from the spot rate and the interest rate differential, which is a common practice in the literature. Hence, the forward exchange rates used in this paper are calculated as

(1) $$f_t^{(h)} = s_t + h \cdot \tilde{i}_t^{(h)} ,$$

where $f_t^{(h)}$ is the logarithm of the *h*-year ahead forward rate, $s_t$ is the logarithm of the spot exchange rate, and $\tilde{i}_t^{(h)}$ is the logarithmic interest rate differential, that is, $\tilde{i}_t^{(h)} \equiv \ln\left((1+i_t^{(h)})/(1+i_t^{*(h)})\right)$, where $i_t^{(h)}$ and $i_t^{*(h)}$ are the domestic and foreign annualized *h*-year zero-coupon yields.

Using eight unit root tests and one stationarity test and almost three decades of monthly

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[6] We highlight that our forecasts are based on error correction models assuming that the long maturity forward exchange rate is stationary and our forecasts are not necessarily – in practice never – equal to the forward rate itself. Consequently, our forecasts are different from the prediction of uncovered interest rate parity. The models of Clarida and Taylor (1997) and Clarida et al (2003) also share this property. We also note that long horizon uncovered interest rate parity was supported for rather long maturities (e.g. 10-year), but tests at these maturities are seriously burdened with the problems associated with overlapping observations. In contrast, our unit root and stationarity tests for any maturity forward rates (see later) are not performed on overlapping observations.

data for the currencies between the US, Germany, UK and Switzerland, Darvas and Schepp (2007) found that, while spot exchange rates are non-stationary, long maturity forward rates are stationary. They also found that while short maturity interest rate differentials are stationary, long maturity interest rate differentials are non-stationary, which implies that the spot exchange rate and the long maturity interest rate differentials are cointegrated with the known cointegrating vector [1, *h*]. We replicate some of the above mentioned tests for the wider set of exchange rates used in this paper in the next section.

Cointegration has the implication that at least one of two variables in the cointegration vector (the spot exchange rate and/or the long maturity interest rate differential) could be forecasted using the previous period long maturity forward rate.[7] In this paper we have found (see Section 3) that the spot exchange rate is not weakly exogenous for the cointegration vector embodied in the long maturity forward rate. This means that a model assuming a stationary long maturity forward rate should be able to forecast the spot exchange rate. As a by-product, we found that long maturity interest rate differentials are weakly exogenous.

We use three possible error correction specifications assuming that long maturity forward rates are stationary, and three long maturity forward rates (3, 5, and 10 years of maturity) alternatively. Consequently, we have nine models altogether assuming stationarity for each exchange rate. Our goal is the study of the general features of the nine models across the nine exchange rate series studied, and we do not aim to determine a single 'optimal' model, nor do

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[7] The key conceptual difference between the models of Clarida and Taylor (1997) and ours is that their model is built on the result that the spot exchange rate and short maturity forward exchange rates are cointegrated (and consequently short maturity interest rate differentials are stationary), while our model builds on the result that the spot exchange rate and the long maturity interest rate differential are cointegrated (and consequently the long maturity forward exchange rate is stationary). Their empirical model is a VECM with 50 parameters to be estimated, while we adopt three possible error-correction representations including 2 to 8 estimated parameters.

we wish to combine the forecasts of different models.

The simplest possible error correction model could be written as

$$(2) \qquad \Delta s_t = \delta_0 + \delta_1 \cdot f_{t-1}^{(h)} + \varepsilon_t ,$$

where Δ is the difference operator, $\Delta s_t \equiv s_t - s_{t-1}$, and we would expect a negative $\delta$ parameter due to equation (1) for the error correction effect to be present. Equation (2) can only be used for one-period ahead forecasting; longer period forecasting could be done by estimating long-horizon regressions with all the associated problems (see, e.g. Berkowitz and Giorgianni, 2001, and Darvas, 2008),

$$(2') \qquad \Delta_p s_t = \delta_0 + \delta_p \cdot f_{t-p}^{(h)} + \varepsilon_t , \qquad p = 1,...,P ,$$

where $\Delta_p s_t \equiv s_t - s_{t-p}$, and $P$ denotes the longest forecast horizon; for example, $P$ = 60 when forecasting 5 years ahead with monthly data. When forecasting for a given horizon ($p$), only two parameters are to be estimated and no specification search is needed. We will refer to this equation in the tables as “EQ F…Y”, and substitute for the dots the maturity – in years – of the forward rate used.

In addition to econometric issues related to estimation and inference on overlapping samples, equation (2’) has at least two weaknesses regarding the use of the information set. First, it does not take into account that the long maturity forward rate is also expected to converge to its stationary mean in the forecast period. Second, when forming forecasts from period $t$ to period $t$+$q$, the estimation sample takes into account information contained in the long maturity forward rate only up to period $t$-$q$. Therefore, we also study a second, rather simple, two-equation model:

$$(3) \qquad \begin{aligned} \Delta s_t &= \delta_0 + \delta_1 \cdot f_{t-1}^{(h)} + \varepsilon_{1,t} \\ f_t^{(h)} &= \phi_0 + \phi_1 \cdot f_{t-1}^{(h)} + \varepsilon_{2,t} \end{aligned} .$$

Note that model in (3) is not estimated on overlapping samples, avoids the two information loss drawbacks described in the previous paragraph, and multi-step out-of-sample forecasts are calculated with a dynamic iteration of forecasts. Note also that only four parameters are to be estimated and no specification search is needed. We will refer to this model in the tables as "MOD S-F…Y", and substitute for the dots the maturity – in years – of the forward rate used.

The third model we study is the most general model, a VECM (vector error correction model) of the spot exchange rate and the interest rate differential,

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\begin{aligned}
\Delta s_t &= \xi_1 + \sum_{j=1}^{k}\left(\xi_{2,j}\Delta s_{t-j} + \xi_{3,j}\Delta \tilde{i}_{t-j}^{(h)}\right) + \xi_4 f_{t-1}^{(h)} + \varepsilon_{1,t} \\
\Delta \tilde{i}_t^{(h)} &= \xi_5 + \sum_{j=1}^{k}\left(\xi_{6,j}\Delta s_{t-j} + \xi_{7,j}\Delta \tilde{i}_{t-j}^{(h)}\right) + \xi_8 f_{t-1}^{(h)} + \varepsilon_{2,t}
\end{aligned}
\quad . \tag{4}
$$

Obviously, samples are not overlapping when estimating this model, the information loss problem mentioned above is avoided, and multi-step out-of-sample forecasts are calculated with a dynamic iteration of forecasts (using the identity in equation (1)). When $k$=1, only eight parameters are to be estimated. Selection of $k$ could involve a simple specification search, although the forecasts are excellent when $k$=1 using our monthly dataset. We will refer to this model in the tables as "VECM S-I…Y", and substitute for the dots the maturity – in years – of the interest rate differential used.

*2.2. A bootstrap test for predictive accuracy*

Since we compare nested models standard asymptotic tests do not apply for testing the null hypothesis of equal forecast accuracy. Clark and West (2006, 2007) showed that under the null hypothesis that the data generating process is the random walk (or any parsimonious model), estimation of parameters of a larger model introduces noise into the forecasting process that will, in finite samples, inflate its RMSPE. Clark and West (2006, 2007) also suggest an adjustment of the mean squared prediction error statistics, which leads to approximately normal tests. However, their test is valid for models estimated in direct form, i.e. in the form of long-horizon regressions, and not when multi-period forecasts are iterated one-step ahead forecasts as in our second and third model specifications. They find, on the other hand, that a bootstrap test has favorable properties both in terms of size and power. Since a bootstrap procedure can be applied in our setup as well, we adopt a non-parametric bootstrap test similarly to related papers on exchange rate forecasting of Mark (1995), Kilian (1999) and McCracken and Sapp (2005). That is, we impose the null hypothesis of no predictability in the bootstrap data generating process (DGP), estimate, and store the estimated residuals; sample with replacement the residuals for a sample of 500 plus the actual length of the time series studied; create bootstrap time series for all variables in the model recursively and then discard the first 500 observations; estimate and forecast using the bootstrapped sample the same way as for the true data set and calculate forecast statistics. We repeated these steps 1000 times to get an empirical bootstrapped distribution of the test statistics and calculated the p-value as the lower tail of this distribution from the test statistics received for the true data.

For models (2'), (3) and (4) the bootstrap DGP we use is the restricted version of model (3) under the null hypothesis of no-predictability:[8]

(5) $$\begin{aligned} \Delta s_t &= \varepsilon_{1,t} \\ f_t^{(h)} &= \phi_0 + \phi_1 \cdot f_{t-1}^{(h)} + \varepsilon_{2,t} \end{aligned}.$$

Restriction under $H_0$ of model (2') would not provide bootstrapped series for $f_t^{(h)}$.

Restriction under $H_0$ of model (4) is:

(6) $$\begin{aligned} \Delta s_t &= \varepsilon_{1,t} \\ \Delta \widetilde{i}_t^{(h)} &= \xi_5 + \sum_{j=1}^{k} \left( \xi_{6,j} \Delta s_{t-j} + \xi_{7,j} \Delta \widetilde{i}_{t-j}^{(h)} \right) + \xi_8 f_{t-1}^{(h)} + \varepsilon_{2,t} \end{aligned}.$$

We note that when studying the monetary model, Kilian (1999) suggested incorporating

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[8] Whether there is a drift in the random walk is just a matter of notation: when there is no separate drift term, then the mean of the residuals will not necessarily be zero.

the assumption of cointegration into the bootstrap DGP. His suggestion could be translated to our model as well and would imply that instead of model (5), model (6) should be used. However, we found that the interest rate differential is weakly exogenous and the point estimate of its error correction coefficient were even positive[9] for most of the exchange rates, although non-significant. Still, the positive point estimate led to an explosive process. Consequently, model (6) could not be used in our case. On the other hand, Kilian (1999) also showed that the corresponding bootstrap DGPs of the monetary models are asymptotically equivalent, which implies that our models (5) and (6) share this property.

For the estimated autoregressive model and the random walk with drift (whose drift parameter should be estimated the same recursive way as the parameters of other models), the bootstrap DGP is the driftless random walk.

## 3. Data and some empirical preliminaries

### *3.1. Data*

We aim to test the forecasting performance of the models for the US dollar against the currencies of the widest available group of industrial countries. Consequently, our sample includes spot and forward exchange rates for nine currencies against the US dollar: German mark, British pound, Japanese yen, Swiss franc, Canadian dollar, Australian dollar, New Zealand dollar, Norwegian krone, Swedish krona.[10] The sample period covers end of month data between January 1979 and December 2006, although a few interest rate series are

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[9] Since the interest rate differential enters the cointegrating vector described in equation (1) with a positive coefficient, we expect a negative error correction parameter.

[10] Since 1999, German mark exchange rates were calculated from euro rates using the fixed conversion rate. For including the rest of the presently EMU-countries we would not have enough observation to distinguish them from Germany. The non-EMU member Denmark has a fixed exchange rate system linked to the mark/euro which would likely lead to similar results as for the German mark, while for Iceland long maturity interest rates are not available for a sufficiently long period.

available only since the mid-eighties or as a monthly average; see details in the Appendix. Hence, our sample includes countries with floating exchange rates against the dollar in the whole period (Germany, UK, Japan, Switzerland, Canada), but also countries that moved from a peg to floating regime (Australia and New Zealand in the mid eighties, Norway and Sweden in the early nineties).

Forward exchange rates were calculated using interest rates and the identity in equation (1) and all data were converted to logarithmic form. 1, 3, 6 and 12 months maturity forward rates (which are used only for assessing the direct forecasting performance of the forward rate itself) were calculated using interbank interest rates. 3, 5 and 10 years maturity[11] forward rates were calculated using constant maturity zero coupon yields for US, Germany, UK, Switzerland and Canada, while only yield to maturity was available for the other countries. In principle, constant maturity yields should be used for calculating forward rates and hence forward rates for about half of our sample are incorrect if constant maturity yields were not equal to yield to maturity. However, our goal is forecasting and we will see in the next section that our models using these somewhat imprecisely calculated long maturity forward exchange rates also significantly outperform the random walk.

We use the 1979-1989 sample to form an initial estimation, adopt a recursive estimation scheme[12] and use the 1990-2006 period for out-of-sample forecasting. That is, we first estimate the models for 1979M1-1989M12 and calculate out-of-sample forecasts 5 years ahead (for 1990M1-1994M12). Next, we estimate the models for 1979M1-1990M1 and

[11] For New Zealand, the 3-year maturity interest rate is not available, but the 2-year one is, therefore, we used models including the 2-year maturity forward rate instead.

[12] We also tried a rolling estimation scheme but forecasting results were somewhat weaker. We attribute the stronger forecasting results of the recursive scheme to the improved estimation accuracy of the cointegration relationship in the longer sample periods used for estimation compared to the rolling scheme.

calculate out-of-sample forecasts for 1990M2-1995M1, and so on. Note that our longest, 5-year horizon forecasts are evaluated on less than 4 independent (non-overlapping) forecasting rounds.

*3.2. Unit root tests*

*** Table 1 ***

As a preliminary check, we run eight unit root tests and one stationarity test for the spot and forward exchange rates.[13] To conserve space, Table 1 reports results only for the spot rate and the 10-year maturity forward rate. Test statistics for forward rates between 1-month and 5-year maturities were between those of the spot and 10-year maturity forward rate, with short maturity forward rates having test statistics closer to that of the spot rate, and longer maturity forward rates having test statistics closer to that of the 10-year maturity forward rate. For four exchange rate series, namely the German mark, the British pound, the Swiss franc, and the Canadian dollar we cannot reject unit root and can reject stationarity in spot exchange rates and short maturity forward rates, while we can reject unit root and cannot reject stationarity in long maturity forward rates. For the other five currencies these conclusions cannot be drawn and the spot rate together with all forward rates seem to be non-stationary.

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[13] In addition to standard tests for unit root of Dickey and Fuller (1979) and Phillips and Perron (1988) we use six other unit root tests. Elliott et al. (1996) proposed a family of test statistics that are invariant to the trend parameters and suggested two particular tests: a modified version of the Dickey-Fuller t-test, which is essentially based on a local GLS detrending, and another feasible point optimal test, both having substantially improved power when an unknown mean or trend is present. Ng and Perron (2001) exploited the findings of Elliott et al. (1996) and applied the idea of GLS detrending to modify existing tests and showed that non-negligible size and power gains can be made when used in conjunction with an autoregressive spectral density estimator at frequency zero. They suggested modifications of three test statistics studied by Perron and Ng (1996) and the feasible point optimal test statistics of Elliott et al. (1996). Furthermore, we also use the test developed by Kwiatkowski et al. (1992) to test the null hypothesis of stationarity against the unit root alternative.

Literally, we should not fit error correction models for the latter five exchange rates. We note however, that, first, in finite samples it is always difficult to distinguish between stationary and non-stationary processes. Stationary and non-stationary processes definitely have different properties asymptotically, but we are always interested in a finite sample analysis. Second, also for these five exchange rates there is a tendency that test statistics decline with the horizon implying that spot rates are more likely to follow unit root processes than long maturity forward rates. Third, the finding that long maturity forward rates are stationary by all nine tests for the four major exchange rates gives us enough confidence for a forecasting exercise. Our goal is out-of-sample forecasting in a reasonably long time span (1990-2006), and we regard it worthwhile to see how models based on the assumption that long maturity forward rates are stationary perform for all nine exchange rates, and not just for those four for which the tests do support this assumption.

*3.3. The one-period regression*

Stationarity of long maturity forward rates implies that the I(1) spot exchange rate and the I(1) long maturity interest rate differential are cointegrated with the known cointegrating vector [1, $h$] according to the identity in equation (1). Cointegration implies that at least of one the two times series is not weakly exogenous. Consequently, we estimated equation (2), that is, the regression of the one period change in the exchange rate on the previous period forward rate. This equation is important from the point of view of forecasting. Berkowitz and Giorgianni (2001) show that when the slope coefficient from the one period regression is zero, then the slope coefficient of the long-horizon regressions is also zero, and hence such a long horizon regression is not suitable for long horizon forecasting. They show that in least squares estimation of long-horizon regressions the slope coefficient is biased away from zero leading to a bias in the *t*-statistics as well. Consequently, they suggest a pivotal role for the one-period regression.

*** Table 2 ***

In our model, however, the one-period slope coefficients are also significantly negative when using long maturity forward rates, as can be seen from the second to the fourth blocks of Table 2. In contrast, when using the three-month maturity forward rate (see the first block of Table 2), the slope coefficient tends to be non-significant, smaller in absolute terms, and these regressions have smaller $R^2$. For comparison, we also estimated this simple error correction model for the interest rate differential. We found that the estimated error correction parameter is positive in most cases, and when negative, it has a small absolute value and never significant.[14] These results indicate that the spot exchange rate is not weakly exogenous for the cointegrating vector (the long maturity forward rate), while the long maturity interest rate differential is.

**4. Out-of-sample forecasting**

*** Table 3 ***

For better readability of our key results, we present the RMSPE of our models as percent of the RMSPE of the driftless random walk for forecasting horizons between one month and five years in Table 3. The table indicates that models assuming that long maturity forward rates are stationary outperform the random walk at longer forecasting horizons, mostly in horizons from one to five years. In contrast, the forward rate itself and the random walk with drift do not outperform the driftless random walk for any of the exchange rate series, and the simple estimated autoregression provides results comparable to our models only in two of the nine exchange rate series (British pound and New Zealand dollar). Let us discuss the results in more details according to the maturity of the forward rate used.

[14] Detailed results are available from the authors upon request.

Models using the 3-year maturity forward rates significantly outperform the random walk in out-of-sample forecasting for eight of the nine exchange rate series studied, in most cases at horizons from one to five years. Rejection of equal predictive accuracy with the random walk is especially sound for the Swiss franc and Norwegian krone (1 percent), and for the German mark, British pound and Swedish krona (between 1 and 5 percent). For the Japanese yen, Australian dollar and New Zealand dollar rejection is made between 5 and 10 percent. For the ninth exchange rate series, the Canadian dollar, results are significant only between 12 and 18 percent levels at the 2 and 3-year forecasting horizons, which are also reasonably favorable results. The point estimate of the improvement of forecast accuracy is also impressive, exceeding 40 percent for the Swiss franc and even 50 percent for the Norwegian krone.

Models using the 5-year maturity forward rates significantly outperform the random walk in out-of-sample forecasting for seven of the nine exchange rate series studied. The marginal significance rates are similar to the ones mentioned for the models including the 3-year maturity forward rate, with perhaps the exception of German mark, which is now significant at 1 percent, and the Swiss franc, which is significant only at 5 percent. The improvement in forecast accuracy is economically significant again for the German mark, the Swiss franc and the Norwegian krone: the RMSPE point estimates are 30-40 percent smaller at the three and four-year forecasting horizons than that of the random walk. The rest of the significant predictions (British pound, Japanese yen, Australian dollar, Swedish krona) indicate improvements between 10 and 30 percent at longer horizons. For the eights and the ninth exchange rate series, the Canadian dollar and the New Zealand dollar, the marginal significance levels are around 8-22 percent and 17-22 percent, respectively, and the RMSPE point estimates are 2 to 10 percent below the estimates of the random walk.

Models using the 10-year maturity forward rates significantly outperform the random walk in out-of-sample forecasting only for three exchange rate series: German mark, Norwegian krone, Swedish krona. The marginal significance levels are around 1 percent for the German mark and in the range of 1 to 6 percent for the two Scandinavian currencies. The improvement in forecast accuracy is economically significant again for the German mark: the RMSPE point estimates are 30-35 percent smaller at the three-year forecasting horizon than that of the random walk, while for the two Scandinavian currencies the improvement is around 10-15 percent. For most of the other six exchange rate series the point estimate of RMSPE is somewhat smaller than that of the random walk, but the marginal significance levels are above 10 percent.

We also note that for the Australian dollar all nine models, and for the British pound the six models including 3 and 5-year forward rates, indicate significant improvement in predictive accuracy within a year as well. Some models for six out of the seven other exchange rates series also indicate within year predictability.[15]

Our empirical results also indicate that the three possible model specifications incorporating the assumption that long maturity forward rates are stationary lead to reasonably similar out-of-sample results. That is, the simply parameterized long-horizon regression in equation (2'), despite to its unfavorable properties reported in the literature, forecasts broadly in line with the other two error corrections models, which does not suffer from problems related to overlapping observations.

Although we do not aim to determine the optimal forecasting horizon of our models, the results indicate that it probably lies between two and four years. In most cases the 5-year ahead forecasts are somewhat worse than the 4-year ahead forecast compared to the driftless random walk (although in most cases it still outperforms the driftless random walk at this

[15] Furthermore, for seven exchange rate series there exists at least one model having a significant one-period ahead forecast test statistics which is larger than 100. Clark and West (2006) found the same phenomenon for the Canadian dollar.

horizon as well).

*** Figures 1 and 2 ***

As graphical illustrations, Figure 1 shows actual exchange rate movements (solid) and out-of-sample forecasts from one month to five years ahead (dashed) for the nine exchange rate series studied. For better readability of the panels, forecasts made only in June and in December of each year are shown. The figure indicates that the models were capable of indicating turning points rather well, although many of the large excessive swings were forecasted to turn around earlier. For a first sight, some of our forecasts could resemble to that of a stationary autoregression of the spot exchange rate, but recall from Table 3 that the estimated autoregression delivered much worse forecast statistics than our models with the exception of the pound and New Zealand dollar. The nine panels of Figure 2 show in a more telling way the forecasting capabilities of the models. Similar figures by Mark (1995, p. 211) showed the *fit* and the actual changes in the exchange rate. Our Figure 2 shows *out-of-sample forecasts* and the actual changes for six forecasting horizons. Panels of Figure 2 clearly indicate the improvement of the forecasts at longer forecasting horizons.

Finally, we note that the predictive performance of the forward rate seems to improve at long horizons; with the only exception of the yen. For example, in all cases (except the yen) the relative RMSPE at the 5-year horizon is smaller than at the 4-year horizon, and in many cases the relative RMSPE at the 5-year horizon is even the smallest among all horizons studied. This finding is consistent with long horizon uncovered interest rate parity results of Chinn and Meredith (2005).

Up to now we have shown forecasts using monthly data. However, some papers, e.g. Clarida and Taylor (1997) use weekly data for the analysis. We selected monthly data because the time series for long maturity forward rates are generally available for longer periods for the monthly than for the weekly frequency. However, British and US yields are available at both frequencies since 1979, therefore we checked the sensitivity of the out-of-sample forecasts to the frequency of the data. It turned out that the differences between the relative RMSPE of monthly and weekly forecasts were rather small at all forecasting horizons, from which we concluded that our results are not sensitive to the frequency of the data.[16]

**5. Interpretation**

Thus far we have shown a statistical model capable of forecasting US dollar based nominal exchange rates. A better understanding of the economic mechanisms leading to our results could be the scope of further research, though we would suggest some factors that could play a role. Part of the explanations could be related to the excess volatility of spot exchange rates. For example, Flood and Rose (1999) documented that the volatility of the exchange rate far exceeds the volatility of any standard measure of macroeconomic fundamentals. A second building block could be related to different behavior of short versus long run expectations. Using exchange rate survey data to measure expectations Froot and Ito (1989) showed that a current, positive exchange rate shock leads investors to expect a higher long-run future spot rate when iterating forward their short-term expectations than when thinking directly about the long run. They conclude that short-horizon expectations may overreact to current exchange rate changes. Encouraging results on long-run UIP (Chinn and Meredith, 2005) would favor different behavior of short and long run expectations.

In an environment where there is a huge noise in the spot foreign exchange rate market and short and long run expectations behave differently, market participants could rather keep their long run expectation reasonably stable and accept adjustment in the spot exchange rate in response to a shock, when the nature of the shock (i.e. whether it is a pure noise or something fundamental) is uncertain. These arguments could support the statistical finding that long

[16] Detailed results are available from the authors upon request.

maturity forward exchange rates are stationary.

Obviously, economists would rather agree to the stationarity of real and not of nominal exchange rates. Indeed, there is a huge literature studying the stationarity of *actual* real exchange rates, which has recently gained more support (Sarno, 2005).[17] However, the long maturity bond yields incorporate inflationary expectations. Consequently, the difference between long maturity bond yields could indicate the expected inflationary differential between the two countries and hence the long maturity forward rate could indicate the required change in the nominal exchange rate (during a period corresponding to the maturity of the bond) for compensating for the expected inflationary differential. On the other hand, in an environment when the expected cumulative inflation differential is close to zero, the bond-yield differential will also be close to zero, and variation of the nominal exchange rate coincides with the real exchange rate. In order this mechanism to work, long run real interest rates should be similar across the two countries implying that the term premium also should not differ much. This argument suggests that our model could be relevant for countries having stable monetary regimes in a sense that the monetary authority enjoys a high credibility in controlling inflation. Perhaps all of the countries studied have achieved such a stage by now, though the degree of their credibility could have varied in time. Significant divergence in inflation differentials in the past could have contributed to the finding that our tests did not find stationarity of long maturity forward rates for five of nine exchange rate series studied. Hence, it is a rather interesting finding and could be the scope of further research that despite the rejection of stationarity of long maturity forward rates, models *assuming* stationarity outperform the random walk in out-of-sample forecasting even for these five exchange rates.

[17] Still, the real exchange rate could evolve along persistent trends, for example, due to divergent productivity trends according to the Balassa-Samuelson effect (Balassa 1964, Samuelson 1964). The non-stationary result of the long maturity forward rate of Japan could be related to this factor.

A further factor playing a role in explaining some of our results could be related to the term premia of long maturity bond yields. We conjecture, without a detailed investigation, that our results could be weaker for a country whose term premia markedly differ from those of the country compared. The term premium of 10-year maturity bonds could be larger and more volatile than that of the 3-year maturity bonds, which could explain our finding that forecasting results were better for most countries when using the 3-year maturity than the 10-year maturity forward rate.

A final issue we would like to raise here is the predictability of the spot exchange rate. The statistical finding of cointegration between the spot exchange rate and long maturity interest rate differential only implies that at least one of these two variables could be forecasted using the previous period long maturity forward rate. We found that the spot exchange is predictable. Our interpretation for this finding, which is consistent with the so called 'yield parity approach' of Darvas et al (2006), is that exogenous shocks to the term structure are at least partly absorbed by the changes in the spot exchange rate. These exogenous shocks could affect both the demand and the supply sides of the bond markets. For example, shocks to domestic and foreign savings, changes in the financial systems, fiscal policies, or investors' anticipations could affect the bond market directly, and these shocks could have an indirect and not necessarily contemporaneous effect on the spot exchange rate in such a direction to keep the long maturity forward exchange rate stationary.

## 6. Summary

This paper presented a new model that has not yet been used for exchange rate forecasting, namely, an error correction model assuming that the long maturity forward rate is stationary. We found that the model significantly outperformed the random walk at forecasting horizons mostly above one year for nine US dollar exchange rate series (German mark, British pound, Japanese yen, Swiss franc, Canadian dollar, Australian dollar, New Zealand dollar, Norwegian krone, Swedish krona), using the 1990–2006 period for evaluating out-of-sample forecasts. The improvement in forecast accuracy of these models is economically significant for most of the exchange rate series and statistically significant according to a bootstrap test. We also found within year predictability for some the exchange rate series studied. Our results are robust to the specification of the error correction model and to the underlying data frequency.

Our forecasting results are without precedent. None of the few papers reporting exchange rate predictability used such a long period for evaluating out-of-sample forecasts, none of them studied nine exchange rate series, and they generally did not receive so universal results across their fewer exchange rate series studied and short evaluation periods as we found for the nine exchange rate series and long evaluation period.

There are at least three apparent ways in which our work could be extended. First, it would be worth to examine some possible non-linear alternatives of our simple linear models. Second, analysis of the profitability of trading strategy simulations based on model forecasts would be helpful. Third, a study of the relation of long maturity interest rate differentials to fundamentals determining long run movements in the exchange rate could contribute to a better understanding of the economic mechanisms leading to our results.

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**Data Appendix**

The sample period covers end of month data between January 1979 and December 2006, although a few interest rate series are available only since the mid-eighties or as a monthly average, as indicated below.

US dollar exchange rates were downloaded from the website of the FED. Since 1999, the German mark exchange rate was calculated from the euro rate using the fixed conversion rate.

Long maturity yields (3, 5 and 10 years except New Zealand for which 2-year is the shortest maturity) were downloaded from the websites of the central banks of the countries under study except Japan. The Japanese 10-year yield is from the IMF IFS (monthly average); 3 and 5-year yields are from the Reuters (available since 1985). Time series available at central bank websites start later than 1979 for the following countries: Switzerland – available since 1988, the 10-year yield up to 1987 is from the IMF IFS (monthly average), 3 and 5-year yields are from the Datastream for 1983-87; Canada – available since 1986, Datastream for 1982M6-1985, IMF IFS up to 1982M5 (monthly average); Australia – the 3-year yield is available only since 1992M6, up to this date the source is IMF IFS (monthly average); New Zealand – available since 1985M3, the 10-year yield up to 1985M2 is from the IMF IFS (monthly average); Sweden – available since 1987, the 10-year yield up to 1986 is from the IMF IFS (monthly average).

Short maturity (1, 3, 6 and 12 months) interest rates (which were used for evaluating the forecasting ability of forward rates and hence should be available only since 1990) are mostly LIBORs downloaded from the website of the British Bankers' Association. Canadian LIBORs are available only since 1990M5; for 1990M1-M4 euro Canadian dollar rates were used from the Datastream. New Zealand LIBORs are available only since 2003M6; for 1990M1-2003M5 money market rates were used from the Datastream. Norway: NIBOR from the website of the Norges Bank. Sweden: STIBOR from the website of the Riksbank.

In cases when an interest rate series was combined from different sources, data for the overlapping periods were carefully checked for similarity.

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**Table 1: Unit root and stationarity tests for the logarithm of spot and 10-year maturity forward rates**

| | | DEM | GBP | JPY | CHF | CAD | AUD | NZD | NOK | SEK |
|---|---|---|---|---|---|---|---|---|---|---|
| ADF | *spot* | -1.25 | -2.09 | -1.23 | -1.38 | -1.40 | -2.07 | -2.52 | -2.29 | -2.21 |
| | *fwd* | -2.63* | -3.14** | -1.69 | -2.56 | -2.23 | -2.49 | -2.71* | -2.08 | -2.28 |
| PP | *spot* | -1.42 | -2.26 | -1.27 | -1.49 | -1.39 | -2.09 | -2.54 | -2.31 | -2.29 |
| | *fwd* | -2.57* | -2.97** | -1.74 | -2.57* | -1.97 | -2.48 | -2.43 | -2.11 | -2.38 |
| ERS DF | *spot* | -1.26 | -1.34 | -0.30 | -1.12 | -1.17 | -0.43 | -0.40 | -0.85 | -0.47 |
| | *fwd* | -2.44** | -2.22** | -0.69 | -1.97** | -2.04** | -0.71 | -1.16 | -0.92 | -0.92 |
| ERS FPO | *spot* | 6.60 | 7.54 | 29.98 | 7.46 | 9.18 | 36.06 | 46.18 | 17.28 | 39.61 |
| | *fwd* | 2.24** | 3.09** | 16.67 | 3.43* | 3.17** | 21.12 | 9.71 | 15.72 | 15.69 |
| NP MZa | *spot* | -3.75 | -3.53 | -0.43 | -3.35 | -2.77 | -0.55 | -0.45 | -1.54 | -0.65 |
| | *fwd* | -11.84** | -11.03** | -1.32 | -7.58* | -9.04** | -1.18 | -2.79 | -1.72 | -1.73 |
| NP MZt | *spot* | -1.26 | -1.33 | -0.30 | -1.12 | -1.17 | -0.42 | -0.39 | -0.84 | -0.46 |
| | *fwd* | -2.40** | -2.18** | -0.68 | -1.95* | -2.02** | -0.70 | -1.15 | -0.92 | -0.91 |
| NP MSB | *spot* | 0.34 | 0.38 | 0.69 | 0.33 | 0.42 | 0.77 | 0.88 | 0.55 | 0.71 |
| | *fwd* | 0.20** | 0.20** | 0.52 | 0.26* | 0.22** | 0.59 | 0.41 | 0.53 | 0.53 |
| NP MPT | *spot* | 6.61 | 6.95 | 27.45 | 7.23 | 8.81 | 31.65 | 39.9 | 15.23 | 27.14 |
| | *fwd* | 2.22** | 2.90** | 15.09 | 3.23* | 3.14** | 18.39 | 8.71 | 14.03 | 13.88 |
| KPSS | *spot* | 0.69** | 0.21 | 1.64*** | 1.08*** | 0.63** | 1.23*** | 0.64** | 0.43* | 0.95*** |
| | *fwd* | 0.09 | 0.30 | 1.58*** | 0.32 | 0.28 | 0.52** | 0.24 | 0.21 | 0.52** |

Notes. The sample includes monthly data between January 1979 and December 2006. ADF: augmented test of Dickey-Fuller (1979); PP: test of Phillips-Perron (1988); ERS DF: DF test with GLS detrending suggested by Elliott-Rothenberg-Stock (1996); ERS FPO: feasible point-optimal test of Elliott-Rothenberg-Stock (1996), NP MZa & MZt & MSB & MPT: four tests suggested by Ng-Perron (2001); KPSS: test of Kwiatkowski-Phillips-Schmidt-Shin (1992). Null hypothesis is unit root for all tests except KPSS, which has stationarity as the null. The 1%, 5%, and 10% critical values are the following. ADF and PP: –3.45, –2.87, –2.57. ERS DF: –2.57, –1.94, –1.62. ERS FPO: 1.96, 3.23, 4.42. NP MZa -13.8, -8.1, -5.7. NP MZt: -2.58, -1.98, -1.62. NP MSB: 0.174, 0.233, 0.275. NP MPT: 1.78, 3.17, 4.45. KPSS: 0.74, 0.46, 0.35. ***, **, and * indicates rejection of the null hypothesis at 1%, 5%, and 10% significance level, respectively.

**Table 2: Regression statistics of the one period change in the exchange rate on the previous period forward rate**

| Maturity of forward rate | | DEM | GBP | JPY | CHF | CAD | AUD | NZD | NOK | SEK |
|---|---|---|---|---|---|---|---|---|---|---|
| 1-month | $\delta_1$ | -0.0115 | -0.0259 | -0.0075 | -0.0136 | -0.0129 | -0.0217 | -0.0157 | -0.0330 | -0.0181 |
| | t | -1.28 | -2.13 | -1.26 | -1.42 | -1.43 | -1.62 | -1.26 | -1.99 | -1.49 |
| | R2 | 0.0049 | 0.0134 | 0.0047 | 0.0060 | 0.0061 | 0.0108 | 0.0064 | 0.0156 | 0.0093 |
| | DW | 1.87 | 1.85 | 1.91 | 1.86 | 2.02 | 1.97 | 1.81 | 1.93 | 1.63 |
| | N | 335 | 335 | 335 | 335 | 335 | 243 | 248 | 251 | 239 |
| 3-year | $\delta_1$ | -0.0212 | -0.0343 | -0.0470 | -0.0245 | -0.0189 | -0.0169 | -0.0316 | -0.0219 | -0.0289 |
| | t | -2.10 | -2.86 | -3.63 | -2.30 | -2.12 | -2.43 | -2.80 | -2.53 | -1.98 |
| | R2 | 0.0130 | 0.0240 | 0.0502 | 0.0182 | 0.0133 | 0.0175 | 0.0294 | 0.0188 | 0.0162 |
| | DW | 1.87 | 1.86 | 1.97 | 1.87 | 2.01 | 1.89 | 1.88 | 1.94 | 1.62 |
| | N | 335 | 335 | 251 | 287 | 335 | 335 | 261 | 335 | 239 |
| 5-year | $\delta_1$ | -0.0287 | -0.0372 | -0.0452 | -0.0301 | -0.0211 | -0.0169 | -0.0280 | -0.0207 | -0.0340 |
| | t | -2.60 | -3.14 | -3.80 | -2.71 | -2.39 | -2.56 | -2.84 | -2.64 | -2.21 |
| | R2 | 0.0200 | 0.0287 | 0.0546 | 0.0252 | 0.0168 | 0.0193 | 0.0303 | 0.0205 | 0.0203 |
| | DW | 1.87 | 1.86 | 1.98 | 1.87 | 2.01 | 1.89 | 1.88 | 1.95 | 1.62 |
| | N | 335 | 335 | 252 | 287 | 335 | 335 | 261 | 335 | 239 |
| 10-year | $\delta_1$ | -0.0450 | -0.0368 | -0.0120 | -0.0476 | -0.0191 | -0.0137 | -0.0192 | -0.0173 | -0.0210 |
| | t | -3.59 | -3.30 | -2.08 | -3.93 | -2.36 | -2.37 | -3.78 | -2.64 | -3.02 |
| | R2 | 0.0373 | 0.0317 | 0.0129 | 0.0444 | 0.0164 | 0.0166 | 0.0412 | 0.0205 | 0.0267 |
| | DW | 1.87 | 1.87 | 1.91 | 1.88 | 2.01 | 1.89 | 1.93 | 1.96 | 1.78 |
| | N | 335 | 335 | 335 | 335 | 335 | 335 | 335 | 335 | 335 |

Notes. Equation estimated: $\Delta s_t = \delta_0 + \delta_1 f_{t-1}^{(h)} + \varepsilon_t$, where $s_t$ denotes the spot exchange rate; $f_t^{(h)}$ denotes the *h*-period maturity forward rate; *h* is showed in the first column. t: OLS t-statistics, R2: coefficient of determinant; DW: Durbin-Watson, N: number of observations. The sample includes monthly data for January 1979 – December 2006, although some of the forward rates are available only since the mid eighties. The maximum number of observations is 335.

**Table 3: Out-of-sample forecast evaluation, RMSPE, Random walk = 100**

| | 1M | 3M | 6M | 12M | 24M | 36M | 48M | 60M |
|---|---|---|---|---|---|---|---|---|
| **German Mark (DEM)** | | | | | | | | |
| Forward rate | 100.7 | 102.0 | 104.3 | 108.3 | 111.3 | 112.2 | 109.0 | 102.4 |
| | (0.887) | (0.932) | (0.987) | (0.999) | (0.999) | (0.999) | (0.999) | (0.773) |
| Random walk with drift | 100.2 | 100.7 | 101.4 | 102.8 | 105.1 | 107.9 | 110.7 | 113.9 |
| | (0.484) | (0.508) | (0.513) | (0.511) | (0.477) | (0.496) | (0.486) | (0.503) |
| AR | 100.3 | 100.8 | 101.5 | 100.4 | 97.9 | 94.5 | 91.8 | 91.3 |
| | (0.359) | (0.334) | (0.348) | (0.252) | (0.220) | (0.193) | (0.190) | (0.222) |
| EQ F3Y | 99.9 | 99.7 | 99.0 | **96.1** | **92.1** | **85.2** | 91.9 | 97.8 |
| | (0.154) | (0.147) | (0.118) | (0.089) | (0.095) | (0.085) | (0.157) | (0.211) |
| MOD S-F3Y | 99.9 | 99.6 | 98.9 | **94.7** | **86.0** | **75.4** | **69.6** | **70.0** |
| | (0.165) | (0.150) | (0.140) | (0.084) | (0.046) | (0.022) | (0.026) | (0.050) |
| VECM S-I3Y | **99.6** | 100.5 | 100.7 | **95.0** | **86.0** | **75.2** | **69.7** | **70.3** |
| | (0.024) | (0.172) | (0.200) | (0.067) | (0.046) | (0.021) | (0.023) | (0.042) |
| EQ F5Y | **99.8** | **99.4** | **98.2** | **93.7** | **83.0** | **69.4** | **72.0** | **75.3** |
| | (0.090) | (0.095) | (0.076) | (0.049) | (0.027) | (0.016) | (0.038) | (0.070) |
| MOD S-F5Y | 99.8 | 99.3 | **98.0** | **92.1** | **79.8** | **66.2** | **60.3** | **62.9** |
| | (0.113) | (0.114) | (0.096) | (0.047) | (0.016) | (0.007) | (0.007) | (0.024) |
| VECM S-I5Y | **99.3** | 100.2 | 99.9 | **92.5** | **80.1** | **66.3** | **60.4** | **63.2** |
| | (0.013) | (0.159) | (0.170) | (0.043) | (0.017) | (0.009) | (0.010) | (0.016) |
| EQ F10Y | 100.0 | 100.0 | 99.2 | **93.3** | **74.5** | **64.2** | **74.5** | 87.4 |
| | (0.163) | (0.152) | (0.108) | (0.035) | (0.004) | (0.004) | (0.034) | (0.140) |
| MOD S-F10Y | 100.0 | 100.2 | 98.8 | **90.8** | **76.2** | **68.4** | **71.1** | **80.6** |
| | (0.177) | (0.207) | (0.110) | (0.026) | (0.001) | (0.003) | (0.021) | (0.097) |
| VECM S-I10Y | **99.9** | 100.5 | 99.7 | **90.8** | **75.8** | **66.7** | **69.0** | **78.7** |
| | (0.051) | (0.219) | (0.164) | (0.022) | (0.012) | (0.008) | (0.021) | (0.073) |
| **British Pound (GBP)** | | | | | | | | |
| Forward rate | 100.5 | 100.9 | 102.0 | 101.6 | 102.8 | 100.5 | 100.1 | 98.3 |
| | (0.658) | (0.618) | (0.668) | (0.600) | (0.673) | (0.535) | (0.503) | (0.406) |
| Random walk with drift | 100.4 | 101.1 | 102.3 | 103.9 | 107.4 | 110.7 | 117.7 | 126.5 |
| | (0.772) | (0.754) | (0.752) | (0.686) | (0.644) | (0.609) | (0.692) | (0.727) |
| AR | **99.7** | **99.1** | **97.8** | **94.3** | **87.4** | **79.8** | **74.6** | **74.0** |
| | (0.090) | (0.078) | (0.068) | (0.059) | (0.058) | (0.039) | (0.036) | (0.044) |
| EQ F3Y | **99.6** | **98.8** | **96.2** | **92.2** | **79.2** | **66.7** | **67.8** | 82.4 |
| | (0.054) | (0.054) | (0.032) | (0.025) | (0.016) | (0.010) | (0.022) | (0.103) |
| MOD S-F3Y | **99.6** | **98.8** | **96.5** | **93.3** | **84.0** | **78.9** | **77.4** | 83.3 |
| | (0.068) | (0.070) | (0.040) | (0.049) | (0.029) | (0.036) | (0.050) | (0.107) |
| VECM S-I3Y | **99.4** | **98.9** | **96.7** | **93.3** | **83.8** | **79.9** | **79.2** | 85.6 |
| | (0.020) | (0.060) | (0.038) | (0.044) | (0.023) | (0.035) | (0.052) | (0.105) |
| EQ F5Y | **99.7** | **99.2** | **96.7** | **94.1** | **83.5** | **79.4** | 86.3 | 104.4 |
| | (0.068) | (0.071) | (0.033) | (0.043) | (0.021) | (0.037) | (0.102) | (0.289) |
| MOD S-F5Y | **99.7** | **99.1** | **96.7** | **94.5** | **86.0** | **85.2** | **87.6** | 99.6 |
| | (0.058) | (0.061) | (0.029) | (0.046) | (0.034) | (0.060) | (0.095) | (0.220) |
| VECM S-I5Y | **99.8** | **99.3** | **96.9** | **94.9** | **86.3** | **86.6** | **89.2** | 101.0 |
| | (0.051) | (0.059) | (0.029) | (0.043) | (0.027) | (0.053) | (0.095) | (0.243) |
| EQ F10Y | 100.9 | 101.9 | 101.8 | 104.7 | 103.9 | 115.4 | 133.4 | 153.6 |
| | (0.767) | (0.601) | (0.322) | (0.434) | (0.265) | (0.512) | (0.712) | (0.783) |
| MOD S-F10Y | 100.9 | 101.1 | 99.4 | 100.7 | 97.9 | 107.5 | 117.8 | 139.4 |
| | (0.756) | (0.373) | (0.116) | (0.196) | (0.138) | (0.391) | (0.614) | (0.800) |
| VECM S-I10Y | 101.3 | 102.1 | 101.0 | 103.7 | 100.5 | 110.8 | 120.6 | 142.4 |
| | (0.407) | (0.503) | (0.212) | (0.362) | (0.195) | (0.464) | (0.622) | (0.787) |

**Table 3, continued**

| | 1M | 3M | 6M | 12M | 24M | 36M | 48M | 60M |
|---|---|---|---|---|---|---|---|---|
| **Japanese Yen (JPY)** | | | | | | | | |
| Forward rate | 101.1 | 102.8 | 105.4 | 112.0 | 115.0 | 116.8 | 125.6 | 139.7 |
| | (0.920) | (0.929) | (0.955) | (0.984) | (0.987) | (0.984) | (0.999) | (0.999) |
| Random walk with drift | 100.2 | 100.6 | 101.0 | 102.2 | 104.7 | 108.0 | 115.8 | 132.8 |
| | (0.559) | (0.510) | (0.459) | (0.473) | (0.497) | (0.539) | (0.690) | (0.796) |
| AR | 100.2 | 100.9 | 101.8 | 103.5 | 109.2 | 119.4 | 132.5 | 149.3 |
| | (0.294) | (0.379) | (0.415) | (0.437) | (0.584) | (0.754) | (0.858) | (0.924) |
| EQ F3Y | 100.7 | 102.0 | 101.6 | 103.6 | 94.1 | **71.9** | 81.8 | 128.0 |
| | (0.491) | (0.462) | (0.259) | (0.291) | (0.140) | (0.047) | (0.120) | (0.511) |
| MOD S-F3Y | 100.4 | 101.0 | 99.3 | 97.7 | **83.6** | **76.5** | **73.2** | 80.7 |
| | (0.23) | (0.255) | (0.166) | (0.169) | (0.066) | (0.055) | (0.074) | (0.153) |
| VECM S-I3Y | **101.0** | 101.5 | 100.8 | **97.4** | **85.8** | **81.6** | **77.6** | **80.4** |
| | (0.046) | (0.150) | (0.130) | (0.099) | (0.046) | (0.048) | (0.058) | (0.089) |
| EQ F5Y | 100.5 | 101.4 | 99.8 | 99.1 | **87.6** | **72.8** | 89.2 | 135.9 |
| | (0.361) | (0.352) | (0.18) | (0.176) | (0.087) | (0.050) | (0.187) | (0.617) |
| MOD S-F5Y | 100.2 | 100.8 | 98.9 | 95.7 | **80.1** | **72.5** | **69.7** | 83.2 |
| | (0.173) | (0.304) | (0.165) | (0.132) | (0.040) | (0.032) | (0.051) | (0.138) |
| VECM S-I5Y | **101.2** | 101.4 | 100.5 | **94.9** | **82.3** | **77.4** | **72.2** | **79.7** |
| | (0.082) | (0.157) | (0.129) | (0.080) | (0.044) | (0.050) | (0.051) | (0.088) |
| EQ F10Y | 99.9 | 100.3 | 99.0 | 98.0 | 95.8 | **85.5** | 82.6 | 141.5 |
| | (0.162) | (0.222) | (0.138) | (0.148) | (0.158) | (0.092) | (0.107) | (0.607) |
| MOD S-F10Y | 99.9 | 100.2 | 100.2 | 99.6 | 98.7 | 99.8 | 96.8 | 95.6 |
| | (0.156) | (0.224) | (0.223) | (0.208) | (0.227) | (0.267) | (0.246) | (0.261) |
| VECM S-I10Y | **100.2** | 100.6 | 101.8 | 99.6 | 100.5 | 104.6 | 105.8 | 108.7 |
| | (0.095) | (0.215) | (0.327) | (0.215) | (0.269) | (0.361) | (0.367) | (0.407) |
| **Swiss Franc (CHF)** | | | | | | | | |
| Forward rate | 100.8 | 101.9 | 103.6 | 107.3 | 111.7 | 114.4 | 111.6 | 107.2 |
| | (0.914) | (0.922) | (0.957) | (0.989) | (0.998) | (0.995) | (0.934) | (0.783) |
| Random walk with drift | 100.2 | 100.6 | 101.3 | 102.8 | 104.9 | 107.1 | 109.0 | 112.4 |
| | (0.441) | (0.488) | (0.501) | (0.545) | (0.475) | (0.455) | (0.448) | (0.471) |
| AR | 100.4 | 101.0 | 102.1 | 101.9 | 100.9 | 98.6 | 97.5 | 96.5 |
| | (0.406) | (0.358) | (0.385) | (0.322) | (0.282) | (0.255) | (0.269) | (0.279) |
| EQ F3Y | 99.8 | 99.7 | 99.1 | **95.1** | **78.0** | **58.2** | **63.3** | **65.1** |
| | (0.133) | (0.147) | (0.142) | (0.072) | (0.013) | (0.002) | (0.031) | (0.061) |
| MOD S-F3Y | 99.8 | 99.6 | 99.3 | 95.9 | **85.8** | **73.8** | **69.4** | 72.9 |
| | (0.151) | (0.152) | (0.179) | (0.142) | (0.094) | (0.063) | (0.072) | (0.114) |
| VECM S-I3Y | **100.5** | 100.6 | 102.6 | 96.7 | **85.3** | **72.1** | **67.6** | **70.8** |
| | (0.094) | (0.190) | (0.356) | (0.151) | (0.076) | (0.044) | (0.047) | (0.095) |
| EQ F5Y | 99.8 | 99.7 | 99.2 | **94.7** | **74.4** | **54.9** | **68.6** | **67.6** |
| | (0.129) | (0.141) | (0.139) | (0.087) | (0.017) | (0.005) | (0.045) | (0.063) |
| MOD S-F5Y | 99.8 | 99.6 | 99.3 | 94.7 | **81.3** | **65.5** | **65.5** | 75.4 |
| | (0.137) | (0.173) | (0.192) | (0.117) | (0.044) | (0.026) | (0.046) | (0.140) |
| VECM S-I5Y | **99.9** | 100.7 | 102.6 | 95.5 | **81.7** | **65.0** | **63.7** | 72.8 |
| | (0.052) | (0.229) | (0.373) | (0.124) | (0.053) | (0.030) | (0.047) | (0.105) |
| EQ F10Y | 100.4 | 101.4 | 103.2 | 107.2 | 93.4 | 90.5 | 104.7 | 125.9 |
| | (0.352) | (0.452) | (0.521) | (0.590) | (0.103) | (0.109) | (0.281) | (0.536) |
| MOD S-F10Y | 100.4 | 101.5 | 102.6 | 104.3 | 96.2 | **89.2** | 98.2 | 117.7 |
| | (0.360) | (0.550) | (0.521) | (0.497) | (0.148) | (0.098) | (0.218) | (0.555) |
| VECM S-I10Y | 100.6 | 101.6 | 103.0 | 104.3 | 96.7 | 90.0 | 98.8 | 118.4 |
| | (0.178) | (0.426) | (0.485) | (0.439) | (0.156) | (0.108) | (0.223) | (0.532) |

**Table 3, continued**

| | 1M | 3M | 6M | 12M | 24M | 36M | 48M | 60M |
|---|---|---|---|---|---|---|---|---|
| **Canadian Dollar (CAD)** | | | | | | | | |
| Forward rate | 100.8 | 102.5 | 103.8 | 105.5 | 104.3 | 101.5 | 97.1 | **90.0** |
| | (0.959) | (0.972) | (0.945) | (0.936) | (0.853) | (0.622) | (0.266) | (0.008) |
| Random walk with drift | 100.2 | 100.6 | 101.2 | 102.4 | 104.9 | 107.2 | 109.2 | 110.0 |
| | (0.431) | (0.399) | (0.385) | (0.405) | (0.413) | (0.417) | (0.402) | (0.378) |
| AR | 100.4 | 101.3 | 102.6 | 103.7 | 101.0 | 99.1 | 98.8 | 98.8 |
| | (0.395) | (0.438) | (0.471) | (0.429) | (0.295) | (0.274) | (0.303) | (0.332) |
| EQ F3Y | 100.3 | 100.9 | 102.7 | 105.2 | 99.9 | 99.6 | 99.5 | 103.0 |
| | (0.283) | (0.280) | (0.379) | (0.394) | (0.178) | (0.182) | (0.205) | (0.266) |
| MOD S-F3Y | 100.3 | 101.4 | 103.6 | 103.6 | 95.8 | 92.5 | 91.9 | 93.9 |
| | (0.299) | (0.419) | (0.593) | (0.382) | (0.135) | (0.120) | (0.143) | (0.175) |
| VECM S-I3Y | 100.7 | 100.9 | 102.4 | 103.3 | 97.8 | 95.7 | 95.9 | 97.3 |
| | (0.176) | (0.225) | (0.349) | (0.323) | (0.153) | (0.163) | (0.189) | (0.210) |
| EQ F5Y | 100.3 | 100.9 | 103.1 | 105.2 | 98.1 | 98.3 | 99.1 | 103.2 |
| | (0.342) | (0.341) | (0.484) | (0.45) | (0.175) | (0.218) | (0.243) | (0.318) |
| MOD S-F5Y | 100.3 | 101.6 | 104.2 | 103.1 | **93.6** | **90.7** | 91.2 | 95.1 |
| | (0.292) | (0.498) | (0.658) | (0.349) | (0.091) | (0.080) | (0.117) | (0.174) |
| VECM S-I5Y | 100.6 | 101.3 | 103.1 | 103.3 | 95.8 | 93.5 | 94.0 | 97.4 |
| | (0.149) | (0.301) | (0.469) | (0.343) | (0.112) | (0.127) | (0.151) | (0.197) |
| EQ F10Y | 101.0 | 101.9 | 104.8 | 106.7 | 102.4 | 107.9 | 114.6 | 121.7 |
| | (0.831) | (0.614) | (0.706) | (0.542) | (0.262) | (0.353) | (0.451) | (0.491) |
| MOD S-F10Y | 100.8 | 102.5 | 105.8 | 104.8 | 97.3 | 96.6 | 99.4 | 105.5 |
| | (0.673) | (0.737) | (0.828) | (0.478) | (0.130) | (0.153) | (0.213) | (0.292) |
| VECM S-I10Y | 101.7 | 101.7 | 104.0 | 104.9 | 99.1 | 98.4 | 101.0 | 107.0 |
| | (0.590) | (0.406) | (0.623) | (0.48) | (0.180) | (0.193) | (0.244) | (0.331) |
| **Australian Dollar (AUD)** | | | | | | | | |
| Forward rate | 101.1 | 103.4 | 106.6 | 108.6 | 107.9 | 106.3 | 105.0 | 98.3 |
| | (0.959) | (0.983) | (0.996) | (0.998) | (0.984) | (0.954) | (0.914) | (0.353) |
| Random walk with drift | 100.5 | 101.5 | 102.9 | 104.5 | 108.0 | 112.4 | 117.4 | 118.5 |
| | (0.827) | (0.847) | (0.844) | (0.758) | (0.721) | (0.707) | (0.710) | (0.643) |
| AR | 100.1 | 100.2 | 99.9 | 99.3 | 98.2 | 97.0 | 94.4 | 92.7 |
| | (0.232) | (0.200) | (0.186) | (0.191) | (0.216) | (0.226) | (0.219) | (0.224) |
| EQ F3Y | **99.5** | **98.6** | **97.5** | **94.9** | **88.9** | **81.1** | **72.0** | **74.1** |
| | (0.092) | (0.092) | (0.098) | (0.090) | (0.077) | (0.060) | (0.048) | (0.087) |
| MOD S-F3Y | **99.5** | **98.6** | **97.0** | **94.7** | 92.2 | 90.4 | 88.0 | 87.8 |
| | (0.069) | (0.074) | (0.070) | (0.083) | (0.117) | (0.145) | (0.150) | (0.178) |
| VECM S-I3Y | 100.4 | **99.2** | **96.8** | **94.3** | 92.2 | 90.5 | 88.1 | 88.1 |
| | (0.141) | (0.093) | (0.056) | (0.072) | (0.109) | (0.137) | (0.153) | (0.175) |
| EQ F5Y | **99.4** | **98.3** | **97.1** | **94.0** | **89.0** | **83.7** | **76.0** | **77.4** |
| | (0.056) | (0.064) | (0.073) | (0.072) | (0.077) | (0.078) | (0.061) | (0.100) |
| MOD S-F5Y | **99.4** | **98.3** | **96.4** | **93.7** | **91.5** | 90.4 | 88.7 | 89.5 |
| | (0.040) | (0.048) | (0.043) | (0.057) | (0.094) | (0.128) | (0.144) | (0.174) |
| VECM S-I5Y | 100.3 | **98.6** | **96.4** | **93.9** | 92.3 | 91.8 | 90.6 | 91.2 |
| | (0.127) | (0.065) | (0.049) | (0.058) | (0.110) | (0.140) | (0.163) | (0.198) |
| EQ F10Y | **99.5** | **98.7** | **97.9** | **95.4** | 93.5 | 93.2 | 87.8 | 88.2 |
| | (0.049) | (0.059) | (0.077) | (0.074) | (0.111) | (0.152) | (0.129) | (0.154) |
| MOD S-F10Y | **99.5** | **98.7** | **97.4** | **95.4** | 94.9 | 96.3 | 96.5 | 98.2 |
| | (0.058) | (0.071) | (0.073) | (0.084) | (0.132) | (0.197) | (0.224) | (0.267) |
| VECM S-I10Y | 100.6 | **99.1** | **97.5** | **95.6** | 95.7 | 97.3 | 97.8 | 99.3 |
| | (0.180) | (0.056) | (0.052) | (0.070) | (0.142) | (0.198) | (0.217) | (0.238) |

**Table 3, continued**

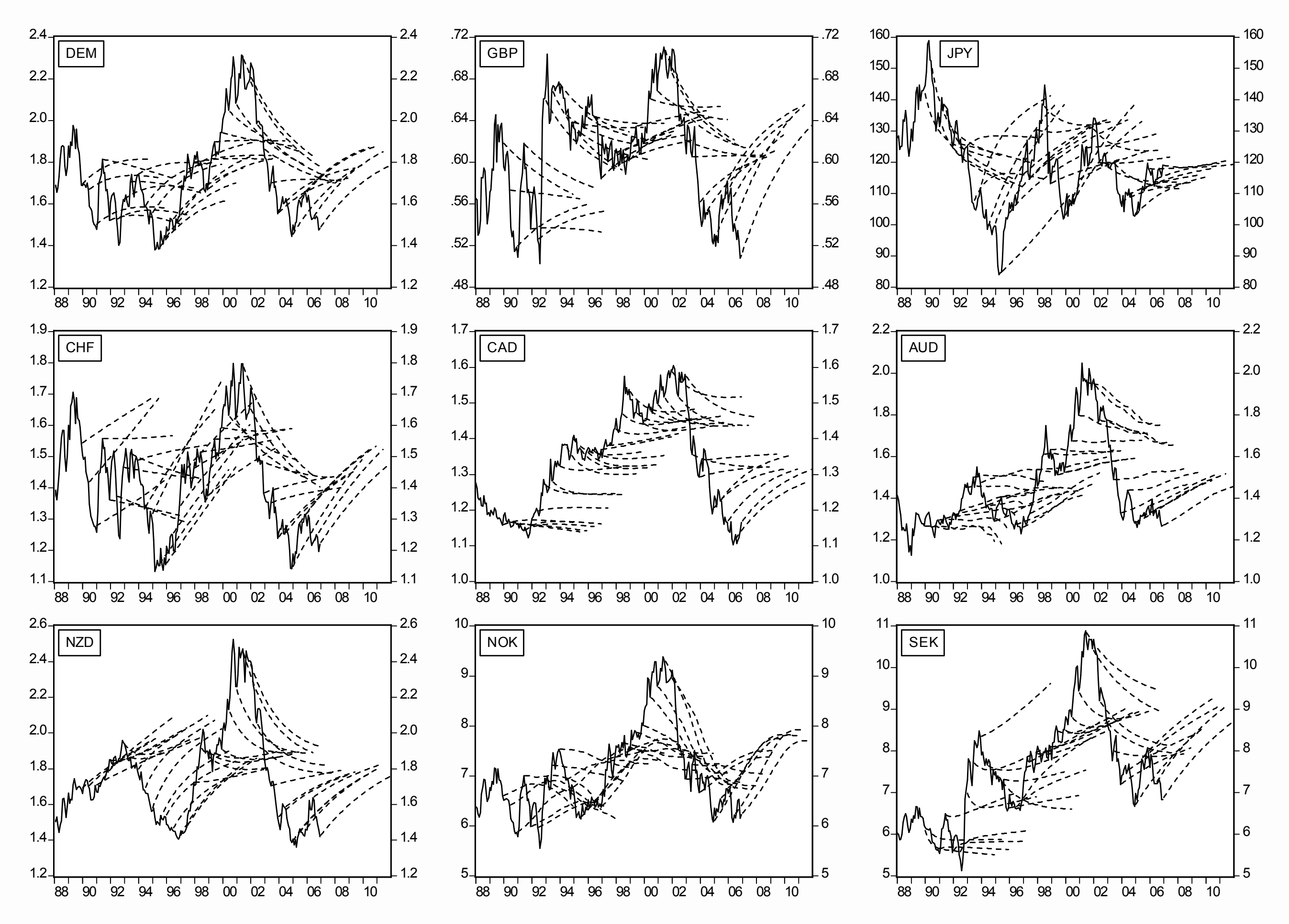
| | 1M | 3M | 6M | 12M | 24M | 36M | 48M | 60M |
|---|---|---|---|---|---|---|---|---|
| **New Zealand Dollar (NZD)** | | | | | | | | |
| Forward rate | 101.7 | 103.7 | 106.2 | 107.6 | 107.4 | 106.9 | 107.3 | 106.2 |
| | (0.979) | (0.972) | (0.987) | (0.989) | (0.982) | (0.977) | (0.976) | (0.918) |
| Random walk with drift | 100.5 | 101.6 | 102.9 | 105.9 | 109.6 | 112.7 | 116.4 | 123.1 |
| | (0.807) | (0.795) | (0.754) | (0.742) | (0.627) | (0.540) | (0.525) | (0.561) |
| AR | 103.9 | 107.9 | 108.4 | 103.6 | **91.2** | **79.6** | **70.8** | **67.0** |
| | (0.990) | (0.974) | (0.814) | (0.324) | (0.055) | (0.017) | (0.007) | (0.006) |
| EQ F2Y | 102.6 | 105.0 | 104.1 | 103.1 | **89.3** | **73.4** | **70.0** | 74.6 |
| | (0.952) | (0.818) | (0.434) | (0.254) | (0.099) | (0.057) | (0.077) | (0.134) |
| MOD S-F2Y | 102.5 | 105.1 | 105.7 | 100.4 | 88.7 | **79.2** | **72.9** | 73.5 |
| | (0.937) | (0.853) | (0.632) | (0.240) | (0.108) | (0.079) | (0.070) | (0.101) |
| VECM S-I2Y | 101.0 | 103.8 | 104.5 | 99.6 | **89.4** | **81.4** | **76.7** | 78.7 |
| | (0.104) | (0.532) | (0.423) | (0.187) | (0.098) | (0.080) | (0.073) | (0.112) |
| EQ F5Y | 101.3 | 102.2 | 101.8 | 103.1 | 100.0 | 96.6 | 97.0 | 92.2 |
| | (0.723) | (0.420) | (0.235) | (0.239) | (0.180) | (0.168) | (0.206) | (0.207) |
| MOD S-F5Y | 101.3 | 103.0 | 103.9 | 101.2 | 97.0 | 94.6 | 93.6 | 97.9 |
| | (0.72) | (0.615) | (0.477) | (0.260) | (0.212) | (0.207) | (0.212) | (0.245) |
| VECM S-I5Y | 99.9 | 101.8 | 102.4 | 100.1 | 97.6 | 97.4 | 98.8 | 105.7 |
| | (0.027) | (0.269) | (0.275) | (0.199) | (0.193) | (0.224) | (0.253) | (0.330) |
| EQ F10Y | 101.2 | 101.9 | 103.0 | 107.5 | 104.8 | 99.4 | 93.1 | 88.9 |
| | (0.722) | (0.417) | (0.356) | (0.444) | (0.270) | (0.220) | (0.205) | (0.197) |
| MOD S-F10Y | **101.3** | **103.1** | **105.1** | **105.7** | 107.4 | 109.5 | 110.9 | 116.0 |
| | (0.084) | (0.078) | (0.076) | (0.085) | (0.121) | (0.170) | (0.195) | (0.247) |
| VECM S-I10Y | **100.7** | 101.7 | 103.0 | 103.6 | 107.0 | 111.4 | 115.5 | 124.2 |
| | (0.057) | (0.242) | (0.310) | (0.297) | (0.357) | (0.388) | (0.418) | (0.479) |
| **Norwegian Krone (NOK)** | | | | | | | | |
| Forward rate | 99.9 | 101.2 | 103.6 | 106.2 | 112.5 | 116.0 | 116.4 | 107.2 |
| | (0.484) | (0.689) | (0.835) | (0.894) | (0.994) | (0.999) | (0.999) | (0.947) |
| Random walk with drift | 100.4 | 101.0 | 102.1 | 103.6 | 107.1 | 109.3 | 113.2 | 115.7 |
| | (0.757) | (0.730) | (0.738) | (0.664) | (0.641) | (0.551) | (0.561) | (0.529) |
| AR | 99.7 | 99.1 | 98.4 | 96.3 | 92.0 | **85.5** | **80.8** | **76.5** |
| | (0.110) | (0.098) | (0.111) | (0.114) | (0.109) | (0.080) | (0.065) | (0.057) |
| EQ F3Y | **99.8** | **99.3** | **98.3** | **94.8** | **81.0** | **57.0** | **44.5** | **52.7** |
| | (0.095) | (0.094) | (0.086) | (0.061) | (0.026) | (0.005) | (0.002) | (0.015) |
| MOD S-F3Y | 99.8 | 99.3 | 98.4 | **95.4** | **87.0** | **75.9** | **68.3** | **70.1** |
| | (0.106) | (0.102) | (0.102) | (0.077) | (0.041) | (0.019) | (0.020) | (0.043) |
| VECM S-I3Y | 101.6 | 100.7 | 99.5 | **95.3** | **86.1** | **74.7** | **67.3** | **70.0** |
| | (0.539) | (0.229) | (0.137) | (0.076) | (0.039) | (0.025) | (0.020) | (0.045) |
| EQ F5Y | **99.7** | **99.4** | **98.5** | **94.7** | **82.1** | **60.7** | **49.3** | **58.7** |
| | (0.073) | (0.097) | (0.091) | (0.055) | (0.026) | (0.004) | (0.002) | (0.020) |
| MOD S-F5Y | **99.7** | **99.4** | **98.5** | **95.3** | **86.7** | **76.4** | **69.0** | **72.1** |
| | (0.073) | (0.089) | (0.087) | (0.058) | (0.031) | (0.025) | (0.018) | (0.041) |
| VECM S-I5Y | 100.8 | 100.6 | 99.7 | **95.5** | **86.9** | **77.1** | **70.2** | **73.9** |
| | (0.206) | (0.198) | (0.127) | (0.064) | (0.039) | (0.025) | (0.021) | (0.044) |
| EQ F10Y | 99.9 | 100.1 | 99.7 | **97.3** | **89.6** | **74.7** | **67.2** | **74.8** |
| | (0.106) | (0.148) | (0.129) | (0.081) | (0.050) | (0.015) | (0.019) | (0.059) |
| MOD S-F10Y | 99.9 | 100.0 | 99.7 | **97.1** | **90.6** | **83.1** | **78.7** | **83.8** |
| | (0.126) | (0.157) | (0.141) | (0.090) | (0.060) | (0.046) | (0.044) | (0.095) |
| VECM S-I10Y | 100.9 | 101.4 | 101.0 | 97.9 | **92.4** | **85.9** | **82.3** | **87.4** |
| | (0.251) | (0.334) | (0.216) | (0.105) | (0.068) | (0.049) | (0.055) | (0.098) |

**Table 3, continued**

| | 1M | 3M | 6M | 12M | 24M | 36M | 48M | 60M |
|---|---|---|---|---|---|---|---|---|
| | | | | **Swedish Krona (SEK)** | | | | |
| Forward rate | 99.6 | 99.5 | 100.3 | 100.5 | 100.4 | 95.6 | **93.1** | **83.6** |
| | (0.399) | (0.443) | (0.525) | (0.535) | (0.526) | (0.203) | (0.070) | (0.001) |
| Random walk with drift | 100.6 | 101.8 | 103.6 | 107.0 | 113.0 | 120.9 | 126.4 | 130.4 |
| | (0.656) | (0.705) | (0.713) | (0.685) | (0.609) | (0.621) | (0.570) | (0.497) |
| AR | 102.4 | 102.5 | 101.0 | 100.9 | 106.4 | 108.6 | 113.7 | 113.3 |
| | (0.881) | (0.333) | (0.172) | (0.202) | (0.39) | (0.436) | (0.534) | (0.519) |
| EQ F3Y | 101.9 | 111.0 | 143.2 | 132.3 | **85.1** | **78.9** | 88.3 | 133.0 |
| | (0.82) | (0.974) | (0.999) | (0.91) | (0.047) | (0.058) | (0.117) | (0.447) |
| MOD S-F3Y | 102.0 | 101.3 | **98.3** | 97.8 | 95.7 | 92.7 | **87.2** | 89.1 |
| | (0.773) | (0.168) | (0.068) | (0.105) | (0.126) | (0.115) | (0.093) | (0.126) |
| VECM S-I3Y | **101.8** | 110.5 | 113.3 | 103.8 | **96.2** | **93.0** | 91.5 | 95.8 |
| | (0.083) | (0.945) | (0.846) | (0.170) | (0.098) | (0.097) | (0.103) | (0.139) |
| EQ F5Y | 100.7 | 102.4 | 117.7 | 105.1 | **71.3** | **75.7** | 88.7 | 116.5 |
| | (0.349) | (0.391) | (0.944) | (0.234) | (0.008) | (0.035) | (0.111) | (0.366) |
| MOD S-F5Y | 101.5 | 101.6 | **98.1** | **93.4** | **85.8** | **85.3** | **82.2** | **87.7** |
| | (0.578) | (0.210) | (0.058) | (0.032) | (0.027) | (0.045) | (0.055) | (0.089) |
| VECM S-I5Y | 101.3 | 107.1 | 106.0 | **97.4** | **87.0** | **88.4** | **89.3** | 96.6 |
| | (0.059) | (0.760) | (0.344) | (0.057) | (0.028) | (0.060) | (0.068) | (0.117) |
| EQ F10Y | 99.8 | 99.4 | **97.7** | **91.8** | **84.5** | 97.1 | 115.9 | 135.3 |
| | (0.106) | (0.111) | (0.072) | (0.040) | (0.050) | (0.211) | (0.480) | (0.641) |
| MOD S-F10Y | 101.3 | **102.6** | **100.5** | **94.4** | **88.0** | **99.7** | **107.6** | 116.6 |
| | (0.140) | (0.091) | (0.030) | (0.009) | (0.007) | (0.050) | (0.077) | (0.102) |
| VECM S-I10Y | **99.9** | 99.8 | **97.7** | **93.2** | **89.3** | 94.7 | 100.2 | 108.2 |
| | (0.061) | (0.117) | (0.062) | (0.048) | (0.065) | (0.176) | (0.274) | (0.365) |

Notes: The sample period includes monthly data against the US dollar from January 1979 to December 2006 for most time series, with the exception of the 3 and 5-year maturity forward rates of the JPY, CHF, SEK, and NZD, which are available from the early or mid eighties. Using the recursive estimation window, out-of-sample evaluation of forecasts was performed in 1990-2006, with the exception of models EQ F3Y and EQ F5Y for JPY and NZD (1992-2006) and SEK (1993-2006). The first row of the table shows the forecast horizon in months. Test statistics shown are the model's RMSPE (root mean squared prediction error) divided by the random walk's RMSPE and multiplied by 100, hence, test statistics less than 100 indicate that model's RMSPE is smaller than that of the random walk. Values in brackets are p-values of one sided test of the null hypothesis of equal predictive accuracy with the random walk and were calculated using the bootstrap technique described in Section 2 for the estimated models, and with the Diebold and Mariano (1995) test for the forward rate. The Diebold and Mariano test was performed for the difference between RMSPE using the Newey and West (1987) covariance. Significant (at 10 percent) statistics are in bold.

**Figure 1: Out-of-sample forecasts**




*Notes.* The panels show actual exchange rate movements (solid) and out-of-sample forecasts from one month to five years ahead (dashed) for the nine exchange rate series against the US dollar. For better readability of the figures, forecasts made only in June and in December of each year are shown. Although data was used in logarithmic form for estimation and forecasting, panels of this figure show data in their natural units. Model 'MOD S-F5Y' was used for DEM, JPY, CHF, CAD and SEK; model 'MOD S-3F' was used for GBP; equation 'EQ F5Y' was used for AUD; model 'MOD S-2F' was used for NZD; equation 'EQ F3Y' was used for NOK.

**Figure 2: Changes in the log exchange rate and out-of-sample forecasts**

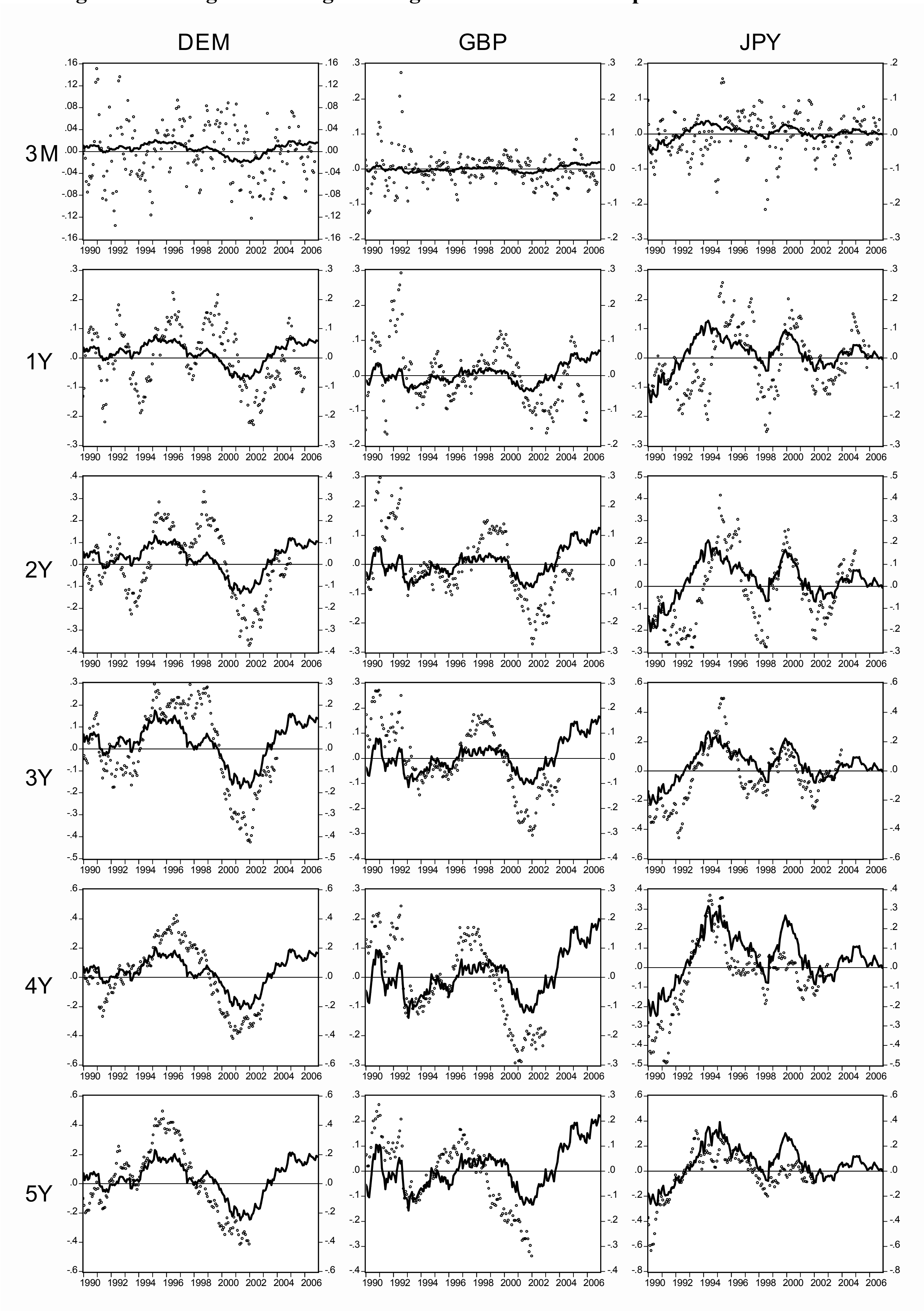


**Figure 2, continued**

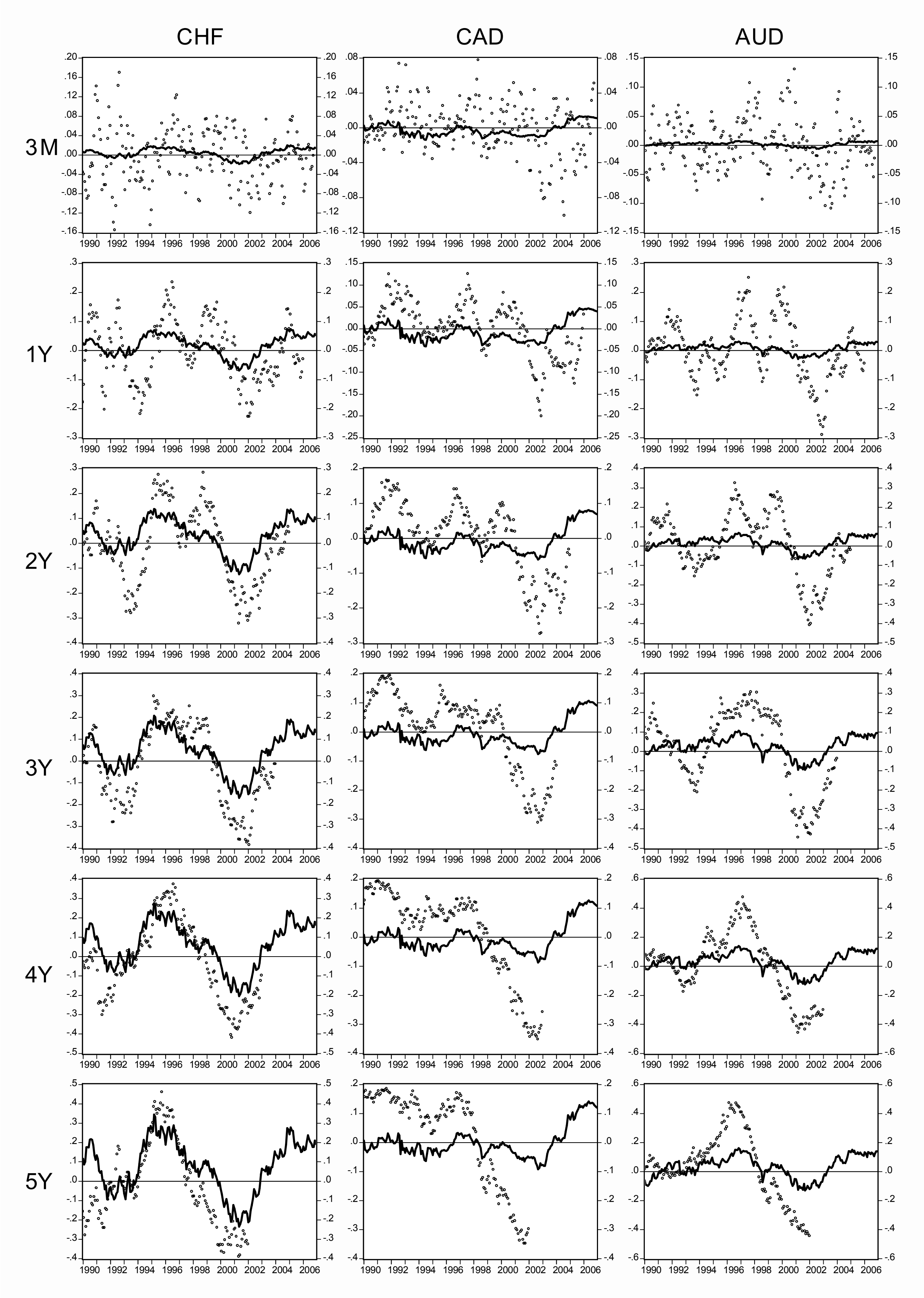
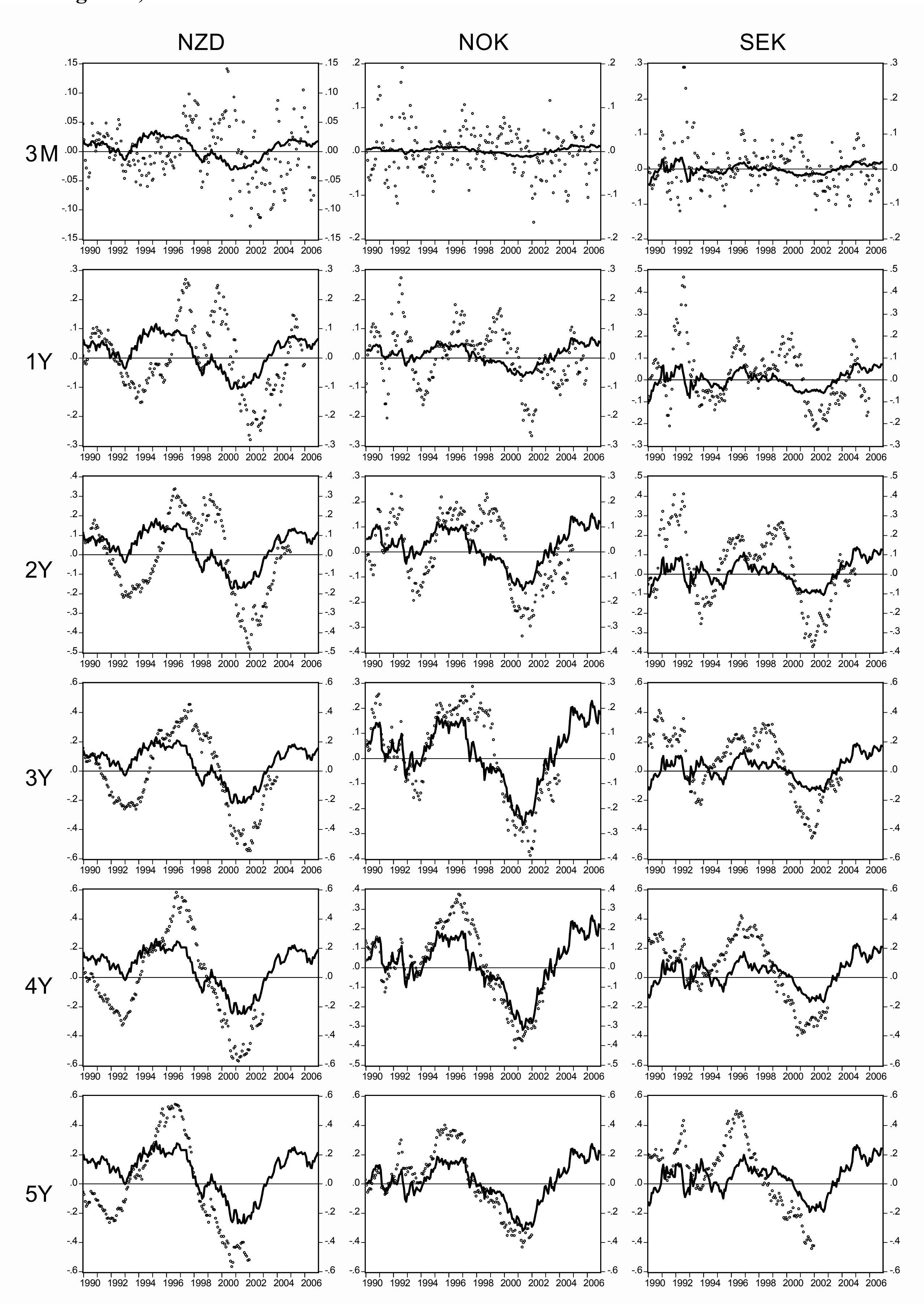


**Figure 2, continued**




*Notes to Figure 2.* The panels show actual forward looking exchange rate changes (open circles) and out-of-sample forecasts (solid line) made at the date shown on the horizontal axis, for 3 months and 1, 2, 3, 4 and 5 years ahead. Model 'MOD S-F5Y' was used for DEM, JPY, CHF, CAD and SEK; model 'MOD S-3F' was used for GBP; equation 'EQ F5Y' was used for AUD; model 'MOD S-2F' was used for NZD; equation 'EQ F3Y' was used for NOK.