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DYNAMIC CORRELATIONS AND FORECASTING OF TERM STRUCTURE SLOPES IN EUROCURRENCY MARKETS

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ABSTRACT

Using monthly data on Euro-rates for 1979-1998, we examine the extent to which cross-country information on term structure slopes can be used to improve upon univariate slope forecasts. This is interesting from the point of view of forecasting economic activity, since term structure slopes are known to anticipate fluctuations in the real economy. Additionally, the Expectations Hypothesis states that the term structure slope summarizes the available information which is relevant for forecasting future short-term interest rates, so that improved slope forecasts might also lead to better forecasts of future interest rates. We find ample evidence of significant explanatory power in term structure slopes across countries. Besides, we document that this information content leads to improved forecasts of the term structure slope in some countries, using a foreign slope as indicator.

Keywords: *Term structure of interest rates, term structure slope, Expectations Hypothesis, Eurocurrencies*

JEL Classification: E37, E43

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1. INTRODUCTION

Recent empirical work by Estrella and Hardouvelis (1991), Stock and Watson (1988), Hardouvelis (1994) and Plosser and Rouwenhorst (1994), among others, has documented the existence of information in the term structure slope which is relevant to forecast future changes in economic activity. This is a notorious result, since it is the spread in nominal returns which turns out to be useful to forecast future changes in the real economy. Besides, the informational content in the term structure slope is additional to that in past economic activity, inflation, or even in the Index of Leading Indicators, in the case of the *US*.

If changes in yield curve slopes in different countries were dynamically related, some of them could hopefully be used to predict changes in other countries' slopes better than from their own past alone. To explore this possibility in Eurocurrency markets is the focus of this paper. A consequence of that possible improvement in slope predictions is that predictions of changes in economic activity might also be improved using information of term structure slopes across countries. The study is also interesting from the point of view of the *Expectations Hypothesis* of the term structure of interest rates, according to which, the term structure slope summarizes all the relevant available information on future short-term rates. Again, if changes in term structure slopes could be anticipated from changes in slopes in other currencies, using that information might help to improve predictions of future interest rates, relative to using domestic data alone.

It is widely believed that monetary policy actions in some countries lead to similar interventions in other countries. This may be particularly true of the *US*, where decisions by the Federal Reserve Board on interest rates influence monetary policy decisions in most other western economies. This effect would lead to interest rate correlations that might appear as contemporaneous in monthly data. In addition, increased monetary policy coordination, as it has been the case in Europe in the recent past, has led to common interest rate fluctuations among countries members of the *EMS*.

However, since monetary authorities in all countries determine very short-term interest rates, we should expect to see high correlations in the shorter end of the term structure, but not necessarily among longer-term rates. Two extreme views of long-term interest rate determination would lead from correlations between short-term rates to correlations between slopes: if longer-term rates were roughly constant (they are much less volatile than short-term rates in all countries) high correlations among short-term rates would also show as high correlations among term structure slopes. A view that the spread between long- and short-term interest rates is roughly constant over time would also lead to high correlations among slopes. However, none of them is fully realistic, and deviations from these views on long-term rates would produce lower correlations among slopes than among interest rates.

Even if term structure slopes are correlated, that does not guarantee that using cross-country data could lead to improved slope forecasts. Given the difficulty of forecasting interest rate spreads, to obtain better forecasts we need systematic correlations among slopes in different currencies that do not get fully transmitted immediately, so that dynamic correlations exist and are stable.

In Section 2 we specify and estimate regression models to capture the dynamics of the relationships between term structure slopes in different currencies, and measure the extent to which there is explanatory power in slope fluctuations across currencies. In Section 3 we analyze whether the detected explanatory power across countries can be translated into improved slope forecasts. The paper closes with some conclusions.

2. RELATIONSHIPS AMONG TERM STRUCTURE SLOPES ACROSS EUROCURRENCIES

Euro-currency markets originated in the 50's to take advantage of the fact that the *US* legislation allowed deposits kept abroad in a currency other than the *US* dollar, not to be subject to reserve requirements. This mechanism generated a process which developed markets in a number of eurocurrencies, with basis in London. The development of Euro-currency markets was stimulated by the successive crisis in oil prices during the 70's, when oil producing countries invested their resulting current account surplus in them, and negotiated volumes have continuously increased since then.

In the London eurocurrency market interest rates are quoted for deposits denominated in a variety of currencies and maturities. Being off-shore, deposits in the eurocurrency market share some important characteristics like the fiscal treatment of returns or the timing of return payments, and they are not subject to possible government interventions like capital controls, which makes their observed returns more comparable than interest rates from domestic markets. We use monthly data on Euro-rates for the *US* dollar, Japanese yen, Deutsche mark, British pound, French franc and Swiss franc for

1979:1-1998:12 to compute their longer spread, that between returns on 12- and 1-month deposits, and examine their dynamic cross-correlations.

A number of papers have provided evidence that Euro-returns on deposits in different maturities and currencies are related, although the appropriate interpretation of these relationships is still open to discussion. Based on causality tests with data for 1979-1988 on Euro-rates on 3-month deposits for a number of european currencies, Karfakis and Moschos (1990) found evidence of a *Deutsche mark-zone*, reflected in a Granger-causality structure running from the 3-month rate on the Deutsche mark, to those on other european currencies. However, deGrauwe (1989), vonHagen and Fratiani (1990) and Katsimbris and Miller (1993) argued against that result for not taking properly into account the common effect of a third factor, *US* interest rates. These authors argue for: *a*) a quite more complex set of interactions among interest rates across countries, and *b*) an almost equally important role for Deutsche mark and *US* interest rates in determining those in *EMS* countries. With an enlarged sample for 1979-1997, Domínguez and Novales (1998) have found Euro-returns on different currencies at a given maturity to be cointegrated, as well as a clear evidence in the pre-1999 years that Deutsche rates were causal prior to those in other *EMS* countries, in line with the results of Karfakis and Moschos (1990).

Leaving aside the discussion on how to interpret these results, the long-run relationships among interest rates at a same maturity across currencies do not guarantee by themselves that an improvement in forecasting slopes will follow. The evidence in favor of cointegration among returns means that they share the same long-run trend, but it leaves open the possibility that short-term fluctuations may be unrelated. As a consequence, correlations among short-term rates across countries, as well as correlations among their long-term rates will not necessarily be large, and correlations among their respective slopes might be even lower. Hence, cointegration between rates on a given maturity on different currencies does not imply that their term structure slopes will fluctuate together, so that there may not be noticeable explanatory power between slopes in different countries, and improving slope forecasts may not be simple.

We analyze the possible connections among *term structure slopes* across different Eurocurrencies, defined as the spread between returns on 12- and 1-month deposits, $r_t^{12} \& r_t^{1}$, shown in Figure 1 for 1984-1998. Their graphs over the whole 1979-1998 period are dominated by wide fluctuations in the first years of the sample, reflecting the high volatility of those years. The high volatility of interest rates in 1979-1984 was not uniform across maturities, which translated into very volatile slopes. The volatility in this initial period dominates graphs of slopes for the full 1979-1998 sample (not shown), rendering an impression of lack of stationarity. Since we are interested on forecasting, we will search for dynamic correlations, measuring the extent to which a foreign slope, used as indicator, adds explanatory and predictive power to a univariate dynamic model for a given slope.

Using Augmented Dickey-Fuller (*ADF*) tests at the 5% significance level [Table 1] in the more stable 1984-1998 subsample we reject the hypothesis that the term structure slopes contain a unit root for all currencies, in spite of the fact that their graphs for this period could throw some doubt about their stationarity [Figure 1]. To be safe, we specified all our models in first differences of the slopes, from which we can recover predictions for the slopes. Since there is no clear evidence of lack of stationarity, we did not specify error correction models. Besides, attempts to estimate significant error correction terms in bivariate models of slopes were not very fruitful.

The relationships among european countries´ interest rates even before their common membership to the *EMS* has produced significant correlations among term structure slopes as well, as shown in Table 2 for 1984-1998 and 1991-1998. Correlations have been higher during the more recent period, due to an increased coordination of monetary policies. Surprisingly, slopes for the *US* dollar, yen and Deutsche mark do not show large correlations. In fact, the yen slope presents its higher correlations with the slopes of the British pound and the Swiss franc. Contrary to an increased globalization of international financial markets, slopes for the yen and the *US* dollar seem to have grown increasingly independent in the second part of the sample. The *US* dollar slope only shows some recent correlation with that of the British pound, maybe because of the recent chronological syncronicity in their business cycles.

As it is the case with returns themselves, we would *a priori* expect the slopes for interest rates on Deutsche mark and *US* dollar Eurodeposits to influence the slopes of the other european currencies, while the slopes of the *US* dollar, Deutsche mark and Japanese yen yield curves might show complex interactions. These relationships, which are not evident in Table 2, might reveal only with some dynamics. To test this set of hypotheses, we estimated an autoregressive model for each slope,

$$\Delta(r^{12}_{1t} - r^{1}_{1t}) = \alpha + \sum_{i=1}^{k} \beta_i \, \Delta(r^{12}_{1t-i} - r^{1}_{1t-i}) + \varepsilon_t$$

then adding to that model the term structure slope from the currency which is supposed to be influential,

$$\Delta(r^{12}_{1t}-r^{1}_{1t}) = \alpha + \sum_{i=1}^{k} \beta_i \, \Delta(r^{12}_{1t-i}-r^{1}_{1t-i}) + \sum_{j=0}^{s} \gamma_j \, \Delta(r^{12}_{2t-j}-r^{1}_{2t-j}) + u_t$$

where $r_{1t}^{j}, j = 1,12$ denotes the one and twelve month interest rates in the affected currency, while r_{2t}^{j}, $j = 1,12$ denotes the returns on the influential currency. If the slope for country 2 is, in fact, influential, we would expect to obtain a substantially higher corrected *R*-squared ($\bar{R}^2$) and a lower Standard Error of Estimate (*SEE*) in the augmented regression model. It is important to bear in mind that we are not searching for all the explanatory power that might exist between slopes, but rather, for whether a given slope, used as indicator, contains information *additional* to that in the past of the slope being explained.

We use the Deutsche mark and *US* dollar slopes as indicators for the slopes of european currencies, and the term structure slopes of the *US* dollar, Deutsche mark and Japanese yens as indicators for each other. We report estimates for the 1979-1997 sample, since we have not found that the higher interest rate volatility at the beginning of the sample produces a significant loss of efficiency in estimation or a deterioration in forecasting performance. We fitted a univariate *AR*(3) model for the slope being predicted in all cases [$k=3$ in the previous equation]. Even though we did not perform a systematic search for a *best* model, the *AR*(3) is flexible enough to accommodate a cyclical behavior (if it has two complex roots), as well as a quite permanent component, if it existed (which it would show as a real root close to the unit circle). Estimated univariate models are presented in the left column of each panel in Table 3, while columns to the right show the models estimated after introducing another country's slope as an indicator, contemporaneously and with some lags. We present the lag specifications that produced the best forecasts, after estimating the proposed model for $s=1,2,3$. The need to predict in advance the contemporaneous value of the indicator when computing slope forecasts in the next Section, occasionally led to notorious deterioration in forecast performance which suggested us to exclude that contemporaneous value in some cases, as shown in Table 3.

Our estimates show that there is widespread evidence that term structure slopes for different currencies contain relevant information on each other, even after the own past of the slope being explained has been taken into account. The $\bar{R}^2$ almost doubles in several cases, with corresponding reductions in the Standard Error of Estimate. The Deutsche mark slope is dynamically correlated with the european slopes, but also with the slopes of the yen and the *US* dollar. Its contemporaneous value and occasionally some lags are significant in these regressions, as indicated by the *t*-ratios, as well as by the *F*-statistics that test for joint significance. The *US* dollar slope shows some dynamic effects on the slopes of the British pound and the Deutsche mark. In addition, the *US* dollar, Deutsche mark and Japanese slopes have significant explanatory power for each other, although the *US* dollar slope is not significant in the equation for the yen slope. The estimated long-run effects of the Deutsche mark and yen slopes on that of the *US* dollar are estimated to be negative, an interesting empirical fact for which do not have at this point a sensible interpretation. The slope of the Swiss franc is the only one for which we have not found any significant indicator.

There is evidence of conditional heteroskedasticity in the residuals of all regressions, as indicated by the statistics to test for *ARCH* structures of order 1 and 4. Although it should not be expected to significantly deteriorate forecasting results, it would be interesting to obtain a more detailed specification capturing those effects. On the other hand, there is no evidence of residual autocorrelation for the British pound and the Deutsche mark. Statistics for residual autocorrelation (Durbin-Watson statistic, Ljung-Box-Pierce *Q* with 36 lagged autocorrelations, as well as Lagrange Multiplier statistics for first and fourth order autocorrelation) provide mixed evidence in models for the French franc and Swiss franc. Since we could not find simple extensions of the lag specifications that would completely eliminate autocorrelation, we interpret these statistics as not giving strong evidence of residual autocorrelation. We must admit, however, significant residual autocorrelation in the models for yen and *US* dollar but, again, we could not find a sensible specification that would eliminate residual autocorrelation. If successful, a systematic search for a model that gets rid of this effect could only lead to better forecasts than those we report in the next Section.

In our monthly frequencies the information content extends beyond the pure contemporaneous correlation, with some lags of the slope used as indicator being significant in each regression. This provides hope for extracting some forecasting gain from the use of indicator models, relative to univariate autoregressions. However, a better fit does not necessarily come together with an improvement in forecasting ability, and we devote next Section to analyze the extent to which a given country's term structure slope can be used to improve forecasts on another country's slope, relative to those based on its own past alone.

3. PREDICTING TERM STRUCTURE SLOPES WITH CROSS COUNTRY DATA.

We discuss in this section the extent to which the in-sample explanatory power in term structure slopes across countries can actually be used to improve upon univariate forecasts. We report forecasts for the term structure slope in each currency, with and without one other country's slope as a possible indicator, using the models estimated in the previous Section. This is quite a strict request, since we are not just testing whether the term structure slope in an influential country produces, by itself, good forecasts for another country but rather, whether it improves upon the forecasts obtained from the own past of the slope being analyzed.

We computed forecasts using the univariate *AR*(3) for each slope, as well as the regression that includes another country's slope as indicator, both models as estimated in Table 3. The forecasting exercise consisted on estimating each model with data up to December 1997 and obtaining forecasts over 1998. We obtained *static* and *dynamic* forecasts. *Static* forecasts are one-step-ahead predictions, which use actual values for all explanatory variables, except the contemporaneous value of the indicator, which needs to be predicted. *Dynamic* forecasts are once-and-for-all predictions for the twelve months of 1998, calculated with models estimated using data up to December 1997. As we ran out of actual data in dynamic forecasting, we used previously obtained forecasts for the lagged slope being predicted, as well as for the contemporaneous and lagged indicator. To obtain forecasts for the indicator, an *AR*(3) model in differences was used again in both forecasting exercises, for the same reasons mentioned in the previous Section.

Percent Root Mean Square Errors are not advisable in this forecasting exercise, since the slope often becomes small in absolute value, to the point that even acceptable forecast errors might produce huge percent errors for a single period, dominating the value of any time aggregate forecasting performance indicator. Hence, we will use their versions in absolute terms. We provide in Table 4 the Mean and Median Absolute Errors, the Root Mean Square Error (*RMSE*), and Theil's *U*-statistic as forecasting performance measures for univariate models as well as for models with indicators. A large forecast error in a particular month will tend to produce a high average measure, so that the Median should be preferred to the Mean Absolute Error. The left column in each panel contains the error measures for univariate forecasts, while the remaining columns show error measures when an indicator is added to the forecasting model. The indicator name and lags used are shown on top of each column. Table 4 shows first the sample average absolute values of the slope being predicted over the forecasting horizon, 1998:1-1998:12. This is the reference with which the forecast statistics could be compared to evaluate forecast quality.

Slopes for the British pound, French franc, Deutsche mark and *US* dollar were stable and positive in the first semester of 1998, declining afterwards, while the term structure was taking an inverted shape [Figure 2]. Slopes for the Swiss franc and yen showed a pattern different from those of other currencies. When trying to anticipate this behavior, dynamic forecasting always produces bigger forecast errors, since they project over the whole 1998 using only data up to December 1997.

Univariate models produced small average one-step-ahead forecast errors relative to the sample mean absolute slope for all currencies except the yen, for which the reduction was minimal. However, even for the yen, the median absolute one-step-ahead forecast error was well below the average absolute slope. For the French franc, Deutsche mark, Swiss franc and *US* dollar, the median absolute forecast error was less than half the average absolute slope.

Considering *static*, one-step-ahead slope forecasts for european currencies (British pound, French franc, Swiss franc), the Deutsche mark slope leads to improved forecasts relative to the univariate *AR*(3) model. The *US* dollar slope also improves slope forecasts for all european currencies, including the Deutsche mark, but with the exception of the Swiss franc. Evidence that the *US* dollar and yen slopes help predict each other is, at most, weak. As expected, the Deutsche mark slope does not help predict that of the *US* dollar, although it helps predict the slope for the yen. This is specially surprising because the yen slope does not help improve *static* forecasts of the Deutsche mark slope. In some cases, percentage reductions in forecasting performance measures are substantial.

Cross-country information on term structure slopes can also be used to improve *dynamic* slope forecasts. The *US* dollar slope again improves univariate forecasts of all european currencies slopes, including the Swiss franc. The Deutsche mark slope also helps predict the slopes of other european currencies, except for the French franc. Dynamic univariate forecasts of the Deutsche mark slope can be improved upon using the *US* dollar and yen slopes as indicators. The Deutsche mark slope can again be used to improve forecasts of the yen slope, but not that of the *US* dollar. Again, Evidence that the US dollar and yen slopes help predict each other is rather weak. These improvements in dynamic forecasting arise because the indicator helps to track somewhat the changed behavior of the slopes during 1998.

That the augmented model may improve forecasts in most cases when expected, is remarkable, given the need to forecast the contemporaneous value of the indicator in static and dynamic forecasting, and its lagged values in dynamic forecasting. When actual values of the indicator are used, forecasts [not shown] significantly improve over univariate autoregressions. Even though further simplification of the regression models might be interesting, we decided not to pursue it at this point, in order not to condition our forecasting results on extensive *data mining*.

Results for *static* and *dynamic* forecasting over each of the two semesters of 1998 [not presented here] show similar qualitative results. On the other hand, forecasting results for 1997, based on models estimated with data up to december 1997, show forecast improvements similar to those we have mentioned.

Summarizing, we have found strong evidence that the Deutsche mark and *US* slopes help predict the slopes of non-German european currencies. The *US* dollar slope helps to improve static and dynamic forecast of the Deutsche mark slope, while there is no forecast gain in the other direction. Somewhat surprisingly, the Deutsche mark slope helps predict that of the yen. There is evidence that the *US* dollar and yen slopes help predict each other, but the evidence is much weaker than expected.

These results should be taken as a lower bound on the forecasting power of cross-country term structure slope data, since we have used a standard *AR*(3) model fitted to differenced data to produce forecasts of the slope indicator in all cases. With that in mind, the results look promising. Carefully searching for a good forecasting model, specific of each slope, might produce better forecasting results, and further clarify this issue.

4. CONCLUSIONS

Using Euro-rates monthly data on the British pound, French franc, Deutsche mark, Swiss franc, Japanese yen and *US* dollar over 1979-1998, we have documented ample evidence of explanatory power in Deutsche mark and *US* dollar slopes relative to those of other european countries. The Japanese yen and the *US* dollar slopes have explanatory power for that of the Deutsche mark and both, the slopes of the yen and the Deutsche mark have explanatory power for the *US* dollar slope. The Deutsche mark slope helps explain that of the yen, for which the slope of the *US* dollar does not seem to contain significant information. This is in all cases information additional to that contained in the past of the slope being explained. Since our estimated models suggest significant contemporaneous and lagged correlations among slopes, we have also examined the extent to which the explanatory power across countries could be translated into improved forecasts.

Our forecasting exercise has been quite strict, since we have not just checked whether an influential slope can produce good forecasts but, rather, whether incorporating it into a univariate model of the slope being predicted, improves forecasts. Even though the contemporaneous effect of the relationship between slopes needs to be predicted in advance, we have found that the *US* dollar slope can be used to improve upon univariate *static* and *dynamic* forecasts of term structure slopes for most countries. Information in the Deutsche mark slope leads to better forecasts of the slopes of european currencies. The slope of the yen improves *dynamic* forecast of the Deutsche mark slope. We have also found two somewhat unexpected results: *a*) using information in the Deutsche mark slope helps to improve forecasts of the term structure slope for the yen, and *b*) evidence that the Japanese and *US* dollar slopes help predict each other is weak. Even though individual term structures for currencies in the euro zone no longer exist, the positive results of our exercise suggest that forecasting slopes for the yen, *US* dollar, euro, and other european currencies not in the euro zone will remain a promising exercise in the next years.

There are theoretical and empirical reasons suggesting that the term structure slope may contain relevant information on future short term rates, as well as on future economic activity. Our results then suggest that forecasts of future short-term interest rates or future economic activity could be improved by exploiting these correlations between term structure slopes across countries. However, these would be composed forecasting exercises, and it is not obvious that some significant forecast gain would arise. Testing for that possibility is a natural avenue for trying to extend the results in this paper.

To escape from the impression that the improved forecasts are the result of data mining, we have not performed an extensive search for the best forecast models for each slope but rather, we have used a common model in all cases. As a consequence, our results should be viewed as a lower bound on the ability of using slope correlations across countries to improve forecasts. Finding more parsimonious, currency-specific parameterizations and characterizing an even better framework for transforming correlations between slopes across countries into improved forecasting performance remain as interesting issues for further research.

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Table 1

Unit root tests in eurocurrency term structure slopes.

Currency	*Augmented Dickey-Fuller*[a] 1979-98	1984-98	*Phillips-Perron statistic* 1979-98	1984-98
British pound	-5.31^{**} (1)	-3.03^{**} (2)	-5.12^{**}	-3.44^{**}
French franc	-2.74^{**} (9)	-3.04^{**} (4)	-6.23^{**}	-3.88^{**}
Deutsche mark	-3.20^{**} (12)	-2.80^{**} (0)	-4.45^{**}	-2.80^{**}
Swiss franc	-1.70 (9)	-3.23^{**} (3)	-3.37^{**}	-5.02^{**}
Japanese yen	-5.31^{**} (12)	-3.44^{**} (4)	-6.81^{**}	-4.89^{**}
US dollar	-3.59^{**} (4)	-3.45^{*} (0,*c*)	-5.66^{**}	-3.45^{*}

Note: Left column sample: 1979-98. Right column sample: 1984-98. Critical values at 95% and 99% confidence levels: -1.94 and -2.58, respectively, for models without constant, -2.88 and -3.47, respectively, for models with constant. An (two) asterisk denotes rejection of the null hypothesis at the 5% (1%) significance level. The number of lags used in the regression for the differenced variable when running the *Augmented Dickey-Fuller* test is shown in brackets. *c* denotes that a constant was included in the test regression.

Table 2

Contemporaneous correlation coefficients between slopes

	British pound	*French franc*	*Deutsche mark*	*Swiss franc*	*Yen*	*US dollar*
British pound	1	0.41	0.41	0.61	0.65	0.49
French franc	0.27	1	0.87	0.72	0.26	0.15
Deutsche mark	0.27	0.73	1	0.82	0.14	0.09
Swiss franc	0.46	0.62	0.76	1	0.44	0.17
Yen	0.54	0.35	0.29	0.47	1	0.20
US dollar	0.32	0.41	0.20	0.32	0.30	1

Note: The lower triangular matrix shows contemporaneous correlations between slopes for the 1984-1998 sample. The upper triangular matrix shows correlations for the 1991-1998 subsample.

Table 3
Regression models for differenced term structure slopes. Estimation sample: 1979:1-1997:12

	British pound			*French franc*			*Deutsche mark*			*Swiss franc*			*Yen*			*US Dollar*		
	Own lags			*Own lags*			*Own lags*			*Own lags*			*Own lags*			*Own lags*		
$i=1$	0.011	-0.079	-0.005	-0.154	-0.134	-0.173	-0.234	-0.259	-0.224	-0.358	-0.348	-0.361	-0.002	-0.050	-0.006	0.087	0.124	0.063
	(0.066)	(0.068)	(0.024)	(0.067)	(0.068)	(0.068)	(0.067)	(0.066)	(0.072)	(0.067)	(0.068)	(0.069)	(0.063)	(0.067)	(0.064)	(0.067)	(0.065)	(0.067)
$i=2$	-0.226	-0.274	-0.222	-0.044	-0.052	-0.057	-0.172	-0.110	-0.129	-0.031	-0.035	-0.032	-0.182	-0.137	-0.184	-0.328	-0.294	-0.321
	(0.063)	(0.064)	(0.066)	(0.068)	(0.069)	(0.069)	(0.068)	(0.062)	(0.073)	(0.071)	(0.072)	(0.072)	(0.056)	(0.058)	(0.056)	(0.063)	(0.060)	(0.059)
$i=3$	-0.132	-0.174	-0.095	0.066	0.061	0.063	-0.108	-0.119	-0.092	0.010	0.002	0.110	0.292	0.258	0.275	-0.121	-0.111	-0.183
	(0.065)	(0.066)	(0.067)	(0.067)	(0.066)	(0.068)	(0.067)	(0.061)	(0.072)	(0.067)	(0.068)	(0.068)	(0.056)	(0.054)	(0.061)	(0.067)	(0.063)	(0.065)
		DM lags	*US lags*		*DM lags*	*US lags*		*Yen lags*	*US lags*		*DM lags*	*US lags*		*DM lags*	*US lags*		*DM lags*	*Yen lags*
$j=0$		0.312	0.017		1.043			0.215	0.055					0.528			0.313	
		(0.093)	(0.041)		(0.321)			(0.037)	(0.030)					(0.102)			(0.150)	
$j=1$		0.266	0.010		-0.156	0.264		0.151	0.068		-0.211	0.020		-0.058	-0.033		-0.719	-0.065
		(0.097)	(0.041)		(0.333)	(0.140)		(0.039)	(0.030)		(0.271)	(0.110)		(0.111)	(0.045)		(0.152)	(0.093)
$j=2$		0.250	0.079		0.103	0.037			0.027		0.255			-0.073				-0.533
		(0.099)	(0.040)		(0.330)	(0.133)			(0.030)		(0.274)			(0.107)				(0.078)
$j=3$		0.089	0.083			0.059			0.070		-0.010							0.003
		(0.095)	(0.040)			(0.141)			(0.029)		(0.271)							(0.085)
$\bar{R}^2$	0.06	0.11	0.09	0.02	0.05	0.02	0.06	0.22	0.09	0.11	0.11	0.11	0.15	0.25	0.14	0.13	0.24	0.27
SEE	0.369	0.359	0.364	1.306	1.280	1.303	0.267	0.243	0.262	1.070	1.073	1.072	0.414	0.389	0.414	0.627	0.590	0.572
F		4.19**	2.36		3.97**	1.28		24.1**	3.28*		0.63	0.03		10.7**	0.54		16.7**	15.8**
Arch(1)	68.3**	66.3**	67.9**	15.3**	15.80**	16.2**	36.2**	25.5**	38.6**	7.6**	7.7**	7.6**	15.8**	13.0**	16.2**	29.5**	23.6**	32.1**
Arch(4)	70.0**	66.9**	69.4**	38.1**	38.38**	37.1**	42.8**	35.1**	45.3**	12.0**	13.2**	11.8**	25.0**	26.6**	24.6**	36.6**	34.8**	35.1**
DW	1.99	1.99	1.98	1.99	2.00	1.95	2.00	2.03	1.97	2.00	2.00	2.00	1.81	1.84	1.80	2.06	2.10	2.03
Q(36)	43.2	42.5	42.9	43.2	46.2	172.6**	68.9**	54.9*	81.0**	50.8	46.8	51.7*	127.8**	91.0**	119.7**	56.4**	63.4*	61.3**
LM(1)	0.10	0.11	0.75	30.1**	26.53**	27.1**	0.59	0.79	0.75	17.6**	11.6**	11.3**	20.6**	15.9**	25.3**	22.9**	5.9*	8.7**
LM(4)	0.34	0.88	1.69	17.6**	12.41**	16.7**	1.45	0.25	1.37	8.9**	5.0**	4.6**	11.4**	8.2**	15.5**	8.5**	8.0**	2.9*

Note: The left column in each panel contains estimates of the univariate model. The remaining columns present estimates of the model with indicator. A constant (generally non-significant) was included in all models. $\bar{R}^2$ and *SEE* denote the coefficient of determination, adjusted for degrees of freedom, and standard error of estimate of each regression. *F* denotes the *F*-statistic for joint significance of the slope being used as an indicator. *Arch*(1) and *Arch*(4) denote the statistics to test for *Arch* structures of order 1 and 4. *DW* is the Durbin-Watson statistic, *Q*(36) is the Ljung-Box-Pierce statistic based on 36 values of the autocorrelation function of the residuals, and *LM*(1) and *LM*(4) are Lagrange multipliers statistics to test for residual autocorrelation of order 1 and 4, respectively. An (two) asterisk denotes rejection of the null hypothesis at the 5% (1%) significance level.

Table 4

Forecasting performance measures

	British pound			*French franc*			*Deutsche Mark*			*Swiss franc*			*Yen*			*US Dollar*		
Slope used as indicator, and number of lags[a]		*DM* (0-3)	*US* (0-3)		*DM* (0-2)	*US* (1-3)		*Yen* (0-1)	*US* (0-3)		*DM* (1-3)	*US* (1)		*DM* (0-2)	*US* (1)		*DM* (0-1)	*Yen* (1-3)
Sample absolute mean values[b]: 1998:1-1998:12	0.268			0.264			0.249			0.288			0.068			0.213		
Static forecasts[c]																		
Mean	0.167	0.151	0.164	0.075	0.067	0.057	0.089	0.094	0.074	0.090	0.080	0.092	0.066	0.062	0.065	0.141	0.150	0.138
Median	0.150	0.108	0.138	0.057	0.043	0.048	0.073	0.093	0.053	0.061	0.044	0.061	0.049	0.043	0.050	0.079	0.109	0.086
RMSE	0.214	0.187	0.205	0.090	0.085	0.075	0.111	0.115	0.098	0.120	0.112	0.121	0.083	0.052	0.082	0.196	0.205	0.187
U	0.332	0.286	0.311	0.142	0.135	0.122	0.188	0.193	0.169	0.183	0.173	0.186	0.562	0.507	0.554	0.447	0.473	0.430
Dynamic forecasts																		
Mean	0.439	0.406	0.416	0.203	0.280	0.151	0.194	0.184	0.166	0.170	0.153	0.168	0.091	0.033	0.086	0.198	0.257	0.196
Median	0.287	0.238	0.258	0.150	0.226	0.090	0.119	0.105	0.087	0.162	0.147	0.159	0.087	0.020	0.082	0.069	0.139	0.084
RMSE	0.564	0.534	0.542	0.256	0.322	0.214	0.268	0.261	0.247	0.207	0.195	0.205	0.094	0.051	0.090	0.289	0.353	0.282
U	0.831	0.836	0.833	0.342	0.389	0.308	0.387	0.382	0.372	0.271	0.260	0.270	0.936	0.418	0.934	0.770	0.736	0.740

Notes:
a) The left column in each panel shows performance measures for univariate forecasts. The remaining columns contain performance measures for models with indicators. The indicator and lags used are shown on top of each column.
b) Mean absolute values of the slope over the forecasting horizon.
c) *Mean* and *Median* are the mean and median absolute values of the forecasting errors. *RMSE* denotes the Root Mean Square Error, while *U* denotes Theil's statistic.