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Models of Exchange Rate Expectations: Heterogeneous Evidence from Panel Data

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SUMMARY

Central to an understanding of how foreign exchange markets work is the nature of the expectations formation process. Of particular interest are the potentially stabilising or destabilising nature of these expectations. The purpose of this paper is to determine the nature of the expectations processes governing agents' expectations formation and the degree of heterogeneity of such expectations. We use a unique desegregate expectations data base to model the expectations formation of around 40 leading foreign exchange forecasters/ dealers. Panel estimators are used to increase the power of the tests.

Four different expectational structures are examined, namely an extrapolative, an adaptive, a regressive and a mixed model. The expectational series used are extracted from the survey data base of Consensus Forecasts of London, and consist of 3 and 12 month expectations of the US dollar bilateral rates of the German mark, Japanese yen and pound sterling, for the period January 1990 to December 1994. Our testing methods center around two panel estimators, namely a fixed effect model and a random coefficient model. The former is seen as a base-line model in which we capture heterogeneities solely in terms of differing intercepts across individuals, whereas in the latter heterogeneity also exhibits itself in terms of differing coefficients and is summarised with a Swamy test. Our results can be summarised as follows.

Firstly, exchange rate expectations seem to be stabilising at both the 3 and 12 month horizons. Estimates of the extrapolative model, which is used by around eighty per cent of the survey respondents analysed, show that agents use a current exchange rate change to predict a future change in the opposite direction. The stabilising nature of exchange rate expectations is further revealed by our panel estimates of the regressive expectations model, where the coefficients on the regressive expectations terms always appear significantly positive at both forecast horizons. The coefficients estimated from the adaptive expectations models are also indicative of stabilising behaviour, in the sense that the magnitude of a current forecast error is offset in the next period by a statistically significant proportion. This finding is something of an antidote to the widely perceived view that foreign exchange markets are dominated by bandwagon, and other forms of non-stabilising, expectations at horizons of three months and greater.

Our second main finding is that the models used and coefficient estimates can differ across individuals. Specifically, a large number of individuals do not use each basic (i.e. extrapolative, regressive or adaptive) model, while few individuals use the three models at the same time (mixed model). This finding shows that the mixed behaviour of the panel average found in previous studies results from the aggregation of heterogeneous individuals. Among individuals who use a specific model, there are important heterogeneities in the coefficients used. We believe our finding of heterogeneous expectation processes across individuals justifies the building of models of exchange rate determination, which are based on the coexistence of various types of agents. This finding may also be important for policy makers who should not expect all speculators to behave in the same way in the foreign exchange market.

Finally, some results differ across currencies and horizons. The differences across currencies should not be taken too seriously since they could be related to the time span considered. The differences across horizons are more significant. Namely, the regressive model, and more specifically, absolute PPP reversion, performs better for the 12 month horizon, while relative PPP performs better for the 3 month horizon. Within the extrapolative specification, there is less heterogeneity for the 12-month horizon than for the 3-month horizon, meaning that forecasters probably rely more heavily on public forecasts in the latter case. Hence, models of exchange rate determination based on the interaction between heterogeneous, sometimes destabilising, forecasters seem to apply only to frequencies of less than three months.

RÉSUMÉ

La compréhension de la dynamique des taux de change passe par la connaissance des modes de formation des anticipations, et en particulier de leur nature potentiellement déstabilisante. Nous étudions ici les modèles d'anticipation utilisés par les agents, ainsi que le degré d'hétérogénéité de ces modèles entre individus, à partir de données d'enquête portant sur une quarantaine de prévisionnistes, et en effectuant des estimations économétriques en panels.

Quatre schémas d'anticipations sont successivement examinés. Il s'agit des modèles extrapolatif, régressif, adaptatif et mixte (régressif/extrapolatif/adaptatif). Les séries d'anticipations sont tirées de la base Consensus Forecasts de Londres. Elles concernent les taux de change du mark allemand, de la livre Sterling et du yen par rapport au dollar US, aux horizons de 3 et 12 mois durant la période janvier 1990-décembre 1994. Chaque modèle est testé sous deux formes : l'une à effets fixes, et l'autre à coefficients aléatoires. Dans les modèles à effets fixes, les hétérogénéités entre individus ne se matérialisent que par des constantes différentes entre eux, alors que dans les modèles à coefficients aléatoires, les coefficients eux-mêmes varient selon les individus, et les hétérogénéités sont résumées à l'aide de tests de Swamy. Nos résultats peuvent être résumés ainsi.

D'abord, les anticipations de change semblent stabilisantes aux horizons de 3 et 12 mois. Les estimations du modèle extrapolatif, qui est utilisé par environ 80% des prévisionnistes du panel, montrent que les agents utilisent la variation passée du taux de change pour prévoir une variation en sens inverse. La nature stabilisante des anticipations est confirmée par les estimations du modèle régressif qui montrent que les agents croient à un retour du taux de change vers son niveau correspondant à la parité de pouvoir d'achat. Enfin, les estimations du modèle adaptatif mettent en évidence un mécanisme stabilisant de correction des erreurs passées. Ces résultats vont à l'encontre, pour les horizons de 3 mois et plus, d'une idée reçue selon laquelle le marché des changes est dominé par des comportements d'entraînement déstabilisants.

Deuxièmement, les modèles utilisés, ainsi que leurs coefficients, varient selon les individus. Chacun des trois modèles de base (extrapolatif, régressif, adaptatif) est négligé par une proportion importante des prévisonnistes, alors que très peu d'entre eux utilisent les trois modèles à la fois (modèle mixte). Ainsi, les résultats satisfaisants obtenus, dans des études antérieures, lors de l'estimation du modèle mixte sur l'anticipation moyenne du panel, peuvent s'interpréter comme le résultat de l'agrégation de comportements hétérogènes. Parmi les individus qui utilisent l'un ou l'autre des modèles de base, les coefficients utilisés varient fortement. Nous pensons que l'hétérogénéité des modèles d'anticipation selon les individus justifie la construction de modèles de détermination du taux de change fondés sur la coexistence de types différents d'agents. Nos résultats sont également importants pour les banques centrales qui ne doivent pas s'attendre à ce que tous les agents se comportent de la même manière sur le marché des changes.

Enfin, nos résultats diffèrent selon les devises et les horizons. Il ne faut pas trop s'attacher aux différences entre devises qui peuvent être liées à la période considérée (1990-1994). Les différences entre horizons sont plus importantes. Ainsi, dans le modèle régressif, l'hypothèse d'un retour du taux de change vers son niveau de parité de pouvoir d'achat est répandue pour les prévisions à 12 mois, alors qu'à 3 mois, les agents semblent s'en tenir à une version relative de la PPA. De même, le modèle extrapolatif est moins hétérogène entre individus pour l'horizon de 12 mois qu'à 3 mois, peut-être parce que les individus s'en remettent davantage à des prévisions publiquement connues. Les modèles de détermination des taux de change fondés sur l'interaction d'agents hétérogènes aux comportements déstabilisants semblent donc s'appliquer seulement aux horizons les plus courts.

Models of Exchange Rate Expectations: Heterogeneous Evidence from Panel Data

Agnès Bénassy-Quéré[*], *Sophie Larribeau*[**] *and Ronald MacDonald*[#]

INTRODUCTION

The dynamic properties of exchange rates (particularly their excessive volatility) has proved a challenge to theorists who emphasise the importance of economic fundamentals in explaining exchange rate movements. This is perhaps most clearly seen in the apparent failure of fundamentals-based exchange rate models to outperform a simple random walk, a finding which 'continues to exert a pessimistic effect on the field of empirical exchange rate modelling in particular and international finance in general' (Frankel and Rose (1995))[1]. One way in which theorists have tried to address this issue is by relaxing the assumption of rational expectations which is central to many traditional theoretical models, such as the monetary approach to the exchange rate. The basis for this kind of work is the noise trader paradigm, introduced by De Long *et al* (1990), which emphasises the interaction of fundamentals-based (rational) traders and irrational or 'noise' traders. This kind of modelling approach has been applied in the exchange rate literature by Frankel and Froot (1986), who theoretically model the interaction of chartists and fundamentals-based traders. Although some efforts have been made to show that specific forecasting methods like imitation can be reconciled with rational expectations (see, for example, Orléan, 1986), little empirical work has been conducted to support the often *ad hoc* assumptions made in the theoretical literature.

The purpose of this paper is to determine the nature of the expectations processes governing agents' expectations formation and the degree of heterogeneity of such expectations. In contrast to other studies in this area, we use panel estimators to address these issues. Four different expectational structures were examined, namely an extrapolative, and adaptive, a regressive and a mixed model. The expectational series used are extracted from the survey data base of Consensus Economics of London, and consisted of 3 and 12 month expectations of the US dollar bilateral rates of the German mark, Japanese yen pound sterling, for the period January 1990 to December 1994. Our testing methods center around two panel estimators, namely a fixed effect model and a random coefficients models. The former is seen as a base-line model in which we capture heterogeneities solely in terms of differing

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[1] Although this view is not universally accepted - see MacDonald (1995).

intercepts across individuals, whereas in the latter heterogeneity also exhibits itself in terms of differing coefficients and is summarised with a Swany test.

We find that the models used and coefficient estimates can differ across individuals. Specifically, a large number of individuals do not use each basic (i.e. extrapolative, regressive or adaptive) model, while few individuals use several models at the same time (the mixed model performs poorly when coefficients are allowed to vary across individuals). This finding shows that the mixed behaviour of the panel average found in previous studies results from the aggregation of heterogeneous individuals. Among individuals who use a specific model, there are important heterogeneities in the coefficients used. For example, some individuals produce very small (and sometimes negative) coefficients of reversion in the regressive model. We believe our finding of heterogeneous expectation processes across individuals justifies the building of models of exchange rate determination which are based on the coexistence of various types of agents. This finding may also be important for policy makers who should not expect all speculators to behave in the same way in the foreign exchange market.

Some results differ across currencies and horizons. The differences across currencies should not be taken too seriously since they could be related to the time span considered. The differences across horizons are more significant. Namely, the regressive model, and more specifically, absolute PPP reversion, performs better for the 12 month horizon, while relative PPP performs better for the 3 month horizon. Within the extrapolative specification, there is less heterogeneity for the 12-month horizon than for the 3-month horizon, meaning that forecasters probably rely more heavily on public forecasts in the latter case. Hence, models of exchange rate determination based on the interaction between heterogeneous, sometimes destabilising, forecasters seems to apply only to frequencies of less than three months.

1. METHODOLOGY AND PREVIOUS EMPIRICAL WORK

In this section we discuss the basic form of the models estimated in succeeding sections; that is, the extrapolative, regressive and adaptive formulations. We then go on to examine the existing empirical evidence on these kinds of relationships. Finally, we present the tests of heterogeneity which are exploited in Sections 4 to 7.

1.1. Standard Expectations Formation Processes

The three basic expectations models have different implications in terms of the information used by individuals. The basic extrapolative model is usually defined as:

$$S^{a}_{i,t,h} - S_t = b(S_t - S_{t-1}), \quad b > 0\,, \tag{1}$$

where $S^{a}_{i,t,h}$ is the logarithm of the exchange rate that is expected by individual i, at time t, for time t+h (in this paper, h=3 or 12 months). S_t is the logarithm of the nominal exchange rate observed at time t. The extrapolative model assumes that forecasters are essentially chartists; that is, their expectations are based on the past evolution of the variable, its present value summing up available information.

The basic regressive model is defined as:

$$S^{a}_{i,t,h} - S_t = d(\bar{S}_t - S_t), \quad 0 < d < 1, \tag{2}$$

where $\bar{S}_t$ denotes a measure of the equilibrium exchange rate. In this model, the exchange rate is assumed to return gradually to the equilibrium value, which can itself move over time. If the equilibrium is a moving average of the actual exchange rate, the regressive model could also be classified as a chartist model. Alternatively, the equilibrium can be related to fundamentals, such as relative prices.

The adaptive expectations model is defined as:

$$S^a_{i,t,h} - S^a_{i,t-h,h} = (1+f)(S_t - S^a_{i,t-h,h}), \quad 0 < (1+f) < 1. \tag{3}$$

So the adaptive model can be considered as a form of learning process where forecasters try to learn the “ true ” level of the variable instead of its underlying process.

The final model we consider is the so-called mixed model which nests within it the other three models (see, for example, Prat and Uctum (1996)):

$$S^a_{i,t,h} - S_t = b(S_t - S_{t-1}) + d(\bar{S}_t - S_t) + f(S_t - S^a_{i,t-h,h}). \tag{4}$$

Given the generality of the mixed model, it may seem more appropriate to estimate only this model rather than estimating the other models sequentially. However, we believe there is value added to be obtained from looking at each model separately. This is because the particular empirical specification of, say, the extrapolative model may depend on the underlying data dynamics which would be difficult to discern if the general model was tested first with no pre-testing on the underlying components. In addition, it is difficult to study the heterogeneity of individual coefficients within the mixed model where the individual coefficients on the various explanatory variables are never significant at the same time. Finally, 12 observations per individual are dropped in the adaptive as well as in the mixed model for the 12 month horizon. This loss of information is especially severe for the mixed model where many coefficients must be estimated.

Previous survey-based work on expectational processes generally utilises the consensus measure of the survey, such as the mean or median.[2] Exceptions are Ito (1990) and MacDonald (1992) who both analyse individual survey data. For example, Ito (1990) estimates an extrapolative model with idiosyncratic coefficients effects, using a panel data set of biweekly surveys on yen/dollar, 1, 3 and 6 month expectations of 44 Japanese institutions, over the period May 1985-June 1987. He finds that "the heterogeneity is more like a constant bias rather than the differences in reacting to the recent changes in the exchange rate" (p. 440). However, the scope of this study is limited both geographically (only Japanese forecasts of the yen/dollar exchange rate are available) and temporally (the period covered was dominated by the dramatic fall of the dollar against the yen).

MacDonald (1992) tested the null of static expectations against the alternative of extrapolative, adaptive and regressive expectations, using the disaggregate data set produced by Consensus Economics of London, for the period October 1989 to March 1991. Implementing single equation estimations on each individual, he was unable to reject the null hypothesis of static expectations for the vast majority of forecasters. However, this failure to reject the null may simply reflect the econometric method used and/or the relatively short data span available.

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[2] See Takagi (1990) or Bénassy-Quéré and Raymond (1997) for a review.

In this paper we also attempt to model the expectations formation process of individual forecasters, and, in particular, the extent of individual heterogeneity in expectations formation. Our approach has certain advantages over earlier studies, noted above: we have access to forecasts produced in all of the G7 financial centres; our sample period is longer than that used in the above studies; most notably, we use panel data sets which potentially have more power to discriminate amongst the various hypotheses; in estimating the various models we specifically test for heterogeneity across individuals. The latter exercise is of interest in itself, since it should help to further clarify the extent of heterogeneity in the foreign exchange market and therefore the usefulness of consensus measures of market expectations. Of more specific interest, however, is the nature of the predominant form of market expectations at different horizons: the policy implications from a finding in favour of regressive expectations will be very different to that from a finding of extrapolative expectations. A finding of the latter, for example, may suggest that a leaning against the wind type policy would be effective. Furthermore, a finding that, say, a minority of individuals follow extrapolative methods may have implications for policy in the sense that it may be easier to push a relatively small number of individuals towards stabilising behaviour than a large number.

1.2. Econometric Methodology

In order to investigate the properties of different expectational mechanisms we propose using two different classes of panel estimators: a base-line model, which we take to be a fixed effects model, and a more general model based on the random coefficients model. The general form of the constant coefficients model with fixed effects is:

$$S^{a}_{i,t,h} - S_{t} = a_{i,h} + b_{h} x_{i,t,h} + u_{i,t,h}\ , \tag{5}$$

where $a_{i,h}$ is a constant that varies across individuals, b_{h} is constant and identical for all individuals, and $x_{i,t,h}$ is the vector of explanatory variables in the adaptive, regressive, extrapolative or mixed model[3]. The general form of the random coefficients model is:

$$S^{a}_{i,t,h} - S_{t} = a_{i,h} + b_{i,h} x_{i,t,h} + u_{i,t,h}\ , \tag{6}$$

where $a_{i,h}$ and $b_{i,h}$ are each the sum of a constant, common mean λ_h and of a random term $\lambda_{i,h}$ with zero mean and a constant variance (idiosyncratic term). Hence, the vector of the coefficients $\Lambda_{i,h} = \begin{pmatrix} a_{i,h} \\ b_{i,h} \end{pmatrix}$ can be written:[4]

$$\Lambda_{i,h} = l_{h} + l_{i,h} \qquad , \qquad \text{with} \qquad E\, l_{i,h} = 0 \text{ for each i}$$

$$\text{and} \qquad E\, l_{i,h}\, l'_{j,h} = \begin{cases} \Delta\, if\ \ i = j \\ 0\, if\ \ i \neq j \end{cases} .$$

In the first model, individual effects are reduced to differing constants across individuals, whereas in the second model, all coefficients are random and vary across individuals. The residuals are assumed to have the following properties:

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[3] $x_{i,t,h} = x_{t,h}$ in the extrapolative and regressive models.

[4] See Hsiao (1986, chapter 6) and Hsiao (1992).

$$u_{i,t,h} = e_{i,t,h} - q_1 e_{i,t-1,h} - q_2 e_{i,t-2,h},$$

$$e_{i,t,h} \longrightarrow N(0, s^2_{i,h}) \text{ for each t,}$$

$$Ee_{i,t,h}e_{i,t',h} = 0 \text{ if t}\neq\text{t'},$$

$$Ee_{i,t,h}e_{j,t',h} = 0 \text{ if i}\neq\text{j for each (t,t')},$$

$$Eu_{i,h}u^{'}_{j\,h} = \begin{cases} s^{\,2}_{i,h}\Theta_h \; if \;\; i = j \\ 0 \;\; if \;\; i \neq j \end{cases},$$

where $u_{i,h}$ is the vector of the individual residuals and Θ_h is derived from the MA2 structure of the residuals. The latter assumption arises because of the overlapping nature of the data which imparts a second order moving average error process (see, for example, Hansen and Hodrick (1980))[5] and, indeed, this kind of process was indeed borne out by our initial diagnostic testing. Besides, the use of such a process has the added advantage that it does not affect the interpretation of *b* as an extrapolative coefficient (which it would were we to use an autoregressive structure for the error process).

In the fixed effects model, individual heterogeneity is evaluated through a Fisher test where the null hypothesis is H_0: $a_{i,h} = a_h$. In the random coefficients model, individual heterogeneity is tested using a Swamy test where the null hypothesis is:

$$H_0\text{: } \Lambda_{1h} = \Lambda_{2h} = \ldots = \Lambda_{Nh},$$

where N denotes the number of individuals. The statistics of the test is:

$$F^* = \sum_{i=1}^{N} \frac{1}{\hat{s}^2_{ih}} \left(\hat{\Lambda}_{ih} - \hat{\Lambda}^*_h\right)' x'_{ih}\Theta_h^{-1}x_{ih}\left(\hat{\Lambda}_{ih} - \hat{\Lambda}^*_h\right),$$

where x_{ih} is the vector of explanatory variables for each individual, $\hat{\Lambda}_{ih}$ is the least-squares estimator for each cross-sectional unit and $\hat{\Lambda}^*_h$ is a matrix-weighed average of $\hat{\Lambda}_{ih}$, the weights being inversely proportional to $\hat{s}^2_{ih}\Theta_h$. Under H_0, F^* has an asymptotic chi-square distribution with K(N-1) degrees of freedom as T, the number of periods, tends to infinity and N is fixed, K being the number of parameters.[6] This test can also be performed on a sub-vector of coefficients.

The Swamy test is, however, not very powerful since only one different coefficient can be enough to reject global homogeneity. We therefore subsequently estimate each model on each individual separately and construct sub-panels for individuals who display significant estimates. We then re-run our panel estimates, and perform the Swamy test on the sub-panels.

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[5] Hansen and Hodrick show that, when data overlap as it is the case here, the residuals by construction follow an MA(h-1) process, where h is the forecast horizon. However, this result applies only when the endogeneous variable is the forecast error, as in unbiaseness tests for instance. Here, the endogeneous variable contains the expectation error, although it is not equal to it.

[6] This statistics is derived from Hsiao (1986) with an MA2 residual process represented by the matrix .

We also test for any individual discrepancy from the sub-panel behaviour with the following Student test:

$$\left| \begin{array}{l} H_0 : \Lambda^k_h(i) = \Lambda^k_h \\ H_1 : \Lambda^k_h(i) \neq \Lambda^k_h \end{array} \right. ,$$

where $\Lambda^k_h(i)$ is the kth component of the vector of estimated parameters *in the individual regression* for individual i, and Λ^k_h is the kth component of the estimated parameter for the sub-panel. The actual statistic for this test is:

$$ST = \frac{\Lambda^k_h(i) - \hat{\Lambda}^k_h}{\hat{s}_{\Lambda^k_h(i)}},$$

where $\hat{s}_{\Lambda^k_h(i)}$ is the estimated standard error of $\hat{\Lambda}^k_h(i)$ in *i-individual* regression. Under the null hypothesis, ST follows a Student distribution with (TT-K) degrees of freedom, TT being the number of observations *per* individual and K the number of explanatory variables (both TT and K vary across the models). It should be noted that the common coefficient used in the latter test ($\hat{\Lambda}^k_h$) is the estimated common coefficient of the sub-panel, while the common coefficients used in the Swamy test ($\hat{\Lambda}^*_h$) are weighed averages of individual coefficients. These two measures of common behaviour can differ when there are few individuals in the sub-panel. This is because an individual coefficient estimated with a large uncertainty, $\hat{s}^2_{ih}$, is far away from the weighed average by construction (its weight in the average is low). Thus, the null hypothesis is easily rejected in the Swamy test, which is not the case in the individual Student test.

2 THE DATA SET

2.1. General Features of the Data

In Table 1 we summarise the salient features of the survey data base, and, in particular, the forecast horizons and data sample. The reliability of survey data has been questioned in a number of ways. For example, respondents to a particular survey may have no idea of the future exchange rate because their working horizon does not fit that of the survey. Additionally, surveyed forecasters may not reveal their true expectations because of their desire to manipulate the overall outcome. A response to the former kind of criticism has been given by Goodhart (1988): "There is little incentive for those paid to forecast the future to confess that it cannot be done, so they are unlikely to put much weight on the random walk view" (p. 451). In addition, Ammer and Brunner (1994) show that at least some of the US commercial banks run dealing positions "with a view as to how markets will move over a period of several weeks or more" (p. 9). This result is based on first-order autocorrelations showing that the reported positions (in the monthly FFIEC regulatory form number 035) are persistent, although mean-reverting. A response to the second kind of criticism would be to argue that only consensus forecasts (i.e. average or median forecasts) are published, and that the publication intervenes with a lag which prevents such information being used for immediate speculation.

Table 1: The Salient Features of the Survey Data.

Surveying institution	Consensus Forecasts, London
Exchange rates	DM/\$, yen/\$, £/\$
Horizons of the forecasts	3 and 12 months
Frequency	monthly
Period of the survey	1990:01-1994:12
Participants of the survey	133 individuals from various cities, of which ¾ are financial institutions.
Collecting method	by fax, on the first monday of each month.

Figure 1 depicts the average expectation of the panel, together with the extreme forecasts and the realisations for the three currencies and the two horizons. Two features of the survey data emerge from this figure:

(i) The uncertainty band is larger for the 12 month horizon than for the 3 month horizon, which is consistent with larger expected variations for longer horizons.

(ii) The average three month expectation follows the realisations with a three month lag, showing that the market average behaviour is close to that of a random walk: the expected rate is close to the observed rate by the time of the forecast. This feature does not apply to the twelve month expectation which appears more independent of the realisations.[7] The former result is consistent with existing econometric results showing that the null hypothesis of a random walk is generally not rejected for short horizons (Bénassy-Quéré and Raymond, 1997). One motivation for the present study is to determine if this result applies to individual expectations formation processes.

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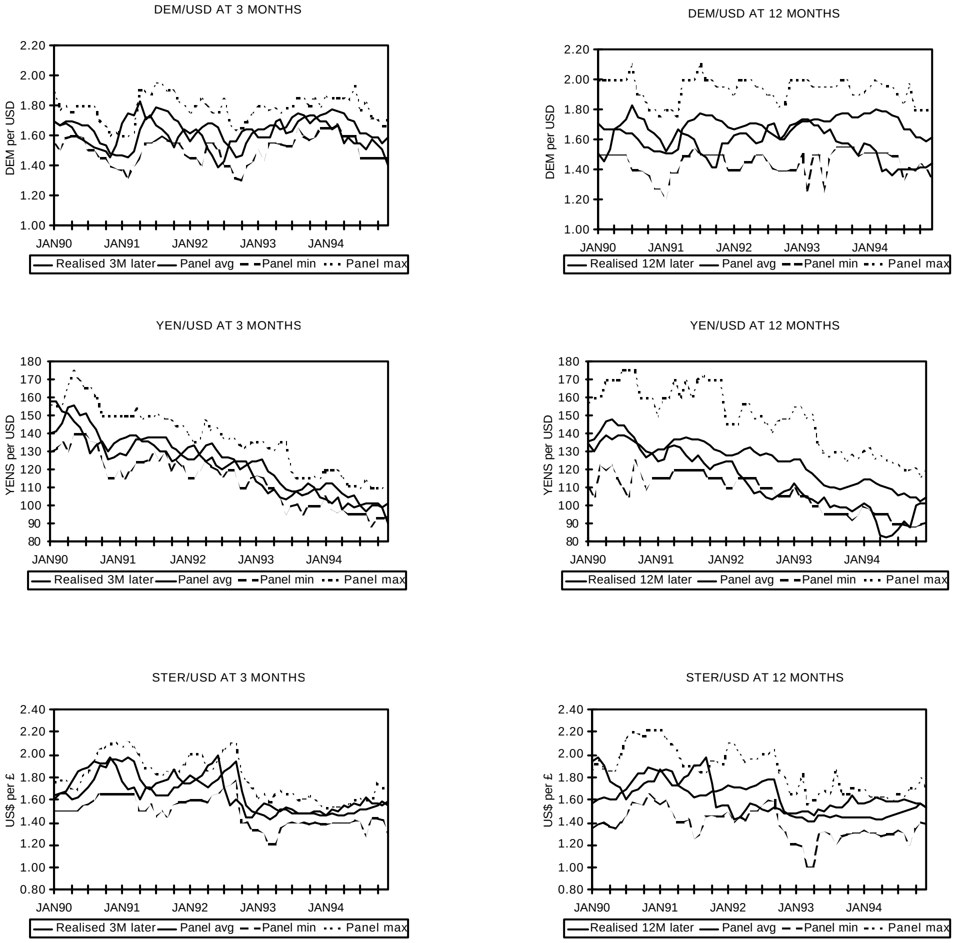
[7] An exception is the pound crisis of September 1991: this crisis was not expected, but it lead to a strong revision of expectations.

Figure 1: Panel Expectations



In attempting to use the data base for econometric applications, the issue of missing values has to be addressed.

2.2. Dealing with Missing Values

During five years, 133 forecasters were asked six predictions monthly (three exchange rates over two horizons). Only seven individuals never failed to give their six expectations, i.e. only seven provided a total of 60 x 3 x 2 = 360 predictions each. All other individuals failed at least once. Some of them participated in the panel only during one sub-period. Others sometimes did not answer, for reasons that are unknown but can easily be understood (holiday, staff restructuring, no time, etc). However, standard econometric methods are not well disposed towards missing values (especially in a model with random coefficients), and it is therefore necessary to address this issue. Several solutions can be considered. The first is to limit the panel to those individuals who never failed to respond. This solution is costly since it means dropping 123 to 125 individuals, depending on the forecast horizon/ currency including those who failed only once or twice. In addition, there is no guarantee that the 100% response rate is a good indicator of quality, since some predictions may have been provided by forecasters who did not take the questionnaire seriously.[8]

The second solution, advocated by MacDonald and Marsh (1996), is to retain those individuals who did not fail more than 4 times (i.e. less than once a year on average) for each exchange rate at each horizon. The blanks are then filled in with the mean expectation of the panel. This solution raises the size of the panel from 8-10 to 33-38 individuals (depending on the currency and on the horizon). Nevertheless even with this approach around 100 individuals are excluded from the panel. Among them, some answered consistently during a sub-period, and the information they provided is therefore wasted using this approach.

The third solution is to use incomplete panel data methods since they facilitate accessing various sub-periods in the same sample. With this method, a much larger number of individuals can be included in the sample, although their forecasts may cover different forecasting periods. Scarce missing values within the sub-periods can be filled in with the mean expectation of the panel, as in the second solution. However, in order to maintain a relatively high quality panel, it is necessary to be quite selective about the individuals included.

On balance we decided that, given our use of random coefficients models, the second solution represents the most practical way of increasing the panel dimensions, and it is this approach which we use here.[9,10] The number of individuals included in each of the exchange rate panels varies from 33 to 38 across currencies/horizons.

In extracting reliable statistical inferences from our estimated relationships, it is important that the variables used are stationary. Although none of the variables employed in this study are first differences, all of the variables discussed in Section 2.1 may be regarded as quasi-differences; i.e. the stationarity properties of the expected change in the exchange rate should be similar to the stationarity properties of the actual change in the exchange rate. In order to check this, we ran standard augmented Dickey-Fuller unit root tests for each of the series used in the study. These tests gave a very clear rejection of the null of non-stationarity (when a constant and constant plus time trend were used as deterministic series), thereby confirming the above assertion regarding the use of quasi-difference series. Furthermore, we also used the panel unit root tests of Levin and Lin (1993) to test if each variable considered in a panel context was stationary. Not surprisingly, given the stationarity on an individual unit basis, the panel tests gave a very clear rejection of the null of non-stationarity (having, on average, adjusted t-ratios of -16.0, compared to the 5% critical values of -2.0).[11]

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[8] Indeed, a descriptive statistics show that the smaller the individual non-response rate, the larger the individual, absolute mean error.

[9] A forthcoming paper will generate a similar set of results for incomplete panel data sets.

[10] A preliminary statistical analysis indicated no relationship between the number of missing values and the standard deviation of the forecasts over time and also the mean absolute error. In any case, our chosen method of replacing missing values will bias the results against finding heterogeneity

[11] These results are available from the authors on request.

3. RESULTS FROM BASIC MODELS

3.1. The Extrapolative Model

As we have noted, in the extrapolative model the expected variation of the exchange rate depends on its past variations. In implementing this model we started with a richer lag structure than that given in (1). In particular, we experimented with up to three lagged changes in the exchange rate. Since the last lag was never significant in any specification we do not report estimates with it included. However, to be consistent we report the estimated two lags, even when they are not significant. Additionally, a time trend was included in each of the estimated equations to capture the potential systematic movements in currencies which are not explicitly model, and a dummy was added to the pound equation to take account of the September 1992 currency crisis.

For our 'base-line' fixed effects model, the specification used is:

$$S^{a}_{i,t,h} - S_t = a_{i,h} + b^{1}_{h}(S_t - S_{t-1}) + b^{2}_{h}(S_{t-1} - S_{t-2}) + c^{1}_{h}t + c^{2}_{h}Crisis_t + u_{i,t,h}\,, \qquad (7)$$

where $Crisis_t$ is a dummy which takes the value of 1 only for the £/USD exchange rate in October 1992; i.e. for the first forecast made on this exchange rate after the pound left the European exchange rate mechanism (otherwise, $Crisis_t = 0$).

The fixed effects estimates are reported in the top half of Table 2 and indicate that all but one of the slope coefficients are significantly negative. This implies that, on average, a currency appreciation generates the expectation of a depreciation. This is a surprising result and conflicts with the basic premise of the model. However, it is, in fact, consistent with the results usually obtained when average data are used. Such studies indicate that for horizons of three months or more the coefficient of extrapolation is negative, while for shorter horizons, the coefficients are positive or zero.[12]

The moving average coefficients are statistically significant thereby confirming our use of an MA2 model for the residuals. The time trend is positive for the mark and yen at both horizons, and negative for the pound.[13] Given that the pound is certain-priced while the two other currencies are uncertain-priced, this result can be interpreted as indicating that the dollar was expected to appreciate against the three currencies to an increasing extent over the period. Since the dollar tended to depreciate against the yen over the period (Figure 1), this result can be interpreted as evidence of mean-reverting expectations. If this interpretation is correct, then a regressive model should be more appropriate for this currency. Finally, the coefficient on the crisis dummy is significant and negative, indicating that the expected value of the pound was revised downwards by 6-7 per cent following the crisis.

We tested for homoscedastic errors using an ARCH test (since it is widely accepted that ARCH effects constitute the most likely source of heteroscedasticity for exchange rates). The null hypothesis of no ARCH effects cannot be rejected, except for the £/$ at 12 months

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[12] See Takagi (1991) and Bénassy-Quéré and Raymond (1997).

[13] It is worth noting that the inclusion of the time trend does not effect the signs or the significance of the estimates of the extrapolative coefficients; it's main effect is to increase the explanatory power of the equation.

where it is rejected at the 5% level (but accepted at the 1% level), and for the DM/$ at 12 months, where it is rejected at any level.

The null hypothesis of no fixed effects is strongly rejected for this panel, with the estimated Fisher statistics all having p-values of 0.000. Given this, we now explore whether there is a richer form of heterogeneity embedded in our panel estimates by examining the random coefficients model.

We subsequently estimate the extrapolative model with random coefficients (see Equation (6). The detailed results are presented in Appendix 1, while Table 2 contains a summary statistic, namely the adjusted R^2. As in the fixed effects case, we find that the common b coefficients are negative and that the coefficient on the last observed exchange rate variation, b^1, is always significant. Now, however, b^2 (on the lagged exchange rate variation) is significant at only the 12 month horizon for two currencies: at longer horizons, forecasters use more information on the dynamic exchange rate process than they do at short horizons. We note that the adjusted R^2s from these regressions range from between 40% to 70% above their values in the fixed effects models, and this may be explained by the greater flexibility this model has in capturing individual heterogeneities. The null hypothesis of homoscedastic residuals cannot be rejected except, again, in the case of the pound at the 12 month horizon.

An important advantage of the random coefficient model is that it provides a test for global heterogeneity. For the extrapolative model we always reject the null hypothesis of homogeneity at the three month horizon for the whole vector of coefficients and also for the sub-vector containing b^1_{ih} and b^2_{ih} (Table 2). At the 12 month horizon, the homogeneity of all the coefficients is also rejected, but the homogeneity of the individual b^1_{ih} and b^2_{ih} coefficients is not rejected at the 10% level for the DM and yen forecasts. This result may stem from the fact that individual forecasters rely more heavily on public forecasts for long horizons. However, it is well known that this test is not very precise since only one significant individual coefficient can be enough to reject the null hypothesis.

In order to get a more precise representation of the heterogeneities, noted above, we estimated extrapolative models for individuals who produced a significant b^1 coefficient. The percentage of individuals who use a version of the extrapolative model is summarised in Table 2. These indicate that about 20 per cent of the forecasters do not extrapolate, and this figure is independent of the horizon. Among the remaining individuals, the dispersion of the b^1_{ih} coefficient is high. For instance, the standard deviation of b^1 across individuals at 3 months is around 50 per cent. However, the dispersion of b^1 is much smaller for the 12 month horizon, which is consistent with the Swamy tests.

Finally, we re-ran the panel estimates, limiting the sample to those individuals displaying a significant b_i^1 in the individual regressions. The results are contained in the rows with the label 'sub-panel' in Table 2. The Swamy tests give the same results as for the whole panel. The extent of individual heterogeneities is obtained by testing the equality of each individual coefficient relative to the sub-panel average. Depending on the coefficient and on the exchange rate concerned, between 13 and 61 per cent of individual coefficients differ significantly from the panel average. It should be noted that the number of individual heterogeneities is systematically smaller for the 12 month horizon: for b^1 (our filter), the percentage of heterogeneities falls from 28-33 per cent at 3 months to 13 per cent at 12 months. A visual impression of these heterogeneities may be gleaned from Figures 1a and 1b in Appendix 2.

The heterogeneities found in our extrapolative tests can be summarised as follows. Around twenty per cent of forecasters do not extrapolate. Among the eighty per cent who use a version of the extrapolative model, there are still many heterogeneities in the coefficients. However, the Swamy test fails to reject the null hypothesis of homogeneity for the most important coefficients (b^1 and b^2) at the 12 month horizon, and although detailed analysis confirms a smaller heterogeneity grouping at 12 months. We believe that this result can be interpreted as indicative of a higher reliance on public forecasts of longer horizons.

Table 2: Extrapolative model

	DM/$		Yen/$		£/$	
	3 months	12 months	3 months	12 months	3 months	12 months
The fixed effects model						
No of individuals	38	36	38	38	33	34
b^1	-0.306**	-0.483**	-0.317**	-0.396**	-0.371**	-0.453**
b^2	-0.041*	-0.185**	-0.034*	-0.150**	0.005	-0.074**
c^1	$6\ 10^{-4}$**	0.001**	$8\ 10^{-4}$**	0.002**	$-2\ 10^{-4}$**	$-9\ 10^{-5}$
c^2	-	-	-	-	-0.061**	-0.067**
θ_1	-0.372**	-0.525**	-0.351**	-0.494**	-0.328**	-0.514**
θ_2	-0.207**	-0.362**	-0.187**	-0.293**	-0.197**	-0.289**
adjusted R²	0.255	0.287	0.285	0.401	0.217	0.233
DW	1.880	1.761	1.790	1.721	1.821	1.828
Arch test (1)						
$\chi^2(1)$ statistics	0.041	9.626	2.644	0.315	0.108	5.176
P-value	0.838	0.002	0.104	0.574	0.742	0.023
Fixed effects:H_0:a_i=a						
Fisher statistics	6.083	11.832	5.284	11.666	7.682	14.089
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Measuring individual heterogeneities						
Random coefficients model						
Adjusted R²	0.370	0.376	0.426	0.551	0.353	0.362
Swamy tests on panel estimates						
On all coefficients	536.9*	498.7*	626.8*	879.3*	622.9*	711.5*
On (b^1,b^2)	250.8*	70.9	227.4*	89.1	380.6*	101.6*
Individuals with significant b^1_i(at 10%) in individual regressions						
% of the panel	81.6	83.3	84.2	81.6	88.2	90.9
SD of b^1_i (%)	47.4	22.3	50.7	29.6	47.7	27.9
Swamy test on sub-panel estimates (individuals with significant b^1_i)						
On all coefficients	336.5*	433.0*	539.9*	751.2*	589.5*	621.8*
On (b^1,b^2)	163.8*	48.2	165.6*	58.7	316.6*	61.2*
% of significantly different individual coefficients in the sub-panel						
b^1_i	29.0	13.3	28.1	12.9	33.3	13.3
b^2_i	29.0	23.3	31.3	16.1	43.3	36.7
c_i	25.8	40.0	40.6	61.3	20.0	30.0

*Notes: ** significant at 1%, * significant at 5%, ## significant at 10%, # significant at 15%.*

(1) H_0: $\rho = 0$ in $\left(\frac{1}{N}\sum_{i=1}^{N} e^2_{i,t,h}\right) = \rho\left(\frac{1}{N}\sum_{i=1}^{N} e^2_{i,t-1,h}\right) + \varepsilon_{t,h}$.

- Swamy tests: * means that the null hypothesis of homogeneity of all coefficients or of a sub-vector of coefficients across individuals is rejected at 10%.
- Individual tests: individual coefficients are those estimated in individual regressions.

3.2. The Regressive Model

In the regressive model, the exchange rate is expected to move towards a reference level, $\overline{S}_t$, which can either be a constant, a moving average, or a fundamental rate based, for instance, on purchasing power parity (PPP). We estimated the model with two alternative specifications for the reference exchange rate. In the first case, $\overline{S}_t$ is assumed to be a non-linear trend of the nominal exchange rate, calculated using a Hodrick-Prescott filter over a longer period than our survey based sample (1974:01-1994:12).[14] The second specification is based on PPP: $\overline{S}_t$ is the nominal exchange rate that would have maintained the real exchange rate at a level equal to its mean over the estimation period (1990:01-1994:12).[15] The period used to calculate $\overline{S}_t$ is shorter in the second specification because the real exchange rate was obviously not expected to remain constant over the period 1974-1994.[16]

Following Prat and Uctum (1996), we introduce a second order term into the regressive equation: that is, when the target exchange rate depreciates more quickly than the observed exchange rate, the expected speed of depreciation rises. Finally, a dummy is introduced for the £/USD exchange rate in order to take the regime shift of September 1992 into account: because the pound moved from a fixed to a floating exchange rate regime, forecasters may have switched to another long run reference rate after September 1992. Thus, we define $Float_t$ as a dummy which is equal to 1 only for the pound after September 1992, zero otherwise. For the fixed effects model the specification is:

$$S^a_{i,t,h} - S_t = a_{i,h} + d^1_h(\overline{S}_t - S_t) + d^2_h((\overline{S}_t - \overline{S}_{t-1}) - (S_t - S_{t-1})) + c^3_h Float_t + u_{i,t,h} \quad (8)$$

Equation (8) can also be re-expressed to explain exchange rate expectations with two lagged regressive terms:

$$S^a_{i,t,h} - S_t = a_{i,h} + (d^1_h + d^2_h)(\overline{S}_t - S_t) + d^2_h(\overline{S}_{t-1} - S_{t-1}) + c^3_h Float_t + u_{i,t,h} \quad (8')$$

It turns out that the estimates are more significant when PPP is used as a target and so only these results are presented.

In Table 3 we present the fixed effects results. Although the adjusted R²s have the same orders of magnitude as in the extrapolative model, this specification may be deemed more satisfactory since the equations do not feature a trend.[17] The residual autocorrelation seems to have been well captured by the MA2 process; however, the null hypothesis of homoscedasticity is still rejected for the 12 month, DM and pound expectations. Both d^1 and d^2 are positive and almost always highly significant. A positive d^1 implies that the nominal exchange rate is expected to return to its PPP level: forecasters believe in absolute PPP. It

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[14] The smoothing parameter was calibrated in order to generate an overvaluation of the dollar between 1983 and 1986.

[15] The real exchange rate is calculated with monthly consumer prices (OECD).

[16] Some empirical studies find that PPP only holds over much longer time periods - see, for example, MacDonald (1995).

[17] The interpretation of the positive trend coefficient in the extrapolative model as a mean reversion behaviour is thus confirmed for the yen.

should be noted that d^1 is higher at the 12 month horizon than at the 3 month horizon. But consistency between 3 month and 12 month expectations would imply $d^1{}_{12}$ to be roughly four times $d^1{}_3$ (in the case of a linear expected adjustment), which is not the case here.[18]

Some interpretation may be put on the d^2 coefficient in the following way. Since the assumption of PPP implies a constant real exchange rate, the variation in the PPP exchange rate must equal the inflation differential:

$$\overline{S}_t - \overline{S}_{t-1} = (P_t - P_{t-1}) - (P_t^* - P_{t-1}^*),$$

where P_t denotes the logarithm of the domestic consumer price index and $P^*{}_t$ the foreign consumer price index. Under the maintained hypothesis, therefore, the acceleration term is equal and opposite to the observed variation of the real exchange rate:

$$(\overline{S}_t - \overline{S}_{t-1}) - (S_t - S_{t-1}) = (P_t - P_{t-1}) - (P_t^* - P_{t-1}^*) - (S_t - S_{t-1}).$$

Hence, a positive d^2 means that the last real exchange rate variation is expected to be reversed, without any level anchor: forecasters believe in relative PPP. Note that d^2 is larger for 3 month than for 12 month expectations, which means that variations in the real exchange rate are expected to revert quickly. This is consistent with the negative coefficients obtained in the extrapolative model (the PPP exchange rate moves only slowly, so the acceleration term resembles an extrapolative term over short horizons).

As in the extrapolative model, fixed effects are highly significant, which encourages us to explore the individual heterogeneities in more detail. The results of the random coefficients regressive model are reported in Appendix 1. The common coefficients, d^1 and d^2, are still positive, but d^1 is no longer significant in two of the 3 month cases. Hence, forecasters seem to believe in relative PPP at this horizon, while they believe in absolute PPP at the 12 months horizon. This would seem to accord with our economic intuition in the sense that absolute PPP is more likely to hold at long horizons.

Other results are in line with the extrapolative model: (i) except for the 12 month expectations of the DM, the adjusted R²s are between 40 and 70 per cent above those obtained with fixed effects; (ii) the two cases of heteroscedasticity obtained with fixed effects remain in the random coefficients model.

The reported Swamy test produces a rejection of the homogeneity of the coefficients across individuals, except for (d^1,d^2) in the 12 month DM/$ regression. The Swamy statistic is very high for (d^1,d^2) in the £/$, due to significantly *negative* values for two individuals. Those individuals seem to extrapolate past deviations from PPP. In sum, we note that individual heterogeneity seems more important here than in the extrapolative case. For example, in two cases, less than 1/3rd of the forecasters produce a significant value of $d^1{}_{ih}$. The heterogeneities on $d^1{}_i$ are more frequent in the case of the 3 month horizon. This result may be due to the fact that many individuals only believe in *relative* PPP for the 3 month horizon (displaying significant $d^2{}_{i,h}$).

Interpreting individuals who produce with a significant d^1 coefficient as those using absolute PPP, we see that significant heterogeneities remain: the Swamy tests reject homogeneity of

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[18] Time-consistency tests suggested by Pesaran (1989) cannot be performed here because we do not have a forecasting model for the one-month exchange-rate variation which appears significant in the twelve-month expectation.

the individual coefficients (except, again, for the 12 month DM/$ expectations), and $d^{1}_{i,h}$ differs from the panel average for 12 to 53 per cent of the individuals [19].

In order to test for heterogeneity among *relative* PPP forecasters, we subsequently used the significance of the d^{2}_{ih} coefficient as a filter, and in Table 3 we report sub-panel results which only include individuals who had a significant d^{2}_{ih} in individual regressions. More individuals are kept in the sub-panel than in the previous case for the 3 month horizon, but less individuals are kept for two currencies at the 12 month horizon. This result confirms that 3 month individual expectations generally follow relative PPP, while 12 month individual expectations follow absolute PPP. Among regressive forecasters, the dispersion of d^{2}_{i} is specially high for the yen. Sub-panel results confirm this high heterogeneity for the yen. In figures 2a and b of Appendix 2 we report the bar charts containing the distributions of the individual coefficients from the sub-panel estimates.

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[19] Sub-panel estimates were not calculated for the DM and the yen at 3 months because the sub-sample were too small.

Table 3: The Regressive Model

	DM/$		Yen/$		£/$	
	3 months	12 months	3 months	12 months	3 months	12 months
The fixed effects model						
No of individuals	38	36	38	38	33	34
d^1	0.0388*	0.395**	0.111**	0.320**	0.029#	0.287**
d^2	0.282**	0.221**	0.251**	0.175**	0.252**	0.230**
c^3	-	-	-	-	-0.010**	-0.042**
θ_1	-0.420**	-0.515**	-0.386**	-0.483**	-0.303**	-0.455**
θ_2	-0.252**	-0.356**	-0.214**	-0.281**	-0.190**	-0.235**
adjusted R²	0.154	0.283	0.255	0.402	0.166	0.245
DW	1.886	1.741	1.830	1.704	1.796	1.727
Arch test (1)						
$\chi^2(1)$ statistics	0.006	9.161	2.675	1.332	0.008	10.214
P-value	0.937	0.002	0.102	0.248	0.930	0.001
Fixed effects:H_0:a_i=a						
Fisher statistics	5.4638*	11.902*	4.992*	11.424*	7.317*	14.474*
Measuring individual heterogeneities						
Random coefficients model						
Adjusted R²	0.238	0.331	0.369	0.539	0.289	0.408
Swamy tests on panel estimates						
On all coefficients	411.3*	420.3*	480.1*	793.6*	462.9*	768.2**
On (d^1,d^2)	243.2*	53.2	279.0*	197.6*	43301.9*	17097.0*
Individuals with significant d^1_i (at 10%) in individual regressions						
% of the panel	18.4	69.4	63.2	84.2	27.3	70.6
SD of d^1_i (%)	-	23.3	54.3	49.6	-	61.6
Swamy test on sub-panel 1 estimates (individuals with significant d^1_i)						
On all coefficients	336.5*	433.0*	539.9*	751.2*	589.5*	621.8*
On (d^1,d^2)	163.8*	48.2	165.6*	58.7	316.6*	61.2*
% of significantly different individual coefficients in sub-panel 1						
d^1i	n.a.	12.0	25.0	53.1	n.a.	16.7
d^2i	n.a.	24.0	45.8	28.1	n.a.	20.8
Individuals with significant d^2_i (at 10%) in individual regressions						
% of the panel	73.7	44.4	86.8	50.0	84.8	58.8
SD of d^2_i (%)	31.4	30.5	70.4	68.7	52.3	36.1
Swamy test on sub-panel 2 estimates (individuals with significant d^2_I)						
On all coefficients	259.6*	218.1*	418.8*	482.9*	389.8*	476.1*
On (d^1,d^2)	165.9*	154.6*	246.0*	414.7*	22289.7*	94880.9*
% of significantly different individual coefficients in sub-panel 2						
d^1i	14.3	25.0	36.4	63.2	28.6	55.0
d^2i	25.0	12.5	30.3	21.1	25.0	35.0

Notes: see Table 3.

n.a.: not available (sub-panel too small to perform the regression).

3.3. The Adaptive Model

Our fixed effects, adaptive model is:

$$S^{a}_{i,t,h} - S_t = a_{i,h} + f_h\,(S_t - S^{a}_{i,t-h,h}) + c^{1}_{h} t + u_{i,t,h}\,, \qquad (9)$$

which is equivalent to the standard adaptive formulation (3), where the previous expectation is corrected for the error observed on it.[20] Because the error on the £/USD exchange rate happened to be very large in September 1992, there is no needs for a crisis dummy in the adaptive model (the correction made in the forecasts is automatically large in October 1992).

Because $(1 + f_h)$ should be bounded by 0 and 1, f_h should be negative in Equation (9). This is what we obtain: f is always significantly negative (Table 4). Generally, the value of f is around -0.1, so $(1+f)$ is around 0.9: a 10% undervaluation of the dollar in the last forecast period produces an increase in the expected dollar value of 9%.

Table 4: The Adaptive model

	DM/$		Yen/$		£/$	
	3 months	12 months	3 months	12 months	3 months	12 months
The fixed effects model						
Nb of individuals	38	36	38	38	33	34
f	-0.124**	-0.170**	-0.129**	-0.093**	-0.087**	-0.078**
c^1	$5\ 10^{-4}$**	$3\ 10^{-4}$**	$6\ 10^{-4}$**	10^{-3}**	$-2\ 10^{-4}$**	$2\ 10^{-4}$#
θ_1	-0.304**	-0.406**	-0.308**	-0.422**	-0.292**	-0.425**
θ_2	-0.179**	-0.293**	-0.193**	-0.248**	-0.126**	-0.198**
adjusted R²	0.233	0.282	0.253	0.353	0.148	0.235
DW	1.872	1.725	1.799	1.697	1.823	1.761
Arch test (1)						
$\chi^2(1)$ statistics	0.277	1.393	0.053	0.122	0.003	0.286
P-value	0.598	0.237	0.818	0.726	0.952	0.593
Fixed effects: H_0: a_i=a						
Fisher statistics	4.578*	10.717*	4.057*	14.138*	5.902*	12.175*
Measuring individual heterogeneities						
Random coefficients model						
Adjusted R²	0.344	0.396	0.353	0.498	0.240	0.377
Swamy tests on panel estimates						
On all coefficients	393.2*	410.9*	369.1*	760.9*	312.6*	454.1*
On f	236.8*	169.9*	149.4*	443.5*	151.6*	124.2*
Individuals with significant f_i (at 10%) in individual regressions						
% of the panel	57.9	63.9	50.0	26.3	48.5	29.4
SD of f_i (%)	63.8	32.0	28.7	20.4	61.7	68.2
Swamy test on sub-panel estimates (individuals with significant b^1_i)						
On all coefficients	131.2*	212.8*	163.1*	195.7*	142.4*	118.2*
On (b^1, b^2)	116.5*	73.1*	53.9*	187.9*	64.8*	51.2*
% of significantly different individual coefficients in the sub-panel						
f_i	22.7	8.7	10.5	0.0	12.5	40.0
c^1_I	13.6	17.4	21.1	20.0	25.0	20.0

Notes: see Table 3.1.

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[20] Although this formulation entails an important loss of information at the 12 month horizon, it is prefered to an "early revision" formulation proposed by Prat and Uctum (1996) where the explanatory variable is not an expectation error.

It is worth noting that for the first time, the null hypothesis of homoscedasticity is accepted for every currency/horizon, which could be explained by the fact that the adaptive model is the only one of our basic models in which the explanatory variable varies across individuals. As in the other models, the null hypothesis of no fixed effects is again strongly rejected for this panel.

The random effects results are reported in Appendix 1. The adjusted R^2's, reported in Table 4 are raised by 40 to 80 per cent, compared to the fixed effects model, and the residuals do not display ARCH effects. The common coefficient on the expectation error, f_h, is always significantly negative, varying from -0.1 to -0.2. As in the extrapolative model, the trend is not significant as a common variable, but it is important for some individuals. Those individuals expect that the exchange rate will move more and more rapidly in one direction, but less rapidly if they have overvalued the last rise. The Swamy tests (reported in Table 4) always reject the null hypothesis of homogeneity for all the coefficients or for $f_{i,h}$, for the whole panel and also in the sub-panel containing those individuals displaying a significant $f_{i,h}$ in individual regressions. Individual regressions show never more than 64% of individuals are adaptative, which is a lower percentage than for other models.

Among adaptive individuals, however, there is less heterogeneity than for other models: the rejection of the null hypothesis of homogeneity seems to be due to a small number of individuals, and the values of f are concentrated around –0.2 for the 3 month horizon and –0.3 for the 12 month horizon. This relative homogeneity can be due to the fact that explanatory variables differ across individuals, which is not the case for other models.[21] Finally, there is no systematic difference in heterogeneity across the horizons, which contrasts with other models. The distributions of the individual coefficients from the adaptive model are reported in Figure 3 of Appendix 2.

In sum, the analysis of simple expectational models highlights the existence of two types of individual heterogeneities:

(i) Model heterogeneities: a large number of individuals do not use each type of model. This is especially the case for the adaptive model at both horizons, as well as for the absolute PPP model at the 3 month and the relative PPP model at a 12 month horizon. Even the most widely used models (the extrapolative model at both horizons and the relative PPP model at 3 months) are not used by 20% of the individuals.

(ii) Coefficient heterogeneities: among individuals that use a specific model, there is evidence of important heterogeneity in the coefficients, especially when a model is used by a large number of forecasters. Within the extrapolative specification, there is less heterogeneity for the 12 month horizon than for the 3 month horizon, meaning that forecasters rely more heavily on public forecasts in the latter case.

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[21] For 12 month expectations of the yen/$, no individual $f_{i,12}$ significantly differs from the panel f_{12}, although the Swamy test rejects the homogeneity of all f_{i12}. This contradictory result may be explained by the fact that individual estimates are not compared to the same coefficient in both tests (see *supra*).

4. THE MIXED MODEL

In this section we present our estimates of a version of the mixed model, given by equation (4). There are two basic reasons for merging the three simple processes estimated seperately above into a single model. The first is econometric and arises from our estimation results. Specifically, the extrapolative model seems to be the most widely used specification, while the regressive model provides a nice interpretation of the trend included in the two other models. However, it is only in the adaptive model that we see the explanatory variables differing across individuals, and it is only in this model that we observe no evidence of heteroscedasticity. So combining the models should give a more satisfactory overall specification.

The second justification for estimating the mixed model is economic. We have shown that an important number of forecasters do not use the extrapolative, regressive or adaptive models. This raises the question of whether the various models are used by different forecasters, or whether the same forecasters use various models at the same time, other forecasters, perhaps, using none of them. This would seem to be an important question for models which attempt to explain exchange rate fluctuations by interactions between market agents with different expectations, such as that of De Long et al. (1990).

The model estimated in this section mixes the three basic specifications. Since the trend term will be captured by the regressive terms, it is dropped from the relationship. However, the dummies used in the extrapolative and regressive models are also introduced here:

$$\begin{aligned} S^{a}_{i,t,h} - S_{t} = {} & a_{i,h} + b^{1}_{h}(S_{t} - S_{t-1}) + b^{2}_{h}(S_{t-1} - S_{t-2}) + d^{1}_{h}(\overline{S}_{t} - S_{t}) + d^{2}_{h}((\overline{S}_{t} - \overline{S}_{t-1}) - (S_{t} - S_{t-1})) \\ & + f_{h}(S_{t} - S^{a}_{i,t-h,h}) + c^{2}_{h}\, Crisis_{t} + c^{3}_{h}\, Float_{t} + u_{i,t,h} \end{aligned} \tag{10}$$

The results for the mixed model are presented in Table 5. Most coefficients are significant with high confidence levels. When significant, their values generally resemble those obtained for the three basic models. However, the second order term of the regressive model (d^{2}) becomes negative (generally not significant), and the adaptive term is significantly positive in one case.

Table 5: The Mixed Model

	DM/$		Yen/$		£/$	
	3 months	12 months	3 months	12 months	3 months	12 months
No of individuals	38	36	38	38	33	34
b^1	-0.402#	-0.924**	-0.422**	-0.963**	-0.466**	-0.565**
b^2	0.010	-0.107**	0.035#	-0.125**	0.002	-0.045##
d^1	-0.029	0.323**	0.089**	0.231**	-0.066**	0.303**
d^2	-0.162	-0.633#	-0.213	-0.657**	-0.092	-0.228
f	-0.092**	0.016	-0.065**	-0.002	-0.026*	0.046**
c^2	-	-	-	-	0.006#	-0.032**
c^3	-	-	-	-	-0.065**	-0.043**
θ_1	-0.400**	-0.442**	-0.383**	-0.462**	-0.291**	-0.415**
θ_2	-0.253**	-0.325**	-0.224**	-0.272**	-0.175**	-0.206**
adjusted R²	0.181	0.391	0.256	0.375	0.216	0.342
DW	1.883	1.755	1.826	1.685	1.744	1.702
Arch test (1)						
$\chi^2(1)$ statistics	0.182	1.686	1.829	0.342	0.280	1.249
P-value	0.669	0.194	0.176	0.558	0.597	0.264
Fixed effects:H_0:a_i=a						
Fisher statistics	4.600	17.083	4.636	16.478	7.305	17.905
P-value	0.000	0.000	0.000	0.000	0.000	0.000
Swamy Test	602.3*	640.4*	603.6*	1145.2*	804.3*	1234.7*

Notes: see Table 2.

The adjusted R² statistics do not always exceed those obtained with simple models. This may be due to a variety of factors: (i) there is likely to be multicolinearity amongst the right-hand-side variables (however, our experiments with sequentially removing variables had little effect on the remaining coefficients); (ii) it may be due to a lack of degrees of freedom resulting from the incorporation of the adaptive term (which means that 3 and 12 observations per individual are dropped for the 3 and 12 month horizon models, respectively, while a total of 8 coefficients are estimated (10 for the pound)); (iii) the fact that the trend term has been dropped. However, the null hypothesis of homoscedasticity is not rejected with a high confidence level. Furthermore, fixed effects are highly significant, which constitutes some evidence that the mixed model estimated with some success on average expectations by Prat and Uctum (1996), is not that of a representative agent, but rather the result of aggregating heterogeneous individuals.

The fixed effects results for the mixed model are confirmed in the random coefficients model (see Appendix 1). The common coefficients are almost never significant, suggesting that the mixed model is not an accurate representation of common behaviour. The relatively high adjusted R² are due to the individual part of the coefficients. But the null hypothesis of homoscedasticity is rejected in one case.

The Swamy tests, reported in the final row of Table 5, all produce a rejection of the null hypothesis of individual homogeneity in the random effects model. We estimated the mixed model for each individual separately, and plotted the Student or Fisher statistics of the relevant coefficients for each individual. The graphs are presented in Appendix 2. The six individual coefficients are never significant at the same time, which again rules out a schizophrenic interpretation of the mixed model. More specifically, the models used differ across individuals, currencies and horizons. At the 12 month horizon, the most frequent model used for all currencies is a regressive model; at the 3 month horizon, the most frequent model is also a regressive one for the yen, while an adaptive process is best for the pound.[22] In all cases, some individuals use several methods simultaneously, but they are not in the majority.

5. SUMMARY AND CONCLUSION

A key theme in recent theorising on the operation of financial markets concerns the importance of heterogeneous expectations amongst agents. The purpose of this paper was to determine the nature of the expectations processes governing agents' expectations formation and the degree of heterogeneity of such expectations. In contrast to other studies in this area, we used panel estimators to address these issues. Four different expectational structures were examined, namely an extrapolative, an adaptive, a regressive and a mixed model. The expectational series used were extracted from the survey data base of Consensus Economics of London, and consisted of 3 and 12 month expectations of the US dollar bilateral rates of the German mark, Japanese yen and pound sterling, for the period January 1990 to December 1994. Our testing methods centered around two panel estimators, namely a fixed effects model and a random coefficients model. The former is seen as a base-line model in which we capture heterogeneities solely in terms of differing intercepts across individuals, whereas in the latter heterogeneity also exhibits itself in terms of differing coefficients and is summarised with a Swamy test. Our results can be summarised as follows.

Firstly, exchange rate expectations seem to be stabilising at both the 3 and 12 month horizons. Estimates of the extrapolative model, which is used by around eighty per cent of the survey respondents analysed, show that agents use a current exchange rate change to predict a future change in the opposite direction. The stabilising nature of exchange rate expectations was further revealed by our panel estimates of the regressive expectations model, where the coefficients on the regressive expectations terms always appear significantly positive at both forecast horizons. The coefficients estimated from the adaptive expectations models are also indicative of stabilising behaviour, in the sense that the magnitude of a current forecast error is offset in the next period by a statistically significant proportion. This finding is something of an antidote to the widely perceived view that foreign exchange markets are dominated by bandwagon, and other forms of non-stabilising, expectations. It is suggestive that policy makers can, with a reasonable degree of confidence, allow exchange markets to find there own equilibrium at horizons of three months and greater. This, of course, does not rule out the possibility of a more active policy stance at shorter term horizons where bandwagon effects may well be the dominant form of expectations behaviour.

Our second main finding is that the models used and coefficient estimates can differ across individuals. Specifically, a large number of individuals do not use each basic (i.e. extrapolative, regressive or adaptive) model, while few individuals use the three models at the same time (the mixed model performs poorly when coefficients are allowed to vary across individuals). This finding shows that the mixed behaviour of the panel average found in previous studies results from the aggregation of heterogeneous individuals. Among individuals who use a specific model, there are important heterogeneities in the coefficients used. For example, some individuals produce very small (and sometimes negative)

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[22] However, these differences across currencies can be due to the specific time span.

coefficients of reversion in the regressive model. We believe our finding of heterogeneous expectation processes across individuals justifies the building of models of exchange rate determination which are based on the coexistence of various types of agents. This finding may also be important for policy makers who should not expect all speculators to behave in the same way in the foreign exchange market.

Finally, some results differ across currencies and horizons. The differences across currencies should not be taken too seriously since they could be related to the time span considered. The differences across horizons are more significant. Namely, the regressive model, and more specifically, absolute PPP reversion, performs better for the 12 month horizon, while relative PPP performs better for the 3 month horizon. Within the extrapolative specification, there is less heterogeneity for the 12 month horizon than for the 3 month horizon, meaning that forecasters probably rely more heavily on public forecasts in the latter case. Hence, models of exchange rate determination based on the interaction between heterogeneous, sometimes destabilising, forecasters seem to apply only to frequencies of less than three months.

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Appendix I

Results for the random coefficients models

Table I.1: The Extrapolative Model

	DM/$		Yen/$		£/$	
	3 months	12 months	3 months	12 months	3 months	12 months
No of individuals	38	36	38	38	33	34
a	-0.006	0.009	-0.022	-0.049	-0.006	-0.035
b^1	-0.306**	-0.478**	-0.316**	-0.399**	-0.372**	-0.452**
b^2	-0.041	-0.178*	-0.035	-0.150*	0.004	-0.076
c^1	7.10^{-4}	1.10^{-3}	8.10^{-4}	2.10^{-4}	-2.10^{-4}	-1.10^{-4}
c^2	-	-	-	-	-0.060	-0.066
θ_1	-0.372**	-0.525**	-0.351**	-0.494**	-0.328**	-0.514**
θ_2	-0.207**	-0.362**	-0.187**	-0.293**	-0.197**	-0.289**
adjusted R²	0.370	0.376	0.426	0.551	0.353	0.362
DW	1.950	1.815	1.891	1.916	1.873	1.910
Arch test (1)						
$\chi^2(1)$ statistics	3.549	2.857	0.151	1.566	0.049	5.251
P-value	0.059	0.091	0.697	0.211	0.825	0.022

*Notes: ** significant at 1%, * significant at 5%, ## significant at 10%, # significant at 15%.*

(1) H_0: ρ = 0 in $\left(\frac{1}{N}\sum_{i=1}^{N} e_{i,t,h}^2\right) = \rho\left(\frac{1}{N}\sum_{i=1}^{N} e_{i,t-1,h}^2\right) + \varepsilon_{t,h}$.

Table I.2: The Regressive Model

	DM/$		Yen/$		£/$	
	3 months	12 months	3 months	12 months	3 months	12 months
No of individuals	38	36	38	38	33	34
a	0.012	0.039	0.001	0.009	0.023	0.280**
d^1	0.041	0.395**	0.110**	0.321**	0.030	0.296**
d^2	0.280**	0.220**	0.252**	0.178*	0.252**	0.224**
c^3	-	-	-	-	-0.011	-0.043
θ_1	-0.420**	-0.515**	-0.386**	-0.483**	-0.303**	-0.455**
θ_2	-0.252**	-0.356**	-0.214**	-0.281**	-0.190**	-0.235**
adjusted R²	0.238	0.331	0.369	0.539	0.289	0.408
DW	1.908	1.760	1.892	1.893	1.889	1.899
Arch test (1)						
$\chi^2(1)$ statistics	1.832	8.400	0.366	3.665	0.299	8.089
P-value	0.176	0.004	0.545	0.055	0.584	0.004

Notes: see Table I.1.

Table I.3: The Adaptive Model

	DM/$		Yen/$		£/$	
	3 months	12 months	3 months	12 months	3 months	12 months
No of individuals	38	36	38	38	33	34
a	-0.005	0.033	-0.017	-0.017	-0.007	-0.043**
f	-0.126**	-0.199**	-0.123**	-0.096*	-0.092**	-0.098**
c^1	$5.\ 10^{-4}$	$3.\ 10^{-4}$	$7.\ 10^{-4}$	$14.\ 10^{-4}$	$-2.\ 10^{-4}$	10^{-4}
θ_1	-0.304**	-0.406**	-0.308**	-0.422**	-0.292**	-0.425**
θ_2	-0.179**	-0.293**	-0.193**	-0.248**	-0.126**	-0.198**
Arch test (1)						
$\chi^2(1)$ statistics	1.252	1.751	0.400	0.193	2.777	1.855
P-value	0.263	0.186	0.527	0.660	0.095	0.173
Adjusted R²	0.344	0.396	0.353	0.498	0.240	0.377
DW	1.992	1.852	1.933	1.917	1.394	1.941

Notes: see Table I.1.

Table I.4: The Mixed Model

	DM/$		Yen/$		£/$	
	3 months	12 months	3 months	12 months	3 months	12 months
No of individuals	38	36	38	38	33	34
a	0.011	0.048	0.001	0.017	-0.078	0.29#
b^1	-0.424	-0.938	-0.459	-0.986	-0.504##	-0.541#
b^2	0.004	-0.112	0.014	-0.127	-0.013	-0.049
d^1	-0.043	0.302	0.096	0.254	-0.063	0.312##
d^2	-0.179	-0.647	-0.226	-0.664	-0.118	-0.208
f	-0.096	$-8\ 10^{-4}$	-0.033	0.048	-0.012	0.048
c^2	-	-	-	-	0.005	-0.035
c^3	-	-	-	-	-0.063#	-0.042
θ_1	-0.400**	-0.442**	-0.383**	-0.462**	-0.291**	-0.415**
θ_2	-0.253**	-0.325**	-0.224**	-0.272**	-0.175**	-0.206**
adjusted R²	0.331	0.478	0.394	0.557	0.430	0.585
DW	1.956	1.805	1.879	1.857	1.895	1.995
Arch test (1)						
$\chi^2(1)$ statistics	3.549	2.857	0.151	1.566	0.033	1.321
P-value	0.059	0.091	0.697	0.211	0.855	0.025

Notes: see Table I.1.

Appendix 2

The Distribution of Individual Coefficients in Simple models

Figure 1a. Extrapolative model: b^1

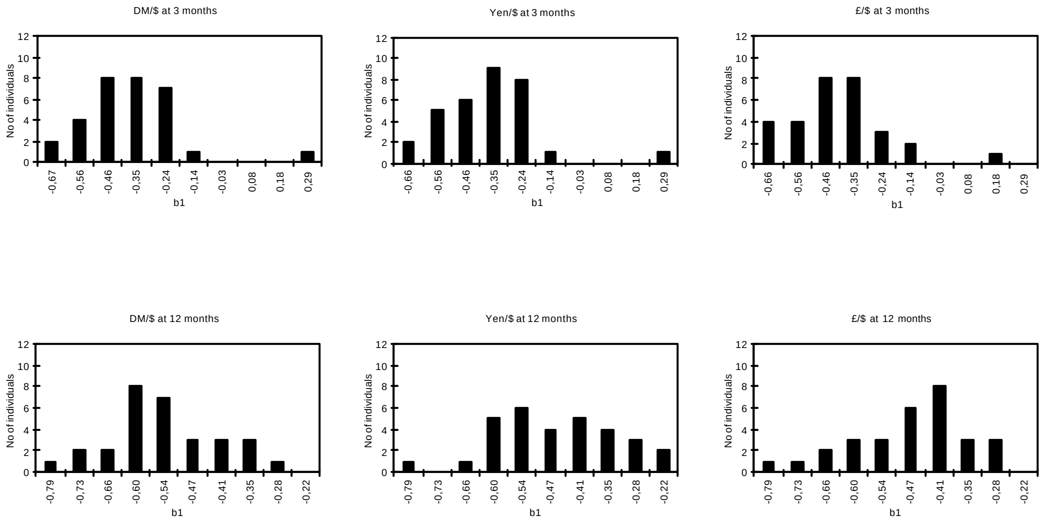


Figure 1b. Extrapolative model: b^2

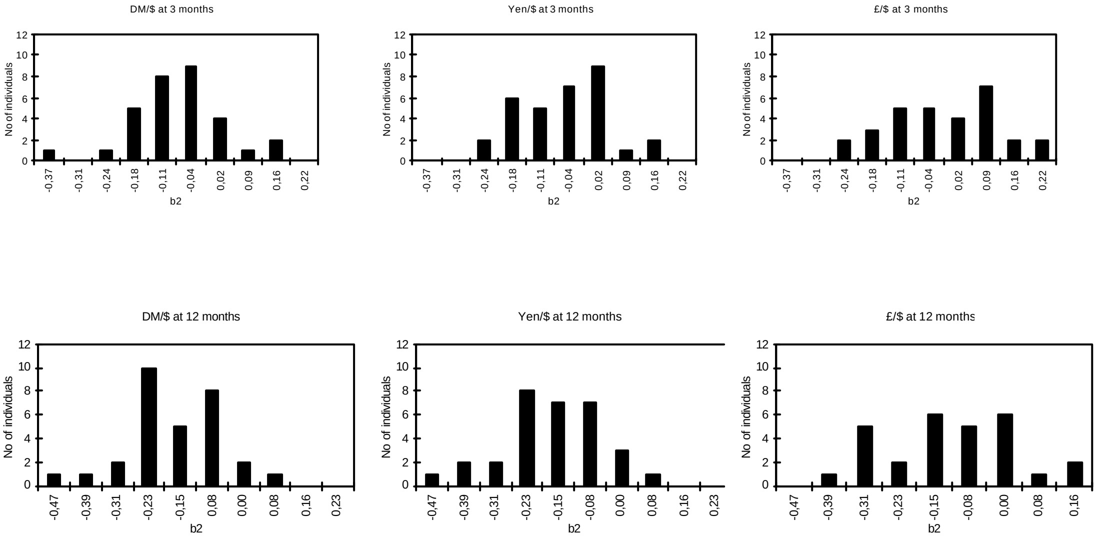


Figure 2a. Regressive model: d^1

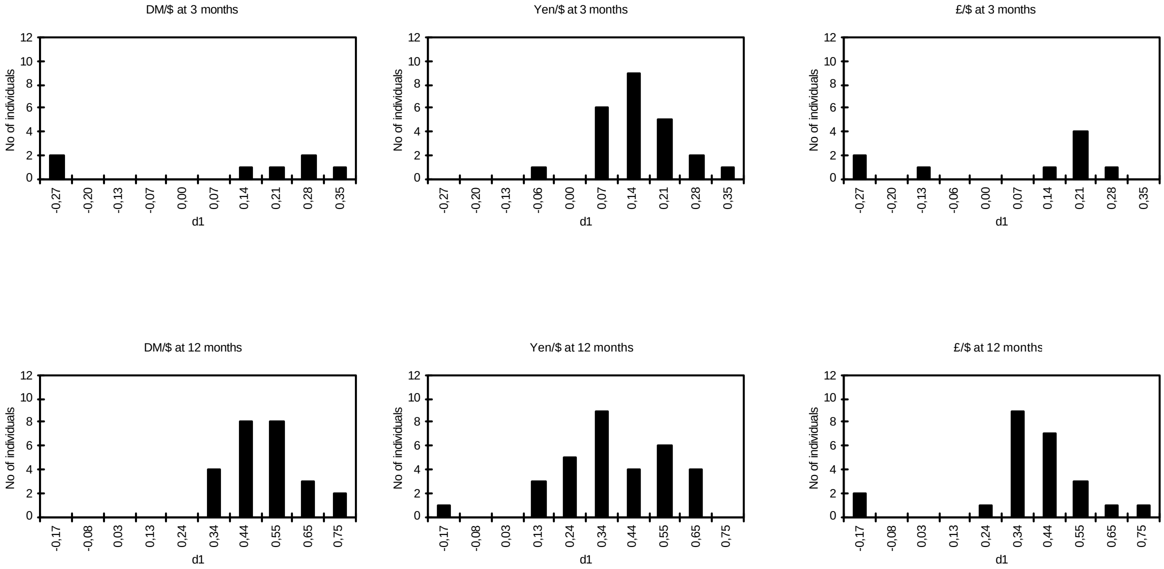


Figure 2b. Regressive model: d^2

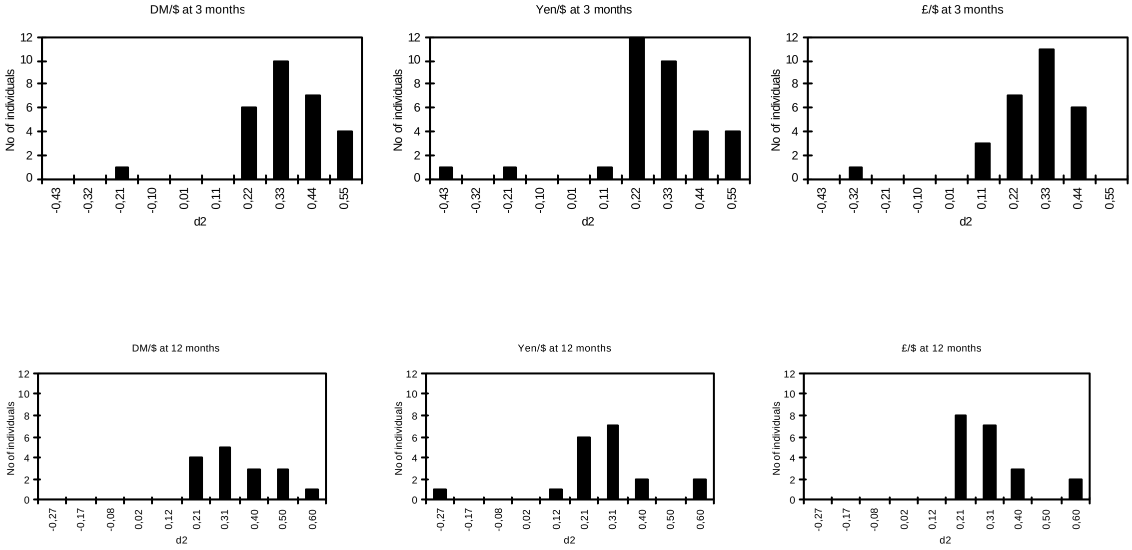
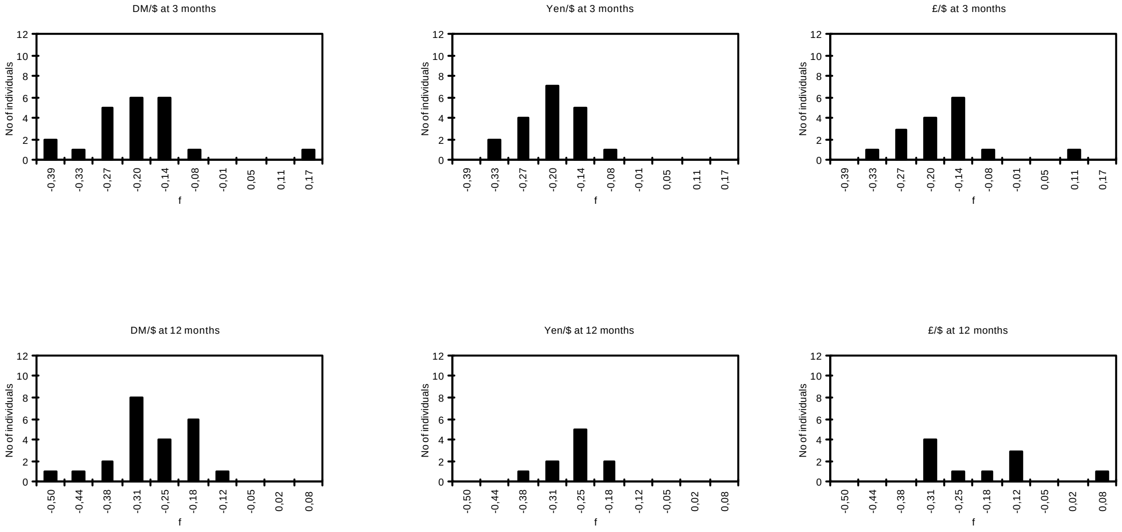


Figure 3. Adaptive model: f



APPENDIX 3[*]

Mapping individuals:
the significance of the simple models nested in the mixed models,
in individual regressions

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