Testing the Asset Pricing Model of Exchange Rates with Survey Forecasts

Anna Naszodi and Robert Lieli

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Abstract

This paper proposes a new test for the asset pricing model of exchange rates. It examines whether forecasts produced by market analysts are more consistent with a simple random walk view of the exchange rate or with a non-trivial rational expectations asset pricing model. The exploited difference between the models is that the forecast is an exponential function of the forecast horizon in the asset pricing model, while it is constant in the random walk model. The asset pricing model is shown to have significantly better in-sample and out-of-sample fit on survey data. As a second contribution, the paper also investigates whether some commonly considered macroeconomic fundamental variables are linked to the exchange rate in a way consistent with the asset pricing model. By using historical data and survey forecasts on both the exchange rate and potential economic fundamentals, we find that GDP, budget deficit, as well as short and long-term interest rates, are important determinants of the exchange rate. They explain between 32 and 45 percent of the variance in excess currency returns over the one year horizon.

Keywords: asset pricing model of exchange rates, latent fundamentals, disconnect puzzle, survey forecast.

JEL: F31, F36, G13.

1 Introduction

Although the asset pricing view has become a widely used building block in the exchange rate literature, it has been rejected by many empirical studies due to its rather poor

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out-of-sample forecasting performance (see Meese and Rogoff (1983)). Notably, it cannot significantly and systematically outperform even the atheoretical random walk model in forecasting the major exchange rates. Engel and West (2005) question the standard criterion based on out-of-sample forecasting for judging exchange rate models. They argue that under certain conditions the standard rational expectations asset pricing model implies that the exchange rate follows a near random walk process. Therefore, evidence that these models do not beat the random walk in forecasting cannot be taken as evidence against the models. It seems essential to look for other means of evaluating exchange rate models.

The main contribution of this paper is that it proposes a new test for the asset pricing model by exploiting its implications for how market participants form their expectations about future spot exchange rates. These expectations, on the other hand, are identified from survey forecasts; specifically, we assume that the observed consensus exchange rate forecasts are noisy versions of the prevailing market expectations. The test exploits a functional form disparity between forecasts from the asset pricing model and its nested alternative, the random walk model. The general asset pricing model implies that the log exchange rate forecast is an exponential function of the forecast horizon, while in the random walk model, the term-structure of forecasts is constant. This difference has not been investigated before in the context of testing the asset pricing model for exchange rates. We present evidence on the in-sample and out-of-sample fit of the models, and find that the results clearly favor the asset pricing model. The interpretation is that the exchange rate model professional forecasters seem to have in mind is closer to a general asset pricing model than to the random walk. If we further assume that forecasters as a group would not, in the long run, use a misspecified model, then a stronger interpretation of the results is that the asset pricing model can be a reasonable approximation of the underlying data generating process.

One potential reason for the rejection of the asset pricing model by the previous empirical literature is the misspecification of the structural macroeconomic models that define the exchange rate fundamentals.[1] Indeed, there is no consensus among economists over what the relevant macro fundamentals are. For instance, Engel and West (2005) present widely-used structural exchange rate models with reduced form representations that fit the asset pricing framework, but with different implications about what the fundamentals should be. A related point is that the fundamental process might contain, or might even be dominated by, "some other variable[s] that models have not captured or that [are] unobserved". ((Engel and West, 2005), p. 499). For example, the risk premium is often assumed to be a fundamental variable, but is generally unobservable.

Therefore, in testing the asset pricing model against the random walk, we take a less theoretical approach and treat the fundamental process as an unobserved latent variable. We show that one can use the Kalman filter to estimate this latent process from the time series of the spot exchange rate and the survey forecasts for various forecast horizons. Filtering the fundamental allows us to bypass the problem of committing to a specific structural model and a specific definition of the fundamental.[2] The key idea is that

[1]Besides the problem of misspecification, Meese and Rogoff (1983) also name simultaneous equation bias, sampling errors, and parameter instability as potential reasons for the disappointing forecasting performance of linear macro models.

[2]The filtering approach has been applied by a number of previous papers in the literature. See for instance, Gardeazabal et al. (1997), Burda and Gerlach (1993) and De Grauwe et al. (1999). This paper

market expectations about future spot rates are based on the relevant set of fundamentals (whatever they might be), and, again, that survey forecasts essentially capture market expectations. Thus, while our results are not contingent on a particular definition of the fundamental, they do rely on the aforementioned interpretation of survey forecasts.

Nevertheless, this atheoretical, and somewhat intrinsic, view of the fundamental can also be construed as a weakness. The problem, in particular, is that the filtered fundamental process is hard to interpret. This motivates the second part of the paper, where we investigate whether some commonly considered economic fundamentals are linked to the exchange rate in a way consistent with the asset pricing model. Specifically, the question is whether the difference between the exchange rate forecast and the spot rate is purely due to some unobservable factors, like market sentiment and risk premia, or it can partly be explained by any of the traditionally considered economic fundamentals.

On the usually available rather short samples, it is difficult to find a strong, statistically significant and stable link between the major exchange rates and those economic indicators that are suggested by international macroeconomic theory to determine these exchange rates. (Obstfeld and Rogoff (2000) called the missing empirical link between exchange rates and macroeconomic fundamentals the disconnect puzzle.) In this paper, we circumvent the short sample problem by using survey forecasts on both the exchange rate and its macro fundamentals in addition to the time series of the target variables of the forecasts. The idea is that the estimated empirical link between the forecasted exchange rate and the forecasted fundamentals can be exploited to identify the relationship between the exchange rate and the fundamentals. Once again, the identification relies on the assumption that market expectations are formed on the basis of the "right" set macro fundamentals with the "right" set of weights, and the consensus forecasts are informative about market expectations. In addition to enriching the commonly used data by survey forecasts, our identification strategy is also facilitated by running panel regressions instead of estimating a model for each exchange rate separately.

We find that GDP, budget deficit, oil price together with the short and long interest rates are significant determinants of the seven major exchange rates investigated in this paper. They explain a substantial part, between 32 and 45 percent of the variance in excess currency returns over the one year horizon.

The rest of the paper is structured as follows. Section 2 introduces the asset pricing exchange rate model and describes the estimation strategy in more detail. Section 3 presents the data and the empirical results. Finally, Section 4 concludes.

2 The Asset Pricing Exchange Rate Model

In the conventional class of asset-pricing models the exchange rate is the discounted sum of current and expected future fundamentals.[3]

$$s_t = (1-b)\sum_{j=0}^{\infty} b^j E_t(x_{t+j}) \quad \text{with} \quad 0 < b < 1\,, \tag{1}$$

distinguishes itself by using survey forecasts to back out the time series of the fundamental.

[3]The asset pricing model of exchange rates has different names in the literature. It is called the "asset market view model"by Frenkel and Mussa (1980), the "canonical model"by Krugman (1992) and by Gardeazabal et al. (1997) and the "rational expectations present-value model"by Engel and West (2005).

where s_t denotes the log exchange rate at time t, while x_{t+j} is the fundamental at time $t + j$. It is important to emphasize that x_{t+j} captures not only the usually considered observable macroeconomic variables, but also the unobservable drivers of the exchange rate. $E_t(.)$ is the expectation operator, where the expectation is conditional on all the information available at time t. Finally, b is the discount factor.

Macroeconomic models that rationalize the asset pricing exchange rate model offer different interpretations of parameter b. For instance, Engel and West (2005) review some standard models, where $\frac{b}{1-b}$ is either the semi-elasticity of money demand with respect to the interest rate, or $1 - b$ is the relative weight of the exchange rate in the Taylor rule. As the empirical identification of the discount factor b is problematic for a number of reasons discussed at a later point in this paper, we calibrate b by relying on the parameter estimates of some structural models in previous empirical studies.

These structural models provide different definitions for the *fundamental* x_t as well. As we do not use the definition of any of these models, our results are general to a broad class of structural models. Part of the cost of this generality is that we have to make an assumption about the dynamics of the fundamental process. The assumed process of x_t is AR(2); specifically,

$$x_t = \alpha + \varphi_1 x_{t-1} + \varphi_2 x_{t-2} + \epsilon_{x,t} \ , \quad \text{where } \epsilon_{x,t} \sim \text{i.i.d.}\, N(0, \sigma_x^2) \ . \tag{2}$$

When the sum of the autoregressive parameters φ_1 and φ_2 is 1, the fundamental process has a unit root. The special case of $\alpha = 0$, $\varphi_1 = 1$ and $\varphi_2 = 0$ corresponds to the random walk. In this case $E_t(x_{t+j}) = x_t$, and equation (1) reduces to $s_t = x_t$, i.e., the log exchange rate trivially follows a random walk regardless of b. Furthermore, past changes in the fundamentals can neither explain nor predict future changes in the log exchange rate. Regarding the general case, when $\alpha \neq 0$ or $\varphi_1 \neq 1$ or $\varphi_2 \neq 0$, near random walk behavior of the exchange rate is still possible. As it is pointed out by Engel and West (2005), one cannot find significant correlation between exchange rate returns and past changes in the fundamentals given that the fundamental process is highly persistent and the discount factor b is "sufficiently large". Therefore, the random walk model is nested practically by the present-value asset pricing model under more than one set of parameter restrictions.

To facilitate the identification of the latent fundamental x_t from survey forecasts, it is helpful to express the expected future exchange rate as a function of present and past fundamentals. As we show in the Appendix, $E_t(s_{t+k})$, $k \geq 0$, is given by the first component of the vector

$$(1-b)F^k(I - bF)^{-1}\xi_t \ , \quad \text{where } \xi_t = \begin{bmatrix} x_t \\ x_{t-1} \\ 1 \end{bmatrix} \quad \text{and } F = \begin{bmatrix} \phi_1 & \phi_2 & \alpha \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} . \tag{3}$$

In the special case of zero forecast horizon, $k = 0$, the expected exchange rate $E_t(s_{t+k})$ is identical to the spot exchange rate s_t. The restriction $k = 0$ reduces equation (3) to

$$s_t = \frac{1-b}{1 - b\varphi_1 - b^2\varphi_2} x_t + \frac{(1-b)b\varphi_2}{1 - b\varphi_1 - b^2\varphi_2} x_{t-1} + \frac{b\alpha}{1 - b\varphi_1 - b^2\varphi_2} \ . \tag{4}$$

Equation (4) shows how the spot exchange rate depends on the contemporaneous and previous period value of the fundamental.

For $k > 0$, the forecast horizon appears in the expression for $E_t(s_{t+k})$ as an exponent. This characteristic distinguishes the general asset pricing model from the random walk model, where forecasts are the same for all forecast horizons. Accordingly, if forecasts, on average, are equal to the theoretical expected value of the target variable, then the "typical" forecast from the asset pricing model must be an exponential function of the forecast horizon. More precisely, we assume that

$$z_{t,t+k} = E_t(s_{t+k}) + \epsilon_{t,k} \ , \tag{5}$$

where $z_{t,t+k}$ is the survey forecast at time t with forecast horizon $k > 0$. The error term $\epsilon_{t,k}$ has a Gaussian distribution, with zero expected value and constant variance denoted by $\sigma^2_{z,k}$. The errors ϵ_{t_1,k_1} and ϵ_{t_2,k_2} for any time t_1 and t_2 ($t_1 \neq t_2$) are assumed to be independent, while errors of the forecasts formed at the same time t but with different forecast horizons k_1, k_2 are allowed to be correlated. The correlation between ϵ_{t,k_1} and ϵ_{t,k_2} is denoted by ρ_{z,k_1,k_2}.

Equations (2), (4) and (5) together with (3) form a state-space system, where (2) is a transition equation specifying the dynamics of the underlying state variable x_t, and equations (4) and (5) are observation equations specifying the observed variables as an affine function of x_t, x_{t-1}, and an error (after substituting in for $E_t(s_{t+k})$ from equation (3)). The coefficients in this system, along with the process x_t, is readily estimable by the Kalman filter.

3 Empirical Analysis

This section tests some empirical implications of the present-value asset pricing model. Section 3.1 describes the data used in the analysis. Section 3.2 investigates whether the way market analysts generate their exchange rate expectations is closer to the one implied by the asset pricing model or to that implied by the random walk model. Section 3.3 investigates which economic fundamentals drive and thought to drive the exchange rate.

3.1 Description of the Data

This section describes the data used in the empirical part of the paper. First, it introduces the survey forecasts on exchange rates. These data are used both for testing the asset pricing model and also for identifying the relevant macro fundamentals in the second empirical exercise. Second, it describes those macro data and their forecasts that are used only in the second exercise.

The survey data on exchange rate forecasts are from the Consensus Economics. Consensus Economics surveys the opinion of the market analysts every month. The survey respondents report their expected 3 months (0.25Y), 1 year (1Y), and 2 years (2Y) ahead end-of-month exchange rates.[4] [5] The survey data used in this paper is the mean of the individual forecasts, therefore it mirrors the consensus view of the professional forecasters.

[4]The reported forecasts are not the expected *log* exchange rates, but the expected exchange rates in *level.* we proxy the expected log exchange rates by the log of the reported expected exchange rates in all calculations and estimations.

[5]The forecast horizons usually differ from 3 months, 1 year, and 2 years by a few days, because the surveys do not take place exactly at the end of each month, while the forecasts refer to the end-of-

The sample spans between January 1999 and September 2008. Therefore, the size of the time series dimension of the sample is 117. The size of the cross-sectional dimension of the data is seven as the surveys cover the following seven major exchange rates: the Canadian dollar (CAD), euro (EUR), the United Kingdom pound (GBP), the Japanese yen (JPY) against the US dollar (USD), and the Swiss franc (CHF), Norwegian krone (NOK), Swedish krona (SEK) against the euro.

For the second empirical exercise presented in this paper, we use the time series of some macroeconomic data together with their forecasts. The time series of the macro variables and their forecasts are collected for the following 8 countries: Canada, Germany (representing the Eurozone), the United Kingdom (UK), Japan, the United States (US), Switzerland, Norway and Sweden. The sample of the economic variables (both the historical data and the survey forecasts) spans between January 1999 and January 2009.

Out of the forecasted variables in the Consensus Economics survey the natural candidates of exchange rate fundamentals are the growth rate of the real gross domestic product (GDP, percent change per annum), government budget balance (in level in local currency),[6] current account (CA, in level in local currency), consumer price index (CPI, percent change per annum), 3-month interest rates (in percent), 10-year government bond yields (in percent) and oil price (WTI price in USD per barrel).

As the exchange rate fundamentals are defined by the domestic and foreign country differences of the economic indicators, and the original budget forecast and CA forecast are published in different currencies for different countries, they need to be transformed. We transform them into budget per GDP forecast and CA per GDP forecast by dividing their original forecasts by the forecasted GDP (also in level and in local currency). Thereby, the transformed data are already measured in the same quantity in the domestic and foreign countries.

Although the considered economic indicators and the survey forecasts are available even on monthly *frequency*, we work with data on annual frequency. The motivation for that is two-fold. First, the annual series of economic indicators are more reliable as they are not exposed to seasonality and less exposed to data revisions. Second, typically the forecast horizon in the surveys shrinks over the course of the year, because it is the end-of-year value of most of the economic indicators that is predicted. The exceptions are the interest rate forecasts and the oil price forecasts, where the forecast horizon is 1 year no matter in which month the forecast is produced.

The source of the survey forecasts on the macro variables is the same as that of the exchange rate forecasts, it is the Consensus Economics. The historical time series of the forecasted variables are from the following sources. The short-term and long-term interest rates are from Bloomberg, while the oil price is from Thomson Reuters Datastream. The series of the rest of the variables are from the OECD's Main Economic Indicators database.

month exchange rates. For instance, the survey can be on the 15th of December of a given year and the participants of that survey are asked to forecast the end-of-March, end-of-December exchange rates of the coming year and the end-of-December exchange rate of the year after. Unfortunately, the discrete time model in this paper cannot account for such an irregularity of the forecast horizons.

[6]Forecast on government budget is published by the Consensus Economics only for Japan, Germany, Canada, the US and the UK out of the eight countries in our sample.

3.2 Testing the Asset Pricing Exchange Rate Model Based on its In-Sample Fit and Out-of-Sample Fit on Survey Forecasts

One way of testing the competing models is to compare their in-sample and out-of-sample fit on survey forecasts. This section explains how the competing models are estimated for these tests, what the test statistics are, and interprets the results.

When comparing the *in-sample fit* of the models the model parameters are estimated from survey forecasts with all the three different forecast horizons (3 months, 1 year and 2 years), and the exchange rate on the survey dates. After estimating the models by the Kalman filter, we compare their filtering likelihoods by the likelihood ratio test. Under the null hypothesis the random walk model and the asset pricing model fit the data equally well. Given that the random walk model is nested by the asset pricing model, the likelihood ratio test provides a theoretically valid comparison of the models.

In addition to comparing the in-sample performances of the models, we also check which of the two models has better *out-of-sample* fit on the survey forecasts. For this exercise the asset pricing model is estimated again by the Kalman filter. However, this time only the survey forecasts with the two longer forecast horizons (1 year and 2 years), and the exchange rate on the survey date are used as observed variables, but not the survey forecasts with the 3-month horizon. The time series of the 3-month forecast is saved to measure the out-of-sample fit. We choose the forecast with the shortest forecast horizon for the out-of-sample test, because distinguishing empirically between the random walk model and the asset pricing model is more difficult on the short horizon.

After estimating the asset pricing model, we investigate how close its fitted 3-month forecast is to the 3-month survey forecast. In case of the random walk model, we do not need to estimate the model in order to obtain its 3-month fitted forecast as it is identical with the spot rate. Accordingly, the models are judged by comparing the distance between the fitted 3-month forecast of the asset pricing model and the 3-month survey forecast on the one hand with the distance between the spot rate and the 3-month survey forecast on the other hand.

The logic of the proposed out-of-sample test can be illustrated by a magician's trick. The magician asks someone from the audience to tell her 1-year and 2-year exchange rate forecast. The person is asked to make a 3-month forecast as well, but instead of telling it to the magician, she should write it down on a piece of paper and hide it in an envelope. If the magician can find out the secret 3-month forecast, then he is likely to know how the forecasts were generated. Moreover, if the forecaster is rational, the model she has in mind is identical to the data generating process of the exchange rate. Therefore, a successful magician knows not only what the forecaster thinks, but also how the exchange rate is determined.

As we have already indicated in Section 2, we use the *Kalman filter* to estimate the unobserved fundamental process in the state space system given by equations (2), (4) and (5).[7] This involves maximizing the filtering likelihood, which is undertaken by the simulated annealing algorithm (see, e.g., Goffe et al. (1994)). When investigating the in-sample fit of the models, we use four observation equations, one for the spot rate and

[7] The Kalman filter toolbox for Matlab written by Kevin Murphy is used. See http://www.ai.mit.edu/murphyk/Software/kalman.html for details.

three for forecasts with horizons 3 months, 1 year and 2 years. When investigating the out-of-sample fit of the models, we use three observation equations, one for the spot rate and two for forecasts with horizons 1 year and 2 years.

All model parameters with the exception of the discount factor b are estimated. So, the following 10 parameters are estimated in the most general model specification, when there is no parameter restriction imposed and all the survey forecasts with three different forecast horizons are used to filter out the fundamentals: φ_1, φ_2, α, σ_x^2, $\sigma_{z,k=0.25Y}^2$, $\sigma_{z,k=1Y}^2$, $\sigma_{z,k=2Y}^2$, $\rho_{z,k_1=0.25Y,k_2=1Y}$,$\rho_{z,k_1=0.25Y,k_2=2Y}$ and $\rho_{z,k_1=1Y,k_2=2Y}$. As opposed to these parameters, setting the discount factor needs special care. Lieli and Naszodi (2013) write the following on the problem of identifying the discount factor: "if the fundamental process is a random walk, then the exchange rate will be a random walk as well regardless of what the value of the discount factor is. To put it somewhat differently, the discount factor is identified solely by the dynamics in the first difference of the fundamental process; if the first difference is white noise (more exactly, martingale difference), then the model has simply no implications about the discount rate." Furthermore, even if the fundamental process is not an exact random walk, just a near random walk, its estimation is still problematic on finite samples of usual length. For the above reason, the discount factor b is calibrated. Its calibrated value is chosen to be consistent with the previous empirical literature. Engel and West (2005, page 497) note that the implied range for the quarterly discount factor is of 0.97-0.98 based on the works of Bilson (1978), Frankel (1979), Stock and Watson (1993, 802, table 2, panel I). Therefore, the annual discount factor should be in the range of 0.885 - 0.922 , while the monthly discount factor should be in the range of 0.990 - 0.993. Accordingly, the annual discount factor is set to 0.9, while the monthly discount factor is set to 0.9913 in this paper.

3.2.1 Results of the Test and their Interpretations

Table 1 presents the parameter estimates of the asset pricing model obtained by using all three survey forecasts. As the sum of the estimated autoregressive parameters is close to unity for all investigated exchange rates, the fundamentals follow a highly persistent process. This finding is consistent with the first condition of Engel and West (2005) that implies the approximately random walk behavior of the exchange rate together with the high discount factor condition. Table 2 presents the parameter estimates obtained also from all three survey forecasts, but this time the estimated model is the random walk model. Accordingly, the parameters α, φ_1 and φ_2 are restricted to 0, 1 and 0, respectively.

When comparing the likelihoods of the two models, we find the following. First, the log likelihood of the broader model, i.e., that of the asset pricing model is higher than that of the nested random walk model for all seven currency pairs. See the last rows in Tables 1 and 2. Second, the differences between the log likelihoods are sufficiently large to reject the null hypothesis of equal *in-sample* performance of the models at any meaningful significance level. This is inferred from the likelihood ratio test statistics that follows a chi-square distribution with three degrees of freedom given that the random walk model is obtained from the asset pricing model by imposing three parameter restrictions.

Not surprisingly, the relative goodness of *out-of-sample* fit of the models also confirm that the asset pricing model out-performs the random walk model. For this comparison of the models, we re-estimate the asset pricing model on a restricted sample that does not cover the 3-month survey forecasts. Once the asset pricing model is estimated, we can easily obtain its fitted 3-month exchange rate forecast $\widehat{z}^{AP}_{t,t+0.25Y}$ by substituting the point estimates of the parameters and the filtered fundamental into equation (3). Obtaining the fitted 3-month exchange rate forecast that is consistent with the random walk model $\widehat{z}^{RW}_{t,t+0.25Y}$ is even simpler as being equal to s_t. Than, we compare the models by using a standard measure on how well they fit the survey data on the expected 3-month ahead exchange rate $z_{t,t+0.25Y}$.

The goodness of fit is measured by the root mean square error (RMSE).[8] Accordingly, the tested hypothesis is that the squared errors of the asset pricing model are equal to that of the random walk model in expected term.

$$H_0 : E\left[(z_{t,t+0.25Y} - \widehat{z}^{RW}_{t,t+0.25Y})^2 - (z_{t,t+0.25Y} - \widehat{z}^{AP}_{t,t+0.25Y})^2\right] = 0 \; . \tag{6}$$

The alternative hypothesis is that the asset pricing model has better out-of-sample fit:

$$H_1 : E\left[(z_{t,t+0.25Y} - \widehat{z}^{RW}_{t,t+0.25Y})^2 - (z_{t,t+0.25Y} - \widehat{z}^{AP}_{t,t+0.25Y})^2\right] > 0 \; . \tag{7}$$

The formal test of the null is missing from this version of the paper. It is an ongoing work to select the adequate test-statistics.

Table 3 shows that the asset pricing model has better out-of-sample fit for all seven currency pairs. It is worth to remark that the asset pricing model out-performs the random walk model not simply because of being broader. A model that is complex enough can fit the data in-sample even perfectly as an extreme example of overfitting. However, the same model usually performs poorly out-of-sample. The intuitive explanation for this finding is that a sufficiently broad model is flexible enough to learn sample specific regularities and consider them falsely as part of the underlying relationship. Since the goodness of fit is measured out-of-sample in this second test, the good performance of the asset pricing model cannot be attributed to the model complexity and to the potential problem of overfitting.

The main finding of this section can be summarized as follows. It is proved that the asset pricing model fits the survey forecasts better than the random walk model does both in-sample and out-of-sample. The intuitive explanation for this finding is that the term-structure of survey forecasts is closer to the exponential curve than to a constant. As it is shown in the theoretical part of this paper in section 2 the exponential term-structure is consistent with the non-trivial asset pricing model, while the constant term-structure is consistent with the random walk model. The exponential relationship between the forecast horizon and the forecast comes from the present-value relationship between the spot exchange rate and future fundamentals, where the discount factor is raised to a higher power for fundamentals more distant in time. So, the finding that the asset pricing model fits the survey forecasts well, provides empirical support to the functional form of the asset pricing model of (1).

By analyzing survey forecasts, Frankel and Froot (1987) also reject the *static expectation hypothesis*. It means that they can also confute that the process of the exchange rate is thought to be random walk by the survey participants. So, the empirical finding of this paper is in line with the previous literature, while its interpretation is new. This paper interprets the results in the context of testing the asset pricing model, while Frankel and Froot (1987) test a number of hypotheses on how the survey forecasts are produced.

[8]By using the mean absolute error as an alternative to the root mean square error, we obtain qualitatively the same results.

3.3 Linking Exchange Rate and Economic Fundamentals

Unfortunately, the test proposed in this paper does not reveal what specific economic variables are important determinants of the exchange rate given that the fundamental is treated as unobservable. Theoretically, it is possible that the filtered fundamental captures mainly some unobservable exchange rate fundamentals, like market sentiment and risk premia, and it fails to capture the traditionally considered observable economic fundamentals. Due to this possibility, this section complements the test by investigating the main economic drivers of exchange rate.

A straightforward approach for identifying the important economic determinants of exchange rate would be to regress the filtered fundamental on various economic indicators. This method is clearly a 2-stage method, where the series of fundamental is filtered in the first stage, while the coefficients of its economic components are estimated in the second stage. The shortcoming of 2-stage methods in general is that it is difficult to take into account in the second stage that the series obtained from the first stage is not directly observed, but are themselves estimates and so contain sampling variation. Due to this issue, we do not use the series of the filtered fundamental in this section. And we identify the economic determinants of exchange rate directly from some observed series.

The analysis in this section centers on the following empirical questions. First, what are the economic fundamentals that drive the exchange rate. Second, what are the economic fundamentals that are thought to drive the exchange rate by the representative forecaster. The important economic determinants of the exchange rate are identified by assuming that the answers to the above two questions are the same.

In this section, we define the fundamental x_t as the index of some economic indicators.

$$x_t = \sum_{j=1}^{J} \alpha_j y_{t,j} \ , \tag{8}$$

where $y_{t,j}$ denotes the jth macroeconomic indicator at time t (also called as the economic fundamentals of exchange rate) and α_j is its weight.

By rearranging the asset pricing equation (1) in two ways, we can make it explicit, how the exchange rate is determined by its present and future fundamentals and by the expected future exchange rate (which is also determined by the future fundamentals). We obtain

$$s_t = bE_t(s_{t+1}) + (1-b)x_t \ , \tag{9}$$

and

$$s_t = b^2 E_t(s_{t+2}) + (1-b)\left[x_t + bE_t(x_{t+1})\right] \ . \tag{10}$$

Equation (9) describes the link between the spot exchange rate s_t and the present fundamental x_t, while equation (10) captures how the expected future exchange rate $E_t(s_{t+2})$ is related to the expected future fundamental $E_t(x_{t+1})$. As we are primarily interested in the first link, the latter link is used only for identifying the former that is in the center of our interested.

By substituting (8) into (9) and (10), and by proxying the expected exchange rates ($E_t(s_{t+1})$ and $E_t(s_{t+2})$) and the expected fundamental components ($E_t(y_{t+1,j})$) by their survey counterparts, we obtain the system of equations of (11) and (12) that is ready to be estimated.

$$s_t = bz_{t,t+1} + (1-b)\sum_{j=1}^{J}\alpha_j y_{t,j} + \eta_1 \ , \quad \text{where } \eta_1 \sim \text{i.i.d.}\ N(0,\sigma^2_{\eta_1}) \ . \tag{11}$$

$$s_t = b^2 z_{t,t+2} + (1-b)\sum_{j=1}^{J}\alpha_j \left[y_{t,j} + bv_{t,t+1,j}\right] + \eta_2 \ , \quad \text{where } \eta_2 \sim \text{i.i.d.}\ N(0,\sigma^2_{\eta_2}) \ . \tag{12}$$

where $v_{t,t+1,j}$ denotes the survey forecast on the 1 period (1 year) ahead jth component of the fundamentals, while $z_{t,t+k}$ is the survey forecast on the k period ahead log exchange rate like before.

Working with the system of equations (11) and (12) as opposed to estimating the single equation of (11) is a novel approach in the disconnect puzzle literature. Previous papers in the literature have not used such a rich set of survey forecasts that allow us to estimate the system of (11) and (12). Those papers in the literature that work with survey data, use survey forecasts only on exchange rates, but not on the economic fundamentals. For instance, Engel et al. (2009) calculate the risk premium from exchange rate forecasts also sourced from the Consensus Economics surveys and use it as one of the economic fundamentals of the exchange rate.

When choosing the *estimation method* adequate to the model and data, the following considerations are made. First, the parameters are the same in equations (11) and (12). Therefore, we opt for estimating them jointly as a system as opposed to estimating them separately. Second, the two error terms η_1 and η_2 are correlated, because they capture correlated noises. For instance, η_1 captures $\epsilon_{t,1}$, the deviations of the 1-year exchange rate survey forecast $z_{t,t+1}$ from the expected 1-year ahead exchange rate $E_t(s_{t+1})$, while η_2 captures $\epsilon_{t,2}$. Due to having correlated error terms, the system of equations is estimated by the *seemingly unrelated regression* (SUR) method.[9] Third, given that the dependent variable s_t is not stationary, we estimate the model in *first difference*. Fourth, we rearrange the equations so as to have the *excess currency return* as the dependent variable, where the excess currency return is defined by the percentage annual changes in the exchange rates that is not explained by the percentage annual changes in the survey forecasts on the exchange rate. The advantage of this approach is that the set of explanatory variables in this new specification of the model consists only of the present and future expected changes in the fundamentals, but not the changes in the forecasted exchange rate, which is not an economic fundamental. Fifth, as the sample spans between January 1999 and January 2009 and the data frequency is annual, the time series consists of only 11 observations. In order to circumvent the short sample problem, estimation is carried out in a panel framework. The cross sectional dimension of the *panel data* covers the same 7 exchange rates that are analyzed previously in this paper. Sixth, when estimating the model, we include a constant term in both of the transformed versions of equations (11) and (12) that can capture non-zero mean of the error-terms. Finally, the discount factor is set the same way as before instead of being estimated. Given that the data frequency is annual in this exercise, b denotes the annual discount factor in this section. So, its calibrated value is 0.9.

[9]We used the EViews built in procedure for estimating the system of equation by SUR. It estimates the parameters of the system, accounting for heteroscedasticity and contemporaneous correlation in the errors across equations. The estimates of the cross-equation covariance matrix are based upon parameter estimates of the unweighted system.

After all these considerations, the system we estimate is:

$$s_t - s_{t-1} - 0.9\left[z_{t,t+1} - z_{t-1,t}\right] = \alpha_{0,1} + 0.1\sum_{j=1}^{J}\alpha_j(y_{t,j} - y_{t-1,j}) + \lambda_1 \ , \quad \text{where } \lambda_1 \sim \text{i.i.d.}\, N(0, \sigma^2_{\lambda_1}) \ . \tag{13}$$

$$s_t - s_{t-1} - 0.9^2\left[z_{t,t+2} - z_{t-1,t+1}\right] = \alpha_{0,2} + 0.1\sum_{j=1}^{J}\alpha_j\left[(y_{t,j} - y_{t-1,j}) + 0.9(v_{t,t+1,j} - v_{t-1,t,j})\right] + \lambda_2 \ , \tag{14}$$

where $\lambda_2 \sim$ i.i.d. $N(0, \sigma^2_{\lambda_2})$.

The important economic determinants of exchange rate can be found by estimating the system of equations of (13) and (14) on a wide range of economic indicators. The economic indicators that are considered to be potential exchange rate fundamentals are the GDP growth rate, budget deficit relative to GDP, current account, inflation rate, short term interest rate, long term interest rate and oil price. More precisely, the potential fundamentals are defined as the difference between the domestic and the foreign values of the above variables with the exception of global oil price.

As a first step, we estimate different specifications of the model that include only one of the economic variables. Than, we select those economic variables to the index of fundamentals that are assigned significant coefficients in the first step. Finally, the weights α_j for the components of the fundamental index are obtained by estimating the final model that controls for all the selected components. This way, we build the final model with the bottom up approach. The economic fundamentals in the final model are the GDP growth rate, the budget deficit relative to GDP, the short and long interest rates and oil price. Surprisingly, neither inflation rate, nor current account are found significant determinants of the exchange rate in the first step. Therefore, they are not included in the final model.

Regarding the oil price, we estimate its effect the following way. We re-estimate the models that control for only one economic variable and its forecast, but this time we also include the oil price and its forecast. These estimates are carried out not only on panel data, but also for each county separately, and for panels of various groups of countries. These estimates suggest that oil is an important determinant of the exchange rate only for some oil producing countries, like Canada, Norway and the UK. The estimated coefficients of oil are very close to each other for these three countries. Therefore, we restrict the coefficient of oil in the final regression model to be the same for the 3 countries, while zero for the rest of the countries.

The results obtained with the final model are presented in Table 4. It shows that four of the five economic indicators are assigned statistically significant weights and each of the weights are significant also in economic terms. For instance, if the difference between the domestic and the foreign annual GDP growth rate increases by one percentage point from one year to another, then the appreciation of the domestic currency is 0.73 percentage higher for that year, ceteris paribus.

The goodness of fit measured by the R^2s are 0.32 and 0.45 for equations (13) and (14), respectively. These values of R^2s indicate fairly good fit, especial in the light of the previous literature. Evans (2010) writes "In fact, my empirical results indicate that between 20 and 30 percent of the variance in excess currency returns over one- and two-month horizons can be linked back to developments in the macroeconomy. This level of explanatory power is an order of magnitude higher than that found in traditional models - even the newly developed monetary models incorporating central banks reaction functions." Although the R^2s of this paper are higher than those in Evans (2010), we cannot say that the results in this paper are stronger. When comparing the results of Evans (2010) and those of this paper, the following considerations should be made. First, Evans (2010) defines the excess currency return differently, than this paper. There, it is the return not explained by the interest rate differential, while it is the return not explained by survey forecasts on exchange rate. Second, another essential difference between Evans (2010) and this paper, is that the former investigates one-month and two-month returns, while the returns in this paper are annual. It is worth noting that Evans (2010) tackled a more challenging problem as it is more difficult to explain exchange rate movements on the shorter than one year horizon.

In order to demonstrate the importance of working with the system of equations of (13) and (14), we estimate also the single equation model of (13). The results are presented in Table 5. As it is apparent from the comparison of Table 4 and Table 5, one can obtain more precise estimates by the system. And also, more economic indicators prove to be significant determinants of the exchange rate with the system, than with the single equation approach. So, exploiting the link between forecasted exchange rate and forecasted economic fundamentals helps us to identify the link between exchange rate and economic fundamentals.

4 Conclusion

For a long while, the main means of evaluating exchange rate models was to compare their out-of-sample forecasting performances. This paper has proposed a new test for the asset pricing model of exchange rate. The primary motivation for proposing an alternative test to the traditional one is that it is found by the recent literature that it is too harsh to require the exchange rate models to outperform the random walk at forecasting. As it is argued by Engel and West (2005), it is almost impossible to come up with a better forecast than the random walk. They point out that if the fundamentals have a persistent process and the discount factor is high enough, then the exchange rate follows a process that is indistinguishable from the random walk on the usual sample sizes. For this reason, even if the traditional test formally rejects the asset pricing model against the random walk model, the former can still be the right one.

The test proposed in this paper uses survey data on exchange rate expectations. It examines whether the way market analysts generate their forecasts is closer to the one implied by the asset pricing model, or to that implied by the naive random walk model. The models differ in their predictions on the term-structure of forecasts. The forecast is an exponential function of the forecast horizon in the general asset pricing model, while it is constant in the random walk model given that under the random walk assumption no change is expected in the exchange rate in any horizon.

The remarkable result of the proposed test is that the asset pricing model has significantly better fit on survey data, than the random walk. The relative goodness of fit of the competing models is found to be robust to whether it is measured in-sample or out-of-sample. We can interpret this result as follows. What the representative professional exchange rate forecaster has in mind about the exchange rate can be better represented by the asset pricing model. If we believe that the model used by the forecasters is identical to the data generating process of the exchange rate, then the asset pricing model captures better not only the way in which the expectations are formed, but also the way the exchange rate is actually determined.

This paper investigated also whether some commonly considered economic fundamentals are linked to the exchange rate in a way consistent with the asset pricing model. The novelty in the applied empirical approach is to use not only historical data, but also survey forecasts both on the exchange rate and on its potential economic fundamentals to identify the significant determinants of the exchange rate. With these rich data, we found that GDP, budget deficit and oil price together with the short and long interest rates are important drivers of the exchange rate. It is also a remarkable result that these economic fundamentals can explain 32 and 45 percent of the variance in excess currency returns over the one-year horizon. These values are comparable in magnitude to those obtained by Evans (2010), whose model and economic fundamentals can explain between 20 and 30 percent of the variance in excess currency returns over one- and two-month horizons.

Appendix

In this Appendix we show that under the assumed process of the fundamental x_t of (2), the k period-ahead expected log exchange rate $E_t(s_{t+k})$ is given by equation (3) in the reduced form asset-pricing model of (1).

First, it is important to note that matrix F is the transition matrix of vector ξ_t.

$$\xi_t = \begin{bmatrix} x_t \\ x_{t-1} \\ 1 \end{bmatrix} = F\xi_{t-1} \ . \tag{15}$$

This implies that

$$E_t(\xi_{t+j}) = F^j \xi_t \ . \tag{16}$$

We know that

$$E_t(s_{t+k}) = (1-b)\sum_{j=0}^{\infty} b^j E_t(x_{t+k+j}) \ . \tag{17}$$

Note from (16) that $E_t(x_{t+k+j})$ is given by the first component of the vector $F^{k+j}\xi_t$. Now consider

$$(1-b)\sum_{j=0}^{\infty} b^j F^{k+j}\xi_t = (1-b)F^k \left(\sum_{j=0}^{\infty} b^j F^j\right) \xi_t \ . \tag{18}$$

The first component of this vector is $E_t(s_{t+k})$. By formula [1.2.46] in Hamilton (1994), the matrix sum in the parenthesis is equal to

$$(I - bF)^{-1} \ . \tag{19}$$

provided that the eigenvalues of F are all less than b^{-1} in absolute value.[10] In sum, the first component of the vector $(1-b)F^k(I-bF)^{-1}\xi_t$ is precisely $E_t(s_{t+k})$ for $k > 0$.

[10] This eigenvalue condition is satisfied by all of the estimates in this paper.

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Table 1: Parameter Estimates of the Asset Pricing Model

	$\frac{\text{CAD}}{\text{USD}}$	$\frac{\text{USD}}{\text{EUR}}$	$\frac{\text{USD}}{\text{GBP}}$	$\frac{\text{JPY}}{\text{USD}}$	$\frac{\text{CHF}}{\text{EUR}}$	$\frac{\text{NOK}}{\text{EUR}}$	$\frac{\text{SEK}}{\text{EUR}}$
b	99.13%	99.13%	99.13%	99.13%	99.13%	99.13%	99.13%
φ_1	0.1626	0.0589	1.0878	0.6684	0.4289	0.5513	0.8589
std.dev.	0.1758	0.0491	0.0172	0.0301	0.5911	0.2094	0.0114
φ_2	0.8173	0.911	-0.0993	0.2459	0.5219	0.2454	0.0399
std.dev.	0.174	0.0488	0.0171	0.0254	0.5732	0.1765	0.0108
α	0.0046	0.0053	0.0057	0.4015	0.0209	0.4251	0.2194
std.dev.	0.0006	0.0008	0.0007	0.0699	0.0089	0.0792	0.0103
σ_x	0.0911	0.1759	0.0587	0.3691	0.0683	0.4125	0.1825
std.dev.	0.012	0.0157	0.0047	0.0571	0.0274	0.074	0.0157
$\sigma_{z,k=0.25Y}$	0.0131	0.0209	0.013	0.0317	0.0088	0.0172	0.0094
std.dev.	0.0012	0.0016	0.0009	0.0029	0.0009	0.0021	0.0008
$\sigma_{z,k=1Y}$	0.0151	0.0402	0.0182	0.0564	0.0143	0.0255	0.0151
std.dev.	0.0015	0.0038	0.0016	0.0077	0.0017	0.004	0.0016
$\sigma_{z,k=2Y}$	0.0158	0.0446	0.0228	0.0625	0.0178	0.0233	0.0176
std.dev.	0.0014	0.0052	0.0019	0.0081	0.0022	0.0033	0.0017
$\rho_{z,0.25Y,1Y}$	0.853	0.8572	0.77	0.8997	0.8469	0.8976	0.6814
std.dev.	0.0276	0.026	0.0359	0.0223	0.0345	0.0253	0.0662
$\rho_{z,0.25Y,2Y}$	0.614	0.7657	0.5623	0.8191	0.668	0.8152	0.5245
std.dev.	0.092	0.0448	0.0679	0.046	0.0755	0.0622	0.0871
$\rho_{z,1Y,2Y}$	0.6502	0.9365	0.7835	0.9644	0.8933	0.9174	0.9439
std.dev.	0.0952	0.0194	0.0443	0.0109	0.0304	0.0285	0.0138
log likelihood	1371	1128	1287	1061	1574	1360	1521

Note: the covariance matrix of the parameter estimates (that is used to calculate the reported standard deviations (std.dev.)) is calculated as the outer product of the gradient.

Table 2: Parameter Estimates of the Random Walk Model

	$\frac{CAD}{USD}$	$\frac{USD}{EUR}$	$\frac{USD}{GBP}$	$\frac{JPY}{USD}$	$\frac{CHF}{EUR}$	$\frac{NOK}{EUR}$	$\frac{SEK}{EUR}$
b	99.13%	99.13%	99.13%	99.13%	99.13%	99.13%	99.13%
φ_1	1	1	1	1	1	1	1
φ_2	0	0	0	0	0	0	0
α	0	0	0	0	0	0	0
σ_x	0.0224	0.0333	0.0267	0.0346	0.0097	0.0174	0.0143
std.dev.	0.0017	0.0018	0.0013	0.0019	0.0007	0.001	0.001
$\sigma_{z,k=0.25Y}$	0.0157	0.0254	0.0141	0.0278	0.0105	0.0144	0.0165
std.dev.	0.0014	0.0016	0.0008	0.0019	0.0009	0.0009	0.0019
$\sigma_{z,k=1Y}$	0.0304	0.0609	0.0272	0.0488	0.0202	0.0246	0.0324
std.dev.	0.0029	0.0042	0.002	0.0036	0.0023	0.0019	0.0041
$\sigma_{z,k=2Y}$	0.0383	0.0817	0.0389	0.062	0.0286	0.0266	0.0404
std.dev.	0.0038	0.0058	0.0032	0.004	0.0032	0.0019	0.0052
$\rho_{z,0.25Y,1Y}$	0.8266	0.8855	0.7619	0.8253	0.9029	0.8012	0.927
std.dev.	0.0305	0.0194	0.0376	0.0272	0.0189	0.0283	0.0165
$\rho_{z,0.25Y,2Y}$	0.7658	0.8286	0.6226	0.6408	0.7989	0.6465	0.8928
std.dev.	0.042	0.0289	0.0562	0.0588	0.0468	0.0651	0.0268
$\rho_{z,1Y,2Y}$	0.9724	0.9789	0.9186	0.9274	0.9469	0.906	0.9882
std.dev.	0.0058	0.0034	0.0135	0.0138	0.0178	0.0183	0.0036
log likelihood	1297	1067	1223	1031	1521	1327	1431

Note: the same as below Table 1.

Table 3: Parameter Estimates of the Asset Pricing Model on the Restricted Sample

	$\frac{\text{CAD}}{\text{USD}}$	$\frac{\text{USD}}{\text{EUR}}$	$\frac{\text{USD}}{\text{GBP}}$	$\frac{\text{JPY}}{\text{USD}}$	$\frac{\text{CHF}}{\text{EUR}}$	$\frac{\text{NOK}}{\text{EUR}}$	$\frac{\text{SEK}}{\text{EUR}}$
b	99.13%	99.13%	99.13%	99.13%	99.13%	99.13%	99.13%
φ_1	0.0638	0.1608	0.2745	0.8384	0.3162	0.7233	0.6215
std.dev.	0.319	0.5819	0.3412	0.0033	0.4538	0.0043	0.0075
φ_2	0.9196	0.8121	0.7046	0.165	0.6193	0.1805	0.2555
std.dev.	0.3166	0.573	0.3369	0.0053	0.4341	0.0041	0.0073
α	0.0039	0.0046	0.0102	-0.0175	0.0274	0.2014	0.2668
std.dev.	0.0011	0.0017	0.0025	0.0126	0.011	0.0005	0.0007
σ_x	0.0846	0.162	0.1079	0.0051	0.0859	0.2048	0.2209
std.dev.	0.0261	0.0523	0.023	0.002	0.0319	0.0008	0.0008
$\sigma_{z,k=1Y}$	0.0179	0.0412	0.0183	0.0437	0.014	0.021	0.015
std.dev.	0.0027	0.0038	0.0017	0.0032	0.0016	0.0008	0.0001
$\sigma_{z,k=2Y}$	0.0169	0.0459	0.0228	0.0513	0.0177	0.0207	0.0175
std.dev.	0.0011	0.005	0.0018	0.004	0.0021	0.0001	0
$\rho_{z,1Y,2Y}$	0.8145	0.9432	0.7899	0.905	0.889	0.8727	0.9433
std.dev.	0.0297	0.0171	0.0433	0.0188	0.0293	0.007	0.0013
RMSE AP	0.0214	0.0525	0.0192	0.0867	0.0086	0.0237	0.0103
RMSE RW	0.0288	0.0752	0.0231	0.0904	0.013	0.0242	0.032

Notes: The restricted sample does not cover the 3-month forecasts. RMSE AP and RMSE RW measure the out-of-sample fit of the asset pricing model and the random walk model on the 3-month survey forecasts, respectively.

Table 4: Estimated Weights of the Components of the Economic Fundamentals Obtained with the System of Equations of (13) and (14)

	Coefficient	Std. Error	t-Statistic	Prob.
α_{GDP}	0.073	0.026	2.822	0.006
$\alpha_{Budget/GDP}$	0.021	0.013	1.591	0.114
$\alpha_{Shortrate}$	-0.062	0.030	-2.084	0.040
$\alpha_{Longrate}$	-0.172	0.066	-2.609	0.010
α_{OIL}	-0.050	0.002	-2.187	0.030
$\alpha_{0,1}$	0.000	0.004	0.106	0.91
$\alpha_{0,2}$	-0.001	0.007	-0.187	0.852

Notes: sample covers the exchange rates of CAD/USD, EUR/USD, GBP/USD, JPY/USD, CHF/EUR, NOK/EUR and SEK/EUR. Sample period: January 1999 – January 2009. Data frequency: annual. Included observations in equation (13): 76. Included observations in equation (14): 43. (Equation (14) includes less observations than equation (13), because budget forecast is not available for Norway, Sweden and Switzerland.) Estimation method: seemingly unrelated regression. R^2 for equation (13): 0.32. R^2 for equation (14): 0.45.

Table 5: Estimated Weights of the Components of the Economic Fundamentals Obtained with Equation (13)

	Coefficient	Std. Error	t-Statistic	Prob.
α_{GDP}	0.060	0.032	1.907	0.061
$\alpha_{Budget/GDP}$	0.018	0.017	1.020	0.311
$\alpha_{Shortrate}$	-0.035	0.038	-0.909	0.367
$\alpha_{Longrate}$	-0.266	0.086	-3.105	0.003
α_{OIL}	-0.006	0.003	-1.875	0.065
$\alpha_{0,1}$	0.001	0.004	0.126	0.900

Notes: sample covers the exchange rates of CAD/USD, EUR/USD, GBP/USD, JPY/USD, CHF/EUR, NOK/EUR and SEK/EUR. Sample period: January 1999 – January 2009. Data frequency: annual. Included observations in the : 76. Estimation method: least squares. R^2 for equation (13): 0.33.