## Are Exchange Rate Forecasts Rational?

Evidence from Central and Eastern European Multi-Horizon Survey Forecasts

By

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## Abstract

In most empirical studies using survey forecasts, researchers assume forecast rationality. If this assumption did not hold, many findings of the pertaining literature would need to be revisited. The goal of this thesis is to test the rationality of exchange rate survey forecasts for three Central and Eastern European currencies: the Czech Koruna, the Hungarian Forint and the Polish Zloty (against the Euro). I use conventional Mincer-Zarnowitz tests, together with tests based on multi-horizon bounds and other regression-based tests that use information from forecast revisions. I find mixed results on forecast rationality: while the bounds tests fail to reject rationality, I find bias and endogeneity on the Hungarian Forint and the Polish Zloty samples, and a rejection of optimality by the Mincer-Zarnowitz test on the HUF/EUR exchange rate.

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## **1** Introduction

Forming expectations about the future based on our currently available information is a necessity in everyday life, as well as in economics, finance and natural sciences. Since individuals, policymakers and other economic actors all use forecasts when making decisions, examining their accuracy is of great importance. In most empirical studies using survey forecasts, researchers assume forecast optimality. If this assumption did not hold, many findings of the relevant literature would not be true. This gives the main motivation of my thesis: in order to check the accuracy of the widely used assumption of forecast rationality, I test whether forecasts are optimal in my samples of three Central and Eastern European currency's exchange rates against the Euro.

The extensiveness of the forecast rationality literature indicates the importance of the analysis. The seminal papers of Granger and Newbold (1986) and Diebold and Lopez (1996) have set the methodological framework that enables forecast rationality testing. Before summarizing existing findings and important research questions in this topic, we first need to define forecast rationality (see e.g. Lieli and Stinchcombe, 2013). Let  $\mathcal{L}(y - \hat{y})$  be the loss function of the forecaster, where y is the realized value of the target variable and  $\hat{y}$  is the forecast of the target. Let  $p_{t-h}(y)$  denote the conditional density function of the target realized at time t,  $Y_t$ , given the forecaster's information set available in t-h (denoting the forecast horizon by h=1,...,H). The forecast  $\hat{Y}^*_{t|t-h}$  made in time t-h given the then available information is a rational forecast of  $Y_t$  if the following equation holds:

$$\widehat{Y}^*_{t|t-h} = \arg\min_{\widehat{y}} \int \mathcal{L}(y - \widehat{y}) \, p_{t-h}(y) \, \mathrm{d}y \tag{1}$$

Assuming a square loss function  $\mathcal{L}(y - \hat{y}) = (y - \hat{y})^2$ , and covariance stationarity of the time series under consideration, forecasts have favorable statistical properties: the optimal forecast is the conditional expected value, therefore, the forecast errors are mean zero (Granger, 1969), errors are serially uncorrelated at the one-period horizon and their conditional variance is a weakly increasing function of the horizon.

Testing these properties is a straightforward way to determine forecast rationality. A popular test in doing so is based on the Mincer-Zarnowitz (MZ) regression. The regression takes the following form:

$$Y_t = \alpha_h + \beta_h \hat{Y}_{t|t-h} + v_{t|t-h}, \tag{2}$$

where  $v_{t|t-h}$  is an error satisfying  $E[v_{t|t-h}] = 0$ . The null hypothesis of rationality:  $\alpha_h = 0 \cap \beta_h = 1$  is then tested against the alternative:  $\alpha_h \neq 0 \cup \beta_h \neq 1$ .

Rationality tests such as the Mincer-Zarnowitz test are frequently conducted on inflation (Croushore, 1998; Romer and Romer, 2000; Elliott et al., 2008; Rossi and Sekhposyan, 2011; Patton and Timmermann, 2012) and output growth survey forecasts (Patton and Timmermann, 2007; Elliott et al, 2008, Patton and Timmermann, 2012). The results and inference of these papers slightly differ, although there is more evidence for forecast optimality then against it.

Using the Federal Reserve's Greenbook forecasts together with commercial survey forecasts on inflation, Romer and Romer (2000) find that both forecasts are rational. Rossi and Sekhposyan (2011) revisit their findings but use a rolling window sampling method and an optimality test corrected for instabilities. This way, they find more evidence against optimality than Romer and Romer (2000). Patton and Timmermann (2012) also use the FED Greenbook forecasts in the empirical application of their proposed tests based on multihorizon bounds. They find limited empirical evidence against rationality of inflation and output growth forecasts. Elliott et al. (2008) apply a more flexible test that allows for asymmetries in forecasters' loss functions. Their results show less evidence against rationality on their inflation- and output growth forecasts from the Survey of Professional Forecasters compared to the case when a symmetric loss function is assumed. In their 2007 paper, Patton and Timmermann also allow for an asymmetric loss function and assume that the forecaster's loss depends on the level of the target variable besides the forecast error. Their optimality test outcomes significantly change when the symmetry assumption is relaxed: assuming a more general loss function, forecast rationality is accepted.

However, apart from a few exceptions (Dominguez, 1986; Mitchell and Pearce, 2005), the rationality of exchange rate forecasts has not been so closely examined. Examining a Wall Street Journal survey dataset, Mitchell and Pearce conclude that exhange rate forecasts are rational, but the forecasts are frequently outperformed by a simple random walk<sup>1</sup>. However, the term-structure models of Naszodi (2011) succeed in performing better than the random walk on a sample of CEE exchange rates. This finding is key in showing that survey forecasts do include some useful additional information for estimating the future value of the outcome, compared to a naive random walk estimation.

Since exchange rate forecasts are indeed useful estimates of the future exchange rates, it is important to examine whether the expectations are rational. Most researchers using exchange rate forecasts assume optimality (see for example Sarno and Sojli, 2009), therefore, their results are conditional on this belief. For this reason, it is crucial to examine whether this assumption holds, since if we found evidence against it, then a large part of the findings of the relevant literature would need to be revisited.

<sup>&</sup>lt;sup>1</sup> The result that exchange rates are inaccurately predicted by survey forecasts was first documented by Frankel and Froot (1987).

To explore the validity of the rationality assumption of exchange rate survey expectations, I apply Patton and Timmermann's (2012) tests based on multi-horizon bounds, together with conventional Mincer-Zarnowitz regressions using Consensus Economics forecast data on three Central and Eastern European exchange rates against the Euro. To my knowledge, Consensus Economics exchange rate data was never used in forecast rationality testing. Another novelty in my application is that I use data on Czech, Hungarian and Polish exchange rates, while optimality tests are most frequently applied to data on inflation and output growth from the US and other major developed countries (see Boero et al., 2012 who use UK data and Elliott et al., 2005, who use G7 data).

Consensus Economics presents exchange rate forecasts as the mean of individual expectations of the questioned 15-25 professional forecasters. I assume that there exists a representative forecaster, whose expectation is given by this mean. I also assume that the time series of the forecasts and the realized outcomes satisfy covariance stationarity after suitable transformations, and that the loss function of the representative forecaster is a square loss. These assumptions are widely used in the literature and are necessary for conducting the rationality tests in this thesis.

However, these assumptions also impose some limitations on my analysis. Several researchers, including Granger (1969), Lieli and Stinchcombe (2013), Elliott et al. (2005, 2008), and Capistrán and Timmermann (2009) point out that the use of a symmetric squared error loss is not thoroughly justified on economic grounds. Some empirical results also confirm this argument: for example, Patton and Timmermann (2007) find evidence for a systematic underprediction of the Fed's output growth forecasts and Elliott et al. (2005, 2008) document their rationality test results significantly changing when allowing for asymmetries in the loss function on budget deficit-, inflation- and output growth forecasts. It is also possible that some forecasters continue a herding behavior when reporting their expectations

in order to minimize the costs of collecting information necessary for producing individual forecasts (Frankel and Froot, 1987), or that some forecasters might intentionally produce outlier forecasts led by the incentive to make themselves mark out from others and gain reputation in case they correctly predict a surprising outcome<sup>2</sup>.

Taking these arguments into account, I acknowledge that in the strictest sense, I am testing a joint hypothesis of the forecast being rational and the representative forecaster having a square loss function. However, if we accept the assumption of a square loss, the tests determine the optimality of the forecasts<sup>3</sup>.

The results of the forecast rationality tests are mixed. While neither of the bounds tests reject the optimality of the forecasts, I find evidence for bias and exogeneity on some horizons of the Polish and Hungarian exchange rate forecasts, as well as rejections of optimality based on the conventional Mincer-Zarnowitz tests. I compare these findings to the power results of the bounds tests presented by Patton and Timmermann (2012).

The remainder of the thesis is organized as follows: Section 2 presents the data. In Section 3, I briefly introduce the rationality tests used in my analysis. Section 4 summarizes the empirical results, while Section 5 concludes.

 $<sup>^{2}</sup>$  This theory is supported by the observation of a high persistence of the relative level of individual expectations: forecasters who severely overpredict inflation or GDP growth in one period tend to continue doing so in the next period (see Batchelor, 2007 and Boero et al., 2012).

<sup>&</sup>lt;sup>3</sup> A further limitation to my analysis derives from the covariance stationarity assumption. Although this basic property is assumed in most papers on the subject, some researchers have become concerned about its consequences on drawing inference regarding forecasting ability. To overcome this limitation, Rossi and Sekhposyan (2011) propose forecast rationality tests that can be used in unstable environments.

### 2 Data

In my empirical analysis, I use Consensus Economics forecasts on exchange rates of three Central and Eastern European currencies against the Euro: the Czech Koruna, the Hungarian Forint and the Polish Zloty<sup>4</sup>. For forecasts on the Polish, Hungarian and Czech economy, Consensus Economics surveys approximately 15 institutions (banks, research institutes) per country. The firm presents the average of forecasters' estimates as a consensus forecast. As stated in the introduction, I assume this mean to be the expectation of a representative forecaster.

The surveys are made at the end of every month<sup>5</sup>, when professional forecasters are asked to give 1-, 3- and 12-month ahead estimates on exchange rates against the Euro. I compare the natural logarithms of these forecasts (denoted by  $\hat{Y}_{t|t-h}$ , h=1,3,12) with realized end-of-month log spot exchange rates (denoted by  $Y_t$ ) acquired from the European Central Bank's database. The sample period starts in May 2008 and ends in December 2013, I have 68 observations for all three currencies with no missing data.

The raw exchange rate data and the forecasts are unit root processes as shown by the Augmented Dickey-Fuller test results (see table 3). To render the series stationary, I conduct a transformation on both the forecasts and the realized values. I transform the variables into annual yields by replacing the target variable,  $Y_t$  with  $Y_t - Y_{t-12}$  and replacing the h-horizon forecast,  $\hat{Y}_{t|t-h}$  with  $\hat{Y}_{t|t-h} - Y_{t-12}$  (h=1,3,12). From now on,  $Y_t$  denotes the transformed log spot exchange rate (log annual yield), and  $\hat{Y}_{t|t-h}$  (h=1,3,12) denotes the transformed log

<sup>&</sup>lt;sup>4</sup> I am indebted to Anna Naszódi for providing me with the Consensus Economics data.

<sup>&</sup>lt;sup>5</sup> In reality, the exact day of collecting the forecasts may vary from month to month. For example, forecasts were collected on the 16<sup>th</sup> June 2008 and next month, they were collected on the 21<sup>th</sup>; altough in both cases, forecasters estimate the exchange rate expected for the last day of the following month. Therefore, in the most strict sense, the horizon is changing slightly. However, supposing that this small change in the forecast horizon will not have a significant effect on my results, I disregard this matter and assume that the horizon is fixed at 1, 3 and 12 months.

forecasts of the exchange rates. These log annual yields appear covariance stationary and therefore satisfy the assumptions of the used rationality tests (see ADF results in table 3). Figure 1 plots the transformed time series used in my analysis. I also plot the forecast errors for every horizon separately in figure 4.



Figure 1: Annual yields of the examined log spot exchange rates against the Euro (left panel) and their 1, 3, and 12 months ahead forecasts (right panel).

## 3 Methodology

In this section I briefly introduce the rationality tests used in my empirical analysis. Most of these tests were adopted from Patton and Timmermann (2012) and are discussed there in detail. For proofs and a more complete discussion, please see their paper. Mincer-Zarnowitz optimality tests are conducted in many papers in the forecast rationality literature (e.g. Mincer and Zarnowitz, 1969; Balduzzi et al., 2001; Elliott et al., 2008). Before moving forward to describing the rationality tests, some assumptions need to be stated.

First, I assume that the mean of the individual expectations is the forecast of the representative forecaster who has a square loss function. Next, I assume that the target variable,  $Y_t$ , is generated by a covariance stationary series. These assumptions imply three basic properties:

1. The optimal forecast is the conditional mean:

$$\hat{Y}_{t|t-h}^* \equiv \arg\min_{\hat{y}\in Y} E[(Y_t - \hat{y})^2 | I_{t-h}] = E[Y_t | I_{t-h}]$$
(1)

where  $Y_t$  is the realized value of the target variable at time t=1,...,T;  $\hat{Y}_{t|t-h}$  is the forecast made for period t in period t-h; h=1,...,H is the forecast horizon;  $\Upsilon$  is the set of possible forecasts and  $I_{t-h}$  is the information set available for all forecasters at time t-h.

2. The forecast is unbiased:

$$E[Y_t - \hat{Y}^*_{t|t-h}] = E[e^*_{t|t-h}] = 0$$
<sup>(2)</sup>

where  $e_{t|t-h}^*$  is the forecast error of the forecast made for period t in period t-h.

3. The forecast and the forecast error are uncorrelated:

$$Cov(\hat{Y}_{t|t-h}^{*}, e_{t|t-h}^{*}) = Cov(\hat{Y}_{t|t-h}^{*}, Y_{t} - \hat{Y}_{t|t-h}^{*}) = 0$$
(3)

Using these properties, Patton and Timmermann (2012) derive additional results that can be used to test whether forecasts are rational.

#### Mean Squared Error Increasing with the Horizon:

Under square loss, the optimal forecast is the conditional mean of the target (Granger, 1969). Formally, this statement can be written as:

$$E_{t-h_{S}}\left[(Y_{t} - \widehat{Y^{*}}_{t|t-h_{S}})^{2}\right] \le E_{t-h_{L}}\left[(Y_{t} - \widehat{Y^{*}}_{t|t-h_{L}})^{2}\right] \quad for \ all \ h_{S} < h_{L} \quad (4)$$

and derives from the fact that the information on  $Y_t$  available at  $t - h_L$  is contained in the information set in  $t - h_S$ . Therefore, the short-horizon forecast is at least as good as the long-horizon forecast.

This feature of forecast optimality can be tested through the hypotheses:

$$H_0: \Delta^e = (\Delta_2^e, \dots \Delta_H^e)' \ge 0 \qquad \qquad H_1: \Delta^e = (\Delta_2^e, \dots \Delta_H^e)' < 0 \tag{5}$$

where  $\Delta_j^e = E[e_{t|t-j}^2 - e_{t|t-(j-1)}^2]$  is the MSE differential and H is the longest forecast horizon. Wolak (1989) proposes three equivalent test statistics that can be used to decide between the null and the alternative hypotheses: a likelihood ratio (LR) test, a Kuhn-Tucker test and a Wald test. I state the LR test statistic here:

$$LR = -2\ln\frac{\tilde{L}}{\tilde{L}} = 2(ln\hat{L} - ln\tilde{L})$$
<sup>(6)</sup>

where  $\tilde{L}$  and  $\hat{L}$  are the maximum values of the likelihood function under the null and the alternative hypotheses, respectively. The distribution under the null hypothesis is the following weighted sum of chi-squared variables:

$$\sum_{i=1}^{H-1} \omega(H-1,i)\chi^{2}(i),$$
(7)

where  $\omega(H - 1, i)$  are the weights that can be obtained through simulation as in Wolak (1989) or in a closed form, following Kudo (1963) and Sun (1988). The form of the test and the test statistics are the same for all bounds tests proposed.

#### Mean Squared Forecast Decreasing with the Horizon:

In their 2012 paper, Patton and Timmermann (2012) present some new forecast rationality tests, one being the test on decreasing mean squared *forecasts*<sup>6</sup>. This novel test is extremely useful since its application does not require data on the target variable. Therefore, it can be used in cases when the target variable is not observed or the available data is noisy and not reliable.

Under the assumptions of the target variable evolving in a covariance stationary manner and that its unconditional mean is finite, mean squared forecasts decrease with the horizon (see Figure 5 in the appendix). For a formal proof, see Patton and Timmermann (2012). I provide a mathematical and an intuitive explanation here. Mathematically, the weakly decreasing nature of rational mean squared forecasts derives from the fact that the mean squared error of such forecasts weakly increases. Since the variance of the target variable is constant over forecast horizons, there is a tradeoff between the MSE and the variance of the forecast: as the former is weakly increasing, the latter has to be weakly decreasing with the horizon:

$$V[Y_t] = V\left[\widehat{Y^*}_{t|t-h}\right] + E\left[e^{*2}_{t|t-h}\right]$$
(8)

$$V[\widehat{Y^*}_{t|t-h_S}] \ge V[\widehat{Y^*}_{t|t-h_L}] \qquad \text{for any } h_S < h_L \tag{9}$$

<sup>&</sup>lt;sup>6</sup> It is important to emphasize the difference between the mean squared error of the forecast (MSE) and the mean squared forecast (MSF). While the former is the mean squared difference between forecasts and actual realizations, the latter is the average of the squared forecasts. The former (MSE) is increasing with the horizon, while the mean squared forecast (MSF) decreases with it.



This tradeoff is illustrated on figure 2 using my data on Polish Zloty/Euro exchange rates.

Figure 2: Tradeoff between the mean squared error of the forecasts (MSE) and the variance of the forecasts ( $V(Y_hat)$ ) for the Polish Zloty data

Due to the unbiasedness property under square loss stated in (2), we can add its squared value to both sides of (9):

$$E\left[\widehat{Y^{*}}_{t|t-h_{S}}^{2}\right] - E^{2}\left[\widehat{Y^{*}}_{t|t-h_{S}}\right] = V\left[\widehat{Y^{*}}_{t|t-h_{S}}\right] \ge V\left[\widehat{Y^{*}}_{t|t-h_{L}}\right]$$

$$= E\left[\widehat{Y^{*}}_{t|t-h_{L}}^{2}\right] - E^{2}\left[\widehat{Y^{*}}_{t|t-h_{L}}\right]$$

$$(10)$$

leading to the following inequality:

$$E\left[\widehat{Y^*}^2_{t|t-h_S}\right] \ge E\left[\widehat{Y^*}^2_{t|t-h_L}\right] \qquad \text{for any } h_S < h_L \tag{11}$$

We can also think about an intuitive explanation of the decreasing MSF. We know that the longer the forecast horizon, the closer the forecast is to the unconditional mean of the target (since the forecaster's information set in t-h is "worth" less and less as the forecast horizon increases: forecasters cannot say much about the far future, their best guess in a longenough horizon would be the unconditional mean of the time series). As the mean forecasts are squared, the mean squared forecast approaches the unconditional mean of the target value from above.

#### **Covariance Decreasing with the Horizon:**

From the decreasing variance of the forecasts stated in (9), it follows that the covariance between the forecast and the target variable should also be decreasing in the horizon. This is due to the property that the examined covariance is the same as the variance of the forecast:

$$cov(\widehat{Y^*}_{t|t-h}, Y_t) = cov(\widehat{Y^*}_{t|t-h}, \widehat{Y^*}_{t|t-h} + e^*_{t|t-h}) = V(\widehat{Y^*}_{t|t-h}).$$
(12)

In equation (12), we use the property in (3), stating that the covariance between the forecast and the forecast error is zero. This result can also be used in case we do not have data on the target variable and proxy it with a short-term forecast:

$$cov(\widehat{Y^*}_{t|t-h_L}, \widehat{Y^*}_{t|t-h_S}) = cov(\widehat{Y^*}_{t|t-h_L}, \widehat{Y^*}_{t|t-h_L} + d^*_{t|h_S, h_L})$$
(13)  
$$= V(\widehat{Y^*}_{t|t-h_L}),$$

where  $d^*_{t|h_S,h_L} = \widehat{Y^*}_{t|t-h_S} - \widehat{Y^*}_{t|t-h_L}$  is the forecast revision between the long and the short horizon and  $h_S < h_L$ .

#### **Covariance Bound and Covariance Bound, with proxy**

Using the previous results, Patton and Timmermann (2012) show that the variance of the forecast revision can be bounded from above. Using the same notation for the forecast revision, they state that for any  $h_S < h_M < h_L$ 

$$V(d^*_{t|h_S,h_L}) \le 2cov(Y_t, d^*_{t|h_S,h_L})$$

$$\tag{14}$$

$$V(d_{t|h_M,h_L}^*) \le 2cov(\widehat{Y}_{t|t-h_S}^*, d_{t|h_M,h_L}^*)$$

$$\tag{15}$$

The latter property can be used in the lack of (reliable) data on the target.

#### **Increasing Mean Squared Forecast Revision:**

Similarly to testing the increasing MSE, we can also set up a test for the increasing mean squared forecast revisions in case we lack data on the target. Formally, the equation states:

$$E\left[d^{*^{2}}_{t\mid h_{S},h_{M}}\right] \leq E\left[d^{*^{2}}_{t\mid h_{S},h_{L}}\right] \qquad \text{for any } h_{S} < h_{M} < h_{L} \qquad (16)$$

and this can be tested by a Wolak-type test (Wolak, 1987, 1989) as well.

#### Mincer-Zarnowitz t-tests and $\chi$ 2-tests on all horizons

In the following part of this methodological summary, I am going to briefly introduce the regression tests used to examine forecast rationality. Conducting a conventional univariate Mincer-Zarnowitz test on all forecast horizons is a straightforward and well-known way to examine forecast rationality (Balduzzi et al. 2001, Elliott et al., 2008). To do this, I run a regression of the form:

$$Y_t = \alpha_h + \beta_h \dot{Y}_{t|t-h} + \upsilon_{t|t-h} \tag{17}$$

and test the null hypothesis of  $\alpha_h = 0 \cap \beta_h = 1$  for all h={1,3,12} (Mincer-Zarnowitz, 1969). I also run separate t-tests on the intercept and slope coefficients.

#### Optimal Revision regression and Optimal Revision regression, with proxy

In the optimal revision regression, the target is regressed on the longest horizon forecast and all intermediate forecast regressions instead of directly regressing it on a short horizon forecast à la Mincer-Zarnowitz (Patton and Timmermann, 2012). In the absence of data on the outcome variable, this test can also be run using the shortest horizon forecast as a proxy for the target. Formally, the regression (using data on the outcome) takes the following form:

$$Y_t = \alpha + \beta_H \hat{Y}_{t|t-h} + \sum_{j=1}^{H-1} \beta_j d_{t|h_j,h_i} + u_t$$
(18)

#### Bonferroni, using actuals; Bonferroni, using forecasts and Bonferroni, joint

Following Patton and Timmermann (2012), I conduct joint tests using Bonferroni bounds to examine rationality. This way, it is possible to look at the combined results of the above tests. I aquire Bonferroni p-vaues by multiplying the minimal p-value in the group of tests examined by the number of tests run. I report three results: one based on the results of the tests that use data on the target variable (tests indicated with the numbers 7,8,9,20,23 in table 1), one using short forecasts as a proxy for the outcome (tests indicated with the numbers 10,11,12,13,24 in table 1) and one combining the results of the above tests (tests indicated with the numbers 7,8,9,10,11,12,13,20,23,24 in table 1). The tests were implemented using Matlab, with the code publicly available on Andrew Patton's website<sup>7</sup>.

<sup>&</sup>lt;sup>7</sup> <u>http://public.econ.duke.edu/~ap172/code.html</u> (date of access: 04/16/2014).

### 4 **Results**

Table 1 presents the results from all rationality tests, together with results from unbiasedness and exogeneity tests. Examining unbiasedness is not a rationality test by itself for general loss functions, but as we assume square loss; having zero bias is a necessary condition of forecast optimality. As we can see in line 3, the forecasts of the exchange rate of the Czech Koruna against the Euro are unbiased on all forecast horizons. In contrast, the unbiasedness of 12 month ahead forecasts are rejected on the used sample of Hungarian Forint exchange rate forecasts. On this sample, I have found evidence of systematic underprediction: the representative forecaster's estimate is expected to be 3.5 percentage points lower than the actual target variable. On the PLN/Euro exchange rate sample, the 1 year ahead forecasts also show bias. The positive bias found on the Polish sample indicates that we should expect the realized exchange rate to be 5 percentage points higher than the consensus forecast.

It is useful to look at the exogeneity of the forecast error besides the rationality tests, since the test of decreasing covariance assumes that the covariance of the forecast and the forecast error is zero (see equation 12). Under unbiasedness,  $E[e_{t|t-h}] = 0$ , so it is enough to check the null hypothesis of  $E(\hat{Y}_{t|t-h} * e_{t|t-h}) = 0$ .

On the Czech sample, I find the forecast errors to be exogenous on all three horizons. Conversely, exogeneity of the error does not hold in any of the examined horizons on the Polish Zloty exchange rates. Similarly, exogeneity is rejected on the HUF/Euro sample for the 1 month and 3 month horizons. It is interesting that despite the rejection of exogeneity on the PLN and HUF datasets, rationality is not rejected based on the decreasing covariance test on either sample. The reason for this is likely the conservativeness of the decreasing covariance test: the Monte Carlo simulation run by Patton and Timmermann (2012) that assumes increasing noise across different horizons, a maximum horizon of 4 periods and a sample size of 100, finds the power of this test to be only 3.4%. As the power of this test is surprisingly low, we would need very strong evidence against the null hypothesis of a decreasing covariance between the forecast and the target variable in order to be able to reject it.

			currency			
#	test	horizon	CZK	HUF	PLN	
1		1 month	0.909	0.861	0.32	
2	Unbiasedness	3 month	0.924	0.793	0.963	
3		12 month	0.291	0.008***	0.04**	
4	Encompite	1 month	0.215	0.065*	0.034**	
5	Exogeneity,	3 month	0.362	0.026**	0.028**	
6	E[enor*lorecast]=0	12 month	0.858	0.992	0.055*	
7	Increasing MSE		0.804	0.721	0.741	
8	Decreasing COV		0.705	0.796	0.744	
9	COV Bound		0.642	0.733	0.677	
10	Decreasing MSF		0.773	0.856	0.76	
11	Increasing MSFR		0.5	0.5	0.5	
12	Decreasing COV, w/ proxy		0.5	0.5	0.5	
13	COV Bound, w/ proxy		0.5	0.5	0.5	
14	Mincer Zernowitz t test	1 month	0.814	0.587	0.467	
15	$\alpha = 0$	3 month	0.974	0.331	0.835	
16	<u>u-0</u>	12 month	0.142	0.005***	0.088*	
17	Mincer-Zarnowitz t-test,	1 month	0.172	0.003***	0.115	
18	β=1	3 month	0.3	0.000***	0.066*	
19		12 month	0.238	0.381	0.637	
20	Mincer-Zarnowitz $\chi^2$ -test,	1 month	0.381	0.008***	0.191	
21	$\alpha=0 \cup \beta=1$	3 month	0.576	0.000***	0.1	
22		12 month	0.302	0.015**	0.066*	
23	Opt. Revision regression		0.997	0.999	0.996	
24	Opt. Revision regr., w/ proxy		0.998	0.989	0.991	
25	Bonferroni, using actuals		1	0.041**	1	
	(7,8,9,20,23)					
26	Bonferroni, using forecasts		1	1	1	
	(10,11,12,13,24)					
27	Bonferroni, joint		1	0.083*	1	
	(7,8,9,10,11,12,13,20,23,24)					

Table 1: Forecast rationality test results.

NOTES: This table presents p-values from rationality tests conducted on exchange rate data. Three currency's exchange rates are examined against the Euro: that of the Czech Koruna, the Hungarian Forint and the Polish Zloty. The sample period is from May 2008 to December 2012. Three forecast horizons are considered: 1 month, 3 month and 12 month. Tests labeled "with proxy" refer to cases where the one month forecast is used in place of the predicted variable.

Based on the bounds tests used, I cannot reject rationality in any of the samples of any horizon. This is quite surprising in the case of Hungary and the Czech Republic. Using these two samples, we have seen that exogeneity was rejected quite significantly on almost all horizons<sup>8</sup>. As the decreasing covariance test is based on the exogeneity assumption, we expected that the test would detect suboptimality of the forecasts.

currency	Czech Koruna		Hungarian Forint			Polish Zloty			
test h	1	3	12	1	3	12	1	3	12
$E[e_{t t-h}^2]$	0.0008	0.0014	0.0030	0.0014	0.0036	0.0049	0.0032	0.006	0.0139
$\operatorname{Cov}(Y_t, \hat{Y}_{t t-h})$	0.0033	0.0028	0.0006	0.0047	0.0037	0.0013	0.0114	0.0093	0.0023
$E[\hat{Y}_{t t-h}^2]$	0.0036	0.0033	0.0007	0.0064	0.0063	0.0011	0.0136	0.0117	0.0033
$\operatorname{Cov}(\widehat{Y}_{t t-1}, \widehat{Y}_{t t-h})$		0.0031	0.0007		0.005	0.0016		0.011	0.003

Table 2: Evidence for the increasing MSE, decreasing MSF and decreasing covariance bounds tests from all samples.

Table 2 shows mean squared errors, mean squared forecasts, covariances between forecasts and actual exchange rates and covariances between long horizon (12 and 3 month) and the shortest horizon (1 month) forecasts. We can see from the values that all bounds tests indicate forecast rationality on each sample and horizon. The mean squared errors are plotted on Figure 3, showing a clearly increasing trend as the horizon grows. In the appendix, I also include a similar plot showing the decreasing trend of mean squared forecasts (see figure 5). Turning to the Mincer-Zarnowitz tests however, forecast optimality can be rejected on several occasions.

**NOTES**: This table illustrates the results from the used bound tests. The first row shows the increasing nature of the mean squared errors of the forecasts with the horizon, the second row presents the covariance between the target and the forecasts (this decreases with the horizon), the third row shows mean squared forecasts (that also decreases with the horizon) and the last row presents covariances between the shortest horizon forecasts and longer horizon forecasts.

<sup>&</sup>lt;sup>8</sup> We cannot reject exogeneity on the 1 year ahead exchange rate forecast for the Hungarian Forint, while it is rejected for the 1- and 3-month forecasts. On the Polish sample, we reject exogeneity on all horizons.



Figure 3: Mean squared errors of Consensus Economics forecasts on exchange rates. CZK, HUF, PLN; against Euro.

Before conducting the conventional Mincer-Zarnowitz joint test, I have estimated the intercept and the slope of the MZ regression separately. In most cases we accept that the intercept is zero; however, on the Polish Zloty and Hungarian Forint sample, the alphas are significant on the 12 month horizon. This is not surprising as we know that in these two cases, we also had to reject unbiasedness, and assuming that the beta is one, the unbiasedness and the MZ intercept tests are equivalent:

Unbiasedness: 
$$Y_t - \hat{Y}_{t|t-h} = bias_{t|t-h}$$
 (19)

Mincer-Zarnowitz: 
$$Y_t = \alpha_h + \beta_h \hat{Y}_{t|t-h} + v_{t|t-h}$$
(20)

Testing whether the slope coefficient from the Mincer-Zarnowitz regression is one, we can reject the null on the 1 and 3 month horizons on the Hungarian Forint sample. The test also rejects the null of the slope being unity on the 3 month horizon Polish Zloty sample. Interestingly, these rejections do not reoccur in any of the bounds tests. Turning to the conventional Mincer-Zarnowitz joint  $\chi^2$ -test, we expect to reject the null in those cases, where either the intercept was significant or the slope was not unity. As expected, we reject ratonality on all horizons on the Hungarian sample. On the Polish sample however, we only reject forecast optimality on the 12 month sample, while on the 3 month horizon, we find borderline significance and just fail to reject the null.

The last regression test of rationality introduced by Patton and Timmerman (2012) is the optimal revision regression. As the p-values are very high in all samples, we cannot reject optimality based on this test.

Bonferroni combinations of the above tests were also examined, in order to test some of these hypotheses jointly. I combined tests using the realized exchange rate yields as the dependent variable (tests indicated with 7, 8, 9, 20, 23 in table 1), along with tests where the target is proxied by the shortest horizon forecast of the yields (tests 10, 11, 12, 13, 24) and a joint test of the above two versions (tests 7, 8, 9, 10, 11, 12, 13, 20, 23, 24). The Bonferronis are quite conservative, so we need very strong evidence against rationality in order to reject them. I was able to reject optimality in two cases: the Hungarian Forint sample based on the Bonferroni using actuals and the joint Bonferroni test; since the joint MZ test strongly rejected the null on the Hungarian sample.

Summarizing the results, I find rather weak evidence against forecast rationality. The acceptance of the null of rationality in most tests indicates that Consensus Economics forecasts are optimal on the May 2008-December 2013 sample for the CZK/Euro, the HUF/Euro and the PLN/Euro exchange rates and the representative forecaster's loss function is symmetric. Nevertheless, it is likely that some of the used tests do not have enough power to detect deviations from optimality on the relatively short samples used. Patton and Timmermann (2012) have conducted Monte Carlo simulations to examine the size and power of the introduced rationality tests. Under the scenario with four forecast horizons, additive measurement error, and a sample of 100 observations, their tests have mixed power results. While the power of the decreasing mean squared forecast test, the optimal revision regression test with proxy, and the covariance bound test have high power, the remaining bound tests have very little power to detect suboptimality. The power of the increasing mean squared forecast revision's power is

even lower (approximately 0%). The probability that the decreasing covariance test correctly rejects the false null hypothesis is only 3.4%, and the power of the latter test's variety (decreasing covariance with proxy) is only 5%.

These results suggest that rationality cannot be strongly rejected nor accepted on my samples: overall, I find mixed results. While some of the used tests do have enough power to detect suboptimality, many tests perform poorly on the Monte Carlo simulation done by Patton and Timmermann (2012). An interesting observation also serves as an argument against rationality: we reject exogeneity on the Hungarian and Polish samples, but the decreasing covariance test that uses the assumption of exogeneity does not reject the null of forecast optimality.

## 5 Conclusion

Many findings of the exchange rate forecast literature are conditional on the forecast rationality assumption. Consequently, such results might not be valid if the assumption was in fact false. The main motivation of this thesis is to examine whether this assumption is valid. To reach this goal, I conduct conventional Mincer-Zarnowitz tests, together with rationality tests based on multi-horizon bounds on my Consensus Economics forecast sample for the Czech Koruna/Euro, the Hungarian Forint/Euro and the Polish Zloty/Euro exchange rates. To my knowledge, the data I use have never been tested for forecast optimality. While a vast majority of research articles use US inflation or output growth forecasts when testing for optimality, I use data on Central and Eastern European exchange rates.

In my empirical application I find limited evidence against rationality. As the forecast series all satisfy the optimality properties on which the used multi-horizon bounds tests are based (e.g. the mean squared error of the forecast increases with the horizon), I cannot reject rationality on any of the samples when using the bounds tests. However, I find evidence for bias and for endogeneity on some horizons of the Hungarian and Polish forecasts. Moreover, the conventional Mincer-Zarnowitz joint  $\chi^2$ -test rejects rationality on all horizons on the Hungarian sample and indicates the Polish exchange rate forecast to be suboptimal on the 12 month horizon. Bonferroni combinations of the tests are also examined; these tests detect irrationality on the HUF/Euro exchange rate forecast sample. From these results, we cannot infere clearly whether the Consensus Economics forecasts are rational on the May 2008-December 2013 sample for the three exchange rates, although the evidence for rationality seems to be slightly stronger than the counterevidence. If we accept rationality and believe that these findings generalize to other exchange rate forecasts, we can state that the results conditional on exchange rate forecast rationality hold and need not be revisited.

Similarily to most analyses conducted in the field, I assume that the representative forecaster's loss function is a square loss. I also assume covariance stationarity of the used forecast and outcome series<sup>9</sup>. These assumptions are necessary for both the Mincer-Zarnowitz and the multi-horizon bound tests of forecast rationality. However, the assumptions pose a possible limitation to my findings. If the MSE assumption failed to hold, a rejection of the optimality might only mean that the forecaster makes expectations based on a loss function that is different from the MSE.

These limitations suggest some questions in need for further investigation. First, it would be interesting to relax the MSE assumption and conduct flexible rationality tests on the same data set that allow for more general loss functions, such as the J-test for overidentification proposed by Elliott et al. (2005, 2008). To correct for instabilities in the data, Mincer-Zarnowitz rationality tests could be run in rolling window samples. Moreover, it would be useful to widen the sample and compare exchange rate forecast rationality results on a larger set of Central and Eastern European countries. I leave these extensions for future work.

<sup>&</sup>lt;sup>9</sup> I do this after applying the augmented Dickey-Fuller test to the series and rejecting the null hypothesis of containing a unit root.

## Appendix



Figure 4: Forecast errors of the 1, 3, and 12 month horizon forecasts of the examined log spot exchange rates against the Euro

		p-value of ADF test on			
currency	forecast horizon	log spot exchange rate	annual yield of exchange rate		
	0	0.820	0.023**		
Czoch Korupa	1	0.782	0.022**		
Czech Koruna	3	0.574	0.032**		
	12	0.333	0.002***		
	0	0.884	0.023**		
Uungomian Famint	1	0.887	0.043**		
Hungarian Formu	3	0.895	0.033**		
	12	0.893	0.001***		
	0	0.861	0.023**		
Doligh 71.4m	1	0.919	0.043**		
Polish Zioty	3	0.878	0.033**		
	12	0.907	0.001***		

Table 3: Results of ADF unit root tests on log spot and annual yield of exchange rates

Notes: This table presents p-values from Augmented Dickey-Fuller tests run on the raw exchange rate data (log spot exchange rate), and the transformed data (annual yield of log spot exchange rate). The transformation included replacing the target variable (horizon=0),  $Y_t$  with  $Y_t - Y_{t-12}$  and replacing the h-horizon forecasts (h={1,3,12}),  $\hat{Y}_{t|t-h}$  with  $\hat{Y}_{t|t-h} - Y_{t-12}$ . Significance is indicated in the usual way: \*,\*\* and \*\*\* indicate significance on the 10, 5, and 1 percent level respectively.



Figure 5: Mean squared forecasts of exchange rates using Consensus Economics data. CZK, HUF, PLN; against Euro.

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