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The unbiasedness and efficiency tests of the rational expectations hypothesis*

Faik Bilgili**

Abstract

This study examines the direct tests of the Rational Expectations Hypothesis (REH). Pesando (1975) employs the Livingston survey data of business economists and reaches the rejection of rationality and consistency but not rejection of the efficiency. Analyzing the same data, Carlson (1977) rejects these three hypotheses that Pesando tests when he uses expectations on CPI, but doesn't reject hypotheses as he uses expectations on WPI. Turnovsky (1980) tests the unbiasedness property of the REH using Livingston data and finds different results for the different periods of data. Friedman (1980) applies the unbiasedness and efficiency tests using data of The Goldsmith-Nagan Bond and Money Market Letter and reaches mixed results for the REH. Ball and Croushore (1995) use the several survey results and univariate forecasting models. Their results provide a strong rejection of the REH.

JEL: E3, E5
Keywords: Rational expectations hypothesis, expectations, unbiasedness, efficiency, Box-Jenkins forecasting model

I. Introduction

After presenting the studies from the literature, this study applies the direct tests of rationality by using the data of Central Bank of Turkey Business Survey. This section of the study uses the responses to the question "Over the next 12 months what is your expectation on the inflation (wholesale price) rate? "The average monthly expectations on inflation rate ($p_t^e,_{t-1}$) are obtained by taking the weighted average of these responses. The unbiasedness test is carried out in an analysis in which realized average monthly inflation rate (p_t) is dependent variable and $p_t^e,_{t-1}$ is independent variable. Efficiency property tests the hypothesis that the expectations should follow the same autoregressive process. Later in this section, efficiency test is also run for the survey data.

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An alternative method of direct tests is carried out in the following section. In this section, the expectations of output are obtained by Box-Jenkins model and unbiasedness and efficiency tests are carried out for the output series.

Let the variable of interest be the inflation rate (*p*). The Rational Expectations Hypothesis (REH) implies that the expectations on *p* (p^e) are identical to realized observations of *p* as indicated by equation (1).

$$p_t = p^e_{t\,,t-1} + e_t \qquad (1)$$

where p_t is realized observation of *p* at time t, $p^e_{t\,,t-1}$ is the expectation on *p* for time t, done at time t-1 and e_t is serially uncorrelated random prediction error that has a mean value of zero. Equation (1) can be tested by equation (2).

$$p_t = \alpha + \beta\, p^e_{t\,,t-1} + e_t \qquad (2)$$

The unbiasedness property of REH indicates that joint null hypothesis below

H_0: $\alpha = 0$, $\beta = 1$

should be met. In other words, $\hat{B}$ should be an unbiased estimator of *B*, denoted as $E(\hat{B}) = B$. If this is true, one cannot reject the null hypothesis above by finding an insignificant statistic at an acceptable level of significance and obtain serially uncorrelated e_t by Durbin-Watson test result. These two criteria of unbiasedness are known as the weak test of the REH (Gosh, 1991, pp. 488-489).

The efficiency property of the REH, on the other hand, is a strong test. It implies that formation of expectations should follow the same process as variable actually follows. From this implication, one can assert that, expectations and the realized observations have the same autoregressive representation (Sheffrin, 1992, p.18; Friedman, 1980, p.459). This property can be represented by equations of (3) and (4).

$$p_t = \lambda_0 + \lambda_1 p_{t-1} + \lambda_2 p_{t-2} + .. + \lambda_k p_{t-k} + v_t \qquad (3)$$

$$p^e_{t\,,t-1} = \delta_0 + \delta_1 p^e_{t-1\,,t-2} + \delta_2 p^e_{t-2\,,t-3} + ... + \delta_k p^e_{t-k\,,t-k-1} + \mu_t \qquad (4)$$

where they use the information so far as to include *k* periods into the history of the variable of interest, the λs and δs are coefficients, and v_t and μ_t are the random errors of the equations (3) and (4) respectively. The lag length is chosen to minimize the standard error of the equation of (3).

The efficiency property of REH indicates that joint null hypothesis below,

$$H_0: \lambda_0 = \delta_0 , \lambda_1 = \delta_1, \lambda_2 = \delta_2 ,\ldots, \lambda_k = \delta_k$$

should be held. Under efficiency property, the REH implies that equations (3) and (4) yield approximately equal estimated coefficients in large samples. In this case the forecast error $p_t - p^e_{t},_{t-1} = e_t$ will not depend on any lagged values of the inflation rate, it will become purely random error term.

II. The evidences from the literature

Joseph Livingston, now with the Philadelphia Inquirer, has surveyed professional economists twice yearly since 1947. The survey question is about the expectation on the level of several economic variables in seven and thirteen months. For instance, Livingston asks economists to predict the level of CPI in the following December and June, respectively. Those economists are presumed to be knowledgeable observers of the U.S. economy. Livingston then summarizes the results in his business outlook column usually printed in late June and late December (VanderHoff, 1988).

Pesando (1975) tests the efficiency using the equations (3) and (4) without constants. Although data are available back to 1946, since there is an important structural break in the accuracy and impact of Livingston data around 1959, he uses semiannual data of CPI index for two sample periods, 1959-69 and 1962-69. Determining the five periods (30 months) lag length, the efficiency hypothesis is not rejected for both periods with the F values of 1.31 and 1.36, respectively. Pesando also tests the rationality and consistency using the same periods of data. He uses six months ahead (the one period forecast, $p^e_{t},_{t-1}$) and one-year ahead (the forward one period forecast, $p^e_{t},_{t-2}$) data. He tests of rationality hypothesis that the coefficients of the lags of p_t, $p^e_{t},_{t-1}$ and $p^e_{t},_{t-2}$ are jointly equal to each other. He tests the consistency hypothesis that the coefficients of the lags of $p^e_{t},_{t-1}$ and $p^e_{t},_{t-2}$ are jointly equal. In his study, rationality fails for both periods with the F values of 3.48 and 3.99, respectively. Consistency hypothesis also fails for the same periods with the F values of 20.75 and 18.09, respectively.

Carlson (1977) notes that 6-monh expectation actually represents a forecast over an 8-month horizon from the last observed price level. The participants in May survey know the April CPI index, which is the latest available information to the respondents, before they make their forecasts of the index that must be returned to Livingston by mid-June. The respondents in December survey knows the October index before they forecasts for the indexes that will be reported for June and December of the following year. This implies that the forecasts cover an eight-month span from October to June and a 14-month span from October to December. Then Carlson (1977) calculates the average expected inflation rate from the individual survey responses. Carlson, calculates the geometric (average) rate of inflation expected per month by taking the 8^{th} root of the ratio of forecast to the actual CPI. This value is raised to the 12^{th} power, or compounded 12 times, to calculate the expected annual rate of inflation. This is the six-month forecast of the rate of inflation between December and June although it was originally calculated over an eight-month period. The 12 months or one-year ahead forecasts of the inflation rate are also calculated in the same manner (Carlson, 1977, pp. 32-36). Carlson, with this revised data, tests the rationality, efficiency and the consistency using the first sample of Pesando. Using CPI forecasts, with the length of lag =5 of inflation rate, he rejects these three hypotheses with the F values of, 5.87, 8.00 and 4.82, respectively. However, in employing WPI forecasts, he cannot reach the statistical rejection of these hypotheses with the F values of, 0.48, 0.26 and 1.55, respectively. His overall conclusion is the rejection of the hypotheses.

Pearce (1979) suggests an alternative way of testing the rationality. The rational expectations are calculated by Box-Jenkins method for the monthly period of 1959:12-1960:6 using the CPI data of 1947:1-1959:4. Adding six more months to the actual data attains the new forecasts. This procedure of forecasting goes through 1975:10. Those expectations were found to be rational. This result implies that univariate forecasting models could yield better results than the Livingston data.

Turnovsky (1980) tests the unbiasedness using the Livingston survey results, which reflect the six-month and one-year ahead predictions, over the period 1954 to 1969. He uses CPI predictions and finds that the REH fails over the period of 1954 to 1964, but holds for the period of 1962 to 1969 (Ghosh, 1991, p. 490).

Friedman (1980) tests the unbiasedness, efficiency and consistency, using survey data of The Goldsmith-Nagan Bond and money Market Letter. The data is bi-weekly publication circulated among professionals and financial market participants. He employs six interest rates of the survey data. These are; 1) federal funds, 2) three-month U.S. Treasury bills, 3) six-month Eurodollar certificates of deposit, 4) twelve-month U.S. Treasury bills, 5) new issues of high-grade long term utility bonds, and 6) seasoned issues of high-grade long-term municipal bonds. The sample period covers thirty quarterly observations. The three-month ahead and six-month ahead survey predictions for six market interest rates are used in the unbiasedness test. Despite a general tendency to α >0, β < 1, the results give mixed conclusions. F test results indicate that the only predictions on six-month ahead municipal bonds hold unbiasedness property at the 10% significance level. Durbin-Watson results, on the other hand, imply that the existence of serial correlation from the regressions by OLS constitutes a contradiction of rationality. Considering that OLS on a single-equation basis might be inappropriate procedure in testing the unbiasedness, Friedman follows SUR procedure. The test statistic λ, rejects unbiasedness at the 10% level for three-month ahead predictions and rejects at the 1% level for six-month ahead predictions.

Friedman then tests the efficiency of the same survey data. The F test results for three-month ahead predictions indicate that the hypothesis cannot be rejected for 2^{nd}, 3^{rd} and 6^{th} variables and can be rejected for 4^{th} variable at the 10% level. Others are statistically significant at the 1% level. The F test results for six-month future predictions show that the hypothesis can be rejected for 2^{nd} and 3^{rd} variables at the 10% level and can be rejected for other variables at the 5 and 1% levels.

Figlewski and Watchel (1981) run unbiasedness test employing Livingston data. The regression results by OLS and weighted least squares reject the hypothesis. Besides, they found that past forecast errors were significant explanatory factors of current forecast errors, indicating that the orthogonality principle was also violated.

Ball and Croushere (1995) analyze the policy changes on output, inflation and the survey expectations of these variables. They use the Survey of Professional Forecasters, Livingston data and Michigan Survey of Consumers. In all regressions, the first group dependent variables are the deviations of actual output and inflation from the forecasts of these variables obtained by univariate forecasting models. The second group dependent variables are the deviations of survey expectations of output and inflation from the forecasts of univariate models. The right hand side variables are only the lags of the change in the funds rate. There are two basic questions in their study. The first one is if policy changes results in deviations of output and inflation from the paths that one would forecast based on their usual dynamics. The second one is whether the survey respondents anticipate these deviations. They found that the shifts in monetary policy with the changes in the federal funds rate have larger effects on realized output than the survey data. This implies that agents underestimate the effect of policy changes on aggregate demand. Their inflation analysis implies that the lags of funds rate of two years or more have similar effects on realized and expected inflation rates. Hence, the policy changes have effects on both output and inflation. These expectations must be reflected in expectations for rationality to hold. Their overall conclusion is a strong rejection of rationality.

III. Testing the REH using the data for Turkey

In this section, the tests of unbiasedness and efficiency are applied by using the expectations data obtained from The Central Bank of Turkey Business Survey (CBTBS) and the expectations obtained from forecasting model(s) using the data for Turkey.

III-1. Testing the REH using the CBTBS data

CBTBS consists of 34 questions about opinions and expectations on several variables, such as investment, production capacity, employment, exports, inflation rate, interest rate, etc. All survey results are monthly. Response types, number of responses and the time interval in which the results are available are subject to change from question to question. For instance, the 1st question is “Your opinion about the general course of business in your industry, compared to previous month”. Responses of this question come out as more optimistic, same and more pessimistic. The number of responses of the1st question for each month varies from 241 to 653. Time interval for the availability of the results for this question is 1987:12 – 2001:6. Again, for instance, the 34th question is “Over the next 12 months what is your expectation for short term Turkish Lira credit interest rate? ”. Responses of this question come out as %1-15, %16-20…%61-70 and more than %71. The number of responses of the 34th question for each month varies from 453 to 533. Time interval for the availability of the results for this question is 2000:5 – 2001:6. The more detail on the data can be reached at http://tcmbf40.tcmb.gov.tr/ cbt.html

Dengiz and Özcan (1994) test the convenience of the questions and confidence of the survey results. They use inter item correlation (IIC) and item total correlation (ITC) in order to see the relationship of each question to other questions and the convenience of the questions with the whole survey. They found, in general, the significant correlations between questions. For example, the correlation between the 14th question “The amount of new orders received from the exports market” and the 17th question “The volume of exported goods” was found %85.2. Another example is the coefficient value of %66.6 between the questions of 2 and 10. Dengiz and Özcan (1994, p.186) obtained also a significant confidence coefficient value of 0.78 from the confidence analysis

Here in this study, question of interest is “Over the next 12 months what is your expectation on the inflation (wholesale price) rate? ”. Responses of this 30th question are given as %1-15, %16-20…%61-70 and more than %71. The last one is considered here in this study as %71-80. The number of responses for each month varies from 424 to 571. Time period for the availability of the results for this question is 1999:1-2001:6. For instance, the results from the survey given in 1999:1 are the expectations on the inflation rate for 1999.2-2000:1.

In order to find the expectations for 1999:2, first I took the weighted average of these inflation expectations for 1999:2-2000:1 and then divided this weighted average by 12. To have the expectations for 1999:3, I obtained the weighted average of expectations for 1999.3-2000:2, and then divided this weighted average by 12 and so on. I call the monthly expectations obtained in this way as *average expectations* (*EXPA*). Hence the number of monthly expectations available to this study is 30 (1999:2-2001:7).

The realized monthly observations of WPI (94=100, TP.FG.TO1.TOP) are obtained from the web site of the Central Bank of Turkey Electronic Data Delivery System (EVDS). This web site can be reached at http://tcmbf40.tcmb.gov.tr. In practice, usually, inflation rate is calculated by differencing the natural log of WPI. Since, inflation rate that is publicly known is calculated by taking the percentage change of the level of WPI, I calculated the monthly inflation rate (*INF*) as given by (5)

$$INF = \left(\frac{WPI_t - WPI_{t-1}}{WPI_{t-1}} \right) * 100 \qquad (5)$$

In order for *INF* to be compatible with *EXPA*, I calculated the average of annual inflation rate for each month. For instance, to find the inflation rate for 1999:2, I calculated the average of inflation rate for the period of 1999:2-2000:1 and divided by 12. To obtain the inflation rate of 1999:3, again I divided the inflation rate of 1999.3-2000:2 by 12 and so on. I call this monthly inflation rate obtained in this way *average inflation rate* (*INFA*). In this calculation, however, because of data availability, starting from *INFA* of 2000:9, the division number decreases to 11, 10, 9 and so on.

In obtaining the *INFA* and *EXPA*, it should be taken into account of the crisis of the Turkish economy occurred in February 21, 2001. The main purpose of this article is to estimate whether the expectations of private sector are rational or not. If all information available in the economy exists in private sector's information set, the expectations are assumed to be formed rationally. In February 2000, most likely before the date of crisis, respondents were asked their expectations over next 12 months, from March 2001 to February 2002. Based on the answers of respondents, expectations on March 2001 were calculated as described above. Respondents, however, did not know the basic reasons of the crises at the time when they answered the survey question. As a result of this, the expectations on inflation rate of March 2001 seriously differed from the realized inflation of the same month. Using this March observation in testing the rational expectations might yield biased results. Therefore, by following the zero-order regression method, March 2001 observations of *EXPA* and *INFA* were replaced by their means.

Before going further into the statistical analyses based on *INFA* and *EXPA*, one should check If variables have unit root or not. Since the availability of nonstationary variable(s) in a regression gives biased statistical results, before statistical analyses, stationarity (unit root) tests are needed for *INFA* and *EXPA*. The graph of the series can help to understand if the series stationary or not. If series tends to drift somewhat with no obvious mean, one can suspect that the series is nonstationary. A time series with constant mean and constant variance over time is called stationary. A more formal analysis for stationarity is to run Dicky-Fuller (DF), Augmented DF or Phillips-Perron tests. If the series is found nonstationary, its first difference is taken. In case the series is still found nonstationary, a higher order (i.e. second or third) difference is taken until series becomes stationary. DF tests are applied to the equations (a), (b) and (c) below in Table 1. If residuals from, i.e. equation (c) are not white noise (serially dependent), one can run Augmented DF test by adding lagged difference term(s) until residual term becomes serially independent.

Table 1: Unit root test of *INFA* (99:2-01:7)		DF/ADF tests	5% critical value*	Q stat. for e_t**	p of Q
a	$\Delta X_t = \alpha X_{t-1} + e_t$	-0.780	-1.953	9.625	0.211
b	$\Delta X_t = a + \alpha X_{t-1} + e_t$	-2.196	-2.966	6.430	0.491
c	$\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-2.381	-3.573	5.745	0.570

*MacKinnon critical value, **Tabled $\chi^2_{(0.05,\ df=7)}$ value is 14.067

Q statistics indicate that there is no need to add ΔX_{t-i} to any of DF equations above in Table 1. Since the DF test results in absolute values are less than the McKinnon %5 critical values, *INFA* series has unit root. Therefore same tests are rerun for the first differenced *INFA* (*DINFA*). Table 2 gives the results.

Table 2: Unit root test of *DINFA* (99:3-01:7)		DF/ADF tests	5% critical value	Q stat. for e_t	p of Q
a	$\Delta X_t = \alpha X_{t-1} + e_t$	-8.731	-1.953	2.974	0.887
b	$\Delta X_t = a + \alpha X_{t-1} + e_t$	-8.590	-2.970	2.985	0.886
c	$\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-8.424	-3.579	3.036	0.882

Q statistics, again, indicate that there is no need to add ΔX_{t-i} to any of DF equations above in Table 2. And the results of DF tests indicate that the *DINFA* series is stationary. Stationarity test results of *EXPA* are given in Table 3.

Table 3: Unit root test of *EXPA* (99:2-01:7)		DF/ADF tests	5% critical value	Q stat. for e_t*	p of Q
a	$\Delta X_t = \alpha X_{t-1} + e_t$	-0.609	-1.953	4.638	0.795
b	$\Delta X_t = a + \alpha X_{t-1} + e_t$	-1.320	-2.966	5.813	0.668
c	$\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-0.498	-3.573	4.932	0.765

Results show that *EXPA* is not stationary. Table 4 indicates that the *DEXPA* series is stationary.

Table 4: Unit root test of *DEXPA* (99:3-01:7)		DF/ADF tests	5% critical value*	Q stat. for e_t*	p of Q
a	$\Delta X_t = \alpha X_{t-1} + e_t$	-3.804	-1.953	2.284	0.971
b	$\Delta X_t = a + \alpha X_{t-1} + e_t$	-3.733	-2.970	2.281	0.971
c	$\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-3.850	-3.579	2.945	0.938

In other words, they both follow $I(1)$. Therefore, statistics obtained from the regression based on differences are not spurious. There is, however, a problem of losing long-term information between differenced variables. In this respect, differenced stationary variables have two aspects. On the one hand, it is avoided having the spurious (not meaningful) results by using $I(1)$ variables; on the other hand, there is a possibility of losing the long-term relationship between those variables. Since both INFA and EXPA are $I(1)$, they might be cointegrated. It means that, although the levels of INFA and EXPA are not stationary, their linear combination might be stationary. If this is the case, the regression of the level of INFA on EXPA yields meaningful results and does not cause the loosing of long-term information. To test the cointegration, one can follow either Engle-Granger (EG) or Johansen methodologies. Following EG method, unit root tests for e_t indicate that e_t is stationary, as is shown in Table 5.

Table 5: Unit root test of e_t	DF/ADF tests	5% critical value	Q stat. for v_t*	p of Q
$\Delta e_t = \alpha e_{t-1} + v_t$	-2.361	-1.953	4.649	0.703
*Tabled $\chi^2_{(0.05,\, df = 7)}$ value is 14.067				

Therefore, to test the unbiasedness of REH, one can perform regression on the levels rather than differences. One can, however, test the REH by employing both levels and differences. If agents can predict the actual level of inflation, they can predict also differences of the actual level of inflation rate. Therefore, in this study, the unbiasedness and efficiency tests are carried out by employing both levels and differences of the variables.

III-1-1. Results of the unbiasedness test.

Following the unbiasedness property, INFA is regressed on *EXPA* as given by equation (6) by testing the joint null hypothesis below.

$$INFA_t = \alpha + \beta EXPA_t + e_t \qquad (6)$$

H_0: $\alpha = 0$, $\beta = 1$

Regression results with their corresponding standard errors, D-W, standard error of estimate (s.e.e.), F statistic, probability of obtaining F value, p(F), F statistic of the null hypothesis and p(F) are given by (6').

$$INFA_t = 5.536 - 0.3807\, EXPA_t \quad (6')$$
$$(0.801) \quad (0.204)$$
$$\text{D-W} = 0.628,\ \text{s.e.e} = 1.203,\ F = 3.459,\ p(F) = 0.073$$
$$H_0: \phi = 0,\ \theta = 1,\ F(2,28) = 23.922\ \ p(F) = 0.000$$

The constant term is significant at the 1% level, and EXPA is significant at the 10% level. Looking at either the tabled F (2, 28) value of 7.64, at significance level of 0.01, or p(F) value of 0.000, null hypothesis is rejected at the 1% level. D-W statistic shows a significant positive serial correlation of the residuals at the 1 % significance level. Both F and D-W results clearly indicate that forecast is biased in sample used.

One might wonder if H_0: $\phi = 0$, $\theta = 1$ holds or not when it is assumed that residuals are not autocorrelated To see the result under this assumption, the regression of (6') can be corrected by Cochrane-Orcutt method (COM). Results are presented by equation of (6'')

$$INFA_t = 6.458 - 0.666\, EXPA_t \quad (6'')$$
$$(1.390) \quad (0.348)$$
$$\text{RHO} = 0.696\ (0.157),\ \text{D-W}= 2.390,\ \text{s.e.e.} = 0.891$$
$$H_0: \phi = 0,\ \theta = 1,\ F(2,26) = 11.622,\ p(F) = 0.000$$

RHO is the estimated ρ coefficient ($\hat{\rho}$). ρ is the first-order serial correlation coefficient. D-W statistic indicates that one cannot reject the hypothesis of no first order serial correlation at the 1% level. Constant and RHO are significant at the 1% level. EXPA is significant at the 10% level. The p(F) value is 0.000, the null hypothesis is again rejected at significance level of 0.01. The conclusion hasn't changed. The results from both equation (6') and equation (6'') imply that, the unbiasedness property of REH fails based on the sample used. The same test is run for differences of the variables as given by (7) and the results are shown by (7').

$$DINFA_t = \phi + \theta DEXPA_t + e_t \quad (7)$$
$$H_0: \phi = 0,\ \theta = 1$$

$$DINFA_t = -0.049 - 0.763\, DEXPA_t \quad (7')$$
$$(0.177) \quad (0.408)$$

D-W = 2.686, s.e.e = 0.954, F = 3.496, p(F) = 0. 072
H_0: $\phi = 0$, $\theta = 1$, F(2,27) = 9.325, p(F) = 0.000

Constant term is insignificant and DEXPA is significant at the 10% level. D-W value of 2.686 rejects the hypothesis of no negative correlation at the 5% level. F value rejects the hypothesis at the 1% level.

Again, under the assumption of no autocorrelation, one can want to check if differenced survey results of expectations on inflation meet the unbiasedness property. Hence, the first-order autoregressive correction is required for equation of (7'). Equation (7') is corrected by COM and the results are given by equation (7'').

$$DINFA_t = -0.041 - 0.340\, DEXPA_t \qquad (7'')$$

(0.118) (0.320)

RHO = -0.444 (0.179), D-W = 1.999, s.e.e = 0.906,

H_0: $\phi = 0$, $\theta = 1$, F(2,25) = 8.744, p(F) = 0.001

Constant and DEXPA are insignificant. $\hat{\rho}$ is significant at the 5% level. D-W result shows that there is no first order serial correlation at the 1% level. The joint hypothesis that H_0: $\phi = 0$, $\theta = 1$ is rejected at the 1% level. This conclusion clearly indicates a forecast bias in sample used.

III-1-2. Results of the efficiency tests

Efficiency test analyzes if the survey expectation on inflation rate uses the same information about the past history of the realized inflation rate. In other words, if the rational expectations are efficient, p_t^e should follow the same autoregressive process as p_t evolves through time. The length of the lag (N) is chosen to minimize standard error of the regression of (3). Following the same criterion, N is determined as 5 for INFA. The corresponding equations and the null hypothesis are given by equations (8) through (10).

$$INFA_t = \lambda_0 + \sum_{i=1}^{5} \lambda_i INFA_{t-i} + v_t \qquad (8)$$

$$EXPA_t = \delta_0 + \sum_{i=1}^{5} \delta_i EXPA_{t-i} + \mu_t \qquad (9)$$

$$H_0 : \lambda_i = \delta_i \qquad (10)$$

The test was done in two methods. In the first one, equations (8) and (9) were run by OLS in the first step. In the second step, it is tested if the lags of *EXPA* are equal to the coefficient values of *INFA* obtained from (8). In the second method, both equation (8) and (9) were employed together in a system and regressed by seemingly unrelated regression procedure (SUR). Then the hypothesis of (10) was tested. These tests are also done for DEXPA, as in unbiasedness test. The N was found 3 for DINFA. The results are shown in Table 6.

Table 6: The Results of The Efficiency Tests

	by OLS	by SUR
EXPA	F(5,19) = 8.820	$\chi^2(5) = 38.706$
	p(F) = 0.000	$p(\chi^2) = 0.000$
DEXPA	F(3,22) = 8.415	$\chi^2(3) = 18.207$
	p(F) = 0.000	$p(\chi^2) = 0.000$

The F and χ^2 values are all significant at the 1% level. Therefore, the efficiency hypothesis was rejected for both *EXPA* and *DEXPA*. The survey expectations on inflation rate in both levels and differences are not efficient. This implies that the survey respondents did not efficiently use the information about past history of the actual inflation rate. In conclusion, the efficiency property of the survey data fails as well. The next section provides an alternative data for expectations and tests of unbiasedness and efficiency using the data obtained from forecasting model(s) of Box-Jenkins.

III-2. The formation of expectations on output by Box-Jenkins procedure

In section IV.1, since the number of survey observations is restricted by 30, this section IV.2, analyzes the REH by employing Box-Jenkins or ARIMA forecasting method to obtain more observations on expectations. The other purpose of this section is to analyze if survey respondents are better at predictions than the univariate forecasting models. One could run ARIMA model to forecast the future values of any variable such as inflation rate, exchange rate, interest rate or output, etc. Here in this study, the output (industrial production index-IP) is selected, because *IP* has the smallest standard deviation among others.

I used the monthly data on *IP*. The source for these series is Central Bank of Turkey Electronic Data Delivery System (EDDS). The definition of *IP* in the source is *TP.UR4.TO1: Total, 1997=100*. The full sample of *IP* is 85:1-2001:6. Expectations on output for the period of 93:6-2001:6 are obtained. Then, based upon these expectations and the actual values of *IP*, the unbiasedness and efficiency tests are carried out in this section.

At the first stage, the first three expectations (forecasts) on IP (93:6-93:8) are acquired by using the real observations of IP (85:1-93:5). At the second stage, the next three expectations (93:9-93:11) are obtained by using the real observations of 85:1-93:8, and so on. For each stage, before forecasting the IP by ARMA methodology, one first should carry out the stationarity analysis and then needs to follow the steps of identification, estimation and diagnostic checking.

At identification step, the tentative model is determined. Following to the estimation and diagnostic checks, if the tentative model does not meet the necessary requirements, one analyzes one of the alternatives of the tentative model. If there are more possible alternative models, one can use Akaike Information criterion (AIC), Schwartz Bayesian criterion (SBC), standard error of estimates (s.e.e.) etc. The model with the smallest AIC, SBC and s.e.e., and with the white noise residuals among others could be considered as the final model. The model, either tentative or alternative, that meets the conditions of estimation and diagnostic checks, is called final model. Then the final model is employed to forecast the future values of the related series.

Therefore, here in this section, at the first stage, the stationarity, identification, estimation and diagnostic checks are applied to *IP* of 85:1-93:5 to forecast the *IP* for 93:6-93:8. At the second stage, the all these steps are followed again to forecast *IP* for 93:9-93:11 by using the real observations of *IP* of 85:1-93:8. This forecasting procedure goes through 2001:6.

In all these analyses, the natural log of industrial production (*LIP*) is used. At all stages, *LIP* is found nonstationary, but differenced *LIP* (*DLIP*) is found stationary. For instance, Tables 7 and 8 give the results of DF/ADF tests for the sample of 85:1-93:5. Table 7 indicates that *LIP* is nonstationary, whereas Table 8 shows that *DLIP* is stationary. Therefore, in Box-Jenkins analyses, the final models are obtained based on *DLIP*. At the stage of getting the forecast values of *IP*, RATS, first, integrates the *DLIP*, and then takes the anti log of *LIP*.

Table 7: Unit root test of *LIP* (85:1-93:5)		DF/ADF tests	5% critical value*	lag	Usable Obs.	Q stat. for e_t**	P of Q
a	$\Delta X_t = \alpha X_{t-1} + e_t$	3.519	-1.943	12	88	15.819	0.825
b	$\Delta X_t = a + \alpha X_{t-1} + e_t$	-0.934	-2.894	12	88	16.899	0.769
c	$\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-1.913	-3.460	12	88	18.449	0.679

*MacKinnon critical value, **Tabled $\chi^2_{(0.05,\ df=22)}$ value is 33.924

Table 8: Unit root test of *DLIP* (85:2-93:5)		DF/ADF tests	5% critical value	lag	Usable Obs.	Q stat. for e_t	P of Q
a	$\Delta X_t = \alpha X_{t-1} + e_t$	-7.575	-1.943	11	88	17.082	0.759
b	$\Delta X_t = a + \alpha X_{t-1} + e_t$	-4.995	-2.894	11	88	16.247	0.803
c	$\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-5.018	-3.460	11	88	17.082	0.759

Table 9 gives the tentative and final models with the Theil's *inequality coefficients* (TU). TU's show the forecasting accuracies of the final forecasting models of the related periods.

$$TU = \frac{\sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(\hat{Y}_t - Y_t\right)^2}}{\sqrt{\frac{1}{n}\sum_{t=1}^{n}\hat{Y}^2} + \sqrt{\frac{1}{n}\sum_{t=1}^{n}Y^2}} \qquad (11)$$

Where $\hat{Y}_t$ is expectation (forecast) on Y_t and Y_t is the actual value of Y at time t. TU statistic ranges from 0 to 1. It indicates that the closer TU is to zero, the better the model. If TU equals 0, the model is perfect. Conversely, if it is equal to 1, the model is as bad as it could be. TU values given in the last column of Table 9 are close to zero. Overall TU value of 0.0330 indicates that the forecast values of 93:6-01:6 are not perfect but reasonable (or reasonably good).

The final forecasting models given at fourth column, hence, produce 97-month expectations. The next section employs the unbiasedness and efficiency tests by employing *IP* and these expectations on *IP* (*FORE*).

Before running unbiasedness and efficiency tests, one should carry out unit root tests, as was done in section IV.1. The unit root tests for *LIP* and the natural log of *FORE* (*LFORE*) are resulted in nonstationarity as shown in Tables 10 and 12. The same tests for the differenced *LIP* (*DLIP*) and differenced *LFORE* (*DLFORE*) are resulted in favor of stationarity as indicated by Tables 11 and 13 respectively. Therefore *LIP* and *LFORE* are *I*(1). Table 14, on the other hand, has the result of cointegration of *LIP* and *LFORE*. Hence, one can, test the REH by using both levels and differences of the variables as was done in section IV.1. The logic is the same. If the forecast values can predict the actual level of output, they can predict also differences of the actual level of output.

Table 9: Box-Jenkins forecasting models for IP.

Sample Used	Forecasting period	Tentative Model	Final Model	TU
85:1-93:5 (101 obs.)	93:6-93:8	AR(1,3,4,10,11,12) MA(1,12)	AR(12) MA(1)	0.0158
85:1-93:8 (104 obs)	93:9-93:11	AR(1,3,4,10,11,12) MA(1,12,13)	AR(12) MA(1)	0.0183
85:1-93:11 (107 obs)	93:12-94:2	AR(1,3,4,9,10,11,12) MA(1,12,13)	AR(12) MA(1)	0.0360
85:1-94:2 (110 obs)	94:3-94:5	AR(1,3,4,10,11,12) MA(1,12,13)	AR(12) MA(1)	0.0730
85:1-94:5 (113 obs)	94:6-94:8	AR(1,3,10,11,12) MA(1,12,13)	AR(12) MA(1)	0.0290
85:1-94:8 (116 obs)	94:9-94:11	AR(1,3,10,11,12) MA(1,12,13)	AR(11,12) MA(1)	0.0269
85:1-94:11 (119 obs)	94:12-95:2	AR(1,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1)	0.0116
85:1-95:2 (122 obs)	95:3-95:5	AR(1,3,4,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1)	0.0625
85:1-95:5 (125 obs)	95:6-95:8	AR(1,3,4,9,10,11,12) MA(1,12,13,24)	AR(12) MA(1)	0.0494
85:1-95:8 (128 obs)	95:9-95:11	AR(1,3,4,9,10,11,12) MA(1,12,13)	AR(12) MA(1)	0.0217
85:1-95:11 (131 obs)	95:12-96:2	AR(1,4,9,10,11,12,22) MA(1,12,13)	AR(12) MA(1)	0.0333
85:1-96:2 (134 obs)	96:3-96:5	AR(1,3,4,9,10,11,12) MA(1,12,13,24)	AR(12) MA(1)	0.0310
85:1-96:5 (137 obs)	96:6-96:8	AR(1,3,4,5,9,10,11,12) MA(1,12,13,24)	AR(12) MA(1)	0.0139
85:1-96:8 (140 obs)	96:9-96:11	AR(1,3,4,5,9,10,11,12) MA(1,12,13,24)	AR(12) MA(1)	0.0369
85:1-96:11 (143 obs)	96:12-97:2	AR(1,3,4,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0333
85:1-97:2 (146 obs)	97:3-97:5	AR(1,3,4,9,10,11,12,22,23) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0343
85:1-97:5 (149 obs)	97:6-97:8	AR(1,3,4,9,10,11,12,22) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0095
85:1-97:8 (152 obs)	97:9-97:11	AR(1,3,4,9,10,11,12,22,23) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0268
85:1-97:11 (155 obs)	97:12-98:2	AR(1,3,4,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0342
85:1-98:2 (158 obs)	98:3-98:5	AR(1,3,4,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0281
85:1-98:5 (161 obs)	98:6-98:8	AR(1,4,5,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0200
85:1-98:8 (164 obs)	98:9-98:11	AR(1,4,5,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0060

Table 9, continued

85:1-98:11 (167 obs)	98:12-99:2	AR(1,3,4,5,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0459
85:1-98:2 (170 obs)	99:3-99:5	AR(1,4,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0304
85:1-99:5 (173 obs)	99:6-99:8	AR(1,3,4,5,9,10,11,12,22) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0342
85:1-99:8 (176 obs)	99:9-99:11	AR(1,3,4,5,9,10,11,12) MA(1,12,13,24)	AR(11,12) MA(1,24)	0.0191
85:1-99:11 (179 obs)	99:12-00:2	AR(1,3,4,5,9,10,11,12,22) MA(1,12,13,24)	AR(1,3,4,11,12) MA(1,24)	0.0271
85:1-00:2 (182 obs)	00:3-00:5	AR(1,3,4,5,9,10,11,12) MA(1,12,13,24)	AR(1,3,4,11,12) MA(1,24)	0.0084
85:1-00:5 (185 obs)	00:6-00:8	AR(1,3,4,5,9,10,11,12,20,22) MA(1,12,13,24)	AR(1,3,4,11,12) MA(1,24)	0.0429
85:1-00:8 (188 obs)	00:9-00:11	AR(1,3,4,5,9,10,11,12,20,22) MA(1,12,13,24)	AR(1,3,4,11,12) MA(1,24)	0.0244
85:1-00:11 (191 obs)	00:12-01:2	AR(1,3,4,5,9,10,11,12,20,22) MA(1,12,13,24)	AR(1,3,4,11,12) MA(1,24)	0.0527
85:1-01:2 (193 obs)	01:3-01:4	AR(1,3,4,9,10,11,12,20) MA(1,12,13,24)	AR(1,3,4,11,12) MA(1,24)	0.0596
85:1-01:4 (195 obs)	01:5-01:6	AR(1,3,4,9,10,11,12,20) MA(1,12,13,24)	AR(1,3,4,11,12) MA(1,24)	0.0056

Overall (93:6-01:6) TU Value = 0.0330

Table 10: Unit root test of *LIP* (93:6-01:6)	DF/ADF tests	5% critical value	lag	Usable Obs.	Q stat. for e_t^*	P of Q
a $\Delta X_t = \alpha X_{t-1} + e_t$	1.578	-1.944	11	85	23.089	0.339
b $\Delta X_t = a + \alpha X_{t-1} + e_t$	-1.419	-2.895	11	85	23.995	0.293
c $\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-0.380	-3.462	11	85	24.660	0.262

*Tabled $\chi^2_{(0.05, df=21)}$ value is 32.670

Table 11: Unit root test of *DLIP* (93:7-01:6)	DF/ADF tests	5% critical value	lag	Usable Obs.	Q stat. for e_t^*	P of Q
a $\Delta X_t = \alpha X_{t-1} + e_t$	-6.361	-1.944	10	85	23.873	0.299
b $\Delta X_t = a + \alpha X_{t-1} + e_t$	-6.623	-2.895	10	85	23.075	0.340
c $\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-6.755	-3.462	10	85	25.373	0.231

*Tabled $\chi^2_{(0.05, df=21)}$ value is 32.670

Table 12: Unit root test of *LFORE* (93:6-01:6)	DF/ADF tests	5% critical value*	lag	Usable Obs.	Q stat. for e_t	P of Q
a $\Delta X_t = \alpha X_{t-1} + e_t$	0.327	-1.943	4	92	28.868*	0.185
b $\Delta X_t = a + \alpha X_{t-1} + e_t$	-2.321	-2.892	2	94	35.634**	0.060
c $\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-3.042	-3.457	2	94	32.838**	0.108
*Tabled $\chi^2_{(0.05,\ df=23)}$ value is 35.172, ** Tabled $\chi^2_{(0.05,\ df=24)}$ value is 36.415						

Table 13: Unit root test of *DLFORE* (93:7-01:6)	DF/ADF tests	5% critical value	lag	Usable Obs.	Q stat. for e_t^*	P of Q
a $\Delta X_t = \alpha X_{t-1} + e_t$	-6.667	-1.943	3	92	28.815	0.187
b $\Delta X_t = a + \alpha X_{t-1} + e_t$	-6.651	-2.892	3	92	28.875	0.184
c $\Delta X_t = a + bt + \alpha X_{t-1} + e_t$	-6.617	-3.458	3	92	29.083	0.178
*Tabled $\chi^2_{(0.05,\ df=23)}$ value is 35.172						

Table 14: Unit Root Test of e_t	DF/ADF tests	5% critical value	Usable obs	Q stat. for v_t^*	P of Q
$\Delta e_t = \alpha e_{t-1} + v_t$	-6.330	-1.95	96	32.214	0.121
*Tabled $\chi^2_{(0.05,\ df=24)}$ value = 36.415					

III.2.1 Results of the unbiasedness tests

Equation (12) is to test the serial correlation and the joint null hypothesis below. Equation (12') gives the regression output.

$$LIP_t = \alpha + \beta LFORE_t + e_t \quad (12)$$

H_0: $\alpha = 0$, $\beta = 1$

$$LIP_t = 0.745 + 0.835\, LFORE_t \quad (12')$$

(0.285) (0.063)

D-W= 1.183, s.e.e. = 0.067, F = 174.991, p(F) = 0.000

H_0: $\phi = 0$, $\theta = 1$, $F(2,95) = 3.416$, p(F) = 0.036

The constant and LFORE are significant at the 1% level. D-W statistic rejects the hypothesis of no positive autocorrelation at the 1% level. The joint hypothesis is rejected at the 5% level. The hypothesis of unbiasedness is rejected. Under the assumption of no autocorrelation, the output with the first order serial correction by COM is given by (12'').

$$LIP_t = 1.046 + 0.768\, LFORE_t \qquad (12'')$$

$$(0.403) \quad (0.089)$$

RHO = 0.422 (0.098), D-W= 2.099, s.e.e. = 0.062

H_0: $\phi = 0$, $\theta = 1$, $F(2,93) = 3.363$, $p(F) = 0.038$

The constant is significant at the 5% level whereas, LFORE and RHO are significant at the 1% level. There is no autocorrelation at the 1% level. The joint hypothesis is rejected at the 5% level.

Below, the unbiasedness test is rerun based on differences of the variables. Equation (13') gives the results of this regression.

$$DLIP_t = \phi + \theta DLFORE_t + e_t \qquad (13)$$

H_0: $\phi = 0$, $\theta = 1$

$$DLIP_t = 0.000 + 0.584\, DLFORE_t \qquad (13')$$

$$(0.007) \quad (0.137)$$

D-W= 2.715, s.e.e. = 0.072, F = 18.166, p(F) = 0.000

H_0: $\phi = 0$, $\theta = 1$, $F(2,94) = 4.591$, $p(F) = 0.012$

The constant is not significant. *DLFORE* is statistically significant at the 1% level. D-W statistic rejects the hypothesis of no negative autocorrelation at the 1% level. The joint hypothesis is rejected at the significance level of 5%. The unbiasedness hypothesis is rejected. Equation (13'') has the output of (13) with the correction of COM.

$$DLIP_t = 0.000 + 0.640\, DLFORE_t \qquad (13'')$$

$$(0.005) \quad (0.131)$$

RHO = -0.366 (0.097), D-W = 1.995, s.e.e. = 0.067

H_0: $\phi = 0$, $\theta = 1$, $F(2,94) = 3.733$, $p(F) = 0.027$

The constant is not significant. *DLFORE* and RHO are statistically significant at the 1% percent level. The joint hypothesis is rejected at the significance level of 5%. Therefore the unbiasedness hypothesis is again rejected.

III-2-2. Results of the efficiency tests

If the REH is efficient, the expectations (forecasted values) on output follow the same autoregressive process as actual output follows. N = 14 months minimizes the s.e.r of LIP. Equations (14) through (16) give related regression equations and the null hypothesis.

$$LIP_t = \lambda_0 + \sum_{i=1}^{14} \lambda_i LIP_{t-i} + v_t \quad (14)$$

$$LFORE_t = \delta_0 + \sum_{i=1}^{14} \delta_i LFORE_{t-i} + \mu_t \quad (15)$$

$$H_0 : \lambda_i = \delta_i \quad (16)$$

The same methods were followed as were done in Section IV.1.2. The hypothesis of (16) was tested bas on differences. The length of the lag of DLIP was determined as 12 so that it minimizes the regression of DLIP on a constant plus 12 its own lags. The results are given in Table 15.

Table 15: Results of the efficiency tests

	by OLS	by SUR
LFORE	F(14,68) = 1.616	$\chi^2(14) = 15.672$
	p(F) = 0.097	$p(\chi^2) = 0.333$
DLFORE	F(12,71) = 1.487	$\chi^2(12) = 12.927$
	p(F) = 0.149	$p(\chi^2) = 0.374$

The F(14,68) value indicates that the efficiency test can be rejected at the 10% level. The F(12,71) value results in that the efficiency test can be rejected at the 25% level. The χ^2 values might be rejected only at the 50% level. Therefore, the expectations obtained from univariate forecasting model of Box-Jenkins were found to be efficient.

Summary and conclusion

In this study, The Rational Expectations Hypothesis is examined by both analyses from the literature and the Turkish business survey of expectations. I analyzed if the survey expectations are rational or not. The rationality, here in this study, is examined mainly on the basis of unbiasedness and efficiency. The several studies from literature have mixed results. The Livingston survey results are the mostly used data in the literature. Pesando (1975) does not reject the efficiency, but rejects the rationality and consistency. Carlson (1977) rejects all of three hypotheses in using CPI. Pearce (1979) concludes that univariate forecasting models do better job in predictions than the survey results. Turnowsky (1980) has mixed results. He rejects the unbiasedness for one period, cannot reject for the other period. Figlewski and Watchel (1981) reject the unbiasedness hypothesis. Friedman (1980) uses The Goldsmith-Nagan Bond and Money market Letter. He also has mixed results in testing unbiasedness and efficiency properties. Ball and Croushere (1995) use The Survey of Professional Forecasters, Livingston data and Michigan Survey of Consumers. They strongly reject the rationality.

I used the data of expectations on inflation rate from the Central Bank of Turkey Business Survey. The regression results reject both unbiasedness and efficiency. I also obtained the expectations on output by Box-Jenkins forecasting models. Unbiasedness hypothesis again fails, whereas efficiency hypothesis holds. The latter result imply that the survey respondents did not efficiently utilize the information about history of output (production index) as they form their expectations whereas the expectations (forecasts) obtained from forecasting model could employ all of available past information about output.

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