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Rationality Tests of a State's Tax Forecasts

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Abstract

Each year, Oklahoma State University publishes its forecasts of several economic and tax measures for the coming year. The purpose of this research is to examine the forecasts of three principal tax revenues in Oklahoma. Using "weak" and "strong" rationality tests and data from the entire history of the model, the forecasts of income and motor fuel taxes passed both tests, and the sales and use taxes ratified none of the tests.

Introduction

Predicting future economic and tax measures is a science and an art. It is a science in the sense that it requires knowledge to design the framework of the model and to use and quantify important variables which influence the prediction. It is also an art because it requires intuition and judgment to switch and reswitch the importance of each variable's influence at the right time.

Typically all economic forecasts, ex ante, deviate from reality, ex post. Economists use two criteria to judge forecasts (Gentry 1989; Nordhaus 1987). First, if forecasts are on target, that is, if the expected values of the errors of the predictions are zero, the forecasts are considered "good." This test is known as the weak rationality test of forecasts. Second, a good forecast utilizes and incorporates all the information related to each variable at the time of prediction. Lack of information and/or inadequate use of information can make the prediction deviate from reality. In addition, the less information used, the larger the errors of the forecasts are likely to be. For instance, if information on income or predictions of income are not used in income tax forecasts, forecast errors grow large and the ex post deviates from the ex ante. The strong rationality test of forecasts addresses the question of full utilization of information.

Each December the Office of Business and Economic Research of Oklahoma State University publishes forecasts of several measures for the coming year in the *Oklahoma Economic Outlook*. These predictions are based on the Oklahoma State University (OSU) Econometric Model, which initially consisted of 63 equations and was constructed by Timothy Charles Ireland in 1978. Since then, the parameters of the model have been re-estimated each year by incorporating more data to the initial eighteen annual observations. As a result, the statistical degrees of freedom of the model have been increasing.

Although the OSU model and its forecasts have been evaluated and compared with others, its accuracy and the rationality of its forecasts have never been tested. The purpose of this study is to evaluate the forecasts by the weak and strong rationality criteria. The OSU model makes a broad range of annual predictions, but evaluation of all of them is beyond the scope of this study. This paper includes the prediction of only three categories of major taxes--personal and corporate income taxes combined, sales and use taxes, and the motor fuel tax.

Examination and analysis of these taxes are appropriate for two reasons. First, tax revenues are more publicized and more difficult to predict than are measures such as employment. Tax variables depend not only on the tax base, which is related to variables such as the state of the economy, including income and employment, but also on ideologies of legislators. For instance, whether the governor and/or the majority of the legislature are Democratic or Republican may have an impact on the likelihood of tax increases. In short, since, in addition to income and employment, tax revenues are also subject to tax rates which depend on politics, forecasting tax revenues requires the inclusion of political factors as inputs.

Second, while in the late 70s and early 80s the state of Oklahoma experienced a revenue surplus, in recent years the state has witnessed tax revenue shortfalls which have caused reductions in state expenditures and tax rate increases. Thus, reasonably accurate tax predictions are crucial to public sector planning. Especially important are predictions of the income tax, sales and use tax, and motor fuel tax revenues, since these three, according to the latest figures, comprise over 65 percent of Oklahoma tax revenues.

The income tax equation of the OSU model depends on personal income. The sales and use tax equation relies upon disposable personal income and the implicit price deflator. The motor fuel tax of the model is regressed on personal income, the gasoline price index, and the population of the state.

For these three taxes, other variables, such as changes in the state income tax rates by usage of dummy variables, were initially added and tried. But these attempts proved unsatisfactory and did not improve the results and the statistical validity of the model.

The structure of the model and related concepts are explained in the following section. Next, the results are presented. The final section provides the summary and conclusions. An appendix illustrates the weak rationality tests graphically.

The overall results show that income and motor fuel tax forecasts passed the weak and strong rationality tests. But sales and use tax forecasts passed neither of the tests.

Model and Concepts

To pass the rationality criterion, the model must pass both weak and strong rationality tests.[1] Weak rationality is a test for unbiased forecasts; that is, the forecasts, F_t, or ex ante, on the average, equal the actual values, A_t, or ex post. This proposition can be evaluated in a regression model as follows:

$$A_t = a_0 + a_1 F_t + u_t, \quad (1)$$

where a_0 and a_1 are the estimated parameters, and $_t$ is the error term. The test of weak rationality is a joint null hypothesis that a_0 is zero and a_1 is one. That is, to pass this test, the estimated simple regression line must simultaneously (1) pass through the origin, and (2) have a slope of one.

The strong rationality tests the complete use of all information known at the time of prediction, t-f. One way to test strong rationality is to show that the information set, Z, which is known at the time of the forecast, does not predict the forecast errors. This can be done by estimating a regression equation of the form as follows:

$$[A_t - F_t] = ß Z_{t-f} + v_t. \quad (2)$$

Here $[A_t - F_t]$ represents the forecast error; Z_{t-f} is the information vector, which may include a constant and past errors; and v_t is the error term. Strong rationality is a null hypothesis that the coefficient of information vector ß equals zero, i.e., it is a test that abnormal errors, $(A_t - F_t)$ are unpredictable. In other words, if information on these variables is used efficiently, it should not predict future forecast errors. Note that failing the strong rationality test does not necessarily suggest that a forecast is biased. It only implies that some information was not used. Moreover, weak rationality is not a necessary condition for strong rationality.

Obviously if there have been any changes in the rate and/or the base of any tax, subsequent forecasts would deviate more from reality. Therefore, the model should incorporate these changes in the variables.

The strong test answers the question of whether forecasters have incorporated all the information available to them at the time of forecasting. For this purpose, data on economic, demographic, and political factors in the state, in addition to the past forecast errors, were used. All of these variables are lagged one year, with the exception of personal income, which has a two-year lag because this information is not available at the time of the forecast.

Results

Table 1 provides statistics of means, standard deviations, and coefficients of variation of the rate of growth of actual values, forecasts, and forecast errors (actual - forecast) of the three major taxes in the state.

First, as is shown in the table, the means of the actual values for these three groups of taxes range from 10.01 to 13.18 percent, and those of the forecasts extend between 6.31 and 11.54 percent. Notice that the mean of actual variables of each is higher than that of the corresponding forecasts. This suggests that, on the average, during 1980-91, the years in which the model was used, the forecasters underestimated these three classes of taxes. Similarly, the standard deviations of actual income taxes and motor fuel taxes were higher than those of the forecasts. The opposite is true about the sales and use taxes.

Table 1 also presents the means and variations of the error of the forecasts. Comparing the errors of the three forecasts, which range from 1.64 to 3.7 percent, the mean of the errors of the sales and use taxes is the lowest of the three. This implies that, although the sales and use taxes had relatively larger variation due to larger growth over time, the model predicts them better, with less uncertainty, as indicated by a lower standard deviation of errors.

Generally, the uncertainty of tax revenue biases the forecasts downward; one would expect that the greater the uncertainty, the larger the downward bias. To test this possibility, the variation of the forecast error as a measure of uncertainty, and as a measure of the difficulty of the forecast, is compared with the size of the mean of the error as a measure of bias. The resultant positive and high correlation coefficient of 0.98 between the means and the standard deviations of the forecast errors confirms this proposition: the more difficult the forecast, the greater its downward bias.

Weak Rationality Tests

Table 2 presents the results of the weak rationality test for income tax, sales and use taxes, and motor fuel tax revenues. Annual rates of the growth of forecast and actual data from 1980 to 1991 were used to estimate the parameters of equation (1) for each of the three categories of taxes.[2] In the Appendix section, Figures 1-6 show the values of forecasts against their corresponding actual values and their regression lines, as well as the errors of

Table 1

Means, Standard Deviations
and Coefficients of Variation of Rate of Growth Actuals,
Forecasts and the Forecast Errors for Three Different Taxes in Oklahoma

	Income Tax	Sales & Use Tax	Motor Fuel Tax
Actuals: (%)			
Mean	10.12	13.18	10.01
Std Dev	11.13	12.33	18.51
CV[1]	01.10	00.94	01.80
Forecasts: (%)			
Mean	07.70	11.54	06.31
Std Dev	06.50	13.81	08.73
CV	00.85	01.20	01.40
Forecast Errors: (Forecast-Actual) (%)			
Mean	-2.42	-1.64	-3.70
Std Dev	07.40	05.45	16.02
CV	03.20	03.20	04.30

[1]CV = Coefficient of Variation, and equals to Standard Deviation/Mean

Table 2

Weak Rationality Tests for Three Taxes in Oklahoma[1]

Coefficients	Income Tax	Sales & Use Tax	Motor Fuel Tax
a_o	0.5123(U)[2]	3.7102(U)	3.3041(U)
	(.126)	(1.710)	(0.480)
a_1	1.2471(U)	0.8208(0)	1.0634(U)
	(3.043)	(6.604)	(1.641)
R^2	0.5366	0.8450	0.2518
Adjusted R^2	0.4786	0.8256	0.1582
DW	2.0699	0.8415	2.2465

[1]'t' statistics are in parentheses.
[2](U) = Underestimation; (0) = Overestimation.

the forecasts.

None of the 't' values of the intercepts reject the null hypothesis that their values are zero, at least at a 5 percent level of significance. The estimated slope of equation (1) for these three categories of taxes deviates from one and ranges from 0.8820 for the sales and use tax to 1.2471 for the income tax. Note that the slope of the sales and use tax equation is less than one, indicating an overestimation bias, and those of the other two equations are higher than one, hinting at underestimation bias.

Finally, Table 3 displays the results of the 'F' statistics of the joint null hypothesis of $a_o = 0$, and $a_1 = 1$ as the test of weak rationality. Accordingly, the null hypothesis for the income tax and motor fuel tax forecasts was not rejected, whereas that of the sales and use tax forecasts was rejected.[3] Thus, based on the estimated 'F' statistics, the first two groups of forecasts--income and motor fuel tax--passed, and the third--sales and use tax--did not pass the weak rationality test.

The result of the Durbin-Watson test for the income tax and motor fuel tax does not indicate any autocorrelation. But for the sales and use taxes, the result of the test indicates bias towards positive autocorrelation. This implies that the model has consecutive downward and consecutive upward predictions (see Figure 4).[4]

In summary, the results of equation (1) for the forecasts of three major tax forecasts in Oklahoma imply that only income and motor fuel taxes passed, and sales and use taxes did not pass the weak rationality test. That is, only the first two predictions, ex ante, were not biased in the sense that, on the average, they were equal to the actual values, ex post. The third tax prediction was biased.

Strong Rationality Test

Recall that the strong rationality test examines whether the forecasters use all the information available to them at the time of the forecasts. Obviously the information variable is related and makes the prediction closer to the reality.

To test strong rationality, the forecast errors of each of the three classes of taxes have been regressed on one-year lags, the rate of growth of the civilian labor force, two-year lagged personal income growth in the state, the rate of growth of population, and the party of the governor.[5] A value of one was assigned for those years that the governor was a Democrat, and zero was assigned for those years that the governor was a Republican.

Table 4 presents the results of the strong rationality test for these three taxes. None of the 't' ratios of the lagged errors of the three categories of taxes are significant and, therefore, the null hypothesis of being equal to zero is not rejected. This suggests that forecasters used past errors efficiently as guidance for future forecasts.

The results of the 'F' statistics for the strong rationality test are shown in Table 4. The null hypothesis of efficient use of all available information, i.e., ß vector is equal to zero for the forecasts of income and motor

Table 3

Analysis of Variance
Test of Weak Rationality for
Three Different Tax Forecasts in Oklahoma

Variables	$(r-Ra)'[R(X'X)^{-1} R']^{-1}(r-Ra)$	q	$e'e_2$	(n-k)	F
Income Tax	44.07	2	517.1	8	0.34
Sales & Use Tax	390.50	2	141.3	8	11.01
Motor Fuel Tax	90.16	2	2306.0	8	0.16

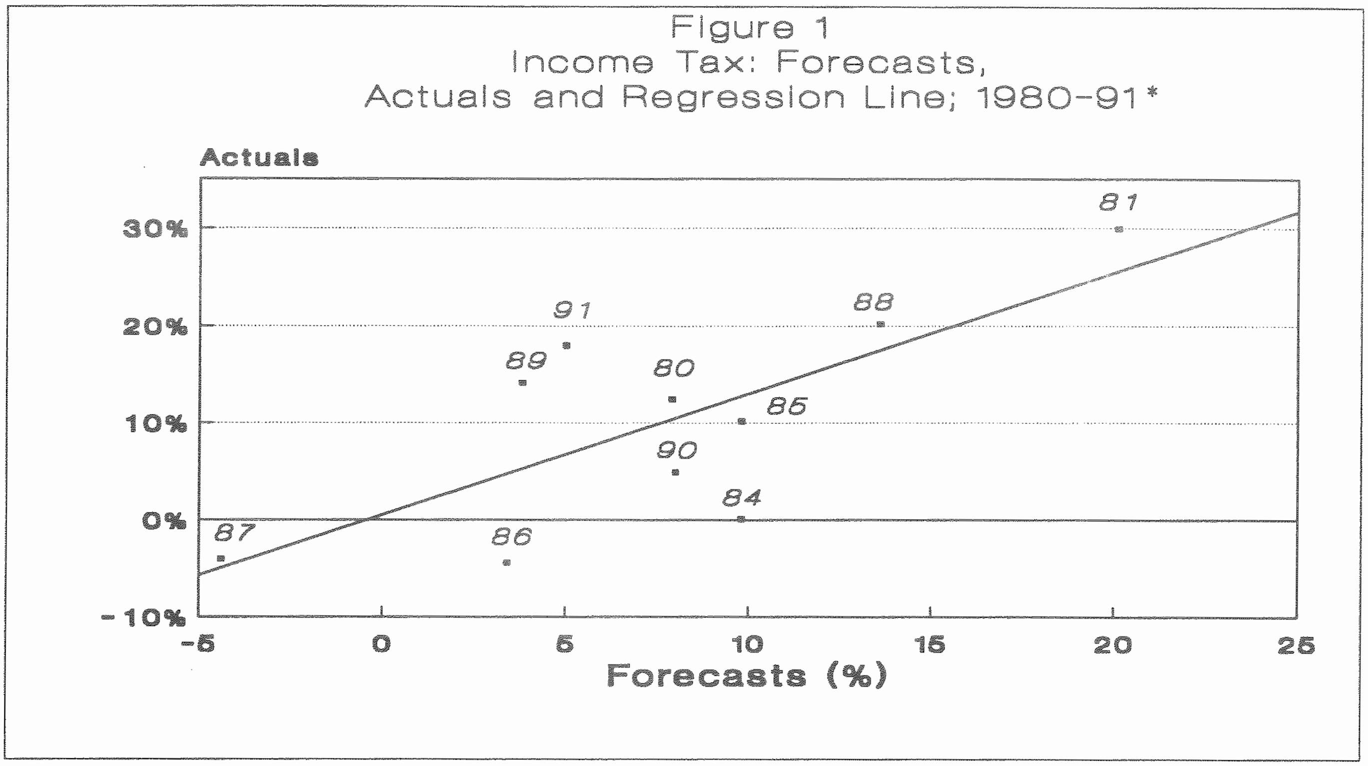
[1]For the symbols in the table, see note 3.
[2]For the sales and use taxes which suggests the existence of autocorrelation, sum square errors are corrected using Hildreth-Lu.

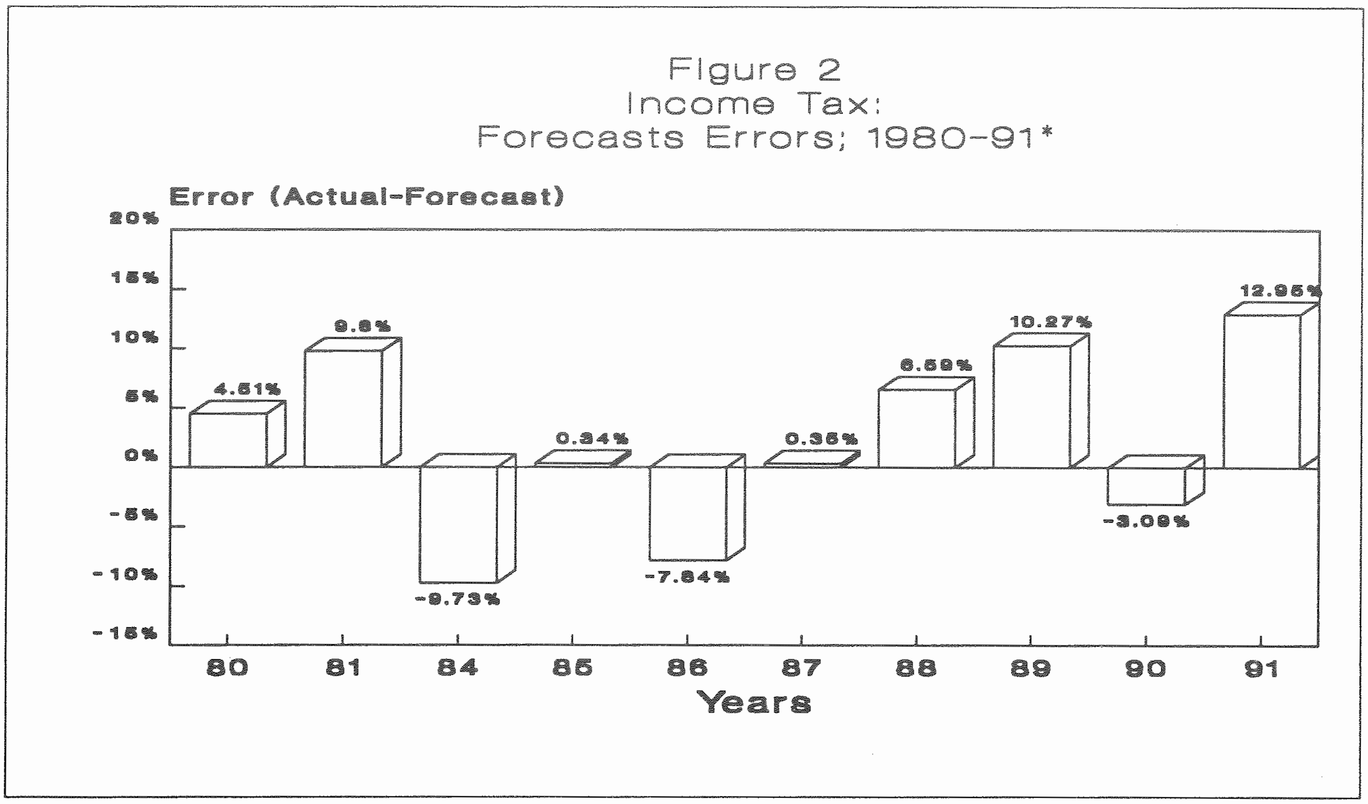
Table 4

Strong Rationality Tests for Three Taxes
with Past Error, Economic, and Political Variables[1]

Variables	Income Tax	Sales & Use Tax	Motor Fuel Tax
Constant	14.118	-1.693	28.030
	(1.237)	(0.957)	(2.681)*
u_{-1}	-1.419	-0.191	-0.511
	(1.267)	(0.960)	(1.185)
CLF_{-1}	0.850	1.157	-2.988
	(0.225)	(2.686)*	(0.695)
EMP_{-1}	2.881	2.247	-3.270
	(0.645)	(4.022)**	(0.577)
PI_{-2}	-0.751	-0.284	0.899
	(0.415)	(0.920)	(0.394)
Pop_{-1}	1.514	-1.937	10.974
	(0.375)	(2.805)*	(2.218)
Gov_{-1}	-14.150	3.551	133.942
	(0.632)	(0.939)	(0.940)
R^2	0.635	0.980	0.870
Adjusted R^2	-0.461	0.920	0.479
DW	1.995	3.388	2.417
F(All Coef = 0)	0.580	16.353**	2.223

[1]'t' statistics are in parentheses.
Asterisks denote significance at the 5%(**) and 10%(*) levels.





*1982 & 1983 forcasts were not reported. 1991 actual is based on preliminary reports.

Figure 3
Sales and Use Taxes: Forecasts,
Actuals, and Regression Line; 1980–91*

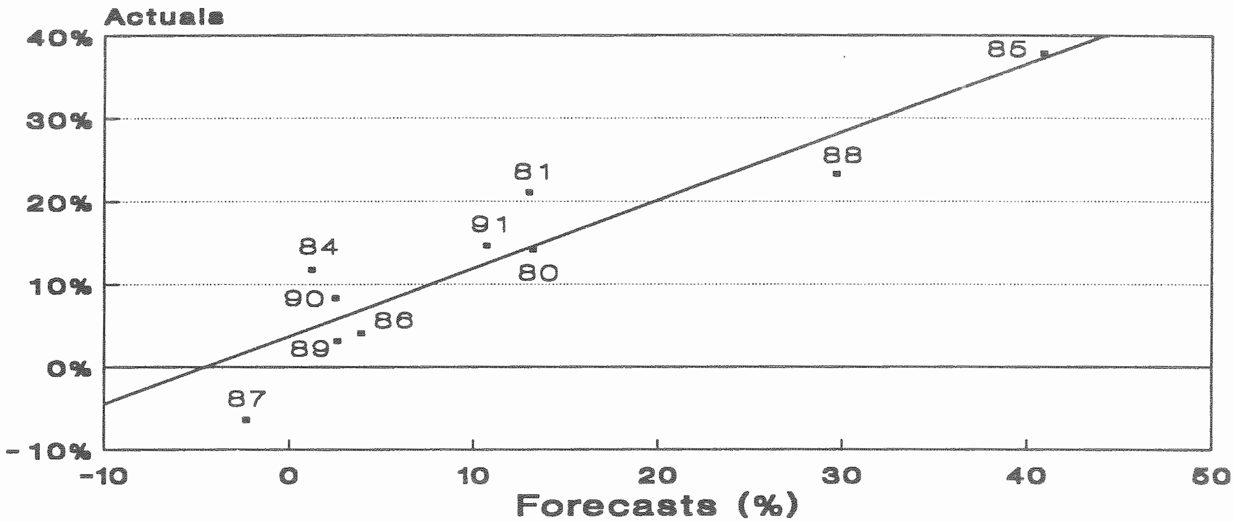
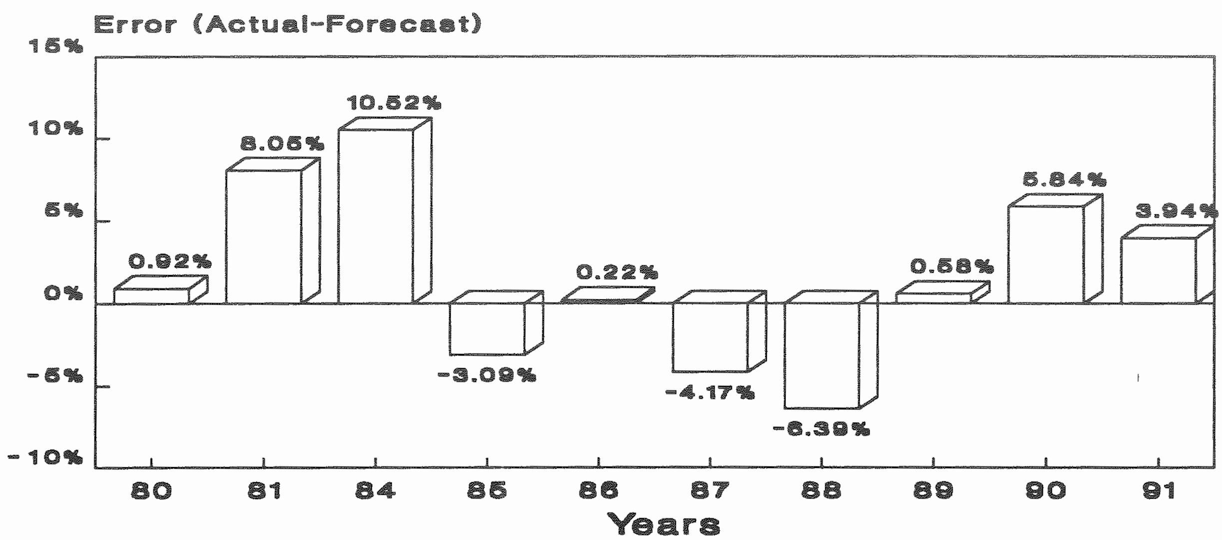


Figure 4
Sales and Use Taxes:
Forecast Errors; 1980–91*



*1982 & 1983 forcasts were not reported. 1991 actual is based on preliminary reports.

Figure 5
Motor Fuel Tax: Forecasts,
Actuals, and Regression Line; 1980-91*

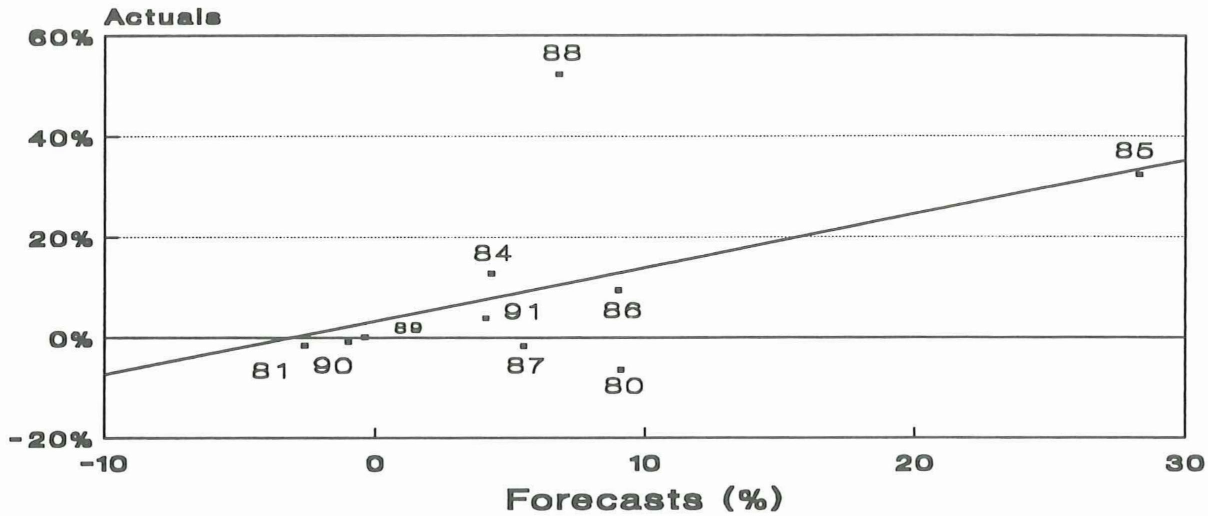
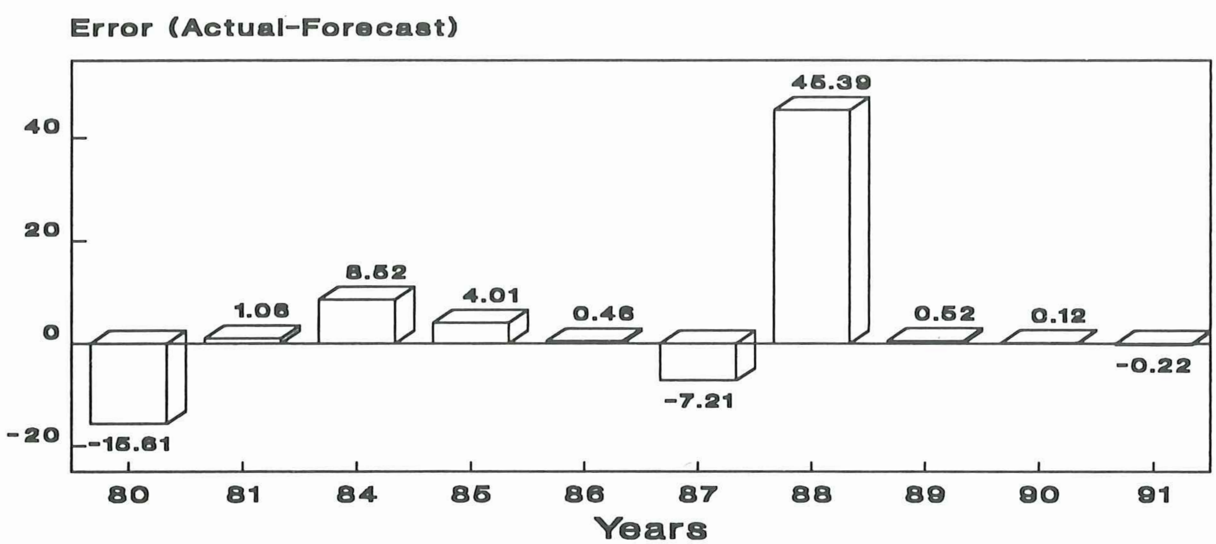


Figure 6
Motor Fuel Tax:
Forecast Errors; 1980-91*



*1982 & 1983 forcasts were not reported. 1991 actual is based on preliminary reports.

fuel taxes, is not rejected. However, the null hypothesis is rejected for the sales and use taxes, suggesting either that the forecasters had not used all the information available or that information was not fully available at the time of the forecasts of this class of taxes.

It should be noted that the strong rationality investigation in this study is the test of the full use of a class of information vector, and not all possible information, including that of a change in the tax rate. There may be some other information variables which were used that are not in this tested information set. Apparently, this is one weakness of the strong test.

In sum, the forecasts of the income and motor fuel taxes passed the strong rationality tests. However, while the information set used predicted the sales and use taxes well, some information was not used efficiently or was not available at the time of the forecast; thus, this class of tax did not pass the strong rationality test.

Summary and Conclusions

The purpose of this study was to analyze and examine the weak and strong rationality of three major Oklahoma tax forecasts by the Oklahoma State University econometric model. To pass the weak test, it is required that the null hypothesis of joint $a_0 = 0$, and $a_1 = 1$ in equation (1) not be rejected. Based on the estimated results of this equation and the test of this hypothesis for each of these three classes of taxes, the income tax and motor fuel tax forecasts passed, and the sales and use tax forecasts did not pass, the weak test.

To pass the strong rationality test, it is required that the forecasters use all the information necessary and available at the time of the forecasts. That is, the null hypothesis, that overall parameters of equation (2)--the ß vector in the equation--be equal to zero, cannot be rejected. According to the estimated outcome, the income tax and motor fuel tax forecasts passed this test. The sales and use tax forecasts failed the test, probably due to the changes in its rate after the forecasts.

NOTES

[1]In addition, it requires that the forecasters not consistently overestimate or underestimate for the political stance of the time. Or if they do, it is assumed the forecasters have a symmetric loss function over the error of the forecasts that is minimized at zero.

[2]The rate of growth or the level of the tax measures can be used for this purpose. Using the latter required adjustment for inflation, whereas the former measure has the advantage of not requiring adjustment for inflation.

[3]This 'F' statistic is equal to

$$F = \frac{(r-Ra)'[R\,(X'X)^{-1}\,R']^{-1}\,(r-Ra)/q}{e'e/(n-k)}$$

where r is the null hypothesis vector so that r'= [0 1], R is a 2 by 2 identity matrix, "alpha" is a vector with the estimated values of two parameters in the equation, $(X'X)^{-1}$ is the inverse of variance-covariance, e'e is the sum square error of the regression, q is the number of parameters tested on (a's = 2), n is the number of observation, and k is the number of parameters in the equation.

[4]Recall that if the equation indicates the existence of autocorrelation, it makes inefficient estimation of parameters and invalidates inference tests. To eliminate this problem, the standard errors of the regression for the sales and use tax equation, which its Durbin-Watson ratio suggests the existence of autocorrelation, are corrected by Hildreth-Lu method.

[5]It should be noted that when the past errors of each of the taxes, as independent variables, were dropped from the equations, the standard errors of only sales and use taxes improved slightly.

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