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The Uncertainty Evaluation of Tax Revenue Forecast in Iran Using a Fan Chart

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ABSTRACT

The present study aimed to analyze the forecast error of the tax revenue forecasting in Iran using the fan chart method. To this end, the tax revenue of Iran was forecasted utilizing the data obtained during 1974-2016, as well as Bayesian linear regression model. Then, the uncertainty of such a tax revenue was derived from the uncertainty in correlated macroeconomic variables. In addition, the tax revenue forecast skewness was obtained by internalizing the subjective assessments of macro variables. In most cases, the uncertainty of macro variables is based on their historical standard deviation. However, in the present study, the uncertainty of macro variables was subjectively adjusted in order to find the reason for less or more uncertainty compared to their historical standard deviations. A subjective balance of risk assessment was applied to identify whether the distributions were symmetric or non-symmetric. The results revealed that the fan chart method has high efficiency in depicting the forecast uncertainty of tax revenue and thus can be used in the budget preparation and formulation in Iran.

1. Introduction

Generally speaking, the budgetary process includes forecasting the revenues and allocating the revenues to the expenditures. A significant difference between the government's revenue and expenditures (expected) from the approved budgets can indicate the lack of access to the set of financial policy goals. In other words, the difference is a budget forecast error.

Tax is considered as one of the main sources of budget revenue thus tax revenue forecasting is an important issue and its effects are of utmost importance in developing countries including Iran. However, it has not been properly studied in this context. It should be noted that no one

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can certainly and definitely forecast a variable in the future since various uncertainties and risks exist in the future. Therefore, expressing the probability distribution of the probability of future economic consequences is impossible. In addition, the predicted and actual values rarely coincide in point estimates. Accordingly, instruments like interval confidence and density forecasts can be used to describe the uncertainty inherent to any point forecast (Tay and Wallis, 2000). Fan chart method, as a density forecast, was first introduced in 1997 by the Bank of England for publishing the inflation report and then was utilized for various variables in different places. This method provides the prediction distribution of a variable based on the available information at the current time and has two important advantages over traditional prediction techniques. Fan chart presents the total marginal forecasting distribution in each period of forecasting time. Further, the marginal distribution may be nonsymmetric. In this case, the probability that the value of the variable is lower than the forecast point differs from the one which assumes that the value of this variable is higher than the forecast point. Therefore, the fan chart is regarded as a desirable instrument for demonstrating the balance of risks regarding the future values of the variable (Julio, 2006).

The estimation of figures with no rational basis is useless and even detrimental, therefore, the present study seeks to present uncertainty in tax revenue forecasting applying the fan chart method. The charts are derived by a combination of historical data uncertainty and subjective judgments about the uncertainty and the balance of the risks of variables which are deemed to affect the tax revenue.

The outline of the present study is as follows. Section 2 reviews the literature of the fan chart method and tax revenue forecasting. Furthermore, the method for deriving conditional density forecasts and building fan chart is described in Section 3. Finally, Section 4 deals with the proposed method which is applied to the economy of Iran, followed by summarizing the main findings in Section 5.

2. Literature review

The history of the implementation of the fan chart method in macroeconomicmodeling isdescribed and then a number of studies related to tax revenue forecasting are reviewed in this section. The central bank of England first used the fan chart in the monetary policy process. During (May) 1997-(December) 2003, the main objective of the UK monetary policy was to achieve inflation (PRIX) 25 per year. The inflation target was set by the government and the Monetary Policy Committee (MPC) of the Bank of England had functional independence regarding achieving this goal. The main feature of this new regime was to publish fan charts as future inflation projections in the seasonal inflation report of the bank. The first charts of the fan chart were published in February 1996 in the Inflation Report. These charts demonstrate MPC's views on the future prospects of inflation, and monetary policy decisions are made based on such predictions. Additionally, the MPC tends to increase the interest rates and vice versa if the fan chart indicates that future inflation is likely to be high. Accordingly, fan charts are considered as a key feature of the decision-making process of monetary policy.

In January 1993, the Central Bank of Sweden determined a specific inflation target indicating that the annual increase of the consumer price index in 1995, and that of the following years should be limited to about two with the fluctuations of around ±1 of the percentage point. In addition, the central bank should set its monetary policy based on evaluating future inflation since the monetary policy influences inflation by a 1-2 year lag. This is accomplished by forecasting inflation, which is conditional upon taking into account all the relevant information, as well as the assumption that the interest rates represent no change over the forecast horizon. The central bank publishes its views of inflation through seasonal inflationary reports. The inflation report has included inflation forecasting and uncertainty bands which surrounds the forecast (fan chart) since December 1997.

Cornec (2010), presented a fan chart for forecasting gross domestic product (GDP) growth in France by modifying the existing methods. In this study, the method used in the bank of England was reviewed to estimate the parameters of the probability density of the inflation forecast, and finally, the uncertainty and risk indices of GDP growth were extracted applying quantile regressions. Mihaela (2014), also compared the fan chart and Monte Carlo simulation methods for assessing the uncertainty of inflation forecasts in Romania. In the current study, fan charts are presented based on VAR and BVAR models and then, the numerical results of uncertainty in the forecast of inflation in Romania are estimated using the Monte Carlo method. Finally, the results of this study are expected to confirm that a fan-chart method is a suitable instrument for evaluating the inflation uncertainty.

Further, Camilleri and Vella (2015), provided an analysis of forecasting errors for Malta for the Ministry of Finance and compared the results with those of the Central Bank of Malta and the European Commission. The present study interpolates the results of previous forecast errors to future forecasts through applying the two-piece normal distribution in addition to presenting a comprehensive analysis of the past forecast errors even at the expenditure component level. This conveys the degree of uncertainty and the balance of risk inherent in GDP growth projections. Finally, the results are displayed as fan charts.

Golosov and King (2002) conducted a study concerning the tax revenue forecasts of low-income countries during 1999-1993 and found that the accuracy of these predictions was low and the average prediction error was nearly 16. Forecast errors, as a percentage of GDP, are biased upward while no clear trend exists in the prediction error of nominal tax revenue.

Evaluating the tax revenue forecast error for New Zealand, Keene and Thomson (2007) concluded that the main source of negative error in forecasting the tax revenue was lower than the real value of the macroeconomic variables of forecast which were related to the tax revenue such as GDP. In other words, tax-rate forecasts were generally less accurate than the predictions of macroeconomic variables.

Furthermore, Chakraborty and Sinha (2008) studied the range and sources of errors in budget forecasting based on rational expectations for India in the 1990s and tested the accuracy of budget forecasts from 1990-1 to 2003-4. To this end, they used the Theil index and the Q statistic to estimate the range of errors and the budget forecast efficiency over time, respectively. The results indicated that the error range in forecasting revenues was higher than the expenditures and, ultimately, the budget forecast efficiency failed to improve significantly.

Arbabian et al. (2012) also examined the budget forecast error in Iran during 1965-2008 and calculated the range of budget forecast error using the Theil index. Additionally, they determined the components of the forecast error of income and budget expenditures, followed by analyzing the budgeting efficiency. The results revealed that the approved revenue and expenditures were higher than their performance in most of the years and the percentage of revenue and expenditure forecast error was significant during this period. The range of revenue forecast error was also greater than the forecast error range of expenditure. Eventually, the results of error component estimation demonstrated that half of the forecast error was due to factors which were outside the control of the government.

3. Fan chart method

Fan chart introduces a prediction distribution of a variable based on available information at the current time and includes two important advantages over traditional prediction techniques. This method offers the whole marginal forecasting distribution in each period of forecasting time. Further, the marginal distribution may be nonsymmetric. The probability that the value of the variable is lower than the forecast point varies from the probability that the value of this variable is higher than the forecast point if the distribution of the forecast is nonsymmetric. As a result, fan chart is a favorable instrument for representing the balance of risks concerning the future values of the variable. In this section, the split normal distribution is described, followed by explaining the fan chart computation steps in the next sections.

3.1 Distributional assumption

The dependent variable (tax revenue) was denoted by T and explanatory variables, which were deemed to affect the dependent variable, were represented by X_j where, j=1 … n. Furthermore, each of the Xj(and T) was assumed to be drawn from a split normal or two-piece normal density with the following probability density function (Julio, 2006):

$$f(x:\mu,\sigma_1,\sigma_2)=\begin{cases} Cexp\{-\frac{1}{2\sigma_1^2}(x-\mu)^2\} x\leq\mu \\ \\ Cexp\{-\frac{1}{2\sigma_2^2}(x-\mu)^2\} x>\mu \end{cases} \quad (1)$$

where,

- $C = k(\sigma_1 + \sigma_2)^{-1}$;
- $k = \sqrt{2/\pi}$;
- μis the mode or more likely value of the variable.

The split normal distribution results from merging the two halves of normal distributions and it reduces to the normal distribution in a special case when $\sigma_1 = \sigma_2$. However, constant C differs from the constant of the normal distribution when $\sigma_1 \neq \sigma_2$. The sign of its third central moment is determined by the difference of $(\sigma_2 - \sigma_1)$. Accordingly, the distribution is skewed to the right if this difference is positive. Otherwise, it is skewed to the left.

Figure 1 displays three split normal densities for (μ,σ_1,σ_2) = (0,1,1), (μ,σ_1,σ_2) = (0,1,0.5),and(μ,σ_1,σ_2) = (0,1,1.5). As shown, the density biases to the left and the balance of risks (i.e., p=P[X≤μ]) is higher than 0.5 if $\sigma_1 > \sigma_2$. Conversely, the density reduces to the normal balancing the risks if $\sigma_1 < \sigma_2$) the opposite happens and if $\sigma_1 = \sigma_2$.

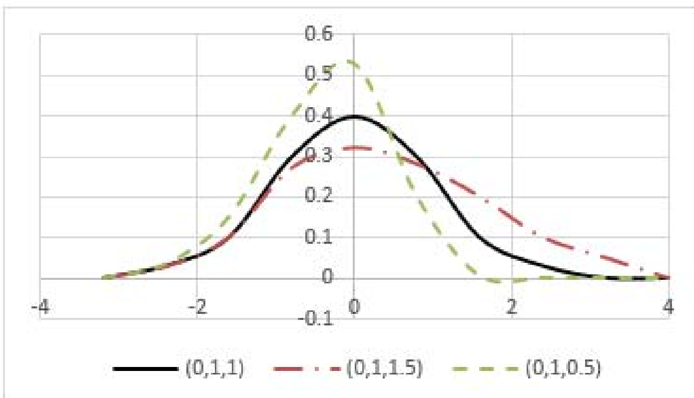

Figure 1. Three split normal densities
Source: Julio (2006)

John (1982) demonstrated that $pr[L_1 \leq x \leq L_2]$ is obtained from the following equation:

$$\int_{L_1}^{L_2} f(x)dx = \frac{2\sigma}{(\sigma_1 + \sigma_2)} [\emptyset\left(\frac{L_2 - \mu}{\sigma}\right) - \emptyset\left(\frac{L_1 - \mu}{\sigma}\right) \tag{2}$$

where$\emptyset(.)$ is the standard cumulative normal distribution function and

$$\begin{cases} \sigma = \sigma_1\, if\, L_1 \leq L_2 \leq \mu \\ \sigma = \sigma_2\, if\, \mu \leq L_1 \leq L_2 \end{cases} \tag{3}$$

Additionally, the variance is obtained as follows.

$$var(x) = (1 - k^2)(\sigma_1 + \sigma_2)^2 + \sigma_1\sigma_2 \tag{4}$$

The third central moment (skewness) is obtained using the following equation :

$$E[x - \mu]^2 = k(\sigma_2 - \sigma_1)[(2k^2 - 1)((\sigma_2 - \sigma_1)^2 + \sigma_1\sigma_2] \tag{5}$$

Since $2k^2 - 1 > 0$, therefore, the following equation is considered as the skewness indicator:

$$\gamma \equiv \tilde{\mu} - \mu = k(\sigma_2 - \sigma_1) \tag{6}$$

Equation (6), compared to (5), is obtained from the difference between the mean and the mode of distribution, which is regarded as its advantage.

3.2 Uncertainty assessment

In addition, the uncertainty assessment of macro variables is needed as the input of the method. The evaluation is partly subjective although historical data are used as a starting point. To formulate the judgment, two questions were proposed for each variable Xj with regard to the forecasting mode as follows.

1. What $p_j = pr[X_j \leq \mu_j]$is? In other words, what is the chance of a lower outcome than the forecasting mode μ? If this question is unanswered, then, 50 would be considered as the response, which is the reference value.
2. How large is the forecast uncertainty as compared to the historical uncertainty which is measured by standard deviation? The answer is represented by h_j. Further, the reference value is considered one unless there is specific information about this question which indicates that uncertainty is less or more than the historical uncertainty and h_j is determined based on that basis.

Consider imports as an example of the answers to the above questions. As a result of Asian crises, the forecast has a downside risk and uncertainty more than the historical uncertainty, which can be approximated by Pj = 0.6 and hj = 1.3.

However, this question arises that how the above-mentioned answers can be used in the prediction distribution specified in Equation (1). In this regard, the variance Xj, scaled with the uncertainty parameter is as follows.

$$\omega_{j,j} = (h_j(t)\sigma_j(t))^2 \tag{7}$$

In this regard, $\sigma_j(t)$ is the historical standard deviation of Xj. Furthermore, the answers to the first and second questions related to hj and Pj are considered to obtain the standard deviation $\sigma_{1,j}$and $\sigma_{2,j}$. Based on Equation (7),$\omega_{j,j}(t)$ is determined by the character of hj.Thus, equation (2) is as follows:

$$\int_{-\infty}^{\mu} f(x)dx = \frac{\sigma_1}{\sigma_1 + \sigma_2}, \qquad \forall\mu$$

Therefore, $\sigma_{1,j}$ and $\sigma_{2,j}$ were chosen so that we had

$$\frac{\sigma_{1,j}}{(\sigma_{1,j}(t)+\sigma_{2,j}(t))}=P_j(t)$$

In addition, according to Equation (4)

$(1-k^2)(\sigma_{2,j}(t)-\sigma_{1,j}(t))^2+\sigma_{1,j}(t)\sigma_{2,j}(t)\ =\omega_{1,j}(t)$

Then, we calculated $\sigma_{1,j}$ and $\sigma_{2,j}$based on Equations (8) and (9) as follows:

$$\sigma_{1,j}\left(t:\omega_{j,j},P_j\right)=\omega_{j,j}(t)\left[(1-k^2)\left(\frac{1-2P_j(t)}{P_j(t)}\right)^2+\left(\frac{1-2P_j(t)}{P_j(t)}\right)\right]^{-1} \quad (8)$$

$$\sigma_{2,j}\left(t:\omega_{j,j},P_j\right)=\omega_{j,j}(t)\left[(1-k^2)\left(\frac{1-2P_j(t)}{P_j(t)}\right)^2+\left(\frac{1-2P_j(t)}{P_j(t)}\right)\right]^{-1} \quad (9)$$

Further, we have

$$\sigma_1^2\cong h^2\sigma^2P/(1-P)$$

$\sigma_2^2\cong h^2\sigma^2(1-P)/P$

Therefore, h had the multiplier effect on the standard deviation so that the large h increased both $\sigma_{1,j}$ and $\sigma_{2,j}$and vice versa. The effect of P may be better understood by the preceding example with some downside down risks such that P = 0.6.

3.3 Tax revenue forecast distribution

In the previous section, subjective judgments played a significant role. This section discusses how to aggregate these assessments.

3.3.1 Tax revenue forecast skewness

In addition, the tax revenue forecast was assumed to have a two-piece normal distribution with parameters μ_y,$\sigma_{1,y}$, and $\sigma_{2,y}$. The key question was how to relate the forecast distributions for the explanatory variables to the dependent variable (tax revenue).In the present approach, there was an assumption that the uncertainty of explanatory variables connects to the dependent variable is as follow:

$$\gamma_T(t)=\sum_{j=1}^{n}\beta_j(t)\,\gamma_j(t) \quad (10)$$

Where γ_T and γ_j represent the skewness of both tax revenue and variable X_j, respectively. Equation (10) indicates that the skewness of variable X_j affects the skewness of the dependent variable with the weight β_j. Additionally, the right skewness parameters of Equation (10) were obtained by subtracting Equations (8) and (9) from Equation (6):

$$\gamma_j(t) \cong \tilde{\mu}_j(t) - \mu_j(t) = k(\sigma_{2,j}(t) - \sigma_{1,j}(t)) \quad (11)$$

Then, Equations (12) and (13) are obtained as follows.

$$\sigma_T^2(t) = (1 - k^2)\left[(\sigma_{2,T}(t) - \sigma_{1,T}(t)\right]^2 + \sigma_{1,T}(t)\sigma_{2,T}(t) \quad (12)$$

$$\gamma_T(t) = k(\sigma_{2,T}(t) - \sigma_{1,T}(t)) \quad (13)$$

Accordingly, two equations and two unknowns were obtained, which reduced to Equation (14)

$$\sigma_{1,T}^2(t) - \sigma_{1,T}(t) + c = 0 \quad (14)$$

Where $b = (\gamma_T/k)$and $c = -\left[\left(1 - \frac{1}{k^2}\right)\gamma_T^2 + \sigma_T^2\right]$. One of two solutions to Equation (14) is relevant. Thus, $\sigma_{2,\varepsilon}(t)$ was obtained by substituting this solution for $\sigma_{1,\varepsilon}(t)$in Equation (13).

3.3.2 Variance of the Tax revenue forecast

In the previous section, the forecast variance was considered as given, which was calculated from past prediction errors.Given some assumptions, we could allow this variance to be influenced by the assumptions of X_j. In particular, if we assumed that

$$\sigma_1^2(t; \sigma_\varepsilon^2) = \beta'(t) \sum (t; \sigma_\varepsilon^2)\beta(t)\, , t = 1, \dots, T \quad (15)$$

Thus, we have

$$\beta' = \left[1\ \beta_1\ \dots\ \beta_n\right] \quad (16)$$

$$\sum(t; \sigma_\varepsilon^2) = \begin{bmatrix} \sigma_\varepsilon^2 & 0 & \dots & 0 \\ \vdots & \omega_{1,1} \ddots & \dots & \omega_{1,n} \\ & \vdots & & \\ 0 & \omega_{n,1} & \dots & \omega_{n,n} \end{bmatrix}$$

$$\omega_{i,j} = \begin{cases} var\left[X_j(t)\right] for\ i = j \\ cov[X_i(t), X_j(t)\ for\ i \neq j \end{cases} \quad (17)$$

The variance of Equation (17) is presented in Equation (7) while its covariance is obtained from Equation(18)

$$cov\left[X_i(t), X_j(t)\right] = \rho_{i,j}\sqrt{\omega_{i,i}(t)\omega_{j,j}} \quad (18)$$

The expression $\sigma_\varepsilon^2(t)$is the shock of the dependent variable and is independent of X_j. In addition, it can be interpreted as a part of forecast uncertainty which increases by extending the forecast horizon.

4. The fan chart of the tax revenue forecast

The fan chart is a way of evaluating the uncertainty inherent in model-based forecasts, which are derived by using the available information that is not primarily included in the modeling. Based on the literature review, as well as the efficiency measures including the Root Mean Square Error for Bayesian linear regression model can be selected to forecast the tax revenue.

In the present study, the annual data (1974-2016) of tax revenue was applied as the dependent variable. According to the mentioned method, determining two-part distribution parameters were required for computing the fan chart. Therefore, the following steps were taken:

- Calculating the historical standard deviations of variables which were considered in the forecasts model;
- Making the judgment of the upward and downward risks of each of the variables;
- Judging whether this historical deviation increases or decreases during the periods of prediction;
- Calculating the sensitivity or the weight of each explanatory variable on the budget variables;
- Accumulating the uncertainty of the variables;
- Accumulating the risk of the variables

4.1 Fan chart for tax revenue

To derive the tax revenue fan chart, variables which were used in Bayesian linear regression model included the value-added of different economic sectors (e.g., agricultural, industrial, and mining, as well as oil and gas and services sectors) and the inflation rate. Further, the accumulation of the result of the subjective judgment on uncertainty, historical uncertainty, and the sensitivity of the tax revenues to macro variables was considered to calculate the uncertainty of the tax revenue. To this end, the upward risk was determined as a judgment for each of the variables, followed by achieving the amount of skewness which was associated with each of the variables. By estimating the skewness of each of the variables, the skewness of the tax revenue was calculated by taking into account the weight of these variables on the tax revenue. Finally, the fan chart in Fig. 2 and Table 1 was obtained by determining the parameters of the two-piece normal distribution of the tax revenue. As shown, the uncertainty ranges and the balance of the risk of the tax revenue for the given periods are presented based on the computation by Visual Basic for Excel.

Figure 2. Fan Chart for Tax Revenue Forecast

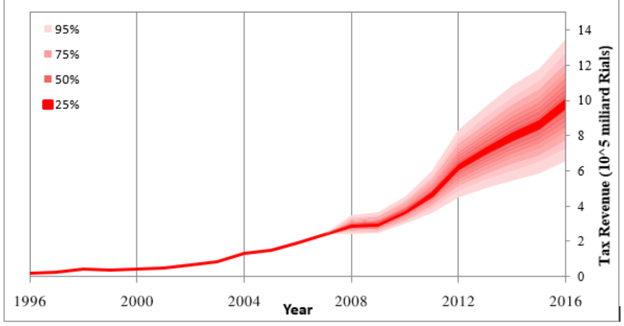

Table 1. Tax revenue forecasts during 2008-2016

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Mode	*2.82*	*2.85*	*3.49*	*4.52*	*6.01*	*6.92*	*7.73*	*8.44*	*9.63*
Median	*2.91*	*2.97*	*3.66*	*4.69*	*6.25*	*7.17*	*7.97*	*8.68*	*9.87*
Mean	*2.93*	*3.00*	*3.71*	*4.74*	*6.32*	*7.23*	*8.04*	*8.74*	*9.94*
S D	*0.30*	*0.32*	*0.42*	*0.68*	*1.12*	*1.37*	*1.59*	*1.77*	*2.10*
Bias	*0.11*	*0.16*	*0.22*	*0.22*	*0.28*	*0.31*	*0.31*	*0.31*	*0.31*

Note. SD: Standard deviation (Source: Paper computation)

Table 2. Probability distribution tax revenues for selected ranges

	2008	2009	2010	2011	2012	2013	2014	2015	2016
Pr.{ <3.5}	95	90.03	36.58	3.16	0.42	0.21	0.14	0.09	0.07
Pr.{3.5-4}	4.7	9.18	37.2	11.7	1.23	0.49	0.27	0.16	0.09
Pr.{4-4.5}	0.1	0.77	19.7	24.3	3.45	1.30	0.66	0.38	0.20
Pr.{4.5-5}	0.0	0.02	5.59	26.5	7.48	2.91	1.43	0.81	0.39
Pr.{5-5.5}	0.0	0.00	0.84	19.2	12.5	5.53	2.77	1.57	0.72
Pr.{5.5-6}	0.0	0.00	0.07	9.99	16.3	8.88	4.74	2.76	1.25
Pr.{6-6.5}	0.0	0.00	0.00	3.71	16.7	12.0	7.19	4.41	2.04
Pr.{6.5-7}	0.0	0.00	0.00	0.98	14.6	13.9	9.68	6.39	3.10
Pr.{7-7.5}	0.0	0.00	0.00	0.19	11.2	13.8	11.5	8.42	4.40
Pr.{7.5-8}	0.0	0.00	0.00	0.03	7.56	12.3	12.2	10.0	5.85
Pr.{8-8.5}	0.0	0.00	0.00	0.00	4.45	10.0	11.7	10.9	7.27
Pr.{8.5-9}	0.0	0.00	0.00	0.00	2.29	7.40	10.4	10.9	8.46
Pr.{ >9}	0.0	0.00	0.00	0.00	1.64	11.0	27.1	43.0	66.1
Pr. {<Mode}	39.	36.2	35.8	40.4	41.79	43.18	44.09	44.66	45.47

Source: Paper computation

The Simpsons rule was used to calculate the integral or the probability of the tax revenue at certain intervals due to the difference between the parameters of the two-part and normal distributions. As shown in Table 2, the probability density function of the distribution of the tax revenue is skew. This skewness is the largest in 2016. Additionally, the forecast for tax revenue variance demonstrates an increase by increasing the forecasting horizon and reaches its highest level in 2016.

5. Conclusion

The fan chart is a suggestive method for evaluating the macroeconomic forecast uncertainty based on the models. The present study attempted to derive the uncertainty bands of tax revenue forecast in Iran (1974-2016) using the fan chart method. In addition, judgment is considered as a significant factor for forecasting government budget variables which are appropriate to be assessed by the fan chart method. Computing the fan charts revealed that the balance of the risks for macroeconomic variables (i.e, the skewness of their distributions) could be linked to the balance of the risks in tax revenue. Further, the skewness of the tax revenue forecast is obtained by internalizing the subjective assessments of independent variables and the historical data deviation.

Overall, the results demonstrated that the fan chart method is a good measure for depicting the forecast uncertainty of the tax revenue. In-sample prediction is useful for representing the effectiveness of the fan chart as well. The comparison of performance variables with the uncertainty ranges of the tax revenue in Iran computed by the fan chart during 2009-2016 indicated that this method is effective for evaluating this variable. Finally, tax revenue is known as a major component of the government budget thus, fan chart can be used in the budget preparation and formulationin order to improve the inadequacies of the budgeting system in Iran.

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