Tax revenue and inflation rate predictions in Banda Aceh using Vector Error Correction Model (VECM)

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Abstract. A country has some important parameters to achieve the welfare of the economy, such as tax revenues and inflation. One of the largest revenues of the state budget in Indonesia comes from the tax sector. Besides, the rate of inflation occurring in a country can be used as one measure, to measure economic problems that the country facing. Given the importance of tax revenue and inflation rate control in achieving economic prosperity, it is necessary to analyze the relationship and forecasting tax revenue and inflation rate. VECM (Vector Error Correction Model) was chosen as the method used in this research, because of the data used in the form of multivariate time series data. This study aims to produce a VECM model with optimal lag and to predict the tax revenue and inflation rate of the VECM model. The results show that the best model for data of tax revenue and the inflation rate in Banda Aceh City is VECM with 3rd optimal lag or VECM (3). Of the seven models formed, there is a significant model that is the acceptance model of income tax. The predicted results of tax revenue and the inflation rate in Kota Banda Aceh for the next 6, 12 and 24 periods (months) obtained using VECM (3) are considered valid, since they have a minimum error value compared to other models.

1. Introduction

A country has several important parameters to achieve economic prosperity. The economic field includes important factors in realizing it, such as tax revenue and inflation rate. One of the largest revenues of the State Budget in Indonesia comes from the tax sector. Also, the rate of inflation occurring in a country can be used as one measure, to measure both the bad economic problems facing a country. Given the importance of tax revenue and inflation rate control in achieving economic prosperity, it is necessary to analyze the relationship and forecasting tax revenue and inflation rate.

Taxes are dues to the country payable by those obliged to pay according to the applicable regulations [1]. Inflation is a condition where prices have increased steadily [2]. Tax receipts and inflation rates have a substantial impact on the economic development of a region. To that end, the government needs to consider policies that can affect both of them, such as monetary policy and fiscal policy. Monetary policy aims to stabilize the economy through regulating the money supply. While the fiscal policy concerns the regulation of government expenditure as well as government revenue (tax) to direct the economy of a country [2]. Thus, forecasting of tax revenue and inflation rate is needed as one of the considerations of policy decision making, which may affect economic development.
This study aims to obtain the VECM model from tax revenue and inflation rate, to know the relationship between tax revenue and inflation rate and to forecast the tax revenue and inflation rate of the VECM model. After knowing the relationship between tax revenue and inflation rate, it is expected to be an input for local government in planning monetary policy and fiscal policy. Also, it can also build models used to forecast tax revenue and inflation rate. In this article, VECM (Vector Error Correction Model) was chosen as the method to be used to look at the relationship, as well as predict tax revenues and inflation. VECM has chosen for this research because of the research using multivariate time series data.

2. Literature review

2.1. The definition of income tax, VAT and inflation rate

Income tax is one of the sources of state revenues derived from people's income, are a form of state obligation and people's participation in financing and national development [7]. Income tax is levied on the subject of tax in respect of the income it receives in the tax year. The tax year may be the calendar year or fiscal year that is not the same as the calendar year, throughout the year the book covers 12 months [8].

Value Added Tax (VAT) is a tax imposed on the consumption of, within the customs area [9]. The general VAT rate is 10%, but according to government regulations, tariffs can be changed as low as 5% and as high as 15%. The nature of the VAT is the tax on consumption, which makes it one of the taxes that has a vast range of tax objects. Also, the VAT characteristic which is an objective tax base the imposition of tax on the object. If there is no tax object, there is no tax that can be charged. VAT Objects include delivery, utilization, export/import of taxable goods or taxable services [7].

The inflation rate is the rate of general price level from year to year and followed by the price increase in certain year from the previous year [10]. With the inflation of the price of goods increased, so people's purchasing power will decline. An increase in the price of one or two items alone cannot be called inflation unless the increase extends or results in price increases in other goods [11].

2.2. VECM (Vector Error Correction Model)

In general, the econometric model of time series is a structural model because it is based on existing economic theory. VAR models (Vector Autoregression) was introduced by Christopher A. Sims in 1980, as an alternative to the macro-economic analysis. VAR models have a simple model structure with many variables that bit where all the variables are considered as an endogenous variable with the independent variable is the lag. VAR models are designed for stationary variables that do not contain the trend. The VAR model cannot be used to model a co-integrated time series data (having a long-term relationship) [12].

In the time series data, the stochastic trend indicates that the long-term component (long-run) and short-term (short-run) in the data. Research on stochastic trends in economic variables had been developed, so Granger developed the concept of co-integration in 1981. Then along Engle-Granger developed the concept of co-integration and error correction (error correction) in 1987. Subsequently, in 1990, Johansen and Juselius VECM developed concepts (Vector Error Correction Model). VECM Model is an econometric analysis model, which can be used to determine the short-term behavior of a variable to the long-term, due to a permanent shock [13]. The model offers an easy working procedure, to separate long-term components and short-term components from the data generation process [14]. Thus, the VECM model differs from the VAR model, where the VECM model can be used to model the time series data which is cointegrated and not stationary. The VECM model is often referred to as terrestrial VAR form [15]. The general model of VECM is as follows.

\[
\Delta Y_t = \phi_1 + \delta t + \lambda_1 \epsilon_{t-1} + \gamma_{11} \Delta Y_{t-1} + ... + \gamma_{1p} \Delta Y_{t-p} + \omega_{11} \Delta X_{t-1} + ... + \omega_{1q} \Delta X_{t-q} + \epsilon_{1t}
\]

(1)

and
\[
\Delta X_t = \varphi_2 + \delta_2 t + \lambda_2 \Delta X_{t-1} + \ldots + \gamma_2 \Delta X_{t-p} + \omega_2 \Delta Y_{t-1} + \ldots + \omega_2 q \Delta Y_{t-q} + \epsilon_2 t
\]  
(2)

where \( e_{t-1} = Y_{t-1} - \alpha - \beta X_{t-1} \).

Here is a theoretical analysis of VECM analysis.

1. **Stationary Test**
   The assumption that must be met in the VECM analysis is that all independent variables must be stationary. It is characterized by all the remnant is white noise, which has a zero mean, constant variance and among the dependent variable was no correlation [13]. There are several ways that can be done to measure the data stationary, one of which is by using Augmented Dickey-Fuller test (ADF). Here are the ADF test statistics.

\[
\Delta Y_t = \alpha_0 + \gamma Y_{t-1} + \beta \sum_{i=1}^{p} \Delta Y_{t-i+1} + \epsilon_t
\]  
(3)

2. **Cointegration Test**
   Cointegration is a long-term relationship between the variables, which although individually are not stationary, but the linear combination of these variables can be stationary [16]. Cointegration is one way to avoid the problem of spurious regression. One way to test cointegration is by using Johansen test as follows [17].

\[
LR_{tr} = (r | k) = -T \log(1 - \lambda_t)
\]  
(4)

3. **Residual Assumption Test**
   The residual assumption test on the VECM model must satisfy the residual criteria. These criteria, namely, residual normal distribution (normality assumption test), there is no serial correlation in the residuals (autocorrelation assumption test), and the residual is homoscedasticity (heteroscedasticity assumption test) [13].

4. **Optimal Lag Test**
   The optimal lag test is the determination of the length of the lag to be used in estimating the VECM. An optimal lag determination is important in the analysis using the VECM method. This is because if the lag set is too long or too short, it will result in the wrong model specification. The criteria can be used to determine the optimal lag in between Final Prediction Error Correction (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Hannan-Quinn Information Criterion (HQ), which has a minimum value among Various lags submitted. Mathematically, the values of AIC, SIC and HQ can be found using the following formula.

\[
AIC = -2 \left( \frac{1}{T} \right) + 2(k + T)
\]  
(5)

\[
SIC = -2 \left( \frac{1}{T} \right) + k \log \left( \frac{T}{T} \right)
\]  
(6)

\[
HQ = -2 \left( \frac{1}{T} \right) + 2k \log \left( \frac{\log(T)}{T} \right)
\]  
(7)

5. **Granger Causality Test**
   The Granger causality test can indicate whether a variable has a two-way or one-way relationship. This test is conducted to determine the influence of one variable with another variable. It should be remembered that in this Granger causality test, what is seen is the effect of the past on the present condition so that the data used is time series data [18].
6. Prediction
Prediction is an objective calculation and by using past data, to determine something in the future [19]. To determine the accuracy of the prediction of the model can use the value of the error follows.

a. Mean Absolute Percentage Error (MAPE)
\[
\text{MAPE} = \frac{\sum |y_t - \hat{y}_t|}{n} \times 100
\]  
(8)

b. Mean Absolute Error (MAE)
\[
\text{MAE} = \frac{\sum |y_t - \hat{y}_t|}{n}
\]  
(9)

c. Root Mean Square Error (RMSE)
\[
\text{RMSE} = \sqrt{\frac{\sum (y_t - \hat{y}_t)^2}{n}}
\]  
(10)

3. Method
The research method used in this research is VECM analysis. The research steps are carried out as follows.
1. Input data into the R Studio software.
2. Perform the stationary test of the data. If the data is stationary, the process of data analysis using Vector Autoregression (VAR) analysis. If the data is not stationary, then differencing process will be conducted to obtain data that is stationary.
3. Data were stationary after differencing; co-integration tests need to be done first. If there is no co-integration (long-term relationship) between variables, then the data analysis using VAR analysis. However, if there is co-integration between variables, then the next stage of analysis uses VECM analysis.
4. The model fit test that is: normality test, autocorrelation test, and heteroscedasticity test.
5. Granger causality test was performed on stationary data.
6. Next, the determination of the length of the lag to be used in the VECM model.
7. At this stage, the VECM model is formulated.
8. Do predictions based on the VECM model obtained.

4. Results and discussion
4.1. Descriptive analysis
The descriptive analysis aims to show a picture of the data that has been collected. Here is the plot of tax revenue and the inflation rate in January 2013 - December 2015.

From Figure 1 it can be seen that the pattern of the seven variables used have similarities. This can be seen from the fluctuations that occur, where the pattern of increase and decrease of each variable occurs at almost the same time. Tax receipts and inflation rates are increasing at the end of each year, while declines occur at the beginning of each year. This illustrates that there is a cointegration relationship between the seven variables. To see more clearly the cointegration relationship for each variable will be tested cointegration Johansen, but previously will be checked stationarity of the seven variables.
Figure 1. Time series plot of tax revenue and inflation rate for January 2013 – December 2015.

4.2. Stationarity test
The assumption that must be met in the VECM analysis is that all independent variables must be stationary. There are several ways that can be done to measure the data stationary, one of which is by using Augmented Dickey-Fuller test (ADF). The following table of ADF test results on tax revenue data and inflation rate.

| No | Variable        | Level Stat. ADF | P-value | 1st differencing Stat. ADF | P-value | 2nd differencing Stat. ADF | P-value |
|----|-----------------|-----------------|---------|-----------------------------|---------|-----------------------------|---------|
| 1  | Income.tax      | -2.830          | 0.250   | -4.312                      | 0.01    | -5.7                        | 0.01    |
| 2  | VAT             | -2.790          | 0.266   | -3.668                      | 0.042   | -4.265                      | 0.011   |
| 3  | BNA.inflation   | -2.448          | 0.398   | -2.696                      | 0.303   | -4.445                      | 0.01    |
| 4  | food.inflation  | -3.112          | 0.140   | -3.419                      | 0.071   | -4.753                      | 0.01    |
| 5  | clothing.inflation | -2.276       | 0.466   | -3.321                      | 0.085   | -3.964                      | 0.023   |
| 6  | health.inflation | -1.353          | 0.825   | -3.434                      | 0.069   | -4.475                      | 0.01    |
| 7  | edu.inflation   | -2.831          | 0.250   | -3.082                      | 0.153   | -4.047                      | 0.020   |

* Reject \( H_0 \) if p-value < \( \alpha \) (0.05) then \( H_0 \) is rejected.

Based on Table 1 it can be seen that all variables used are not stationary at the level. It can be seen at the level, ADF statistical p-value for each variable is greater than \( \alpha \) (0.05). That is, cannot reject \( H_0 \) or data is not stationary. Meanwhile, the results of the first differencing can be seen that there are several variables that have not been stationary or ADF statistic p-value is greater than \( \alpha \) (0.05). While the results of the second differencing can be seen that the ADF statistic p-value of each variable is smaller than \( \alpha \) (0.05). That is, reject \( H_0 \) or data is stationary. Thus the variable is a non-stationer variable of second order.

4.3. Cointegration test
Presence or absence of cointegration based on the value of the test statistic trace (LRtr). If the value of the test statistic trace (LRtr) greater than the critical value (\( \bar{T}_\alpha \)) then there is cointegration on many variables.

Table 2 shows that all endogenous variables are cointegrated. It can be seen from the LRtr > \( \bar{T}_\alpha \). Thus, it can be concluded that there is a long-term relationship between these variables, so the analysis is continued by using the VECM model.
Table 2. Results of the Johansen cointegration test with trace test.

| Null hypothesis | 0.05 Trace Critical Value ($\hat{T}_\alpha$) | Trace Test ($LR_t$) |
|-----------------|-------------------------------------------|-------------------|
| $r = 0^*$       | 131.70                                    | 362.50            |
| $r = 1^*$       | 102.14                                    | 244.91            |
| $r = 2^*$       | 76.07                                     | 155.02            |
| $r = 3^*$       | 53.12                                     | 88.87             |
| $r = 4^*$       | 34.91                                     | 48.32             |
| $r = 5^*$       | 19.96                                     | 27.55             |
| $r = 6^*$       | 9.24                                      | 11.58             |

* Reject $H_0$ (trace test value > 0.05 trace critical value)

4.4. Residual assumption test

In the VECM model, there is three residual assumptions test that must be met, namely normality test, autocorrelation test and heteroscedasticity test. The third test of residual assumption is:

Table 3. Residual assumption test.

| Assumption     | Test Name       | Chi-squared | df  | p-value |
|----------------|-----------------|-------------|-----|---------|
| Normality      | Jarque Bera test| 2.66        | 7   | 0.915   |
| Autocorrelation| Portmanteau test| 665.69      | 644 | 0.269   |
| Heteroscedasticity | White's Test    | 868.00      | 1176| 1.000   |

* Reject $H_0$ if $p$-value < $\alpha$ (0.05) then $H_0$ is rejected.

The results of the tests Jarque Bera, Portmanteau dan White's in Table 3, showed that the $p$-value > $\alpha$ (0.05) or cannot reject $H_0$. That is, the residual of the data used in normal distribution, there is no autocorrelation and homoskedasticity. The three assumption test results indicate that the data used has fulfilled the assumption.

a. Granger causality test

The Granger Causality Test was conducted to determine the short-term relationships between observed variables. The results of Granger causality test show that the inflation rate of health as the dependent variable, income tax, VAT and the inflation rate of food have $p$-value < $\alpha$ (0.05), so reject $H_0$. Thus, it can be concluded that there is a short-term relationship between income tax, VAT and the inflation rate of food with the inflation rate of health. While other variables have no short-term relationship.

b. Optimal lag test

The optimal lag test is the determination of the length of the lag to be used in estimating the VECM. An optimal lag determination is important in the analysis using the VECM method. If the lag set is too long or too short, it will result in the wrong model specification. The following table determines the optimal lag length.

Table 4. Optimal lag length determination results.

| Lag | AIC  | HQ   | SC   | FPE  |
|-----|------|------|------|------|
| 1   | 1.222| 2.067| 3.813| 3.691|
| 2   | 0.593| 2.176| 5.450| 3.358|
| 3   | -4.784| 2.462| 2.339| 0.099|

The VECM approach is sensitive to the determination of the amount of lag used, so it is necessary to determine the optimal number of lags. Determination of the number of lags is to determine the duration of the influence of a variable, to the variable past or other variables. Determination of lag length can be seen through minimum FPE, AIC, SIC and HQ values. Table 4 shows that the optimal lag for the VECM estimate is the $3^{rd}$ lag or VECM (3). This is because the values of AIC, HQ, SC and FPE show the minimum value in the $3^{rd}$ lag.
c. **VECM model estimation**

Based on the model specification using optimal lag analysis, then obtained the best model for data of tax revenue and the inflation rate that is VECM (3). From the seven models created, only one model that is significant, that is the model for income tax, so it can be concluded that there is a long-term relationship between the VAT, the inflation rate of Banda Aceh, the inflation rate of food, the inflation rate of clothing, the inflation rate of health and the inflation rate of education to income tax. Here is the model of income tax with VECM (3).

\[
\Delta \text{income.tax} = -0.877 + 0.004 - 0.748\Delta\text{income.tax}_{t-1} - 0.690\Delta\text{income.tax}_{t-2} + 1.123\Delta\text{income.tax}_{t-3} - 0.992\Delta\text{VAT}_{t-1} - 0.491\Delta\text{VAT}_{t-2} + 0.174\Delta\text{VAT}_{t-3} + 0.485\Delta\text{BNA.inflation}_{t-1} - 0.076\Delta\text{BNA.inflation}_{t-2} - 0.394\Delta\text{BNA.inflation}_{t-3} - 0.017\Delta\text{food.inflation}_{t-1} - 0.034\Delta\text{food.inflation}_{t-2} - 0.137\Delta\text{food.inflation}_{t-3} + 0.119\Delta\text{clothing.inflation}_{t-1} + 0.152\Delta\text{clothing.inflation}_{t-2} + 0.094\Delta\text{clothing.inflation}_{t-3} - 0.159\Delta\text{health.inflation}_{t-1} + 0.867\Delta\text{health.inflation}_{t-2} + 0.196\Delta\text{health.inflation}_{t-3} + 0.230\Delta\text{edu.inflation}_{t-1} - 0.038\Delta\text{edu.inflation}_{t-2} + 0.026\Delta\text{edu.inflation}_{t-3}
\]

From this model it is known that the magnitude of the absolute value of the variable coefficient ECT (Error Correction Term) amounted to 0.877 who explained that about 88% discrepancy between the actual value of income tax revenue in the short term and the value of the balance of income tax revenue in the long term, will be corrected each month. This shows that there is a long-term relationship from VAT, the inflation rate of Banda Aceh, the inflation rate of food, clothing inflation rate, inflation rate and the inflation rate health education on the income tax.

d. **Predicted results**

Furthermore, based on the model specification using optimal lag analysis, the best model for tax revenue variable and the inflation rate in Banda Aceh is VECM with 3rd optimal lag or VECM (3). The plot of predicted tax revenue and the inflation rate in Banda Aceh using VECM (3), for the next 6 periods (months) are as follows:

![Figure 2](image_url)

*Figure 2. The plot of predicted income tax and the inflation rate in Kota Banda Aceh for the next six periods (months).*

Table 5 below presents the MAPE, MAE and RMSE values of the six periods (months) predictions. In the table can be seen that the value of MAPE, MAE and RMSE minimum is the variable acceptance of income tax. That is, the result of the acceptance of income tax obtained by using VECM (3) is considered valid, because it has minimum error value that is, MAPE (2.497%), MAE (0.613) and RMSE (0.480).
Table 5. The accuracy of predicted results six periods (months).

| Error Value | Income tax | VAT | Inflation BNA | Inflation BM | Inflation SDG | Inflation SHT | Inflation PDK |
|-------------|------------|-----|---------------|--------------|---------------|---------------|---------------|
| MAPE        | 2.497      | 5.564 | 1473.289      | 344.917      | 9261.81       | 12550.92      | 23944.32      |
| MAE         | 0.613      | 1.320 | 23.372        | 19.072       | 27.975        | 24.669        | 24.910        |
| RMSE        | 0.480      | 1.094 | 23.090        | 19.075       | 24.835        | 24.215        | 23.234        |

The plot of predicted tax revenue and the inflation rate in Band Aceh city using VECM (3), for the next 12 periods (months) are as follows:

Table 6. The accuracy of predicted results 12 periods (months).

| Error Value | Income tax | VAT | Inflation BNA | Inflation BM | Inflation SDG | Inflation SHT | Inflation PDK |
|-------------|------------|-----|---------------|--------------|---------------|---------------|---------------|
| MAPE        | 1.882      | 4.033 | 905.285       | 233.038      | 6196.906      | 7080.919      | 12448.45      |
| MAE         | 0.464      | 0.970 | 21.399        | 16.364       | 27.259        | 24.076        | 23.419        |
| RMSE        | 0.503      | 1.057 | 21.496        | 16.663       | 27.336        | 24.089        | 23.488        |

The plot of predicted tax revenue and the inflation rate in Kota Banda Aceh using VECM (3), for the next 24 periods (months) are as follows:
Figure 4. The plot of predicted income tax and the inflation rate in Banda Aceh City for the next 24 periods (months).

The following table 7 presents the values of MAPE, MAE, and RMSE from 24 periods (months) prediction results. In the table can be seen that the value of MAPE, MAE and RMSE minimum is the variable acceptance of income tax. That is, the result of the acceptance of income tax obtained by using VECM (3) is considered valid, because it has minimum error value that is, MAPE (1.714%), MAE (0.424) and RMSE (0.480).

Table 7. The accuracy of predicted results 24 periods (months).

| Error Value | Income tax | VAT | Inflation BNA | Inflation BM | Inflation SDG | Inflation SHT | Inflation PDK |
|-------------|------------|-----|---------------|--------------|---------------|---------------|---------------|
| MAPE        | 1.714      | 4.129 | 4468.999      | 539.829      | 6196.906      | 3655.223      | 6587.806      |
| MAE         | 0.424      | 0.992 | 22.982        | 18.602       | 24.662        | 24.205        | 23.189        |
| RMSE        | 0.480      | 1.094 | 23.090        | 19.075       | 24.835        | 24.215        | 23.234        |

5. Conclusion

In this paper we concluded that: the specifications of the model using the analysis of optimal lag, we obtained that the best model for data obtained tax revenues and the inflation rate is VECM with 3rd optimal lag or VECM (3). From the seven models created, there is one model that significant is a model of income tax.

The result of predictions tax revenues and inflation in Banda Aceh for 6, 12 and 24 periods (months) ahead obtained by using VECM (3) to be valid, due to it has the minimum error compared with other models in this research.

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