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Modeling Inflation and Money Supply using Spatial Vector Autoregressive Model with Calendar Variation: Restricted vs Non-restricted Coefficient

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Abstract. One of the tasks of the government is to maintain price stability reflected in the stability of inflation through the regulation of the money supply. Therefore the government needs to know the forecast of the inflation rate and the money supply. In modeling inflation and the money supply simultaneously in Indonesia, three things need to be accommodated, namely the relationship between variables, the existence of space-time relationships and the effect of Eid al-Fitr. The spatial vector autoregressive model with calendars variation can accommodate these three things. The purpose of this study is to compare two types of spatial vector autoregressive models with calendar variations, namely restricted and non-restricted coefficient to model inflation and the money supply in Surabaya, Malang, Kediri, and Jember simultaneously. Results of this study indicate that the non-restricted spatial vector autoregressive model with calendar variation is better than the restricted one. This can be seen from the value of MSE of the non-restricted model that is smaller than the restricted model.

1. Introduction

High inflation is one of the important problems facing a country. This problem is very disturbing to the community and of course the government. High inflation shows the poor economy of a country. Therefore inflation needs to be controlled. The government, in this case the central bank is in charge of controlling inflation to be stable. Bank Indonesia as the country's central bank maintains inflation stability by controlling the money supply. Increasing the money supply will result in a higher inflation rate. To reduce inflation the government seeks to reduce the money supply by (i) selling securities, (ii) increasing loan interest rates and (iii) increasing the required reserve ratio [1]. This shows that inflation and the money supply need to be predicted.

Inflation and the money supply have a space-time relationship. An increase in inflation in a city will usually be followed by an increase in inflation in other cities, especially the closest cities. This is because of economic relations between the closest cities. The money supply between cities is also related to the existence of relations between BI regional offices in meeting the demand for money from the public. Research on inflation and the money supply in Indonesia includes [2-6].

Inflation and the money supply in Indonesia have unique characteristics, namely increasing in the month of Eid al-Fitr and or in the month before Eid Al-Fitr. The occurrence of Eid al-Fitr follows a lunar



calendar so that it occurs on different dates and months each year. Such an event is commonly called calendar variation in this case is holiday variation. Holiday variation refers to fluctuations in economic activity because of the effects of certain holidays or religious holidays that are set on a lunar calendar so that the holiday occurs on a different date and month each year. Calendar Effect modeling can be done by adding a dummy variable that represents periods related to the holiday which is a concern in the regression model [7], ARIMA model [8-10], and GSTAR model [11].

Based on the previous explanation, a model that can accommodate three aspects is needed to predict inflation and the money supply, namely: the relationship between variables, the existence of space-time relationships and the effects of calendar variations. The Space-time model for one variable that has developed includes the Vector Autoregressive (VAR) model developed by [12], Space Time Autoregressive (STAR) model developed by [13] and [14], and Generalized Space Time Autoregressive (GSTAR) model by [15] and [16]. STAR and GSTAR models are VAR models whose coefficients are restricted. Meanwhile, the space-time model for more than one variable is the Spatial Vector Autoregressive (SpVAR) model developed by [17] and [18].

To accommodate the effect of exogenous variables on one space-time data, the GSTAR model with exogenous variables has been developed by [19] and [11]. Meanwhile, for space-time data with more than one variable, it has been developed the SpVAR model with calendar variation, (see [20] and [6]). The SpVAR model with calendar variations has two types of coefficient forms, namely non-restricted and restricted. The purpose of this study is to compare the two types of SpVAR models with calendar variations, namely the non-restricted and restricted coefficients for modeling inflation and the money supply in Surabaya, Malang, Kediri, and Jember simultaneously.

2. Methodology

In this section, data and methods that are used in this study are presented.

2.1. Data

The data used in this study is monthly inflation and money supply data from January 2003 to December 2014. Inflation data is obtained from the website of bps.go.id while the money supply data is obtained from Bank Indonesia.

2.2. Spatial Vector Autoregressive Model with Calendar Variation

Spatial Vector Autoregressive [SpVAR (1, p)] model with Calendar Variation can be stated as

$$\mathbf{y}_t = \Gamma \mathbf{x}_t + \mathbf{B}_1 \mathbf{y}_{t-1} + \dots + \mathbf{B}_p \mathbf{y}_{t-p} + \boldsymbol{\xi}_t, \quad (1)$$

where

$$\mathbf{y}_t^* = [\mathbf{y}_{1t}, \mathbf{y}_{2t}, \dots, \mathbf{y}_{Kt}]', \mathbf{y}_{kt} = [y_{1kt}, y_{2kt}, \dots, y_{Nkt}]'$$

y_{nkt} : the value of k -th variable at n -th location at time t and

$\Gamma = \text{diag}(\gamma_{11}, \dots, \gamma_{N1}, \dots, \gamma_{1K}, \dots, \gamma_{NK})$, is coefficient matrix for calendar variation dummy variables.

$$\mathbf{x}_t = [\mathbf{x}'_{1t} \quad \mathbf{x}'_{2t} \quad \dots \quad \mathbf{x}'_{Kt}]', \mathbf{x}_{kt} = [\mathbf{x}'_{1kt} \quad \mathbf{x}'_{2kt} \quad \dots \quad \mathbf{x}'_{Nkt}]',$$

$$\mathbf{x}_{nkt} = [x_{nkt1} \quad x_{nkt2} \quad \dots \quad x_{nkm}]', m \text{ is the number of dummy variable for calendar variation,}$$

x_{nkl} is the l -th dummy variable for calendar variation for the k -th endogenous variable at n -th location at time t .

$\mathbf{B}_h (h=1, \dots, p)$ is $NK \times NK$ non-restricted coefficient matrix,

$$\boldsymbol{\xi}_t = [\xi_{1t}, \xi_{2t}, \dots, \xi_{Kt}]', \xi_{kt} = [\xi_{1kt}, \xi_{2kt}, \dots, \xi_{Nkt}]',$$

$$E(\boldsymbol{\xi}_t) = \mathbf{0}, E(\boldsymbol{\xi}_t \boldsymbol{\xi}_t') = \boldsymbol{\Sigma},$$

$$E(\xi_t \xi'_{t-h}) = \mathbf{0}, h=1, 2, \dots$$

2.3. Restricted Spatial Vector Autoregressive Model with Calendar Variation

Restricted Spatial Vector Autoregressive Model with Calendar Variation is Spatial Vector Autoregressive Model with Calendar Variation as in (1), but the coefficient matrix \mathbf{B} is restricted by the restriction as

$$\mathbf{B}_i = \begin{bmatrix} \mathbf{A}_{11}^{(i)} & \mathbf{A}_{12}^{(i)} & \dots & \mathbf{A}_{1K}^{(i)} \\ \mathbf{A}_{21}^{(i)} & \mathbf{A}_{22}^{(i)} & \dots & \mathbf{A}_{2K}^{(i)} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{A}_{K1}^{(i)} & \mathbf{A}_{K2}^{(i)} & \dots & \mathbf{A}_{KK}^{(i)} \end{bmatrix}, \text{ where } \mathbf{A}_{kr}^{(i)} = \boldsymbol{\beta}_{kr}^{(i0)} + \boldsymbol{\beta}_{kr}^{(il)} \mathbf{W}_{kr}, \quad (2)$$

$$\boldsymbol{\beta}_{kr}^{(il)} = \text{diag} \left\{ \left[\beta_{1kr}^{(il)}, \dots, \beta_{Nkr}^{(il)} \right] \right\}, \quad k, r = 1, \dots, K; h = 1, \dots, p, \quad (3)$$

where \mathbf{W}_{kr} is $N \times N$ spatial weight matrix, where the element $w_{kr}(i, j)$ has been previously known and assumed to be non-negative and positive if location i and j are neighbors and are zero if $i = j$. Spatial weight is assumed to be constant over time. Autoregressive coefficients are assumed to vary between locations.

2.4. Procedure

The steps in this study are:

Step 1. Test the stationary of data using a panel data unit root test proposed by [21]. If the data is not stationary, then the difference is done so that the data is stationary.

Step2. Determine the dummy variable for calendar variations

Step 3. Determine the order of time with the following steps:

(i) Eliminate the effects of calendar variations by modeling

$$\mathbf{y}_t^* = \Gamma \mathbf{x}_t + \mathbf{w}_t \quad (4)$$

and estimate the parameter using GLS.

(ii) Calculating the residual from equation (4), determining the spatial weight and determining menentukan bobot spasial dan menentukan model SpVAR untuk \mathbf{w}_t ,

$$\mathbf{w}_t = \mathbf{B}_1 \mathbf{y}_{t-1}^* + \dots + \mathbf{B}_p \mathbf{y}_{t-p}^* + \boldsymbol{\xi}_t. \quad (5)$$

(iii) Test the null hypothesis and the following alternative hypothesis uses the Likelihood Ratio Test in sequence.

$$H_0^1 : \boldsymbol{\beta}^{(M)} = \mathbf{0} \text{ vs } H_1^1 : \boldsymbol{\beta}^{(M)} \neq \mathbf{0}, \quad (6)$$

where M is positive integer number. If the null hypothesis is not rejected, then the hypothesis test for the order $(M-1)$ is carried out. Each null hypothesis is tested conditional on the previous null hypothesis is correct. This procedure stops if one null hypothesis is rejected. If H_0^i is rejected, then $\hat{p} = M - i + 1$ is chosen as the order of the SpVAR model with calendar variation.

Step 4. Estimate the parameter of SpVAR model with calendar variation using Full Information Maximum Likelihood (FIML) method.

Step 5. Get the best model by comparing MSE from the non-restricted SpVAR model with calendar variation and restricted SpVAR models with calendar variation.

3. Result and Discussion

In this results and discussion section, the results of the stationary test, order determination and parameter estimation are discussed.

3.1. Stationary test results

The results of the stationary test for inflation data are presented in Table 1.

Table 1. Stationary Test Results for Inflation using the LLC Test

Deterministic Variable	<i>Adjusted t</i>	<i>p-value</i>
<i>Zero Mean</i>	-2.52	0.0059
<i>CS Fixed</i>	-13.53	<.0001
<i>CS Fixed, Time</i>	-24.10	<.0001
<i>TS Fixed</i>	-17.65	<.0001
<i>CS, TS Fixed</i>	-19.35	<.0001
<i>CS, TS Fixed, Time</i>	-27.68	<.0001

Table 1 shows that the *p*-value is less than 5 percent, this means that inflation in all four cities is stationary.

Table 2. Stationary Test Results for the Money Supply Using the LLC Test

Deterministic Variable	<i>Adjusted t</i>	<i>p-value</i>
<i>Zero Mean</i>	2.44	0.9927
<i>CS Fixed</i>	5.84	1.0000
<i>CS Fixed, Time</i>	6.36	1.0000
<i>TS Fixed</i>	1.78	0.9625
<i>CS, TS Fixed</i>	4.83	1.0000
<i>CS, TS Fixed, Time</i>	6.41	1.0000

Table 2 shows that the *p*-value is more than 5 percent. This means that the money supply is not stationary so it needs to be differenced. The stationary test results of the money supply after differencing are presented in Table 3. The table shows that the *p*-value is less than 5 percent so it can be concluded that the data is stationary.

Table 3. Stationary Test Results for the Money Supply after the difference using the LLC Test

Deterministic Variable	<i>Adjusted t</i>	<i>p-value</i>
<i>Zero Mean</i>	-37.98	<.0001
<i>CS Fixed</i>	-43.77	<.0001
<i>CS Fixed, Time</i>	-49.34	<.0001
<i>TS Fixed</i>	-37.79	<.0001

Deterministic Variable	Adjusted t	p-value
CS, TS Fixed	-44.74	<.0001
CS, TS Fixed, Time	-50.58	<.0001

3.2. Order Determination

In this order determination, dummy variables are determined for periods of calendar variation. In this study 8 variables calendar variations were used and defined:

$$x_{bi,t} = \begin{cases} 1, & \text{if } t \text{ is one month before Eid al Fitr} \\ & \text{where Eid al Fitr at the } i\text{-th week} \\ 0, & \text{for another month} \end{cases}$$

$$x_{i,t} = \begin{cases} 1, & \text{if } t \text{ is Eid al Fitr month} \\ & \text{where Eid al Fitr at the } i\text{-th week} \\ 0, & \text{for another month} \end{cases}$$

for $i = 1, 2, 3, 4$

For example, the data used are inflation and the money supply from January 2003 to December 2014. Eid al-Fitr in 2003 occurred on November 25, 2003 or the fourth week of November. Dummy variable value $x_{b4,10} = 1; x_{4,11} = 1$, while $x_{b1,10} = x_{b2,10} = x_{b3,10} = 0$, likewise $x_{1,10} = x_{2,10} = x_{3,10} = 0$.

Furthermore, dummy variables are chosen which significantly influence the endogenous variables using the backward procedure. The parameter estimation method used is Generalized Least Square (GLS). The results of selecting this dummy variable are presented in Table 4.

Table 4. The Significant Calendar Variations Variable

Endogenous Variable	Significant Dummy Variables for Calendar Variations
Inflation in Surabaya	x_{b1t}, x_{b2t}
Inflation in Malang	x_{b1t}, x_{b2t}
Inflation in Kediri	x_{b1t}, x_{2t}
Inflation in Jember	x_{b1t}, x_{2t}
Money Supply in Surabaya	$x_{b1t}, x_{b2t}, x_{1t}, x_{3t}, x_{4t}$
Money Supply in Malang	$x_{b1t}, x_{b2t}, x_{1t}, x_{3t}, x_{4t}$
Money Supply in Kediri	$x_{b1t}, x_{b2t}, x_{1t}, x_{3t}, x_{4t}$
Money Supply in Jember	$x_{b1t}, x_{b2t}, x_{1t}, x_{2t}, x_{4t}$

The modeling results with calendar variations variables are

$$\hat{y}_{11t} = 3.6799x_{b1t} + 0.4522x_{b2t}, \quad (7)$$

$$\hat{y}_{21t} = 3.781x_{b1t} + 0.3951x_{b2t}, \quad (8)$$

$$\hat{y}_{31t} = 5.3702x_{b1t} + 0.4147x_{2t}, \quad (9)$$

$$\hat{y}_{41t} = 3.9088x_{b1t} + 0.3327x_{2t}, \quad (10)$$

$$\hat{y}_{12t} = 1.9500x_{b1t} + 1.3329x_{b2t} - 2.7404x_{1t} + 0.8639x_{3t} + 1.8153x_{4t}, \quad (11)$$

$$\hat{y}_{22t} = 0.6446x_{b1t} + 0.4015x_{b2t} - 0.8298x_{1t} + 0.3467x_{3t} + 0.5373x_{4t}, \quad (12)$$

$$\hat{y}_{32t} = 0.9125x_{b1t} + 0.5024x_{b2t} - 1.2564x_{1t} + 0.4140x_{3t} + 0.6276x_{4t}, \quad (13)$$

$$\hat{y}_{42t} = 0.4558x_{b1t} + 0.2306x_{b2t} - 0.6333x_{1t} - 0.1063x_{2t} + 0.2282x_{4t}, \quad (14)$$

where \hat{y}_{11t} is the predicted value of inflation in Surabaya at time t ,
 \hat{y}_{21t} is the predicted value of inflation in Malang at time t ,
 \hat{y}_{31t} is the predicted value of inflation in Kediri at time t ,
 \hat{y}_{41t} is the predicted value of inflation in Jember at time t ,
 \hat{y}_{12t} is the predicted value of money supply in Surabaya at time t ,
 \hat{y}_{22t} is the predicted value of money supply in Malang at time t ,
 \hat{y}_{32t} is the predicted value of money supply in Kediri at time t ,
 \hat{y}_{42t} is the predicted value of money supply in Jember at time t ,

Then the residuals are calculated from the model (7) up to the model (14). This residual is modeled using the SpVAR model to determine the order of the SpVAR model with calendar variations for inflation and the money supply in the cities of Surabaya, Malang, Kediri and Jember.

In determining this order, the maximum order is determined which is four. The G value for the fourth order is 4.3806 while the value $\chi^2_{(0.10,32)} = 42.5847$, so the null hypothesis fails to be rejected. Furthermore, the G value for the third order is calculated and the G value is 32.75188, so the null hypothesis still fails to be rejected. The next step is to calculate the G value for second order and the G value of 342.7024 is obtained, so the null hypothesis is rejected. Based on this procedure, the order chosen is two.

3.3. Parameter estimation results

Comparison of MSE values from non-restricted SpVAR models with calendar variations and restricted SpVAR models with calendar variations on inflation and the money supply modeling in Surabaya, Malang, Kediri, and Jember are presented in Table 5. The table shows that the non-restricted SpVAR model with calendar variations have MSE values that are smaller than the restricted SpVAR model with calendar variations. Therefore the selected model is the non-restricted SpVAR model with calendar variations and the results of estimating the parameters are presented in Table 6.

Table 5. MSE Comparison

Equation	MSE	
	Non-restricted SpVAR (1,2) with calendar variation	Restricted SpVAR (1,2) with calendar variation
y_{11t}	0.450414	0.467466
y_{21t}	0.518846	0.528772
y_{31t}	0.911847	0.925423
y_{41t}	0.632692	0.64156
y_{12t}	0.598552	0.732718
y_{22t}	0.042527	0.056566
y_{32t}	0.098445	0.123183
y_{42t}	0.021207	0.026587

Table 6. Parameter Estimation Results

Variable	Equation							
	y_{11t}	y_{21t}	y_{31t}	y_{41t}	y_{12t}	y_{22t}	y_{32t}	y_{42t}
x_{b1t}	3.6379*	3.7424*	5.3564*	3.9848*	2.1511*	0.6898*	0.9997*	0.4633*
x_{b2t}	0.4656*	0.4072*	-	-	0.8992*	0.2552*	0.3503*	0.1937*
x_{1t}	-	-	-	-	-0.8614	-0.302*	-0.3959	-0.3074*
x_{2t}	-	-	0.4137*	0.3339*	-	-	-	-
x_{3t}	-	-	-	-	2.2474*	0.8139*	0.9667*	0.3244*
x_{4t}	-	-	-	-	1.8115*	0.4769*	0.6435*	0.2557*
y_{11t-1}	0.0114	0.1518	0.0144	0.0967	0.2078	0.1329*	0.0848	0.0717
y_{12t-1}	-0.359*	-0.2962	-0.479*	-0.416*	-0.949*	-0.113*	-0.220*	-0.0640
y_{11t-2}	-0.1699	-0.0626	0.1757	-0.1812	-0.2593	-0.138*	-0.1532	-0.0619
y_{12t-2}	-0.1112	0.0442	-0.0351	-0.0520	-0.412*	-0.0148	0.0002	-0.0145
y_{21t-1}	-0.0659	-0.2381	-0.0248	-0.2602	0.0861	-0.0147	-0.0337	-0.0182
y_{22t-1}	1.0852	0.2935	1.0207	0.7525	-1.924*	-1.177*	-0.787*	-0.487*
y_{21t-2}	0.1102	-0.1090	-0.0428	0.0561	0.2541	0.1199*	0.1801*	0.0657
y_{22t-2}	-0.1038	-0.3947	-0.6056	-0.1088	-2.474*	-0.993*	-1.106*	-0.549*
y_{31t-1}	-0.1860	-0.0810	-0.2784	-0.2229	-0.1315	-0.0330	-0.0484	-0.0071
y_{32t-1}	0.7859	1.0254*	1.2812*	1.0537*	1.2361*	0.3229*	0.0314	0.2677*
y_{31t-2}	0.0634	0.1244	-0.0742	0.2585	-0.0205	0.0293	0.0060	0.0096
y_{32t-2}	0.8421*	0.4817	1.3585*	0.6622	1.2271	0.3779*	0.2813	0.2872*
y_{41t-1}	0.3820*	0.3406*	0.4231*	0.5574*	-0.1989	-0.0932	-0.0303	-0.0430
y_{42t-1}	-1.1733	-0.8043	-1.3638	-0.8546	1.7293*	0.7435*	0.7557*	-0.1825
y_{41t-2}	-0.0868	-0.0660	-0.1436	-0.2936	-0.1173	-0.0691	-0.1266	-0.0547
y_{42t-2}	-1.1762	-0.6635	-1.9052	-0.9035	1.9923*	0.4323	0.5668	0.0480

where *: coefficient with p -value less than 10%

Table 6 shows that there is one calendar variation dummy variable that affects all equations, namely x_{b1t} , with a positive coefficient for all equations. This means that if Eid al-Fitr occurs in the first week then inflation and the money supply in the month of Ramadan (one month before Eid) increase in all cities. In addition, there are two calendar variation dummy variables that effect on the money supply in all cities, namely x_{3t} and x_{4t} with positive coefficients. This means that if Eid al-Fitr occurs in the third or fourth week, the money supply will increase in the month of Eid. Table 6 also shows that there is a relationship between inflation and the money supply and there is a space-time relationship on inflation and the money supply.

4. Conclusion

Conclusion of this study is the non-restricted SpVAR (1, 2) model with calendar variations better than the restricted SpVAR model (1, 2) with calendar variations. Moreover, there is the effect of Eid al-Fitr both on inflation and the money supply. Furthermore, there is a space-time relationship in inflation and the money supply.

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