Spatial Lag Fixed Effect Panel Model with Weights Queen Contiguity for Economic Growth Data of ASEAN Member Countries

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Abstract. The development of a country is in line with its economic growth, the greater percentage of economic growth, makes the greater development in the country, and vice versa. Economic growth is the process of changing a country's economic condition that is sustainable towards a better state during a certain period. Currently, world economic growth is getting stronger, including the economic growth of ASEAN member countries. This paper will discuss about estimating the model of economic growth of ASEAN member countries using spatial lag fixed effect panel data with weights queen contiguity. In this research, the author uses the spatial panel data approach. Panel data model is a regression model that uses panel data. The use of panel data aims to reduce collinearity between independent variables. Spatial effects are used to determine the magnitude of geographical factors. This research data consists of some indicators of world economy issued by the IMF in Southeast Asia region during the period of 1980 to 2017. The results of this research can be used to give consideration in determining policies to increase economic growth of ASEAN member countries.

1. Introduction
Economic growth is the process of changing a country's economic condition that is sustainable towards a better state during a certain period. The development of a country is in line with its economic growth, the greater percentage of economic growth, makes the greater development in the country, and vice versa. Therefore, in carrying out the development of a country, the government needs accurate planning and expected to be able to evaluate the development carried out.

In 2018, the International Monetary Fund (IMF) through the World Economic Outlook released economic growth figures for 2017 throughout the world including Southeast Asia. The largest economic growth rate for ASEAN member countries is owned by Cambodia, amounting to 6.95%, followed by Laos at 6.83%, Vietnam at 6.81%, Myanmar at 6.72%, Philippines at 6.67%, Malaysia at 5.90%, Indonesia at 5.07%, Thailand at 3.90%, Singapore at 3.62%, and the last one Brunei Darussalam at 0.38% [9]. Efforts to improve economic growth can be done by knowing the factors that influence the high and low of economic growth.

The econometric model is a model that uses a combination of cross section and time series data, or commonly called panel data. One of the advantages of panel data is that it gives a greater number of observations so that it increases the degree of freedom. The large number of degree of freedom can reduce collinearity among independent variables [8]. Tobler stated in his first geographic law that...
something is related to one another but something close has more influence than something far away [1]. In 2016, Septiyaningrum conducted a study using a spatial panel regression on the poor population of districts/cities in Central Java [15]. Furthermore in 2016, Purba and Setiawan conducted a modeling of economic growth in North Sumatra Province using a spatial panel data approach [13].

In 2010, Yang conducted a study using a spatial panel autocorrelation model with tested variables namely economic growth, local GDP, and logistics for data in several provinces in China. This study concludes that significant spatial correlation between GDP and logistics, but logistics has a small influence on economic growth. This is due to the level of modernization of logistics, poor logistics network systems, lack of application of information technology, and low logistics management [16].

In 2012, Millo and Piras stated that the analysis of spatial panel data is part of econometrics that has developed methodologies, but the application of its application is still constrained by available software. The splm package in software R is a package that serves to estimate and test the diagnostic of various models of spatial panels. The splm packages are also available for MATLAB and STATA software, where this package provides a comprehensive tool for statistical programming [12].

In 2012, Budiyanti and Lisnawati conducted a study of the effect of the three financial sectors on economic growth in five ASEAN countries in 1990-2010 using panel data analysis with a variable level of credit to GDP, the ratio of money supply to GDP, and the ratio of investment to GDP [4]. Furthermore, in 2017, Sari conducted a study on the analysis of factors that affect the economic growth of ASEAN member countries using data from 2011-2016 with panel data analysis, variables used namely economic growth, imports, exports, foreign direct investment, competitiveness index, government expenditure, and labor force [14]. Based on the explanation above, this research will study the characteristics of economic growth in ASEAN member countries by considering the existence of spatial dependencies between countries using fixed effect panel data with weights queen contiguity.

2. Theoretical Model

2.1. Panel Data Model

The multiple regression model can be developed into a panel data model in general [8], as shown in equation (1):

\[ y_{it} = \beta_i + \beta_1 x_{1it} + \beta_2 x_{2it} + \ldots + \beta_K x_{Kit} + \epsilon_{it}; i = 1,2,\ldots,N; t = 1,2,\ldots,T \]  \hspace{1cm} (1)

with

- \( y_{it} \): observation of the dependent variable in the \( i \)-th data and \( t \)-th time.
- \( x_{kit} \): observation of \( k \)-independent variable in the \( i \)-th data and \( t \)-th time.
- \( \beta_i \): \( i \)-th observation intercept for the \( t \)-th time period.
- \( \beta_k \): \( k \)-th regression variable independent coefficient.
- \( \epsilon_{it} \): error that is normally distributed and the form of the \( i \)-th and \( t \)-th observations with mean 0 and variance \( \sigma^2 \).

2.2. Spatial panel data model

Spatial linear regression models without interaction can be written as follows in equation (2):

\[ y_{it} = x_{it} \beta + \mu_i + \epsilon_{it}; i = 1,2,\ldots,N; t = 1,2,\ldots,T \]  \hspace{1cm} (2)

with

- \( i \): index for cross-section dimensions (spatial units).
- \( t \): index for the time dimension (time period).
- \( y_{it} \): observation of the dependent variable in the \( i \)-th data and \( t \)-th time.
- \( x_{it} \): row vector \((1, K)\) from the observation of the independent variable.
- \( \beta \): matrix \((K, 1)\) with unknown parameters.
- \( \mu_i \): spatial specific effects.
- \( \epsilon_{it} \): error that is normally distributed and the form of the \( i \)-th and \( t \)-th observations with mean 0 and variance \( \sigma^2 \).
When there are specific interactions between spatial units, the model contains spatial lag on the dependent variable or there is a spatial autoregressive process on error. The spatial lag model shows that the dependent variable depends on the neighboring dependent variable and one part of the local characteristics. Here is a model of spatial lag in equation (3):

\[ y_{it} = \delta \sum_{j=1}^{N} w_{ij} y_{jt} + x_{it} \beta + \mu_i + \epsilon_{it} \]  

with \( \delta \) is the spatial autoregressive coefficient and \( w_{ij} \) is the element of spatial weights matrix \( (W) \) [1].

2.3. Spatial weights matrix

The spatial weighting matrix \( (W) \) can be obtained based on distance information from neighborhoods, or in other words the distance between one region and another region [11]. In this study we will use a weights matrix of queen contiguity. Where this interface defines \( w_{ij} = 1 \) for the area that are common side or common vertices to meet the area of concern, \( w_{ij} = 0 \) for the other area [11].

2.4. Lagrange Multiplier Test

Lagrange Multiplier test is used to test spatial dependencies on the model. The hypothesis testing is follows and the test statistics provide in equation (4):

\[ H_0: \delta = 0 \] (no spatial lag dependencies in the model)
\[ H_1: \delta \neq 0 \] (there are spatial lag dependencies in the model)

Test statistics:

\[ LM_\delta = \left( \frac{e'(I_T \otimes W) y / \hat{\sigma}_e^2}{J} \right)^2 \]  

with \( I_T \) is the identity matrix, \( e \) is the error vector of the pooled model, and \( \hat{\sigma}_e^2 \) is the error estimated variant of the pooled model [7].

2.5. Likelihood Ratio Test

The likelihood ratio test is used to determine whether the fixed effect spatial model is significant and can be used. The hypothesis is to test the likelihood ratio as follows in equation (5):

\[ H_0: \mu_1 = \mu_2 = \cdots = \mu_N = \mu \] (spatial fixed effect in each region are identic)
\[ H_1: \text{At least one } \mu_i \neq \mu_j, \text{where } i \neq j; i, j = 1, 2, \ldots, N \] (at least there are a couple of regions with different spatial fixed effects)

Test statistics: \( LR = -2s = -2[L(\hat{\theta}) - L(\bar{\theta})] \)  

with \( L(\bar{\theta}) \): log-likelihood from restricted model (global spatial model)
\( L(\hat{\theta}) \): log-likelihood from unrestricted model (fixed effect spatial model).

The LR test has a chi-square (\( \chi^2 \)) distribution \( N - 1 \) degrees of freedom. Reject \( H_0 \) if \(-2s > \chi^2(\alpha; N - 1) \) [7].

2.6. Goodness of Fit

The good criteria of the model in the spatial panel data model can be seen from the coefficient of determination \( (R^2) \). The coefficient of determination \( (R^2) \) is the proportion of the variation in data that can be given or explained by the model. The value of \( R^2 \) can be used as a model selection criterion. The selected model is the model with the largest \( R^2 \). The value of \( R^2 \) is obtained using the following equation (6):

\[ R^2(\varepsilon) = 1 - \frac{\varepsilon^T \varepsilon}{(Y - \bar{Y})'(Y - \bar{Y})} \]  

with \( \varepsilon \) is the error vector of the model, \( Y \) is the vector of the dependent variable, and \( \bar{Y} \) is the average vector of the dependent variable [7].
2.7. Wald Test
Wald test is used to test the significance of parameters in a model. The test statistics can be written as follows in equation (7), (8), and (9):

\[
Wald_{\hat{\beta}_p} = \frac{\hat{\beta}_p}{Se(\hat{\beta}_p)}
\]  
(7)

\[
Wald_{\hat{\delta}} = \frac{-\hat{\delta}}{Se(\hat{\delta})}
\]  
(8)

\[
Wald_{\hat{\rho}} = \frac{-\hat{\rho}}{Se(\hat{\rho})}
\]  
(9)

with

\(\hat{\delta}\): estimator of spatial lag coefficient parameters.
\(\hat{\rho}\): estimator of the error spatial parameter coefficient.
\(\hat{\beta}_p\): estimator of the \(p\)-th parameter coefficient of independent variable with \(p = 1, 2, ..., K\).
\(Se\): error standard of the parameter estimation value.

Reject \(H_0\) if \(|Wald| > t_{(\alpha,n-K-1)}\) [5].

2.8. Classical Assumption Checking

2.8.1. Normality Test. The assumption of normality is used to determine whether the error of the model is normally distributed. One way of testing normality can be done by the Geary normality test [6].

2.8.2. Autocorrelation Test. The test of independence assumption or error autocorrelation test can be done with the Runs test. Runs are sequences of one of the unbroken positive (+) or negative (-) symbols [5].

2.8.3. Heteroscedasticity Test. An error is call to be identical if error variance is homoschedastic. Testing for heteroscedasticity using the Glejser test is \(|\hat{\epsilon}_i| = \beta_{1i} + \beta_{2i}x_{1it} + \cdots + \beta_{ki}x_{kit}\) or model an absolute error value with a significant independent variable in the model [8].

2.8.4. Multicollinearity Test. Multicollinearity test is a situation of correlation between independent variables, which describes the relationship between the independent variables is higher than the relationship of independent variables to the dependent variable. The presence of multicollinearity can be seen from the value of the variance inflation factor (VIF) on each independent variable. If \(VIF_k > 10\) then there is multicollinearity in the panel data model [8].

3. Data description
This research uses data obtained from the International Monetary Fund (IMF) through the April 2018 edition of World Economic Outlook which was released in July 2018. The area under observation is Southeast Asia (ASEAN) which consists of ten countries namely Indonesia, Malaysia, Singapore, Brunei Darussalam, Thailand, Philippines, Vietnam, Cambodia, Myanmar, and Laos from 1980 to 2017 [9].

Table 1. Variables that used in the economic growth model

| Variables | Description | Units |
|-----------|-------------|-------|
| \(Y\)   | Percentage of economic growth | %     |
| \(X_1\) | Total investment | %GDP  |
|           | The annual percentage of GDP based on constant prices that change from year to year. |       |
|           | the ratio of total investment in local currency compared to GDP in local currency. Gross investment or capital formation is measured by the total value of gross fixed |       |
capital formation and changes in inventories and acquisitions less the release of valuables for units or sectors.

- \( X_2 \): Gross national savings
  - The ratio of gross national savings in local currency compared to GDP in local currency. Gross national savings are obtained from gross income less consumption expenditure after taking into account the adjustment of pension funds.

- \( X_3 \): Inflation
  - An annual percentage of the average consumer price that changes from year to year.

- \( X_4 \): Import
  - The percentage change in import volume which refers to aggregate changes in the total amount of imports whose characteristics have not changed. Goods and services and prices remain constant.

- \( X_5 \): Export
  - The percentage of change in export volume which refers to aggregate changes in the total amount of exports whose characteristics have not changed. Goods and services and their remains remain constant.

- \( X_6 \): The unemployment rate
  - The percentage of the number of unemployed compared to the number of labor force (number of workers plus unemployment). As defined by the International Labor Organization (ILO), unemployment is those who are not working but are willing and able to work and are actively seeking work.

- \( X_7 \): Population
  - All people who enter the scope of the census. In a broad sense, the population is the population of the country or all people present in the country at the time of the census.

- \( X_8 \): Government revenues
  - Consist of taxes, social contributions, grants, accounts receivable, and other income. Income increases government net worth which is the difference between assets and liabilities.

- \( X_9 \): Total government expenditure
  - Consists of total costs and acquisition of non-financial net assets.

- \( X_{10} \): Gross debt
  - Consists of all obligations that require payment or payment of interest and/or principal by the debtor to the creditor at this time or in the future. This includes debt obligations in the form of SDRs, currencies and deposits, debt securities, loans, insurance, pensions, and standardized guarantee schemes, as well as other debts. Debt can be valued based on current market value, nominal or value.

- \( X_{11} \): The current account balance
  - All transactions other than those in financial and capital items. The main classifications are goods and services, income and current transfers.

4. Results and discussion

4.1. Panel data model

Based on the results of the panel data analysis, a significant model is obtained in equation (10):

\[
\hat{y}_{it} = 3.300 + 0.0343 \ x_{1it} + 0.0679 \ x_{4it} + 0.03343 \ x_{5it} - 0.3011 \ x_{6it} - 0.0453 \ x_{11it} + 0.00498 \ x_{7it} + 0.03337 \ x_{10it} - 0.0453 \ x_{11it}
\]
equation (10) has value $R^2 = 40.61\%$ with variables that have a positive effect on economic growth are investment, import, export, population, gross debt. Conversely, variables that negatively affect economic growth are unemployment and current account balance.

Based on classical assumption checking; the assumption of normality, the assumption of non-heteroscedasticity, and the assumption of non-multicollinearity are fullfil, and there is a problem of autocorrelation or independence, then continue to the Lagrange Multiplier test.

4.2. Lagrange multiplier test

Lagrange Multiplier test is used to test spatial dependencies on the model. The hypothesis testing is follows:

$H_0$: $\delta = 0$ (no spatial lag dependencies in the model)

$H_1$: $\delta \neq 0$ (there are spatial lag dependencies in the model)

Level of significance = 0.10

Test statistics = 30.908 with p-value = 0.000

because of p-value = 0.000 less than 0.10, so reject $H_0$ or there are spatial lag dependencies in the model. Then formed the spatial weights matrix.

4.3. Spatial weights matrix

In this study we will use a weights matrix of queen contiguity. Where this interface defines $w_{ij} = 1$ for the area that are common side or common vertices to meet the area of concern, $w_{ij} = 0$ for the other area. The spatial weights matrix ($W$) dan standardized lines spatial weights matrix ($W'$) formed are as follow

$$W = \begin{bmatrix}
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 \\
0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 0 \\
0 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\
1 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0 \\
0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 0
\end{bmatrix} \quad W' = \begin{bmatrix}
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}$$

4.4. Spatial lag panel data model

4.4.1. With individual effect. Based on the results of the spatial lag panel data analysis, a significant model is obtained in equation (11):

$$\hat{y}_{it} = 0.240289 \sum_{j=1}^{10} w_{ij}y_{jt} + 0.0925861x_{1it} + 0.0507757x_{2it} + 0.0266927x_{3it} + 0.1242468x_{4it} + 0.0246422x_{5it} + \mu_i$$

From the equation (11) variables $x_1$: total investment, $x_2$: import, $x_3$: export, $x_4$: total government expenditure, and $x_5$: gross debt. The spatial specific effect value for each countries are as follows:

Table 2. The spatial specific individual effect

| Countries          | Spatial specific effect ($\mu_i$) | Countries          | Spatial specific effect ($\mu_i$) |
|--------------------|----------------------------------|--------------------|----------------------------------|
| 1. Brunei Darussalam | -2.62319                         | 6. Myanmar         | 2.76763                          |
| 2. Cambodia        | 1.38356                          | 7. Philippines     | -1.91295                         |
| 3. Indonesia       | -0.75851                         | 8. Singapore       | -1.33737                         |
| 4. Laos            | 1.40615                          | 9. Thailand        | -0.88880                         |
| 5. Malaysia        | 1.04343                          | 10. Vietnam        | 0.92004                          |
4.4.2. With individual effect. Based on the results of the spatial lag panel data analysis, a significant model is obtained in equation (12):

\[
\hat{y}_{it} = -0.111451 \sum_{j=1}^{10} w_{ij}y_{jt} + 0.0421426x_{1it} + 0.0459520x_{2it} + 0.0277588x_{3it} - 0.3016284x_{4it} + 0.0306533x_{5it} - 0.650584x_{6it} + \mu_t
\]  

From the equation (2) variables \(x_1\): total investment, \(x_2\): import, \(x_3\): export, \(x_4\): the unemployment rate, \(x_5\): gross debt, and \(x_6\): the current account balance. The spatial specific effect value for each for period of time 1980-1985 and 2013-2017 are as follows:

| Period of time | Spatial specific effect \((\mu_t)\) | Period of time | Spatial specific effect \((\mu_t)\) |
|---------------|----------------------------------|---------------|----------------------------------|
| 1. 1980       | 0.672879                         | 34. 2013      | -0.647675                        |
| 2. 1981       | 1.413252                         | 35. 2014      | -0.718352                        |
| 3. 1982       | -0.711285                        | 36. 2015      | -0.642597                        |
| 4. 1983       | -0.680363                        | 37. 2016      | -1.159302                        |
| 5. 1984       | -0.258058                        | 38. 2017      | -0.713930                        |

5. Conclusions
There are two possible spatial lag fixed effects models that can be used are (1) with specific individual effects or (2) time-specific effects. If we want to know the specific model for each country, the model that can be used is a model with individual specific effects. Whereas if we want to know the specific model for each time period, the model used is a model with a specific time effect.

If a model (1) is used are a model with individual specific effects, then several things need to be done so that economic growth optimal are: optimizing the total investment and export, balancing the import and gross debt, and minimizing total government expenditure. Whereas if a model (12) is used are a model with time specific effects, then several things need to be done so that economic growth optimal are: optimizing the total investment and export, balancing the import and gross debt, reducing the unemployment rate, and minimizing the current account balance.

For readers who are interested in the topic of this study can use random effect models with different weighting. For readers who want to develop a model to get a higher \(R^2\) value it is recommended to use a second or higher order model. Another way to increase the value of the \(R^2\) model is to add independent variables that significantly influence the economic growth of ASEAN countries.

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References
[1] Anselin L 2005 Exploring Spatial Data with GeoDa: A Workbook (Champaign Urbana: University of Illinois)
[2] Bank of Indonesia 2017 Laporan Perekonomian Indonesia 2017 (Jakarta: Bank of Indonesia)
[3] Bank of Indonesia 2018 Perkembangan Ekonomi Keuangan dan Kerja Sama Internasional Edisi I 2018 (Jakarta: Bank of Indonesia)
[4] Budiyanti E and Lisnawati 2012 Pengaruh Tiga Indikator Sektor Keuangan Terhadap Pertumbuhan Ekonomi di Lima Negara ASEAN pada Tahun 1990-2010. Jurnal Ekonomi & Kebijakan Publik Vol. 3 No. 1. Page 1-11.
[5] Caraka R E and Yasin H 2017 Spatial Data Panel (Wade Group: Ponorogo)
[6] Cho D W and Im K S 2002 A Test of Normality Using Geary’s Skewness and Kurtosis Statistics
https://www.itd.bus.ucf.edu/cdn/economics/workingpapers/2002-32.pdf

[7] Elhorst J P 2014 Spatial Econometrics: From Cross-Sectional Data to Spatial Panels (Heidelberg, New York, Dordrecht, London: Springer)

[8] Gujarati D N and Porter 2009 Basic Econometrics 5th Edition (New York: McGraw Hill Companies Inc.)

[9] IMF 2018 World Economic and Financial Surveys: World Economic Outlook Database https://www.imf.org/external/pubs/ft/weo/2018/01/weodata/index.aspx accessed on August 1, 2018

[10] IMF 2017 *Ekonomi Asia yang Dinamis Terus Memimpin Pertumbuhan Global* International Monetary Fund

[11] LeSage J P 1998 Spatial Econometrics www.spatial econometrics.com/html /wbook.pdf

[12] Millo G and Piras G 2012 splm: Spatial Panel Data Model in R Journal of Statistical Software Vol. 47 Issue 1

[13] Purba O N and Setiawan 2016 *Pemodelan Pertumbuhan Ekonomi Provinsi Sumatera Utara dengan Pendekatan Ekonometrika Spasial Data Panel* Jurnal Sains dan Seni ITS Vol. 5 No. 2 2337-3520

[14] Sari A C P 2017 *Analisis Faktor-Faktor yang Mempengaruhi Pertumbuhan Ekonomi Negara Anggota ASEAN pada Tahun 2011-2016* Jurnal JIBEKA Vol. 11 No. 1 Page 24-29

[15] Septiyaningrum 2016 *Model Regresi Panel Spasial Pada Penduduk Miskin Kabupaten/Kota di Jawa Tengah* Thesis of Department Mathematics (Surakarta: Universitas Sebelas Maret)

[16] Yang S 2010 *An Application of Spatial-Panel Analysis: Provincial Economic Growth and Logistics in China* Canadian Social Science Vol. 6 No. 3 Page 83-89