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THE SPATIAL ECONOMETRICS OF STUNTING TODDLERS IN NUSA TENGGARA TIMUR PROVINCE 2019

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Abstract: Stunting is caused by chronic malnutrition, which impairs toddlers' growth, brain development, and immune systems. Paying attention to toddler nutrition, water use, and other socio-economic factors have become the solution to reducing stunting rates. This study used seven predictor variables which are indicated to have an effect on increasing or decreasing stunting in NTT. The spatial lag model (SAR) was considered. We used the Euclidean distance method to determine the neighborhood and Moran's I test was applied to identify the autocorrelation. The R shiny program was developed to estimate the model parameters. The SAR model's diagnostic checking shows that the normality, non-autocorrelation, and homogeneity assumptions have been satisfied. The nutrition variable indicating that toddler malnutrition has a significant and positive effect on increasing stunting in NTT. The effect of malnutrition has the greatest effect on increasing stunting. The household variable indicating that surface water

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(rivers/lakes/reservoirs/irrigation ponds) is the primary source of bathing/washing/cooking have a significant and positive effect on increasing stunting in NTT. We also found that the use of wells as the primary source of drinking water has a significant and negative effect on stunting in NTT. Increasing access to safe drinking water can be one solution to reduce stunting rates. Economic growth has a significant and negative effect on decreasing stunting, while the population density has a positive effect on increasing stunting in NTT. Increasing economic growth in high stunting areas are needed. Education and poverty variables do not have a significant effect.
Keywords: stunting; R shiny; moran's I; SAR.

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1. INTRODUCTION

Stunting is a condition in which toddlers experience growth failure as a result of chronic malnutrition and repeated infections, particularly during the first 1000 days of life [1]. According to BPS (2019), a child is considered stunted if his or her length or height is less than minus two standard deviations of the child's or her age's length or height. Stunting toddlers may have suboptimal intelligence levels, are more susceptible to disease, and may eventually experience decreased productivity [1]. The National Strategy for the Acceleration of Stunting Prevention 2018-2024 was released at the end of 2017. Stunting reduction in Indonesia is a significant challenge, given the country's size [2]. Indonesia ranks third among ASEAN countries in terms of stunting toddler prevalence, behind Timor Leste and Lao PDR. As a result, Indonesia has made accelerating stunting reduction a national priority. By 2024, the Indonesian government hopes to reduce stunting prevalence to 14%.

According to the National Development Planning Agency (Bappenas), Indonesia will suffer annual losses of approximately 300 trillion rupiah if the prevalence of stunted toddlers is not reduced [1]. In 2019, Indonesia has a stunting rate of 27.67%, making it the highest in NTT (43.82%). Timor Tengah Selatan (TTS) has the highest rate of stunted toddlers in NTT, with 11781 stunted toddlers, followed by Kupang (9207 toddlers) and Timor Tengah Utara (TTU) (7456 toddlers). Stunting is caused by a variety of factors, including insufficient food intake, poor water quality, breastfeeding, economic circumstances, and education. Stunting is more prevalent in adjacent districts/cities in NTT. A region with a high prevalence of stunting is surrounded by other regions with a high prevalence of stunting, allowing for consideration of a model that incorporates spatial elements. The Moran Index test has established a spatial dependence on the incidence of stunting in Indonesia [3].

Because of its ability to accommodate various spatial dependency structures, econometric spatial modeling has become widely used in epidemiological studies [4]. Spatial analysis in the context of stunting is still not widely used in Indonesia, and it may not even be used as a decision support system in policy or program development at the national and regional levels. Therefore, Indonesia needs information on nutrition data which is analyzed by considering the regional context given the vastness of Indonesia's territory and its different regional variations [2].

Models of spatial econometrics include spatial autoregressive (SAR), spatial error (SEM), and independent spatial autoregressive (SLX) [4]. The open-source software R can be used to estimate model parameters. Software R can be quite simple for those who are used to it, but it will be difficult for those who are new to it. Many researchers have worked to make the R package more user-friendly. Shiny is one of R's visualization packages that makes it simple to create interactive web applications directly from R. A user can visualize data in a quick and customizable manner using the app [5]. This research uses R shiny to analyze spatial econometric models of stunting toddlers in NTT province in 2019.

2. METHOD

This study used data from Central Bureau of Statistics and NTT provincial government. The variables consist of one response variable and seven predictor variables. The units of analysis in this study are 22 districts/cities in NTT. All data used in this study are taken from public domain.

Table 1. Response variable and seven predictor variables

Variable	Notation
The number of stunting toddlers	Y
The number of undernourished children under five	X_1
Percentage of households that use surface water (rivers/lakes/reservoirs/irrigation ponds) as the primary source of bathing/washing/cooking	X_2
Percentage of households using wells as the primary source of drinking water	X_3
Population density	X_4
Economic growth	X_5
Percentage of population aged 10 years and over who have a primary school diploma	X_6
Percentage of poor people	X_7

In this study, the development of R shiny was focused on econometric spatial models. R Shiny is composed of two components: a UI (user interface) and a server. The UI's purpose is to display all input and output, whereas the server's purpose is to process input into output. The framework in R shiny is as follows [6]:

```
library(shiny)
ui <- fluidPage( # or other layout function
  # contents of ui.R file
)
server <- function(input, output) {
  #contents of server.R file
}
shinyApp(ui = ui, server = server)
```

The stages of R Shiny developed had complied with the stages in the analysis of the econometric spatial models, as follows:

1. Descriptive analysis and map
2. Classic assumption test

3. Model selection using LM test and Akaike Information Criterion (AIC)
4. Parameter estimation using the maximum likelihood estimator (MLE)
5. Diagnostic checking

Through the variables used in this study, descriptive analysis and mapping can be used to denote the characteristics of districts/cities in NTT. The Shapiro-Wilk test, the Durbin-Watson (DW) test, the VIF multicollinearity test, and the Breusch-pagan test are used to test the residual normality, independency, multicollinearity, and homoscedasticity assumptions, respectively, with a 5% alpha. The Euclidean distance method was used to determine spatial weighted. Two locations with coordinates (u_i,v_i) and (u_j,v_j), whose distance will be measured using the Euclidean distance with the following formula:

$$d_{ij} = \sqrt{\left(u_i - u_j\right)^2 (v_i - v_j)^2} \tag{1}$$

Inverse distance:

$$w_{ij} = \begin{cases} \frac{1}{d_{ij}^{\propto}} & \text{, jika } i \neq j \\ 0 & \text{, jika } i = j \end{cases} \tag{2}$$

generally, $\alpha = \{1,2\}$

Spatial autocorrelation or spatial dependence can be tested using Moran's I with the following formula [4]:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(y_i-\bar{y})(y_j-\bar{y})}{\sum_{i=1}^{n}(y_i-\bar{y})^2} \tag{3}$$

with,

n : number of spatial units

y_i : observation variable at location i

w_{ij} : elements of the spatial weight matrix W

I : Moran’s I global coefficient

Moran's I values range from -1 to 1. Local Moran's I can be used to identify spatial dependencies on each unit with the following formula [4]:

$$I_i = \frac{y_i-\bar{y}}{\sum_{i=1}^{n}(y_i-\bar{y})^2/n} \sum_{j=1}^{n} w_{ij}(y_j - \bar{y}) \tag{4}$$

The null hypothesis for autocorrelation is I = E(I) no spatial dependence. The formula of test statistics can be written as follows:

$$Z(I) = \frac{I - E(I)}{\sqrt{Var(I)}} \sim N(0,1) \tag{5}$$

with,

$$E(I) = -\frac{1}{n-1}$$

$$Var(I) = \frac{n^2.S_1 - n.S_2 + 3.S_0^2}{(n^2-1)S_0^2} - [E(I)]^2$$

$$S_0 = \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \quad ; \; S_1 = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}(w_{ij} + w_{ji})^2 \quad ; \; S_2 = \sum_{i=1}^{n}(\sum_{j=1}^{n} w_{ij} + \sum_{j=1}^{n} w_{ji})^2$$

Reject the null hypothesis at significance level α if $Z(I) > Z_{1-\alpha}$. There are several spatial econometric models, so we can use Lagrange Multiplier (LM) and Akaike Information Criterion (AIC) as the best model selection criteria. LM test for Spatial Autoregressive (SAR) model can be written as follows:

$$\mathbf{y} = \rho\mathbf{Wy} + \mathbf{X\beta} + \boldsymbol{\varepsilon} \;\; ; \; \boldsymbol{\varepsilon} \sim iidN(0, \sigma^2\mathbf{I}) \tag{6}$$

$$LM_{lag} = \frac{(\boldsymbol{\varepsilon}^t\mathbf{Wy})^2}{s^2((\mathbf{WX\beta})^t\mathbf{M}(\mathbf{WX\beta}) + Ts^2)} \tag{7}$$

with,

$$\mathbf{M = I - X(X^tX)^{-1}X^t}$$

Reject the null hypothesis if $LM_{lag} > X^2_{(\alpha,1)}$ or *p-value* < α, so the SAR model can be used. LM test for Spatial Error Model (SEM) can be written as follows:

$$\mathbf{y} = \mathbf{X\beta} + \boldsymbol{\varepsilon} \;\; ; \; \boldsymbol{\varepsilon} = \lambda\mathbf{W}\boldsymbol{\varepsilon} + \boldsymbol{\zeta}; \; \boldsymbol{\zeta} \sim iidN(0, \sigma^2\mathbf{I}) \tag{8}$$

$$LM_{err} = \frac{(\frac{\boldsymbol{\varepsilon}^t\mathbf{W}\boldsymbol{\varepsilon}}{s^2})^2}{T} \tag{9}$$

with,

$$T = tr\,((\mathbf{W}^t + \mathbf{W})\,\mathbf{W}); \; s^2 = \frac{\boldsymbol{\varepsilon}^t\boldsymbol{\varepsilon}}{n}$$

Reject the null hypothesis if $LM_{err} > X^2_{(\alpha,1)}$ or *p-value* < α, so the SEM model can be used. Spatial Autoregressive Moving Average (SARMA) model can be written as follows:

$$\mathbf{y} = \rho\mathbf{Wy} + \mathbf{X\beta} + (\mathbf{I} - \lambda\mathbf{W})^{-1}\boldsymbol{\varepsilon}; \; \boldsymbol{\varepsilon} \sim iidN(0, \sigma^2\mathbf{I}) \tag{10}$$

SARMA model will be used when LM_{lag} and LM_{err} are significant. The best model will be used when the LM test are significant and have smallest AIC. Parameter in the model will be estimated using the maximum likelihood estimator (MLE). Parameter estimator of the SAR, SEM, and SARMA model are as follows:

$$\widehat{\boldsymbol{\beta}}_{\mathrm{SAR}} = (\mathbf{X}^{t}\mathbf{X})^{-1}\mathbf{X}^{t}(\mathrm{I} - \rho\mathbf{W})\mathbf{y} \tag{11}$$

$$\widehat{\boldsymbol{\beta}}_{\mathrm{SEM}} = \left((\mathbf{X} - \lambda\mathbf{W}\mathbf{X})^{t}(\mathbf{X} - \lambda\mathbf{W}\mathbf{X})\right)^{-1}(\mathbf{X} - \lambda\mathbf{W}\mathbf{X})^{t}(\mathbf{X} - \lambda\mathbf{W}\mathbf{X})\mathbf{y} \tag{12}$$

$$\widehat{\boldsymbol{\beta}}_{\mathrm{SARMA}} = \left((\mathbf{X} - \lambda\mathbf{W}\mathbf{X})^{t}(\mathbf{X} - \lambda\mathbf{W}\mathbf{X})\right)^{-1}(\mathbf{X} - \lambda\mathbf{W}\mathbf{X})^{t}(\mathbf{I} - \lambda\mathbf{W} - \rho\mathbf{W})\mathbf{y} \tag{13}$$

3. Results and Discussion

In 2019, NTT province has 84299 stunted toddlers. Ngada district has the lowest stunting rate at 1207 toddlers, while TTS district has the highest at 11781 toddlers. TTS is a district that borders Kupang, TTU, and Malaka. The high stunting toddler area depicted in Figure 1 is surrounded by additional high stunting toddler areas. Five districts have a high proportion of stunted toddlers: TTS, Kupang, TTU, Flores Timur, and Malaka. The characteristics of each area are depicted in Figure 2. Undernourished toddlers are most prevalent in areas with a high rate of stunting.

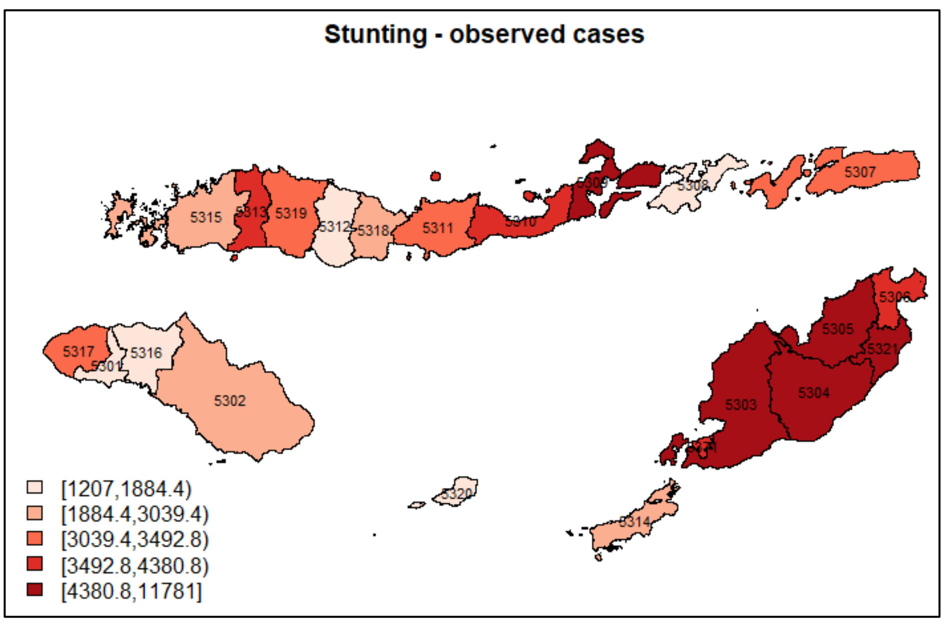

Figure 1. Map of stunting case quantile

Table 2. ID of districts/cities in NTT

ID	Districts/cities	ID	Districts/cities
5301	Sumba Barat	5312	Ngada
5302	Sumba Timur	5313	Manggarai
5303	Kupang	5314	Rote Ndao
5304	Timor Tengah Selatan	5315	Manggarai Barat
5305	Timor Tengah Utara	5316	Sumba Tengah
5306	Belu	5317	Sumba Barat Daya
5307	Alor	5318	Nagekeo
5308	Lembata	5319	Manggarai Timur
5309	Flores Timur	5320	Sabu Raijua
5310	Sikka	5321	Malaka
5311	Ende	5371	Kota Kupang

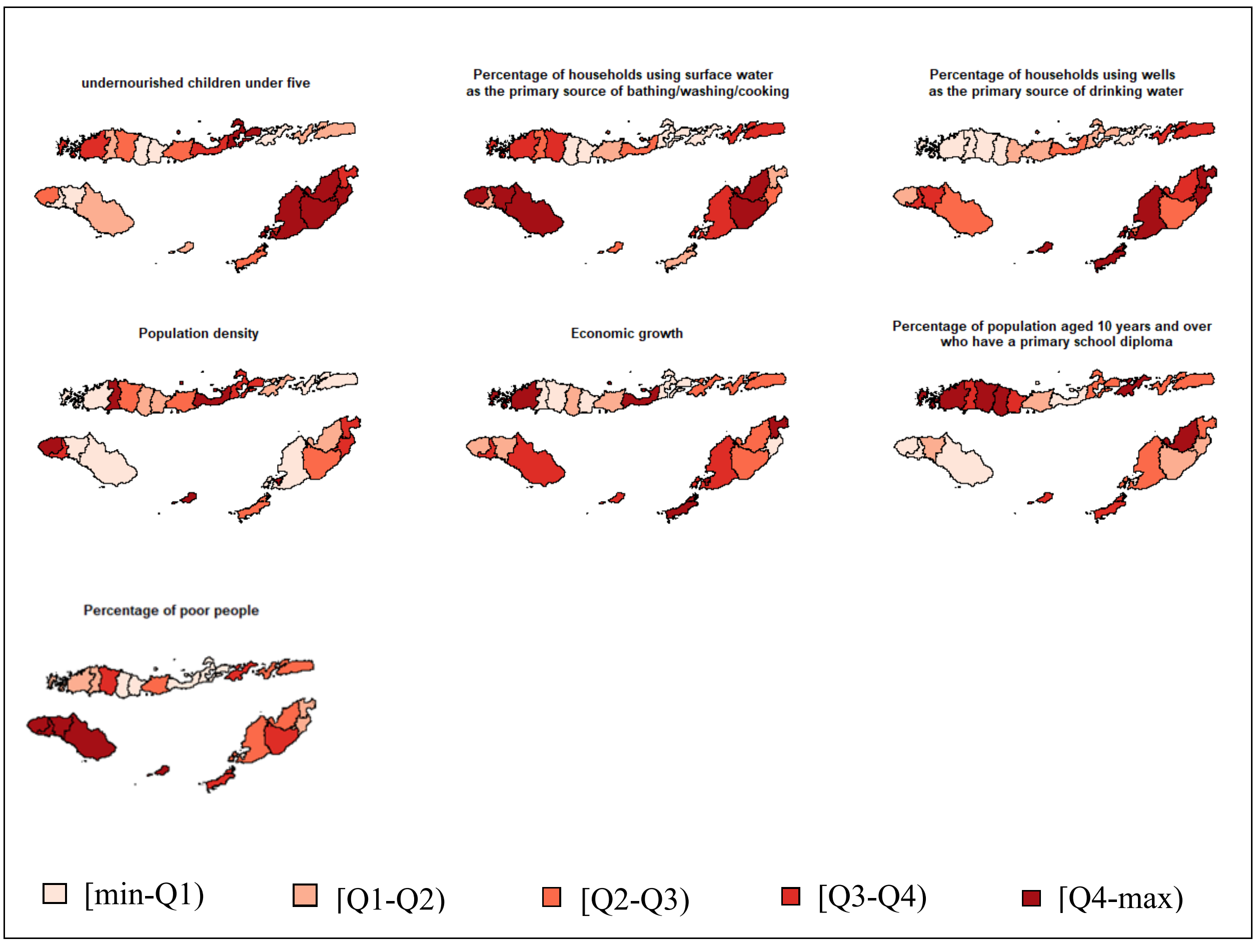

Figure 2. Map of the quantiles of the seven predictor variables

Appropriate nutritional requirements are critical in areas with a high rate of stunting. Stunted children are more susceptible to illness and death as a result of inadequate nutrition in utero and early childhood, as well as frequent infections prior to or after birth [7]. While Indonesia has long struggled with food security and nutrition issues, the country is currently confronted with an unprecedented crisis triggered by the COVID-19 pandemic [8]. To avoid an increase in wasting and stunting during the COVID-19 crisis, the government should increase the availability of supplementary foods (fortified biscuits, for example) to assist children and pregnant and lactating mothers from vulnerable groups in meeting their nutritional requirements [8].

Malaka, Flores Timur, Nagekeo, Manggarai, and Manggarai Timur have the slowest economic growth. Flores Timur and Malaka have a high rate of stunting. The evidence for a link between economic growth and stunting is inconsistent [9]. Economic growth as a policy will be effective at reducing stunting prevalence only if it is used to improve children's diets, address gender inequalities and strengthen women's status, improve sanitation, and alleviate poverty and inequity [9]. Sumba island, TTS, Lembata, and Manggarai Timur have a high percentage of poor people, and TTS district has the highest stunting rate as well. Poverty rates have a relatively high contribution to increase stunting cases in Indonesia [10]. To reduce poverty and stunting rate cannot be resolved in the short term, there needs to be an inclusive and sustainable policy to overcome these problems [10]. The problems of economic growth, poverty rates, and stunting prevalence are relatively insoluble in the short term. Inclusive and sustainable policies are needed to overcome these problems [10].

In 2019, NTT province has more than 50% of the population (10+ years) without any formal education certificates. The majority of population with formal education have primary school education. In districts/cities of NTT province, there are at least three characteristics that can illustrate the relationship between education and stunting. Ngada district has the lowest stunting rate and the majority of the population has primary school education. This characteristic is also shared by other districts, namely Sabu Raijua, Lembata, Rote Ndao, Manggarai Barat, and

Nagekeo. TTS has the highest stunting rate and the majority of the population do not has any formal education certificates. TTS districts has a low rate of population with primary school education. This characteristic is also shared by other districts, namely Sikka and Malaka. Sumba island, Sikka and Ende have a low rate either on stunting and population with primary school education. The majority of these district's population do not have any formal education certificates. Three different characteristics of districts/cities in NTT indicate that the relationship between education and stunting is inconsistent. Several studies have shown that better education can reduce the prevalence of stunting. Both maternal and paternal education are strong predictors of child stunting: greater levels of formal education achieved by both mothers and fathers were associated with a decreased odds of child stunting [11].

TTS and TTU have a high rate of stunting and many households use surface water as the primary source of bathing, washing, and cooking, which can be seen in Figure 2. Sabu Raijua and Rote Ndao have a low rate of stunting and many households use wells (drill/pump, protected, and unprotected) as the primary source of drinking water. Increasing access to clean water, sanitation facilities, and maintaining environmental hygiene can reduce the prevalence of stunting [12].

Table 3. Statistic test result of classic assumptions, R-squared, and Moran's I

Statistic test	**p-value**
Shapiro-Wilk	0.581
Durbin-Watson	0.288
VIF multicollinearity	All variables < 5
Breusch-pagan	0.807
Adjusted R-squared	0.924
Moran's I	0.000 (I = 0.176)

Table 3 shows that classic assumptions in multiple linier regression model have been fulfilled, and 92.4% of stunting rate in NTT province can be explained by the seven predictor variables. The probability of Moran's I is 0.000, so the null hypothesis is rejected, which means that there is spatial autocorrelation on stunting rate in NTT province. Moran's index is 0.176 indicating that there is a positive autocorrelation. High stunting area will be surrounded by high areas as well, and low stunting area will be surrounded by low areas as well. Based on the results of local Moran's I test which is visualized in Figure 3, it can be seen that there is significant spatial autocorrelation in high stunting areas.

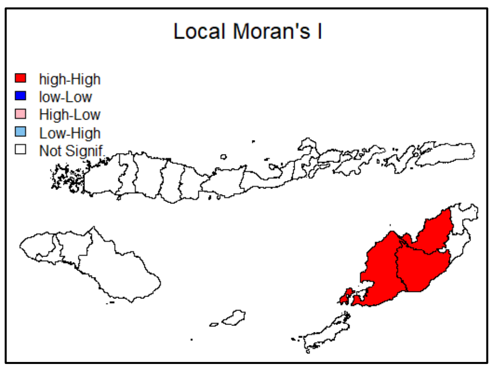

Figure 3. Local Moran's I

Table 4. Lagrange Multiplier (LM) test result

Statistic test	p-value
LM_{err}	0.264
LM_{lag}	0.029

The Lagrange multiplier test of the spatial lag (SAR) model is significant, as shown in Table 4. The maximum likelihood estimator will be used to estimate the parameter model. Table 5 illustrates the result of parameter estimation using the following equation:

$$\hat{y}_i = 0.446 \sum_{j=1, i \neq j}^{n} w_{ij} y_j + 0.225 + 0.86 \log(X_{1i}) + 0.016X_{2i} - 0.006X_{3i} + 0.0002X_{4i} - 0.456X_{5i} - 0.005X_{6i} + 0.009X_{7i}$$

Table 5: Model parameter estimation results

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	0.225	1.195	0.188	0.851
Log(X_1): log-undernourished	0.86	0.055	15.703	0.000
X_2: surface water	0.016	0.007	2.262	0.024
X_3: wells	-0.006	0.002	-3.895	0.000
X_4: population density	0.0002	0.000	2.109	0.034
X_5: economic growth	-0.456	0.119	-3.822	0.000
X_6: education	-0.005	0.004	-1.256	0.209
X_7: poverty	0.009	0.006	1.531	0.126
Rho	0.446			
LR test value: 5.656, p-value: 0.017				
Asymptotic standard error: 0.159				
z-value: 2.816, p-value: 0.005				
Wald statistic: 7.929, p-value: 0.005				
AIC: -13.644				

Table 6. Akaike Information Criterion (AIC) and Likelihood Ratio (LR) test result

Model	**df**	**AIC**	**logLik**	**Test**	**L. Ratio**	**p-value**
SAR	0.264	-13.644	16.822	1		
Multiple linier regression	0.029	-9.989	13.994	2	5.656	**0.017**

According to the results in Tables 5 and 6, the probability value of the LR test is 0.017, indicating that adding the lag to the model improves it and may result in a decrease in the AIC value. Because the AIC of the SAR model is smaller than that of the multiple regression model, the SAR model is preferable to multiple regression for analyzing the relationship between predictors and stunting cases in NTT province. The value of Rho is 0.446 and the probability of the Wald test is 0.005, indicating that the relationship between stunting and all predictor variables is spatially dependent. Simultaneously, all predictor variables and the spatial lag all contribute significantly to stunting in NTT province. While the test results indicate that the lag is a useful addition, it complicates reading the remainder of the model's parameter estimation in Table 5. Partially, undernourished variable (X_1), surface water (X_2), wells (X_3), population density (X_4), and economic growth (X_5) have a significant effect on stunting rate in NTT province at significance level 0.05 of alpha. These five predictors will be interpreted using the impact measure in Table 7. Education and poverty variables do not have a significant effect on stunting in NTT province.

Table 7. Direct and indirect impact measure of SAR model

	Direct impact	**p-value of direct impact**	**Indirect**	**p-value of indirect impact**	**Total**	**p-value of total impact**
Log(X_1) : log-undernourished	0.882	0.000	0.671	0.254	1.554	0.023
X_2: surface water	0.016	0.029	0.012	0.318	0.028	0.116
X_3: wells	-0.006	0.000	-0.005	0.416	-0.011	0.173
X_4: population density	0.0002	0.029	0.000	0.371	0.000	0.156
X_5: economic growth	-0.468	0.000	-0.356	0.364	-0.824	0.116
X_6: education	-0.005	0.159	-0.004	0.487	-0.008	0.307
X_7: poverty	0.009	0.151	0.007	0.483	0.015	0.313

The impact of covariates that are quantified in Table 7 represents the global average. Direct impact refers to changes that occur locally in an area as a result of changes in a predictor. Indirect impact refers to the spill-over effect, which occurs when predictor variables in the surrounding area change. Additionally, total impact refers to the changes that occur in an area as a result of changes in the area and its surroundings. Five predictor variables have a significant direct effect on stunting cases, but none have an indirect effect. The following table summarizes the direct impact of these five predictors. In NTT province, the undernourished variable has a direct effect on increasing stunting. Each unit increase in the natural logarithm of undernourished toddlers in an area increases the natural logarithm of stunted toddlers in that area by 0.882 units. In the NTT province, malnutrition has the greatest direct effect on increasing stunting. Economic growth has a direct and significant effect on stunting reduction in NTT province. Each percent increase in economic growth reduces the natural logarithm of stunted toddlers in that area by 0.468 units. Accelerating economic growth may be one strategy for reducing stunting in NTT province. In NTT province, population density has the smallest and most significant direct effect on stunting. Each unit increase in population density increases the natural logarithm of stunted toddlers by 0.0002 units in that area. The household variable indicating that the primary source of bathing, washing, and cooking is surface water (rivers/lakes/reservoirs/irrigation ponds) has a significant direct effect on increasing stunting. Each additional 1% of households that use surface water increases the natural logarithm of stunted toddlers in that area by 0.016 units. Utilizing wells as the primary source of drinking water has a direct effect on stunting reduction. Each additional 1% of households in an area that use wells reduces the natural logarithm of stunted toddlers in that area by 0.006 units. The diagnostic check performed on the SAR model in Table 8 demonstrates that the normality, non-autocorrelation, and homogeneity assumptions are satisfied.

Table 8. Diagnostic checking of SAR model

Statistic test	p-value
LM test for residual autocorrelation	0.056
Shapiro-Wilk	0.124
Breusch-Pagan	0.832

Because R shiny is built directly from R software, its development results are freely accessible. Due to the fact that R is a free piece of software with an open source code, it can be shared and improved by users who wish to do so [5]. statistikterapan.shinyapps.io/Spatial_Econometrics/ is the URL for the developed of R shiny. This tool assists users in data processing, provides efficient and accurate results, and does so by minimizing errors in formulating R code for spatial econometric model analysis. This tool is lacking in the area of map creation. Users can only create maps using pre-existing files in R. While this tool does not allow users to create maps outside of R using shape files, it does allow users to analyze each step of the analysis of social econometric models using coordinates saved in CSV format. Figure 4 illustrates the menus contained within this R shiny of SAR.

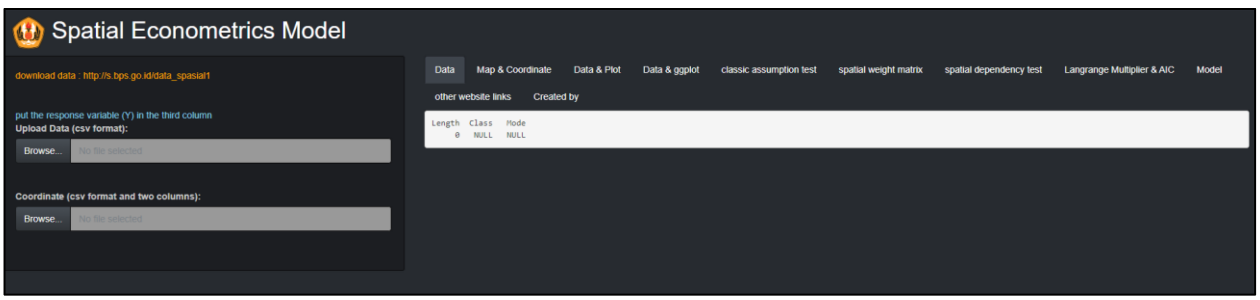

Figure 4. R shiny development result

3. CONCLUSION

Stunting cases in NTT province exhibit spatial autocorrelation. The spatial econometric model that can be used to analyze is the spatial lag model, based on the result of the Lagrange multiplier test (SAR). The R shiny program that can be freely accessed at https://statistikterapan.shinyapps.io/Spatial_Econometrics/ contains used to estimate the model parameters. Because the undernourished variable has the greatest effect on stunting in NTT toddlers, it is critical to increase awareness of the nutritional needs of NTT toddlers. Additionally, water use, economic growth, and population density all have a significant effect on stunting in NTT province. Economic growth is one of the most important variables affecting stunting rates in NTT province.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

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