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MODELLING THE PREVALENCE OF MALNUTRITION TODDLERS USING BAYESIAN SEMIPARAMETRIC REGRESSION

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Abstract: The malnutrition toddler is caused by low consumption of energy and protein and other socio-economic variables. The units of analysis in this study are all provinces in Indonesia. This study uses five explanatory variables which are indicated to have an effect on increasing or decreasing the weight of toddlers. Based on the preliminary exploration of data, the Bayesian Semiparametric model was considered. The results showed that complete basic immunization and education variables had a negative effect on the malnutrition. Therefore, the more toddlers who received complete basic immunization and the more educated the population in an area, the incidence of malnutrition could be reduced. The results of this study also found that birth weight and exclusive breastfeeding had no effect on malnutrition. This can happen because malnutrition can be prevented by improving the nutrition of toddlers even though, at birth, they have low body weight, and vice versa, malnutrition can occur in toddlers even though they are

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exclusively breastfed when they are under six months old. The variable of poverty has a positive effect on increasing the malnutrition.

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2010 AMS Subject Classification: 93A30, 62G05, 92C60.

1. INTRODUCTION

In 2019 Indonesia ranked the second-highest for the prevalence of malnutrition among 17 countries in the Southeast Asia and Pacific region, which was 12.1% [1]. Currently, the Government of Indonesia has a target to reduce the prevalence of malnutrition, both stunting and wasting, as stated in the 2020-2024 National Medium-Term Development Plan (RPJMN) [2], [3]. The province with the highest prevalence of malnutrition toddlers is Papua Barat, while the province with the lowest percentage is Bengkulu [1]. Fulfillment of child nutrition has become a top priority in Indonesia and is part of the commitment to the Sustainable Development Goals (SDGs) to reduce nutritional problems such as low birth weight, malnutrition and stunting [4]. Currently, other challenges arise with the outbreak of COVID-19, where it can threaten the process of monitoring the growth of toddlers by health workers. Therefore, monitoring the growth of toddlers during the COVID-19 pandemic must continue to be carried out through various alternative efforts to ensure that toddlers can still be monitored for their growth and development [1].

Factors that influence the prevalence of malnutrition are socio-economic status, mother's knowledge, low birth weight (LBW), breastfeeding, and immunization [5]–[12]. Healthy toddlers will not lose their appetite so that their nutritional status remains good [8]. In addition to these five factors, there are several other factors that influence the condition of malnutrition toddlers. These factors are protein intake, family parenting, and growth monitoring [13], [14]. Education is one of the factors of high cases of malnutrition toddlers. The low level of knowledge of parents, especially mothers, is the most important underlying factor due to the requirement of nutrition toddlers depend on their family [15]. Knowledge of a mother is needed in the care of her child, in terms of giving and providing food, so that a child does not suffer from being malnutrition. Malnutrition can be caused due to the selection of food ingredients that are not correct. The choice of food is influenced by the mother's level of knowledge about food ingredients. Ignorance can lead to errors in food selection and processing, even though food ingredients are available. Lack of knowledge about nutrition or the ability to apply this information in daily life is an important cause of nutritional disorders [12].

The prevalence of malnutrition in Indonesia is still quite high, so efforts are needed to overcome this problem. One of the efforts that can be done is to find out the factors and the magnitude of their effect on the prevalence of malnutrition in Indonesia through regression model analysis. Regression models that can be used is the Bayesian semiparametric regression model. This model is able to accommodate the pattern of relationships between explanatory variables and response variables that are linear or non-linear. Research on the malnutrition using Bayesian semiparametric regression analysis has been conducted by Tilahun and Derbachew (2015) in Gamo Gofa, Ethiopia. This study analyzes the determinant of the prevalence of malnutrition toddlers in Indonesia using Semiparametric Bayesian modeling which is developed by researchers previously.

2. METHOD

This study uses data from the Health Ministry and the Central Bureau of Statistics in 2020. All data are taken from the public domain and health profile of Indonesia. This study uses one response variable and five explanatory variables that show in Table 1 below:

Table 1. Response variable and five explanatory variables

notation	Variables	Variable’s definition
y	The prevalence of malnutrition toddlers	toddlers whose weight per age is less than minus 3 times the standard deviation of body weight of toddlers at the same age.
x_1	The percentage of low birth weight (LBW)	Low Birth Weight (LBW) is a baby born weighing less than 2500 g.

notation	Variables	Variable’s definition
x_2	The percentage of toddlers who are exclusively breastfed	toddlers who are exclusively breastfed is babies who are breastfed until the age of six months
x_3	The percentage of toddlers who received complete immunization	toddlers who received complete immunization before the age of one year.
x_4	Average length of school	the number of years used by the population of 25 years and over in formal education
x_5	The percentage of poor people	the inability from an economic point of view to meet basic food and non-food needs as measured from the expenditure side

The statistical analysis in this study is based on a Bayesian approach which allows a framework for realistically complex models. Bayesian methods have become popular in modern statistical analysis and are being applied to a wide spectrum of scientific and research fields. Bayesian data analysis involves the inference of data using probability models for observed quantities and for quantities to be studied or in other words analyzing statistical models by combining prior knowledge about the model or model parameters. If a researcher is not sure of the true value of the parameter to be estimated in the model, then the parameter is considered a random variable that has a certain distribution. Therefore, this study uses a Bayesian approach to estimate the parameters in the model. The stage of this study is explained in the flowchart in Figure 1.

Semiparametric regression is one of the statistical methods used to determine the pattern of the relationship between response variables and predictors where some of the patterns are known, and some are unknown, consisting of parametric regression $\mathbf{X\beta}$ and nonparametric regression $\mu(x_i)$. Semiparametric regression is a combination of parametric and nonparametric regression [16], the following is a semiparametric model:

$$y_i = \beta_0 + \beta x_{1i} +, \dots, \beta x_{Ki} + \mu(x_i) + \varepsilon_i, \; i = 1, 2, \dots, n \quad (1)$$

where K is the number of variables and x is the covariate. Equation (1) above can be rewritten with the following formula:

$$\mathbf{y} = \mathbf{X\beta} + \mu(x) + \boldsymbol{\varepsilon} \quad (2)$$

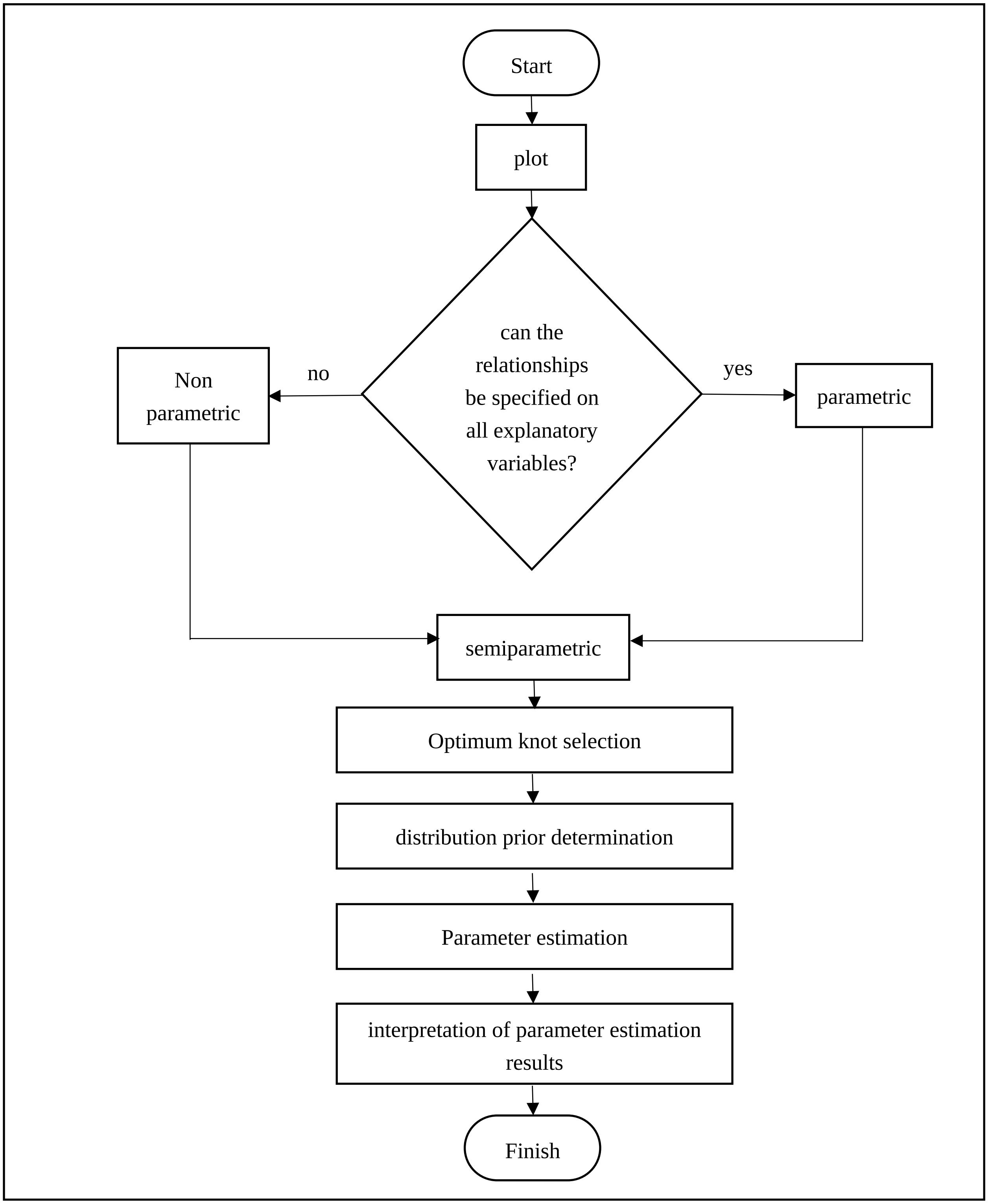


Figure 1. Research flowchart

The first step that must be done is the selection of optimum knots. The knot points are the controller of the balance between the smoothness of the curve and the suitability of the curve to the data. The selection of the number of knot points can be done using the Generalized Cross Validation (GCV) method. The selection of the number of knot points and the location of the optimum knot points is done by looking at the minimum GCV value.

In the R package BNSP (Bayesian non and semiparametric), Bayesian regression models with Gaussian errors and with mean and log-variance functions can be modeled as general functions of the covariates [17], so because covariates x can be modeled in general terms, eq. (2) can be rewritten as follows:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \tag{3}$$

Eq. 3 can be rewritten by separating the intercept and the regression coefficient vector of covariates as follows:

$$\mathbf{y} = \beta_0 \mathbf{1}_{\boldsymbol{n}} + \mathbf{X}\boldsymbol{\beta}_{\mathbf{1}} + \boldsymbol{\varepsilon} \tag{4}$$

where $\mathbf{y} = (y_1, \dots, y_n)^\top$ is the vector of response variable, $\mathbf{X} = [x_{k1}, \dots, x_{kn}]^\top$ is denote design matrices, $\mathbf{1}_n$ is the n-dimensional vector of ones, β_0 is an intercept term, $\boldsymbol{\beta}_{\mathbf{1}}$ is a vector of regression coefficients and $\boldsymbol{\varepsilon} = (\varepsilon_1, \dots, \varepsilon_n)^\top$ is an n-dimensional vector of independent random errors. Each ε_i, $i = 1, 2, \dots, n$, is assumed to have a normal distribution, $\varepsilon_i \sim N(0, \sigma_i^2)$, with variances that are modeled in terms of covariates. Let $\boldsymbol{\sigma}^2 = (\sigma_i^2, \dots, \sigma_n^2)^\top$. The model of the variance vector is as follows [17]:

$$\log(\sigma^2) = \alpha_0 \mathbf{1}_n + \mathbf{Z}\boldsymbol{\alpha}_{\mathbf{1}} \tag{5}$$

where α_0 is an intercept term, $\boldsymbol{\alpha}_1$ is a vector of regression coefficients, and $\mathbf{Z} = [z_{k1}, \dots, z_{kn}]^\top$ is denote design matrices. Equivalently, the model for the variances can be expressed as [17]:

$$\log(\sigma_i^2) \quad = \alpha_0 + \boldsymbol{z}_i^\top \boldsymbol{\alpha}_1, \; i = 1, 2, \dots, n$$

$$\sigma_i^2 \quad = \exp(\alpha_0 + \boldsymbol{z}_i^\top \boldsymbol{\alpha}_1)$$

$$\sigma_i^2 = \exp(\alpha_0) \times \exp\,(\boldsymbol{z}_i^\top \boldsymbol{\alpha}_1)$$

with $\sigma^2 = \exp(\alpha_0)$ [17] then,

$$\sigma_i^2 = \sigma^2 \exp\,(\boldsymbol{z}_i^\top \boldsymbol{\alpha}_1) \tag{6}$$

Let $\boldsymbol{D}\,(\boldsymbol{\alpha})$ denote an n-dimensional, diagonal matrix with elements $\exp\left(\frac{\boldsymbol{z}_i^\top \boldsymbol{\alpha}_1}{2}\right), i = 1, 2, \dots, n$. Then, the model in eq. (4) can be expressed as [17]

$$\mathbf{y} = \mathbf{X}^* \boldsymbol{\beta} + \boldsymbol{\varepsilon}, \quad \boldsymbol{\varepsilon} \sim N\left(\mathbf{0}, \sigma^2 \boldsymbol{D}^2(\boldsymbol{\alpha})\right) \tag{7}$$

where $\boldsymbol{\beta} = [\beta_0, \boldsymbol{\beta}_1]$ and $\mathbf{X}^* = [\mathbf{1}_n, \mathbf{X}]$.

Locally adaptive models for the mean and variance functions (general functions of the covariates) are obtained utilizing the methodology developed by Chan et al. (2006) [17]. The mean function $\mathbf{y}$ is achieved by utilizing a large number of basis functions, q_1. Over-fitting, and problems associated with it, is avoided by allowing positive prior probability that the regression coefficients are exactly zero [17]. The latter is achieved by defining binary variables $\gamma_j, j = 1, \dots, q_1$, that take value $\gamma_j = 1$ if $\beta_j \neq 0$ and $\gamma_j = 0$ jika $\beta_j = 0$ [17]. Hence, vector $\boldsymbol{\gamma} = (\gamma_1, \dots \gamma_{q_1})^\top$ determines which terms enter the mean model. The vector of indicators $\boldsymbol{\delta} = (\delta_1, \dots, \delta_{q_2})^\top$ for the variance function is defined analogously. Semiparametric model in eq. (7) can be written as [17]:

$$\mathbf{y} = \mathbf{X}_\gamma^* \boldsymbol{\beta}_\gamma + \boldsymbol{\varepsilon}, \quad \boldsymbol{\varepsilon} \sim N\left(\mathbf{0}, \sigma^2 \boldsymbol{D}^2(\boldsymbol{\alpha}_\delta)\right) \tag{8}$$

where $\boldsymbol{\beta}_\gamma$ consisting of all non-zero elements of $\boldsymbol{\beta}_1$ and $\mathbf{X}_\gamma^*$ consists of the corresponding columns of $\mathbf{X}^*$. Sub vector $\boldsymbol{\alpha}_\delta$ is defined analogously.

Let $\widetilde{\mathbf{X}} = \mathbf{D}(\boldsymbol{\alpha})^{-1}\mathbf{X}^*$. The prior for $\boldsymbol{\beta}_\gamma$ is specified as (Zellner, 1986) [17]

$$\boldsymbol{\beta}_\gamma | c_\beta, \sigma^2, \boldsymbol{\gamma}, \boldsymbol{\alpha}, \boldsymbol{\delta} \sim \mathrm{N}(\mathbf{0}, c_\beta \sigma^2\, (\widetilde{\mathbf{X}}_\gamma^\top \widetilde{\mathbf{X}}_\gamma)^{-1}) \tag{9}$$

The prior for $\boldsymbol{\alpha}_\delta$ is specified as [17]:

$$\boldsymbol{\alpha}_\delta|c_a, \boldsymbol{\delta} \sim N(\mathbf{0}, c_a\mathbf{I}) \tag{10}$$

Independent priors are specified for the indicator variables γ_j as $P\big(\gamma_j = 1\big|\pi_\mu\big) = \pi_\mu, j = 1, \dots,$ q_1, from which the joint prior is obtained as

$$P\big(\boldsymbol{\gamma}\big|\pi_\mu\big) = \pi_\mu^{N(\gamma)}(1-\pi_\mu)^{q_1-N(\gamma)} \tag{11}$$

where $N(\gamma) = \sum_{j=1}^{q_1}\gamma_j$ Similarly, for the indicators δ_j specified independent priors$P\big(\delta_j = 1\big|\pi_\sigma\big) = \pi_\sigma, j = 1, \dots, q_2$. It follows that the joint prior is [17]

$$P(\boldsymbol{\delta}\,|\pi_\sigma) = \pi_\sigma^{N(\delta)}(1-\pi_\sigma)^{q_2-N(\delta)}, \tag{12}$$

where $N(\delta) = \sum_{j=1}^{q_2}\delta_j$. Inverse Gamma priors for C_β and C_α and Beta prior for π_μ and π_σ [17]:

$$C_\beta \sim \mathrm{IG}\big(\alpha_\beta, b_\beta\big), c_a \sim \mathrm{IG}(a_a, b_a), \tag{13}$$

$$\pi_\mu \sim \mathrm{Beta}\big(c_\mu, d_\mu\big), \pi_\sigma \sim \mathrm{Beta}(c_\sigma, d_\sigma) \tag{14}$$

lastly, for σ^2 specified inverse Gamma and half-normal priors [17]:

$$\sigma^2 \sim \mathrm{IG}(a_\sigma, b_\sigma) \text{ and } |\sigma| \sim N(0, \phi_\sigma^2) \tag{15}$$

The mean model from eq. (4) with single covariate can be formulated as follows [17]:

$$\begin{aligned}\mu_i &= \beta_0 + \mathbf{x}_i^{\mathrm{T}}\boldsymbol{\beta}_\mathbf{1} \\ &= \beta_0 + \sum_{j=1}^{q_1}\beta_j\,\phi_{1j}(u_i) \\ &= \beta_0 + f_\mu(u_i)\end{aligned} \tag{16}$$

so, the mean model in eq. (16) can be extended for the multiple covariates to the following [17]:

$$\mu_i = \beta_0 + \mathbf{u}_{ip}^{\top}\boldsymbol{\beta} + \sum_{k=1}^{K_1} f_{\mu,k}\,(u_{ik}), i = 1, \dots, n, \tag{17}$$

where $\mathbf{u}_{ip}^{\top}$ includes the covariates the effects of which are modeled parametrically, $\boldsymbol{\beta}$ denotes the corresponding effects, and $f_{\mu,k}(u_{ik})$, $k = 1, \dots, K_1$, are flexible functions of one or more covariates expressed as [17]:

$$f_{\mu,k}(u_{ik}) = \sum_{j=1}^{q_{1k}} \beta_{kj}\, \phi_{1kj}(u_{ik}), \tag{18}$$

where $\phi_{1kj}, j = 1, \dots, q_{1k}$ are the basis functions used in the kth component. The variance function of eq. (4) is clearly found in Papageorgiou (2019). In this study, we just focus on the mean function.

3. Result and Discussion

In 2020, the average percentage of malnutrition toddlers in Indonesia is 1.179%. The province with the lowest percentage of malnutrition toddlers is in the Bangka Belitung Islands (0.1%), and the highest is in Papua Barat (2.9%). Low birth weight (LBW) is one of the causes of malnutrition toddlers. Birth weight is a sign that there is a nutritional problem during pregnancy that causes the fetus to fail to grow properly. The consequences of LBW continue into adulthood, increasing the risk of chronic conditions such as obesity and diabetes [11]. The average percentage of LBW toddlers in Indonesia is 3.368%. The province with the lowest percentage of LBW toddlers is in Riau at 0.8%, and the highest is in Nusa Tenggara Timur (NTT) at 6.9%. The plot between malnutrition toddlers and LBW is as follows:

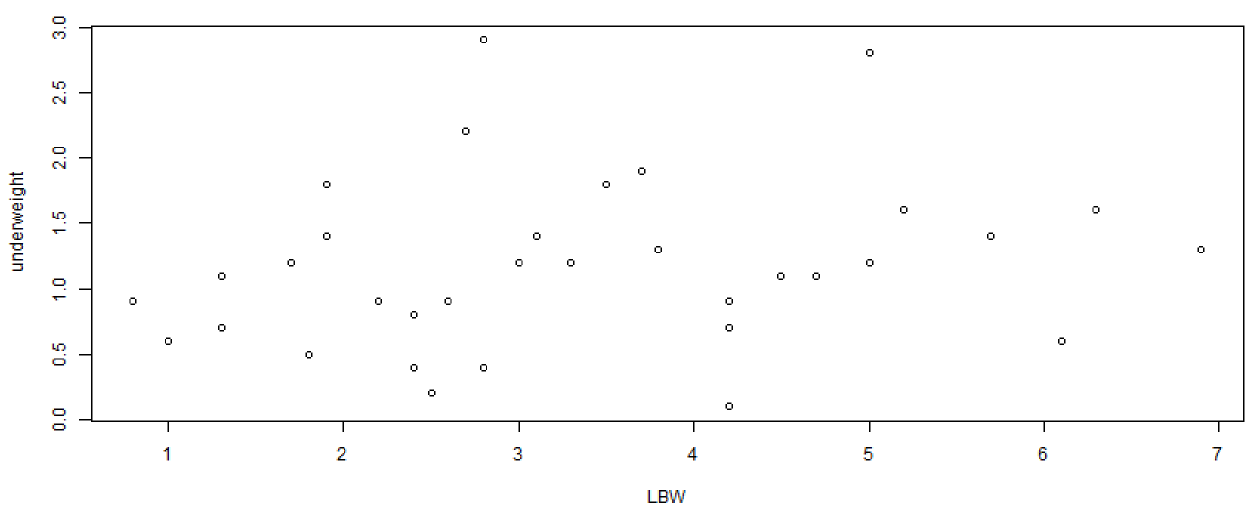
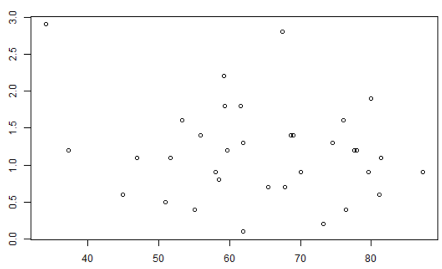
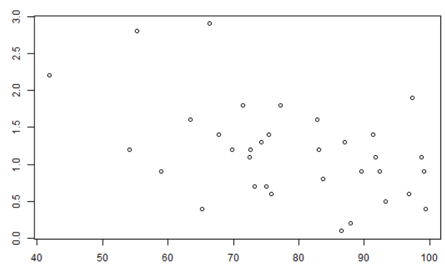


Figure 1. Scatter plot between malnutrition toddlers and LBW

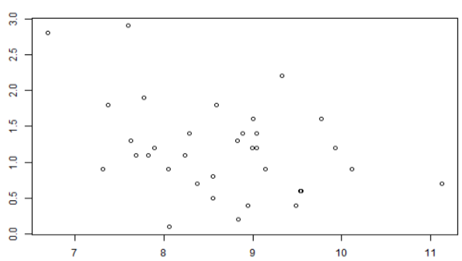
Figure 1 shows that the relationship between malnutrition toddlers and LBW is difficult to specify parametrically. This also occurs in three other explanatory variables, namely breastfeeding, immunization, and education variables which are shown in Figure 2 (a, b, and c). The poverty variable in Figure 2 (d) gives a pattern that tends to increase, so that poverty can increase cases of malnutrition toddlers.



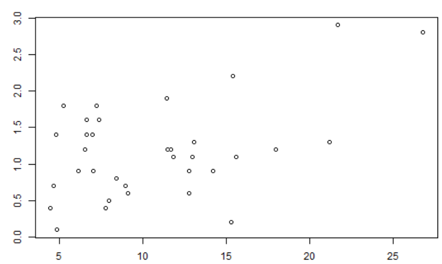
(a) breastfeeding



(b) immunization



(c) education



(d) poverty

Figure 2. Scatter plot between response variable and explanatory variables

Based on the plots in Figures 1 and 2, it can be seen that a semiparametric model is needed to answer the effect of each explanatory variable on malnutrition toddlers in Indonesia.

Exclusive breastfeeding for infants has been regulated by the government in law number 33 of 2012. The average percentage of infants who are exclusively breastfed in Indonesia is 64.21%. The province with the highest percentage of infants receiving exclusive breastfeeding is in Nusa Tenggara Barat (NTB) at 87.3%. This shows that the government regulations have not been implemented 100% in all provinces in Indonesia.

The province with the lowest percentage of infants receiving exclusive breastfeeding is in Papua Barat at 34%, where this province also has a high percentage of malnutrition toddlers. Exclusive breastfeeding has a significant effect on cases of malnutrition toddlers [18]. This shows that the absence of exclusive breastfeeding is one of the causes of the high malnutrition toddlers' rate in Papua Barat.

Completeness of immunization also has a significant relationship with malnutrition toddlers because immunization provides immune substances to toddlers so that they are not susceptible to disease. Healthy toddlers will not lose their appetite so that their nutritional status remains good [8]. The average percentage of infants receiving complete basic immunization in Indonesia is 78.55%, which is still below the government's target of 79.1% [19]. The province with the highest percentage is in the province of Bali at 99.4%, and the lowest is in Aceh at 41.8%.

Knowledge is very closely related to education, where someone with higher education is expected to have more extensive knowledge [20]. The average length of schooling in Indonesia is 8,649 years. The province with the highest percentage was in Jakarta at 11.13 years and the lowest was in Papua at 6.69 years. In line with research by Jamra, V. & Bankwar (2013), the results showed that 22.1% of children suffered from malnutrition caused by various factors, one of which was low parental education.

The level of education in the family, especially the mother, can affect the health status because the mother's education affects the quality of child care. The higher the level of education, the easier it will be to capture information obtained from formal or non-formal media. So that the higher the education level of the mother, the less the possibility of toddlers experiencing malnutrition. On the other hand, the lower the education level of the mother, the greater the risk of experiencing malnutrition [21].

Low economic problems are one of the most dominant factors experienced by many families. In meeting the nutritional needs of children, many parents find it difficult, the cause is a weak economic situation, insufficient income from work and expensive food prices. In fact, the critical period of malnutrition experienced by children occurs between the ages of one to three years [10].

The average percentage of poverty in Indonesia is 10.806%. The province with the highest percentage is in Papua at 26.8% and the lowest is in Bali at 4.45%.

The selection of optimum knots using the GCV method was carried out to smooth the curves in Figures 1 and 2 which can describe the effect of each explanatory variable on malnutrition toddlers in Indonesia. The results of selecting the optimum knots are as follows:

Table 2. The results of optimum knot selesction using GCV method

Variable	knot
LBW (x_1)	5
Breastfeeding (x_2)	5
Immunization (x_3)	5
Education (x_4)	7
Poverty (x_5)	5
GCV	0,333

From the results of selecting the optimum knots in table 2, the mean model of Bayesian semiparametric to be estimated is as follows:

$$\hat{\mu}_i = \hat{\beta}_0 + \hat{\beta}_1 x_{i1} + \hat{\beta}_2 x_{i2} + \cdots + \hat{\beta}_5 x_{i5} + \sum_{k=1}^{5} \sum_{j=1}^{q_{1k}} \hat{\beta}_{kj} \phi_{kj}(x_{ik}) \tag{19}$$

with $q_{11} = q_{12} = q_{13} = q_{15} = 5$, $q_{14} = 7$, and $i = 1, \dots, n$.

Tabel 3. The result of estimation parameter using BNSP method

	LBW (x_1)	Breastfeeding (x_2)	Immunization (x_3)	Education (x_4)	Poverty (x_5)
Intercept	1,138				
β_k	$-4{,}599 \times 10^{-4}$	$-3{,}478 \times 10^{-4}$	$-2{,}066 \times 10^{-3}$	$-9{,}832 \times 10^{-3}$	$2{,}942 \times 10^{-3}$
β_{k1}	$5{,}903 \times 10^{-4}$	$-4{,}057 \times 10^{-6}$	$-2{,}245 \times 10^{-6}$	$-3{,}679 \times 10^{-4}$	$-3{,}095 \times 10^{-5}$

	LBW (x_1)	Breastfeeding (x_2)	Immunization (x_3)	Education (x_4)	Poverty (x_5)
β_{k2}	$-8{,}981 \times 10^{-4}$	$4{,}736 \times 10^{-7}$	$-1{,}112 \times 10^{-6}$	$-2{,}047 \times 10^{-4}$	$3{,}733 \times 10^{-5}$
β_{k3}	$4{,}459 \times 10^{-5}$	$9{,}361 \times 10^{-6}$	$3{,}3 \times 10^{-6}$	$-1{,}591 \times 10^{-3}$	$7{,}474 \times 10^{-5}$
β_{k4}	$-1{,}645 \times 10^{-3}$	$6{,}077 \times 10^{-6}$	$7{,}198 \times 10^{-6}$	$-9{,}086 \times 10^{-4}$	$7{,}773 \times 10^{-6}$
β_{k5}	$2{,}421 \times 10^{-5}$	$-4{,}694 \times 10^{-6}$	$8{,}49 \times 10^{-6}$	$3{,}921 \times 10^{-3}$	$1{,}28 \times 10^{-6}$
β_{k6}				$6{,}263 \times 10^{-3}$	
β_{k7}				$2{,}099 \times 10^{-3}$	

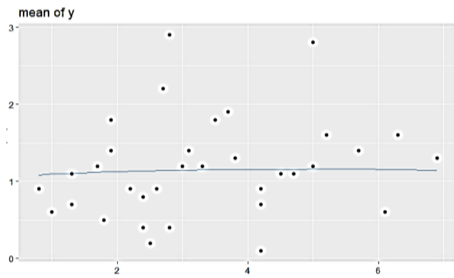
Based on the parameter estimation results in table 3, eq.19 can be written as follows:

$$
\begin{aligned}
\hat{\mu}_i = {} & 1{,}138 - (4{,}599 \times 10^{-4})x_{i1} - (3{,}478 \times 10^{-4})x_{i2} - (2{,}066 \times 10^{-3})x_{i3} \\
& - (9{,}832 \times 10^{-3})x_{i4} + (2{,}942 \times 10^{-3})x_{i5} \\
& +\{(5{,}903 \times 10^{-4})\phi_{111}(x_{i1}) - (8{,}981 \times 10^{-4})\phi_{112}(x_{i1}) + (4{,}459 \times 10^{-5})\phi_{113}(x_{i1}) \\
& - (1{,}645 \times 10^{-3})\phi_{114}(x_{i1}) + (2{,}421 \times 10^{-5})\phi_{115}(x_{i1})\} \\
& -\{(4{,}057 \times 10^{-6})\phi_{121}(x_{i2}) + (4{,}736 \times 10^{-7})\phi_{122}(x_{i2}) + (9{,}361 \times 10^{-6})\phi_{123}(x_{i2}) \\
& + (6{,}077 \times 10^{-6})\phi_{124}(x_{i2}) - (4{,}694 \times 10^{-6})\phi_{125}(x_{i2})\} \\
& -\{(2{,}245 \times 10^{-6})\phi_{131}(x_{i3}) - (1{,}112 \times 10^{-6})\phi_{132}(x_{i3}) + (3{,}3 \times 10^{-6})\phi_{133}(x_{i3}) \\
& + (7{,}198 \times 10^{-6})\phi_{134}(x_{i3}) + (8{,}49 \times 10^{-6})\phi_{135}(x_{i3})\} \\
& -\{(3{,}679 \times 10^{-4})\phi_{141}(x_{i4}) - (2{,}047 \times 10^{-4})\phi_{142}(x_{i4}) - (1{,}591 \times 10^{-3})\phi_{143}(x_{i4}) \\
& - (9{,}086 \times 10^{-4})\phi_{144}(x_{i4}) + (3{,}921 \times 10^{-3})\phi_{145}(x_{i4}) \\
& + (6{,}263 \times 10^{-3})\phi_{146}(x_{i4}) + (2{,}099 \times 10^{-3})\phi_{147}(x_{i4})\}
\end{aligned}
$$

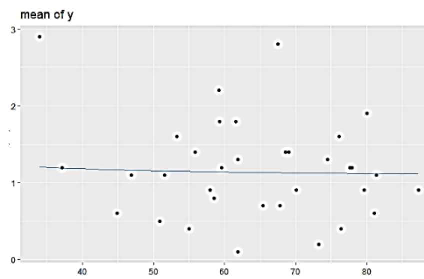
$$-\{(3{,}095 \times 10^{-5})\phi_{151}(x_{i5}) + (3{,}733 \times 10^{-5})\phi_{152}(x_{i5}) + (7{,}474 \times 10^{-5})\phi_{153}(x_{i5})$$

$$+ (7{,}773 \times 10^{-6})\phi_{154}(x_{i5}) + (1{,}28 \times 10^{-6})\phi_{155}(x_{i5})\}$$

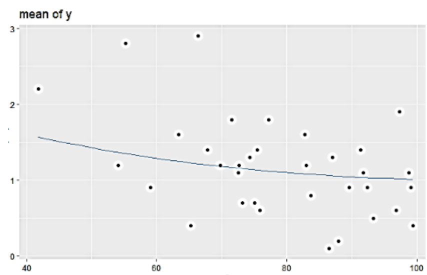
The effect of each explanatory variable can be done by looking at the following figure:



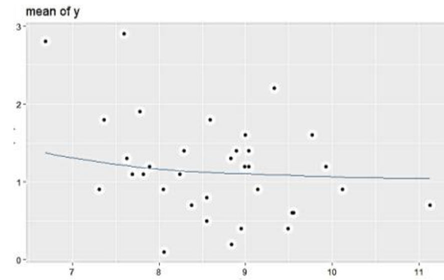
(a) LBW



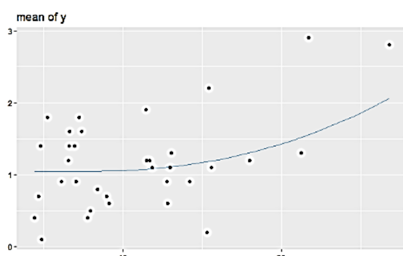
(b) breastfeeding



(c) immunization



(d) education



(e) poverty

Figure 3. Relationship between malnutrition and each explanatory variable

Figures 3(a) and 3(b) show that LBW and exclusive breastfeeding have no effect on malnutrition, as well as the research conducted by Oktavia and Widajanti (2019) which showed there was no relationship between LBW and malnutrition. Malnutrition in infants under the age of six months can occur in the womb or after birth, or as a result of congenital diseases/disorders.

Prevention of malnutrition in this group is often long-term and indirect, because it is related to the health status and condition of the mother before/during pregnancy and during breastfeeding as well as other risk factors. If a congenital disease/disorder is found, the baby needs to be referred immediately for adequate and timely service. Children who have low birth weight but as long as the child gets adequate intake, maintains health, and takes short-term prevention by giving colostrum/IMD and meeting the needs of breastfeeding (exclusive breastfeeding), then by understanding the interrelationships of various risk factors and the impact of deficiency problems nutrition since in the womb, efforts to prevent malnutrition can be carried out in a more focused manner [22].

Complete basic immunization has a negative effect on malnutrition, so that more children under five who receive complete basic immunization will reduce the incidence of malnutrition, as well as research by Kaunang, et al (2016) which shows that completeness of basic immunization affects growth, development, and nutritional status of children under five. This is because the provision of complete basic immunization makes the growth and development of toddlers more optimal, namely healthy toddlers, good cognitive development, and not susceptible to infectious diseases [23]. The condition of healthy toddlers is followed by a good body metabolism on nutritional intake so as to reduce the incidence of malnutrition in toddlers. Toddlers with incomplete basic immunization are at risk of experiencing malnutrition by 2.3 times greater than toddlers with complete basic immunization [24].

Education has a negative effect on malnutrition, where the higher the education of the population, the lower the incidence of malnutrition. This is in accordance with the theory, that the level of education also determines whether or not a person easily absorbs and understands the knowledge they gain, the higher a person's education, the better his knowledge [25]. A similar study was conducted by Anindita (2020) which showed that there was a relationship between mother's education level and malnutrition in toddlers. The low level of education of parents, especially mothers, is the most important underlying factor, because it greatly affects the level of ability of individuals, families and communities in managing existing resources, to obtain adequate food ingredients and the extent to which the available health care facilities, nutrition and environmental sanitation are utilized as well as possible good. Education has the aim of providing assistance to the full development of children [15].

The family's economic ability to meet the nutritional needs of toddlers is one of the determining factors for toddlers experiencing malnutrition. Poverty has a positive influence on malnutrition, so the poorer people, the more the incidence of malnutrition. This is in line with the research of Saputra & Nurizzka (2012) that poverty has implications for sufferers of malnutrition and malnutrition. Several cases of malnutrition that have occurred so far, both in Indonesia and globally, have found that poverty is a big risk for cases of malnutrition. Poor people with lower economic access have the greatest risk of suffering from malnutrition and undernourished children under five [26].

4. CONCLUSION

Based on the results and discussions that have been described previously, it is concluded that the model formed from the relationship between malnutrition and the variables that influence it is a semiparametric model that can be estimated using a Bayesian approach. The variables of complete basic immunization and the average length of schooling have a negative effect on reducing malnutrition, while poverty has a positive effect on increasing malnutrition. Variables of low birth weight and exclusive breastfeeding have no effect on malnutrition.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests.

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