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Modelling The Stunting Prevalence Rate in Indonesia Using Multi-Predictor Truncated Spline Nonparametric Regression

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Abstract

Introduction/Main Objectives: Stunting is the impaired growth and development that children experience from poor nutrition, repeated infection, and inadequate psychosocial stimulation. **Background Problems:** Based on data from the National Nutrition Status Survey (SSGI) in 2022, the prevalence of stunting in Indonesia was 21.6%, which is still above the WHO standard of below 20%. **Novelty:** This study was conducted with the aim of analysing the factors that influence the stunting prevalence rate in Indonesia using multi-predictor truncated spline nonparametric regression. **Research Methods:** The research data is secondary data taken from Health Statistics 2022 with response variables in the form of stunting prevalence. **Finding Result:** Based on the analysis, the best model to model the stunting prevalence rate is a multi-predictor truncated spline with three knots. In addition, it was found that four predictor variables which are the percentage of infants under 6 months old receiving exclusive breastfeeding, the average age of a mother's first pregnancy, the percentage of married women aged 15-49 using contraception, and the percentage of mothers who gave birth to a live child in the past two years and initiated early breastfeeding had a significant effect simultaneously and partially on the stunting prevalence rate in Indonesia.

1. Introduction

The health problem of stunted toddlers in Indonesia remains a serious issue that needs to be addressed by the government and society [1]. Based on data from the National Nutritional Status Survey in 2022 (SSGI), the prevalence of stunting in Indonesia is 21.6%. In 2022, Indonesia became the 10th highest contributor to stunting rates in the Southeast Asia region, based on data from the Asian Development Bank. Even though this figure has decreased from 24.4% in 2021, it is still above 20%, the standard rate according to the WHO. The prevalence of stunting in Indonesia has indeed decreased, but it is still far from the National Medium-Term Development Plan (RPJMN) 2024's target of a 14% reduction [2].

Stunting is a chronic malnutrition disease that occurs in children, often caused by long-term malnutrition. This condition has a serious impact on children's physical, cognitive, and developmental growth and may hinder their ability to achieve optimal productivity as adults [3]. According to World Health Organization (WHO) standards, toddlers are considered stunted if their height is less than minus two standard deviations compared to the average child's growth.

Stunting in toddlers is a chronic nutritional problem caused by many factors, including the mother's nutritional status during pregnancy, the family's socio-economic conditions, the child's health status, and child malnutrition. In such conditions, stunted toddlers will have difficulty achieving optimal physical and cognitive development [4]. Thus, special handling is needed in accordance with the targets of the Indonesian government [5]. Handling stunting is also an important effort in achieving the second point of the Sustainable Development Goals (SDGs), namely "End hunger, achieve food security and improved nutrition, and promote sustainable agriculture" [6].

Many studies on stunting in toddlers have been carried out, including the one using the Geographically Weighted Regression method and Multivariate Adaptive Regression Splines by Alif Yuanita [7]. Based on the study, it was concluded that the factors that influence the prevalence of stunting include the percentage of newborns receiving Early Breastfeeding Initiation (IMD), the percentage of infants receiving exclusive breastfeeding, the percentage of toddlers getting vitamin A, the percentage of toddlers having KMS or KIA books, the percentage of toddlers being weighed four times or more in the last six months, and the percentage of households that use clean water. Apart from that, another research was conducted by Marisa Rifada [8] regarding stunting modelling in toddlers using parametric and non-parametric ordinal logistic regression models [8]. Through a parametric ordinal logistic regression model approach, the study concluded that three variables, namely birth length, mother's height, and health services had a significant effect on stunting in toddlers, with an accuracy rate of 73.98%.

In "The Elements of Statistical Learning" by Hastie, Tibshirani, and Friedman (2009), nonparametric regression is described as a method for predicting the relationship between a dependent variable and an independent variable without assuming a specific functional form. It emphasises the flexibility of nonparametric regression methods that allow the data to determine the shape of the relationships rather than imposing a predetermined model structure [9]. Based on several previous studies that have been carried out, other research is needed to determine the factors that influence the prevalence of stunting in Indonesia based on data obtained from the publication of the Central Bureau of Statistics, namely Statistics Indonesia using a multi-predictor truncated spline nonparametric regression model [10]. This research was carried out using a non-parametric regression method because the data on the prevalence of stunting and the factors suspected to influence it did not form a particular pattern. The function that can be used in nonparametric regression in this research is spline. The spline function is part of a segmental polynomial, so it shows high flexibility and can adapt to the local characteristics of the data [11].

The use of nonparametric spline regression is very effective in handling data samples that show variations in behaviour within certain sub-intervals and has excellent generalisation capabilities in complex and complicated statistical models. [12]. Splines have an advantage in their ability to interpret data patterns according to their movement [13]. Moreover, this modelling uses the truncated concept to limit the response variable, namely the prevalence of stunting to a certain range appropriate to the context. This can help avoid bias that may arise due to outliers or irrelevant data [14].

Based on this description, research is needed to model the prevalence of stunting in Indonesia by taking data by province in 2022 [15]. It is hoped that the results of this modelling will provide a better understanding of the factors that contribute to stunting in Indonesia in 2022 as well as the grouping of provinces in Indonesia based on the best model knots. The modelling in this research is also expected to be a solution in handling stunting in order to achieve the second point of SDGs sustainable development goals, namely to end hunger, achieve food security, and improve the nutrition of Indonesian people.

2. Material and Methods

2.1. Type of Research

This research regarding modelling the prevalence of stunting in Indonesia utilises quantitative research methods. This method emphasises research on certain samples, analysis of quantitative or statistical data, and testing of predetermined hypotheses.

2.2. Location and Time Research

This research regarding modelling the prevalence of stunting in Indonesia was carried out in approximately three months from September to November 2023.

2.3. Data Collection Sources and Strategies

The data used in this research is secondary data on the prevalence of stunting in Indonesia in 2022 which comes from the website katadata.id and the data on factors that influence the prevalence of stunting which come from Health Statistics 2022 and the website bps.go.id.

2.4. Research Variables

The variables used in modelling the prevalence of stunting in Indonesia consist of response and predictor variables. The response variable used is the prevalence of stunting based on provinces in Indonesia in 2022. Meanwhile, the predictor variables used are contributing factors in the prevalence of stunting based on previous research obtained from the Health Statistics 2022. Details of the variables used in the research are aluented in Table 1.

Table 1. Research Variables

Variable	Description	Unit	Measure
Y	The Stunting Prevalence Rate in Indonesia	Percent	Ratio
X_1	Percentage of Infants Under 6 Months of Age Who Received Exclusive Breastfeeding	Percent	Ratio
X_2	Average Age of Mother's First Pregnancy	Year	Ratio
X_3	Percentage of Married Women Aged 15-49 Years Old Currently Using Contraception Methods	Percent	Ratio
X_4	Percentage of Mothers Who Gave Birth to Live-Born Children in the Past Two Years and Initiated Early Breastfeeding	Percent	Ratio

2.5. Operational Definition

Operational definitions of response variable and predictors used in this study are presented in Table 2.

Table 2. Operational Definition of Variable

Variable	Operational Definition
The Prevalence of Stunting	Children aged 0-59 months in the nutritional status category based on the body length index for age (PB/U) have a z-score of less than -2SD.
Percentage of Infants Under 6 Months of Age Who Received Exclusive Breastfeeding	The percentage of infants 0-6 months who are exclusively breastfed is calculated by accumulating the numerator (infants 0-6 months who are exclusively breastfed) and the denominator (the number of infants 0-6 months recorded in the breast-feeding registration register).
Average Age of Mother's First Pregnancy	The average age of a mother's first pregnancy at a certain age.
Percentage of Married Women Aged 15-49 Years Old Currently Using Contraception Methods	The proportion or percentage of the married female population of childbearing age (15-49 years) who use contraception methods.
Percentage of Mothers Who Gave Birth to Live-Born Children (ALH) in	Early initiation of breastfeeding is the process of a baby breastfeeding immediately after birth, where the baby is allowed to look for its mother's nipple on its own.

Variable	Operational Definition
the Past Two Years and Initiated Early Breastfeeding	
Percentage of Children Aged 12-23 Months Who Received Complete Basic Immunisation	The complete basic immunisation that children aged 12-23 months must receive consists of Hepatitis B immunisation four times, BCG once, Polio four times, DPT-HB three times, and Measles once.

2.6. Research Procedures

To model the prevalence rate of stunting in Indonesia and analyse the factors that influence it, it is necessary to carry out a data analysis process through the description and flowchart presented in Figure 1.

1. Look for data regarding the stunting prevalence rate by province in Indonesia in 2022 as well as the factors that influence it.
2. Tabulate raw data in which the response variable is the stunting prevalence rate in Indonesia in 2022 and predictor variables are the factors that affect the stunting prevalence rate.
3. Make a scatter plot to ensure that the data used does not form a particular functional relationship pattern.
4. Try several orders and knot points to find the model with the highest R^2 and minimum Generalised Cross Validation (GCV) value.
5. Choose the best model that has the highest R^2 value and minimum GCV.
6. Interpret the best model that has been obtained.
7. Create data visualisations using maps to map the prevalence of stunting in Indonesia based on the best model that has been obtained.
8. Draw conclusions.
9. Compile research reports and articles.

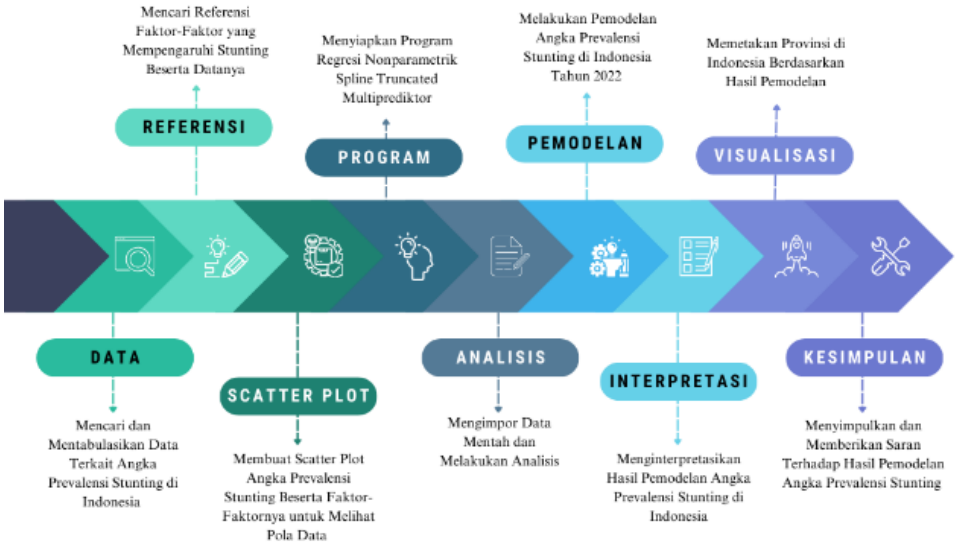

Figure. 1. Research Flow Diagram

3. Results and Discussion

The prevalence rate of stunting in Indonesia in 2022 is shown in Figure 2:

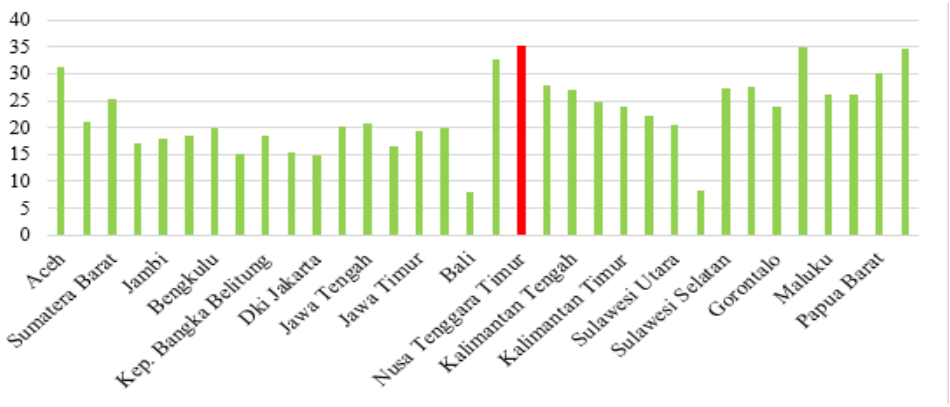

Figure. 2. Stunting Prevalence in Every Province of Indonesia

The province with the lowest stunting prevalence rate is Bali at 8% and the province with the highest stunting prevalence rate is East Nusa Tenggara at 35.3%.

3.1. Regression Model with One Knot Point

The truncated spline nonparametric regression model formed with one knot point and five predictors to model the stunting prevalence rate in Indonesia is as follows.

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 (x_1 - K_1)_+^1 + \hat{\beta}_3 x_2 + \hat{\beta}_4 (x_2 - K_2)_+^1 + \hat{\beta}_5 x_3 + \hat{\beta}_6 (x_3 - K_3)_+^1 + \hat{\beta}_7 x_4 + \hat{\beta}_8 (x_4 - K_4)_+^1 + \hat{\beta}_9 x_5 + \hat{\beta}_{10} (x_5 - K_5)_+^1 \quad (1)$$

Based on equation (1), the GCV and R^2 value obtained for each knot point are presented in Table 3.

Table 3. Measures of Goodness of Fit in Nonparametric Regression Model with One Knot

GCV	R^2	X_1	X_2	X_3	X_4	X_5
38.24	62.21	71.70	22.63	53.89	66.02	65.10
38.37	62.08	72.24	22.69	54.83	66.53	66.36
38.57	61.88	78.63	23.39	66.05	72.58	81.39
38.77	61.69	71.17	22.58	52.96	65.52	63.85
38.80	61.66	73.30	22.81	56.70	67.54	68.86

Based on Table 3, the minimum GCV value is 38.24 with knot points for each predictor variable respectively being 71.7033, 22.6345, 53.8935, 66.0227, 65.1033.

3.2. Equation of Two Knots

The truncated spline nonparametric regression model formed with two knot points and five predictor variables to model the stunting prevalence rate in Indonesia is as follows.

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 (x_1 - K_1)_+^1 + \hat{\beta}_3 (x_1 - K_2)_+^1 + \hat{\beta}_4 x_2 + \hat{\beta}_5 (x_2 - K_3)_+^1 + \hat{\beta}_6 (x_2 - K_4)_+^1 + \hat{\beta}_7 x_3 + \hat{\beta}_8 (x_3 - K_5)_+^1 + \hat{\beta}_9 (x_3 - K_6)_+^1 + \hat{\beta}_{10} x_4 + \hat{\beta}_{11} (x_4 - K_7)_+^1 + \hat{\beta}_{12} (x_4 - K_8)_+^1 + \hat{\beta}_{13} x_5 + \hat{\beta}_{14} (x_5 - K_9)_+^1 + \hat{\beta}_{15} (x_5 - K_{10})_+^1 \quad (2)$$

Based on equation (2), the GCV and R^2 value obtained for each knot point are presented in Table 4.

Table 4. Measures of Goodness of Fit in Nonparametric Regression Model with Two Knots

GCV	R^2	X_1	X_2	X_3	X_4	X_5
37.29	48.32	53.60	20.65	22.10	48.87	22.52
		79.69	23.51	67.92	73.59	83.89
38.24	62.21	53.60	20.65	22.10	48.87	22.52
		71.70	22.63	53.89	66.02	65.10
38.24	62.21	71.70	22.63	53.89	66.02	65.10
		79.69	23.51	67.92	73.59	83.89
38.37	62.08	53.60	20.65	22.10	48.87	22.52
		72.24	22.69	54.83	66.53	66.36
38.37	62.08	72.24	22.69	54.83	66.53	66.36
		79.69	23.51	67.92	73.59	83.89

Based on Table 4, the minimum GCV value obtained is 37.29 with knot points for each predictor variable being 53.6 and 79.69 for variable X_1, 20.65 and 23.51 for variable X_2, 22.1 and 67.92 for variable X_5.

3.3. Three Point Knot Equation

The truncated spline nonparametric regression model formed with three knot points and five predictors to model the stunting prevalence rate in Indonesia is as follows.

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \hat{\beta}_2 (x_1 - K_1)_+^1 + \hat{\beta}_3 (x_1 - K_2)_+^1 + \hat{\beta}_4 (x_1 - K_3)_+^1 + \hat{\beta}_5 x_2 + \hat{\beta}_6 (x_2 - K_4)_+^1 + \hat{\beta}_7 (x_2 - K_5)_+^1 + \hat{\beta}_8 (x_2 - K_6)_+^1 + \hat{\beta}_9 x_3 + \hat{\beta}_{10} (x_3 - K_7)_+^1 + \hat{\beta}_{11} (x_3 - K_8)_+^1 + \hat{\beta}_{12} (x_3 - K_9)_+^1 + \hat{\beta}_{13} x_4 + \hat{\beta}_{14} (x_4 - K_{10})_+^1 + \hat{\beta}_{15} (x_4 - K_{11})_+^1 + \hat{\beta}_{16} (x_4 - K_{12})_+^1 + \hat{\beta}_{17} x_5 + \hat{\beta}_{18} (x_5 - K_{13})_+^1 + \hat{\beta}_{19} (x_5 - K_{14})_+^1 + \hat{\beta}_{20} (x_5 - K_{15})_+^1 \quad (3)$$

Based on equation (3), the GCV value and the R^2 value obtained for each knot point are presented in Table 5.

Table 5. Measures of Goodness of Fit in Nonparametric Regression Model with Three Knot Points

GCV	R^2	X_1	X_2	X_3	X_4	X_5
		61.59	21.53	36.13	56.44	41.31
36.04	88.62	65.31	21.93	42.67	59.97	50.07
		78.63	23.39	66.05	72.58	81.39
		68.51	22.28	48.28	63.00	57.59
36.19	88.57	72.77	22.75	55.76	67.03	67.61
		73.83	22.87	57.63	68.04	70.11
		64.78	21.88	41.74	59.46	48.82
36.26	86.72	66.38	22.05	44.54	60.98	52.58
		66.91	22.11	45.48	61.48	53.83
		67.98	22.23	47.35	62.49	56.34
37.26	88.24	72.77	22.75	55.76	67.03	67.61
		73.83	22.87	57.63	68.04	70.11
		65.31	21.93	42.67	59.97	50.07
37.42	86.30	66.38	22.05	44.54	60.98	52.58
		66.91	22.11	45.48	61.48	53.83

Based on Table 5, the minimum GCV value is 36.04 and the R^2 is 88.62.

3.4. Selection of the Best Model

Next, it is necessary to compare the GCV values to obtain the best model for modelling the stunting prevalence rate in Indonesia which is presented in Table 6.

Table 6. GCV Values for Models with Multiple Knot Points

Number of Knot Points	GCV
One Knot Point	38.24
Two Knot Points	37.29
Three Knot Points	36.04

Based on Table 6, it was found that the best model for modelling the stunting prevalence rate in Indonesia is a model with three knot points. The best model equation for modelling the stunting prevalence rate in Indonesia is presented in the following equation.

$$\begin{aligned}\hat{y} = {} & 353.7738 + 1.03x_1 - 3.821(x_1 - 61.5867)_+^1 + 3.308(x_1 - 65.3139)_+^1 + 9.076(x_1 - \\ & 78.6251)_+^1 - 6.072x_2 + 33.404(x_2 - 21.5255)_+^1 - 16.632(x_2 - 21.9341)_+^1 - \\ & 285.91(x_2 - 23.3933)_+^1 - 2.989x_3 + 8.789(x_3 - 36.1265)_+^1 - 6.344(x_3 - \\ & 42.6722)_+^1 + 5.294(x_3 - 66.0498)_+^1 - 2.967x_4 + 6.432(x_4 - 56.4373)_+^1 - \\ & 4.184(x_4 - 59.9688)_+^1 + 61.464(x_4 - 72.581)_+^1 - 1.149x_5 + 3.963(x_5 - \\ & 41.3067)_+^1 - 2.877(x_5 - 50.0739)_+^1 - 34.55(x_5 - 81.3851)_+^1\end{aligned} \quad (4)$$

3.5. Simultaneous Parameter Testing

Simultaneous tests are used to determine whether the regression model parameters are significant or not. The following is a hypothesis from simultaneous parameter testing.

$H_0: \beta_1 = \beta_2 = \cdots = \beta_{20} = 0$
H_1: There is at least one $\beta_j \neq 0, j = 1, 2, \ldots, 20$

Table 7. GCV Values for Models with Multiple Knot Points

Source	df	*Sum Square*	*Mean Square*	F	*P-Value*
Regression	20	1395.2	69.8	5.06	0.002
Error	13	179.1	13.8		
Total	33	1574.3			

The p-value obtained was 0.002216 which was less than the significance level α (0.05). Thus, the decision is to reject H_0, meaning that there is at least one parameter that is not equal to zero or there is at least one predictor variable that has a significant effect on the response variable.

3.6. Partial Parameter Testing

Individual or partial significance testing of model parameters was carried out to find out which parameters have a significant effect. The hypothesis used in this test is as follows.

$H_0 : \beta_j = 0$

$H_1 : \beta_j \neq 0, j = 1, 2, \ldots, 20$

Table 8. Result of Parameter Testing

Variable	Parameter	*P-Value*	Significance
	β_0	0.025	Significant
X_1	β_1	0.128	Not Significant
	β_2	0.025	Significant
	β_3	0.017	Significant
	β_4	0.057	Not Significant
X_2	β_5	0.259	Not Significant
	β_6	0.071	Significant
	β_7	0.403	Not Significant
	β_8	0.014	Significant
X_3	β_9	0.003	Significant
	β_{10}	0.004	Significant
	β_{11}	0.008	Significant
	β_{12}	0.048	Significant
X_4	β_{13}	0.073	Not Significant
	β_{14}	0.017	Significant
	β_{15}	0.012	Significant
	β_{16}	0.011	Significant
X_5	β_{17}	0.015	Significant
	β_{18}	0.002	Significant
	β_{19}	0.004	Significant
	β_{20}	0.002	Significant

Using α=0.05, all variables have a significant effect on the model because the p-value is less than α.

3.7. Best Model Equation

If other variables except X_1 are held constant, the influence of the percentage of infants aged under 6 months of age who received exclusive breastfeeding (X_1) on the prevalence of stunting in Indonesia in 2022 is presented through the following equation.

$$\hat{y} = 353.7738 + 1.03x_1 - 3.821(x_1 - 61.5867)_+^1 + 3.308(x_1 - 65.3139)_+^1 + 9.076(x_1 - 78.6251)_+^1 \quad (5)$$

$$\hat{y} = \{353.7738 + 1.03x_1 \ , \ x_1 < 61.5867 \ 589.0966 - 2.79x_1 \ , \ 61.5867 \leq x_1 < 65.3139 \ 373.0382 + 0.52x_1 \ , \ 65.3139 \leq x_1 < 78.6251 \ -340.5632 + 9.59x_1 \ , \ x_1 \geq 78.6251$$

The mapping of provinces in Indonesia based on the percentage of infants under 6 months of age who received exclusive breastfeeding with the best knot points is as follows.

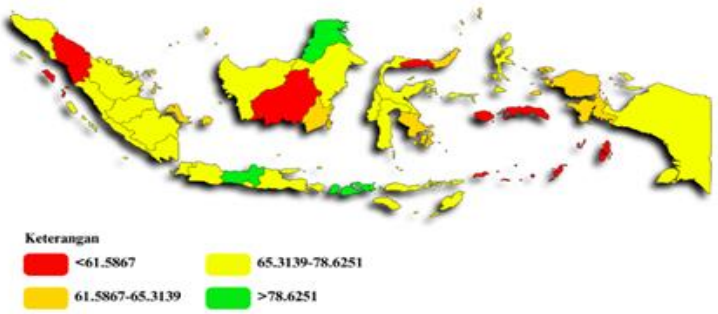

Figure. 3. The Mapping of Provinces based on X_1

Based on Figure 3, provinces that have a percentage of infants under 6 months of age who received exclusive breastfeeding below 61.6% consist of Maluku, North Sumatra, Central Kalimantan, and Gorontalo. Meanwhile, provinces that have a percentage of infants under 6 months of age who received exclusive breastfeeding above 78.6% consist of the provinces of North Kalimantan, Central Java and West Nusa Tenggara. The higher the percentage of infants under 6 months of age who are exclusively breastfed, the smaller the chance of the baby being stunted. On the other hand, the lower the percentage of infants under 6 months of age who are exclusively breastfed, the higher the stunting prevalence rate in that province.

If other variables except X_2 are held constant, the effect of the average age of a mother's first pregnancy (X_2) on the prevalence of stunting in Indonesia in 2022 is presented through the following equation.

$$\hat{y} = 353.7738 - 6.072x_2 + 33.404(x_2 - 21.5255)_+^1 - 16.632(x_2 - 21.9341)_+^1 - 285.91(x_2 - 23.3933)_+^1 \quad (6)$$

$$\hat{y} = \{353.7738 - 6.072x_2 \ , \ x_2 < 21.5255 \ -365.264 + 27.332x_2 \ , \ 21.5255 \leq x_2 < 21.9341 \ -0.4561 + 10.7x_2 \ , \ 21.9341 \leq x_2 \ll 23.3933 \ 6687.9224 - 275.21x_2 \ , \ x_2 \geq 23.3933$$

If an area has an average age of a mother's first pregnancy less than 21.5255, then a one-year increase in the average age of a mother's first pregnancy will cause a reduction in the prevalence of stunting by 6,072 units. If an area has an average age of a mother's first pregnancy in the interval 21.5255 to 21.9341, then a one-year increase in the average age of a mother's first pregnancy will cause an increase in the prevalence of stunting by 27,332 units. If an area has an average age of a mother's first pregnancy in the interval 21.9341 to 23.3933, then a one-year increase in the average age of a mother's first pregnancy will cause an increase in the prevalence of stunting by 10.7 units. If an area has an average age of a mother's first pregnancy of more than 23.3933, then a one-year increase in the average age of a mother's first pregnancy will cause a reduction in the prevalence of stunting by 275.21 units.

The mapping of provinces in Indonesia based on the average age of a mother's first pregnancy with the best knot points is presented in Figure 4.

Figure. 4. The Mapping of Provinces based on X_2

Based on Figure 4, the provinces that have an average age of a mother's first pregnancy for mothers under 21.5 years consist of the provinces of Central Kalimantan, Gorontalo, West Sulawesi, Jambi, South Kalimantan, Central Sulawesi, Bengkulu, Bangka Belitung Islands, West Kalimantan, West Nusa Tenggara, South Sumatra, West Java, Lampung, Southeast Sulawesi, North Maluku, Papua, East Java, Central Java and North Sulawesi. Meanwhile, the provinces that have an average age of first pregnancy for mothers above 23.4 years consist of the provinces of Jakarta and Riau Islands. Based on modelling results, the average gestational age of mothers who are not too old or still of childbearing age will reduce the prevalence rate of stunting in an area.

If other variables except X_3 are held constant, the effect of the percentage of married women aged 15-49 years who use contraception methods (X_3) on the prevalence of stunting in Indonesia in 2022 is presented through the following equation

$$\hat{y} = 353.7738 - 2.989x_3 + 8.789(x_3 - 36.1265)_+^1 - 6.344(x_3 - 42.6722)_+^1 + 5.294(x_3 - 66.0498)_+^1 \quad (7)$$

$$\hat{y} = \{353.7738 - 2.989x_3 \ , \ x_3 < 36.1265 \ 36.258 + 5.8x_3 \ , \ 36.1265 \leq x_3 < 42.6722 \ 306.9704 - 0.544x_3 \ , \ 42.6722 \leq x_3 < 66.0498 \ -42.6972 + 4.75x_3 \ , \ x_3 \geq 66.0498$$

The mapping of provinces in Indonesia based on the percentage of married women aged 15-49 who are currently using/wearing contraception methods with the best knot points is as follows.

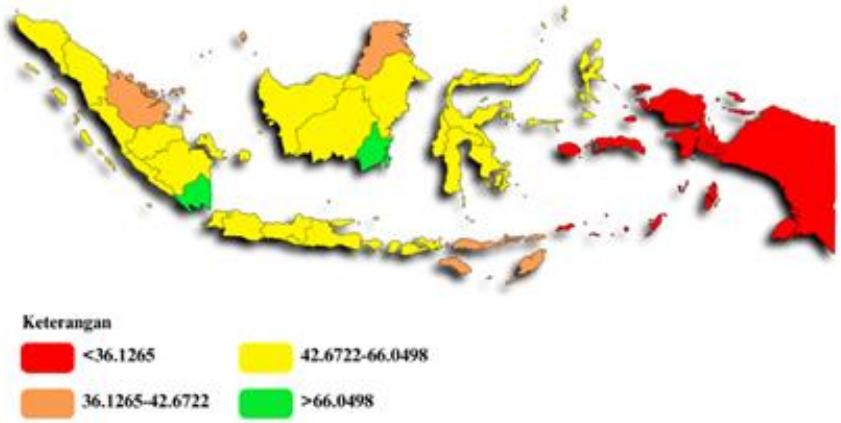

Figure. 5. The Mapping of Provinces based on X_3

Based on Figure 5, provinces that have a percentage of married women aged 15-49 years who are currently using/wearing contraception/birth control methods below 36.1% consist of the provinces of Papua, West Papua and Maluku. Meanwhile, provinces with a percentage of married women aged 15-49 years who are currently using/wearing contraception methods above 66.1% consist of Lampung and South Kalimantan provinces. The higher the percentage of women aged 15-49 years and married who are currently using/wearing contraception methods, the smaller the chance of stunting occurring in toddlers in an area. On the other hand, the lower the percentage of married women aged 15-49 years who are using/wearing contraception/birth control methods, the higher the stunting prevalence rate in an area.

If other variables except X_4 are held constant, the effect of the percentage of mothers who gave birth to live-born children in the past two years and initiated early breastfeeding (X_4) on the prevalence of stunting in Indonesia in 2022 is presented through the following equation.

$$\hat{y} = 353.7738 - 2.967x_4 + 6.432(x_4 - 56.4373)_+^1 - 4.184(x_4 - 59.9688)_+^1 + 61.464(x_4 - 72.581)_+^1 \quad (8)$$

$$\hat{y} = \{353.7738 - 2.967x_4 \ , \ x_4 < 56.4373 \ -9.231 + 3.465x_4 \ , \ 56.4373 \leq x_4 < 59.9688 \ 241.679 - 0.719x_4 \ , \ 59.9688 \leq x_4 < 72.581 \ -4219.44 + 60.745x_4 \ , \ x_4 \geq 72.581$$

The mapping of provinces in Indonesia based on the percentage of mothers who gave birth to live-born children (ALH) in the past two years and initiated early breastfeeding with the best knot points is as follows.

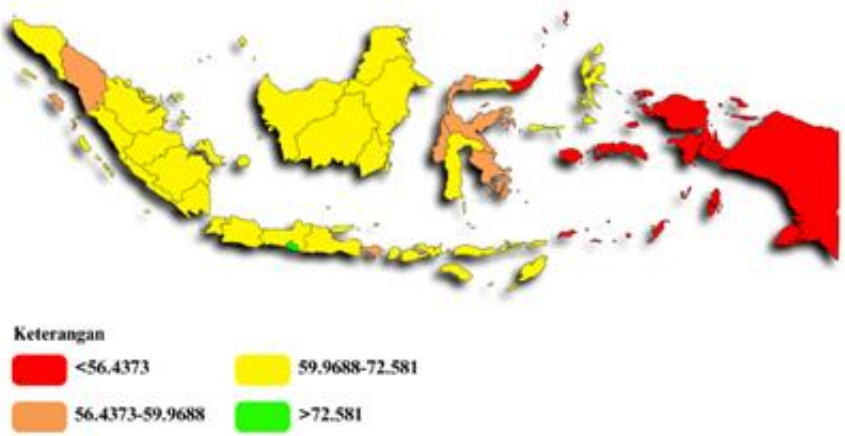

Figure. 6. The Mapping of Provinces based on X_4

Based on Figure 6, the provinces that have a percentage of mothers who gave birth to live-born children (ALH) in the last two years and initiated early breastfeeding below 56.4% consist of the provinces of Maluku, Papua, West Papua and North Sulawesi. Meanwhile, the province that has a percentage of mothers who gave birth to live-born children (ALH) in the last two years and initiated early breastfeeding above 72.6% is the province of Yogyakarta. The higher the percentage of mothers who gave birth to live-born children (ALH) and initiated early breastfeeding, the lower the risk of a child being stunted. On the other hand, the lower the percentage of mothers who gave birth to live-born children and initiated early breastfeeding, the higher the stunting prevalence rate in an area.

If other variables except X_5 are held constant, the effect of the percentage of children aged 12-23 months who receive complete basic immunisation (X_5) on the prevalence of stunting in Indonesia in 2022 is presented through the following equation.

$$\hat{y} = 353.7738 - 1.149x_5 + 3.963(x_5 - 41.3067)_+^1 - 2.877(x_5 - 50.0739)_+^1 - 34.55(x_5 - 81.3851)_+^1 \quad (9)$$

$$\hat{y} = \{353.7738 - 1.149x_5 \ , \ x_5 < 41.3067 \ 190.075 + 2.814x_5 \ , \ 41.3067 \leq x_5 < 50.0739 \ 334.138 - 0.063x_5 \ , \ 50.0739 \leq x_5 < 81.3851 \ 3145.993 - 34.613x_5 \ , \ x_5 \geq 81.3851$$

The mapping of provinces in Indonesia based on the percentage of children aged 12-23 months who receive complete basic immunisation with the best knot points is as follows.

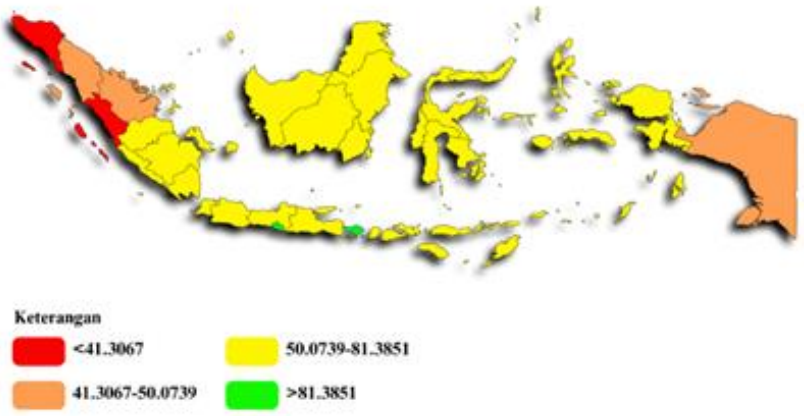

Figure. 7. The Mapping of Provinces based on X_5

Based on Figure 7, provinces that have a percentage of children aged 12-23 months who receive complete basic immunisation below 41.3% are Aceh and West Sumatra. Meanwhile, the provinces that have a percentage of children aged 12-23 months who receive complete basic immunisation above 81.4% consist of the provinces of Bali and Yogyakarta. The higher the percentage of children who receive complete basic immunisation, the smaller the chance of children suffering from stunting. Conversely, the lower the percentage of children who receive complete basic immunisation, the higher the risk of the child experiencing stunting.

3.8. Solutions to Reduce Stunting Prevalence

The problem of the high prevalence of stunting can be overcome with several solutions. First, provide education or training regarding stunting to increase public awareness. Other solutions include providing access to adequate health services, encouraging the government to implement policies that support stunting management, empowering women, regularly conducting research on stunting in Indonesia, and finally carrying out evaluations to improve in the future.

4. Conclusions

The best model for the prevalence of stunting in Indonesia using non-parametric truncated spline multi-predictor regression is modelling with three knot points because it has the minimum Generalised Cross Validation (GCV) value and the largest coefficient of determination compared to models with one and two knot points. Based on the results of hypothesis testing, at a significance level of 5%, it was concluded that the variables, which are the percentage of infants under 6 months of age who were exclusively breastfed, the average age of the mother's first pregnancy, the percentage of married women aged 15-49 years who are currently using/wearing contraception/birth control methods, the percentage of mothers who gave birth to Live-Born Children (ALH) in the last two years and initiated early breastfeeding, and the percentage of children aged 12-23 months who received complete basic immunisation had a significant simultaneous and partial effect on the prevalence of stunting in Indonesia.

Ethics approval

This study was conducted in accordance with the ethical standards. Informed consent was obtained from all individual participants included in the study.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

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