A Nonparametric Regression Approach Address Poverty Problems in East Nusa Tenggara Province

Narita Yuri Adrianingsih[1*], Mariana Mungkabel[2], Andrea Tri Rian Dani[3] and Ludia Ni'matuzzahroh[2]
[1,2] Department of Mathematics, FMIPA, Tribuana Kalabahi University, Alor, Indonesia
[3] Statistics Study Program, Department of Mathematics, FMIPA, Mulawarman University, Samarinda, Indonesia
[4] Department of Mathematics, FMIPA, YPPI Rembang, Rembang, Indonesia
*Corresponding author: naritayuria98@gmail.com

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ABSTRACT – The administration is focused on reducing poverty, which is still a significant issue. Since the regression curve is unknown and the truncated spline nonparametric regression approach offers a high degree of flexibility, the study was conducted to determine what factors influence it, particularly in the East Nusa Tenggara area. The goal of this study is to develop a nonparametric regression model. The average length of schooling, life expectancy, percentage of the illiterate population aged 15 and over, labor force participation rate, percentage of households based on the information source, and population density affect poverty in the East Nusa Tenggara area. With a minimum GCV of 39.57, it was determined that 1 knot point were the ideal knot point. To some extent, the characteristics that influenced poverty were life expectancy, labor force participation rate, percentage of households with a proper light source, and population density. The best model met these criteria with an R^2 of 81.28%. The findings suggest that targeted interventions to improve these factors can significantly reduce poverty in East Nusa Tenggara.

Keywords– **poverty, East Nusa Tenggara, nonparametric regression, spline truncated.**

I. INTRODUCTION

Poverty is the main issue facing the government that is given top priority and is a serious worry when creating a strategy for its growth. Poverty is become a global issue, not just one for national governments. The primary goal of the Millennium Development Goals (MDGs) program, which was announced by the United Nations in 2002, is to end poverty. An agenda to carry out the MDGs known as Sustainable Development Goals (SDGs) is required in order to build a conceptualization in the context of the post-2015 development agenda. Ending poverty, ensuring universal access to high-quality education, and ending hunger are three of the 17 Sustainable Development Goals (SDGs) [1].

One of the primary concerns of the government is poverty, which is given top priority when creating development plans for all nations, including Indonesia. Since Indonesia's independence, poverty has persisted as a concern and has not been addressed, according to [2]. The degree of poverty in an area can be used to gauge its level of development success. The degree of community welfare increases with decreasing poverty. [3] asserts that a region's economic growth is one of the prerequisites for a successful reduction in poverty.

The number of impoverished individuals in Indonesia fell from 26.36 million in September 2022 to 25.90 million in March 2023, a decrease of 0.46 million. The amount of the impoverished shows that poverty is still an issue in Indonesia and that efforts to eradicate it must always be made [4]. Three out of five provinces have the greatest rate of poverty, with East Nusa Tenggara Province ranking third. According to [4], the percentage of the poor in NTT fell from 20.23%, or 1.149 million people in September 2022 to 19.96%, or 1.141 million people in March 2023.

According to previous studies, poverty is influenced by a number of factors, including: The human development index, open poverty rate, regional minimum wage, and rate of inflation are some of the elements that impact poverty, according to [2]. The poverty level is a determining factor in poverty, according to [5]. However, poverty is influenced by the Gross Regional Domestic Product (GRDP) [6] [7]. The population dependency ratio and per capita income are factors that impact poverty, according to [8].

The issue of poverty is one of the many domains in which nonparametric regression can be applied, particularly in the social sciences. Nonparametric regression is a local approach that assumes that not all observations have the same parameters [9]. Visually, this nonparametric regression has an unpredictable pattern [10]. The nonparametric regression approach is the most appropriate if the relationship pattern between the response variable and the predictor variable is unknown [11]. Many nonparametric regression approaches include truncated splines, kernels, Fourier series, wavelets, and local polynomials. A truncated spline is a perfect model that can adjust to the local nature of the data [12]. In addition, this estimation method models data whose patterns change at certain sub-intervals [13]. Another advantage is overcoming patterns that rise and fall sharply with the help of knot points [14].

Several studies on poverty using nonparametric regression have been carried out, including by [15], modelling using multivariable truncated spline regression, the results of which are that poverty is influenced by economic growth, the level of open unemployment, and the level of education. [16] modelled poverty cases in Central Java using nonparametric regression using the B-Spline method. Then, [17] modelled the percentage of poor people in Maluku using nonparametric spline regression. In [11] modelled data on the percentage of poor education in Papua Province for 2016-2019 using truncated spline nonparametric regression. Meanwhile, response spline nonparametric regression was used to model the percentage of poor people and the depth of poverty index in East Kalimantan in 2015 by [18].

Based on a number of studies, the researcher used the nonparametric truncated spline regression method to study the relationship between poverty and the factors that are thought to affect it, such as life expectancy, average years of schooling, percentage of illiterate people over the age of 15, labor force participation rate, percentage of households with a particular type of lighting, and population density. It is hoped that this study's findings will advance statistical science. Selection of modeling with nonparametric regression by considering its advantages and flexibility in modeling.

II. LITERATURE REVIEW

A. Regression Analysis

One statistical technique for figuring out the pattern of relationships between predictor and response variables is regression analysis [19]. In general, the regression analysis model with data pairs (x_i, y_i) can be written as follows [20]:

$$y_i = f(x_i) + \varepsilon_i \quad ; i = 1, 2, \dots, n \tag{1}$$

with,

y_i : response variable

x_i : predictor variables

$f(x_i)$: the regression curve to be approximated

ε_i : random errors, $\varepsilon_i \sim N(0, \sigma^2)$

B. Truncated Spline Nonparametric Regression

A segmented polynomial model is the spline. A function that is created by altering a polynomial function but nonetheless preserves its characteristics is known as a truncated spline function [11]. The truncated spline function of degree m where ϕ is the knot points, namely $\lambda_1, \lambda_2, \dots, \lambda_r$, is given by the equation [15]:

$$f(x_i) = \sum_{j=0}^{m} v_j x_i^j + \sum_{k=1}^{r} v_{m+k}(x_i - \lambda_k)_+^m \tag{2}$$

Truncated splines have knot points, which are fusion points that show changes in curve behaviour at different intervals [20]. One of the advantages of truncated splines is that this model tends to find its data estimates wherever the data pattern moves [21]. This advantage occurs because in the truncated spline function, there are knot points.

The estimated parameters model with Ordinary Least Squares (OLS) is $\hat{\boldsymbol{v}} = (\boldsymbol{X}(\lambda)^T \boldsymbol{X}(\lambda))^{-1} \boldsymbol{X}(\lambda)^T \boldsymbol{y}$ [21]. The estimated regression curve of $f(x_i)$ is obtained:

$$\begin{aligned} \hat{f}(x_i) &= \boldsymbol{X}\hat{\boldsymbol{v}} \\ &= \boldsymbol{X}(\lambda)[(\boldsymbol{X}(\lambda)^T \boldsymbol{X}(\lambda))^{-1} \boldsymbol{X}(\lambda)^T \boldsymbol{y}] \\ &= \boldsymbol{F}(\lambda)\boldsymbol{y} \end{aligned} \tag{3}$$

Where the matrix $\boldsymbol{F}(\lambda)$ is given by:

$$\boldsymbol{X}(\lambda)[(\boldsymbol{X}(\lambda)^T \boldsymbol{X}(\lambda))^{-1} \boldsymbol{X}(\lambda)^T] \tag{4}$$

C. Hypothesis Test

Simultaneous hypothesis testing in the truncated spline regression model uses the F test statistic [12], [22]. The steps for simultaneous hypothesis testing are as follows:

Hypothesis formulation

H_0 : $v_1, v_2, \dots, v_m, v_{m+r} = 0$

H_1 : there is at least one $v_j \neq 0$, $j = 1, 2, \dots, m + r$

Test statistics

The test statistics used are displayed in the Analysis of Variance (ANOVA) in Table 1.

Table 1 ANOVA

Sources	df	SS	MS
Regression	m+r	$SS_{reg} = \hat{\boldsymbol{v}}^T \boldsymbol{X}(\lambda)^T \boldsymbol{y} - n\bar{y}^2$	$MS_{reg} = \frac{SS_{reg}}{\mathrm{m+r}}$
Error	n-(m+r)-1	$SS_{error} = \boldsymbol{y}^T \boldsymbol{y} - \hat{\boldsymbol{v}}^T \boldsymbol{X}(\lambda)^T \boldsymbol{y}$	$MS_{error} = \frac{SS_{error}}{\mathrm{n-(m+r)-1}}$
Total	n-1	$SS_{total} = \boldsymbol{y}^T \boldsymbol{y} - n\bar{y}^2$	

Furthermore, F can be calculated [15]:

$$F = \frac{MS_{reg}}{MS_{error}} \tag{5}$$

Under the hypothesis H_0 , the F follows the F distribution, with df is (m+r, n-(m+r)-1). Partial hypothesis testing is carried out to determine which parameters in the truncated spline nonparametric regression model have a partial (individual) influence on the model [24]. The steps in partial hypothesis testing are as follows:

Hypothesis formulation

$H_0 : v_j = 0$

$H_1 : v_j \neq 0 , j = 1, 2, \dots, m + r$

Test statistics

The t test statistic is given by:

$$t = \frac{\hat{v}_j}{\sqrt{Var(\hat{v}_j)}} \tag{6}$$

where $\hat{v}_j$ is the jth element of the parameter vector $\hat{\boldsymbol{v}}$, and $Var(\hat{v}_j)$ is the j-th diagonal element of the variance-covariance matrix of $\hat{\boldsymbol{v}}$.

III. METHODOLOGY

The data collection technique used is secondary data collection in 2023, obtained from the Central Statistics Agency. Consists of one response variable, namely the percentage of poor people with six predictor variables, including average years of schooling, life expectancy, percentage of illiterate population aged 15 years and over, labor force participation rate, percentage of households with adequate light sources, and Population density. The observation unit is the Regency/City in East Nusa Tenggara Province.

The steps of analysis taken to complete the research objectives are as follows:

1. Conduct data exploration using descriptive statistics
2. Make a scatter plot for each predictor variable with the response variable
3. Modeling with spline truncated nonparametric regression (parameter estimation and determining the best model).

IV. RESULTS AND DISCUSSIONS

This section will describe the analysis results and discuss modelling district/city poverty problems in East Nusa Tenggara Province using a truncated spline nonparametric regression approach.

A. Data Exploration

The data exploration will be provided by displaying descriptive statistics for each response and predictor variable variable.

Table 2 Desciptive statistics

Variable	Mean	Minimum	Maximum
Percentage of Poor Population	20.61	8.61	31.78
Average Years of Schooling	7.79	6.38	11.62
Life Expectancy	66.91	61.06	70.52
Percentage of Illiterate Population Aged 15 Years and Over	5.182	0.76	13.39
Labor Force Participation Rate	75.41	61.33	82.55
Percentage of Households with Adequate Light Sources	5.17	0.03	19.70
Population Density	234.5	36.00	2583.00

Table 2 presents the unique characteristics of each Regency/City in East Nusa Tenggara Province for all response and predictor variables. For example, the percentage of individuals living in poverty is the response variable. The highest rate of poverty, 31.78%, is found in Central Sumba Regency. At 8.61%, Kupang City has one of the lowest rates of poverty among the areas. In districts and cities within East Nusa Tenggara Province, the average percentage of impoverished individuals is 20.61%.

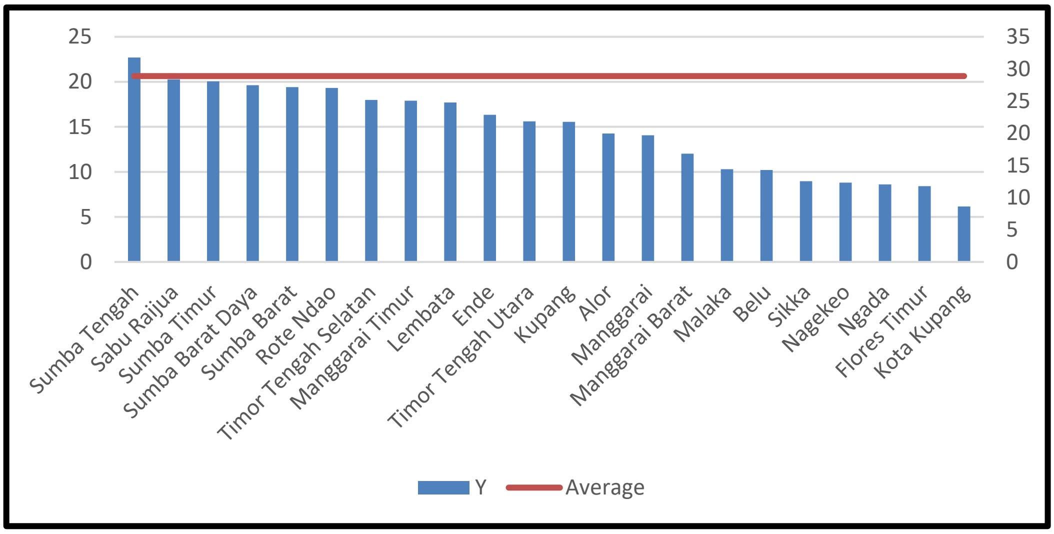


Figure 1 Variable percentage of poor population in a bar chart

We know from Figure 1 that a number of East Nusa Tenggara districts have higher averages than the province. This specific message is intended to help local and national governments lower their rates of poverty.

B. Scatter Plot

Understanding the pattern of relationships between the predictor and response variables is a prerequisite for performing regression modelling. A nonparametric regression approach can be employed if the pattern of relationships between the predictor and response variables is unknown. Figure 2 displays the data pattern analysis between each predictor variable and the response variable.

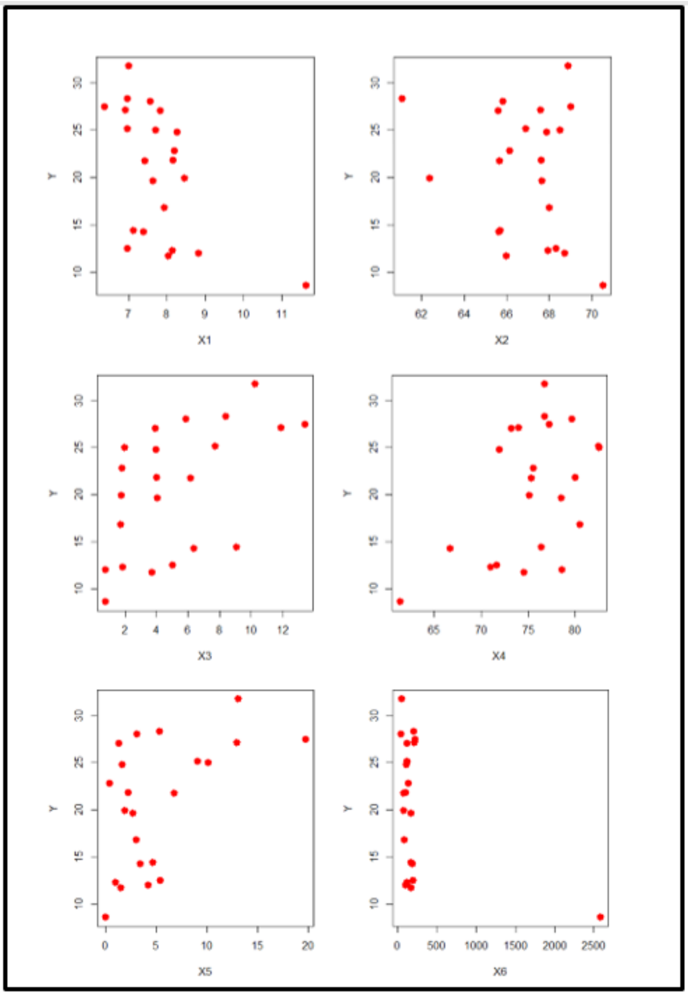


Figure 2 Scatter plot

Figure 2 indicates that there is no discernible pattern in the association between any of the predictor variables and the response variable. Some relationships display wildly erratic patterns without any prior knowledge, and relationships tend to shift at specific sub-intervals. Truncated spline nonparametric regression will be the method employed.

C. Modeling with Truncated Spline Nonparametric Regression

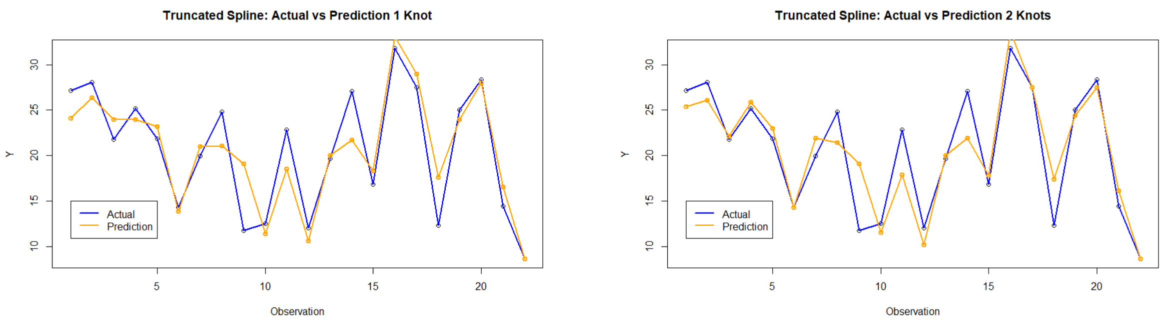
1. Parameter Estimation

The number of knot points utilized in the first phase of nonparametric regression modeling of truncated spline series must be taken into account. Only one and two knot points may be utilized in this study. The minimal GCV value from a number of models that were evaluated based on a combination of different knot point locations and the number of knot points will be used to determine which best truncated spline nonparametric regression model to use in this study. Table 3 displays the obtained minimum GCV values.

Table 3 Knot point location based on GCV value

Number of Knot Points	Knot Point Location						GCV	MSE	R^2
	X_1	X_2	X_3	X_4	X_5	X_6			
1 Knot Point	7.47	63.03	3.39	65.75	4.13	566.62	39.57	8.17	81.28%
2 Knot Points	7.63	63.31	3.76	66.38	4.71	642.43	57.48	7.60	82.59%
	11.37	70.06	12.78	81.53	18.76	2461.71			

Table 3 allows for the formation of a visualization based on the minimum GCV of the actual and predicted values for each best model. Figure 3 shows a visual graph that compares actual and expected data.



(a) (b)

Figure 3 Visualization of actual comparison with predictions for each best model

Based on Table 3, the minimum GCV value for the truncated spline model with a 1 knot point is 39.57. This is similar to the visualization in Figure 3, which shows that the truncated linear spline model predictions with 1 knot point sufficiently follow the actual data pattern. Next, hypothesis testing will be carried out simultaneously to see the significance of the predictor variables on the response variable. The hypothesis formulation used is as follows:

$H_0 : v_1, v_2, \dots, v_{12} = 0$
$H_1 :$ there is at least one $v_j \neq 0 , j = 1, 2, \dots, 12$

The results of simultaneous hypothesis testing are presented in Table 4.

Table 4 Simultaneous testing

Sources	df	SS	MS	F	P-Value
Regression	12	781.02	65.08	7.96	0.00
Error	9	179.86	8.17		
Total	21	960.88			

Simultaneous hypothesis testing uses the F -test statistic. Based on Table 4, the P-value is 0.00, which is smaller than the significance level used α=0.05 , it was decided to reject H_0. The response variable is concurrently influenced by the predictor factors, it can be concluded. To determine the individual or partial relevance of the predictor variable on the response variable, partial hypothesis testing is used.

The hypothesis formulation used is as follows:

$H_0 : v_j = 0$
$H_1 : v_j \neq 0 , j = 1, 2, \dots, 12$

The results of partial hypothesis testing are presented in Table 5.

Table 5 Partial testing

Variable	Parameter	Parameter Estimation	P-Value	Decision
	$\hat{\varphi}_0$	0.2026	0.0130	Unable to Reject H_0
X_1	$\hat{\varphi}_1$	10.3530	0.1338	Unable to Reject H_0
	$\hat{\varphi}_{11}$	-12.7636	0.0991	Unable to Reject H_0
X_2	$\hat{\varphi}_2$	-8.0812	0.0073	Reject H_0
	$\hat{\varphi}_{21}$	8.6186	0.0148	Reject H_0
X_3	$\hat{\varphi}_3$	2.6904	0.0665	Unable to Reject H_0
	$\hat{\varphi}_{31}$	-1.9533	0.2462	Unable to Reject H_0
X_4	$\hat{\varphi}_4$	6.8341	0.0108	Reject H_0
	$\hat{\varphi}_{41}$	-6.4910	0.0157	Reject H_0
X_5	$\hat{\varphi}_5$	-2.0768	0.0311	Reject H_0
	$\hat{\varphi}_{51}$	3.2299	0.0031	Reject H_0
X_6	$\hat{\varphi}_6$	-0.0482	0.0218	Reject H_0
	$\hat{\varphi}_{61}$	0.0743	0.0125	Reject H_0

Based on Table 5, of the 12 parameters, eight parameters are significant. Variables that partially influence the model are Life Expectancy, Labor Force Participation Level, Percentage of Households with a Proper Light Source, and Population Density.

2. **Best Model**

The best model with the number of knot points used as 1 can be written in the equation:

$$\hat{y}_i = \hat{\varphi}_0 + \hat{\varphi}_1 x_{1i} + \hat{\varphi}_2 x_{2i} + \hat{\varphi}_3 x_{3i} + \hat{\varphi}_4 x_{4i} + \hat{\varphi}_5 x_{5i} + \hat{\varphi}_6 x_{6i} + \hat{\varphi}_{11}(x_{1i} - \lambda_{11})_+ + \hat{\varphi}_{21}(x_{2i} - \lambda_{21})_+ + \hat{\varphi}_{31}(x_{3i} - \lambda_{31})_+ + \hat{\varphi}_{41}(x_{4i} - \lambda_{41})_+ + \hat{\varphi}_{51}(x_{5i} - \lambda_{51})_+ + \hat{\varphi}_{61}(x_{6i} - \lambda_{61})_+$$

$$\hat{y}_i = 0.2026 + 10.3530\, x_{1i} - 8.0812 x_{2i} + 2.6904 x_{3i} + 6.8341 x_{4i} - 2.0768 x_{5i} - 0.0482 x_{6i} - 12.7636(x_{1i} - 7.47)_+ + 8.6186(x_{2i} - 63.03)_+ - 1.9533(x_{3i} - 3.39)_+ - 6.4910(x_{4i} - 65.75)_+ + 3.2299(x_{5i} - 4.13)_+ + 0.0743(x_{6i} - 566.62)_+$$

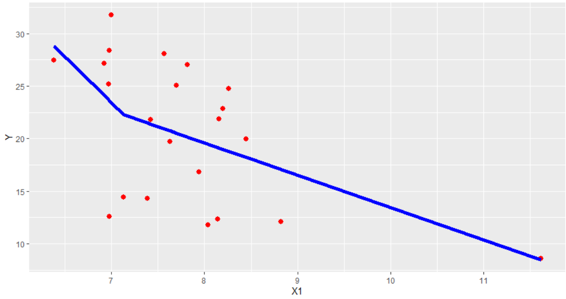
A graphic illustration of the comparison of actual data with predictions from the 1-knot truncated spline nonparametric regression model is shown in Figure 4.

V. CONCLUSIONS AND SUGGESTIONS

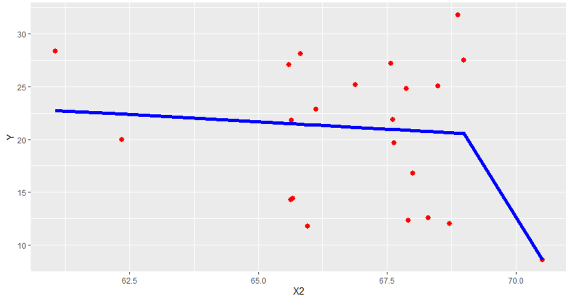
The conclusion obtained from this research is that the best-truncated spline nonparametric regression model with 2 knot points has a minimum GCV value of 57.48, and the criteria for the best model with R^2 is 82.59%. Factors that partially influence poverty are Life Expectancy, Labor Force Participation Rate, Percentage of Households with Adequate Light Sources, and Population Density. The model obtained is:

$$\hat{y}_i = 0.2026 + 10.3530\, x_{1i} - 8.0812 x_{2i} + 2.6904 x_{3i} + 6.8341 x_{4i} - 2.0768 x_{5i} - 0.0482 x_{6i} - 12.7636(x_{1i} - 7.47)_+ + 8.6186(x_{2i} - 63.03)_+ - 1.9533(x_{3i} - 3.39)_+ - 6.4910(x_{4i} - 65.75)_+ + 3.2299(x_{5i} - 4.13)_+ + 0.0743(x_{6i} - 566.62)_+$$

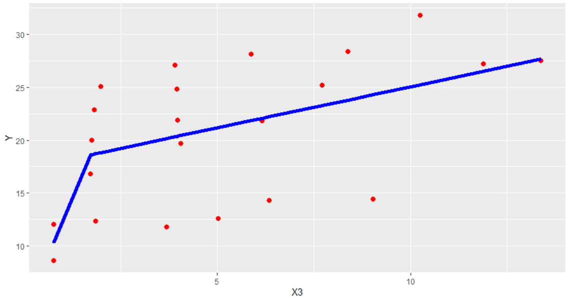
The findings can inform policy decisions aimed at addressing poverty. For example, governments can prioritize healthcare, education, and infrastructure investments to improve life expectancy and labor force participation. Additionally, policies to increase access to electricity and improve housing conditions can reduce poverty. Suggestions for further research include developing a nonparametric mixed regression estimator by adjusting the estimator to the regression curve.



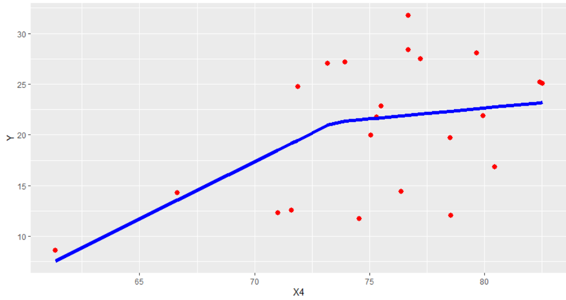
(a) X_1



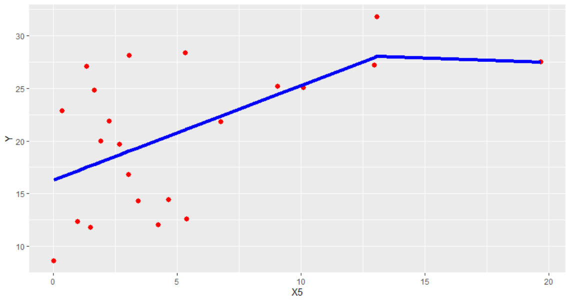
(b) X_2



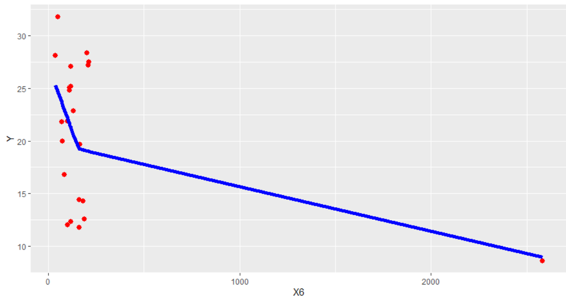
(c) X_3



(d) X_4



(e) X_5



(f) X_6

Figure 4 Visualization of optimal knot points for each predictor variable

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