Agricultural Sector Growth and Rural Poverty: Evidence via Semiparametric Spline Path Analysis

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Abstract. This study aims to analyze the causal relationship of the variables of Rural Population Migration, Land Use of Agriculture, and Village Funds to the variables of Agricultural Sector Growth and Poverty in Rural areas. The data used is secondary data of 33 provinces in Indonesia in the period 2015-2022 obtained from the publication of the Central Bureau of Statistics, and related ministries. There are linear and non-linear variable relationships, so it is appropriate to use the Truncated Spline semiparametric path analysis model which is the novelty of this research. The measurement results with Truncated Spline show that: (1) the variables of population migration, land use change, and village funds have a significant effect on the growth of the agricultural sector and rural poverty, (2) the truncated spline semiparametric path analysis model is very effective in this study, especially for non-linear forms of relationships between variables. (3) the variable of land use change in rural areas can increase the growth rate of the agricultural sector before finally reducing poverty with a maximum land area limit of 602. 721 hectares, and (4) the village fund variable can reduce rural poverty at a higher rate if the allocation amount is more than IDR. 4,037,405,060.00 per village in one fiscal year during the observation period.

Keywords: Growth of the Agricultural Sector, Rural Poverty, Semiparametric Path Analysis, Truncated Spline, Village Funds

1 Introduction

The Poverty in rural areas of Indonesia currently still quite large. Data from the Indonesian Central Bureau of Statistic (BPS) show that in 2015 there were 17,893,710 people or 14.09 percent of the total population in rural areas still below the poverty line, then in 2022 as many as 14,382,950 people or 12, 36 percent of the population in rural areas is still below the poverty line. Means the number of poor people in Indonesia's rural areas only decreased by 1.64 percent during the 2015-2022 period. The condition of poverty in these rural areas has encouraged the young workforce and rural potential to migrate out of the village, either to other villages. as well as to cities and overseas. This is shown by BPS data for a decrease in the number of residents in rural areas by 4.6 percent during the period from 2015 to 2022.

In the last few decades, economic development in rural areas has increased, triggering the growth of increasingly diverse economic activities and land use change in rural

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areas. This has triggered a reduction in agricultural land which is a source of livelihood for rural communities because it has changed its function to housing and industrial locations. This condition is related to the structural theory put forward by Brady (2019) that the current expansion of the industrial and service sectors has become dominant and shifts the role of the agricultural sector as the leading sector and the main driver of the rural economy to other economic sectors [1]. The conversion of agricultural land in rural areas also tends to lead to an increase in unemployment and poverty in rural areas, especially for farmers who have lost their land as a result of this conversion.

To overcome this condition, the government seeks to improve rural economic performance through policies to implement programs focused on encouraging rural economic performance improvement. One form of government policy currently being implemented is the Village Fund program. The Ministry of Finance's 2022 report shows that the government has allocated IDR. 20.8 trillion in village funds in 2015 and has set a ceiling of IDR. 68 trillion in 2022, resulting in an increase of 8.3 percent compared to 2021. Therefore, the implementation of the Village Fund programme is expected to increase the growth of agriculture as the leading economic sector in rural areas and significantly reduce poverty. Such conditions are relevant to study conducted by Artino, A., et al [2], Dwitayanti, et al. [3], Hartojo, et al. [4], Indartuti [5], and Yusuf & Khoirunurrofik [6] shows that village funds have been able to improve the economy of rural communities and influence the level of welfare of rural communities and rural economic growth as well as can reduce poverty in village. However, the research results Arham and Payu [7] show that the result reveals that the transfer of village funds is not significant in alleviating the issue of poverty in rural areas. By that, it is recommended to increase the amount of the fund of the program to reduce the rate of poverty in all villages in Indonesia.

Based on the description, the problem of poverty faced by rural areas in Indonesia is still very important to be studied in depth, especially studies that focus on aspects of the factors that influence growth of the agriculture sector and poverty. This study introduces a novel approach to modeling the growth of the agricultural sector and its impact on rural poverty in Indonesia by employing semiparametric truncated spline path analysis. While previous studies have focused on parametric models or simpler linear frameworks, the application of semiparametric splines allows for a more flexible modeling approach that can capture non-linear relationships and complex dynamics between agricultural growth and rural poverty. This method provides a more robust analysis by accommodating the varying effects of different regions, sectors, and time periods, which have often been overlooked in traditional models. By using truncated splines, this study also addresses the issue of censoring, common in rural poverty data, thus offering more precise insights into the underlying mechanisms.

There is a significant gap in the existing literature regarding the detailed modeling of the agricultural sector growth and its interaction with rural poverty in Indonesia, particularly with respect to non-linear effects and the complexities of censored data. Most existing research uses either linear or parametric models that assume constant relationships across all data points, ignoring the inherent variations in regional development and economic conditions. Furthermore, there is limited use of advanced econometric methods like semiparametric models that can provide more nuanced insights

into the multifaceted relationship between agricultural growth and rural poverty. This research seeks to fill this gap by applying semiparametric truncated spline path analysis, offering a more adaptive and context-sensitive approach to modeling these issues.

The main objective of this research is to model the relationship between the growth of the agricultural sector and rural poverty in Indonesia, using semiparametric truncated spline path analysis to understand the non-linear and region-specific effects of agricultural growth on poverty levels. The problem statement stems from the need to better understand how agricultural sector development can be effectively leveraged to reduce poverty in rural areas. Current models are insufficient to capture the complex, nonlinear nature of the agricultural economy and its diverse impacts across different regions in Indonesia. This research aims to provide a more accurate and region-specific analysis of these dynamics, identifying key factors that drive growth in the agricultural sector and mitigate rural poverty

2 Literature Review

Migration refers to the relocation of residents from rural villages to urban areas or to other rural locations. In Indonesia, a major driver of migration is the scarcity of employment opportunities in villages, particularly within agriculture, which remains the dominant sector in many rural economies. When migration is concentrated among working-age individuals, it can erode the local labor supply available for farm activities and related agribusinesses, thereby constraining agricultural sector performance. Evidence consistent with this argument is reported by Morales, G. J. et al. [8], who find a negative association between rural to urban migration and total agricultural output in the Philippines.

Land use change in agriculture denotes the conversion of agricultural land to nonagricultural purposes, including housing, offices, and industrial sites. Such conversion reduces the area of cultivable land and can weaken the production base for agricultural commodities, with potential implications for food security. Given the continued growth in global demand for food, maintaining and enhancing agricultural production remains a strategic priority. Accordingly, policies aimed at limiting agricultural land conversion should be complemented by measures that support productivity improvements, which may sustain agricultural expansion even under land constraints.

Hinz, R., et al. [9] emphasize that meeting future food demand will likely require both the expansion of agricultural land and the intensification of existing farmland. At the subnational level, Juliansyah and Zubaidah [10] show that agricultural sector growth contributes positively and significantly to district and city economic growth in Aceh Province. Their findings further indicate that land carrying capacity and agricultural sector growth jointly exert a positive and significant influence on local economic growth in the same context.

Village fund allocations have generally been directed toward village governance administration and local development. Over time, these funds have increasingly supported empowerment-oriented initiatives intended to strengthen village autonomy and community welfare. Since economic growth and poverty reduction are central indicators of

development success, the agricultural sector remains strategically important, particularly as a foundation for food provision and rural livelihoods in Indonesia.

Penggalih, PM et, al. [11] report that village funds have materially improved physical infrastructure that supports farming operations, strengthened institutional arrangements, and stimulated complementary agricultural activities. However, they also highlight an imbalance in allocation priorities, with infrastructure investments dominating relative to human capital development. Given agriculture's continuing prominence in rural Indonesia, they argue that future allocations should better balance infrastructure and human resource investments. Such an integrated approach may advance food selfsufficiency, improve rural livelihoods, and align with sustainable development goals, including the empowerment of SMEs and the broader agricultural economy.

Rural poverty describes deprivation experienced in rural areas, where residents often face limited access to productive resources, infrastructure, and essential services, resulting in lower living standards relative to urban populations. Economic disparities across areas can also encourage rural to urban migration. Using Indonesian panel evidence, Sugiyarto et al., [12] document substantial poverty reductions among both migrants and non-migrants, suggesting that poverty dynamics may improve through multiple pathways. They show that poverty among non-migrants declined from 18 percent in 2000 to 4.7 percent in 2007, while the poverty rate among migrants fell from 16 percent in 2000 to 3.3 percent in 2007.

A broader body of research similarly indicates that migration can alleviate poverty under certain conditions. Skeldon R. [13], Yang, Du, et al, [14], Peng, Jia, et al, [15], and Xu, Ning, and Chang'an, Li [16] collectively suggest that migration may reduce the probability of remaining in a relatively poor condition among rural workers, potentially by increasing household income and improving access to labor markets. These studies also report that migrants can experience gains in per capita income and that the poverty-reducing effectiveness of migration may weaken over time, implying the need for renewed policy approaches. Lessons from China are frequently presented as potentially informative for development strategies in other developing economies.

Agricultural land use change can influence rural poverty in both beneficial and adverse ways, depending on the form of transformation and local institutional and economic conditions. Shi et al., [17] examine rural development under poverty governance and identify notable patterns, including a decline in the number of lowand high-income districts over time and growth in the number of middleand upper-income districts, suggesting positive spatial correlation in rural income. Their analysis further indicates that drivers of dominant land morphology remain strong and consistent, while the influence of recessive morphology strengthens gradually over time. These results are interpreted as supporting poverty alleviation efforts and rural revitalization through sustainable land use in developing-country settings.

Related evidence also shows that land-use transitions may reshape inequality through labor market channels. Research on oil palm land dynamics suggests no statistically meaningful effect on overall rural inequality in some settings, while still indicating distributional shifts across groups. Specifically, although oil palm cultivation may increase inequality among farmers, it can reduce income inequality among non-agricultural households through employment and labor market effects [18].

Village funds are widely viewed as a potentially effective instrument for combating rural poverty, given their role as targeted fiscal resources earmarked for village-level development. By enabling local communities to plan and manage development priorities, such funds can foster ownership and participation in shaping local economic trajectories.

Empirically, Arham, M.A, & Payu, B.R, [7] find that village fund transfers significantly reduce rural poverty, implying that consistent increases in transfers can contribute to alleviating deprivation in rural areas. However, evidence is not uniform. Hariyanto, Asep [19] reports that allocations devoted to village government administration do not contribute to poverty reduction, whereas spending in development implementation, community development, community empowerment, disaster management, and emergency-related programs is associated with poverty alleviation, reflected in negative regression coefficients. Consequently, they recommend reducing the share of funds used for administrative purposes and reallocating toward higher-impact categories.

Moreover, A. R. Razak, et al. [20] report that village funds do not moderate the relationship between migration and rural poverty, indicating limitations in using this fiscal instrument to strengthen the linkage between reduced out-migration and poverty reduction. Their results suggest that annual village fund receipts may be insufficient to expand employment opportunities at scale to absorb productive labor and raise village incomes, particularly when out-migration is dominated by younger and more skilled workers.

3 Data and Methodology

3.1 Data

This study aims to find out how the influence of Population Migration, Land Use Change of Agriculture and Village Funds has on Rural Poverty and Growth of the Agricultural Sector. The data used is panel data type which is data from 33 provinces by excluding DKI province because it does not have villages, with a time span of 20152022 (eight years). Sources of data are taken from publications issued by the Central Bureau of Statistics, Bank Indonesia, and related Ministries, so that all of them are secondary data collected using documentation techniques. The data collected is data on rural poverty, growth of the agricultural sector, village funds, population migration, and land use change from all provinces. The unit of analysis in this study is 33 provinces in Indonesia. The number of samples used is the same as the population of the study, so the sample technique used in this study is saturated sampling technique. Data analysis used is Path Analysis Truncated Spline Semiparametric with the help of R software. The analysis model is shown in Figure 1.

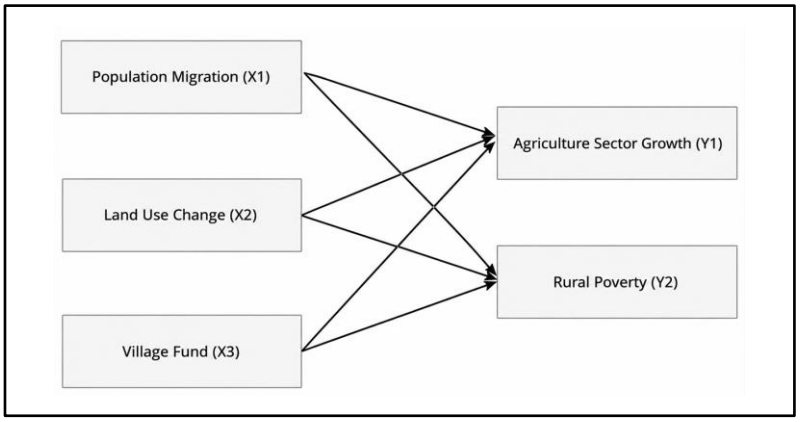

Fig. 1. Research Model.
Source: Developed by Author, 2025

3.2 Methodology

Path analysis extends conventional regression by accommodating more complex systems in which multiple response variables are modeled simultaneously. Standard regression frameworks are often limited when the research objective involves tracing a network of relationships rather than estimating a single outcome equation. Accordingly, path analysis was introduced to overcome these limitations. The earliest formulation is commonly attributed to Sewall Wright in 1934 [21], developed to quantify both direct and indirect effects among variables within a causal structure.

In path analysis, the model is represented by more than one structural equation. A typical specification includes at least one exogenous variable, at least one intervening variable, and one or more endogenous variables. Exogenous variables act as predictors that influence other variables, whereas intervening variables both affect and are affected by other variables in the system [22]. The inclusion of intervening endogenous variables distinguishes path analysis from ordinary regression, which generally does not incorporate such intermediate mechanisms. Endogenous variables are those determined within the system and are not specified to influence other variables. Solimun [22] emphasizes that, in conventional path analysis, relationships between variables are assumed to be linear and additive.

Parametric path analysis is a multivariate approach designed to evaluate causal linkages between exogenous and endogenous variables with the objective of identifying efficient paths. Its application typically requires the linearity assumption to hold and the functional form of the regression relationship to be known in advance, because the parametric specification does not accommodate an unknown regression function. To address these constraints, nonparametric path analysis has been developed by integrating principles of nonparametric regression into the path framework. The general form of the nonparametric path specification is expressed as follows:

$$y_{1i} = f_1(x_{1i}) + f_1(x_{2i}) + f_1(x_{3i}) + \varepsilon_{1i};\ i = 1,2,\dots,n$$
$$= f_1(x_{1i}, x_{2i}, x_{3i}) + \varepsilon_{1i};\ i = 1,2,\dots,n \quad (1)$$

$$y_{2i} = f_2(x_{1i}) + f_2(x_{2i}) + f_2(x_{3i}) + f_2(y_{1i}) + \varepsilon_{2i};\ i = 1,2,\dots,n$$
$$= f_1(x_{1i}, x_{2i}, x_{3i}, y_{1i}) + \varepsilon_{2i};\ i = 1,2,\dots,n \quad (2)$$

Semiparametric truncated spline path analysis provides a further refinement by allowing some relationships to be modeled parametrically (linear) while permitting other relationships to follow flexible non-linear forms. This approach is particularly suitable when the underlying associations are heterogeneous and cannot be adequately captured using a purely linear specification. In semiparametric modeling, the linear component captures structured parametric effects, whereas the spline component accommodates non-linear patterns. Thus, the semiparametric path framework combines a parametric path model with spline-based regression for the nonparametric component. For a simplified case with an independent variable X and a dependent variable Y, the semiparametric formulation can be expressed as:

$$y_i = \beta_0 + \beta_1 x_i + \sum_k^K \gamma_k f_k(x_i) + \varepsilon_i \quad (3)$$

To capture non-linear relationships, this study adopts a truncated spline approach, which is well suited for situations in which the response function exhibits changes in behavior across different ranges of the predictor. Truncated splines approximate the regression function using piecewise components separated by knots, enabling the model to represent abrupt increases or decreases more effectively. Because the approach relies on sub-interval estimation, it typically requires the identification of an appropriate set of knot locations. A key advantage of truncated splines is their ability to flexibly model sharp structural changes in the data by introducing knot-based segments.

4 Results

4.1 Linearity Assumption Test

A linearity assessment was conducted to characterize the functional form of the relationships among variables and, consequently, to determine the most appropriate estimation strategy. In this study, each relationship is classified into one of two forms, linear or non-linear. Based on the Ramsey RESET Test, relationships that satisfy linearity are estimated using a parametric specification, whereas relationships exhibiting non-linearity are modeled using a semiparametric specification. The Ramsey RESET Test outcomes are reported in Table 1.

Table 1. Secondary Data Linearity Test.

Relationships	*P-values*	Conclusion
X1 → Y1	0.189	Linear
X2 → Y1	0.043	Nonlinear
X3 → Y1	0.177	Linear
X1 → Y2	0.112	Linear
X2 → Y2	0.025	Nonlinear
X3 → Y2	0.042	Nonlinear

Source: Data Processed by Author, 2025

Table 1 summarizes the Ramsey RESET Test results for six links between the exogenous and endogenous variables. For the relationship between population migration and agricultural sector growth, the p-value exceeds the 0.05 significance threshold, indicating a linear association. Conversely, the relationship between land use change and agricultural sector growth yields a p-value below 0.05, implying a departure from linearity. Village funds and agricultural sector growth also show a p-value above 0.05, supporting a linear specification. Similarly, the relationship between population migration and rural poverty is classified as linear because its p-value is greater than 0.05. In contrast, both the land use change–rural poverty relationship and the village funds–rural poverty relationship present p-values below 0.05, suggesting non-linear functional forms. Overall, these findings support the adoption of a semiparametric modeling framework, as it allows the analysis to accommodate linear and non-linear relationships across the specified paths.

4.2 Parameter Estimation and Hypothesis Testing

Furthermore, in table 2 can be seen the results of coefficient estimation and hypothesis testing for parameterized and non-parametric models as follows:

Table 2. Hypothesis Test Results

Relations Between Variables	Parameter	Coefficient	P-values	Decision
Population Migration (X_1) → Growth of the Agricultural Sector (Y_1)	β_0	0.455	0.0001	Significant
	β_{11}	-0.0000007	0.0351	Significant
Land use change (X_2) → Growth of the Agricultural Sector (Y_1)	β_{02}	0.2799	0.0008	Significant
	β_{12}	0.0000003	0.0025	Significant
	β_{22}	0.0000011	0.0017	Significant
	β_{32}	0.0000015	0.0008	Significant
Village Funds (X_3) → Growth of the Agricultural Sector (Y_1)	β_{03}	-0.1346	0.0011	Significant
	β_{13}	0.000000009	0.0289	Significant
Population Migration (X_1) → Rural Poverty (Y_2)	β_{04}	5.3316	0.0251	Significant
	β_{14}	0.00004	0.0048	Significant

Land Use Change (X_2) → Rural Poverty (Y_2)	β_{05}	5.3871	0.0210	Significant
	β_{15}	0.000009	0.0005	Significant
	β_{25}	0.000011	0.0017	Significant
	β_{35}	-0.00000015	0.0001	Significant
Village Funds (X_3) → Rural Poverty (Y_2)	β_{06}	34,685	0.0039	Significant
	β_{16}	-4×10^{-10}	0.0135	Significant
	β_{26}	-5.6×10^{-9}	0.0001	Significant

Source: Data Processed by Author, 2025

4.3 Effect of the All Variables

Effect of Population Migration on The Growth of the Agricultural Sector. The relationship between population migration (X_1) and the growth of the agricultural sector (Y_1) can be seen in the following figure 2.

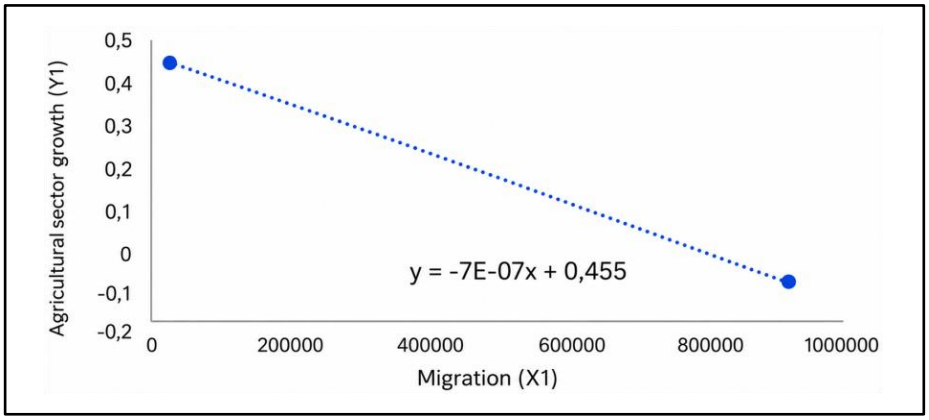

Fig. 2. Relationship between Population Migration and Growth of the Agricultural Sector
Source: Developed by Author, 2025

Based on the results in Table 2, It can be seen that the intercept or coefficient β_0 of 0.455. This means that when population migration does not exist ($X_1 = 0$), then the growth of the agricultural sector is estimated at around 0.455. While the coefficient β_0 is -0.00000007, meaning that everyone hundred thousand people increase in population migration (X_1) will reduce the growth of the agricultural sector (Y_1) by 0.0000007. The P value of the parameter β_{11} is less than 0.05, so reject H_0. This means that population migration (X_1) has a significant effect on the growth of the agricultural sector (Y_1).

Effect of Land Use Change of Agricultural on the Growth of the Agricultural Sector. Based on the data in table 2, It can be seen that all p-values for each parameter are less than 0.05, so they are rejected H_0. This means that land use change has a significant effect on the growth of the agricultural sector. The relationship between land use change

of agriculture (X_2) and the growth of the agricultural sector (Y_1) can be seen in the following figure 3.

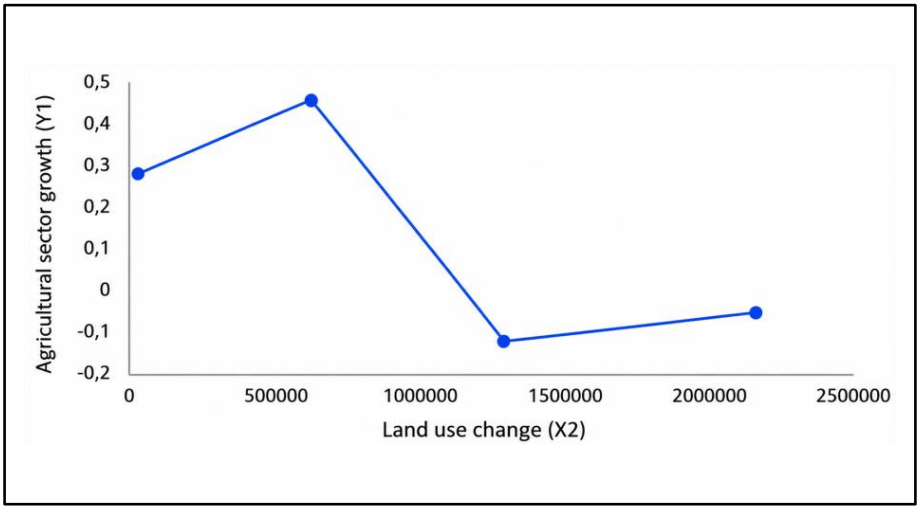

Fig. 3. Relationship between Land Use Change and Growth of the Agricultural Sector
Source: Developed by Author, 2025

Tuncated Spline Nonparametric Model in analyzing the relationship between Land use change of agriculture (X_2) against the growth of the agricultural sector (Y_1).

$$Y_{1i} = \beta_{02} + \beta_{12}X_{2i} + \beta_{22}(X_{2i} - k_{11})_+ + \beta_{32}(X_{2I} - k_{12}) + \varepsilon_{1i} \quad (4)$$

Truncated Function:

$$(X_{2i} - k_{11})_+ = \begin{cases} X_{2i} - k_{11}, & X_{2i} > k_{21} \\ 0, & X_{2i} < k_{21} \end{cases} \quad (5)$$

$$(X_{2i} - k_{12})_+ = \begin{cases} X_{2i} - k_{22}, & X_{2i} > k_{22} \\ 0, & X_{2i} < k_{22} \end{cases} \quad (6)$$

With $k_{21} = 602.721$ and $k_{22} = 1.334.358$

- For $X_{2i} < k_{21}$, So the value $(X_{2i} - k_{21})_+$ and $(X_{2i} - k_{22})_+ = 0$,

$$Y_{1i} = \beta_{02} + \beta_{12}X_{2i} + \varepsilon_{1i}$$
$$Y_{1i} = 0{,}2799 + 0{,}0000003X_{2i} + \varepsilon_{1i}$$

Interpretation: If the total area of agricultural land experiencing land use change of agriculture in rural areas is less than 602,721 hectares during the 2015-2022 period,

then everyone hectare increase in land use change will increase the growth of the agricultural sector in rural areas by an average of 0.00003 Percent.

- $k_{21} < X_{2i} < k_{22}$, means the value $X_{2i} > k_{21}$ and $X_{2i} > k_{22} = 0$

$$Y_{1i} = \beta_{02} + \beta_{12}X_{2i} + \beta_{22}(X_{2i} - k_{21})_+ + \varepsilon_{1i}$$
$$Y_{1i} = \beta_{02} + \beta_{12}X_{2i} + \beta_{21}X_{2i} - \beta_{22}k_{21} + \varepsilon_{1i}$$
$$Y_{1i} = (\beta_{02} - \beta_{22}k_{21}) + (\beta_{12} + \beta_{22})X_{2i} + \varepsilon_{1i}$$
$$Y_{1i} = \beta_{02} - \beta_{22}k_{21} + (\beta_{12} + \beta_{22})X_{2i} + \varepsilon_{1i}$$
$$Y_{1i} = -0{,}6585 - 0{,}00000011X_{2i} + \varepsilon_{1i}$$

Interpretation: If the total area of land use change of agricultural is between 602,721 and 1.334.358 hectares during the period 2015-2022, then an increase of one hectare of land use change will reduce the growth of the agricultural sector in rural areas by an average of 0.000011 Percent.

- For $X_{2i} > K_{22}$, so the value $(X_{2i} - k_{21})_+$ and $(X_{2i} - k_{22})_+ \neq 0$

$$Y_{1i} = \beta_{01} + \beta_{11}X_{2i} + \beta_{21}(X_{2i} - k_{21})_+ + \beta_{31}(X_{2I} - k_{22}) + \varepsilon_{1i}$$
$$Y_{1i} = \beta_{01} + \beta_{11}X_{2i} + \beta_{21}X_{2i} - \beta_{21}k_{21} + \beta_{31}X_{2i} - \beta_{31}k_{22} + \varepsilon_{1i}$$
$$Y_{1i} = \beta_{01} - \beta_{21}k_{21} - \beta_{31}k_{22} + (\beta_{11} + \beta_{21} + \beta_{31})X_{2i} + \varepsilon_{1i}$$
$$Y_{1i} = -0{,}2711 - 0{,}0000001X_{2i} + \varepsilon_{1i}$$

Interpretation: If the total area of land use change of agriculture in rural areas is more than 1.334.358 hectare during the 2015-2022 period, then an increase of one hectare of land use change will reduce the growth of the agricultural sector in rural areas by an average of 0.00001 Percent.

Effect of Village Funds on the Growth of the Agricultural Sector. The relationship between Village Funds (X_3)and the growth of the agricultural sector (Y_1) can be seen in the following figure 4.

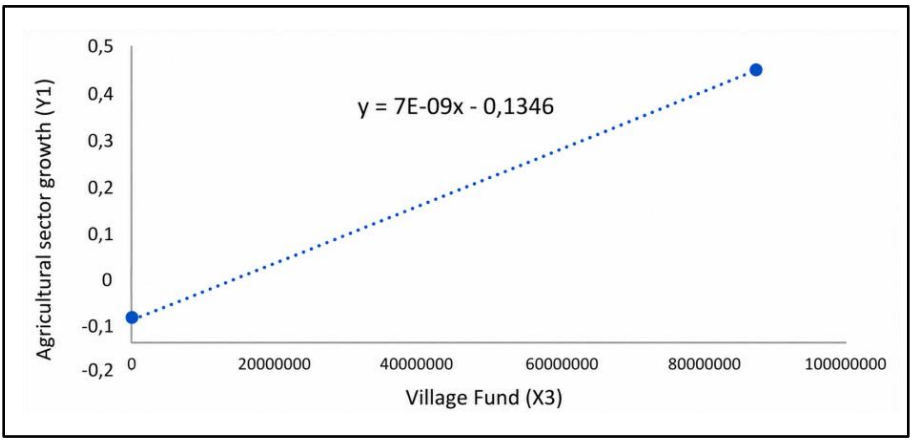

Fig. 4. Relationship between Village Funds and Growth of the Agricultural Sector
Source: Developed by Author, 2025

The data in table 2 shows that the intercept or coefficient β_{03} of -0.1346. This means that when there are no village funds ($X_3 = 0$), then the growth of the agricultural sector is estimated at approx -0.1346. While the coefficient β_{13} is 0.000000009, meaning that every increase of IDR. 1 billion in village funds (X_3) will increase the growth of the agricultural sector (Y_1) by 0.000000009 percent. Besides that, the P value of the parameter β_{13} shows less than 0.05, so H_0 it is rejected. This means that village funds (X_3) have a significant influence on the growth of the agricultural sector (Y_1).

Effect of Population Migration to Rural Poverty. The relationship between Population Migration (X_1) and Rural Poverty (Y_2) can be seen in the following figure 5.

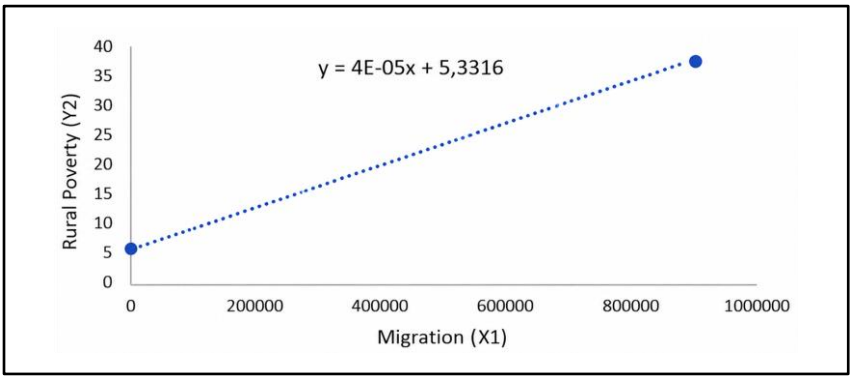

Fig. 5. Relationship between Population Migration and Rural Poverty
Source: Developed by Author, 2025

Based on the data in table 2, it can be seen that the intercept or coefficient β_{04} of 5.3316. This means that when there is no population migration (X_1= 0), then rural poverty is estimated to be around 5.3316. While the coefficient $\beta_{14}$is known to be 0.00004, meaning that every increase of one hundred thousand people migration (X_1) will increase rural poverty (Y_2) by 0.00004. In addition, the P value of the parameter $\beta_{14}$is known to be less than 0.05, so H_0 it is rejected. This means that population migration (X_1) has a significant effect on rural poverty (Y_2).

Effect of Land Use Change of Agriculture on Rural Poverty. The in table 2 showed that all *p*values for each parameter are less than 0.05, so they are rejected H_0. This means that land use change of agriculture has a significant effect on rural poverty. The relationship between Land Use Change ($\boldsymbol{X_2}$) and Rural Poverty ($\boldsymbol{Y_2}$) can be seen in the following figure 6.

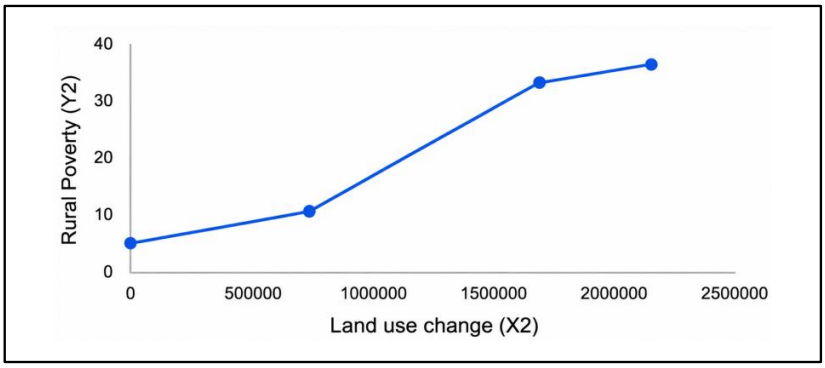

Fig. 6. Relationship between Land Use Change of Agriculture and Rural Poverty
Source: Developed by Author, 2025

Tuncated Spline. Model Relationship Between Land Use Change (X_2) against Rural Poverty (Y_2).

$$Y_{2i} = \beta_{05} + \beta_{15}X_{2i} + \beta_{25}(X_{2i} - k_{21})_+ + \beta_{35}(X_{2I} - k_{22}) + \varepsilon_{1i} \quad (7)$$

Truncated Function:

$$(X_{2i} - k_{21})_+ = \begin{cases} X_{2i} - k_{21}, & X_{2i} > k_{21} \\ 0, & < k_{21} \end{cases} \quad (8)$$

$_2$

X

$$(X_{2i} - k_{22})_+ = \begin{cases} X_{2i} - k_{22}, & X_{2i} > k_{22} \\ 0, & < k_{22} \end{cases} \quad (9)$$

$_2$

X

With $k_{21} = 731834$ and $k_{22} = 1721695$

- For $X_{2i} < k_{21}$, so the value $(X_{2i} - k_{21})_+$ and $(X_{2i} - k_{22})_+ = 0$

$$Y_{2i} = \beta_{05} + \beta_{15}X_{2i} + \varepsilon_{2i}$$
$$Y_{2i} = 5{,}3871 + 0{,}000009X_{2i} + \varepsilon_{2i}$$

Interpretation: If the total area of land use change of agriculture in rural areas is less than 731,834 hectares during the 2015-2022 period, then every one hectare increase in land function specialists will increase rural poverty by an average of 0.0009 Percent.

- $k_{21} < X_{2i} < k_{22}$, means the value $X_{2i} > k_{21} = X_{2i} - k_{21}$ and $X_{2i} < k_{22} = 0$

$$Y_{2i} = \beta_{05} + \beta_{15}X_{2i} + \beta_{25}(X_{2i} - k_{21})_+ + \varepsilon_{2i}$$
$$Y_{2i} = \beta_{05} + \beta_{15}X_{2i} + \beta_{25}X_{2i} - \beta_{25}k_{21} + \varepsilon_{2i}$$
$$Y_{2i} = (\beta_{05} - \beta_{25}k_{21}) + (\beta_{15} + \beta_{25})X_{2i} + \varepsilon_{2i}$$
$$Y_{2i} = \beta_{05} - \beta_{25}k_{21} + (\beta_{15} + \beta_{25})X_{2i} + \varepsilon_{2i}$$
$$Y_{2i} = 9{,}552 + 0{,}000011X_{2i} + \varepsilon_{2i}$$

Interpretation: If the total area of land use change of agriculture is between 731,834 and 1,721,695 hectares during the 2015-2022 period, then an increase of one hectare of land use change unit will increase rural poverty by an average of 0.0011 Percent.

- For $X_{2i} > k_{22}$, so the value $(X_{2i} - k_{21})_+$ and $(X_{2i} - k_{22})_+ \neq 0$

$$Y_{2i} = \beta_{05} + \beta_{15}X_{2i} + \beta_{25}(X_{2i} - k_{21})_+ + \beta_{35}(X_{2I} - k_{22}) + \varepsilon_{2i}$$
$$Y_{2i} = \beta_{05} + \beta_{15}X_{2i} + \beta_{25}X_{2i} - \beta_{25}k_{21} + \beta_{35}X_{2i} - \beta_{35}k_{22} + \varepsilon_{2i}$$
$$Y_{2i} = \beta_{05} - \beta_{25}k_{21} - \beta_{35}k_{22} + (\beta_{15} + \beta_{25} + \beta_{35})X_{2i} + \varepsilon_{2i}$$
$$Y_{2i} = -20{,}079 - 0{,}0000001X_{2i} + \varepsilon_{1i}$$

Interpretation: If the total area of land use change is more than 1.334.358 hectare during the 2015-2022 period, then an increase of one hectare of land use change unit will reduce the rural poverty rate by an average of 0.00001 Percent.

Effect of Village Funds on Rural Poverty. The data in table 2 also showed that all *p*-values for each parameter are less than H_0. This means that village 0.05, so reject

funds have a significant effect on rural poverty. Village Fund Relations ($\boldsymbol{X_3}$) with Rural Poverty ($\boldsymbol{Y_2}$) can be seen in the following figure 7.

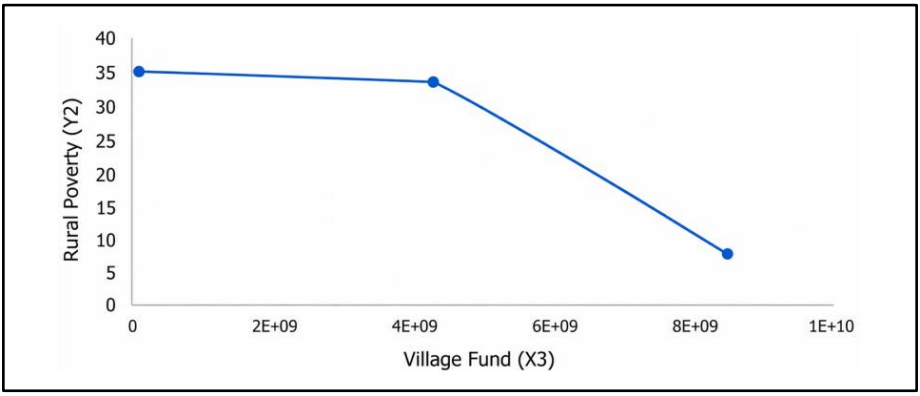

Fig. 7. Relationship between Village Funds and Rural PovertySource: Developed by Author, 2025

Tuncated Spline Model of Relationship Between Village Funds (X_3) Against Rural Poverty (Y_2)

$$Y_{2i} = \beta_{06} + \beta_{16}X_{3i} + \beta_{26}(X_{3i} - k_{31})_+ + \beta_{36}(X_{3I} - k_{32}) + \varepsilon_{3i} \quad (10)$$

Truncated Function:

$$(X_{3i} - k_{31})_+ = \begin{cases} X_{3i} - k_{31}, & X_{3i} > k_{31} \\ 0, & < k_{31} \end{cases} \quad (11)$$

X

3

With $k_{31} = 4037405060$

- For $X_{3i} < k_{31}$, so value $(X_{3i} - k_{31})_+ = 0$

$$Y_{2i} = \beta_{06} + \beta_{16}X_{2i} + \beta_{26}(X_{2i} - k_{31})_+ + \varepsilon_{3i}$$
$$Y_{2i} = \beta_{06} + \beta_{16}X_{3i} + \varepsilon_{3i}$$
$$Y_{2i} = 34{,}685 - 0{,}0000000004X_{3i} + \varepsilon_{3i}$$

Interpretation: If the government allocates village funds of less than IDR. 4.037.405.060,00 per village every year during the 2015 2022 period, then every increase of IDR. 1 billion village funds will reduce the rural poverty rate by an average of 0.00000004 Percent.

- For $X_{3i} > k_{31}$, so value $(X_{3i} - k_{31})_+ \neq 0$

$$Y_{2i} = \beta_{06} + \beta_{16}X_{2i} + \beta_{26}(X_{2i} - k_{31})_+ + \varepsilon_{3i}$$
$$Y_{2i} = \beta_{06} + \beta_{16}X_{3i} + \varepsilon_{3i}$$
$$Y_{2i} = \beta_{06} + \beta_{16}X_{3i} + \beta_{26}X_{3i} - \beta_{26}k_{31} + \varepsilon_{3i}$$
$$Y_{2i} = (\beta_{06} - \beta_{26}k_{31}) + (\beta_{16} + \beta_{26})X_{3i} + \varepsilon_{3i}$$
$$Y_{2i} = 57{,}175 - 0{,}0000000006X_{3i} + \varepsilon_{3i}$$

Interpretation: If the government allocates more than IDR. 4.037.405.060,00 per village every year during the 2015-2022 period, then every increase of IDR. 1 billion village funds will reduce the rural poverty rate by an average of 0.00000006 Percent.

5 Discussion

The empirical results indicate that the exogenous variables examined in this study are statistically associated with both agricultural sector growth and rural poverty. Regarding population migration, the estimates suggest that higher out-migration is linked to lower growth in the agricultural sector. When migration is assumed to be zero, the predicted agricultural sector growth is approximately 0.455 percent. Moreover, an increase of 100,000 migrants is associated with a decline in agricultural growth of 0.0000007 percent. This pattern is consistent with the argument that migration reduces the availability of agricultural labor and, in turn, constrains sectoral expansion [8].

Land use change in agriculture, modeled using a truncated spline specification, also exhibits a substantive association with agricultural sector growth. The estimated function suggests that when land use change remains below 602,721 hectares, it is correlated with an increase in agricultural sector growth. Once land conversion exceeds this threshold, the relationship turns adverse, indicating that further land use change tends to suppress agricultural growth. These findings underscore the importance of managing land conversion to avoid undermining agricultural productivity [10], and they reinforce calls for sustainable land-use practices that safeguard the agricultural land base to support long-run rural development [9].

Village funds display a positive and statistically significant relationship with agricultural sector growth. The estimates imply that even incremental increases in village funding are associated with higher agricultural growth. Specifically, an additional IDR 1 billion in village funds corresponds to an estimated increase in agricultural sector growth of 0.000000009 percent. Although the magnitude is small, the direction of the effect highlights the potential of fiscal transfers to contribute to rural economic development when directed toward productive uses [4], including agricultural infrastructure, support for smallholders, and stimulation of local economic activities [10].

Population migration is also significantly related to rural poverty. The model predicts rural poverty at approximately 5.33 when migration is set to zero, while an increase of 100,000 migrants is associated with a 0.00004 percent increase in rural poverty. This association suggests that migration may intensify vulnerability in origin areas, potentially through reduced local labor capacity and weaker rural economic resilience, which may worsen the economic conditions of those who remain [12, 13].

The link between land use change in agriculture and rural poverty further indicates a non-linear and context-sensitive relationship. In general, greater land conversion is associated with higher rural poverty, plausibly because conversion can reduce access to productive land and natural resources that support rural livelihoods. Such losses can decrease farm income and increase household exposure to poverty risks [18]. The

findings therefore imply the need for land-use governance that limits harmful conversion and mitigates distributional consequences for rural populations [17].

Finally, village funds are significantly associated with rural poverty reduction, although the effect varies by allocation level. When village fund allocation per village is below IDR 4.037 billion, the estimated reduction in rural poverty is limited. When allocations exceed this level, the poverty-reducing association becomes substantially stronger. This result is broadly consistent with evidence emphasizing the role of village funds in poverty alleviation through local development investments [7]. Nevertheless, the effectiveness of village funds depends critically on implementation quality, including efficient, transparent, and accountable governance arrangements, as highlighted in prior work and policy discussions [6, 19].

Taken together, the findings point to interdependent relationships among migration, agricultural land use change, village funds, agricultural sector growth, and rural poverty. They suggest that policy responses are likely to be most effective when designed as an integrated package that simultaneously addresses demographic pressures, landuse transformation, and fiscal capacity in rural areas to support sustainable development and poverty reduction in Indonesia.

In addition, the functional-form assessment provides methodological justification for the modeling strategy. The linearity tests indicate that the relationships between population migration and agricultural sector growth, and between village funds and agricultural sector growth, can be adequately represented using parametric specifications. By contrast, the relationships involving land use change with agricultural sector growth, land use change with rural poverty, and village funds with rural poverty exhibit nonlinear patterns, supporting the use of a semiparametric approach to capture these complexities [21]. This evidence highlights that rural economic processes may operate differently across ranges of key predictors, and that policy design should be informed by such non-linearities.

Overall, rising migration is consistently linked to weaker agricultural growth and higher rural poverty, whereas village funds are positively associated with agricultural growth and, above a threshold, more strongly associated with poverty reduction. Landuse change shows threshold behavior, where extensive conversion beyond a critical level, particularly above 602,721 hectares, is associated with reduced agricultural growth and heightened poverty risks. These dynamics imply that rural development strategies should align land-use regulation with poverty alleviation objectives, while ensuring that village fund allocations prioritize high-impact programs capable of strengthening productive capacity and livelihoods in rural communities.

6 Conclusion

Based on the results of this study, several key conclusions can be drawn. The variables of population migration, land use change of agriculture, and village funds all have significant effects on both the growth of the agricultural sector and rural poverty. The relationships between population migration and growth of the agricultural sector, as well as between village funds and growth of the agricultural sector, are linear. On the

other hand, the relationships between land use change of agriculture and both growth of the agricultural sector and rural poverty, as well as between village funds and rural poverty, are non-linear. This justifies the use of the spline truncated semiparametric path analysis model employed in this study. Furthermore, the study finds that the total area of land use change in rural areas should not exceed 602,721 hectares. Exceeding this threshold would have a detrimental effect on the rural economy, reducing agricultural growth and exacerbating rural poverty.

Regarding village funds, the study shows that these funds can effectively reduce rural poverty at a higher rate if the allocation per village exceeds IDR 4,037,405,060.00 per year. This finding emphasizes the need for the government to increase the allocation of village funds proportionally, considering regional economic conditions and ensuring that financial capacity is not overextended. The study also suggests that strengthening supervision and coaching functions in village governments is crucial to ensuring that the funds are used efficiently, effectively, transparently, and accountably.

In terms of policy recommendations, it is essential for the government to not only increase the allocation of village funds to a level that significantly contributes to poverty alleviation but also to consider the varying financial needs of each village. A more regionally tailored approach, which factors in local economic conditions, can lead to more equitable development across different rural areas. Additionally, there should be a focus on improving land use policies to prevent excessive land conversion, particularly in areas where agricultural productivity is still vital for the local economy. Policies that promote sustainable agricultural practices and limit harmful land use changes could protect rural communities from the negative consequences of land conversion. Lastly, strengthening institutional capacity at the village level through training, support, and accountability mechanisms will ensure that the allocated funds are utilized for their intended purpose—driving growth in the agricultural sector and improving the living standards of rural populations.

This study has certain limitations. The problem of poverty faced by rural areas in Indonesia is still very important to be studied in depth, not only, focus on aspects of the factors that influence population migration, land use change and village funds. The article focuses on aspects of the factors that influence growth of the agriculture sector and poverty. The limitations of the problem in this study are as follows, the variables used are population migration, land use change, village funds, agricultural sector growth, and rural poverty, the analysis used is semiparametric path analysis

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