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The Application of Truncated Spline Semiparametric Path Analysis on Determining Factors Influencing Cashless Society Development

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ABSTRACT

Semiparametric path analysis is a combination of parametric and nonparametric path analysis. One approach to semiparametric pathways is truncated spline. Truncated spline semiparametric path analysis will be applied to this study to determine the variables that have a significant effect on the development of the Cashless Society. The data used is the result of a questionnaire with respondents of mobile banking users in Jakarta as many as 100 people. Based on the results of the analysis, it was found that the optimal knot point in the truncated spline function is 3 with many knots is 1, thus dividing the condition of digitizing electronic money into 2 regions. It was concluded that the product and digitalization of electronic money had a significant effect on the development of cashless society where the modeling obtained could explain 83.87548% of the data.

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A. INTRODUCTION

Path analysis is a development of regression analysis that can accommodate multiple structural equations. One of the characteristics of structural equations in path analysis is that it involves at least one exogenous variable, at least one intervening endogenous variable and there is one pure endogenous variable (Fernandes & Solimun, 2021). Path analysis can also be used to test regression equations involving several exogenous and endogenous variables at once, thus allowing testing of intervening variables or intermediate variables (Cahyoningtyas et al., 2020). Exogenous variables in path analysis are variables that affect other variables. As for variables that are influenced by a variable without affecting other variables, they are referred to as pure endogenous variables while intervening endogenous variables are variables that affect and are influenced by other variables (Krämer et al., 2014).

Similar to regression analysis, path analysis also has several assumptions, including the assumption of linearity, the assumption of residual normality and the assumption of homoscedasticity. The assumption of linearity is an assumption that must first be fulfilled before path analysis is performed. In path analysis, it is assumed that the relationship between exogenous variables and endogenous variables can be explained through a known function and that function is a linear function. If the relationship between exogenous variables and endogenous variables is described by functions that are not linear and have no known form, then estimating parametric path parameters cannot be done so that a nonparametric approach is used(Fernandes et al., 2015). There are two ways to check the linearity assumption, namely by looking at the scatter diagram and testing the linearity assumption using the Regression Specification Error Test (RESET) developed by Ramsey (Ubaidillah et al., 2022).

If in a modeling path the variable relationship is partly known curves while some are not known in shape, semiparametric path analysis is used. The semiparametric path approach is a combination of parametric and nonparametric approaches so that in one model estimating parameters and functions is carried out (Fernandes & Solimun, 2021; Rasyidah et al., 2021).

One approach to nonparametric pathways is spline. Splines are used in nonparametric pathway analysis because they can follow patterns of relationships between exogenous variables and endogenous variables and are very flexible. According to Hidayat & Achmad (2019), spline is a part or pieces of polynomials that have segmented and continuous (truncated) properties. The advantage of truncated splines is that they tend to find their own form of estimating the regression curve (Handayani et al., 2023). This can happen because splines have compound points that show a pattern of data behavior called knot points.

The knot point is a very effective adjustment point to local characteristics so that the spline has high flexibility. There is a method to select optimal smoothing parameters in the spline model, namely Generalized Cross Validation (GCV). The best spline estimator is obtained when the knot point is optimal leading to parsimony or simplicity of the model (Devi & Pratama, n.d.; Utami et al., 2020).

Semiparametric path analysis can be applied in various fields, one of which is in banking economics. As in this study, we want to analyze the relationship between the influence of the variables Product and Electronic Money Digitalization on the variables of Cashless Society Development. (Doan et al., 2015) emphasizes that the product is the first and one of the key marketing elements. A product is defined by Išoraitė (2016) as anything that can be put on the market to attract attention, purchased, used, or eaten in order to fulfill a need or want. Electronic money is the context in which this product is being discussed.

The electronic payment (e-payment) system is known as a cashless payment system (Kabir et al., 2015). The content of a cashless payment system is usually some form of digital financial instruments or credit cards that are backed by banks or nonbanks (Fatonah et al., 2018). Cashless payment is financial transactions executed online between buyers and sellers. This payment system helps companies to do businesses with a low cost of financial transactions (Alzoubi et al., 2022; Yakean, 2020). Cashless payments allow for trade of goods and services through electronic media and non-electronic transfers via checks (Tee & Ong, 2016).

The advantages of using e-money for small-value payment transactions with the greatest degree of flexibility have been demonstrated by numerous research. For instance, in transportation, movie theaters, nightclubs, and the fulfillment of penalties, taxes, and court mandates. Making calculations online is a pretty simple process when purchasing both traditional and technological goods, such as computer software, among other things (Wulandari et al., 2016). The procedure of paying with e-money is fast, and there are no typical issues like lines. In a matter of seconds, e-money is sent from the payer to the beneficiary. When compared to cash, e-money has many benefits, but it also has disadvantages (Popovska-Kamnar, 2014).

During that COVID-19 epidemic, little droplets from coughing, sneezing, and talking might transfer the virus to those in close proximity. Since the COVID-19 pandemic, society has adopted a new culture of delayed transaction. The coronavirus can transfer between individuals in close proximity by tiny droplets expelled during coughing, sneezing, and talking. People who come into contact with cash or checks from COVID-19 infected individuals run the risk of becoming infected themselves. Thus, a cashless society was created in order to minimize physical contact during the pandemic (Yakean, 2020).

Pal & Bhadada (2020) stated that digital transactions present a viable substitute. However, given the unusual stability of SARS-CoV-2 on plastic, using debit or credit cards is also not a safe option. Additionally, card transactions typically call for the entry of a PIN or signature on merchant-owned devices, which may be a potential source of infection.

There are previous studies that examined factors that influence the development of cashless society namely research conducted by Chern et al., (2018). In research conducted by Chern et al., it was found that convenience, social influence and speed has significant relationship towards adoption of E-wallet. Namun penelitian ini masih terbatas dilakukan di lingkup kampus UTAR.

Research related to the development of cashless society has also been carried out by Sanrach (2021).The study was conducted in Thailand and found that the main factors influencing cashless transactions were its ability to simplify daily life and lower the expense of traveling to banks or counter service providers. Eight items were different at the statistical significance level of 0.05 when the various factors influencing cashless payment of goods and services were compared according to the age of the consumers.

A similar analysis was also performed by Suprapto (2020) related to factors that affect cashless society in Batam. It was discovered from the research that the variables of behavioral beliefs and financial costs do not significantly affect the intention to use cashless mobile payments, but attitude, security, and social influence do have a significant positive impact.

Research related to the development of cashless society in Indonesia is still rarely carried out. Therefore based on the description above, research will be carried out in order to find out what factors affect the development of *cashless society* using semiparametric *Truncated spline* Analysis which is expected to be used as a reference for banks in marketing *e-money* products to the public and as a reference for statistical users related to the use of semiparametric path analysis.

B. METHODS

The data used in this study was questionnaire data. This data was obtained from a survey with the customer population of a bank that uses Mobile Banking in Jakarta with a sample taken the size of 100 respondents. The study was conducted using latent variables derived from the Likert measurement scale. The variables measured in the analysis of moderation variables with a multigroup approach are Product (X_1), Digitalization of electronic money (Y_1), and Development of cashless society (Y_2). Respondents were given a questionnaire to provide an assessment based on the alternative answers provided, namely using a Likert scale of five, namely a score of 1 strongly disagrees until a score of 5 strongly agrees. The research path can be seen in Figure 1.

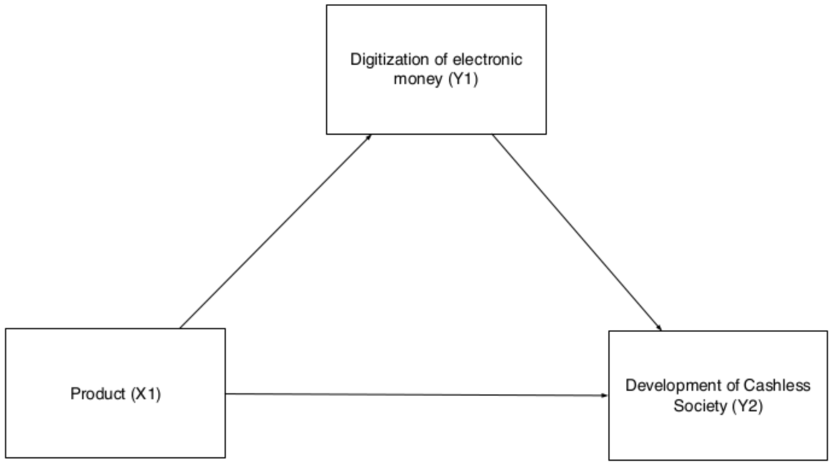

Figure 1. Path Diagram

The following are the steps of the research carried out.

1) Construct a path diagram based on the structural model design which can be seen in Figure 1.
2) Convert a path chart into a system of equations which can be seen on equation (1).

$$\begin{aligned} \hat{Y}_{1i} &= \hat{\beta}_{01} + \hat{\beta}_{11} X_{1i} \\ \hat{Y}_{2i} &= \hat{\beta}_{02} + \hat{\beta}_{12} X_{1i} + \hat{\beta}_{22} Y_{1i} + \hat{\delta}(Y_{1i} - K)_+ \\ (Y_{1i} - K)_+ &= \begin{cases} Y_{1i} - K, & Y_{1i} > K \\ 0, & Y_{1i} < K \end{cases} \end{aligned} \tag{1}$$

3) Testing linearity assumptions using Ramsey's RESET to determine the shape of relationships between variables. If some relationships satisfy the assumption of linearity and others do not, then proceed to the next stage. The general model used to describe the relationship between exogenous and endogenous variables can be seen in the equation (2) dan (3).

$$Y_{1i} = \beta_0 + \beta_1 X_{1i} + \varepsilon_{1i} \tag{2}$$

$$Y_{2i} = \beta_0 + \beta_1 X_{1i} + \beta_2 Y_{1i} + \varepsilon_{2i} \tag{3}$$

RESET linearity testing uses the following hypotheses.

$H_0: \beta_{p+1} = \beta_{p+2} = \cdots = \beta_{p+m}$

H_1: There is at least one β_{p+j} different, $j = 1,2, \dots, m$

The following is the procedure for using Ramsey's RESET based on opinion Sari et al. (2019).

a. Forming the old *regression equation* Y_i pada $X_1, X_2, X_3, \dots, X_p$ so that the estimated value $(\hat{Y}_i)$ is

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \hat{\beta}_2 X_{2i} + \cdots + \hat{\beta}_p X_{pi} \tag{4}$$

b. Forming new regression equation Y_i^* pada $X_1, X_2, X_3, \dots, X_p$ and adding exogenous variable (Y_i^2) so that $\hat{Y}_i^*$ obtained using equation (5)

$$\hat{Y}_i^* = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \hat{\beta}_2 X_{2i} + \cdots + \hat{\beta}_p X_{pi} + \hat{\beta}_{p+1} Y_i^2 + \hat{\beta}_{p+2} Y_i^3 + \cdots + \hat{\beta}_{p+m} Y_i^{m+1} \tag{5}$$

c. Calculating coefficient of determination (R^2) from regression obtained on step a) and b that can be written as R^2_{old} dan R^2_{new}.

$$R^2_{old} = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{y})^2} \tag{6}$$

$$R^2_{new} = 1 - \frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n}(Y_i - \bar{y})^2} \tag{7}$$

d. From equation (6) and (7), $F - statistics$ can be calculated using this following equation

$$F - stat = \frac{(R^2_{new} - R^2_{old})/m}{(1 - R^2_{new})/(n-p-1-m)} \sim F_{m,n-p-1-m} \tag{8}$$

Reject H_0 if the p-value $= P(F_{n-p-1-m} \geq F - stat) < \alpha$

Information:

$j = 1,2 \dots, m,$ m: number off addition exogenous latent variable

p: number of exogenous variable

$i = 1,2,3, \dots n, n$: number of observations

Based on hypothesis testing above, F-statistics is distributed by F distribution with degree of freedom m and $(n - p - 1 - m)$. Jika $F - stat > F_{(\alpha;m,n-p-1-m)}$ or $p - value < \alpha$, so it can be concluded that H_0 is rejected therefore the model is not linear.

4) Perform semiparametric path modeling so as to obtain the optimal knot point using GCV and a function estimator will be obtained to determine the degree of polynomial.
   The smallest GCV value is the optimal knot point written as (Fernandes et al., 2014):

$$GCV(\boldsymbol{K}) = \frac{MSE(\boldsymbol{K})}{[n^{-1} trace(\boldsymbol{I} - A(\boldsymbol{K}))]^2} \tag{9}$$

where $MSE(\boldsymbol{K}) = n^{-1} \sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2$, $\boldsymbol{K}$ is knot point and $\boldsymbol{A}(\boldsymbol{K})$ is obtained from

$$\hat{\boldsymbol{Y}} = \boldsymbol{A}(\boldsymbol{K})\boldsymbol{Y}$$

$$\boldsymbol{A}(\boldsymbol{K}) = \hat{\boldsymbol{Y}}^{-1}\boldsymbol{Y}$$

$$A(\boldsymbol{K}) = \boldsymbol{X}[\boldsymbol{K}](\boldsymbol{X}[\boldsymbol{K}]^T\boldsymbol{X}[\boldsymbol{K}])^{-1}\boldsymbol{X}[\boldsymbol{K}]^T \tag{10}$$

equation (2) is a function of knot points $\boldsymbol{K} = (K_1, K_2, \dots, K_k)^T$

5) Perform partial hypothesis testing to determine the significance of parameters and functions
6) Calculate the value of the coefficient of determination to determine the goodness of the model
7) Interpret the results of truncated spline semiparametric paths analysis.

C. RESULT AND DISCUSSION

1. Linearity Assumption Test (Ramsey's RESET)

Linearity assumption test is performed using Ramsey's RESET. Relationships that are non-linear and have no or unknown data pattern types are relationships that use a nonparametric approach.

Table 1. Linearity Test Results (Ramsey's RESET)

Relationship between Variables	p-value	Result
$X_1 \rightarrow Y_1$	0.3086	Not significant
$X_1 \rightarrow Y_2$	0.7094	Not significant
$Y_1 \rightarrow Y_2$	0.006038	Significant

Based on the test results above, it can be seen that there is a nonlinear relationship between the variables of Electronic Money Digitalization (Y_1) and the Development of a Cashless Society (Y_2), while the rest have a linear relationship. Then the analysis that will be carried out at the next stage is semiparametric path analysis.

2. Determination of the Optimal Knot Point

In this study, a truncated spline semiparametric path model with knots and polynomial order as much as one can be seen in the following equation.

$$\hat{Y}_{1i} = \hat{\beta}_{01} + \hat{\beta}_{11} X_{1i}$$
$$\hat{Y}_{2i} = \hat{\beta}_{02} + \hat{\beta}_{12} X_{1i} + \hat{\beta}_{22} Y_{1i} + \hat{\delta}(Y_{1i} - K)_+ \quad (11)$$
$$(Y_{1i} - K)_+ = \begin{cases} Y_{1i} - K, & Y_{1i} > K \\ 0, & Y_{1i} < K \end{cases}$$

The optimal knot point layout is determined based on Generalized Cross Validation (GCV) and Mean Square Error (MSE). The knot point that has the smallest GCV and MSE is the optimal knot point. The knot point and GCV value can be seen in table 2.

Table 2. Optimal Knots based on GCV and MSE

No	Knot	GCV	MSE
1	3.5	0.1106698	0.1097862
2	4.0	0.1106865	0.1098028
3	3.2	0.1108436	0.1099586
4	2.8	0.1108626	0.1099774
5	3.3	0.1108886	0.1100033

Based on the results of GCV and MSE calculations in table 2, it can be seen that knot point 3.5 has the smallest GCV and MSE values so it is determined as the optimal knot point.

3. Truncated Spline Semiparametric Path Modeling

Based on the selection of optimal knot points in the previous subchapter, semiparametric path modeling can be done with knots = 1 and linear polynomial order which can be written in the following equation.

$$\hat{Y}_{1i} = 2.6552 + 0.2386 X_{1i}$$
$$\hat{Y}_{2i} = -0.3101 + 0.1731 X_{1i} + 0.9293 X_{1i} - 0.6465 (Y_{1i} - 3.5)_+ \quad (12)$$
$$(Y_{1i} - 3.5)_+ = \begin{cases} Y_{1i} - 3.5, & Y_{1i} > 3.5 \\ 0, & Y_{1i} < 3.5 \end{cases}$$

4. Partial Test and Goodness of Fit Model

A partial test was conducted to determine the significance of the estimator parameters and functions that have been obtained in the truncated spline semiparametric path model. The partial test is performed using the t-test which can be seen in table 3.

Table 3. t-test Result

Estimator	p-value	Result
β_{01}	0,000	Significant
β_{11}	0,000	Significant
β_{02}	0,000	Significant
β_{12}	0,000	Significant
β_{22}	0,000	Significant
δ	0,000	Significant

Based on the partial tests that have been done, it can be seen that all relationships between variables in this study are significant, in other words product (X_1) and digitization of electronic money (Y_1) Significantly affects the development of cashless society (Y_2). Based on the model obtained, the total coefficient of determination (total diversity) can be calculated which aims to determine the goodness of the model. The formula for the coefficient of total determination is as follows.

$$R_t^2 = 1 - P_{e1}^2 P_{e2}^2 \ldots P_{ep}^2 \quad (13)$$

The calculation of residual influence is written as:

$$P_{ei}^2 = \sqrt{1 - R_i^2} \quad (14)$$

where:

$$R_i^2 = 1 - \frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n} (Y_i - \bar{Y}_i)^2} \quad (15)$$

The calculation of the total coefficient of determination is 0.8387548 means that the model obtained is able to explain 83.87548% of data diversity. It can be concluded that the model is considered as good for modeling the case for the development of cashless society.

5. The Relationship Pattern Of Each Variable

The relationship pattern of each variable can be seen in figure 2. It can be seen that the pattern of the relationship of the Product (X_1) towards the digitization of electronic money (Y_1) is linear. The relatinship pattern between Product (X_1) towards the Development of Cashless Society (Y_2) is also linear. While the relationship pattern of variable relationships of digitization of electronic money (Y_1) towards the Development of Cashless Society (Y_2) is nonlinear. It can be seen on the Figure 3 that there is an inflection point, when $Y_1 = 3.5$.

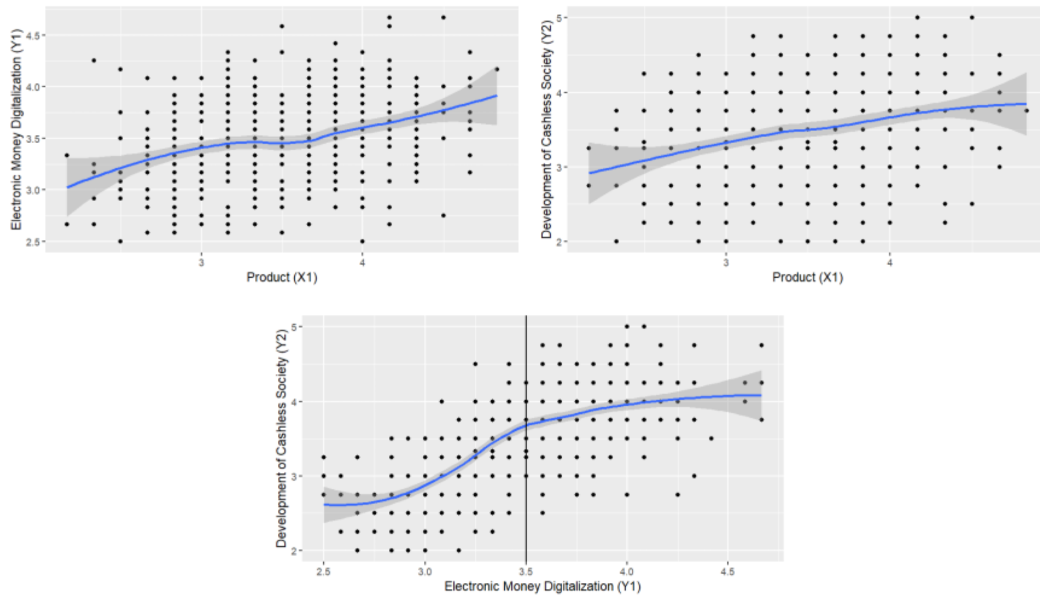

Figure 2. Scatterplot of Each Relationship between Two Variables

In scatterplot of relationship between electronic money digitalization (Y_1) and the development of the Cashless Society (Y_2), there is a point where there is a change in data patterns, it is at point 3.5 which is the optimal knot point. The Knot point divides the data into 2 regimes. The first regime is when $Y_{1i} < 3.5$, which is when the digitization of electronic money is considered weak to quite weak. While in the second regime is when $Y_{1i} \geq 3.5$ or when the digitization of electronic money is considered good enough (at 3.50) to very good.

The picture shows that when the condition of digitalization of electronic money is considered not good enough at point 2 to very good at point 5 by customers, the cashless society will develop. However, after passing the knot point, the development of cashless society tends to be more sloping when compared to regime 1. This could be due to people who are not ready when the condition of digitizing electronic money is increasingly sophisticated because the available electronic money features are increasingly complex. Therefore, it is important for banks to pay attention to the sophistication of electronic money features provided to customers and adjust the target market so that customers are more accustomed and comfortable to use electronic money in the future.

D. CONCLUSION AND SUGGESTIONS

Based on the analysis that has been done, it can be concluded that the truncated spline semiparametric path model obtained is good for modeling the development of cashless society. Variables that have a significant influence on the development of cashless society are products and digitalization of electronic money. Therefore to continue to develop a cashless society, banks need to pay attention to the quality of digital money products provided and the sophistication of electronic money's available features so that customers are consistenly using electronic money In order to realize a cashless society until the future.

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