Logit and probit model in toll sensitivity analysis of Solo-Ngawi, Kartasura-Palang Joglo segment based on Willingness to Pay (WTP)

Dewi Handayani, Hera Cahyaning Putri and AMH Mahmudah

Civil Engineering Department, Sebelas Maret University, Ir. Sutami Road 36 A Surakarta, Central Java, Indonesia.

Email: (dewihandayani9@yahoo.com)

Abstract. Solo-Ngawi toll road project is part of the mega project of the Trans Java toll road development initiated by the government and is still under construction until now. PT Solo Ngawi Jaya (SNJ) as the Solo-Ngawi toll management company needs to determine the toll fare that is in accordance with the business plan. The determination of appropriate toll rates will affect progress in regional economic sustainability and decrease the traffic congestion. These policy instruments is crucial for achieving environmentally sustainable transport. Therefore, the objective of this research is to find out how the toll fare sensitivity of Solo-Ngawi toll road based on Willingness To Pay (WTP). Primary data was obtained by distributing stated preference questionnaires to four wheeled vehicle users in Kartasura-Palang Joglo artery road segment. Further data obtained will be analysed with logit and probit model. Based on the analysis, it is found that the effect of fare change on the amount of WTP on the binomial logit model is more sensitive than the probit model on the same travel conditions. The range of tariff change against values of WTP on the binomial logit model is 20% greater than the range of values in the probit model . On the other hand, the probability results of the binomial logit model and the binary probit have no significant difference (less than 1%).

1. Introduction

PT Solo Ngawi Jaya as the toll management company of Solo - Ngawi toll project divides the work packages into several sections based on the length of the road. Segment Kartasura - Palang Joglo is classified as short segment with a distance of ± 13.65 km. Although the Kartasura - Palang Joglo segment is classified into a short segment, but the potential demand for toll road users is estimated to be quite large. Kartasura is one of alternative route that connects Boyolali District with Surakarta City as well as the gate of triangle area of Yogyakarta - Semarang - Solo. This condition causes most of the arterial road in Kartasura to be very crowded especially during rush hour. These Traffic congestion is a global problem that almost everyone living in big cities has to face, which causes a great waste of time for the urban commuters. At the same time, the rapid development of transportation, especially the current unrestrictive use of private cars, also brings about the severe air pollution and energy crisis problem. It is well known that all these traffic problems seriously restrict the further development for the cities all over the world. And therefore, there is clearly an urgent need for effective measures and policies to combat all these issues caused by the unsustainable transportation systems and then to develop a sustainable, low-carbon, and energy-saving urban transportation systems.Road toll pricing, which is a

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type of traffic demand management measure, is widely recognized as a useful tool for alleviating traffic congestion and reducing vehicular emissions [6]. There is a substantial body of literatures on road toll pricing, and the policy objectives of these works can be generally summarized as follows: minimizing total travel time of transportation networks with fixed travel demand, maximizing total social welfare of all travelers in the network with elastic travel demand, maximizing the network capacity, or maximizing the network travel time reliability [5]. However, as the issues of society, environment, and energy caused by traffic congestion become worse and worse, improving the sustainability of the urban transportation systems is nowadays the urgent concern of transportation network management. In this paper, we attempt to analyze the sensitivity of the Solo-Ngawi toll for designing a financially and environmentally sustainable transportation system. Research on sensitivity analysis of Tariff based on Willingness To Pay (WTP) has previously been performed by Ryandika [17] and Panjaitan [4], but the analysis model used in this research is different. This study uses probit and logit models that are compared to each other, while research conducted by Ryandika [17] and Indra Ferdinan Panjaitan [4] only use multinomial logit model in analyzing data. Comparison of logit and probit model which is performed in this research is similar as research done by Rahardjo [16], Supriyanto [18] and Panjaitan [10] who analyzed the mode transport selection using probit and logit model. The advantage of the probit model is the type of predictor variable, which is assumed to be qualitatively binary, i.e. 0 or 1, so it can use the normal distribution approach. logit model has predictor variable with nominal or ordinal scale. From such conditions, the probit model is more appropriate if used for economic analysis [18]. While this research analyzes the selection of route between toll road and non-toll consider the sensitivity of Willingness to Pay (WTP) toll tariff to travel time. This is what distinguishes this research with previous studies.

2. Theoretical Background

2.1 Toll Road

Toll road is a public road that is part of the road network system and as a national road whose use is required to pay the toll. While the toll itself is a certain amount of money paid for toll road users. Toll road users are liable to pay the tolls used for return on investment, maintenance and development of toll roads. Toll road users will benefit from vehicle operating cost savings and time versus passing non-toll roads. Meanwhile, business entities get return on investment through toll tariffs paid by toll road users (UU No. 38 Tahun 2004).

2.2 Willingness to Pay (WTP)

Willingness to Pay (WTP) is the willingness to pay for services received. The approach used in the analysis of WTP are based on the user 's perception of the rates of public transport services [2]. Willingness to Pay (WTP) is the maximum willingness to pay according to the services they receive [1], or the willingness to pay for the quality of service expected [22]. The approach used in the WTP analysis is based on the user's perception of the tariff of the public transport service. In this study, the value of WTP is calculated by approach NEV (Nett Economic Value) which can be seen in Equation (1).

$$WTP = NEV = P(x) \times x / d \quad (1)$$

where,

$P_{(x)}$ = probability of respondent for price X (Rp)
x = offered toll charges (Rp),
d = mileage.

2.3 Stated Preference Method

Stated preference is a method that uses a respondent's statement about respondent's preference for transportation options to estimate utility function. The basic principle of Stated Preference is its ability

to present a scenario of choice of situation, then guide the respondent to choose according to respondent's wishes [7].

2.4 Logit Binomial Model

Probability analysis in this study is performed by binomial logit model. The probability formula of the binomial logit model can be seen in Equation (2) [13]

$$P_{jt} = \frac{1}{1 + e^{-\mu\beta(U_{jt} - U_{jnt})}} \quad (2)$$

Where,

P_{jt} = probability of toll road selection,
β = calibration parameter,
U_{jt} = toll road selection utility,
U_{jnt} = non toll road selection utility.

2.5 Binary Probit Model

The probability analysis using the toll in this study uses binary probit model based on the equation which can be seen in Equation (3) [13].

$$P_{jt} = \varphi\left(\frac{U_{jt} - U_{jnt}}{\sigma}\right) \quad (3)$$

where,

P_{jt} = probability of toll road selection,
φ = cumulative normal distribution,
σ = deviation standar,
U_{jt} = toll road selection utility,
U_{jnt} = non toll road selection utility.

2.6 Test Statistic

A study using statistical data will perform a statistical test used to test the level of confidence (reability) of the model obtained, by measuring its ability to estimate utility values. In this research, the statistical test of utility model are: coefficient of determination (R^2), chi square test and Overall Percentage test [13].

2.7 Sensitivity Analysis

Sensitivity analysis aims to determine the sensitive parameters in a model. The sensitivity of the model is intended to understand the change in probability value of route selection (toll road and non-toll road) if gradual attribute value change is performed. For parameters categorized as insensitive, then this sensitivity analysis also aims to determine the range of values that change the parameters that do not change the optimal results [3].

3. Research Method

The location of this research is carried out along the arterial road that connect Solo-Ngawi city along 90.25 Km located in 5 districts and 2 Province of Boyolali, Surakarta, Karanganyar, Sragen (Central Java Province) and Kabupaten Ngawi (East Java Province). The location of this research can be shown in Figure 1.

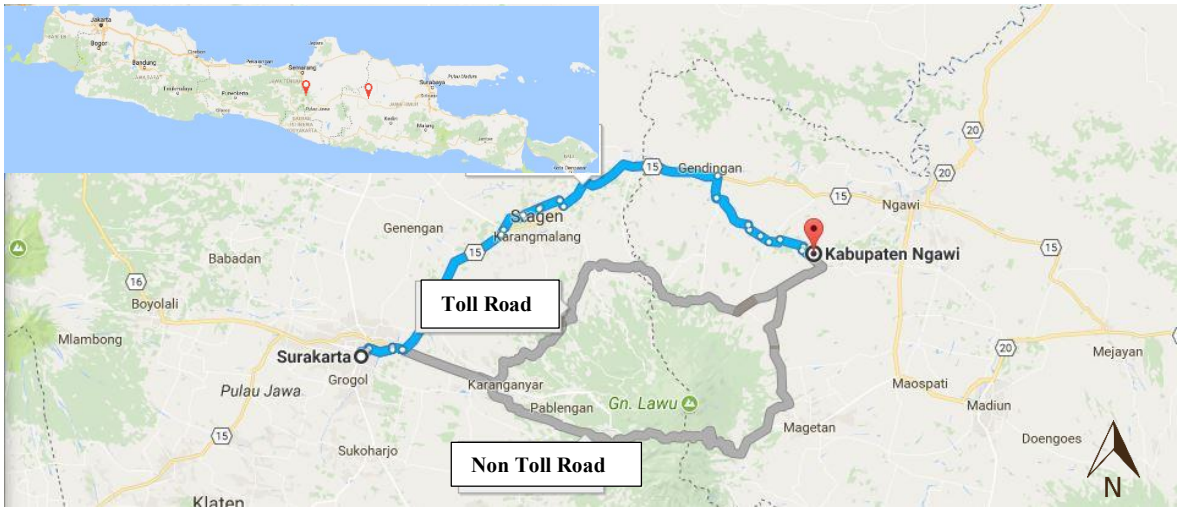


Figure 1. Location of The Research

Primary data obtained by distributed questionnaires stated preference to four wheeled private vehicle users on Kartasura-Palang Joglo artery roads.The survey form is grouped into 2 forms, namely the form 1 contains the respondent's characteristic data and the form 2 contains the respondent's choice of 9 scenarios obtained from 2 attributes ie the cost Travel and travel time Each attribute is the difference in using toll road and non-toll road The data analysis is done with the help of Microsoft Excel and SPSS 17.0

The first stage of research is to calculate the equation of utility value difference using multiple linear regression approach. Multiple linear regression analysis is calculated using SPSS and Microsoft Excel software to obtain parameter coefficients. In the regression analysis, some statistical tests, ie coefficient of determination (R^2) to measure the size of the contribution / contribution of the independent variables to the changes of the dependent variable, and F test to see whether all the regression coefficients and the independent variables present in the regression model can be used as a basis for predicting data. The utility value of the prospective users of the Solo-Ngawi toll road is then analyzed by probability using logit and probit model so that the value of Willingness to Pay (WTP) can be obtained. The value of WTP is then became the basis data to analyze the sensitivity of toll rates Solo-Ngawi.

4. Result and Discussion

4.1 Analysis of Toll Road Utility Using Binomial Logit Model

In this study to determine the utility of toll road used multiple linear regression approach. Before looking for coefficient value, the calculation of the deviation of two variables should be performed. The deviation is between toll road and non toll road. Through the calculation using SPSS 17.0 and Microsoft Excel, obtained the value of regression coefficient to estimate the model, therefore it can be obtained the following utility model:

$$U_t = 2.821 - 0.374\ (C_t - C_{nt}) + 0.091\ (T_t - T_{nt}) \quad (4)$$

Where,

U_t = toll road utility,
T_t = time spent by toll road users,
T_{nt} = time spent by non-toll road users,
C_t = cost incurred by toll road users,
C_{nt} = costs incurred by non-toll road users.

4.2 Test Statistic for Logit Binomial Model

After obtaining the value of utility then statistical tests are performed using Microsoft Excel and SPSS 17.0.

1. Coefficient of Determination Test (R^2)
   Based on calculation using SPSS 17.0 obtained value of Nagelkerke R Square equal to 0,226. The pseudo-R^2 value is then analogized to the value of R^2 by using pseudo-R^2 mapping graph to linear R^2 so that R^2 value of 0,52 is obtained. The variability of model of Solo-Ngawi Toll Road Selection of Kartasura-Palang Joglo toll road can be explained by independent variable of 52 % And there are 100% - 52% = 48% explained by other variables.
2. Chi Square Statistics Test
   Based on the calculation using SPSS 17.0, Chi-Square value of 67,646 or 0.000 (<0,05) indicates that the addition of independent variable can give real effect to the model, or in other words the model is stated fit.
3. Overall Peercentage Test
   Based on the calculation using SPSS 17.0 obtained Overall Percentage result from research data of Toll Road toll road route selection by 69,6% Overall Percentage Result in this analysis according to statistical requirement. The approximate value of y estimation with the survey results data is quite large.

4.3 Analysis of Probability Model of Toll Road Using Binomial Logit Model

In the model analysis with binomial logit, based on data that has been analyzed previously obtained a model derived from the deviation in utility between Toll Road and Non Toll Road. Probability of Toll Road selection can be calculated as follows:

$$P_{tol} = \frac{1}{1 + \exp^{-(2.821 + 0.374(C_{tol} - C_{non\,tol}) + 0.091 T_{tol} - T_{non\,tol}}} \quad (5)$$

The amount of probability of using tolls can be obtained by substituting the rate and time of each scenario into the probability model. While the amount of WTP (Willingness to Pay) can be obtained using the approach NEV (Nett Economic Value)

4.4 Toll Sensitivity Analysis Using Binomial Logit Model

To find out whether the resulting model is relevant, sensitivity analysis of the model is required. The model sensitivity analysis is performed on certain conditions by varying one of the variables, so that the probability value of route selection can be determined. Sensitivity analysis is done on the variable of travel cost and travel time. Here are the variations of conditions given for testing the model shown in Figure 2.

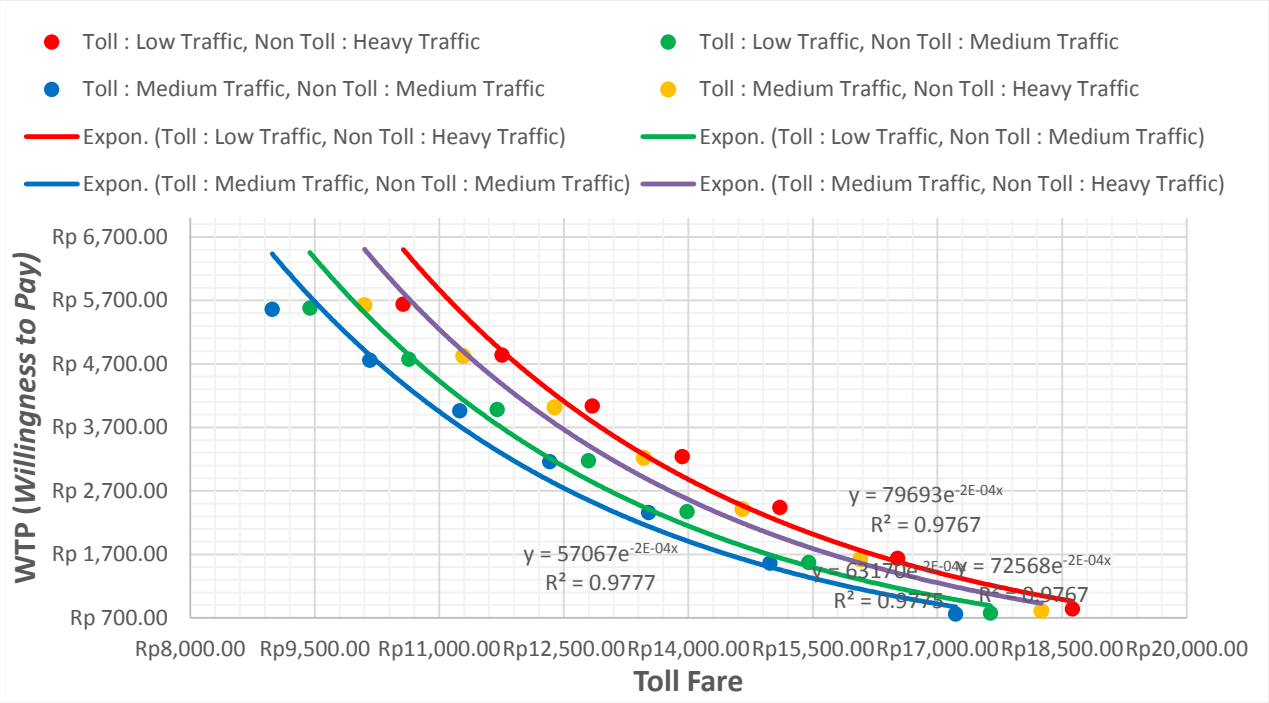


Figure 2. Toll Sensitivity Chart Using Binomial Logit Model on Willingness to Pay (WTP) in Various Conditions

4.5 Analysis of Toll Road Utility Using Binary Probit Model

In this study the same calculation is performed using binary probit model, to determine the utility of toll road used multiple linear regression approach. Before looking for coefficient value, the calculation of the deviation of two variables should be performed. The deviation is between toll road and non toll road. Recapitulation of questionnaire result data is then processed using SPSS 17.0. The response of the "Yes" response on the interview form is summed for each scenario along with the total interview form. The total response answer "Yes" in each scenario will be inserted at the "Response Frequency" input; The total interview form on each scenario will be included in the "Total Observed" input and the variables X1 and X2 are inputted to the "Covariates" input. Through the calculation using SPSS 17.0, obtained the value of regression coefficient to estimate the model, therefore it can be obtained the following utility model:

$$U_t = 1.737 - 0.002\ (C_t - C_{nt}) + 0.055\ (T_t - T_{nt}) \quad (6)$$

4.6 Test Statistic for Binary Probit Model

After obtaining the value of utility then performed statistical tests using the help of Microsoft Excel software and SPSS 17.0.

1. Coefficient of Determination Test (R^2)
   Based on calculation using SPSS 17.0 obtained value of Nagelkerke R Square equal to 0.225. The pseudo-R^2 value is then analogized to the value of R^2 by using pseudo-R^2 mapping graph to linear R^2 so that R^2 value of 0.52 is obtained. The variability of model of Solo-Ngawi Toll Road Selection of Kartasura-Palang Joglo toll road can be explained by independent variable of 51.5 % And there are 100% - 51.5% = 48.5% explained by other variables.
2. Chi Square Statistics Test
   Based on the calculation using SPSS 17.0, Chi-Square value of 70,641 or 0.000 (<0,05) indicates that the addition of independent variable can give real effect to the model, or in other words the model is stated fit.

3. Overall Percentage Test
   Based on the calculation using SPSS 17.0 obtained Overall Percentage result from research data of Toll Road toll road route selection by 69,61% Overall Percentage Result in this analysis according to statistical requirement. The approximate value of y estimation with the survey results data is quite large.

4.7 Analysis of Probability Model of Toll Road Using Binary Probit Model

In the model analysis using binary probit, based on data that has been analyzed previously obtained a model derived from the deviation in utility between Toll Road and Non Toll Road. Probability of Toll Road route selection can be calculated as follows:

$$P_{tol} = \varphi\left(\frac{1.737 - 0.002(C_{tol} - C_{nontol}) + 0.055(T_{tol} - T_{nontol})}{\sigma}\right) \quad (7)$$

The amount of probability of using tolls can be obtained by substituting the rate and time of each scenario into the probability model. While the amount of WTP (Willingness to Pay) can be obtained using the approach NEV (Net Economic Value)

4.8 Toll Sensitivity Analysis Using Binary Probit Model

To find out whether the resulting model is relevant, sensitivity analysis of the model is required. The model sensitivity analysis is performed on certain conditions by varying one of the variables, so that the probability value of route selection can be determined. Sensitivity analysis is done on the variable of travel cost and travel time. Here are the variations of conditions given for testing the model shown in Figure 3.

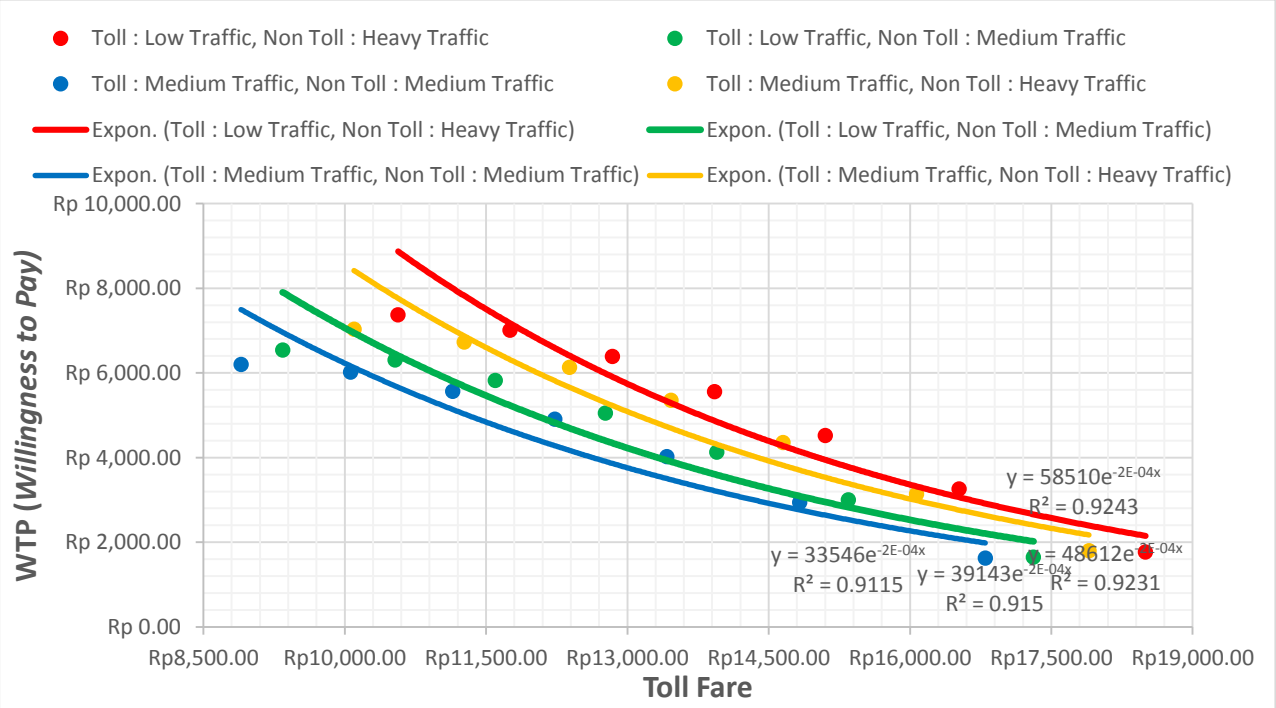


Figure 3. Toll Sensitivity Chart Using Binary Probit Model on Willingness to Pay (WTP) in Various Conditions

4.9 Comparison of Toll Sensitivity Analysis Using Binomial Logit Model and Probit Binary Model

Based on the calculation. it shows that the probability of choosing toll roads from the binomial logit model and the binary probit has a difference of less than 1%. Based on the graphs in Graph 1. and Graph 2. showing on all travel conditions, the direction of the slope is negative, ie the greater the toll tariff will be the smaller the WTP (Willingness to Pay) potential toll users. This is in line with the NEV (Nett Economic Value) approach used in this study where the WTP Value is a representation of the probability value of the respondent's choice to the price (toll rate) offered (trade-off).

Based on the graphs in Figure 2 and Figure 3. it can be seen that the range of WTP binary probit models is larger than the binomial logit model. This is indicated by the graph of sensitivity in the binary probit model is more declivous than the binomial logit model graph. Changes in tariffs significantly affect the value of WTPs significantly compared to the probit model. The effect of tariff change on the binomial logit model on the 20% WTP is more significant than the probit model under the same travel conditions. On the other hand, the rate range of tariff change to WTP on the binomial logit model is greater than the range of values in the probit model of Rp. 25.000,00 (assumption when probability using toll road less than 1%). The rate range of tariff change on binary probit model is Rp. 22,500.00 is assumed when probability of using toll road less than 1%. This value range indicates that meanwhile toll fare is more than Rp. 25.000,00, then the amount of WTP is not significantly affected and the probability of users using toll less than 1%.

The results of this study support the research of Supriyanto [18] which shows that the probit and logit model produces values that are not much different. Similarly, research by Ryandika [17] which shows that the greater time savings encourage respondents to pay more. The above research also supports the research of Rahardjo [16] which shows that probit model is more suitable applied to complex modeling, while logit model will be very useful in the use of simple calculation. On the other hand, the research that has been done by the author does not support the research of Rahardjo [16] which explains that the probit model more accurately describes the behavior of private vehicle users and public transportation in Semarang City. The results of statistical accuracy analysis of this study did not appear to be a significant difference, or in other words very small differences in accuracy between logit and probit models. This is possible because in the research Rahardjo [16] involves two different modes, while this study involves only one mode of passenger cars.

5. Conclusion

Based on the results of research and discussion, it can be concluded that the effect of rate changes on the amount of Willingness to Pay (WTP) on the binomial logit model is more sensitive than the probit model on the same travel conditions. The range of tariff change against values of WTP on the binomial logit model is 20% greater than the range of values in the probit model . On the other hand, the probability results of the binomial logit model and the binary probit have no significant difference (less than 1%).

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