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TRIPLE HURDLE MODEL WITH ZERO EXPENDITURES

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ABSTRACT

The Tobit model is a one-step decision method, implying that the decision to participate and the decision of how much to spend are influenced by the same variables and in the same manner. The double hurdle model is a two-step decision process; consumers first decide whether or not to participate, and then a second decision is made on how much to spend. The triple hurdle model has three separate stochastic decision choices for the first stage of awareness, the second stage of participation, and a final stage of consumption decision. This study provides a guidance in the choice of an appropriate model, which all observations can be used in the estimation for awareness and participation decisions, but only positive observations that pass awareness, participation and consumption decisions simultaneously can be used in the estimation based on a censored and truncated sample, allowing for richer interpretation of consumer choice behavior.

Contribution/Originality: This study provides guidance in the choice of an appropriate model in the Tobit model, double hurdle model, and triple hurdle model in empirical expenditure analyses, which contain a high proportion of zero expenditure in the microdata, based on the Likelihood Ratio test.

1. INTRODUCTION

Microeconomic models have become an important tool of econometric analysis since microdata were made available and computer programs gave the necessary computing assistance. In particular, limited dependent models have been successfully applied to problems in many fields of economic research. Modeling consumer choice behavior with microdata from household expenditure surveys presents well-known problems that often contains a significant proportion of observations with reported zero expenditures in the sample particularly.

Using traditional econometric techniques, such as ordinary least squares estimation based on all or positive observations, the parameter estimates are biased and inconsistent (Maddala, 1983; Amemiya, 1985). In addition, excluding the zero observations also causes the loss of efficiency (Greene, 1983). However, use of microdata allows examination of the effects of detailed household characteristics and provides the degree of freedom to estimate a large number of parameters. In empirical expenditure analyses, the sample containing high proportion of zero observations presents a unique problem with cross-sectional data. Therefore, a better understanding of the nature of the data helps in selecting an appropriate econometric model for economic research.

Recognizing this, researchers have commonly employed the Tobit model to perform the expenditure analysis. The Tobit model assumes that zero expenditures are observed when desired consumption is non-positive; thus, the dependent variable is truncated at zero. With the Tobit framework, zero observations represent corner solutions in consumer choices. On statistical grounds, the Tobit parameterization also imposes an unnecessary restriction on the data-generating process because the same set of variables and parameters determine both the discrete probability of a non-zero outcome and the level of positive expenditures. Consequently, the probability of a non-zero outcome is tied closely to the conditional density of the positive observations and this is an undesirable property.

However, the Tobit model is just one among several censored and truncated regression models that can be used to model consumer choice behavior. The specification of an appropriate model depends on the phenomenon that is assumed to give rise to the zeros. In particular, when the population group of interest includes those who are non-users, as well as those who are potential users, the double hurdle model is more attractive. In practical, the double hurdle model has been addressed important attentions in empirical applications associated with a significant proportion of zero expenditures in the sample because it allows two separate stochastic processes for participation and consumption, which takes into account the probability of consumption and the level of consumption simultaneously.

The studies that used the double hurdle model include Deaton and Irish (1984) on household expenditures; Haines *et al.* (1988) and Popkin *et al.* (1989) on food consumption; Reynolds (1990) on fresh vegetable consumption; Jones (1989; 1992) on cigarette expenditure; Yen (1993) and Jensen and Yen (1996) on food expenditure away from home; Yen and Huang (1996) on finfish consumption; Burton *et al.* (1996) on meat consumption; Yen and Jones (1997) on household cheese consumption; Newman *et al.* (2003) on household expenditure on prepared food; Fabiosa (2006) on wheat consumption; Aristei *et al.* (2008) on alcohol consumption; Akinbode and Dipeolu (2012) on fresh fish consumption; and Eakins (2014) on petrol and diesel household expenditures.

In addition, Blundell and Meghir (1987) discussed some generalizations of the Tobit model including the double hurdle model that allow for distinct processes determining the censoring rule and the continuous observations. Haines *et al.* (1988) and Popkin *et al.* (1989) used the double hurdle model to analyze food consumption decision as a two-step process. Jones (1989) showed the importance of the double hurdle model for modeling individuals' cigarette consumption, and argued that participation and consumption should be treated as separate individual choices.

Recently, the triple hurdle model, a three-stage procedure in consumer choice behavior, has been drawn attention to the importance in empirical applications in agricultural economics and agribusiness. Burke *et al.* (2015) applied the triple hurdle model to evaluate production and market participation in Kenya's dairy sector, and to examine the factors associated with the decision to produce or not produce; the decision of producers whether to participate or not participate in the market; and the decision of market participating producers on how much to buy or sell.

Jensen *et al.* (2015) employed the triple hurdle model to estimate cattle farmer willingness to adopt or expand prescribed grazing on pasture in response to a hypothetical incentive program. Interest in adoption/expansion was estimated first, then willingness to participate in the program, followed by intensity of participation measured as additional acres enrolled.

In the process of selecting an appropriate censored and truncated regression model consistent with consumer choice behavior, the Tobit model, the double hurdle model and the triple hurdle model can be estimated by maximizing the logarithm of the likelihood function using the censored and truncated regression procedures, respectively. In these practical applications, the Likelihood Ratio test seems a popular one for selecting an appropriate model in empirical expenditure analysis.

This study provides a guidance in the choice of an appropriate model in the Tobit model, double hurdle model, and triple hurdle model in empirical expenditure analyses, which contain a high proportion of zero expenditures in the microdata, based on the Likelihood Ratio test. Hence, this study provides a guidance in the choice of an appropriate model, which all observations can be used in the estimation for awareness and participation decisions, but only positive observations that pass awareness, participation and consumption decisions simultaneously can be used in the estimation based on a censored and truncated sample, allowing for richer interpretation of consumer choice behavior.

2. ECONOMETRIC MODELS

According to the consumer choice theory, an individual attempts to maximize her/his utility subject to budget constraints. That is, the following constrained utility maximization problem can be solved:

$$\text{Maximum} \quad u = u(q_i)$$
$$\text{Subject to} \quad m = \sum p_i q_i \qquad i = 1, \ldots, n$$

where u(.) represents the utility function which is assumed to be continuous, increasing, and quasi-concave, q_i is a vector of market goods the individual purchased in the marketplace, p_i is a vector of corresponding market prices for market goods q_i, and m is the individual's income. The individual's ordinary demand function can be expressed as:

$$q_j = f_i(p_i, m) \qquad i = 1, \ldots, n$$

Generally, the demand function gives the quantity o f a market good that the individual will purchase as a function of market prices and the individual's income. Hence, given the individual's income and prices of goods, the quantities demanded by the individual can be determined from the individual's demand functions. In general, the quantity demanded of each good can be expressed as a function of the individual's income, own price, and the prices of substitutes and complements (Varian, 2014).

2.1. Tobit Model

The Tobit model, originally proposed by Tobin (1958) is a commonly used econometric technique to deal with the unique problem of zero expenditures. The Tobit model can be used to analyze the demand for any specific goods when household expenditures can be observed only in a limited value, usually zero. Statistically, the Tobit model can be defined as:

$$y_i = y_i^* \qquad \text{if } y_i^* = x_i'\beta + e_i > 0 \qquad i = 1, \ldots, n$$
$$y_i = 0 \qquad \text{otherwise}$$

where y_i is a vector of individual observed expenditures, y_i^* is a vector of the corresponding desired expenditures, x_i is a vector of explanatory variables that influence expenditures, β is a vector of unknown parameters, and e_i is an independently distributed error term with distribution $N(0, \sigma^2)$ (Greene, 2008). For the observations y_i that are zero,

$$\text{Prob}(y_i = 0) = 1 - \text{Prob}(y_i > 0) = 1 - \Phi(x_i'\beta/\sigma)$$

and for the observations y_i that are greater than zero,

$$\text{Prob}(y_i > 0)f(y_i|y_i > 0) = (1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]$$

where φ(.) and Φ(.) are the standard normal density and cumulative distribution functions evaluated at $(x_i'\beta/\sigma)$, respectively. Using 0 to denote zero observations and + denote positive observations, the likelihood function for the Tobit model can be specified as Greene (2008):

$$L = \Pi_0[1 - \Phi(x_i'\beta/\sigma)]\ \Pi_+\{[(1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]\}$$

The log-likelihood function for the Tobit model is:

$$\ln L = \Sigma_0 \ln[1 - \Phi(x_i'\beta/\sigma)] + \Sigma_+ \ln\{[(1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]\}$$

The maximum likelihood estimation technique can be used to estimate the unknown parameters. Based on the assumptions of normality of the error term, the probability of non-zero consumptions can be expressed as:

$$\text{Prob}(y_i > 0) = \Phi(x_i'\beta/\sigma)$$

The marginal effects of the independent variables on the probability of non-zero consumptions can be specified as:

$$\partial Prob(y_i > 0)/\partial x_k = \phi(x_i'\beta/\sigma)(\beta_k/\sigma)$$

where β_k is the k^{th} component of β. Because the dependent variable y_i is truncated at zero, the expected value of conditional consumptions is simply $x_i'\beta$ plus the expected value of the truncated normal error term, which can be expressed as:

$$E(y_i|y_i > 0) = x_i'\beta + E(e_i|e_i > -x_i'\beta) = x_i'\beta + \sigma[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]$$

The marginal effects of the expected value of conditional consumptions with respect to the independent variables can be shown as:

$$\partial E(y_i|y_i > 0)/\partial x_k = \beta_k\{1 - (x_i'\beta/\sigma)[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)] - [\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]^2\}$$

Hence, the expected value of total consumptions is directly related to the expected value of conditional consumptions via the probability of non-zero consumptions. The expected value of total consumptions can be expressed as:

$$E(y_i) = Prob(y_i > 0)E(y_i|y_i > 0) + Prob(y_i = 0)E(y_i|y_i = 0)$$
$$= \Phi(x_i'\beta/\sigma)\{x_i'\beta + \sigma[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]\} + [1 - \Phi(x_i'\beta/\sigma)] * 0$$
$$= \Phi(x_i'\beta/\sigma)\{x_i'\beta + \sigma[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]\}$$

Following McDonald and Moffit (1980), the marginal effects of the expected value of total consumptions with respect to the independent variables can be decomposed as:

$$\partial E(y_i)/\partial x_k = Prob(y_i > 0)[\partial E(y_i|y_i > 0)/\partial x_k] + E(y_i|y_i > 0)[\partial Prob(y_i > 0)/\partial x_k] = \Phi(x_i'\beta/\sigma)\beta_k$$

McDonald and Moffitt (1980) also described that the change in the expected value of total consumptions can be disaggregated into two parts: the change in the expected value of conditional consumptions, weighted by the probability of non-zero consumptions; and the change in the probability of non-zero consumptions, weighted by the expected value of conditional consumptions.

2.2. Double Hurdle Model

The double hurdle model, originally proposed by Cragg (1971) is established as a useful extension of the univariate Tobit model because it allows two separate stochastic processes for participation and consumption. Systematically, the double hurdle model can be defined as:

$$y_i = y_i^* \qquad \text{if } h_i = z_i'\alpha + u_i = 1, \text{ and } y_i^* = x_i'\beta + e_i > 0 \qquad i = 1, \ldots, n$$
$$y_i = 0 \qquad \text{otherwise}$$

where h_i characterizes the decision of whether to participate, z_i is a vector of explanatory variables that influence participation; α is a vector of unknown parameters; and u_i is an independently distributed error term with distribution $N(0, 1)$ (Jones, 1989). For the observations y_i that are zero,

$$Prob(y_i = 0) = 1 - Prob(h_i = 1)Prob(y_i > 0) = 1 - \Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)$$

and for the observations y_i that are greater than zero,

$$Prob(y_i > 0)f(y_i|y_i > 0) = \Phi(z_i'\alpha)(1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]$$

The likelihood function for the double hurdle model can be specified as Cragg (1971); Blundell and Meghir (1987); Jones (1989):

$$L = \Pi_0[1 - \Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)]\ \Pi_+\{[\Phi(z_i'\alpha)(1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]\}$$

The log-likelihood function for the double hurdle model is:

$$\ln L = \Sigma_0 \ln[1 - \Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)] + \Sigma_+ \ln\{[\Phi(z_i'\alpha)(1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]\}$$

The maximum likelihood estimation technique can also be used to estimate the unknown parameters. Based on the assumptions of normality and independence of the error term, the probability of non-zero consumptions can be expressed as:

$$Prob(y_i > 0) = \Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)$$

The marginal effects of the independent variables on the probability of non-zero consumptions can be specified as:

$$\partial Prob(y_i > 0)/\partial x_k = \phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)\alpha_k + \Phi(z_i'\alpha)\phi(x_i'\beta/\sigma)(\beta_k/\sigma)$$

where α_k and β_k are the k^{th} component of α and β, respectively. It can be seen that the marginal changes of the probability of non-zero consumptions depend upon both the first hurdle parameters (α), and the second hurdle parameters (β).

Because the dependent variable y_i is truncated at zero, the expected value of conditional consumptions is simply $x_i'\beta$ plus the expected value of the truncated normal error term, which can be expressed as:

$$E(y_i|y_i > 0) = x_i'\beta + E(e_i|e_i > -x_i'\beta) = x_i'\beta + \sigma[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]$$

The marginal effects of the expected value of conditional consumptions with respect to the independent variables can be shown as:

$$\partial E(y_i|y_i > 0)/\partial x_k = \beta_k\{1 - (x_i'\beta/\sigma)[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)] - [\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]^2\}$$

Hence, the expected value of total consumptions is directly related to the expected value of conditional consumptions via the probability of non-zero consumptions. The expected value of total consumptions can be expressed as:

$$E(y_i) = Prob(y_i > 0)E(y_i|y_i > 0) + Prob(y_i = 0)E(y_i|y_i = 0)$$
$$= \Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)\{x_i'\beta + \sigma[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]\} + [1 - \Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)] * 0$$
$$= \Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)\{x_i'\beta + \sigma[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]\}$$

Following McDonald and Moffit (1980), the marginal effects of the expected value of total consumptions with respect to the independent variables can be decomposed as:

$$\partial E(y_i)/\partial x_k = Prob(y_i > 0)[\partial E(y_i|y_i > 0)/\partial x_k] + E(y_i|y_i > 0)[\partial Prob(y_i > 0)/\partial x_k]$$
$$= \Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)\beta_k + \phi(z_i'\alpha)[(x_i'\beta)\Phi(x_i'\beta/\sigma) + \sigma\phi(x_i'\beta/\sigma)]\alpha_k$$

From above equation, it can be seen that the marginal changes of the expected value of total consumptions also depends upon both the first hurdle parameters (α), and the second hurdle parameters (β). This decomposition of the change in the expected value of total consumptions with respect to the independent variables includes two effects: the change in the expected value of conditional consumptions weighted by the probability of non-zero consumptions (the first term on the right hand side); and the change in the probability of non-zero consumptions weighted by the expected value of conditional consumptions (the second term on the right hand side).

As a result, the change in the expected value of total consumptions with respect to the independent variables can be decomposed into two additive terms: the conditional effect plus the probability effect. These effects are useful for interpretation of the estimates of the double hurdle model. The probability of non-zero consumptions in the double hurdle model considered here requires consideration of the probability from the participation and consumption equations simultaneously. Otherwise, the maximum likelihood estimates and the estimates of the marginal effect of the expected value of total consumptions with respect to the independent variables would be biased.

2.3. Triple Hurdle Model

The triple hurdle model integrates three separate stochastic decision choices for the first stage of awareness, the second stage of participation, and a final stage of consumption. Statistically, the triple hurdle model can be expressed as:

$$y_i = y_i^* \quad \text{if } g_i = w_i'\gamma + v_i = 1\text{, and } h_i = z_i'\alpha + u_i = 1\text{, and } y_i^* = x_i'\beta + e_i > 0 \qquad i = 1, \ldots, n$$
$$y_i = 0 \quad \text{otherwise}$$

where g_i characterizes the decision of whether to participate in the first stage, w_i is a vector of explanatory variables that influence participation in the first stage; γ is a vector of unknown parameters; and v_i is an independently distributed error term with distribution N(0, 1); h_i characterizes the decision of whether to participate in the second stage, w_i is a vector of explanatory variables that influence participation in the second stage; α is a vector of unknown parameters; and u_i is an independently distributed error term with distribution N(0, 1). For the observations y_i that are zero,

$$\text{Prob}(y_i = 0) = 1 - \text{Prob}(g_i = 1)\text{Prob}(h_i = 1)\text{Prob}(y_i > 0) = 1 - \Phi(w_i'\gamma)\Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)$$

and for the observations y_i that are greater than zero,

$$\text{Prob}(y_i > 0)f(y_i|y_i > 0) = \Phi(w_i'\gamma)\Phi(z_i'\alpha)(1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]$$

The likelihood function for the triple hurdle model can be specified as:

$$L = \Pi_0[1 - \Phi(w_i'\gamma)\Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)]\ \Pi_+\{\Phi(w_i'\gamma)\Phi(z_i'\alpha)(1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]\}$$

The log-likelihood function for the triple hurdle model is:

$$\ln L = \Sigma_0 \ln[1 - \Phi(w_i'\gamma)\Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)] + \Sigma_+ \ln\{\Phi(w_i'\gamma)\Phi(z_i'\alpha)(1/\sigma)\phi[(y_i - x_i'\beta)/\sigma]\}$$

The maximum likelihood estimation technique can be used to estimate the unknown parameters. Based on the assumptions of normality and independence of the error term, the probability of non-zero consumptions can be expressed as:

$$\text{Prob}(y_i > 0) = \Phi(w_i'\gamma)\Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)$$

The marginal effects of the independent variables on the probability of non-zero consumptions can be specified as:

$$\partial\text{Prob}(y_i > 0)/\partial x_k = \phi(w_i'\gamma)\Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)\gamma_k + \Phi(w_i'\gamma)\phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)\alpha_k + \Phi(w_i'\gamma)\Phi(z_i'\alpha)\phi(x_i'\beta/\sigma)(\beta_k/\sigma)$$

where γ_k, α_k and β_k are the k^{th} component of γ, α and β, respectively. It can be seen that the marginal changes of the probability of non-zero consumptions depend upon the first hurdle parameters (γ), the second hurdle parameters (α), and the third hurdle parameters (β).

Because the dependent variable y_i is truncated at zero, the expected value of conditional consumptions is simply $x_i'\beta$ plus the expected value of the truncated normal error term, which can be expressed as:

$$E(y_i|y_i > 0) = x_i'\beta + E(e_i|e_i > -x_i'\beta) = x_i'\beta + \sigma[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]$$

The marginal effects of the expected value of conditional consumptions with respect to the independent variables can be shown as:

$$\partial E(y_i|y_i > 0)/\partial x_k = \beta_k\{1 - (x_i'\beta/\sigma)[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)] - [\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]^2\}$$

Thus, the expected value of total consumptions is directly related to the expected value of conditional consumptions via the probability of non-zero consumptions. The expected value of total consumptions can be expressed as:

$$E(y_i) = \text{Prob}(y_i > 0)E(y_i|y_i > 0) + \text{Prob}(y_i = 0)E(y_i|y_i = 0)$$
$$= \Phi(w_i'\gamma)\Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)\{x_i'\beta + \sigma[\phi(x_i'\beta/\sigma)/\Phi(x_i'\beta/\sigma)]\}$$

The marginal effects of the expected value of total consumptions with respect to the independent variables can be decomposed as:

$$\partial E(y_i)/\partial x_k = \text{Prob}(y_i > 0)[\partial E(y_i|y_i > 0)/\partial x_k] + E(y_i|y_i > 0)[\partial\text{Prob}(y_i > 0)/\partial x_k]$$
$$= \Phi(w_i'\gamma)\Phi(z_i'\alpha)\Phi(x_i'\beta/\sigma)\beta_k + \Phi(w_i'\gamma)\phi(z_i'\alpha)[(x_i'\beta)\Phi(x_i'\beta/\sigma) + \sigma\phi(x_i'\beta/\sigma)]\alpha_k$$
$$+ \phi(w_i'\gamma)\Phi(z_i'\alpha)[(x_i'\beta)\Phi(x_i'\beta/\sigma) + \sigma\phi(x_i'\beta/\sigma)]\gamma_k$$

The probability of non-zero consumptions in the triple hurdle model considered here requires consideration of the probability from the first stage of awareness, the second stage of participation, and a final stage of consumption equations simultaneously. Otherwise, the maximum likelihood estimates of the expected value of total consumptions with respect to the independent variables would be biased.

2.4. Likelihood Ratio (LR) Test

Selection between the Tobit model, the double hurdle model and the triple hurdle model can be tested by the LR test, which is based on the principle of maximum likelihood estimation. It can be used to test the hypotheses that the Tobit model performs as well as the double hurdle model and the triple hurdle model by comparing the values of the maximized likelihood functions under the restricted (H_0) and unrestricted (H_1) models. Systematically, the LR test is based on the statistic:

$$\lambda_{LR} = -2[L(H_1) - L(H_0)]$$

where (H_0) and (H_1) are the maximized values of the log-likelihood function under the restricted and unrestricted models, respectively. The null hypothesis (H_0) is rejected when $\lambda_{LR} > \chi^2_c$, where χ^2_c is a chosen critical value from the $\chi^2_{(j)}$ distribution, and j is the number of the restrictions under the null hypothesis (Greene, 2008).

3. DISCUSSION AND CONCLUSIONS

The Tobit model is a one-step decision method, implying that the decision to participate and the decision of how much to spend are influenced by the same variables and in the same manner. The double hurdle model is a two-step decision process; consumers first decide whether or not to participate, and then a second decision is made on how much to spend. The triple hurdle model has three separate stochastic decision choices for the first stage of awareness, the second stage of participation, and a final stage of consumption decision.

Under the Tobit specification, zero expenditure implies zero consumption and hence represents a true corner solution (Gould, 1992). On statistical grounds, the Tobit model is very restrictive in its parameterization which implies that the probability of consumption and the level of consumption are determined by the same sets of variables and parameters. Hence, drawing inferences from the Tobit model would lead to erroneous conclusions (Bockstael *et al.*, 1990).

The double hurdle model features two separate stochastic processes for participation and consumption; it allows for examining the determinants of both participation and consumption decisions and provides more useful insight on consumer choice behavior than the Tobit model. For positive expenditures to occur, two hurdles have to be overcome: to participate in the market (i.e., to be a potential consuming household) and to actually consume. The double hurdle model may provide a better interpretation of consumer behavior that takes into account the probability of consumption and the level of consumption.

To compare the Tobit model and the double hurdle model, all observations can be used in the estimation for the Tobit model based on a censored sample, but only positive observations which pass participation and consumption decisions simultaneously can be used in the estimation for the double hurdle model based on a censored and truncated sample. The double hurdle model is identical to the Tobit model when $\Phi(z_i'\alpha) = 1$, as the Tobit model is nested in the double hurdle model. The Tobit model is also a particular form of the double hurdle model when $z_i = x_i$ and $\alpha = (\beta/\sigma)$ in this case.

In applied econometrical applications, different decision mechanisms have been put forward to explain the appearance of zero expenditure observations. Due to diversity of consumer choices, consumer may face multiple stages to make decision to participate and consume for the desired item in order to satisfy ones desires. For example, the first stage is the awareness of the desired item; the second stage is the participation to purchase the desired item; and the third stage is the decision on the desired amount of quantity purchased for the item. Given this type of multiple-stages decision making processes, the double hurdle model may not be the appropriate one, but the triple hurdle model could be a possible selection for data fitting in empirical expenditure studies.

This paper aims to propose the triple hurdle model that integrates the three separate stochastic decision choices with regard to awareness, participation, and consumption decisions. The triple hurdle model integrates a binary framework to model the first stage decision, followed by a binary choice to capture the second stage decision determining whether or not to participate in the desired item. The third stage employs a censored and truncated regression analysis to analyze determinants of consumer decision choice for the desired item. The estimates for the parameters can be obtained by running a relevant separate regression model for each stage.

Empirically, most expenditure studies have to confront the problem of how to handle zero expenditures in the survey period. The LR test seems a popular one for selecting an appropriate model in empirical expenditure studies between the Tobit model, the double hurdle model and the triple hurdle model.

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