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CONSUMER BEHAVIOUR IN LOTTO MARKETS: THE DOUBLE HURDLE APPROACH AND ZEROS IN GAMBLING SURVEY DATA

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Abstract

Governments world-wide increasingly rely on gambling revenues, increasing the importance of understanding who gambles and why. previous literature used Tobit and Heckman models to statistically analyze participation in gambling. These models make strong assumptions about the nature of gambling participation. We examine the double hurdle model as an alternative to other statistical approaches to modeling gambling participation and spending. Our results, based on data from a 2002 survey of gambling prevalence in Alberta, clearly prefer the double hurdle mode, which yields different results than the commonly used Tobit model.

JEL Codes: L83, C13
Key Words: gambling, censored regression, double hurdle model

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Legal gambling is increasingly available throughout the world and also represents a growing source of government revenue. All levels of government around the world are increasingly introducing and relying on legalized gambling to generate additional revenues to augment general funds and to fund specific activities such as education, infrastructure and youth sport programs. For example, the state of Delaware recently introduced an NFL parlay style betting product to curb recent budget deficits brought on by the global economic recession. Understanding why consumers participate in various types of gambling and the determinants of consumer expenditure on gambling has important public policy implications and can also increase understanding of consumer behaviour in this setting.

Many previous studies have analyzed gambling participation and the frequency of participation using survey data. The key feature of survey data on consumer participation in gambling is the presence of a large number of "zeros" – observations where the respondent reports not gambling during the sample period – in most data sets. The presence of a large number of zeros leads to statistical problems that must be corrected for in any empirical analysis. The two most commonly used statistical techniques to correct for zeros are the Tobit model and the Heckman sample selection model (sometimes called the "heckit" model). In the literature on lottery participation and spending, Livernois (1989), Kitchen and Powells (1991), Stranahan and Borg (1998), Sawkins and Dickie (2002), and Worthington, et al. (2007) use Tobit models. Both Scott and Garen (1994) and Farrell and Walker (1999) use both Tobit and Heckman sample selectivity models in their analysis of lottery participation.

Zeros exist in many other settings investigated using survey data, including the purchase of durable goods like automobiles and television sets and the purchase of cigarettes and alcohol. Generally, zeros are present in survey data for three different reasons. First, the respondent did not purchase the good, or undertake the activity, in question during the sample time period in the survey because the good is purchased infrequently. This scenario typically applies to consumer durable goods like cars and television sets. Second, the respondent would never purchase the good in question under any circumstance or at any price. For gambling research this scenario is important as many people abstain from gambling due to religious or ethical reasons. Third, the respondent would be interested in purchasing the good or participating in the activity in question, but the cost of purchase or participation is currently too high to elicit purchase or participation given the respondents preferences and level of income. This scenario is also common in gambling as a person may have to travel a long distance to visit a casino because none are located close to the person's residence. In economics, this scenario is called a "corner solution" because consuming zero units of this good is a utility maximizing decision represented by a point on one of the axes, hence at the "corner" of the graph, in the familiar graphical solution to the indifference curve/budget constraint model of consumer utility maximization from microeconomics. The second scenario, non-participation because of religious or ethical concerns, can be thought of as a special case of the third scenario, a corner solution, if the religious taboo or moral repugnance associated with purchase of the good or participation in the activity can be interpreted as an extremely high "cost" of purchase or participation.

Recent research suggests that the cause of zeros observed in survey data has important statistical consequences. Jones (2000) points out that the Heckman selectivity model applies to non-observed responses described in the first scenario described above, while Tobit and other two part models apply to the second and third scenarios.

In this paper we examine gambling participation and frequency of participation using a number of alternative two-part models, including the commonly used Tobit model and an important alternative, the double hurdle model. The key distinction is that the Tobit model assumes that the factors explaining participation and frequency of gambling have the same effect on these two decisions while the double hurdle model allows for these effects to differ. The Tobit model is nested in the double hurdle model, permitting direct statistical tests to determine which best fits the data. We use data from a 2002 gambling participation survey from the province of Alberta to examine the ability of these two alternative statistical models to explain consumer participation in lotto and spending on lotto tickets. Our results indicate that the double hurdle model fits the sample data better than the Tobit model, and that the source of the difference relates to the implicit assumption made by the Tobit model about the determinants of participation in gambling.

Modeling Zeros in Gambling Survey Data

When statistically modeling gambling behaviour, two important and distinct issues must be addressed: how to model consumers' decision to participate in gambling and how to model consumers' decision about how often to gamble, or how much to spend on gambling, conditional on the participation decision. The participation decision is typically addressed by a simple "Yes"/"No" question in gambling surveys. If a consumer chooses to participate in some form of gambling (answering "Yes" to the participation question), a second question is asked, eliciting some measure of the respondent's intensity of participation, either frequency of participation in that type of gambling or total spending on that type of gambling. As a result, gambling survey data typically contain variables describing both these decisions.

Two statistical models have been used to analyze consumer participation in gambling and intensity of participation: the Tobit and Heckman models.[1] In general, economic decisions about gambling can be motivated by a latent variable model linking unobserved utility derived from gambling to observed behavior. Formally, an individual's decision to participate in gambling can be represented by an indicator function

$$I^*_i = \alpha' Z_i + \nu_i \qquad (1)$$

where I^*_i is an unobservable indicator variable that determines whether or not individual i participated in gambling ($I^*_i = 1$) or not ($I^*_i = 0$). α is a vector of unobserved parameters to be estimated, Z_i is a vector of observed independent covariates that explain individual i 's decision to participate in gambling, and ν_i is an unobserved random variable capturing all factors other than Z_i that influence the decision to participate in gambling. This function describes the process that generates observed gambling behavior in the sample. Equation (1) is often called the "first hurdle," because it is the first step in the two-step process that generates observed gambling in survey data. Formally, Equation (1) implies that individual i will participate in gambling if $\nu_i > -\alpha' Z_i$, and the probability of observing individual i participating in gambling is $P(\nu_i > -\alpha' Z_i)$.

An individual's decision about intensity of gambling can be represented by a function

$$g^*_i = \beta' X_i + \varepsilon_i \qquad (2)$$

where g^*_i is a latent variable reflecting how frequently an individual gambles, or how much is spent on gambling – a measure of latent demand for gambling— where β is a vector of unobserved parameters to be estimated, X_i is a vector of independent covariates that explain individual i 's decision about intensity of gambling, and ε_i is an unobserved random variable capturing all factors other than X_i that influence the decision about intensity of gambling. This function describes the process that generates observed intensity of demand for gambling, for example how frequently each individual in a sample reports gambling or how much individuals report spending on gambling. Equation (2) is often called the "second hurdle" in the two-step process.

One commonly used estimator in the literature is the Tobit estimator. The Tobit estimator applies to a special case of the two-step process described by Equations (1) and (2): the case where the first hurdle is irrelevant, so $P(\nu_i > - \alpha' Z_i) = 1$, and all observed gambling activity in the data can be attributed to $g_i = \max(g^*_i, 0)$. Zero expenditure on gambling ($g_i = 0$) means that no spending on gambling is made, but the Tobit estimator cannot determine why consumers did not spend any money on gambling in the sample. If ε_i is a normally distributed random variable with zero mean and constant variance, then the likelihood function for the Tobit estimator for this set up is

$$L_T = \Pi_1 P(\varepsilon_i > -\beta' X_i)\, f(g_i | \varepsilon_i > -\beta' X_i)\, \Pi_0 (1 - P(\varepsilon_i > -\beta' X_i)) \quad (3)$$

where Π_0 is the product operator for observations where $g_i=0$, Π_1 is the product operator for observations where $g_i = 1$, and $f(\cdot)$ is the pdf for a normally distributed random variable. This function can be evaluated numerically to obtain estimates of the parameters β. The limitation of Tobit comes from the assumption that the participation decision is irrelevant. It forces the participation decision to be identical to the intensity decision. Under Tobit, all zeros represent "corner solutions", and all observed non-gamblers do not gamble because the price of gambling is too high given consumers' preferences and income.

One alternative to the Tobit model is the double hurdle model. This model has been used to examine the determinants of participation and intensity of cigarette smoking (Jones, 1989; Garcia & Labeaga, 1996), physical activity and exercise (Humphreys & Ruseski, 2007) and to examine the relationship between participating in the labour force and the number of hours worked (Blundell, Ham, & Meghir, 2007). Abdel-Ghany and Sharpe (2001) use a double hurdle model to investigate consumer participation and expenditure on lotteries in Canada.

The double hurdle model simply relaxes the assumption that the participation decision is irrelevant. It includes the possibility that $P(\nu_i > - \alpha' Z_i) <= 1$. If both ε_i and ν_i are normally distributed and independent random variable with zero mean and constant variance, the likelihood function for the double hurdle model is

$$L_{DH} = \Pi_1 P(\nu_i > -\alpha' Z_i) P(\varepsilon_i > -\beta' X_i) f(g_i | \varepsilon_i > -\beta' X_i) \bullet \Pi_0 (1 - P(\nu_i > -\alpha' Z_i) P(\varepsilon_i > -\beta' X_i)). \quad (4)$$

The double hurdle model allows for the observable and unobservable factors that affect participation (ν_i, $\alpha' Z_i$) to differ from the factors that affect intensity of gambling (ε_i, $\beta' X_i$). Since Z_i can contain variables not in X_i, the double hurdle model also allows for some factors to affect only participation in gambling, and not intensity. Note that the difference between the double hurdle model and the Tobit model is the inclusion of $\Pi_1 P(\nu_i > - \alpha' Z_i)\ \Pi_0 (1 - P(\nu_i > - \alpha' Z_i)$ in the double hurdle model. This expression is a probit model for the participation decision. By including the participation decision, the double hurdle model allows for observed non-gamblers in a sample to include both those that abstain from gambling and corner solutions. The double hurdle model is more general than the Tobit model. Because the Tobit model is nested in the double hurdle model, the restrictions placed on the double hurdle model can be tested, using a likelihood ratio test.

Garen and Scott (1993) and Farrell and Walker (1999) examine the relationship between observable characteristics of consumers of lotteries and expenditure on lotteries using a

Heckman selectivity model. Jones (1989) points out that the Heckman selectivity model may not be appropriate for examining certain consumer behavior like gambling because of "first hurdle dominance," a condition in which the participation decision receives greater importance than the intensity decision. Additionally, under first hurdle dominance, the decision not to participate due to cost, is explicitly ruled out. To see this, note that first hurdle dominance can be expressed statistically as $P(g^*_i<0|\ I^*_i=1)=0$; in other words, conditional on participation in gambling, the probability of observing an individual with negative latent demand for gambling is zero. First hurdle dominance rules out corner solutions and abstentions because all zeros are attributed to $I^*_i=0$. For this reason, we do not use the Heckman selectivity model.

Both the Tobit and double hurdle model account for the presence of zeros in gambling survey data. However, each model explains observed zeros in the data differently. In the Tobit model, all zeros observed in the data are attributed to corner solutions; every respondent in the survey would participate in gambling if the total effective price was low enough. Also, under the Tobit model the participation decision is irrelevant and only the intensity decision matters for participation in gambling. In the double hurdle model zeros observed in the data can be either corner solutions or abstentions; some respondents in the survey would not participate in gambling. Additionally, the double hurdle model treats the participation decision and the intensity decision separately.

In summary, previous research examining participation and frequency of gambling primarily used either a Tobit or Heckman selectivity model. These models each have limitations in terms of how zeros in the data are generated and interpreted. The double hurdle model relaxes the restrictions placed on zeros by the Tobit and Heckman selectivity models and emphasizes the two separate decisions consumers make when gambling. Since the Tobit model is nested in the double hurdle model, one can formally test which model better fits any data set. We compare these two approaches using data from a survey of gambling behavior carried out in the province of Alberta, Canada, in 2002.

Data

We analyze the data from a 2002 survey of gambling participation among residents in Alberta, Canada. The survey asked questions about 29 different gambling activities. Here, we focus on purchase of 6/49 Lotto tickets, a popular low odds-high payoff lottery game widely available throughout the province. Alberta offers a wide variety of gambling options throughout the province as evidenced from the 2002-2003 annual report of the Alberta Gaming and Liquor Commission, the provincial gambling regulatory agency in Alberta. Based on this report, Alberta had 2,111 establishments that sold lottery tickets in 2002. $200 million in revenue generated from gambling in the province funded many programs including amateur sports, community recreation, arts, and medical research.

The 2002 survey asked participants various questions regarding gambling participation, attitude towards gambling, and questions about other demographic and economic characteristics. Of particular interest for this paper are the questions regarding the purchase of Lotto tickets and other questions related to gambling behaviour. The survey had 1,804 participants. Table 1 presents the summary statistics on the characteristics of the survey respondents.

<INSERT TABLE 1>

57% of the sample reported purchasing Lotto tickets in the past 12 months and the average monthly spending on Lotto tickets was $8.28. The average age was 43.31 years with a median age of 42 years, which suggests a close symmetry of the data. The sample was exactly 50 percent male and 50 percent female. Average income was $49,280, and respondent had, on average, just over 14 years of formal education. 63% were married. The survey asked a question about whether or not the respondent agreed with the statement: “While gambling, you could win more if you used a certain system or strategy.” We interpret this to identify individuals who believe that gamblers can be systematically successful. 22% of the sample either agreed or strongly agreed with this question, which we will exploit in the empirical analysis that follows.

Empirical Analysis

We use the Tobit and double hurdle models described above to examine participation in Lotto and spending on Lotto tickets. The province has over 2,000 retail outlets where Lotto tickets can be purchased and drawings are twice a week. This wide availability and frequent draw dates should guarantee that none of the zeros observed in the data are attributable to infrequency of purchase of Lotto tickets; these zeros should be due to either corner solutions or abstentions. We estimated a Tobit model, Equation (3), and a double hurdle model with independent error terms, Equation (4) by maximum likelihood. The explanatory variables included in these models have been used extensively in previous research on consumer participation in lottery and spending on lottery tickets. The explanatory variables include the respondent’s age, income, education in years, gender and marital status. The Tobit model has only one dependent variable, average monthly spending on Lotto tickets. The double hurdle model has two dependent variables: an indicator variable for participation in Lotto and average monthly spending. Both models contained a constant term that is not reported. Table 2 contains parameter estimates, t-statistics, and other regression diagnostics obtained using the Tobit and double hurdle models.

<INSERT TABLE 2>

The parameter estimates on age and years of education underscore the differences between these two alternative approaches to modeling participation and spending on lotto. The results from the Tobit model in the two columns on the right of Table 2 indicate that spending on lotto tickets by Albertans rises with age and falls with years of formal education. The results from the double hurdle model paint a different picture. From the participation equation results, the probability that an individual in the sample purchased lotto tickets declined with age and increases with years of formal education, exactly opposite the results from the Tobit model. The estimated parameters from the spending equation in the double hurdle model, in columns two and three on Table 2, indicate that spending on lotto tickets increases with age and decreases with formal education, like those from the Tobit model.

In this case, the Tobit model produces parameter estimates that reflect the overall effect of the separate participation and spending decisions included in the double hurdle model. In the case of age, the Tobit results indicate that as people age, they spend more on lotto tickets, other things equal. However, the double hurdle results indicate that participation actually falls as individuals age, but that those who do participate in lotto spend more on tickets as they get older. The double hurdle results indicate an even stronger spending by older participants. In the case of education, the Tobit model results indicate that spending on lotto tickets declines among more educated individuals; the double hurdle results indicate that participation in lotto rises, but spending falls with formal education. In both cases, the spending effect outweighs the participation effect, which is reflected in the parameter estimates from the Tobit model. Note that if the participation effect was stronger relative to the spending effect, the Tobit model could potentially generate parameter estimates that were not statistically significant, completely masking these two effects.

Note that differences between the Tobit and double hurdle results also exist for the income variable. The Tobit results indicate that spending on lotto increases with income; the double hurdle results indicate that spending increases, but participation does not increase. Low income individuals are no more likely to participate in lotto than high income individuals, but conditional on participation, high income individuals spend more on lotto tickets. This has important implications for understanding participation in lotto, since lotto can be viewed as an effective tax on participants, given that only 65% of lotto revenues are paid out as prizes, and the participation results indicate that the burden of this tax does not fall disproportionately on lower income individuals. This result has also important implications for governments looking to either add lotto to the gambling or to introduce other types of lotto games in their jurisdiction but are hesitant on the fear of adding an additional strain to low income residents of their jurisdiction.

Recall from the discussion above that the Tobit model is nested in the double hurdle model. This nesting provides a formal test of how each model fits the sample data using a standard likelihood ratio test. If L_T is the maximum value of the log-likelihood function for the Tobit model and L_{DH} the maximum value of the log-likelihood function for the double hurdle model, then the likelihood ratio LR = -2 (L_{DH} - L_T) is distributed as a χ^2 random variable with degrees of freedom equal to the number of parameter restrictions that must be placed on the double hurdle model to produce the Tobit model. The null hypothesis for this test is that the restrictions placed on the double hurdle model that generate the Tobit model are appropriate given the sample data; the alternative hypothesis is that the restrictions placed on the double hurdle model are not appropriate. In this case, the parameters of the participation equation must be equal to zero for the double hurdle model to be equivalent to the Tobit model, generating six restrictions. The likelihood ratio statistic is 26.44, which has a p-value smaller than 0.001. The restricted model, in this case Tobit, does not fit the data as well as the unrestricted double hurdle model.

We performed several robustness checks on the results reported on Table 2. First, although the double hurdle literature makes no specific reference to the need for exclusion restrictions, in practice many double hurdle applications include them. In this setting, an exclusion restriction means excluding one or more variables from the spending equation in the double hurdle model that appears in the participation equation. Exclusion restrictions are used in instrumental variables estimation to identify the endogenous variable in the second stage. In this setting, and exclusion restriction would identify the participation effect, although the double hurdle model is not an instrumental variable estimator. In terms of the statistical models developed above, an exclusion restriction means that a variable appears in the vector of explanatory variables for the participation equation Z_i that does not appear in the vector of explanatory variables for the spending equation X_i. We added an indicator variable identifying individuals who agreed or strongly agreed with the idea that use of a “system” would lead to larger gambling winnings. This belief could affect individual’s decision to participate in gambling. Adding this variable to the participation equation did not affect any of the other results reported on Table 2, and did not affect the likelihood ratio test. The parameter estimate on this variable was not statistically significant in the double hurdle model. Second, the estimates on Table 2 are for the case where the two error terms in the double hurdle model, ν_i and ε_i, are assumed to be independent. We also estimated a double hurdle model assuming that these two error terms were not independent, and instead were correlated. The results from this double hurdle model with dependent errors was nearly identical to those from the independent model results on Table 2.

Conclusions

Any sample of individuals asked about gambling will contain a significant number who report never gambling. These non-participants generate zeros in the survey data. In this paper, we discuss how these non-participants arrive at this decision, and show how this decision has important statistical ramifications. In the case of gambling, where most of the observed non-participants reflect either abstentions or corner solutions, this decision process implies that the Heckman selectivity model does not apply, because this model explicitly rules out corner solutions, while methods that permit corner solutions like the Tobit model or the double hurdle model can be used. We also show that, in the case of data from a survey of gamblers in Alberta, the double hurdle model fits the data better than the Tobit model.

Our results have several important implications for gambling research. Although much gambling research focuses on distinguishing problem gamblers from other gamblers, we point out that much can be learned from the other margin, by analyzing differences between gamblers and non-gamblers. The decision not to gamble can be systematically categorized into non-participation due to lack of access to gabling opportunities, abstentions, and corner solutions representing individuals who would gamble if effective prices were lower or their income was higher. Our results indicate that many of the non-participants in this sample may be abstentions, since this would be consistent with the double hurdle model fitting the data better than the Tobit model. If abstentions are important, then participation in gambling will be relatively insensitive to changes in the effective price of gambling. This has important policy implications, especially where policy makers are concerned with the spread of gambling in a population. In addition, since our results show that gamblers and non-gamblers differ systematically, results from studies that focus only on the behaviour of gamblers may not generalize to the entire population. These systematic differences imply that non-gamblers may respond differently to policy interventions than gamblers.

Second, from a methodological perspective, our results indicate that the heavy reliance on the Tobit model to analyze consumer spending on gambling may be misplaced. The Tobit model restricts the participation decision to be identical to the spending decision. Our results indicate that, for important explanatory variables like age, income, and education, this assumption may not fit the data well. Future research on gambling participation and expenditure should recognize this limitation to the Tobit model, and use alternative methods like the double hurdle model that make less restrictive assumptions about the decision to participate in gambling.

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Table 1: Summary Statistics

Variable	Mean	S.D.	Min	Max
Participated in Lotto in last year	0.57	0.50	0	1
Average monthly spending on Lotto	8.28	19.51	0	350
Age	43.31	15.51	18	90
Income (000s)	49.28	29.64	0	120
Education (years)	14.36	2.87	3	23
Male	0.50	0.50	0	1
Married	0.63	0.48	0	1
Believes in successful "systems"	0.22	0.41	0	1

Table 2: Double Hurdle and Tobit Estimates

	Double Hurdle Spending		Double Hurdle Participation		Tobit	
Variable	Parameter	t-Stat.	Parameter	t-Stat.	Parameter	t-Stat.
Age	0.294	5.28	-0.078	-3.61	0.180	3.65
Income (000s)	0.052	1.73	0.009	0.75	0.067	2.24
Education (years)	-1.589	-5.47	0.204	2.72	-1.242	-4.44
Male	6.254	4.15	1.062	2.15	7.169	4.82
Married	2.545	1.43	-0.261	-0.58	3.197	1.84
Log Likelihood	-5299				-5312	
N	1788				1788	

[1] This discussion draws on the application of Tobit and double hurdle models to cigarette smoking by Garcia and Labeaga (1996).

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