The (Aggregate) Demand for State Lottery Tickets: What Have We Really Learned?

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Abstract

Lottery demand models using aggregate data are often used to make inferences regarding individual behavior, the most important being the distributional burden of lottery ticket expenditures. It is shown here that estimates for the income elasticity and the cross-price elasticity will only be representative of individual behavior under extremely restrictive assumptions. In fact, estimation of aggregate-demand models presupposes that the income elasticity is equal to one. Cross-sectional analyses using micro-level data face similar restrictions on consumer behavior. Remedies are discussed, but more conclusive evidence on the distributional burden of lotteries will remain elusive until better individual-level data become available.

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1. Introduction

Empirical estimation of aggregate demand functions (aggregated over individuals) is quite common in the literature that examines the demand for state-lottery tickets (e.g., Mikesell 1989; Cook and Clotfelter 1993; Hansen 1995; Price and Novak 1999, 2000; Tosun and Skidmore 2004; Garrett and Couglin 2009; Ghent and Grant 2010).[1] Estimation of aggregate lottery demand is due to a general lack of individual-level data on a consumer's income and lottery ticket purchases, and therefore these data have only been used in a small percentage of all lottery demand studies (Scott and Garen 1994; Farrell and Walker 1999; Perez and Humphreys 2011).

Aggregate data on lottery sales and income, which are commonly at the zip-code or county-level, are often used in regression analysis of an aggregate lottery demand function to estimate an income elasticity of demand for lottery tickets. The income elasticity of demand for lottery tickets is the most common statistic in the policy debate on the efficacy of state lotteries as an appropriate means of state government finance, as it provides evidence on the distributional burden (by income) of lottery ticket expenditures (i.e., lottery "regressivity"). In addition, aggregate lottery-demand models have been used to estimate the own-price elasticity of demand and the cross-price elasticity of demand for lottery tickets, with the latter providing evidence on the substitutability or complementarity of different lottery games (Forrest, Gulley, and Simmons 2000; Grote and Matheson 2006; Perez and Forrest 2011).

Most studies using aggregate lottery-demand models have estimated an income elasticity of demand that is less than one (and conclude that lotteries are regressive), whereas evidence on the cross-price elasticity of demand is mixed. This area of research has implicitly assumed and has

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[1] These studies are only a few examples of the work done in the area of state-lottery demand. See Grote and Matheson (2011) for additional studies and further discussion. Throughout the paper, aggregation refers to the aggregation over individuals rather than the aggregation of commodities. However, many studies use a measure of aggregate lottery sales, which is comprised of sales for different types of individual lottery games.

tacitly accepted that an income elasticity of demand and cross-price elasticity of demand estimated from an aggregate lottery-demand model reflect the behavior of individual consumers. However, the income elasticity of demand and the cross-price elasticity of demand have strict micro-economic definitions that result from an individual's utility maximizing calculus. The literature has provided no discussion of the essential microeconomic assumptions needed for equating the estimated behavior from aggregate lottery-demand models with the behavior of an individual consumer and, therefore, the questionable interpretation of empirical estimates for the "income elasticity" and the "cross-price elasticity" obtained from aggregate lottery-demand models. This is true even for the few aforementioned studies that have estimated an income elasticity of demand using cross-sectional micro-level data.

This paper serves as a cautionary warning for researchers (including this author) who empirically estimate aggregate lottery-demand functions, as it raises questions about the interpretation of previous results and conclusions regarding the distributional burden of lottery ticket expenditures (i.e., income elasticity of demand), the substitutability or complementarity of lottery games, and the welfare implications of state-lottery financed public expenditures. The next section of the paper demonstrates that empirical estimates from aggregate lottery-demand functions cannot, except under very restrictive assumptions, be interpreted as representative of the demand behavior of individual consumers. This is true even for lottery-demand estimates using a cross-sectional sample of micro-level data. The discussion here thus calls into question the interpretation of the estimated income elasticity of demand and price elasticities of demand as representing individual behavior (as well as the interpretation of the coefficient at all), as well as the estimation of aggregate lottery-demand functions in general. Given the restrictive assumptions behind the common estimation of aggregate lottery-demand functions, possible solutions are then discussed. Although this paper focuses on aggregate state-lottery demand, the main points and conclusions are relevant to the estimation of aggregate-demand functions in any field of economics.

2. Aggregate Lottery Demand and the Individual Consumer

Lottery demand studies typically estimate a cross-sectional regression equation of the form

$$lnX_i = \gamma + \beta \cdot ln(P_i) + \delta \cdot ln(M_i), \tag{1}$$

where X = the quantity of lottery tickets; P = the price of lottery tickets, and M = income.[2] To simplify the initial analysis, the error term has been omitted from equation (1) along with "demand shifters" such as education, race, and the prices of other goods that all may influence lottery ticket purchases.[3] The subscript i denotes the unit of observation, which is usually a zip-code or a county. Because equation (1) is in log-log form, the estimate of δ has been interpreted as the income elasticity of demand. Notice that equation (1) is simply a monotonic transformation of

$$X_i = \alpha P_i^{\beta} M_i^{\delta}, \text{ where } \alpha = e^{\gamma}. \tag{2}$$

The implicit assumption in previous studies is that the aggregate demand for lottery tickets (X_i) is representative of the demand for each consumer j. For the subsequent analysis, the subscript i is dropped and aggregate Marshallian demand for lottery ticket is represented as $X(p, M)$. The Marshallian lottery demand for an individual consumer j is denoted as $x_j(p, m_j)$. It follows that the aggregate Marshallian demand for lottery tickets ($X(p, M)$) is equal to the sum of individuals' Marshallian demands for lottery tickets ($\sum_i x_j(p, m_j)$). Assuming that all consumers face the same price for lottery tickets, consumers differ only in their level of income and their ticket purchases.[4] The relationship between the aggregate Marshallian demand and individuals' Marshallian demands, assuming there are only two consumers (j = 1, 2), can be written as

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[2] Lottery revenues are often used as the dependent variable as these data are more readily available, but there is a close relationship between quantity and revenues because most lottery tickets cost $1.

[3] Aggregate panel-data have also been used, but this does not change the subsequent analysis or conclusions.

[4] Here "price" refers to the price-point of lottery tickets (what tickets sell for, usually $1), not the expected price which is less than the price-point. However, since a lottery is operated at the state level, all consumers in a state will face both the same price-point and the same expected price for a lottery game. Price-points are very similar across states, but expected prices can vary by state since each state offers different lottery games and some lotto-type games have variable jackpots.

$$X(p, M) \equiv x_1(p, m_1) + x_2(p, m_2) \tag{3}$$

where $M = m_1 + m_2$. By substituting the functional form of equation (2) without regard to the unit of observation i, equation (3) can be rewritten as

$$\alpha P^\beta M^\delta \equiv \alpha P^\beta m_1^\delta + \alpha P^\beta m_2^\delta. \tag{4}$$

If the equality in equation (4) holds, then aggregate lottery demand, and thus aggregate behavior, is representative of the demand for each individual consumer. Or, in other words, the behavior of an individual consumer can be captured by estimating the aggregate demand function. The key question, therefore, is under what conditions does the equality in (4) hold? Simplifying equation (4) yields

$$M^\delta \equiv m_1^\delta + m_2^\delta$$

or, $(m_1 + m_2)^\delta \equiv m_1^\delta + m_2^\delta.$ \hfill (5)

It should be clear that the equality in equation (5) only holds if $\delta = 1$. Recall that δ is the income elasticity of demand from equation (1). Thus, the aggregate demand function is only equal to the sum of the individual demands if *each* consumer has an income elasticity of demand for lottery tickets that is equal to one. If each consumer has an income elasticity of demand that is equal to one, then the aggregated demand function (which also has an income elasticity of demand equal to one) is representative of the demand of a single consumer. So an important conclusion emerges thus far; namely, that under aggregation there is no reason to estimate (1) to get an income elasticity of demand for a representative consumer because the functional form *assumes* that the income elasticity for each consumer must be equal to one if the aggregate demand function is to be representative of individuals' demands.

The above result provides insight into the form of consumers' preferences that is assumed when estimating equation (1). An income elasticity of demand equal to one implies that all consumers' preferences are homothetic (and identical). Recall that a preference relation is said to be homothetic if the slope of the consumer's indifference curves remains constant along any ray from the origin, i.e. the consumer's indifference curves are "radial blowups" of each other. Only if preferences are homothetic can the aggregate demand function implied by equation (1) be representative of individuals' demands.

The estimation of equation (1) assumes several additional and related restrictions that make inference of individual behavior from aggregate lottery-demand functions difficult. First, consider the marginal propensity to consume lottery tickets (defined as the additional spending on lottery tickets that results from an additional increase in income) for each individual (MPC_j) as well as in aggregate (MPC_A). Using each demand expression from equation (4), it can be shown that

$$MPC_A \equiv \frac{\partial X(p,M)}{\partial M} = \alpha P^\beta \delta M^{\delta-1}$$

$$MPC_1 \equiv \frac{\partial x_1(p,m_1)}{\partial m_1} = \alpha P^\beta \delta m_1^{\delta-1} \qquad (6)$$

$$MPC_2 \equiv \frac{\partial x_2(p,m_2)}{\partial m_2} = \alpha P^\beta \delta m_2^{\delta-1} \;.$$

With $\delta = 1$, the expressions in (6) reduce to

$$MPC_A \equiv \frac{\partial X(p,M)}{\partial M} = \alpha P^\beta$$

$$MPC_1 \equiv \frac{\partial x_1(p,m_1)}{\partial m_1} = \alpha P^\beta \qquad (7)$$

$$MPC_2 \equiv \frac{\partial x_2(p,m_2)}{\partial m_2} = \alpha P^\beta \;.$$

The set of expressions in (7) demonstrate that the aggregate demand function will be representative of an individual consumer's demand only if $MPC_1 = MPC_2 = MPC_A$. In addition, each consumer's demand must be linear in income. [5]

Second, now consider each consumer's share of income spent on lottery tickets under homotheticity. The income elasticity of demand for each consumer (ε_j) and the aggregate income elasticity of demand (ε_A) can be calculated, in general, as

$$\varepsilon_j = \frac{\partial x_j}{\partial m_j} \cdot \frac{m_j}{x_j} \text{ and } \varepsilon_A = \frac{\partial X}{\partial M} \cdot \frac{M}{X}. \tag{8}$$

Since it has already been established that $\varepsilon_j = \varepsilon_A = 1$, and recognizing that the partial derivatives in (8) are the marginal propensities to consume, the income elasticities in (8) can be rewritten as

$$MPC_j = \frac{x_j}{m_j} \text{ and } MPC_A = \frac{X}{M}. \tag{9}$$

Since all consumers face the same price for lottery tickets, the right-hand-side of each equality in (9) reflects expenditure shares.[6] From the equality of the marginal propensities established in (7), one can see that

$$\frac{x_1}{m_1} = \frac{x_2}{m_2} = \frac{X}{M}, \tag{10}$$

which says that each consumer must spend the same percentage of his or her income on lottery tickets in order for the aggregated demand function to be representative of an individual consumer's demand.

The focus thus far has been on the restrictive assumptions with regard to income and expenditure shares that are required for aggregate lottery-demand estimates to reflect the behavior

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[5] Since $\frac{\partial MPC_A}{\partial M} \equiv \frac{\partial MPC_j}{\partial m_j} = 0$.

[6] See note 4. It is easy to see that multiplying each ratio by P does not change the equality of the ratios.

of individual consumers. Inferring consumer behavior from the aggregate demand function in equation (1) also places severe restrictions on the price-responsiveness of each consumer's demand, namely the own-price elasticity of demand and the cross-price elasticity of demand. These restrictions are derived and described below.

Because it has been established that estimation of equation (1) assumes constant expenditure shares, this restriction further implies that the own-price elasticity of demand is equal to -1 and the cross-price elasticity of demand (assuming there now exists an additional good y *in* equation (1) having price p_y) is equal to zero. This should be intuitive - an increase in p_x must decrease the quantity of X by a proportional amount since the expenditure share of X is constant. This then implies that the own-price elasticity of demand is equal to -1. Following the same logic, an increase in p_y will have no effect on the demand for X under constant expenditure shares, which implies that the cross-price elasticity of demand is equal to zero.

Although the restriction of own-price elasticity equal to -1 and cross-price elasticity equal to zero is intuitive given constant expenditure shares, a more formal demonstration is useful. Consumer theory tells us that a consumer's demand, derived from the utility maximization calculus, is homogenous of degree 0 in prices and income. That is, equal percent changes in income and prices will leave the utility-maximizing quantity unchanged. Ignoring cross-price effects for the moment and considering only the own-price elasticity, Euler's theorem for homogenous functions demonstrates that, for each consumer j having the Marshallian demand $x_j(p, m_j)$,

$$\frac{\partial x_j}{\partial p} \cdot p + \frac{\partial x_j}{\partial m_j} \cdot m_j = 0.$$

Dividing this expression by x_j yields

$$\frac{\partial x_j}{\partial p} \cdot \frac{p}{x_j} + \frac{\partial x_j}{\partial m_j} \cdot \frac{m_j}{x_j} = 0. \tag{11}$$

Similarly, for aggregate Marshallian demand $X(p, M)$,

$$\frac{\partial X}{\partial p} \cdot p + \frac{\partial X}{\partial M} \cdot M = 0.$$

Dividing this expression by X yields

$$\frac{\partial X}{\partial p} \cdot \frac{p}{X} + \frac{\partial X}{\partial M} \cdot \frac{M}{X} = 0. \tag{12}$$

Both (11) and (12) show that the sum of the own-price elasticity of demand and the income elasticity of demand is equal to zero (the degree of homogeneity).[7] Since it has been shown earlier than the income elasticity of demand is equal to one, it must be the case that the own-price elasticity of demand in equations (11) and (12) are both equal to -1. This then implies that β = -1 in equations (1) and (2). Thus, another restrictive assumption that is required for the aggregate lottery-demand function to be representative of individuals' demands is that the price elasticity of demand for each consumer must be equal to -1.

To consider the cross-price elasticity of demand, assume there now exists an additional good y having price p_y. Typically good y is another lottery game, but good y could be any consumption good or a composite good. It should be clear that p_y can be reflected in the demand function shown in equation (2) by simply including the term p_y^θ, where θ represents the cross-price elasticity of demand. Because this two-good demand function is also homogeneous of degree zero in income and prices, a similar application of Euler's theorem as done above yields

$$\frac{\partial x_j}{\partial p} \cdot \frac{p}{x_j} + \frac{\partial x_j}{\partial p_y} \cdot \frac{p_y}{x_j} + \frac{\partial x_j}{\partial m_j} \cdot \frac{m_j}{x_j} = 0 \text{ for each consumer } j, \text{ and}$$

$$\frac{\partial X}{\partial p} \cdot \frac{p}{X} + \frac{\partial X}{\partial p_y} \cdot \frac{p_y}{X} + \frac{\partial X}{\partial M} \cdot \frac{M}{X} = 0 \text{ for aggregate demand.}$$

Since it has been established that the income elasticity of demand is equal to one and the own-price elasticity of demand is equal to -1, it must be the case that the cross-price elasticity of demand is equal to zero.[8] Thus the aggregate lottery-demand function shown in equation (1) that is

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[7] Euler's theorem shows, for a function $f(x_1, x_2, \dots x_n)$ that is homogeneous of degree h, then $f_1' \cdot x_1 + f_2' \cdot x_2 + \cdots + f_n' \cdot x_n = h \cdot f(x_1, x_2, \dots x_n)$. For a function like Marshallian demand that is homogenous of degree zero, the right-hand side of this expression is equal to zero since $h=0$.

[8] If the prices for multiple goods are considered, then Euler's theorem shows that the *sum* of the cross-price elasticities must equal zero. This requires, therefore, that each cross-price elasticity is equal to zero, or that some goods are substitutes (positive cross-price elasticity) and others are complements (negative cross-price elasticity) where the sum of the positive and negative values are restricted to equal zero.

commonly used to estimate cross-price elasticities for different lottery games implicitly assumes that there are no cross-price effects across lottery games, i.e. lottery games are neither substitutes or complements.

To summarize thus far, it has been shown that only under the assumption that consumers have identical and homothetic preferences will the aggregate lottery-demand function be representative of individuals' demands. In fact, the above results can provide insight into the functional form of preferences (i.e., the utility function) of each consumer that is inherently assumed by equation (1). Since it has been determined that the income elasticity of demand is equal to one and the price elasticity of demand is equal to -1, the aggregate Marshallian demand shown in equation (2) simplifies (ignoring subscripts) to $X = \alpha M/P$. But it can be shown through integrability that this Marshallian demand function implies a utility function having the form $U(X) = X^{\alpha}$ (Deaton and Muellbauer 1980). This is just the familiar Cobb-Douglas utility function.[9] So, empirical estimation of equation (1) assumes that all consumers have identical Cobb-Douglas utility functions. The assumption of Cobb-Douglas utility puts quite severe restrictions on consumer behavior; namely, that each consumer's income elasticity of demand for lottery tickets is equal to one, all consumers have equal marginal propensities to consume lottery tickets, and the lottery-ticket expenditure shares for all consumers are the same. In addition, all consumers must have an own-price elasticity of demand equal to -1 and the cross-price elasticities of demand for each consumer must be equal to zero.[10]

Given these restrictive assumptions, the aggregate demand function used in lottery demand studies is not likely to represent the demand functions for individual consumers. Therefore, one cannot make inferences about individual consumer behavior, including the distributional burden of lottery ticket expenditures, based on the often-used regression specification shown in equation (1).

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[9] Recall that the exponents in the Cobb-Douglas utility function represent expenditure shares. In the case of one good, the expenditure share on that good is equal to one.

[10] Goldberger (1981) discusses the relationship between the elasticities that is implied by utility maximization under various assumptions regarding consumer preferences.

An "income elasticity of demand" estimated from equation (1) using, say, county-level data, can only reveal the response of county lottery sales with respect to changes in county income. Put this way, it is easy to see that it is inappropriate to make any inference regarding the distributional burden of lottery ticket expenditures for a representative consumer.

Based on the previous discussion, it thus seems that micro-level data on individuals' incomes and lottery ticket purchases would be an improvement over the use of aggregate data. However, the above issues still exist to some degree even when a cross-sectional sample of micro-level data is used to estimate the income elasticity of demand and the price elasticities of demand (Scott and Garen 1994; Farrell and Walker 1999; Perez and Humphreys 2011). Studies typically estimate a cross-sectional regression model similar to equation (1) where each unit of observation (i) is an individual rather than a zip-code or county. The variability in income and lottery ticket purchases is therefore captured from differences in income and lottery ticket purchases *across* individuals since there is no variation in lottery ticket purchases and income for each consumer (i.e., there is only one observation on income and lottery ticket purchases for each consumer). Thus, the micro-level studies are really estimating a representative demand function where the income elasticity estimate and the cross-price elasticity estimate are assumed to be representative of each consumer. This inherently assumes that all consumers in the sample have identical preferences. Even if one is willing to accept the assumption of identical preferences (an assumption that is neither uncommon nor entirely unreasonable), it is unclear if the estimated elasticities can be representative of all consumers in the sample without specifying the form of preferences that is underlying the empirical models.

3. Discussion

The previous analysis has shed light on the highly restrictive assumptions behind aggregate models of lottery demand and the resulting inability of aggregate demand models to generally

provide insight into individual consumer behavior. The logical question is, therefore, what can researchers do, if anything, to obtain insight into individual behavior? This is an important next step, given the public debate over the distributional burden of lottery ticket expenditures and the numerous empirical studies that have provided evidence toward this debate. The question extends beyond the state-lottery literature as well, since aggregate demand functions are commonly estimated in many economic disciplines.

An important starting point is to return to the basics of consumer theory and ask what form of consumer preferences (utility function) can be aggregated so that an aggregate demand function reflects the behavior of a representative consumer, while imposing fewer restrictions on consumer behavior than does the strict assumption of homothetic preferences. The price theory literature has shown that one form of consumer preferences that is more amenable to aggregation are preferences of the Gorman form (Deaton and Muellbauer 1980).[11] Utility functions of the Gorman form assume non-homothetic preferences, which provide for non-linear Engle curves (i.e., an income elasticity of demand not equal to one) and thus different expenditure shares across consumers.[12] Several empirical models have been established in the literature to estimate demand functions based on the Gorman form of preferences, including the PIGLOG (Price-Independent Generalized Logarithmic) model and the Quadratic Almost Ideal model (Deaton and Muellbauer 1980; Deaton 1984; Chiappori 2011). An important outcome of these models is that the identical functional form can be used at both the individual and the aggregate level. In addition, these models could be particularly attractive for lottery researchers as they do not require significant variation in (lottery ticket) prices, which is a situation that occurs frequently with lottery demand estimation.

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[11] See Chiappori (2011) for a detailed discussion and literature survey on aggregate demand functions and under what assumptions individual behavior can be represented by an aggregate demand function. Deaton (1984) provides a survey of technical issues that arise in empirical estimations of demand.
[12] One common representation of Gorman preferences is the quasi-linear utility function. Although the Gorman form does not assume an income elasticity of demand equal to one, the income elasticity of demand will tend to one as income increases.

Some issues remain, however. First, the aggregate demand models mentioned above assume that all consumers have identical preferences. Thus, interpreting individual behavior from the aggregate demand function can only be done if we assume that all consumers have the same preferences. These models may still be seen as an improvement, however, because they relax several restrictive assumptions of homothetic preferences, namely an income elasticity of demand that is equal to one and equal expenditure shares for all consumers. Second, and probably the most significant practical issue, is that the estimation of these models requires individual-level data on income and quantities. And this goes back to the biggest issue facing lottery researchers — the general lack of individual-level data on lottery ticket purchases and income.

The resulting conclusion is that lottery researchers need to have individual-level data on lottery expenditures and income *over time* that provides multiple observations on lottery expenditures and income for an individual. As discussed earlier, the few studies that have used micro-level data (Scott and Garen 1994; Farrell and Walker 1999; Perez and Humphreys 2011) only used a cross-sectional sample of consumers, where the variability in income and lottery ticket purchases is only captured by differences in income and lottery ticket purchases *across* individuals rather than differences in income and lottery ticket purchases for each specific consumer. The studies using cross-sectional micro-level data implicitly assume that each consumer has identical values for β and δ in equation (2). Although using cross-sectional micro-level data is arguably an improvement over more aggregate data, even micro-level studies using a cross-sectional sample of demand should clearly state the inherent assumptions regarding preferences and make some attempt to capture individual lottery-demand based on preferences that relax, to some degree, the restrictive assumptions on consumer behavior imposed by homotheticity.

If a time series of micro-level data were available to provide multiple observations for lottery expenditures and income, researchers could perform several different parametric and non-parametric estimations of lottery demand, including the income elasticity of demand and cross-

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price elasticity of demand, without having to presume a functional form for all consumers' utility functions that inherently requires restrictive assumptions about consumer behavior in the aggregate. As an example, time series data on a consumer's income and lottery purchases would allow parametric estimation of an income elasticity of demand (like equation (1)) for *that consumer* without having to specify the consumer's preferences. It could just be assumed that the consumer is a utility maximizer and that the observed quantity of lottery ticket purchases is the utility maximizing quantity for the individual consumer given his or her income and prices.

Finally, even in the absence of time-series data, more detailed cross-sectional micro-data on income, lottery tickets purchases, and other demographic characteristics may allow the researcher to "match" individuals having similar demographic characteristics but having different incomes and different lottery tickets purchases. Non-parametric estimation of the income elasticity of demand could then be done using the cross-individual differences in income and lottery ticket purchases. This procedure simply assumes that all individuals with similar demographic characteristics are "the same" without having to parametrically assume each individual's preferences. Again, the only additional assumption here is that the observed quantity of lottery tickets is the consumer's utility maximizing quantity.

4. Conclusion

This paper has shown that the empirical model of aggregate lottery demand common to the literature cannot be used to make inferences about the individual consumer except under very restrictive and unrealistic assumptions. Therefore, estimates of an income elasticity of demand and a cross-price elasticity of demand from these models do not provide clear evidence on the distributional burden of lottery ticket expenditures or cross-price responses. This is true as well for empirical models using a cross-sectional sample of micro-level data. It was shown that the common model of lottery demand used in the literature presupposes that, for each consumer, the

income elasticity of demand is equal to one and that the cross-price elasticity of demand is equal to zero. The findings here are relevant for two reasons: 1) the distributional burden of lottery ticket expenditures remains an important policy issue for state government finance, and 2) aggregate demand functions are used in many economic disciplines, with the implicit assumption that the results from these models reflect the behavior of a representative consumer.

The results also suggest that researchers using aggregate data or cross-sectional micro data should be quite cautious when conducting welfare analyses under too-restrictive assumptions regarding consumer preferences. From the analysis presented herein, it should be apparent without detailed exposition that welfare analysis under restrictive assumptions regarding consumer preferences can lead to misleading conclusions regarding the welfare consequences of policy.[13] This is relevant to the public finance literature, for example, that examines the welfare implications of commodity excise taxation (e.g., cigarettes, alcohol, taxable retail sales) and taxation in general. Indeed, conclusions regarding the welfare effects of policy changes that are based on results obtained from aggregate data may be masking quite different welfare effects occurring at the individual level.[14]

It is worthwhile to conclude with several points. First, the author is not claiming that estimation of aggregate lottery-demand functions should not be done; rather, researchers (including himself) should state outright that the coefficients representing "income elasticity of demand" and "cross-price elasticity of demand" should not be interpreted as representative of an individual consumer and thus do not provide clear evidence (in the case of income elasticity) on the distributional burden of state lotteries (i.e., "regressivity" or "progressivity"). After all, income elasticity of demand and cross-price elasticity of demand are concepts specific to an individual's utility maximizing calculus and therefore are generally not interpretable, as demonstrated here, from a lottery-demand model using aggregate data or a cross-section of micro-level data .

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[13] Chiappori (2011) discusses welfare analysis under data aggregation.
[14] See Dow and da Costa Werlang (1988).

Second, the author is not claiming that lottery ticket expenditures are not made disproportionately by lower income individuals. Probably the earliest evidence of this is from surveys of lottery players (Clotfelter and Cook 1987, 1989) that simply show, as a group, lower income individuals spend a higher share of their income on lottery tickets than higher income individuals. However, similar to the first point made above, this finding does not necessarily equate with lottery regressivity and the income elasticity of demand for lottery tickets, since these are concepts based on an individual's utility-maximization behavior and thus require individual-level data on lottery ticket purchases and income over time in order to estimate.

Third, given that better individual-level data are necessary for determining income elasticities and cross-price elasticities, it is hoped that this paper serves as a call for an entrepreneurial researcher (graduate student?) to acquire and assemble such data. The fact that these data have not already been collected suggests the task of doing so could be quite difficult, however.

Finally, researchers need to critically understand and disclose the underlying assumptions and restrictions on consumer behavior that aggregate-demand models, and even models using micro-level data, may impose. What is it that is truly being estimated in these models? Today's technology allows easy estimation of complex empirical models, but arguably this has, to some degree, caused researchers to lose sight of the important micro-economic assumptions behind lottery-demand models, and demand models in general. Economic behavior fundamentally occurs at the individual-level, and ignoring or failing to acknowledge the implications of this when conducting empirical work can result in misleading, or even incorrect, conclusions and policy recommendations.

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