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Lottery Participants and Revenues: An International Survey of Economic Research on Lotteries

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Abstract

Government sponsored lotteries operate around the world. Their popularity has grown substantially over time. Legal lottery gambling generates significant public revenue, much of it from the lower part of the income distribution. Lottery is almost always an unfair bet, so explaining the purchase of lottery tickets by risk-averse consumers has long challenged economic theory. Lotteries can be analyzed from the perspective of public finance, as source of public revenue, or consumer theory, as a consumer commodity. We survey the state of economic research on lotteries from both perspectives, focusing on the key empirical findings.

Keywords: Lottery, implicit tax, effective price, jackpot, conscious selection

JEL: D12; H30; L83

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1. Introduction

Lottery is a type of gambling based on the drawing of lots, or random numbers, to determine the winner of a prize. Lotteries currently operate in a large number of countries around the world. Some of the largest lotteries operate in Spain, the United Kingdom, Ireland and across several Australian and US states. Lotteries are usually operated by governments for profit and the large sums extracted from consumers can be regarded as an implicit (and regressive) tax (Clotfelter and Cook, 1987) on those who choose to participate. Since lotteries exist all over the world and their popularity has grown, a large literature on economic aspects of lotteries has developed.

Outside the United States, lottery dominates most gambling markets for a number of reasons. For example, in Spain the sales of lottery tickets surpassed 9.4 billion Euros in 2007; this represents over 94% of the revenues generated by games managed by the government in Spain and about a 30% of the all gambling expenditure in Spain. It is a very simple game that does not require specific knowledge such as is needed for other gambling activities like sports betting or casino table games. Tickets are relatively inexpensive and can be purchased at a large number of retail outlets. This simple, cheap and widely accessible nature makes lottery gambling much more popular than other forms of gambling and therefore lottery participation rates are expected to be higher than for other types of gambling.

Although the basic rules are the same, modern lotteries include many different formats and may be known by different names in different countries. The main lottery formats are: draw (passive) lotteries, where tickets are pre-numbered and prizes are set in advance, so the role of the player is limited to buying the ticket; active or semi-active lottery games like Lotto, where the player selects a large set of numbers which are entered into the draw and winners are determined by a randomly drawn set of numbers, or numbers games, where players attempt to pick three or four digits to match those that will be randomly drawn; and instant lotteries or scratch cards where players scratch a latex-based surface to instantly determine if the ticket is a winner or a loser. Lotto is also referred to as the Genoese format and represents the largest source of revenue for European lottery organizations. The primary difference between Lotto and numbers games is that the former is a pari-mutual game but the latter is not. In addition, with the explosion of the internet, several web-based lotteries, and traditional lotteries with web-based purchase and payments, have recently surfaced. For example, it is now possible to buy tickets for the UK National Lottery on the web.

Given the popularity and growth of lotteries, economic research on lotteries has also grown over time. There are several reasons for the growing interest in economic research on lottery. Lottery is an important and growing source of revenue for state, provincial, and national governments. Although the purchase of lottery tickets violates the premises of some economic models (risk aversion, expected wealth maximizing and rational behavior) lottery probably is the most popular form of gambling in many countries. Risking small sums of money for the chance to win a very large prize attracts many players. So economic analysis could provide information about whether the demand for lottery games responds to expected return, as maximizing behavior predicts, or whether the remote chance of winning a life changing sum is the single feature players take into account. Lotteries can thus be analyzed from either of two economic perspectives: as a source of public revenue or as a consumer commodity.

As lottery games have grown in popularity, the demand for these products has received considerable attention from economists. An extensive literature exists on the economics of lotteries focusing on issues like its importance as a source of tax revenue and the behavior of lottery participants. Numerous papers have analyzed the demand for lottery games around the world. Demand for lottery determines who buys lottery tickets and in what quantities. The empirical literature in this area has focused on four key questions: (1) who plays lottery games? (2) why do people buy lottery tickets? (3) why do governments sponsor lotteries, how important are lotteries as a source of government funds, and what re the implications of raising public funds from lottery?; and (4) how do game features – such as rules or the prize structure – affect the demand for lottery tickets? We survey the literature on all four of these questions in this paper.

In the extensive body of literature on the economics there is no survey of the primary empirical findings. This paper reviews the theoretical research on lotteries, tracing the contribution of seminal papers, examines key empirical issues in modelling and estimating lottery demand functions, and discusses the empirical regularities found in the literature, in the hope of stimulating new lines of inquiry. Notably, we summarize the salient features of a number of relevant studies and develop an extensive bibliography to aid in research on the economics of lottery.

2. Lottery games

Sprowls (1970) proposed three measurable characteristics to describe a lottery gamble: the expected value, the probability of winning a prize, and the inequality of the prize distribution. The expected value refers to the mathematical expectation of winnings from the purchase of a ticket given the prize distribution. The general prize distribution of a lottery features one top prize, the jackpot, several smaller prizes awarded to tickets that match many of the winning numbers, and a number of small prizes, often equal to the nominal price of a ticket. In general, lottery gambles are unfair bets. The total amount paid out in prizes is less than the total revenue derived from the sale of tickets. The difference between these two is the expected loss. In addition, lottery games take different formats according to the player's role and the way the lottery is run.

Draw games constitute a relatively important share of annual worldwide lottery sales, are fairly universal – except in the United States and UK - and remain an important part of the lottery industry. Draw lotteries are passive games. The tickets are pre-numbered and the player cannot choose the numbers played. Instead, draw lottery players buy a ticket, or a fraction of a ticket, and wait for the draw that indentifies the winning ticket. Selling periods between draws are usually long and prizes are set in advance and do not depend on sales.

Lotto-type games differ from draw lotteries; they are pari-mutuel games in which the expected monetary value of a winning ticket depends on sales. Lotto emerged worldwide as an important gambling medium following its successful introduction in New Jersey in 1974 and New York in 1978. Lotto is a simple game where a player must guess *n* numbers out of a set of *m* numbers regardless of order and prizes are awarded according to how many of the numbers in the winning combination were picked. Most modern lotto-type games are variations of the pari-mutuel lotto design in which the structure of the game is defined by the number of digits the player chooses and the size of the matrix of available numbers. For example, in a 6/49 lotto game, a bettor chooses 6 numbers without replacement from a set of 49. In this particular case the odds of matching the winning combination are 1 in 13,983,816. 7/49 is another common Lotto format. In a 7/49 Lotto, the winning combination is seven numbers from the set 1 to 49. A 7/49 Lotto has more than 85 million possible number combinations. When multiple players win the largest prize, or jackpot, the prize is shared among them. Lotto-type games are active games which allow players to choose their own numbers. Active lottery games increase demand by providing an "illusion of control", whereby players believe they can select winning numbers through skill or foresight. "Illusion of control" refers to the tendency for human begins to believe they can control, or at least influence, outcomes that they demonstrably have no influence over. Lotto-type games are pari-mutual, as multiple jackpot winners split the prize, which depends on the number of tickets sold.

Lotto games differ in respect to the structure of the prize pool; most Lotto games award a jackpot and several smaller prizes for matching, for example, six of the seven winning numbers. If there are no winners of the jackpot, the value of the jackpot is added to the top prize in the next draw, an event is known as a rollover. In lotto games it is possible for top prizes to accumulate to very large amounts. For example, in 2007 lotto games in Spain paid out over 2 billion Euros as prizes. Walker (1998) observed that Lotto is intrinsically more interesting than other lottery formats because of the variation in jackpot size. The face price of a unit bet also differs across lotto games, but it usually does not vary much over time in any one game. Draw frequency also distinguishes different Lotto games. Weekly or bi-weekly are common draw frequencies for Lotto games.

Numbers games resemble Lotto in that the bettor attempts to correctly pick three or four digits (1 to 10) to match a randomly drawn winning combination. In numbers games, winning numbers are determined by the outcome of a random drawing of numbered balls. Numbers games are usually fixed odds rather than pari-mutuel and do not feature rollovers. Most numbers games have a daily draw, and some have more than one draw every day.

Instant win or scratch-off lottery games are also common around the world. These games do not have officially drawn winning numbers. The prize structure is set in advance and pre-printed tickets are sold to players. The player's role is limited to scratching off a latex-based surface which obscures the numbers or values printed on the ticket to determine if the ticket is a winner and how much is won. The variety of scratch-off games is endless.

Lottery tickets can be viewed as financial assets with uncertain payoffs where the prizes are the returns to a certain investment (the price of a ticket or bet). In most lottery games, the takeout rate (the share of the revenues that is kept by the government and not distributed as prizes) ranges from 0.3 to 0.5, making the expected return on many lottery gambles negative. If lottery players are rational, wealth maximising, risk averse economic agents, it is difficult to explain why so many people play the lottery. Every time someone buys a lottery ticket, common assumptions underlying economic models appear to be violated. However, lotteries exist and their worldwide popularity increases more and more. This fundamental tension highlights the importance of a review of the economic explanations for consumers' participation in lottery games.

3. Lottery Participants

Explaining participation in lotteries by risk-averse consumers represents a challenge for standard expected utility theory (Quiggin, 1991). Lottery tickets can be considered a risky financial asset, where prizes represent uncertain returns to investment, and also a consumption good providing entertainment value to ticket buyers. Thus, understanding why people participate in lottery has not only been the concern of economic analysis: psychologists and sociologists have also paid attention to this topic. In the presence of large jackpots, due to accumulating rollovers, it is possible to place a bet on a lottery with a positive return (Thaler and Ziemba, 1988), but most lotteries feature unfair bets; the average payout rate for most lotteries is around 50% of the revenues collected. This raises questions about why risk-averse consumers purchase lottery tickets.

Clotfelter and Cook (1989) analyzed responses from surveys of lottery players to formulate two competing hypotheses about lottery participation: some bettors play for the entertainment value while others play hoping for financial gain; consumers appear to buy lottery tickets for either fun or profit. In general, three alternative theoretical approaches, with different normative implications, have been advanced to explain why people purchase lottery tickets; the hope of private gain is likely what sells the bulk of lottery tickets (Clotfelter and Cook, 1990).

3.1. The Friedman and Savage explanation: Expected Utility Maximization

The central idea underlying expected utility models is that an individual's expected utility as a function of wealth is not strictly concave. Rather, expected utility is initially concave, then becomes convex, and finally returns to being concave as wealth (or income) increases. Individuals make the decision to participate in lottery at a level of wealth where winning a prize would move them through a range of wealth where the utility function predicts they are risk lovers, making them willing to accept unfair bets. This approach is based on the model developed by Friedman and Savage (1948) that focused on wealth as the key variable determining the willingness to assume risk. However, this theory cannot explain why people continue to purchase lottery tickets or why participation in lottery markets is not concentrated in the part of distribution where such non-convexities are most commonly observed (Walker, 1998).

3.2. The Kahneman and Tversky Explanation: Prospect Theory

Kahneman and Tversky (1979) posited that instead of making decisions under uncertainty like the purchase of lottery tickets based on the true probabilities of winning the top prize or other secondary prizes, individuals tend to overweight low probability events like winning a Lotto jackpot. In this model, preferences systematically differ from those assumed by expected utility theory in that losses affect utility differently than gains. *Prospect theory* makes consumer behavior consistent with the fact that many people purchase lottery tickets because they make decisions based on the size of a lottery jackpot rather than on the probability of winning that jackpot (Camerer, 2000).

3.3. The Conlisk Explanation: The Utility of Gambling

Conslik (1993) argued that the decision to bet or not does not depend only on expected utility, but also on an additional term representing utility, or consumption benefits, derived from the act of gambling. As mentioned in Scott and Gulley (1995), in addition to the monetary return from the bet, there also exists a nonmonetary return, i.e., the value derived from watching the numbers being drawn on television, discovering whether an instant ticket is a winner, thinking of how any prize money would be spent, or discussing lotto strategy with friends. Thus, for some people, playing the lottery can be considered an amusing pastime (Clotfelter and Cook, 1990). In this case risk averse consumers could decide to gamble even if the bet had a negative expected monetary value (Le Menestrel, 2001).

Based on expected utility theory, consumers gamble for financial gain; based on Conlisk's (1993) model, consumers gamble for fun. According to prospect theory, the decision to gamble can be motivated by monetary characteristics of the gamble that are unrelated to the expected return on the bet. The utility of gambling approach, and the Prospect Theory approach, clearly apply to lotteries where the stakes are small and tickets are widely available. Explaining lottery participation by the non-pecuniary pleasure derived is also compatible with empirical evidence that participation occurs across the income distribution (Walker, 1998). Conscious selection of numbers in lotto games represents another source of consumption benefits. Conscious selection refers to the case where bettors exhibit preferences for particular combinations of numbers such as important dates, birthdays and anniversaries for example, specific number sequences, for example 1 through 6, and "lucky" numbers like 7. This can generate consumption benefits from gambling even if preferences are uncorrelated across bettors. However, conscious selection reduces the expected value of lottery tickets for those who play these numbers, because it increases the probability that the jackpot will be split among multiple winners.

From an empirical perspective, the main question arising from these three explanations for lottery participation is whether consumer demand for lottery games responds to expected returns, as expected utility maximizing behavior predicts, or whether consumers respond to factors like the size of the jackpot that do not affect the expected return on a lottery ticket, like Prospect Theory predicts. While the utility of gambling model has considerable appeal, no explicit tests of this model have been conducted, probably because of difficulty identifying an appropriate observable proxy for the consumption benefits generated by gambling.

The most common approach in the empirical lottery demand literature employs the "effective price" model (Cook and Clotfelter, 1993, Gulley and Scott, 1993; Scott and Gulley, 1995; Walker, 1998; Farrell and Walker, 1999; Farrell et al., 1999; Forrest et al., 2000b). The effective price model, rooted in expected utility theory, focuses on financial motivations for participating in lottery markets. In this model lottery tickets are considered to be risky financial assets and the prizes are the returns to a certain investment (the price of a ticket). The effective price of a bet is then defined as the difference between the nominal cost of a ticket and the expected value of a ticket. Although the price of a bet itself does not usually vary from draw to draw, the expected value of a ticket does vary from draw to draw in lotto games because the prizes change due to variation in participation or jackpot rollovers.

The expected value of a lottery ticket was first derived by Sprowls (1970) and subsequently estimated by Clotfelter and Cook (1989), DeBoer (1990), Gulley and Scott (1989), Shapira and Venezia (1992), Cook and Clotfelter (1993), Gulley and Scott (1993), Scoggins (1995), Farrell et al. (1999), Farrell and Walker (1999) and Matheson (2001) in many settings. The presence of both a grand prize, or jackpot, and secondary prizes complicates the estimation of an effective price for a lottery game since the nature of secondary prize payouts differs from game to game.

In general, the calculation of the expected value of a lottery ticket is straightforward. Consider the simple case where there is only one prize in a lottery and where a unit price is assumed for each bet. Cook and Clotfelter (1993) defined the expected value (EV) of a bet under these conditions as the amount of the prize adjusted by the probability of having a winning ticket and divided by the expected number of winners. Following Farrell and Walker (1999), the expected value of a lotto ticket assuming a single jackpot and uniform number selection can be expressed

$$ev = \left[\frac{r}{q} + (1-\tau) \right](1-\pi) \qquad (1)$$

where r is the value of any rollover from a previous draw without winners, q is the total number of tickets sold, τ is the *take-out rate* (the share of the revenues that is not distributed as prizes), and (1- π) is the probability of not having a winning ticket (so, the probability of a rollover exists).

From equation (1), the expected value of a lotto ticket depends on the structure of the game, including the probability of winning, the value of previous jackpots rolled over into the current jackpot, and the number of tickets bought for the draw. The expected value will vary from draw to draw due only to variation in sales and rollover variation because the odds structure of the game does not usually change from draw to draw. Rollovers generate systematic variation in the level of sales across draws because a rollover induces an exogenous change in the effective price that causes a movement along the demand curve. This allows the occurrence and size of rollovers to be used as instruments to determine effective price in some empirical research on lotto sales.

Scott and Gulley (1995) found that, in general, lottery bettors' decisions to play generated a level of sales linked to a forecast of the expected value of a ticket. Gulley and Scott (1993) and Farrell and Walker (1999) included the expected value in their empirical models. Furthermore, if the demand for lottery is estimated on a draw-by-draw basis, a price variable can be included on the right-hand side of an empirical model (Gulley and Scott, 1993). Farrell and Walker (1999) identified the price of a lottery ticket though changes in the expected value of a ticket generated by a rollover that occurred while survey data were being collected. This way, a demand function can be estimated.

Cook and Clotfelter (1993) found that rollover-induced variation in the expected value of a ticket is an important determinant of sales. One problem with this approach is that rollovers are expected to occur infrequently in lottery games where the number of potential number combinations is roughly equal to the number of plays in each draw. Surprisingly this usually has not been the case for most lotteries, as rollovers happen frequently. Farrell et al. (2000) show that one reason for frequent rollovers is that players appear to pick their numbers in a non-uniform way. This leads to a lower coverage of the possible number combinations, increasing the probability of a rollover occurring.

Most empirical papers on demand for lotto consider the case where players are assumed to select numbers uniformly from the set of all possible number combinations, despite the evidence that the number combinations selected by players is not uniformly distributed across all possible number combinations. Cook and Clotfelter (1993), speculate that the theoretical structure of the game is unchanged if individuals pick their numbers non-randomly, that is conscious selection takes place, and Farrell et al. (2000) show that conscious selection has a minimal impact on the estimated elasticity.

Since the "effective price" is the mathematically expected price buyers would calculate if they were able to predict sales and all of participants choose numbers randomly (Forrest et al. 2002), effective price cannot be observed *ex ante*. The expected value of the bet's payoffs depends on the behavior of other bettors and is determined by current sales, which are only known *ex-post*. Researchers using this model typically argue that bettors form rational expectations of the "effective price" using all the available information – such as sales in previous draws, trends in sales, and the amount rolled over from previous drawings - and they then forecast expected value based on what they think other bettors will do (Scott and Gulley, 1995). The concept of rational expectations has typically been assumed in the analysis of consumer demand in betting markets. This assumption was supported by Forrest et al. (2000a) using information for the UK National Lottery.

On the other hand, the expected value of a lottery ticket depends not only on the rollover and the share of the revenue allocated to the prize pool, as suggested in Scoggins (1995), but also on the total amount bet by other players. So there are two externalities generated by each additional lottery ticket sold: a positive externality, raising the jackpot available, and a negative externality, increasing the probability of sharing the prize if won. Cook and Clotfelter (1993) refer to this as the "Peculiar Scale Economies of Lotto" and conclude that adding another player to the pool increases the expected value of a bet, so the first effect dominates the second. Cook and Clotfelter (1993) also analyzed lotto sales in 17 US states using a cross-sectional approach and found that sales increase with the scale of operation, presumably because sales are mainly sensitive to the size of the jackpot.

Farrell and Walker (1999) used micro data on weekly individual lottery spending, coupled with the fact that the UK National Lottery experienced a rollover while the data were being collected, to calculate a time varying effective price of a lottery bet. This effective price was included as an explanatory variable, together with income and demographic characteristics of participants. This allowed them to estimate both price and income elasticities; the price elasticity of demand for lottery tickets shows how demand varies with the expected values of the return from a ticket and allowed for a calculation of consumer surplus generated by this lottery. Scott and Gulley (1995) further discussed the relationship between sales and expected value in lotto games. The income elasticity determines how regressive (or otherwise) a lottery is, while the price elasticity gives relevant information about efficiency. Farrell and Walker (1999) found low income elasticities and high price elasticities and concluded that the former implies that taxing lotto is regressive while the latter implies that is inefficient. Note the limited variability of the effective price variable in this analysis. The effective price variable consists of only two observations, since it does not vary across households, only across the two draws. This affects the identification and estimation of price elasticity in the analysis.

Before Farrell and Walker (1999), earlier papers examined rollover-induced changes in the expected value of a lottery ticket to infer a price elasticity of demand using aggregate time series data (Gulley and Scott, 1993; Farrell et al., 1999). Gulley and Scott (1993) showed that because of the rollover feature in lotto games, the effective price of a bet can change dramatically from one draw to the next, and estimated a lottery demand function using data from consecutive draws including a variable capturing the effect of this effective price variation. Time series analysis of aggregate data on draws is not able to identify the income elasticity because there is little variation in income over a relatively short time periods.

Forrest et al. (2002) questioned the usefulness of the "effective price" model for assessing the relative importance of the effective price or the jackpot to explain observed variation in lottery sales. The effective price model is based on total expected prize payouts, so it does not take account of possible consumer preferences in regard to the structure of prizes. Furthermore, the explanatory variables included in these models do not explain why bettors accept an unfair gamble. Quiggin (1991) argued that, in regard to lottery tickets, there is no acceptable explanation that includes risk aversion and concluded that the only reason for betting is the chance of winning a large jackpot. Therefore, Forrest et al. (2002) propose an alternative model to explain the demand for lotto, the "jackpot" model.

The "jackpot" model incorporates a more direct explanation for why people buy lottery tickets, assuming that fun or pleasure is derived from gambling activities. This links the jackpot model to both the utility of gambling model and prospect theory. The jackpot model can also be traced to Clotfelter and Cook (1989) who remarked that bettors are buying a hope (or a dream) each time they buy a lottery ticket and that hope increases with the size of the jackpot. The "jackpot" model does not use the effective price but instead includes the amount of the top prize as the primary observable variable affecting the number of tickets sold in each draw. A number of papers examine the relationship between jackpot size and lotto sales, including DeBoer (1990), Shapira and Venezia (1992), Gulley and Scott (1989), Scott and Gulley (1995), and Matheson (2001). Garret and Sobel (2004) analyzed sales for 135 lotto games in the US and found sales responded to the size of the jackpot and the odds of winning the jackpot, but not to the expected value of lower prizes. Because the chances of winning a large prize are usually known to be very remote bettors do not really expect to win but enjoy the dream of spending the prize that could be won. This explains how variation in sales is not affected primarily by the effective price but rather by the jackpot.

Since the effective price model and the jackpot model have different implications in terms of the demand for lottery, each model reflects different views of bettor behaviour, and the variables included respond in a different way to changes in the structure of prizes. García and Rodriguez (2007), among others, suggest a model in which both variables, the effective price and the jackpot, are included. They estimate a demand equation for football pools in Spain using instrumental variables that includes both the effective price and the jackpot. Following Kelejian (1971), the set of instruments used makes the matrix of instruments of a sufficient rank to obtain consistent estimates, making it possible to simultaneously include both variables (the effective price and the jackpot) in the model and estimate their effect consistently. The nonlinearity in variables (but linearity in parameters) of their model allows them to use polynomials of the original instruments and the predetermined variables to form the final set of instruments. However, Forrest et al. (2002) note that collinearity is a practical obstacle to obtaining reliable estimates on how sales respond separately to the two changes associated with a rollover, the fall in effective price and the greater weighting of the top tier prize in the expected value of a ticket.

(Insert TABLE 1 here)

Since expected value depends on sales, the effective price in a lottery demand model is endogenous, so the unknown parameters in these models cannot be estimated by ordinary least squares. Most of the studies of demand for lotteries reported on Table 1 use a two-stage least squares estimator for modelling lotto demand. Because rollovers cause most of the variation in effective price, and occur randomly, their frequency and size are the most common instruments in these studies. The empirical findings show, as expected, a consistent negative relationship between effective price and sales and a statistically significant and positive effect of the jackpot on sales. In addition, most long-run price elasticity estimates are around minus one.

Apart from price, rollover, and jackpot, other influences on lotto demand such as time trends, structural changes, or special events or draws are often included in most of these studies. The goodness of fit is always high.

The jackpot model can motivated by players buying consumption benefits from the lottery as well as by an expected monetary return, where the benefits of "buying a dream" are related to bettors' perception of the third statistical moment of the lotto's payoff distribution. The theoretical basis for this argument is justified in the sense that the expected utility does not only depend on the expected effective price and its variance, but also on the third moment, which implies that risk averse individuals could still accept unfair bets (Golec and Tamarkin, 1998). Furthermore, if consumers are misinformed, their demand for lottery might respond to the top prize, but would not systematically respond to the expected value of the bet. Including the first three statistical moments of the prize distribution in the analysis is equivalent to allowing variations in the top prize to affect the decision to buy independent of its contribution to the effective price. Garret and Sobel (1999), Walker and Young (2001) and Wang et al. (2006) offer examples in which the third moments of the effective price are included in the specification of the demand function. Note that including higher moments of the prize distribution is justified even without consumption benefits. The individual who buys an investment will consider more than the first moment if his utility of wealth function is non-linear.

Walker and Young (2001) proposed an alternative approach, modelling demand as depending on the probability distribution of prize amounts that might be won from a single ticket. The distribution was to be summarised by the first three moments of the distribution: the mean (expected value), variance and skewness. Walker and Young (2001) used data from the principal game in the United Kingdom, the National Lottery and found that sales patterns responded positively to mean (i.e. expected value), negatively to variance and positively to skewness. Walker and Young observe that mean, variance and skewness are endogenous to the extent that they can be influenced by, and influence, sales. Despite this, this model was estimated by ordinary least squares because too few potential instruments could be found relative to the number of endogenous regressors. Nevertheless, they argued that the parameter estimates will be little affected because variation in sales will not have influenced mean, variance and skewness very much within the range of sales figures experienced in the data period. However, the precision of their coefficient estimates was low. This is likely due to collinearity among the moments. Once again, the problem is that all variation in the data is induced by rollovers and, in this case, rollovers always move mean, variance and skewness together with a positive relationship among the moments. This problem could potentially be resolved by examining a case where a lottery design change produces exogenous impacts on mean, variance and skewness.

The mean-variance-skewness model represents a new framework in which changes in the prize structure generated by lower prizes, even if they do not change the effective price, nevertheless affect the number of bets. However, if more (or less) of the payout goes to the jackpot, the effective price will fall (or rise) because more sales dollars go to a prize which might not be won in the current draw. It is important to estimate how demand for lottery responds to changes in the statistical moments as well as to differences in game characteristics. For this reason, future research needs to move on from the first generation of lotto demand studies and focus on characteristics of the prize structure as well as on the effective price of a ticket.

3.4 International Evidence

From the earliest analysis of state lotteries in the 1970s and 1980s, to the empirical papers on the determinants of lottery demand in the 1990s, most research focused on economic aspects of lottery-type games in the United States, Canada, and the United Kingdom. The current empirical research is based fundamentally on the application of the three primary lottery demand models, the “effective price” model, the “jackpot” model, or the “higher moments” model, to lotteries around the world in order to understand the effects of ticket pricing, jackpot announcements or prize structure on demand for lottery.

Table 2 summarizes some of the empirical papers that estimate the demand for lottery throughout in an international context. These papers examine the pattern of lottery demand in different countries in order to identify socio-economic characteristics that help to explain lottery consumption.

(Insert TABLE 2 here)

The main empirical findings from this literature, in terms of the effect of prize structure, game characteristics, and gamblers' behaviour on the demand for lottery are described below.

Shapira and Venezia (1992) investigated the effects of ticket prices, the probability of winning the jackpot, and prize structure on the demand for lotto in Israel; they found that larger jackpots are preferred to larger secondary prizes, and more frequent secondary prizes are preferred to lower ticket prices, using time series data from lottery draws in Israel. They also found a direct, positive effect on sales from increases in the announced jackpot and an inverse relationship between sales and the price of a ticket. Beenstock and Haitovsky (2001) extended Shapira and Venezia's (1992) research using data from a later period. Beenstock and Haitovsky (2001) also found that jackpot size increased sales, and that sales declined with ticket price; they also found evidence that consumers prefer a number of smaller prizes, other things equal, based on the addition of a sixth small prize. Both papers extend the research of Clotfelter and Cook (1990) who analyzed the effect of changing prices and payoffs on lottery ticket sales, and Quiggin's (1991) analysis of the optimal prize structure in lottery design that questioned whether it is better to have a single prize or a multiple prizes.

Several lotto games in continental Europe have been analyzed in the literature, including the Greek lotto 6/49 (Papachristou and Karamanis, 1998) the Austrian Lotto 6/45 (Hauser-Rethaller and Köning, 2002), the German Lotto 6/49 (Henze, 1997) and the Swiss Lotto (Henze and Riedwyl, 1998). Most of these papers focus on the choice of numbers by players.

Papachristou and Karamanis (1998) analyzed the Greek market for the 6/49 lotto under the assumption of uniform random number selection and conscious selection leading to non-uniform number selection by players and found that no potential for excess (in this case positive) profits by selecting unpopular numbers. Hauser-Rethaller and Köning (2002) performed a similar empirical study of demand for lotto in Austria and calculated an implicit price given the evidence of "conscious selection," players choosing numbers non-randomly, in this market. They concluded that accounting for "conscious selection" leads to higher price elasticity estimates. The existence of preferred numbers is also analyzed in Henze (1997) for the German 6/49 lotto and in Roger and Broihanne (2007) for the French lottery market. Both these studies reported evidence of widespread "conscious selection" in these markets. Henze (1997) reports significant numbers of tickets that select the winning numbers from the previous week's draw and sequences like 1,2,3,4,5,6. Roger and Broihanne (2007) report that, in a draw with 70 million tickets sold, the most popular 1% of the number combinations selected on tickets accounted for 10% of the tickets. If combinations of numbers were selected randomly, there should have been no more than 5 occurrences of any combination of numbers.

Optimal lottery pricing rules have also been analyzed around the world. Geronikolau and Papachristou (2007) examined optimal lottery pricing in Greece. Both models proposed in the empirical literature, the effective price model and the jackpot model, were estimated in this paper, and the corresponding point elasticities are calculated on the basis of the time-series of a 5/45 + 1/20 lotto game (*Joker*). This paper found lottery demand in Greece to be twice as price elastic as in any other game, so the game appears to be overpriced compared to international standards.

Lin and Lai (2006) estimated the effective price elasticity of a lotto type game (Big Lotto) in Taiwan. They used method developed by Gulley and Scott (1993) and Scoggins (1995) to calculate the effective price and found the expected negative relationship between effective price and the number of tickets sold. The estimated effective price elasticity was -0.145, which suggests increasing the effective price would increase revenues in this setting. This small elasticity may reflect the fact that lottery is not popular in Asia. Garrett (2001b) reports only 10 government sponsored lotteries in Asia and the middle East, and in countries in this region with lotteries lottery spending per dollar of GDP is less than half that in Europe and North America.

4. Lottery adoption, revenue generation and incidence

Lottery is a publicly provided form of gambling. State, provincial and national governments operate lotteries, or contract with a single private operator, and benefit from the revenues generated from lotteries. The importance of government lottery revenues has grown over time. Since lotteries represent an important and growing source of revenues, the decision to create a lottery, the size and uses of government lottery revenues, and the incidence of these revenues represent important elements of the literature on the economics of lotteries.

Coughlin et al. (2006) recently surveyed the adoption of lotteries by US states. In the US, lotteries were common mechanisms for raising money to fund public activities from the colonial era until the mid 1800, but corruption and public distrust lead to a national ban on lotteries. In the early 1960s, New Hampshire residents voted to establish a state lottery. By 2005, 42 US states offered lottery games, and several multi-state lottery games were also offered across the country. This expansion of state sponsored lotteries coincided with broad changes in public attitudes toward legalized gambling. Coughlin et al. (2006) discuss the increase in state sponsored lotteries in the context of the adoption of new taxes, because both represent new sources of public funds, and explore the political economy of lottery adoption. They identify six factors associated with state lottery adoption: economic development, fiscal health, election cycles, single party control of state legislatures, regional diffusion and idiosyncratic situational factors. States with higher income per capita and higher population density are more likely to adopt lotteries, suggesting that revenue generation potential drives this decision. Regional diffusion also plays an important role, suggesting that competition between states for revenue also drives lottery adoption. These conclusions support the idea that states see lotteries as an important source of public revenues.

Alm et al. (1993) analyzed lottery adoption decisions by US states. They identified fiscal stress, as reflected by increases in state short term debt and decreases in state income per capita, the presences of relatively high tax rates in a state, and the prior adoption of a lottery in nearby states as important determinants of lottery adoption. Again, the importance of lotteries as sources of revenues emerges as a key factor in this study. Alm et al. (1993) also point out that lottery revenues, like taxes, can be viewed primarily as a source of public funds; they refer to a state lottery as a "painless tax" because participation by consumers is voluntary.

A number of other papers examined the determinants of state lottery adoption. These include Davis, Filer and Moak (1992), Caudill et al. (1995), Mixon et al. (1997), Erekson et al. (1999), and Garrett (1999). Glickman and Painter (2004) show that the presence of tax and expenditure limits on state governments also explain the adoption of a state lottery. In general, these studies compare lottery revenues to tax revenues, and emphasize the role of lottery funds as a source of public revenues. Factors that affect the potential for lotteries to generate significant revenues, like income per capita and population, factors that limit the ability of states to raise tax revenues from other sources, and geographic competition in the form of lottery adoption by nearby states emerge key determinants of the adoption of a lottery in a state. Even though lottery participation is voluntary, government officials appear to view lottery revenues as a source of public funds.

Given that governments view lotteries as an important source of funds, a number of papers have analyzed lottery revenues in the context of other sources of government funds. Clearly, lottery revenues will never rival income taxes or sales taxes as a source of government funds. In a series of early studies, Mikesell and Zorn (1986, 1988) and Mikesell (1990) compared state lottery revenues to other state revenues. Lottery revenues were about 1.5% of state government revenues in 1978, in those states with lotteries. This increased to about 2% in 1984. Throughout the 1980s lottery revenues grew at more than 20% per year (Miksell and Zorn 1988), much faster than other government revenue sources. By the late 1980s lotteries represented more than 2% of state government revenues, and in some states the fraction exceeded 5% (Mikesell 1990). By the early 1990s lottery revenues accounted for well over 2% of total state revenues (Szakmary and Szakmary 1995). However, lottery revenues as a fraction of total state revenues remained at this level; Humphreys and Matheson (2010) reported that lottery revenues averaged 2% of total state revenues since the introduction of state lotteries, and total gaming revenues accounted for about 3% of total provincial revenues in Canada. In any event, many US states and Canadian provinces collect as much lottery revenues as they do in excise tax revenues on items like tobacco and alcohol (Humphreys and Matheson 2010). Garrett (2001a) analyzed lottery revenues around the world. Lottery sales averaged 0.5% of per capita GDP in North America. The fraction was slightly lower in South and Central America (0.49%) and significantly higher in Europe (0.55%) and Australia and New Zealand (0.57%). If countries in these regions have a similar revenue structure to North America, then lottery revenues also represent an important source of government revenues outside the US and Canada.

Unlike other sources of government funds, revenues from lotteries are often used to fund specific programs or activities, particularly in the US and Canada. In many cases, directing lottery revenues to a specific public activity mitigates public resistance to the legalization of gambling. Mikesell and Zorn (1986) identified a number of types of government provided activities tied to lottery revenues, including education, transportation, and senior citizens. Livernois (1987) documented the use of lottery funds to finance recreational and cultural activities in the western provinces of Canada. Mikesell (1990) identified a larger and more specific set of activities, including property tax relief, but concluded that education was emerging as the primary beneficiary of state lottery revenues. In the UK, Feehan and Forrest (2007) reported that sports, cultural and heritage grants received funding from the National Lottery.

Earmarking of lottery funds for specific activities highlights an important point about the relationship between lottery funds and other sources of public revenues. Earmarking of lottery funds is intended to supplement existing expenditure on a particular activity. But government funds are "fungible" and devoting a particular stream of revenues to a specific activity may lead to unintended effects. Research on the effect of earmarking state lottery funds for education makes this point clear. Spindler (1995) found that earmarking state lottery revenue to education reduced total spending on education in seven states over the period 1975-1995. Garrett (2001b) found that lottery funds directed to education in Ohio were completely offset by reductions in educational funding from other sources, suggesting that lottery funds did not harm education in Ohio, but also did not help it, as was intended. Novarro (2005) found that each dollar of lottery revenues earmarked for education increased spending on education by only $0.79 based on data from 17 states that tied all or part of the revenues generated by state lotteries to education. While not as strong as the effect reported by Garrett (2001b), these results also suggest that earmarking lottery revenues does not benefit the targeted government provided activities as much as advertised.

In addition to the issue of fungibility of lottery revenues, a number of other problems associated with raising government revenues from lotteries have been identified in the literature. Mikesell and Zorn (1986) noted that lottery revenues varied significantly from year to year, the operation of state lotteries typically entailed large operating costs, especially when fees paid to retail operators were included in these costs, and lottery marketing campaigns typically emphasize lotteries as a way to increase personal wealth and not a form of entertainment. Szakmary and Szakmary (1995) also show that lottery revenues exhibit significant variation over time, although they show that variation in lottery revenue is not highly correlated with variation in other government revenue sources. Fink et al. (2004) show that increases in lottery revenue are associated with decreases in overall state tax revenues. They posit that the creation of lotteries leads to declines in private spending on other goods and services that generate sales and excise tax revenues. Kearney (2005) found evidence consistent with this using micro-level data on consumer spending.

Although the revenues are not large when compared to sales and income taxes, lotteries represent a sizable and growing source of government funds. As a source of public funds, a substantial body of research has examined the incidence of lottery funds as a source of government revenues.

Some of this research revolves around the specific method governments use to raise revenue from lotteries. Government lotteries retain a fraction of all lottery sales as revenues, and return the rest to players, in the form of prizes. The fraction of revenues retained, called the takeout rate, typically amounts to 40% to 50% of lottery sales and covers operating costs. This takeout rate can be interpreted as an effective tax on lottery participants. Some analyses of lottery includes the takeout rate as an explanatory variable (Vrooman, 1976; Vasche, 1985; Mikesell, 1987, DeBoer, 1986; Clotfelter and Cook, 1989) which tests whether consumers respond to the effective tax on lotteries. The evidence on the effect of the takeout rate on lottery sales is mixed. DeBoer (1986) used panel data for some state lotteries from 1974 to 1983, and found a significant negative effect of the takeout rate on sales. Clotfelter and Cook (1989) also found a negative effect in an alternative approach using a cross-section of states lotteries in 1986. However, Vrooman (1976), Vasche (1985) and Mikesell (1987) did not find a significant relationship between the takeout rate and sales. A likely econometric problem in these studies is the endogeneity of takeout rate.

Introducing lottery games provides governments access to a new and substantial revenues. The takeout rate on lottery tickets can be interpreted as a large implicit tax on lottery tickets. Note that consumer participation in lottery markets is voluntary and the takeout rate is not itself a tax because it covers operating costs. Despite the voluntary nature of participation in lottery, the takeout on lottery has been viewed as an implicit tax in the literature (Clotfelter and Cook, 1987).

Since lotteries generate revenue for the government, and a large number of people participate in lotteries, the impact of lottery participation on the relative distribution of income among the population to assess whether the implicit tax on lotteries is progressive, neutral or regressive. In general, the main conclusion reached in studies analyzing the relationship between lottery play and household income is that the lottery is regressive, in the sense that as a percentage of income, spending on lotteries, and the government revenues generated from lotteries, decline as income increases (Clotfelter and Cook, 1990; Mikesell, 1989). A large body of literature addresses this topic; in general, researchers refer to this topic as the implicit tax incidence of lotteries

The analysis of the incidence of implicit lottery taxation employs several empirical approaches to identify the relationship between lottery expenditures and income: research based on data collected from questionnaires (Scott and Garen, 1994) or surveys of winners (Spiro, 1974; Borg and Mason, 1988), analysis of aggregate lottery sales by geographic area with census data used to infer the economic characteristics of players (Clotfelter, 1979; Price and Novak, 2000), investigation of the income incidence of lottery taxation assuming demand homogeneity across states, counties, communities or zip codes (Brinner and Clotfelter, 1975; Mikesell, 1989; Clotfelter and Cook, 1987; Davis, Filer and Moak, 1992; Jackson, 1994), and studies using household expenditures survey data to analyze tax incidence (Kitchen and Powells, 1991; and Worthington, 2001).

Most of the papers that analyze data at the individual level use a Probit model to estimate the effect of explanatory variables on the probability that an individual plays lottery games and a truncated Tobit model to estimate the amount that an individual spends on lottery tickets as a function of these variables conditional on participating because of the presence of zeros (non-participants) in the data. Analysis of aggregate data does not face this issue, as no zeros appear in aggregate data sets. Scott and Garen (1994), Stranahan and Borg (1998), Humphreys et al. (2010) and others raise important model specification issues for addressing the presence of zeros in gambling data. Scott and Garen (1994) propose that estimation of a demand function for lottery tickets requires a maximum likelihood procedure instead of a Tobit model. They use sample selection methods not previous utilized in this literature and find that income, in the presence of other socioeconomic and demographic variables, has no apparent impact on how many tickets lottery players monthly buy. Stranahan and Borg (1998) follow a similar procedure when examining how demographic differences affect lottery tickets purchase, focusing on the horizontal equity of the lottery tax. Income is found to have a negative and significant effect on the probability of playing lottery but does not affect lottery expenditure conditional on participation. Humphreys et al. (2010) point out that both the tobit and sample selection approach place strong assumptions on the nature of the underlying behaviour by consumers and propose an alternative approach, the double hurdle model, for analyzing gambling data containing zeros. Estimates of the income elasticity of lottery demand appear to be sensitive to model specification, so this topic needs further attention from empirical researchers.

Research on the incidence of the implicit lottery tax has been conducted for at least 25 years. Spiro (1974), Suits (1977) and Clotfelter (1979), used information on the expenditure and characteristics of lottery players from a variety of data sources, including household surveys, and found evidence of a regressive implicit tax in many individual state lotteries. Clotfelter (1979) analyzed the relationship between income and sales of daily and weekly games in Maryland, and reported negative income elasticities less than one in absolute value, implying a regressive implicit tax on these games. Brinner and Clotfelter (1975) found, at the state level, that families with lower income spend a higher percentage of their income on state lotteries than families with higher income. Even where these studies differ in empirical approach and in type of data used, aggregate or individual level, this regressive pattern persists. Clotfelter and Cook (1987, 1989) used data on individuals to analyze the regressive character of the implicit tax on lottery games; Borg and Mason (1988) found that age, race, and place of residence affect the propensity to play the lottery and confirm the regressive character of the implicit lottery tax. Mikesell (1989) questioned the conventional wisdom about the regressive character of lottery expenditure. This paper found that estimated income elasticities for instant games and on-line games in Illinois were not statistically different from one.

A good early survey of the literature on state lotteries in the US is Clotfelter and Cook (1990), who discuss the importance of state lotteries as consumer commodities and as sources of public revenue, as well as other topics like the effect of changing prices and payoffs on lottery expenditures. They concluded that lottery play is systematically related to social class, although perhaps not always as strongly as conventional wisdom suggests. Clotfelter and Cook (1990) represented a starting point for a number of studies on the determinants of the decision to play lottery and the factors that affect player's expenditure. Jackson (1994), in the case of the Massachusetts lottery, provided additional evidence on the relationship between participation in multiple lottery games and income and demographic variables through time. This paper found a less than one income elasticity for each game studied and concluded that, in later years, the lottery was a regressive source of government revenue because per capita sales for each of the games did not increase proportionately with income.

This increasing interest in lottery participation and tax incidence continued as economic analysis of state lotteries extended beyond the United States. Kitchen and Powells (1991) evaluated the relationship between a set of socio-economic and demographic variables and household lottery expenditures in the six regions of Canada; Worthington (2001) included demographic factors in an analysis of several gambling activities in Australia. In both papers lottery expenditures were, like research from the US, found to be regressive. However, these findings differed from other Canadian studies (Livernois, 1987) in which the income level was not found to significantly influence lottery expenditure.

Table 3 summarizes several empirical studies where lottery expenditures are regressed on income and other socioeconomic and demographic control variables in order to estimate the income elasticity. Apart from Mikesell (1989), who found lottery taxes to be proportional, there is remarkable consistency in these studies of the regressive character of the implicit lottery tax. Despite the volume of work on this topic we still know very little about the specific nature of this regressivity. In one exception, Oster (2004) used a zip code level panel data set to analyze how the regressivity of lottery varies according to the prize level. She found that lottery was less regressive at higher prize levels.

(Insert TABLE 3 here)

Some argue that regressivity should be measured by estimating lottery expenditure as a function of income with no controls because of confounding effects. For example including the level of education in the model might lead to positive income elasticity estimates even though high income people (who are typically highly educated) buy fewer lottery tickets. This point is supported by the results in Kearney (2005). The Suits index of implicit tax incidence shown on Table 3 is an example of an unconditional measure. However, the income elasticity estimates shown on Table 3 are conditional on other factors.

Overall, papers that estimate demand functions for lottery use cross sectional data and include nonprice determinants of lottery demand. Gulley and Scott (1993) point out that this approach is used because there is usually no change in the nominal price of a lottery ticket over long periods of time: states typically do not vary the take-out rate, and the takeout rate also does not vary much across states

From Table 3, the income elasticity estimates are uniformly less than one. This suggests that lottery spending increases less than proportionately with income; lower income individuals spend more on lottery than higher income individuals, other things equal. The estimates of the Suits index are uniformly negative, suggesting that the implicit lottery tax is regressive. Despite the "painless" nature of lotteries as a source of government funds, this source of funds appears to have an undesirable feature: a disproportionate share of the public funds generate by state lotteries appears to come from the bottom portion of the income distribution.

Coughlin and Garrett (2009) examine the relationship between spending on lottery and income from work, transfer payments, and wealth. This is an interesting exercise because other research uses total income, which could, in general, include earned income, unearned income, and transfer payments. Coughlin and Garrett (2009) report marginal spending on lottery tickets, but not estimates of income elasticity. These marginal spending estimates suggest what the sign of the income elasticity would be, as a negative marginal spending estimate would imply a negative income elasticity. This paper analyzes spending on instant lottery tickets and lotto in seven states in 2005. The reported marginal spending on lottery out of different forms of income varies widely; the pooled estimates across states and games suggest that the marginal spending out of labor income and transfer income is positive, and the marginal spending out of transfer income is larger than the marginal spending out of labor income. However, these results cannot be easily compared to those on Table 3 because income elasticity estimates are not reported.

A handful of papers perform a spatial analysis of the demand for lottery, but information on regional variation in the determinants of lottery expenditure is largely ignored in the literature. With the exception of Kitchen and Powells (1991) across Canadian regions, few previous papers had dealt with the analysis of variables affecting the level of lottery expenditure across regions. Some of them use cross-section data to estimate income elasticities at zip level getting a soft idea of demand spatial distribution, while others, as Barr and Standish (2002), only analyze the optimal location of gambling activities. Moreover, in both cases the effect of economic variables such as the expected value of the prize distribution or the top prize on the demand for lotto is not considered.

5. Complements, substitutes and statistical fallacies

Lottery games do not exist in a vacuum. Access to legal gambling opportunities has expanded around the world over time. Lottery was an early form of legal gambling, but following the legalization of lottery in the 1960s a number of other types of legal gambling activities became available. In addition, lottery agencies frequently introduce new games, and following the introduction of state lotteries a number of large multi-state lotto games were introduced in the US, Canada, and Europe to take advantage of the scale economies generated by large jackpots (Clotfelter and Cook, 1990). The introduction of new forms of legal gambling provides economists with a number of natural experiments that reveal interesting information about the demand for lottery. We review this literature in this section, and also summarize a number of interesting examples of anomalous consumer behaviour from the literature on the economics of lottery.

5.1 Complementarities and cannibalization among competing lottery games

Most state lottery agencies offer a variety of games to suit the tastes of players in order to maximize government revenues (Forrest et al., 2004). One strand of empirical research on lottery demand examines the coexistence of multiple lotto games with different formats, frequency and prize structures. This literature focuses on potential substitutability or complementarity among competing lottery games. Gulley and Scott (1993) estimated a demand function for competing lotto games in Massachusetts. The demand functions included the expected value of the competing lotto games and controlled for the existence of rollovers. They found that increased sales in one game generally did not reduce sales in other games. Price and Novak (2000) examined the relationship between sales of three lottery games offered in Texas in 1994. They included variables describing expenditures on competing games in lottery demand models. They found that the three games, a numbers game, lotto and instant lottery, were complementary and apparently, those who gamble on one game tend to gamble on the others. Forrest et al. (2004) analyzed weekly data from three competing United Kingdom National Lottery games. They reported partial substitution between two of the three games offered, and also found substantial intertemporal substitution between Wednesday and Saturday draws of the UK lotto game. Grote and Matheson (2006) found evidence of complementarities between a single state lotto game and a larger jackpot multi-state lotto game. Lin and Lai (2006) found no significant substitutive or complementary relationship between Big Lotto and Lotto in Taiwan.

Guryan and Kearney (2008) found no evidence of substitution in overall sales of different lottery games in Texas, even during periods of increased demand during jackpot rollovers in a large, multi-state lotto game. Forrest and McHale (2007) found that UK lotto sales respond positively to increases in the jackpot in EuroMillions, a European multi-country lotto game.

Evidence of substitution, in the form of cross price effects or substitution in consumer spending between lottery and other types of gambling, also exists. Forrest et al. (2010) found evidence of substitution between book maker betting and lotto in the UK. Siegel and Anders (2001) found that an expansion of casino gambling in Arizona reduced lottery revenues in that state, suggesting that casino gambling and casinos are substitutes. Purfield and Waldron (1999) analyzed changes in lotto sales and fixed-odds betting to determine the complementary character of their relationship in the particular case of the Republic of Ireland betting market. Unlike previous studies based on annual data they use semi-weekly, draw-by-draw, turnover data to find that Irish players appear to complement their lotto purchase with fixed-odds bets. Note that Purfield and Waldron (1999) examine not fixed-odds bets in general but fixed odds bets on which numbers will win in the Irish lotto game. Farrell and Forrest (2008) also found evidence of complementarities between lottery and casino gaming, and evidence of displacements between lottery and electronic gaming machines in Australia. Kearney (2005) investigated the relationship between lottery spending and spending on other types of gambling and spending on non-gambling consumer goods. She found that increased spending on lottery was associated with decreases in spending on other consumer goods.

Another area of lottery research focuses on the relationship between existing lottery games and the introduction of new products, or products in nearby states; this research focuses on the issue of cannibalization, the effect of new lottery products on existing lottery sales. Clotfelter and Cook (1989) examined displacement and cannibalisation issues and conclude that sales of existing games in the United States were not hurt by the introduction of lotto games during the 1980s. Stover (1990) analyzed sales of instant games, numbers games and lotto from 1984 and found that contiguous US state lotteries were substitutes. Garrett and Marsh (2002) investigated the effects of lotteries in contiguous states on lottery sales in Kansas in 1998, controlling for spatial dependence in the data. The presence of lotteries in nearby states significantly reduced lottery sales in Kansas. Tosun and Skidmore (2004) found that the adoption of new lottery games in contiguous states reduced lottery sales in West Virginia over the period 1987-2000.

Lottery expansion and cannibalization also took place in Europe. Before the introduction of lotto in Europe, the primary large jackpot gambling activity involved parlay-style betting on professional soccer (football) matches. Football pools – a pari-mutuel betting medium based on the results of professional soccer (football) games – can be considered as lottery-type games since they share a number of important characteristics with lottery games. This type of gambling is not a lottery in the sense that the winning combination is not the outcome of a random number draw. But football pools are pari-mutuel games, so the size of the jackpot depends on ticket sales, feature long-odds and high-prizes and jackpot rollovers. Football pools long occupied a prominent place in European gambling markets, offering the potential to win a single large jackpot when no other form of gambling did (Forrest, 1999). The fact that football pools and Lotto games appear to be substitutes also argues for treating football pools as a type of lottery game.

Since football pools incorporate rollovers, variation in expected return are induced, allowing estimation of a demand function for football pools from the correlation between variations in coupon sales and changes in the effective price. In fact, rollovers make the pools more like lotto. However, given the information players have about the *ex ante* probabilities of the final result of any match, the number of players getting all forecasts right is much higher than that would be expected if the final results were completely random. This implies, given the pari-mutuel structure of both games, that prizes are larger in lottery games than in football pools, so the expected effective price of a coupon is lower in the former game, implying a higher demand.

Although football pools held an effective monopoly on high-prize betting in both Spain and the United Kingdom, it became evident to European governments from American experience that it would be likely to generate much greater tax revenue by allowing a lottery to replace the pools because, even if the takeout rate in both products were almost the same, the lottery could be marketed year-round (rather than just for the soccer season) with simpler rules and lower costs (Forrest, 1999). For several years *La Quiniela*, the Spanish football pool, together with the *Loteria Nacional*, the state draw lottery, and the Spanish National Organization for the Blind (ONCE) lottery (a daily draw) were the only legal betting games available in Spain. Within a decade, lotto games had been introduced in a majority of American and Canadian states and provinces and national lottery games had appeared in countries as diverse as Australia and Brazil (Forrest, 1999). The impact of the introduction of a competing state lottery on the pools was severe. For instance, the large decline in Spanish football pools sales, close to 80%, between the year 1985 and 1990 can largely be explained by the appearance of a 6/49 lotto game on the Spanish gambling market. This also happened in the case of British football pools (Forrest, 1999).

5.2 Anomalies in the demand for lottery

The empirical literature in economics has also dealt with other topics in the demand for lottery including several empirical phenomena that are apparently inconsistent with expected utility theory. People facing choices under uncertainty often fall prey to statistical fallacies, described by Tversky and Kahneman (1974) as heuristics and biases. One strand in this literature focuses on "lotto fever," which occurs when an increase in ticket sales reduces the expected value of a lottery ticket despite a higher jackpot (Matheson and Grote, 2004; Matheson and Grote, 2005). They found that the "lotto fever" phenomenon is exceedingly rare, occurring in less than 0.1% of more than 17,000 US draws examined. Ticket sales increase due to jackpot size almost never reach the level of hysteria resulting in a reduction of expected value despite the larger jackpot. Another anomalous event is "lottomania," the effect on the demand for lottery induced by rollover over and above that generated by the effect of the rollover on the effective price, and "prize fatigue," when demand decreases though the announced jackpot does not change. Both were analyzed by Beenstock and Haitovsky (2001), who reported evidence of both in data from lotto 6/49 in Israel.

The importance of non random selection of numbers by players, called "conscious selection," also appears to be difficult to explain in the context of rational decision making. Certain numbers or combinations of numbers (memorable dates, birthdays, lucky numbers, etc.) have a higher probability of being selected in many lottery games. Many researchers have shown that gamblers prefer numbers they choose themselves because this choice allows them to feel more in control of the (random) outcome (Goodman and Irwin, 2006). The 'Conscious selection' phenomenon was analyzed by Cook and Clotfelter (1993), Walker (1998), Farrell et al. (2000), Farrell and Walker (1999) and Hauser-Rethaller and Köning (2002). All these studies report evidence of the importance of conscious selection in lottery.

Using data from the UK Lottery Walker (1998) found that non-random selection exists because different numbers have different levels of popularity. Ziemba et al. (1986) also analyzed popular and unpopular numbers and combinations in the Canadian Lotto. Although the problem of conscious selection seems not to be crucial in the case of lotto, as pointed out by Farrell et al. (2000) it is probably more important in the case of other pari-mutuel betting mediums such as football pools or horse track betting.

Lottery players may also believe that the history of a purely random event, such as numbers drawn in a lottery game, contains information about its future realization. In fact, some players believe that they can improve their chance of winning by adjusting their bets according to which numbers have won in recent drawings (Clotfelter and Cook, 1991). A number of papers, including Tversky and Kahneman (1974), Thaler (1992), Clotfelter and Cook (1991, 1993), Terrell (1994), and Papachristou (2004) address this 'gambler's fallacy,' the belief that the probability of an event decrease when the event has occurred recently, even though the probability of the event is known to be independent across trials. Tversky and Kahneman (1974) found that subjects are guided by a "negative dependence" existing between independent events. Clotfelter and Cook (1991, 1993) reported evidence supporting the existence of the 'gambler's fallacy' in an analysis of data from the Maryland lottery numbers game. They found a significant reduction in betting on the same numbers on the day after they win. Terrell (1994) reported evidence of the gamblers fallacy in the New Jersy lottery numbers game. Recently, Papachristou (2004) investigated the existence of the 'gambler's fallacy' among lotto players in the UK and concluded that history marginally affects the number of winning tickets, this could be interpreted as evidence of some lotto players believing in some form of statistical fallacy.

Lottery jackpots also appear to have persistent positive effects in some cases. Farrell et al. (2000) and Matheson and Grote (2005) found an unusually high level of lotto sales after a large jackpot has been won. This 'Halo Effect' is also discussed in Grote and Matheson (2007) who offer several explanations for this phenomenon besides the possibility of addiction driving these results. Guryan and Kearney (2008) found that lottery retailers in Texas experienced abnormally high sales for up to 40 weeks following the sale of a jackpot winning ticket; they call this the "lucky store" effect.

Again, both the effective price and the jackpot, the main economic models of demand for lottery, depend on sales of current drawings. And sales are not known ex-ante by players. Thus, the behaviour of players regarding the purchase of lotto tickets depends crucially on their expectations on sales. Some studies, including Forrest et al. (2000a), test whether players "act rationally" and show evidence that lotto players act rationally using the best information available. Farrell et al. (2000) investigated rational addiction among lotto players and suggest that there is considerable addiction in lottery, which is essentially induced by rollovers. Following Becker and Murphy (1988) they estimate a myopic addiction model by including a lag of consumption in the regression of current sales and find that the coefficient on lagged consumption is positive and significant (0.33). However, this argunment has a flaw. A lagged dependent variable is often significant models explaining observed variation in consumption of many goods and services. This persistence does not require the good to be addictive; the good could be frequently purchased by households, like most non-durables. So addiction must be carefully distinguished from persistence in spending.

The presence of a large number of anomalies in lottery data suggests that a number of lottery players do not purchase lottery tickets as a financial investment. They appear to have different goals in mind when purchasing lottery tickets. Furthermore, the presence of these anomalies appears to be consistent with the heuristics and biases identified by Tversky and Kahneman (1974) as departures from rational consumer choice.

6. Summary and concluding remarks

Understanding gambling, in this context lottery, has long been a challenge for economic theory. The purchase of lottery tickets appears inconsistent with risk aversion, income or wealth maximization, and rational decision making. However, playing lotteries has become an increasingly popular gambling activity around the world. Lottery sales have increased over time, along with the number and variety of lottery games. The inability of economic theory to adequately explain a type of consumer behavior continues to generate tension in this literature.

There is a large literature in economics investigating the characteristics and motivations of lottery players. Early empirical research used cross-sectional data from surveys of consumers, and other data sources, to analyze the determinants of household expenditure on lotteries and investigate the regressive character of the implicit tax included in the price of a lottery ticket. A later strand of research used aggregate data at the draw level to investigate the effects of expected returns, prize structure and other statistical phenomena. Studies using aggregated data consider price determinants as explanatory variables. This allowed them to estimate price and income elasticities for lottery. Most of the seminal papers in the US and Canada found the implicit lottery tax to be weakly regressive. Since government continues to view lottery as a convenient and important source of revenues, this regressivity continues to raise questions about lotteries as a source of public funds. However, many estimates of the price elasticity of lottery suggest that lottery generates significant consumer surplus, mitigating the regressive nature of the implicit lottery tax to some extent.

Trying to explain why people continue to play lottery has yielded several alternative empirical models in the economics literature. The effective price model, based on expected utility theory, the jackpot model, and the mean-variance-skewness model have all been used to analyze lottery demand. Under the assumptions of the effective price model, lottery tickets are considered to be risky financial assets and the prizes interpreted as the returns to an investment (the price of a bet). The effective price of a bet is then defined as the difference between the nominal ticket value and the expected return. However, as mentioned by Forrest et al. (2002), the main limitation of the effective price model is that, in the case of games with multiple prizes, a change in the structure of prizes might not generate a change in the effective price and therefore could not cause a change in demand. So jackpot model, rather than the effective price, proposes using the amount of the top prize as the main observable variable affecting sales. The jackpot model is based on an idea proposed by Clotfelter and Cook (1989) who considered that bettors are buying hope (or a dream) each time they buy a ticket and that hope increases with the amount of the jackpot.

Given that even large jackpot lotteries very rarely have a positive expected value, most theories of why people play lotteries rely either on a “fun” component of gambling which generates utility, or on players having a poor understanding of the true odds of the game. In addition, if consumers are misinformed, their demand for lottery might respond to the size of the top prize, but would not respond to the expected value. The mean-variance-skewness model includes the first three moments of the prize distribution in order to allow variations in the top prize to have a direct influence on sales rather than only an indirect one through effective price. Under this relatively new model, changes in the prize structure, though they may not cause changes in the effective price, nevertheless affect lottery sales.

Outside the US and Canada, work in this field continues to focus on applications of two economic models: the effective price model and the jackpot model. Demand for lotteries has been investigated in a large number of settings around the world and many variables to represent bettors’ changing behaviour over time and their response to exogenous events have been included in empirical models of lottery demand. The characteristics of lottery players around the world appears to be quite similar.

The relationship between consumers' spending on different types of gambling or between different lottery games has also been extensively addressed in the empirical literature. Most of the empirical evidence has been derived from aggregate data while a few papers use cross-sectional data from surveys of consumers. The general consensus here is that the introduction of new games attracts new customers, and potentially induces additional expenditure from existing lottery players. Considerable evidence of cannibalization of lottery revenues across state boarders also exists.

The discussion here provides evidence that much remains to be learned though about the demand for lottery. Each of the three competing empirical models can explain some aspects of lottery demand, but none of them has emerged as the best approach to empirically modelling lottery demand. Fortunately, lottery remains a popular type of gambling and the number and variety of lottery games available throughout the world continues to expand. These games also generate a significant volume of easily accessible data, so future empirical research will have no shortage of new and interesting settings for analysing lottery demand. In addition, governments around the world continue to view lottery as an important source of funds, despite the evidence that much of the money raised from the implicit lottery tax comes from the lower portion of the income distribution. This trend will provide additional motivation for research on the economics of lottery.

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TABLE 1. Demand for Lottery Papers

Paper	Game	Date	Area	Price elasticity [a]	Jackpot elasticity	Other findings
Clotfelter and Cook (1990)	Lotto	mid-1980s	Massachusetts (US)			For each $1,000 increase in the predicted jackpot due to "rollover", sales increase by $333
Cook and Clotfelter (1993)	Lotto	1984-86	Massachusetts		0.347 to 0.541	
Gulley and Scott (1993)	Lotto (6/42)	1990-91	Kentucky (US)	- 1.15		
	Lotto (6/46)	1987-90	Massachusetts (US)	- 1.92		
	Lotto (6/44)	1989-90	Ohio (US)	- 1.2		
Walker (1998)	National Lottery (6/49)	1994-96	United Kingdom	- 1.07		
Farrell and Walker (1999)	National Lottery (6/49)	1994-95	United Kingdom	- 1.785 to - 2.633		Income elasticity from 0.267 to 0.449
Farrell et al. (1999)	National Lottery (6/49)	1994-97	United Kingdom	- 1.05 to - 1.55		Addiction [b]
Forrest et al. (2000a and 2000b)	National Lottery (6/49)	1994-97	United Kingdom	- 0.66 (- 1.03)		
Forrest et al. (2002)	National Lottery (6/49)	1997-99	United Kingdom	(- 0.88) [c] (- 1.04) [d]		
Forrest et al. (2004)	National Lottery (6/49)	1997-00	United Kingdom	(- 0.90) [c] (- 3.2) [d]		

NOTES: [a] Values in brackets are long-run elasticities. [b] The coefficient on lagged consumption is positive and significant (0.33) suggesting that lottery play is addictive since consumption in the previous period has a positive and significant effect on consumption in this period. Myopic addiction or habit? [c] For the Saturday draw. [d] For the Wednesday draw

TABLE 2. International Evidence

Paper	Game	Date	Area	Price elasticity	Jackpot elasticity	Topic
Purfield and Waldron (1999)	Lotto and fixed-odds betting	1990´s	Ireland			Complementary relationship between lotto and fixed-odds betting on lotto
Beenstock and Haitovsky (2001)	Lotto 6/49	1985-96	Israel	- 0.65	0.4	“lottomania” and “prize fatigue”
Hauser-Rethaller and Köning (2002)	Lotto 6/45	1986-87	Austria	- 1.3 to – 1.7		Conscious selection
Lin and Lai (2006)	Lotto 6/49	2004	Taiwan	- 0.145		Complementary relationship between single draws of Big Lotto and Lotto
Roger and Broihanne (2007)	Lotto 6/49		France			“preferred numbers”
Geronikolau and Papachristou (2007)	Lotto 5/45+1/20	1999-03	Greece	- 2.1	0.33	Papachristou (2004) deals with “gambler’s fallacy”

TABLE 3. Effective Lottery Tax Incidence Papers

Paper	Game	Year	Area	Income elasticity	Incidence Index [a]
Spiro (1974)	Draw Lottery	1971	Pennsylvania (US)		- 0.20
Brinner and Clotfelter (1975)	Draw Lottery	1973	Connecticum (US)		- 0.41
	Draw Lottery	1973	Massachusetts (US)		- 0.46
	Draw Lottery	1973	Pennsylvania (US)		- 0.45
Suits (1977)	Several games[b]	1975	US Lottery States		- 0.31[d]
Clotfelter (1979)	Numbers	1978	Maryland (US)	0.062 to – 1.112	- 0.41[f]
Livernois (1987)	Draw Lottery and Lotto	1983	Edmonton, Alberta (Canada)	0.72	- 0.10
Clotfelter and Cook (1987)	Instant	1986	California (US)		- 0.32
	3-digit numbers	1984	Maryland (US)		- 0.42
	4-digit numbers	1984	Maryland (US)		- 0.48
	Lotto	1984	Maryland (US)		- 0.36
Borg and Mason (1988)	Lottery	1984-86	Illinois (US)	0.11 to 0.25	
Mikesell (1989)	Instant and on-line lottery	1985-87	Illinois (US)	0.94 to 1.49	
Kitchen and Powells (1991)	Lottery	1986	Atalantic Canada	0.80	- 0.21
	Lottery	1986	Quebec (Canada)	0.70	- 0.13
	Lottery	1986	Ontario (Canada)	0.78	- 0.19
	Lottery	1986	Manitoba/Saskatchewan (Canada)	0.73	- 0.19
	Lottery	1986	Alberta (Canada)	0.92	- 0.16
	Lottery	1986	British Columbia (Canada)	0.71	- 0.18
	Lottery	1986	Canada		- 0.18
Davis, Filer and Moak (1992)	Lottery	n.a.	US Lottery States	0.04	
Price and Novak (2000)	Lotto	1994	Texas (US)	0.24	- 0.058
	Instant lottery	1994	Texas (US)	- 0.21	- 0.129
	3-digit numbers	1994	Texas (US)	0.07	- 0.035
Worthington (2001)	Several games [f]	1993-94	New South Wales (Australia)	0.082 to 0.112 [g]	
Oster (2004)	Lotto	1999-2001	Connecticut (US)	0.00214 to 0.00261 [h]	
Garrett and Coughlin (2007)	Multiple games	1980s-2000s	West Virginia, Florida, Iowa	-0.9 to 0.6[i]	
Combs, Kim and Spry (2008)	Seven games	2004	Minnesota		-0.13 to -0.34
Ghent and Grant (2010)	Instant, lotto, fixed-odds	2003	South Carolina		-0.139 to -0.266

NOTES: [a] Suits (1977) index of regressivity. Values can range from -1 (extreme regressivity) to +1 (extreme progressivity). A value of 0 indicates a proportional tax. Calculation of this index is analogous to calculating the Gini coefficient. It is defined as $S=1-(L/K)$ where L is the area under a Lorenz type curve and K is the area under the diagonal. [b] Horse track, state lotteries, casino games, “illegal” numbers, sport cards, off-track betting parlors and sport books. [c] Commission for the Review of the National Policy Toward Gambling. [d] State lotteries. [e] Daily numbers. [f] Lottery, Lotto-type games and instant lotto, on-course betting, poker machines and ticket machines, blackjack, roulette and casino-type games, other gambling. [g] Lotto-type games and instant lotto (0.082), and lottery tickets (0.112). [h] Income elasticity of sales with respect to prize size. [i]: Varied over the sample period.

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