

Lotto Fever! Do Lottery Players Act Rationally Around Large Jackpots?

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RRH: MATHESON AND GROTE: LOTTO FEVER

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ABSTRACT

Lotteries typically experience increased sales as advertised jackpots increase. This phenomenon can either be explained by irrationality on the part of bettors who get caught up in the excitement of a large jackpot or by rationality on the part of bettors increasing their purchases due a higher expected return. Our analysis of over 16,000 lotto drawings from numerous state and multi-state lotteries in the United States suggests that in nearly all cases, increases in ticket sales are matched by increases in expected returns. “Lotto Fever” is therefore an act of rationality rather than an act of madness.

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## I. INTRODUCTION

“Lotto” is among the most popular games offered by state lottery associations accounting for 28% of total revenues for state-run U.S. lotteries in 1997. (Census Bureau, 1999) As of January, 2002, 38 states had state-run lotteries, and every state with a lottery offered some version of a lotto game either through their own game or through a multi-state association such as the twenty-three state Multi-State Lottery Association (Powerball) or the nine state Big Game association.

Lotto games generally consist of an individual picking a set of five or six numbers from a group of approximately 35-55 choices. Winning numbers are then randomly selected at a weekly or bi-weekly drawing. A player whose ticket matches all of the winning numbers wins the jackpot prize while players matching some but not all of the winning numbers win smaller consolation prizes. In part, Lotto derives its popularity from the large jackpot prizes that can be won in this game. While lottery games such as instant tickets, numbers, or keno might offer top prizes ranging from \$100 to \$100,000, Lotto games typically advertise jackpot prizes starting at \$1 million or higher.

The jackpot prize is funded by allocating a percentage of ticket sales to the jackpot prize pool. This percentage varies from state to state but is typically 25-35% of gross ticket sales. A player who matches all numbers exactly wins the amount in the jackpot fund. If more than one ticket matches all the numbers, the money in the fund is divided evenly among the number of winning tickets. If no ticket matches the winning numbers, the money in the fund is carried over into the next drawing and is added on to the allocated funds from ticket sales in the next period. Because the jackpot prize fund is allowed to roll-over in this manner, the jackpot prize can become

quite large if no one hits the jackpot in a large number of successive periods. Indeed, advertised jackpots exceeding \$50 million are quite common in numerous state lotteries, and occasionally lotto jackpots have been known to exceed \$250 million. See Table 1 for a list of the largest U.S. lotto jackpots to date.

Since the price of a lotto ticket and the odds of winning remain fixed regardless of the size of the jackpot, it is natural to assume that the expected return of purchasing a lotto ticket will increase along with the size of the jackpot. The complicating factor, however, is that as the advertised jackpot grows, the number of ticket buyers typically increases as well. It is a well established fact that higher advertised jackpots lead to higher ticket sales. The news media is full of stories of long lines at lottery outlets and frenzied ticket buying when jackpots reach high levels. Numerous academic articles also note the connection between jackpot size and ticket sales including DeBoer (1990), Shapira and Venezia (1992), Gulley and Scott (1993), Scott and Gulley (1995), Matheson (2001), and Forrest, *et al*, (2002). The increased number of ticket buyers increases the probability that the winning numbers will be shared by two or more tickets. Thus, the increase in expected return due to the increase in the size of the jackpot is tempered by the prospect of potentially having to share this larger jackpot among several winners.

The notion of rationality first requires one to define the goal of a lottery player. Some may question whether one can ever consider rational any gambling activity with a negative expected return. While this is a valid concern, gambling clearly offers non-pecuniary benefits to players in the form of thrills or excitement. In the words of one Big Game ticket buyer during the record \$363 million, May 2000 drawing, “One dollar is a small price to pay to be able to dream about winning \$300 million.” Following Scott and Gulley (1995), if one assumes that lottery players are

expected utility maximizers, the utility function for the player can be written as

$$(1) \quad U_t = f(ER_t, PL_t)$$

where  $ER_t$  is the expected monetary return for drawing  $t$ , and  $PL_t$  is the anticipated pleasure or non-monetary return from betting. It is assumed that  $U_t$  is strictly increasing in both  $ER_t$  and  $PL_t$  and that  $PL_t$  is strictly increasing with the size of the jackpot. In other words, the utility of the bettor increases as the expected return increases, and the non-pecuniary pleasure increases along with the jackpot. Forrest, *et al*, (2002) take this analysis even further by suggesting a strong connection between ticket sales and the maximum possible prize that can be won. In their own words, "Perhaps bettors do not really expect to win at all but enjoy the dream (unavailable to non-purchasers) of spending whatever is the largest amount that *could* be won from holding the ticket." Their results from the UK National Lottery indeed demonstrate that the maximum possible prize is a much better predictor of ticket sales than the expected return from the purchase of a ticket.

Undoubtedly, the psychological component of lotto gambling is crucial to the understanding of ticket buyers' behavior. Unfortunately, it is difficult to read players' minds, and therefore this analysis will follow Scott and Gulley (1995) in that it will "not attempt to formally incorporate such non-monetary returns in our empirical analysis. Snyder (1978) points out the difficulty in disentangling, at least statistically, the pecuniary and non-pecuniary aspects of the bet." Therefore, the formal analysis will include only the monetary benefits of gambling. This does not mean that the non-monetary benefits will be ignored, merely that observable monetary benefits will be useful in informing the reader about lotto player behavior. Where applicable, non-monetary benefits will be used to augment the presented arguments.

For lottery players' actions to be considered rational, we propose that two conditions must

be satisfied. First, as the expected return from the purchase of a lottery ticket increases, ticket sales must also increase. It should be noted that it does not matter for the purposes of this paper whether the higher ticket sales are a result of increased purchases among a fixed set of buyers or whether the increase is due to higher jackpots attracting previously uninterested buyers. A higher expected return lowers the net expected price of a lottery ticket, and as price falls, demand for tickets should increase. If ticket sales do not strictly increase with the expected return of a ticket, then lottery players' actions in the aggregate are not rational. We term this phenomenon "lotto apathy."

The second condition required for player rationality is that as lottery ticket sales increase, the increase in ticket sales must be justified by an increase in expected return. If ticket buying reaches such a frenzied pace such that the expected return falls despite an increase in the advertised jackpot, then it is reasonable to conclude that lotto players are acting irrationally. Lottery players' actions in the aggregate are irrational if the expected return falls as ticket sales increase. We term this second condition "lotto fever."

The rest of this paper is divided into three sections. In the first section we examine observed ticket sales from 33 state and multi-state lotteries around the country, encompassing nearly every lotto game offered in the United States, to determine whether our first condition for lottery player rationality holds. In other words, are observed ticket sales strictly increasing with expected return? In the next section we examine ticket sales from the same set of lotteries to see whether our second condition for lottery player rationality holds: does observed expected return always increase as ticket sales increase? The paper closes with conclusions and recommendations for state lottery associations.

## II. TESTING THE FIRST RATIONALITY CONDITION

Lottery buyers' behavior is most easily examined if one realizes that sales of lotto tickets occur in cycles. The cycle begins in a sales period just after the jackpot has been won. At this point the jackpot fund contains only contributions from ticket sales in the current period. The advertised jackpot is based on an estimate of ticket sales in the current period.<sup>1</sup> If the jackpot is not won in a particular sales period, the money in the jackpot fund rolls over into the next period and is added to the money allocated to the jackpot fund from ticket sales in the next period. Because the jackpot prize fund rolls over in this manner, the advertised jackpot always increases from drawing to drawing until there is a jackpot winner. The cycle is completed once the jackpot is won by a player (or players) matching all of a particular drawing's numbers.

The average length of a cycle varies widely from state to state and depends upon factors such as average ticket sales, responsiveness of ticket sales to the advertised jackpot, and the odds of a particular player hitting the jackpot. For example, from the beginning of the Florida Lotto in May 1988 until it changed to a twice-weekly drawing in October 1999, the average length of the jackpot cycle for the Florida Lotto was only 1.7 drawings with less than half of all cycles rolling over even once. On the other hand, the multi-state Powerball Lottery averaged a jackpot cycle just over 10.0 drawings between the debut of its new format in November 1997 and May 2002.

Examining ticket sales within cycles is useful because it allows us to ignore the impact on ticket sales of other variables such as demographic change, population growth, the business cycle, and the availability of alternative forms of gambling. While these factors clearly influence ticket sales, their rate of change is small enough to cause little impact on ticket sales within a particular cycle. Therefore, while in the long-run, ticket sales for a lotto drawing with a specific expected

return may rise or fall depending on the aforementioned variables, within a single drawing cycle, ticket sales are likely to be influenced largely by the expected return.

Over the short-run, if lottery players are rational, total ticket sales should increase as the expected return of the drawing rises. If the assumption is made that the number of ticket buyers is constant, as the jackpot increases in size, the expected return from the purchase of a lottery ticket also increases. With the number of ticket buyers held constant, the increase in the jackpot merely serves to increase the potential winnings of the ticket buyer. Since the jackpot is strictly increasing with each draw in the cycle, ticket sales should also be strictly increasing within each cycle. Of course, rationality will not be satisfied if the response to a higher jackpot is so great that the expected value falls, but the first rationality condition only asks if the ticket sales increase. The second rationality condition will ask whether or not the ticket sales increase too much.

Examining ticket sales within cycles also means that the first rationality condition is valid even if one includes non-monetary benefits in a player's utility function. Since the jackpot is strictly increasing within every draw of the cycle, the non-pecuniary benefits must also be strictly increasing within every draw of the cycle due to the assumption that the pleasure or thrills of gambling increase with the size of the potential jackpot. Since both monetary and non-monetary returns increase with the size of the jackpot, ticket sales must also be strictly increasing with the size of the jackpot within any given cycle. In other words, if lottery consumers' decisions are not consistent with the first rationality condition with respect to expected value then these consumers' decisions will certainly not be consistent with respect to a utility function that also includes non-monetary factors such as the size of the jackpot not adjusted for the number of expected winners.

One particular factor complicates the simple first rationality rule. The majority of lotto

games hold drawings twice a week. Because the sales period of these drawings is of an uneven length (three days versus four days) and because players' ticket buying habits are affected by the day of the week (with ticket sales typically being higher on weekends), ticket sales may not rise uniformly throughout a drawing cycle and may instead follow a stepwise increase in sales. Gulley and Scott (1993), Scott and Gulley (1995), and Forrest, *et al*, (2002) all note the complexities introduced by the bi-weekly drawings. For games with a biweekly drawing, every other draw within a cycle should exhibit strictly increasing ticket sales so that sales should strictly increase between one draw and the draw in the following week corresponding to the same portion of the week. In the handful of lotteries that have tri-weekly drawings, ticket sales should be strictly increasing between every third drawing in a cycle.

To test lottery player rationality, we examined whether observed ticket sales in 33 state and multi-state lotteries were indeed strictly increasing with each drawing within a cycle or with every second or third drawing for bi- and tri-weekly drawings. Table 2 shows each lottery examined. The dates over which the tickets sales numbers were examined were based solely on availability of data in each individual lottery association. Several lotteries switched from a weekly to a bi-weekly drawing over the course of the available data, and these lotteries are treated as separate lotteries for the purpose of this study. Table 2 also presents the total number of drawings covered by the period examined for each lottery. Of course a weekly cycle must be of a length of at least two drawings and a bi-weekly cycle of at least three weeks before a test of rationality can be performed. The second column of numbers shows the total number of tests for rationality performed. The third column of numbers shows the number of cycles for each lottery examined. The final column shows the largest advertised jackpot for each specific lotto over the time frame examined.

Tables 3 and 4 show the total number of tests for rationality performed number as well as the number of times rationality was rejected with Table 4 including states that are members of the two large multi-state games, Powerball and the Big Game, and Table 3 including the remaining states as well the actual Powerball and Big Game lottos themselves. The reason for this division will be discussed later in this section.

The results show that ticket sales largely reflect rational decision-making on the part of consumers. Only 74 of the 4,473 drawings (1.7%) examined in Table 3 showed violations. Of these 74 drawings where rationality was rejected, 23 occurred during a holiday period, usually the Christmas holiday but also including drawings over Thanksgiving, Labor Day, the Fourth of July, and Memorial Day. It is completely reasonable to conclude that even rational consumers will alter their ticket buying habits during these periods. Another 6 rejections of rationality can be explained by other reasons such as weather events (blizzards or hurricanes) or some sort of significant change in the structure of the lotto game. The results in Table 4 are not as robust in demonstrating the rationality of lotto players. 1,251 of the 7,076 drawings (17.7%) showed violations. As before, many of these can be explained by holidays (310 drawings) or other reasons (18 drawings).

While we can conclude that ticket sales largely reflect rationality on the part of ticket buyers, we do identify two trends that reflect true irrationality on the part of ticket buyers. First, lottery ticket sales tend to be high in the sales period immediately following a large jackpot being won. The publicity following the award of a large jackpot prize apparently influences consumers to make lottery ticket purchases despite the fact that the jackpot prize, and hence the expected value of the ticket, falls back to lower levels following the payoff of a large jackpot. By a full week following a large jackpot award, the excitement over the previous jackpot has subsided, and

lottery ticket sales may therefore fall. We observed that 33 of the 74 violations in Table 3 and 131 of the 1,251 violations in Table 4 occurred either in the third or fourth drawing of a bi-weekly cycle or the second drawing of a weekly cycle. In other words, following a large jackpot, the drawings in the first following week of rollovers tend to be lower than in the week directly following the large jackpot.

The second widespread violation of player rationality comes in the form of strong substitution and complementary effects between lotto games in states that host both a state lottery and one of the two large multi-state games. For example, nearly every lotto game in states that were also members of the Powerball game experienced declines in their own state lotto game sales in the week following the record \$295 million Powerball jackpot in August, 1998. Similarly, over one-quarter of the violations in the Wisconsin game that are not explained by other reasons occurred in the week after a large drawing was won in the Powerball game. This pattern is repeated in other games offering both a state lottery and a multi-state game. Apparently lotto games are complementary goods: as sales of Powerball tickets increase, sales of state lotto tickets in states selling Powerball tickets also increase. While this may at first seem irrational, the phenomenon can be explained from the viewpoint of opportunity costs. While lottery players are already purchasing tickets for the huge Powerball jackpot, it is very convenient to also purchase tickets for the other lotto game. The explanation could also be that players mistakenly purchase tickets for the wrong game. A final explanation for the frequency of violations in states offering both types of lotto games is that in states where players must keep track of two separate jackpot amounts for two different games it is reasonable to believe that increases in the jackpot of the smaller game may go unnoticed or may receive scant advertising. Therefore, one should expect

that lottery players will have a more muted reaction to increases in state lotto jackpots in states where Powerball or the Big Game tickets are also offered. The data supports this line of reasoning as the frequency of unexplained violations in states where two or more lotto games are played is 11.0% with 20 of the 24 games examined showing at least one violation while those states offering only a single game have a frequency of unexplained violations of only 0.25% with only 3 of the 16 games displaying any unexplained violations. The full extent of lotto game substitutability is beyond the scope of this paper, but is certainly a topic that suggests further research.

Overall, 93% of the drawings displayed rationality on the part of ticket buyers, a very high percentage for any test in empirical microeconomics. Of the unexplained violations of rationality, many occurred in lottery games where total ticket sales were low and where advertised jackpots, therefore, grew at slow rates. For example, in a game such as the Tri-State (Maine, Vermont and New Hampshire) “Win Cash” lottery, average ticket sales are so low that the advertised jackpot typically rises by less than \$50,000 per drawing which represents a median drawing by drawing increase in the size of the jackpot of less than 8%. Ticket buyers are simply not responsive enough to expected return for these tiny increases in the jackpot to be reflected in consistent drawing by drawing increases in ticket sales. Simple random fluctuations in ticket sales are frequently enough to overwhelm the effects of the regular increases in the jackpots.

The final columns of Tables 3 and 4 show the average increase in jackpot and the average decrease in ticket sales for all drawings which showed an unexplained violation of rationality. On average for all drawings where a violation occurred, ticket sales fell 3.5% while the advertised jackpot rose 17.1%. The effective price of a lottery ticket is equal to the price of the ticket less the expected value of the winnings of the ticket. While expected winnings are largely correlated with

the size of the jackpot, it is not possible within the scope of this paper to precisely determine the expected value of a lottery ticket, and therefore it is not possible to determine the effective own-price elasticity of demand for lottery tickets that this data suggests. It is clear, however, that the changes in the expected price are likely to be small and the change in quantity demanded are very small leading to an elasticity, though of the wrong sign, very close to zero.

### III. TESTING THE SECOND RATIONALITY CONDITION

While half of the rationality equation is satisfied any time that lottery ticket sales are strictly increasing with each draw within a cycle, the other half of consumer rationality requires that the expected return from the purchase of a lottery ticket increase as ticket sales increase. Testing whether this part of consumer rationality holds in actual lottery ticket markets requires an estimate of the expected return from the purchase of a lottery ticket. Several researchers have presented estimates of this expected return starting with Clotfelter and Cook (1989) and including DeBoer (1990), Shapira and Venezia (1992), Gulley and Scott (1993) and Matheson (2001).

Matheson (2001) presents the most detailed equation for the expected return,  $ER_t$ , from the purchase of a single lottery ticket. The equation is directly derived from the definition of expected value which states that the expected return from a lottery ticket is simply the probability of winning a particular prize times the value of the prize won summed over all potential prize levels.

$$(2) \quad ER_t = \sum_{i=0}^m w_i V_{it} + \sum_{j=0}^{B_t} w_j DV_{jt} - p_m / (m - 1)$$

where  $w_i$  is the probability of winning lower-tier prize  $i$ ,  $V_{it}$  is the cash value of lower-tier prize  $i$  at

time  $t$ ,  $w_j$  is the probability of winning the jackpot prize,  $DV_{jt}$  is the discounted present value of the advertised jackpot prize at time  $t$ ,  $m$  is the number of tickets bought by competing players matching the jackpot prize,  $p_m$  is the probability that exactly  $m$  other tickets match the jackpot prize,  $B_t$  is the number of other ticket buyers for the drawing in period  $t$ .

While the probabilities that exactly  $m$  other tickets match the jackpot prize can be calculated exactly using the binomial distribution, the second term in equation (2) can be very closely approximated using the Poisson distribution as shown in equation (3).

$$(3) \quad ER_t = \sum_i w_i V_{it} + DV_{jt} (1 - e^{-B_t w_j}) / B_t$$

The term  $(1 - e^{-B_t w_j}) / B_t$  can be interpreted as a divisor on the jackpot that corrects for the probability of winning the jackpot as well as the probability of having to share the jackpot with other potential winners.

The final consideration necessary for the proper calculation of the expected return of the purchase of a lottery ticket is the issue of taxation. Lottery winnings are fully taxable as income at least at the federal level. Furthermore, the purchase price of any lottery tickets are tax deductible to the extent of any lottery winnings. For the purchase of a single ticket, this essentially means that all winnings are taxable but that the price of the ticket is fully tax deductible if one wins a prize. As noted by Matheson (2001), the inclusion of taxes changes equation (3) to

$$(4) \quad ER_t = \sum_i w_i V_{it} + DV_{jt} (1 - e^{-B_t w_j}) / B_t (1 - \tau) + \sum_i w_i w_j$$

where  $\tau$  is the tax rate and  $p$  is the price of a ticket.<sup>2</sup>

The results of the previous section demonstrated that lottery ticket sales are nearly always strictly increasing from drawing to drawing within a jackpot cycle. Therefore, rationality requires the expected return from the purchase of a lottery ticket to also be strictly increasing from drawing to drawing in order to explain the increasing ticket sales. Rationality thus requires  $ER_t > ER_{(t-1)}$  for all drawings within a jackpot cycle. Setting  $ER_t > ER_{(t-1)}$  and canceling out like terms leaves equation (5).

$$(5) \quad DV_{jt} (1 - e^{-B_t w_j}) / B_t > DV_{j(t-1)} (1 - e^{-B_{t-1} w_j}) / B_{t-1}$$

This arrangement is convenient because it eliminates problematic issues such as the appropriate tax rates to use as well as avoiding the problem of determining the size of the lower-tier prizes when these prizes are determined in a para-mutuel fashion. Equation (5) can be further rearranged to leave equation (6).

$$(6) \quad DV_{jt} / DV_{j(t-1)} > B_t (1 - e^{-B_{t-1} w_j}) / B_{t-1} (1 - e^{-B_t w_j})$$

Equation (6) has a straight-forward and intuitive interpretation. As long as the discounted value of the jackpot is growing at a faster rate than the jackpot divisor, the expected return from the purchase of a lottery ticket will continue to increase from drawing to drawing. If the jackpot divisor is growing faster than the jackpot, then lotto fever, i.e. irrational behavior on the part of lottery ticket buyers in the aggregate, is taking place.

In all of this analysis the assumption must be made that bettors are well-informed about the information required to implicitly calculate the values in equations (2) through (6). Lottery associations prominently publish estimates of the jackpot during each drawing as well as the odds of winning the jackpot and lower-tier prizes, so assuming perfect information on the part of bettors for these variables seems reasonable. What remains is that one must assume that bettors are able to reasonably predict the number of other ticket buyers in any particular drawing despite the lack of explicit information regarding the number of tickets being purchased for a particular drawing. Krautmann and Ciecka (1990) argue that the number of ticket buyers can be closely inferred simply by examining the increase in the size of the advertised jackpot from period to period. Scott and Gulley (1995) demonstrate that bettors in three state lotteries examined are able to make accurate predictions of the expected value of a lottery ticket without making systematic forecasting errors. Based on these past studies, the assumption of (nearly) perfect information on the part of bettors may be a reasonable one.

We searched the 33 state and multi-state lotteries for instances of lotto fever. One slight change to equation (6) was made to facilitate the examination of the lotteries. In general, the data we obtained from lottery associations listed ticket sales and the advertised jackpot for each drawing period. Except for a handful of small cash lottos (such as the Delaware All-Cash Lotto, Kansas Cash!, Minnesota Gopher 5, and the multi-state Wild Card Lotto), traditionally state lotteries require winners to take jackpot winnings in annuity payments over an extended time period, usually between 20 and 30 years. The jackpot prize fund is invested in interest bearing accounts from which the winner receives annuity payments over a specified number of years. Lottery associations advertise the jackpot prize to be the undiscounted nominal sum of these annuity

payments. While it is possible to convert an advertised jackpot  $AV_{jt}$ , paid in equal amounts of  $(AV_{jt}/n)$  over  $n$  years given a discount rate of  $r$  into a discounted present value,  $DV_{jt}$ , using prevailing interest rates, since interest rates are likely to change little between two consecutive drawings, the ratio of advertised jackpots,  $AV_{jt}/AV_{j(t-1)}$  will be nearly identical to the ratio of discounted jackpots,  $DV_{jt}/DV_{j(t-1)}$ , used in equation (6). Furthermore, Matheson and Grote (2003) find that lottery players can generally accurately translate annuitized jackpots into present values so that one might not worry about whether advertised or discounted jackpots are used.. Therefore, the ratio of advertised jackpots was generally used in lieu of the ratio of discounted jackpots in testing rationality.

In total, a mere eleven instances of lottery fever were found among the over 17,000 drawings tested. The drawings and the associated jackpots are shown in Table 5. In addition, Table 5 shows the expected value of the purchase of a single \$1.00 lottery ticket for the jackpot drawing as well as for the drawing immediately proceeding it. These values are calculated using equation (4) and assuming a marginal tax rate of 30% for all drawings.

Several interesting observations can be drawn from the handful of drawings that exhibit “lotto fever.” First, each instance is for a drawing with a large jackpot, and the list includes several of the largest jackpots on record from Table 1. Next, the examples tend to be from further in the past. Eight of the eleven instances are from the late 80s and early 90s with only three having recently occurred despite the increased availability of data in recent time periods. This suggests that lottery players have become less likely to engage in irrational, frenzied buying as time has gone on. A declining popularity of lotto games could also contribute to this phenomenon. Data was not available for the recent large jackpots in California and Big Game jackpots, so it will be interesting

to see whether “lotto fever” took hold in either of the games during their recent record jackpots. The case of the Virginia drawing in 1992 is also interesting to note. In this lotto game, an Australian consortium attempted to buy the “trump ticket,” in other words buy every combination in order to guarantee themselves at least a share of the jackpot. While their large scale ticket purchase drove the ticket sales during the drawing high enough to make expected return on a lottery ticket fall, their attempt to purchase the jackpot was actually a rational decision according to Matheson (2001).

Unlike the case of the first rationality condition where the inclusion on non-monetary benefits to gambling only augments any findings of irrationality, the inclusion of non-pecuniary benefits to gambling in the test of the second rationality condition serves to potentially explain away even the rare cases of “lotto fever.” The fall in the expected monetary return of the game may be counterbalanced by an even larger increase in the non-monetary value of the drawing. For example, while the monetary return of the \$102 million April 8, 1998 drawing of the California Super Lotto fell slightly from \$0.5307 per dollar played to \$0.5221 per dollar played in the previous drawing, it is easily conceivable that the excitement of a \$102 million drawing versus a “mere” \$44 million drawing generates well in excess of \$0.0086 in non-monetary benefits per ticket. Therefore, even “lotto fever” may not necessarily indicate irrationality.

## CONCLUSIONS

The results presented in this paper provide several significant conclusions. First, many state lotteries experience regular declines in ticket sales despite an increase in the expected return of their game. In these states, it is clear that either the game is poorly promoted or that the current

jackpot is badly advertised. These states may benefit from a redesign of their game or change in the method that the current jackpot is publicized.

Second, lottery players are fairly sophisticated in their ticket buying decisions. They react to higher expected returns by purchasing more tickets, but their ticket buying almost never reaches the extent that the expected value of a lottery ticket falls. In fact, the general notion that lottery players engage in irrational, frenzied ticket buying in the face of large jackpots is, in fact, incorrect. In almost all cases, lottery players buy more tickets in the face of large jackpots in response to a higher expected return rather than an irrational decision to buy in the face of wild dreams. It is much more common (by a factor of roughly 80 times) for lottery players to reduce their ticket purchases despite an increased expected return than it is for them to increase their ticket purchases in spite of a decreased expected return. In other words, if lottery players are to be considered irrational, it is because they purchase too few tickets rather than too many tickets.

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U.S. Census Bureau, 1999, Statistical Abstract of the United States, Table 529.  
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## FOOTNOTES

\*This is a revision of a paper presented at the Western Economic Association International 77<sup>th</sup> annual conference, Seattle, July 1, 2002, in a session organized and chaired by Daniel Swaine. The authors are grateful for the comments made by Daniel Swaine and anonymous referees. The authors would also like to thank the numerous state lottery associations who have graciously provided us with extensive information regarding their lotto games.

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1. Alternatively, during the first few drawings of a new cycle many lottery associations guarantee an initial jackpot amount and a minimum drawing by drawing increase in the jackpot. For example, since 1997 the multi-state Powerball Lotto has guaranteed a minimum jackpot of ten million dollars, with minimum increases of five million dollars per drawing. If ticket sales are not sufficient to meet these requirements, the jackpot is funded out of lottery reserves. Therefore early in the draw cycle, the increase in the jackpot may be based on defined lottery rules and not upon actual ticket sales.

2. It must be noted that Equation (4) represents the expected value of a lottery ticket only when all ticket buyers select their numbers in a random fashion. In fact, most lotto games allow ticket buyers the option to select their own numbers, and a non-negligible number of players of

these games do, in fact, opt to choose their own numbers. There is no reason to believe that individuals selecting their own numbers will result in a random distribution of numbers. Indeed, as shown by Thaler and Ziemba (1988) and MacLean, *et al*, (1992), in practice lottery players can increase their expected returns by choosing relatively unpopular numbers thereby reducing the expected number of other ticket buyers with whom they would have to split any winnings. Similarly, choosing popular numbers serves to reduce the expected value of a lottery ticket. For example, the Florida lottery reported that in their popular Lotto game, roughly 10,000 people chose the number combination of 7-14-21-28-35-42 in each drawing. In the unlikely event (1 in 13,983,816) that this combination would be drawn, the “lucky” winners would each take home only about \$1,000 during a typical jackpot. While the non-random nature of the chosen number distribution is problematic for determining an exact expected value, this issue will not be further explored in this paper. Since the rationality test will examine the ratio of expected values in sequential drawings, this should cause few problems in determining rationality as long as any premium that a “smart” player can achieve is the same in successive periods.

**TABLE 1**

Twenty Largest U.S. Lotto Jackpots through January 1, 2003

<b>Jackpot</b>	<b>Lottery</b>	<b>Drawing Date</b>
\$363 million	Big Game	5/19/00
\$325 million	Big Game	4/16/02
\$315 million	Powerball	12/25/02
\$296 million	Powerball	7/29/98
\$295 million	Powerball	8/25/01
\$197 million	Big Game	4/06/99
\$195 million	Powerball	5/20/98
\$193 million	California Super Lotto Plus	2/16/02
\$160 million	Powerball	6/30/99
\$150 million	Powerball	3/04/00
\$141 million	California Super Lotto Plus	6/23/01
\$131 million	Powerball	11/29/00
\$119 million	California Super Lotto	4/17/91
\$116 million	Pennsylvania Super 7	4/26/89
\$111 million	Powerball	7/07/93
\$107 million	Florida Lotto	9/15/90
\$107 million	Big Game	1/30/01
\$104 million	Powerball	9/14/02
\$102 million	Powerball	3/04/95
<u>\$102 million</u>	<u>California Super Lotto</u>	<u>4/08/98</u>

**TABLE 2**

## Lotteries Examined

<b><u>Lottery</u></b>	<b><u>Drawings</u></b>	<b><u>Dates</u></b>	<b><u># of Drawings</u></b>		<b><u>Cycles</u></b>	<b><u>Max. Jackpot</u></b>
Multi-“The Big Game” #1	Weekly	9/06/96 - 2/06/98	75	57	18	\$ 77,000,000
Multi-“The Big Game” #2	Bi-weekly	2/10/98 - 5/04/99	139	82	14	\$190,000,000
Multi-“Powerball”	Bi-weekly	4/22/92 - 7/06/02	1,067	811	135	\$295,700,000
Multi-“Tri-State Megabucks”	Bi-weekly	3/12/97 - 5/29/99	201	153	28	\$ 8,235,000
Multi-“Tri-State Win Cash”	Bi-weekly	9/12/97 - 5/28/99	179	161	8	\$ 2,333,000
Multi-“Tri-West/Wild Card Lotto”	Bi-weekly	2/04/95 - 7/28/01	670	597	33	\$ 2,060,000
Arizona “Lotto”	Bi-weekly	11/28/98 - 5/22/99	51	38	2	\$ 10,100,000
CA “Super Lotto” #1	Weekly	10/18/86 - 9/26/87	50	27	23	\$ 17,300,000
CA “Super Lotto” #2	Bi-weekly	9/30/87 - 3/03/99	1,193	381	496	\$118,800,000
Colorado “Lotto”	Bi-weekly	7/07/90 - 7/28/01	1,150	730	237	\$ 27,000,000
CT “Lotto” #1	Weekly	11/18/83 - 4/04/86	125	65	60	\$ 17,200,000
CT “Classic Lotto” #2	Bi-weekly	4/08/86 - 11/15/94	899	407	289	\$ 31,600,000
CT “Classic/Wild-Card Lotto” #3	Bi-weekly	11/18/94 - 8/07/01	702	580	56	\$ 26,000,000
Delaware “All-Cash Lotto”	Tri-weekly	10/27/98 - 5/18/99	88	73	4	\$ 1,125,000
Florida “Lotto” #1	Weekly	5/07/88 - 10/23/99	599	240	359	\$106,500,000
Florida “Lotto” #2	Bi-Weekly	10/27/99 - 7/28/01	179	94	45	\$ 81,600,000
Georgia “Lotto”	Weekly	9/14/96 - 8/04/01	211	179	32	\$ 26,000,000
Illinois “Lotto”	Bi-weekly	7/03/96 - 8/01/01	530	373	85	\$ 36,000,000
Indiana “Hoosier Lotto” #1	Weekly	9/03/94 - 2/14/98	181	156	25	\$ 32,000,000
Indiana “Hoosier Lotto” #2	Bi-weekly	2/18/98 - 8/01/01	361	313	24	\$ 42,000,000
Kansas “Cash”	Tri-weekly	8/18/96 - 5/12/99	428	272	60	\$ 2,000,000
Kentucky “Lotto”	Bi-weekly	3/01/95 - 7/28/01	670	592	39	\$ 20,000,000
Louisiana “Lotto”	Bi-weekly	4/19/98 - 5/22/99	114	92	11	\$ 2,050,000
Maryland “Megabucks”	Bi-weekly	1/03/98 - 7/14/99	160	142	9	\$ 18,500,000
MA “Mass Millions”	Bi-weekly	11/06/97 - 8/13/01	394	374	11	\$ 30,600,000
MA “Megabucks”	Bi-weekly	11/05/97 - 8/11/01	394	314	43	\$ 14,300,000
Michigan “Lotto”	Bi-weekly	8/28/96 - 5/08/99	215	174	23	\$ 34,000,000
Minnesota “Gopher 5”	Bi-weekly	2/03/98 - 7/24/01	363	236	67	\$ 1,400,000
Missouri “Lotto”	Bi-weekly	1/03/96 - 6/30/99	459	392	33	\$ 11,600,000
New Jersey “Pick 6 Lotto”	Bi-weekly	7/03/95 - 4/05/99	393	192	114	\$ 35,000,000
New York “Lotto”	Bi-weekly	1/03/98 - 7/03/99	375	174	112	\$ 45,000,000
Ohio “Super Lotto”	Bi-weekly	1/12/91 - 5/22/99	1,100	535	306	\$ 45,000,000
Oregon “Megabucks”	Bi-weekly	4/19/95 - 4/28/99	421	346	36	\$ 18,000,000
Pennsylvania “Super 6”	Bi-weekly	9/12/98 - 8/01/01	303	242	20	\$ 73,000,000
South Dakota “Dakota Cash”	Bi-weekly	7/03/96 - 8/11/01	530	389	23	\$ 339,872
“Lotto Texas”	Bi-weekly	11/14/92 - 2/13/99	668	260	243	\$ 75,000,000
Virginia “Lotto” #1	Weekly	1/27/90 - 10/27/90	40	27	13	\$ 22,000,000
Virginia “Lotto” #2	Bi-weekly	10/31/90 - 5/05/99	889	534	193	\$ 28,000,000
Washington “Lotto”	Bi-weekly	1/01/97 - 5/26/99	251	176	39	\$ 24,000,000
<u>Wisconsin “Megabucks”</u>	<u>Bi-weekly</u>	<u>6/20/92 - 5/15/99</u>	<u>721</u>	<u>569</u>	<u>34</u>	<u>\$ 16,500,000</u>
Total			17,538	11,549	3,402	

Except as noted, maximum jackpot listed is the advertised annuity jackpot, not the net present value of jackpot.

**TABLE 3**

## Rationality Violations for Independent Lotto Games

<b><u>Lottery</u></b>	<b><u>Drawings</u></b>	<b><u>Violations</u></b>	<b><u>Holidays</u></b>	<b><u>Roll-over</u></b>	<b><u>Other</u></b>	<b><u>Unexp.</u></b>	<b><u>Average</u></b>
Multi-"The Big Game" #1	57	0	0	0	0	0	n.m.
Multi-"The Big Game" #2	82	3	2	1	0	0	n.m.
Multi-"Powerball"	811	36	6	28	2	0	n.m.
CA "Super Lotto" #1	27	2	0	1	0	1	99.5% / -0.5%
CA "Super Lotto" #2	381	0	0	0	0	0	n.m.
Colorado "Lotto"	730	2	1	0	1	0	n.m.
CT "Lotto" #1	65	4	0	0	3	1	50.2% / -0.2%
CT "Classic Lotto" #2	407	1	1	0	0	0	n.m.
Florida "Lotto" #1	240	1	0	0	1	0	n.m.
Florida "Lotto" #2	94	0	0	0	0	0	n.m.
New Jersey "Pick 6 Lotto"	192	2	2	0	0	0	n.m.
New York "Lotto"	174	1	1	0	0	0	n.m.
Ohio "Super Lotto"	535	1	0	1	0	0	n.m.
Pennsylvania "Super 6"	242	21	8	3	1	9	32.2% / -4.2%
"Lotto Texas"	260	0	0	0	0	0	n.m.
Washington "Lotto"	<u>176</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>n.m.</u>
Total	4,473	74	21	33	8	11	40.0% / -3.5%

**TABLE 4****Rationality Violations for Secondary Lotto Games**

<b><u>Lottery</u></b>	<b><u>Drawings</u></b>	<b><u>Violations</u></b>	<b><u>Holidays</u></b>	<b><u>Roll-over</u></b>	<b><u>Other</u></b>	<b><u>Unexp.</u></b>	<b><u>Average</u></b>
Multi-“Tri-State Megabucks”	153	11	5	2	1	3	11.8% / -19.7%
Multi-“Tri-State Win Cash”	161	44	12	6	2	24	41.2% / -2.5%
Multi-“Tri-West / Wild Card Lotto”	597	175	36	7	5	127	9.7% / -3.8%
Arizona “Lotto”	38	4	0	0	0	4	15.3% / -3.5%
CT “Classic/Wild-Card Lotto” #3	580	96	31	8	0	57	15.2% / -2.8%
Delaware “All-Cash Lotto”	73	6	1	1	2	2	22.0% / -4.1%
Georgia “Lotto”	179	13	3	4	0	6	25.8% / -2.7%
Illinois “Lotto”	373	17	9	1	1	6	28.5% / -2.1%
Indiana “Hoosier Lotto” #1	156	10	3	2	0	5	24.7% / -1.6%
Indiana “Hoosier Lotto” #2	313	61	23	8	0	30	21.0% / -3.2%
Kansas “Cash”	272	8	2	4	2	0	n.m.
Kentucky “Lotto”	592	135	28	17	0	90	16.5% / -4.8%
Louisiana “Lotto”	92	26	6	5	0	15	17.0% / -6.4%
Maryland “Megabucks”	142	47	11	8	0	28	15.0% / -2.0%
MA “Mass Millions”	374	112	22	1	0	89	13.9% / -3.7%
MA “Megabucks”	314	104	23	23	0	58	27.7% / -1.5%
Michigan “Lotto”	174	34	6	15	0	13	14.1% / -4.3%
Minnesota “Gopher 5”	236	1	1	0	0	0	n.m.
Missouri “Lotto”	392	98	24	16	0	58	14.6% / -3.5%
Oregon “Megabucks”	346	38	11	2	2	23	18.5% / -3.6%
South Dakota “Dakota Cash”	389	96	16	0	2	78	15.6% / -3.7%
Virginia “Lotto” #1	27	0	0	0	0	0	n.m.
Virginia “Lotto” #2	534	1	1	0	0	0	n.m.
<u>Wisconsin “Megabucks”</u>	<u>569</u>	<u>114</u>	<u>36</u>	<u>1</u>	<u>1</u>	<u>76</u>	<u>17.2% / -3.1%</u>
<b>Total</b>	<b>7,076</b>	<b>1,251</b>	<b>310</b>	<b>131</b>	<b>18</b>	<b>792</b>	<b>16.8% / -3.5%</b>

**TABLE 5**

Observed Instances of “Lotto Fever”

<b>Date</b>	<b>Game</b>	<b>Jackpot</b>	<b>Expected Value</b>	<b>Previous EV</b>
6/04/88	California “Lotto”	\$ 51.2 million	\$0.5089	\$0.5277
10/29/88	California “Lotto”	\$ 60.8 million	\$0.5164	\$0.5252
4/07/90	Florida “Lotto”	\$ 58.3 million	\$0.5072	\$0.5749
9/15/90	Florida “Lotto”	\$106.5 million	\$0.5034	\$0.5617
2/21/90	California “Lotto”	\$ 68.6 million	\$0.4940	\$0.5206
10/26/91	Florida “Lotto”	\$ 89.8 million	\$0.5707	\$0.5903
4/17/91	California “Lotto”	\$118.8 million	\$0.5760	\$0.6634
2/15/92	Virginia “Lotto”	\$ 25.0 million	\$0.6819	\$0.6977
4/08/98	California “Lotto”	\$102.0 million	\$0.5221	\$0.5307
7/29/98	Multi-state Powerball	\$295.6 million	\$0.5910	\$0.6628
8/25/01	Multi-state Powerball	\$295.0 million	\$0.6479	\$0.6655

*Notes:* Expected value numbers represent the discounted after-tax expected return from the purchase of a single \$1.00 lottery ticket assuming that taxes are paid on all winnings at a marginal tax rate of 30%.