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Abstract

Lotteries as sources of public funding are of particular interest because they combine elements of both public finance and gambling in an often controversial mix. Proponents of lotteries point to the popularity of such games and justify their use because of the voluntary nature of participation rather than the reliance on compulsory taxation.

Whether lotteries are efficient or not can have the usual concerns related to public finance and providing support for public spending, but there are also concerns about the efficiency of the market for the lottery products as well, especially if the voluntary participants are not behaving rationally.

These concerns can be addressed through an examination of the U.S. experience with lotteries as sources of government revenues. State lotteries in the U.S. are compared to those in Europe to provide context on the use of such funding and the diversity of options available to public officials. While the efficiency of lotteries in raising funds for public programs can be addressed in a number of ways, one method is to consider whether the funds that are raised are supplementing other sources of funding or substituting for them. If lottery profits are "fungible" or substituting for other sources that would have been used in the absence of such profits, then the issues of equity and efficiency of lotteries relative to other sources are certainly heightened. The literature suggests that some degree of fungibility does exist, bringing these very concerns into question.

Whether the lottery markets are efficient can be addressed, in part, by examining the rationality of its participants. This can be done by considering how consumers participate in the market, how they respond to changing prices (or effective prices in the case of lotteries), and whether the market ever provides its participants with a "fair bet," a gamble in which there is a positive expected value from participating. While empirical studies provide somewhat mixed results, there are indications that consumers of lottery products are relatively rational and that lottery markets seldom provide "fair bets," both indicators of efficient markets.

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U.S. LOTTO MARKETS

1. Introduction

Lotteries have been commonplace in America from the earliest days of colonialism. Many public works including Boston's famous Faniuel Hall as well as projects at illustrious universities such as Harvard and Princeton were partly funded by lotteries, which remained popular in throughout the country until the American Civil War. A nationwide backlash against gambling led to the decline of state-sponsored lotteries, however, and by the 1890s only Louisiana still operated a lottery game. Interestingly, as was seen again over a century later, the Louisiana Lottery Corporation's monopoly on legalized gambling led to demand far outside the state's borders with only 7% of the company's revenues being generated within Louisiana (Louisiana Lottery Corporation, 2007). Allegations of corruption led to the collapse of the Louisiana Lottery in 1894 and left the United States without any state-sponsored games for 70 years.

In 1964, New Hampshire became the first state to reinstate a lottery game and other states soon followed suit. The first Canadian provinces restarted lotteries in 1970. By 2007, 42 states and the District of Columbia, as well as every Canadian province, sponsored lotteries. In the mid-1970s, state and provincial lottery associations began to join together to offer lotto games beginning with the formation of the Western Canada Lottery Corporation in 1974, the Tri-State Lotto, joining Maine, New Hampshire, and Vermont, in 1985, the Multi-State Lottery Corporation (now more commonly known as Powerball) in 1988, and the Big Game/Mega-Millions Association in 1996 (Grote and Matheson, 2006a). Table 1 provides a list of every state lottery in the U.S. along with its year of initiation, the year that it joined a multi-state lottery as well as the multi-state association it joined, the annual sales and profits of each lottery association, and the per capita sales of lottery tickets in each state.

The expansion of legalized gambling through state lotteries has proven popular for at least two reasons that will be explored in depth in this chapter. First, as more states legalized lottery games or other types of gambling, bordering states felt increasingly pressured to legalize lotteries within their own states. If gambling opportunities were widely available across state lines, a prohibition on gambling with the state may not result in a lower incidence of gambling but could instead simply lead to gambling dollars being spent in neighboring jurisdictions. The potential loss of local revenues to lotteries or casinos in other nearby states has been a prime argument for legalizing and expanding gambling in the United States.

Second, lottery associations typically designate all or a portion of the fund collected to "good works." In the UK, for example, 40% of the sales price of each ticket is retained by the government with a significant percentage of this amount designated for the Department of Culture, Media and Sport. In the United States, more often than not, lottery funds are also designated for special purposes with education being the most common recipient of lottery proceeds. Thus, lottery tickets, like church bingo or other charitable gambing, may be perceived as a more "conscientious" choice by gamblers than privately run casinos or racetracks. Critics of lotteries, however, argue that all government revenues are fungible, and that by designating lottery proceeds towards eduction, for example, government officials simply find it easier to reduce other funding sources for education.

States typically offer a wide variety of gambling products through their lottery associations which can be placed in a variety of categories. The most popular lottery product in the United States are instant win scratchcard games. These lottery tickets sells for between $1 and $20 and allow gamblers to instantly win small to medium sized prizes. These games have the advantage of providing instant gratification (or despair) to players, but instant games cannot award large prizes without placing significant risk on the lottery association. For example, suppose a scratchcard game offers a single $1 million prize to the lucky winner and suppose the lottery association distributes 2 million $1 dollar tickets. On the surface it appears that this game will return a 50% payout to players and 50% to the lottery association. If players find out immediately whether they have won the grand prize, however, the lottery association will only be able to sell tickets to this game until the prize is won, which on average will occur at the one-millionth ticket. Thus, a game that initially appears to have a 50% payoff to the lottery association will actually have zero net expected return to the seller. For this reason, instant win games generally award many modest prizes rather than a small number of larger prizes.

The other type of games are on-line or drawing games such as lotto, numbers, or keno. These games involve players selecting numbers from a set of possibilities. Players are issued a ticket with their choices, and these numbers are checked against numbers selected at a designated drawing. Players who match more of the numbers win increasingly large prizes. Lotto games in particular have the interesting feature that when no player wins the grand prize by matching all of the numbers in a particular drawing, the money allocated to the jackpot pool is typically "rolled-over" into the jackpot pool for the next drawing, raising the potential jackpot for the subsequent drawing. 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 number of successive periods. Indeed, advertised jackpots exceeding $50 million are quite common in both the U.S. and Europe, and occasionally lotto jackpots have been known to exceed $250 million.

In some states, on-line instant win games and video lottery are available. On-line instant win games are a hybrid of scratchcards and on-line games that provide the instant satisfaction of scratchcards with the ability to win the larger prizes that offer. Video lottery is simply a state-sponsored gaming machine more akin to slot machines or other casino gaming than traditional lottery games. The availability of video lottery explains at least some of the variation in state-by-state per capita lottery sales shown in Table 1.

2. Differences Between American and European Lotteries

While in many aspects European and American lotteries tend to be quite similar, there are noticeable differences between the two continents. First, the share of tickets sales accruing to the government is typically larger in Europe than in the U.S. The UK National Lottery keeps 40% of ticket proceeds as government revenue and returns 50% as prize money with the remainder going to pay for retailer commissions and administrative costs. In the United States, only Oregon and West Virginia exceed a 40% government take with the average association receiving only 28% of ticket sales. Two states, Rhode Island and South Dakota, retain less than 20% of revenues as profits. As administrative expenses and commissions are similar in America and the UK, the portion of ticket sales designated to prize money is correspondingly higher in the U.S. It must be noted, however, that lottery winnings are subject to income taxes in the United States while they are exempt in Britain and Canada, at least, significantly reducing net returns in the U.S. and raising government's share of the total ticket price.

Next, lotto jackpot prizes in Europe are paid in cash while lotto jackpots in the U.S. are paid in annuities usually over 20-30 years. The advertised prize in the U.S. is the undiscounted sum of the annuity payments. Lottery winners can choose to take their lottery winnings in a lump sum instead of the annuity payments, but the lump sum is typically 50-60% of the size of the advertised jackpot depending on the length of the annuity and the prevailing interest rates. Thus, while the large American multi-state lotteries, Powerball and Mega-millions, like to advertise that as of 2007 between the two games they have awarded the 15 largest jackpots in the history of gambling, in fact, at least three advertised jackpots in the EuroMillions lottery would rank among the 5 largest jackpots in history in terms of cash value rather than advertised value. (See Grote and Matheson (2003) for an analysis of the effects of annuity payments on gambler behaviour.) Combining the effects of annuities and the taxability of prize winnings, the net present after-tax value of the advertised jackpots of American lotteries tend to be roughly one-third the size of their advertised values.

Finally, the most popular European lotteries tend to be much more egalitarian in their distribution of prizes than the most frequently played games in the U.S.. In Europe, lower tier prizes are awarded larger shares of the prize pool and game matrices are set so that roll-over jackpots are relatively less common. For example, the UK National Lottery sells tickets for 1£, and players choose 6 numbers from a field of 49. Players who match 3 of the 6 numbers correctly win 10£, the smallest prize that can be won. At least 11 state lottery games in the U.S. have offered an identical play matrix. In these games the prize for a $1 ticket for matching 3 of 6 numbers averaged roughly $3.50 and ranged from $0 to $6, generally less than half that offered by the UK Lottery for its smallest prize.

The allocation of prize money to the jackpot prize pool is correspondingly higher in America as well. While the UK Lottery and and Euromillions each allocate 16-17% of every euro or pound wagered to the jackpot prize pool, a random survey of roughly 40 American lotto games finds the corresponding percentages allocated to the grand prize ranges from 19% to 43% of each dollar wagered with the average lottery providing slightly more than 30% of the funds collected to the jackpot, nearly double the percentage of the two European lotteries.

The jackpot prize pool also tends not to roll over as much in European lotteries as compared to those in the U.S. Lottery associations face a tradeoff in determining the optimal odds for a lotto game. By offering games with longer odds but bigger grand-prizes, they could potentially attract more buyers. Numerous authors including Garrettt and Sobel (1999: 2004) and Forrest, *et al.*, (2002) and have suggested that lotto players are attracted by the high jackpots and not the expected return, and lotto is popular due to the "skewness" of the bet rather than its expected return. Lottery associations realize, however, that if the odds are too high, jackpots will be won very infrequently, and, therefore, the games will not benefit from frequent media exposure surrounding jackpot winners. Indeed, Britiain's Lotto Extra game was discontinued in 2006 after several long stretches without a winner (Forrest and Alagic, 2007). Lottery officials are, therefore, forced to choose between offering games with high jackpots and ones with frequent winners.

To this end, in the mid 1970s, state and provincial lottery associations began to join together to offer lotto games beginning with the formation of the Western Canada Lottery Corporation in 1974, the Tri-State Lotto, joining Maine, New Hampshire, and Vermont, in 1985, the Multi-State Lottery Corporation (now more commonly known as Powerball) in 1988, and the Big Game/Mega-Millions Association in 1996. By merging games, states could offer larger jackpots, but the increased number of players would assure that the grand prize was won on a regular basis.

Until the early 2000s, states with smaller populations generally offered lotto by being a member of one of the two major multi-state games (Powerball and Big Game/Mega-Millions) while more populous states could offer high prizes through independent lotto games. For example, as of January 2000, eight states (CA, TX, NY, FL, PA, OH, WA, and CO) operated lotto games but not did belong to a multi-state game. Of these eight states, six ranked among the seven largest states by population.By the early 2000s, however, perhaps due to the record $250 million adevertised jackpots offered during several Powerball and Mega-Millions drawings, even these hold-out states began to join in the multi-state associations so that by July 2005, only Florida remained independent from any multi-state lotto game. Similarly, in 2004 the national lottery associations of the UK, France, Spain, and six other countries joined together to offer EuroMillions, which offers among the highest jackpots in Europe. See Table 1 for a list of state lotteries and the multistate lottery to which they belong.

Because of the larger number of ticket buyers, both the Megamillions and Powerball multi-state games can offer substantially higher advertised jackpots than most state games. While the odds of winning these games are also lower than those of the state lotto games, there is not as much sacrifice in terms of the frequency of jackpot winners as there was in single state games. The relationship between population of potential ticket buyers and the structure of the game can be more precisely explained through an odds to population ratio.

Clotfelter and Cook (1993) note that most frequent odds to population ratio for lotto games in the U.S. in the early 1990s was roughly 1. That is, a lottery association serving a population base of 13 million could offer a game with odds of roughly 1 in 13 million and maintain a reasonable frequency of jackpot winners. The U.K. National Lottery, on the other hand, serves roughly 60 million people with a game that offers odds of 1 in about 14 million for a 0.25 odds to population ratio. The EuroMillions game offers odds of 1 in 76 million to a population base of just over 200 million or a 0.38 ratio. The National Lottery ratio is less than half that of the lowest ratio reported by Clotfelter and Cook for state lotteries in 1990, and the EuroMillions lottery's ratio is less than one-third that of either of the two large multistate games in the U.S., Powerball (1 in 146 million odds and 126 million population for a ratio of 1.15) and MegaMillions (1 in 175 million odds and 137 million population for a ratio of 1.27).

Table 2 provides comparisions two American lotto games in Florida and Texas as well as the two large multi-state games, Megamillions and Powerball, compared to two European games, the UK National Lotto and Euromillions. The time frames for each game examine periods over which the prize structure in each game remained unchanged. Column 3 lists the average jackpot pool for each drawing of the games converted to net present value in the case of the American games and to dollar values using average annual exchange rates in the case of the European games. Column 4 lists the average number of times per year that the jackpot is won by at least one ticket in each game. Column 5 lists the average number of rollovers before the jackpot is finally won in each game. The final column lists the average number of winners when the jackpot is actually awarded.

As can be seen, the American games offer larger jackpots which are less frequently won than their European counterparts. Note that Euromillions has weekly rather than biweekly drawings, as did the UK National Lottery for roughly its first two years of existence, so the figures in Column 4 actually understate the relative frequency at which American games are won in comparison to European games. The data also show that the UK lotto only infrequently rolls over, and Euromillions rolls over at a rate less than one-third that of its big American counterparts. Even when a jackpot is won, it is much more likely to be shared among multiple winners in Europe than in the United States.

3. Fungibility of Lottery Revenues

As stated previously, one possible reason for the popularity of state (and multi-state, national, and multi-national) lottery games is that the revenues from such games can be used to enhance funding of particular state programs. This earmarking of funds for a designated purpose appears to be important to both the successful passage of and the ongoing support for state lottery games. Of the 42 U.S. states (plus the District of Columbia) that provide lottery games, only 17 allow for the revenues from those games to go directly into that state's general fund.[1] Ten of those states earmark at least a portion of lottery revenues for a designated purpose. The remaining 25 states earmark all revenues from lottery games for specific government programs, with education being the primary beneficiary. Table 3 provides a more detailed summary of the legislated use of lottery revenues by state.[2]

A question that has arisen in the literature on lotteries as a source of state finances is whether these earmarked funds actually enhance spending dollar-for-dollar for the designated programs or if state legislators substitute earmarked dollars for dollars that would have come from the state's general funds had earmarking not occurred. The latter concept of substitution of state funds is referred to as fungibility, and the fungibility of funds can either be partial or total depending on the degree of substitution that occurs.

Several published studies have tested for the fungibility of government revenues from lotteries in U.S. states using different variables and statistical techniques, but most tend to agree that fungibility, at least to some degree, is present when funds are earmarked for specific state and local programs.

Mikesell and Zorn (1986) construct a time-series for government expenditures on education in a state as a percent of overall state and local government spending. They find that this percentage only increases in one of the three states examined after the introduction of earmarked funding from a state lottery game. In the other two states, there was actually a decrease in the percentage of funding to education immediately

[1] Some states designate that excess lottery revenues will be available for general funds if a threshold level of revenues for earmarked spending is met.

[2] Note that "revenues" are more accurately designated as "profits" on the table since it is assumed that administrative costs and prize money are already removed by the time the money is used to fund state expenditures.

following the introduction of earmarked lottery revenues. While the authors note that this is not the best test of fungibility since other factors may also be influencing the change in relative spending on education, it is an indicator that there was not a greater relative emphasis on education spending after the introduction of earmarked funding for that specified purpose.

Borg and Mason (1988; 1990) provided two studies of fungibility. The 1988 contribution considers the state of Illinois and its expenditures on education both before and after the introduction of a state lottery with profits earmarked for education. Using regression analysis and a Chow test, there is shown to be a statistically signifant change in the trend for expenditures on education, with education expenditures rising at a lower rate after the introduction of the lottery, in spite of the lottery revenues available for such spending.

The 1990 contribution by Borg and Mason includes analysis of state expenditures on education in five states with lotteries that earmark profits for education and in seven states without lotteries. While there are mixed results for nominal spending on education in the five lottery states, real spending on education declines in all five of those states. Taken alone, this may indicate that fungibility of real spending on education is occurring; however, the seven non-lottery states also experienced a decline in real education spending over the same time period. Similar to Mikesell and Zorn (1986), this is not necessarily direct evidence of fungibility, but it certainly brings into question the commitment of funding to education after the introduction of lottery games that pledge the commitment of funds for that purpose.

Borg, Mason and Shapiro (1991) performed a cross-sectional analysis of states to detect the impact of lottery funding on per-student expenditures on education. A dummy variable is included in the regression analysis to indicate if a state provides for earmarked funding to education via a state lottery. Their findings indicate that states with such funding have a statistically significant lower level of spending per-student, providing an indirect indication of fungibility.

Spindler (1995) tests for the fungibility of lottery revenues in seven states that earmark such revenues for educational programs. Using the ratio of education expenditures to general expenditures for each state as the dependent variable, Spindler constructs time-series ARIMA models to provide statistical evidence of fungibility in varying degrees in all seven states. Even more conclusively, however, there is evidence that the ratio of education to general expenditures actually declines significantly in four of those states after the introduction of a lottery game.

Three studies consider the impact of earmarked funding on state education expenditures in the state of Florida. Stark, Wood and Honeyman (1993) provide evidence that there is not enough of an increase in per-student funding for education in Florida to account for the added state revenues from its lottery. They estimate that over 55% of the funds devoted to education from lottery revenues were, in fact, substituting for funding that would have come from the state if the lottery were not present. Summers, Honeyman, Wattenbarger and Miller (1995) provide some support for the fungibility of education spending in Florida by considering the impact of lottery revenues on total allocations to community colleges in the state. They find that the combined allocation to community colleges from both the lottery and general funds from the state account for a smaller share of total funding sources available community colleges after the state lottery began. Similarly, Land and Alsikafi (1999) find that there is a statistically significant decline in the growth rate of per-student (FTE) expenditures in community colleges in Florida after the introduction of the lottery. This is due, in large part, to the significant decline in per-student allocations from the state to community colleges in the post-lottery years. Part of this decline is due to a substantial increase in community college enrolments in the post-lottery years. However, the authors note that rather than providing additional funding to maintain current levels of per-student revenues to community colleges, the legislature opted to substitute lottery revenues for the necessary general funds.Garrett (2001) also focuses his empirical study of fungibility on a single state, Ohio, that like the state of Florida also earmarks its profits from the state lottery to education. Similar to the study by Spindler, Garrett also uses an ARIMA model for his regression analysis, although real education expenditures per student are used as the dependent variable. Garrett also attempts to measure the degree of fungibility in lottery funding that occurs. His study finds that the earmarking of lottery funds in Ohio does not lead to a significant increase in per-student expenditures on education by the state, concluding that the funds are, to a large degree, fungible.

Erekson, DeShano, Platt and Ziegert (2002) conduct both a cross-sectional and time-series analysis of all 50 states over a five-year period to provide for a more complete study of fungibility. The models regress the expenditures on education as percentage of general revenues for each state on a variety of theoretically important economic variables as well as a dummy variable for states that introduce a lottery and a variable for lottery revenues per capita. The estimation on the coefficient for lottery revenues per capita is negative and significant, indicating that fungibility does occur when lottery revenues are used to finance state expenditures, regardless of whether they are earmarked or not. Additional results indicate that for every $1 per capita in lottery revenues generated as funding for a state, there is a loss of approximately 1 to 1.5% of education funding available.

Novarro (2005), similar to Erekson, DeShano, Platt and Ziegert also theorizes the importance of including both cross-sectional and time-series analysis to address the fungibility issue. The dependent variable used in the analysis is similar to previous studies, however, in that she utilizes state expenditures on education per student. She also uses lottery profits per student as one of the independent variables in the model; however, she separates the effects of lottery profits depending on whether the profits are earmarked for educational purposes or are used as general funds by the state. By separating out the two types of earmarking, Novarro is able to conclude that while earmarking funds does indeed result in fungibility, earmarking provides relatively more revenues to a designated program than if the lottery revenues are not earmarked. Her model estimates that earmarked lottery profits for education tend to increase spending on education by approximately 79 cents for every $1 in lottery profits, while $1 in non-earmarked lottery profits tend to increase education spending by only 43 cents on average.

Given the statistical evidence, both direct and indirect, on the presence of fungibility of earmarked lottery revenues in these studies, it should bring into question the practice of earmarking lottery revenues if it merely allows for substitution of state dollars for legislative programs rather than supplementing those dollars. Obviously the degree of fungibility that occurs is highly important, as is the issue of whether earmarking lottery revenues is relatively better than allowing state legislatures more discretion regarding their use

4. Efficiency of Lottery Markets – Part 1

Since the price of a lotto ticket and the odds of winning remain fixed regardless of the size of the jackpot, the expected return from the purchase of a lottery ticket continuously changes along with the size of the jackpot. This varying return from a repeated game with fixed odds makes lotto almost unique among games of chance. Craps, slots, roulette, bingo, keno, instant win lottery tickets, and lotto games without a rollover component all have fixed odds but also constant expected returns. Horse racing provides varying rates of return but is not a repeated game with fixed odds. Perhaps the only other similar gamble is blackjack when played by an expert card-counter where the game exhibits fixed payoffs but varying odds of winning depending upon which cards have already been played. The non-constant nature of the expected return of lotto has made the game the subject of extensive academic research and provides for interesting opportunities to explore the efficiency of betting markets and the rationality of gamblers.

Of course, 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."

Accepting the idea of gambling itself as rational behavior, one may address more detailed concepts of rationality and market efficiency. At least three notions of rationality can be explored using lotto games. First, rationality requires that individual bettors choose the gamble with the highest expected return per dollar played. Second, as expected return rises, more bettors should enter into the market and existing bettors should gamble more. Finally, lotto games should never provide a positive expected return.

It is generally conceded that state lotteries have among the worst average expected payoffs among games of chance. While sports betting returns 91%, slot machines return 89%, bingo returns 74%, and blackjack returns 97%, state lotteries generally return only 50% to 60% gross revenues to players in the form of prizes. Several theories explain the popularity of lottery tickets in the face of such low expected returns.

First, lottery tickets are an extremely convenient form of gambling. While horse racing and dog racing are offered at roughly 150 and 45 tracks around the U.S., respectively, and casino gambling is legal in about 1,200 American casinos (roughly 2/3 of which are in just 5 states: Nevada, Montana, California, Washington, and Oklahoma), lottery tickets are sold at over 150,000 retailers across the country. Furthermore, unlike casinos and racetracks, which are specialized gambling institutions, most lottery tickets are sold in gas stations and convenience stores and can be purchased along with other items.

Second, a noted previously, lottery associations more often than not designate proceeds to specific "good works" such as education or sport and recreation. Similarly, bingo, which is often offered by churches or other non-profit organizations, also offers a relatively low return.

Finally, the skewness of the bet and the high potential winnings offer one of the few gambling opportunities that present the possibility of a truly "life-changing" event. Few gamblers are likely to dream about what their life would be like if they won $100 in their weekly local football pool, but thoughts of instantly becoming a multi-millionaire are another thing entirely. Indeed, the handful of lotteries known to return even less than half of revenues to prizes have offered very high jackpots. High maximum prizes tend to reduce the importance of expected value in lotteries.

Once the decision to play lotto over other games of chance is made, the question becomes whether or not bettors play the game in a way that reflects rationality in terms of maximizing expected return subject to the conditions of the game. The evidence of rationality on the part of lotto players is mixed but tends to reflect at least some degree of rational decision-making on the part of lotto players.

Since the jackpot and often the lower tier prizes are paid in a pari-mutuel fashion in lotto games, players can increase their expected returns by playing "rare" numbers. On the reasonable assumption that every number combination is equally likely to be chosen, by selecting rarely played numbers, bettors can decrease the number of fellow players with whom they have to share the prize pool if they win. Most lotto games either allow a computer to randomly select numbers or allow players to choose their own numbers. When players select their own numbers, certain combinations such as multiples of 7, birthdays, or vertical or diagonal columns on the play slip, are more commonly played than others.

For example, an examination of the first 801 drawings in the Texas Lotto shows that the average payout for choosing 5 out of 6 numbers correctly was $1,656 and $105 for choosing 4 of 6 correctly. However, in the 6 drawings where the smallest number drawn was 29 or higher, the average payouts were $2,040 and $141 respectively while in the 13 drawings where the highest number drawn was 28 or lower, the average payouts were $922 and $67 on average. Playing rare numbers, in this case numbers that did not correspond with dates, resulted in roughly a 25% increase in return above the average and over a 100% increase over the "common" numbers. Similarly, the January 14, 1995 drawing of the UK Lotto resulted in 133 grand-prize winners, approximately 25 times the expected number, due to the selection of a set of numbers corresponding to an interesting pattern on the lotto play slip. The resulting jackpot prize of 122,510£ per winner was the lowest in the history of the National Lottery and roughly 5% of the size of the typical grand-prize.

The extent to which the distribution of numbers played deviates from a uniform distribution, and hence the ability that players have to earn above normal returns, is examined in depth elsewhere in this volume (Haigh, 2008) as well as by others (Farrell et al., 2000; Papachristou and Karamanis, 1998). As an approximation, however, since roughly 70% of all lotto tickets sold in the U.S. use computer generated numbers, which can be reasonably assumed to follow a uniform distribution, any supernormal expected returns are limited to the deviation from uniformity by the 30% of tickets that are sold to players who select their own numbers. Furthermore, as lotto jackpots grow, the percentage of players selecting their own numbers falls, further reducing any ability of players to select advantageous numbers during periods of high jackpots. Still, this phenomenon is a clear violation of rationality and has been widely examined by Clotfelter and Cook (1989), MacLean et al. (1992), Thaler and Ziemba (1988), and

MacLean and
Ziemba (1999) among others. The observed deviation in existing lotteries has been shown to occasionally be large enough to allow some lotteries to provide positive net expected returns to bettors playing the rarest combinations. While returns exceeding $2.00 per dollar played have been reported, due to the long odds involved, the player would have to play hundreds of thousands of draws before the strategy would, on average, pay a positive return (Ziemba, 1986).

5. Efficiency of Lottery Markets – Part 2

Another possible definition of rationality is that ticket sales will always increase when the expected return rises and will always fall when expected returns fall. An examination of the correlation between advertised jackpots and ticket sales shows a clear increase in ticket sales in response to higher expected returns as would be expected in efficient markets.

Violations of rationality that occur when ticket sales rise despite a decrease in the expected return can occur during rollovers when the number of ticket buyers rises at a faster rate than the advertised jackpot and have been named “Lottomania” or “Lotto Fever” by Beenstock and Haitovsky (2001) and Grote and Matheson (2004).

Testing whether lotto fever exists 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.

(1) $$ER_t = [\sum^{i} w_i V_{it} + (AV_{jt} / dvr_t)(1 - e^{-B_t w_j}) / B_t\ ](1-\theta) + [\sum^{i} w_i + w_j]\ \theta\ \tau$$

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, AV_{jt} is the advertised jackpot prize at time t,dvr_t is a divisor used to convert the advertised annuitized jackpot into a net present value, B_t is the number of other ticket buyers for the drawing in period t, θ is the tax rate, and τ is the price of a ticket.

Lottery ticket sales almost always increase from drawing to drawing if the jackpot is not won, so 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. This requires $ER_t > ER_{(t-1)}$ for all drawings within a jackpot cycle. Setting $ER_t > ER_{(t-1)}$ and canceling out like terms, assuming that the conversion factor from the advertised jackpot to the net present value of the jackpot remains unchanged between drawings, leaves equation (2).

(2) $$V_{jt}(1 - e^{-B_t w_j}) / B_t > V_{j(t-1)}(1 - e^{-B_{t-1} w_j}) / B_{t-1}$$

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 (2) can be further rearranged to leave equation (3).

(3) $$V_{jt} / V_{j(t-1)} > B_t (1 - e^{-B_{t-1} w_j}) / B_{t-1} (1 - e^{-B_t w_j})$$

If equation (3) does not hold as the jackpot rises, then the purchase of a lottery ticket becomes an increasingly worse investment as the jackpot rises. In practice, however, Grote and Matheson (2004; 2005) have shown that lotto fever is exceedingly rare, occurring in only 12 cases out of over 23,000 American lottery drawings examined. Such instances are concentrated in record-sized jackpots in large games and have become less common over time.

Violations of rationality that occur when ticket sales do not rise despite an increase in expected return are known in the literature as "lottery apathy" or "jackpot fatigue" and have been investigated by DeBoer (1990), Grote and Matheson (2005; 2007a). It is an observed fact that lottery sales for most individual games has fallen over time. This decline is explained in part by the rise of recently legalized forms of non-lottery gambling or the introduction of new lottery products. For example, the expansion of casino gaming or the adoption of lotteries by neighboring states may have significant effects on lotto sales within a state.

The effects of casino gaming on lottery sales in the United States have not been well explored because of the difficulty obtaining gaming revenue data from Native American casinos, which operate in roughly half of the states.The effects of neighboring lottery games has been well explored, however, as have the effects of the introduction of new games on existing games within a state. Researchers including Stover (1990) and Garrett and Marsh (2002) have clearly identified significant cross-border effects for lottery gambling. The expansion of lotteries to nearly every state has led to a decline in lotto play for states that had state lotteries previously as a decrease in cross border play occurs. Some cross-border gambling still exists, particularly between states that are members of different multistate games. Advertised jackpots exceeding $250 million are attractive lures for neighboring states. Border counties have been shown to experience disproportionately large increases in ticket sales during large multistate jackpots when the neighboring state is not a member of their particular multistate game (Oster, 2004).

Forrest, Gulley, and Simmons (2004) find that within country competition between lotto games appears quite limited in the UK, but Grote and Matheson (2006a; 2007b) suggest a significant degree of cannibalism between games in American states that offer multiple lotto games. The degree of substitutability appears to be particularly high in states where two or more lotto games have similar characteristics in terms of average jackpots. Forrest, Gulley, and Simmons discovered no such evidence in the UK Lottery, attributing this result to the fact that the UK lottery association, Camelot, "has successfully designed and marketed games that each appeal to bettors in different ways." Forrest, Gulley and Simmons also find little evidence that the different lotto games in the UK are complements for one another while Grote and Matheson find that while the presence of a multistate lottery game decreases sales overall for an existing state lotto game, during periods of large multistate jackpots ticket sales for other lotto games within states that are members of the multistate lottery association increase modestly as well. Grote and Matheson attribute this increase to a reduction in transaction costs.

A final anomaly identified in lotto sales is the the “Halo Effect,” that is an increase in lottery ticket sales in the periods immediately following a large jackpot being won. Various researchers have attributed this bump in sales to irrational bettors influenced by increased media attention surrounding the recent large jackpot. Grote and Matheson (2007), however, suggest that the anomaly may be explained as simply as bettors cashing in tickets winning smaller prizes and reinvesting the proceeds in new tickets.

6. Efficiency of Lottery Markets – Part 3

A final definition of rationality in lottery markets, first proposed by Scott and Gulley (1995), is that lottery games should never, or at least quite rarely, provide their participants with a bet with a positive expected value. Several papers have identified specific instances of “fair bets” in lotto drawings including Krautmann and Ciecka (1993) and Matheson (2001). Grote and Matheson (2005; 2006b) present the most ambitious tests of this definition of rationality by examining nearly 23,000 drawings of American lottery games. Using the expected return found in equation (1), they find 290 instances where the purchase of a single randomly selected lottery ticket would have provided an after-tax expected return exceeding the cost of the ticket. The returns here exclude any additional money that could be earned by playing rare combinations as described previously. Examples of fair bets tend to be concentrated in smaller state lotteries that advertise relatively low jackpots but with substantially better odds of winning than the biggest state and multistate games. The smaller games do not attract as many additional ticket buyers when their jackpots become relatively large, and therefore the higher returns they offer are not as diluted by the prospect of potentially having to share the jackpot among multiple winners.

With less than 1.3% of drawings providing a positive expected return, it can reasonably be concluded that lottery games are generally efficient. Even those drawings providing positive returns subject the player to substantial risk, and only provide a fair bet if the player is assumed to be risk neutral. Investment strategies based on buying single tickets during draws with the “best” jackpots would only provide positive median returns with investment horizons that, literally, exceed one-hundred thousand years in length.

As noted by Haigh (2008), suppose a gambler utilizes a strategy that considers both large jackpots and the playing of rare combinations as examined by MacLean et al (1992) and MacLean and Ziemba (1999). Under scenario A the lotto game has a medium-sized rollover, and the winning combination is fairly unpopular while under scenario B the game has a large rollover, and the winning combination is very unpopular. Because the bulk of the expected winnings in either case comes from an event with very low probability, in scenario A if an investor aims to have at least a 50% chance of turning an initial one million dollars into ten million dollars before losing half the initial capital, it will take on average some 22 million years for this to occur playing an optimal strategy. Scenario B offers only a slightly better investment opportunities. If an investor is satisfied with a 95% chance of reaching ten million dollars before falling to 25 thousand dollars, the average time to wait is down to a “mere” 2.5 million years.

Matheson (2001) and Grote and Matheson (2005; 2006b) note, however, that while the purchase of individual lottery tickets rarely provide a fair bet, the purchase of every number combination is much more likely to result in a positive net expected return at a significantly reduced level of risk. First, the purchase of every combination, denoted as the “Trump Ticket” by Krautmann and Ciecka (1993), guarantees the purchaser at least a portion of the jackpot, reducing the risk simply to how many other tickets have the winning combination as opposed to whether or not the jackpot is won in the first place. Second, the purchase of a Trump Ticket results in a higher jackpot payoff due to the large number tickets purchased and the allocation of the proceeds to the jackpot pool. Third, the purchase of the Trump Ticket has certain tax advantages as described by Matheson (2001).

Grote and Matheson (2005; 2006b) find that nearly 12% of the almost 23,000 drawings they examine would have provided a positive net return for the purchase of a Trump Ticket with many drawings providing an expected return in excess of 50%. The fact that few attempts to corner a lottery drawing have been attempted is likely due to two factors. First, even the purchase of a Trump Ticket may involve significant risk. While the Trump Ticket guarantees a share of the jackpot, it does not preclude other tickets from winning. In most of the cases identified by Grote and Matheson, the return from the Trump Ticket is only positive if no other tickets share the jackpot prize.

Furthermore, the act of physically purchasing the every possible combination for a particular lottery drawing is a daunting task. In fact, in February 1992, an Australian consortium attempted to corner a $25 million advertised jackpot in the Virginia Lotto. Despite a massive effort that included enlisting the aid of a major lottery ticket retailer, the consortium was only able to purchase 2.4 million of the 7,059,052 possible combinations before time ran out. Cornering one of the larger games such as Powerball, Megamillions, or Euromillions would be even more difficult. Such a strategy is likely to be possible only for the smallest state games. However, with smaller games, while the rate of return might be high, the small size of the jackpot would limit the total return from such an effort.

7. Conclusions

Lottery games have considerable appeal as sources of public revenues. The diversity of products available as well as the adaptability of lotto structures allow government officials to choose games that appeal to their consitutents as well as provide for appropriate levels of public funding. However, as sources of public funding, the literature suggests that fungibility of lottery revenues does exist, providing for lesser gains to public programs than might be expected. In fact, if the funds are completely fungible, programs designated as beneficiaries of lottery profits may be receive just as much revenue after this designation as before.

The evidence on fungibility as an argument against the efficiency of state-run lotteries is both consistent and stronger than the arguments that the market for the lottery products are not efficient. Particularly in the instance of state-run lotto games in the United States, consumers tend to exhibit rational behavior and the markets themselves do not tend to exhibit positive net expected returns on a general basis. However, individual violations of market efficiency do appear to occur in the form of positive expected returns from certain number combinations, the presence of lottery fatigue and the potential positive expected returns from a “Trump ticket.”

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TABLES

Table 1

State	Start Date	Multi-state	2006 Revenues ($ millions)	2006 Profit ($ millions)	2006 per capita sales
Alabama	None		$ -	$ -	$ -
Alaska	None		$ -	$ -	$ -
Arizona	1981	Powerball (1994)	$ 468.70	$ 141.12	$ 76.01
Arkansas	ballot 2008		$ -		$ -
California	1985	Mega-Millions (2005)	$ 3,585.00	$ 1,240.57	$ 98.33
Colorado	1983	Powerball (2001)	$ 468.80	$ 125.60	$ 98.62
Connecticut	1972	Powerball (1995)	$ 970.33	$ 284.87	$ 276.86
Delaware	1975	Powerball (1991)	$ 727.99	$ 248.80	$ 852.97
District of C.	1982	Powerball (1988)	$ 266.20	$ 73.40	$ 457.76
Florida	1988	None	$ 4,030.00	$ 1,230.00	$ 222.78
Georgia	1993	Powerball (1995) Mega-Millions (1996)	$ 3,177.59	$ 822.40	$ 339.34
Hawaii	None		$ -	$ -	$ -
Idaho	1989	Powerball (1990)	$ 131.13	$ 33.00	$ 89.42
Illinois	1974	Mega-Millions (1996)	$ 1,964.83	$ 637.67	$ 153.12
Indiana	1989	Powerball (1990)	$ 816.40	$ 218.00	$ 129.31
Iowa	1985	Powerball (1988)	$ 339.52	$ 80.88	$ 113.85
Kansas	1987	Powerball (1988)	$ 236.05	$ 67.09	$ 85.40
Kentucky	1989	Powerball (1991)	$ 742.30	$ 204.30	$ 176.48
Louisiana	1991	Powerball (1995)	$ 332.12	$ 118.76	$ 77.46
Maine	1974	Tri-State Lotto (1985) Powerball (1990-1992) Powerball (2004)	$ 229.69	$ 51.70	$ 173.80
Maryland	1973	Mega-Millions (1996)	$ 1,560.91	$ 500.97	$ 277.95
Massachusetts	1972	Mega-Millions (1996)	$ 4,534.12	$ 951.24	$ 704.36
Michigan	1972	Mega-Millions (1996)	$ 2,212.37	$ 688.02	$ 219.14
Minnesota	1990	Powerball (1992)	$ 450.00	$ 121.30	$ 87.09
Mississippi	None		$ -		$ -
Missouri	1986	Powerball (1988)	$ 913.52	$ 260.67	$ 156.35
Montana	1987	Powerball (1988)	$ 39.92	$ 9.11	$ 42.26
Nebraska	1993	Powerball (1994)	$ 113.11	$ 30.32	$ 63.96
Nevada	None		$ -	$ -	$ -
New Hampshire	1964	Tri-State Lotto (1985) Powerball (1996)	$ 262.74	$ 80.32	$ 199.82
New Jersey	1970	Mega-Millions (1999)	$ 2,406.57	$ 849.25	$ 275.84
New Mexico	1996	Powerball (1996)	$ 154.71	$ 36.86	$ 79.15
New York	1967	Mega-Millions (2002)	$ 6,803.00	$ 2,203.00	$ 352.37
North Carolina	2006	Powerball (2006)	$ 229.53	$ 64.59	$ 25.92
North Dakota	2004	Powerball (2004)	$ 22.33	$ 6.92	$ 35.12
Ohio	1974	Mega-Millions (2002)	$ 2,221.00	$ 646.30	$ 193.50
Oklahoma	2005	Powerball (2006)	$ 204.84	$ 68.95	$ 57.23
Oregon	1985	Powerball (1988)	$ 1,104.00	$ 483.00	$ 298.32
Pennsylvania	1972	Powerball (2002)	$ 3,070.00	$ 975.85	$ 246.77
Rhode Island	1974	Powerball (1988)	$ 1,731.47	$ 323.90	$1,621.82
South Carolina	2002	Powerball (2002)	$ 1,144.60	$ 319.40	$ 264.88
South Dakota	1987	Powerball (1990)	$ 686.16	$ 118.99	$ 877.53
Tennessee	2004	Powerball (2004)	$ 996.27	$ 277.66	$ 164.98

Texas	1992	Mega-Millions (2003)	$ 3,774.69	$ 1,036.11	$ 160.57
Utah	None		$ -	$ -	$ -
Vermont	1978	Tri-State Lotto (1985) Powerball (2003)	$ 104.88	$ 22.88	$ 168.10
Virgina	1988	Mega-Millions (1996)	$ 1,365.00	$ 454.90	$ 178.60
Washington	1982	Mega-Millions (2002)	$ 477.89	$ 116.95	$ 74.72
West Virginia	1986	Powerball (1988)	$ 1,522.00	$ 610.00	$ 836.97
Wisconsin	1988	Powerball (1989)	$ 508.90	$ 150.60	$ 91.59
Wyoming	None		$ -	$ -	$ -

Sources: National Association of State and Provincial Lotteries; Grote and Matheson (2007b)

Table 2: Jackpot Statistics

Game	Period	Average jackpot pool ($ millions)	Average number of times jackpot won per year	Average number of rollovers	Average number of winners
Florida	1/1/03 - 12/30/06	6.05*	28.75	2.65	1.27
Texas	5/7/03 - 4/22/06	14.72*	6.08	15.28	1.06
Megamillions	5/17/02 - 12/29/06	32.56*	12.67	7.93	1.05
Powerball	10/9/02 - 8/27/05	27.50*	12.28	7.65	1.20
UK Lottery	11/19/04 - 12/29/07	10.77**	85.34	0.21	3.35
Euromillions	2/13/04 - 12/28/07	31.28**	32.79	2.17	1.72

*Value of cash option.
**Pound and euro values converted to dollars.

Table 3: Use of Lottery Profits by State

State/D.C.	Education	General Fund	Environment / Conservation	Development	Gambling Treatment	Tax Relief	Other
Arizona		x	x	x			x
California	X						
Colorado		x	x				
Connecticut		x					
Delaware		x					
D.C.		x					
Florida	x						
Georgia	x						
Idaho	x						x
Illinois	x						
Indiana						X	x
Iowa		x			x		x
Kansas		x		x			x
Kentucky		x					
Louisiana		x			x		
Maine		x	x				
Maryland		x					x
Massachusetts							x
Michigan	x						
Minnesota		x	x				
Missouri	x						
Montana		x					
Nebraska	x	x	x		x		
New Hampshire	x						
New Jersey	x						x
New Mexico	x						
New York	x						
North Carolina	x						
North Dakota		x					
Ohio	x						
Oklahoma	x						
Oregon	x		x	x			x
Pennsylvania							x
Rhode Island		x					
South Carolina	x						
South Dakota		x				X	x
Tennessee	x						
Texas	x						
Vermont	x						
Virginia	x						
Washington	x						
West Virginia	x		x				x
Wisconsin						X	
Total:	23	17	7	3	3	3	12

Sources: Novarro (2005) and the websites of state lottery associations.