The Economics of Demand for the South African National Lottery

By Lyndal Keeton-Stolk[1]

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[1] Economics Department at Wits University. Email: lyndal.keeton@wits.ac.za

Abstract

The first South African National Lottery draw took place on the 11th March 2000 and is an alternative method for the government to raise revenue. A portion of the revenue collected from the South African lottery is allocated to a number of ‘good causes.’ The jackpot is awarded to the ticket in which all six numbers (of a possible forty nine) match the winning numbers drawn. A motive for purchasing a lottery ticket is the enjoyment of playing which helps to explain why risk averse consumers purchase lottery tickets which are recognised as an unfair gamble. When purchasing a ticket for the lottery, the real cost to the purchaser is the effective price which is the face price of R2.50 less the expected value of the ticket. In order for the National Lottery to maximise revenue, the elasticity of demand with respect to the effective price needs to equal -1. In order to establish whether the revenue collected from the national lottery is being maximised, the model used by Forest, Gulley and Simmons(2000) on the UK lottery is adapted and applied to data for the local lottery. Simulations are then carried out to observe the effects of lottery design changes on the elasticity of demand. It would appear that adjusting the model to a 6 from 51 game may improve revenue maximization. Through this alteration of game design, the National Lottery Board can ensure that it will continue to meet its goal of revenue maximisation and thereby maximise the funds available to “good causes”.

JEL Codes

H50, L83

1. Introduction

The first South African National Lottery draw took place on the 11^{th} March 2000 and is an alternative method used by the government to raise public funds. The South African lottery is designed such that bettors choose six numbers out of forty-nine. The odds of matching the winning numbers are 1 in 14 million. The jackpot is awarded to the ticket in which all six numbers match the winning numbers in the lottery draw (South African National Lottery, 2006).

In order to assess the economics of demand for lottery tickets, the factors that determine why consumers purchase lottery tickets will be examined. The lotto is an unfair gamble that risk averse people are meant to decline, yet there is still demand for lottery tickets (Walker, 1998: 365). The reasons for demand still existing for lottery tickets include Nyman's(2004) "something for nothing," Walker's(1998) "non-pecuniary pleasure" of playing, and Rubner's(1966) "charitable elation" in which bettors can soothe their consciences. Walker (1998) also argues that the marketing of the lottery leads to misperception of the odds.

The aim of this paper is to establish whether the South African National Lottery has been designed to maximise the revenue collected, thereby maximising the funds allocated to "good causes." In order for this condition to be met, the price elasticity of demand for the lottery needs to equal -1 (which means that demand responds in proportion to changes in the effective price). When purchasing a ticket for the lottery, the cost to the purchaser is the effective price. Therefore, in order for the National Lottery to maximise revenue the elasticity of demand with respect to effective price needs to equal -1. In this situation, the lottery is providing the optimal benefit to society.

The paper proceeds as follows. Section 2 provides justification for the lottery as a revenue producing tool for public policy which is an alternative to taxation. Section 3 then presents evidence from other countries where similar studies have been carried out. The fourth section examines lottery design and mechanics. Section 5 looks specifically at the South African National Lottery, the organisations responsible and how the funds are allocated. Insights on what motivates lottery play and whether it is rational behaviour are shown in Section 6. Section 7 presents the effective price model used to analyse the lottery demand function. The results of the model are presented in Section 8 followed by the results of simulations of alternative lottery design in Section 9. Conclusions and policy recommendations follow.

2. The Lottery as a Tool for Public Policy

Public policy studies the balance between tax revenue collection and government spending. Tax collection is the most traditional form of raising revenue, but the lottery is an alternative way to raise public funds. Governments generally operate or license lotteries in order to raise revenue in new ways for three reasons: firstly, increased demands for state expenditure, secondly taxpayer objections to higher taxes and thirdly the pressure to balance budgets (Walker, 1998: 362-363). Alm, Mckee and Skidmore (1993:466) include that an additional reason for states choosing to hold national lotteries is because the game is a form of recreation.

Alm, Mckee and Skidmore (1993:472-475) find that in the United States, fiscal stress has not been the main reason for the introduction of state lotteries in recent times. Instead, it has been the state's fear of lost revenue and rent-seeking on the part of lottery service providers that have led to the introduction of state lotteries. A secondary factor that has caused US states to introduce lotteries has been the activities of neighbouring states. The motivation in this instance is the fear of loss of revenue to the neighbour. Rubner (1966) argues that a lottery run as a monopoly satisfies society's urge to gamble with fewer resources than a private company would. Therefore, lotteries are usually state-run or strictly licensed by state.

The revenue generated from lotteries can be used for general revenue or earmarked for specific purposes such as education and health spending, cultural activities, debt repayment (as was the case for Montreal's Expo and Olympics), worker compensation (Illinois), transport infrastructure (Arizona) and terrorist victim compensation (Spain). The lottery allows government the freedom to strategically reduce spending in response to or in anticipation of lottery funds being awarded (Walker, 1998: 362-363).

The public policy decision to instigate a national lottery in South Africa is not without costs to society. Lotteries are often called a 'painless tax,' because participation is voluntary and the game is a form of recreation. There is opposition to the lottery on religious and moral grounds. Also, although the revenue from a national lottery may alleviate fiscal stress, they may be objectionable as lotteries are 'inconsistent with the principles of good government,' they target the poor through marketing campaigns that do not always reflect the true odds of winning the jackpot[2], promote gambling in society and generate small, unstable revenues. Therefore lotteries could potentially cost a political party votes in a future election (Alm, Mckee and Skidmore, 1993:465).

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[2] (Walker, 1998)

When lottery tickets are bought disproportionately by people with low incomes, this leads to distributional concerns. The general concern about lotteries is that players squander the little they have in the irrational hope of a large win. In addition, social costs arise from concerns regarding addiction or play by those below the minimum age permitted. If the size distribution of the prizes is skewed too highly, then the lottery may prove too tempting. The social cost of lotteries ultimately arises when the true odds of winning are not comprehended by players (Walker, 1998: 363-364).

3. Evidence from National and State Lotteries in Other Countries

The literature on this topic is fairly limited but there have been a number of studies on the UK Lottery. Forrest, Gulley & Simmons (2000) find that the revenue from the UK lottery is maximized as does Walker (1998). However, Farrell, Morgenroth & Walker (1999) find this is not the case in the long-run. A study by Forrest, Simmons & Chesters (2002) finds that the price elasticity of lottery not significantly different from -1, but also that rollovers have a significant impact on lottery demand.

Farrell, Morgenroth and Walker (1999) estimate price elasticity through changes in the expected value of holding a ticket. The variations in the expected value are driven by rollovers (which are exogenous). The results from this particular model suggest that the implied long-run elasticity does not indicate revenue maximization. The paper also tested for addiction among lottery players and concludes that lottery play is less addictive than physically addictive consumption goods such as cigarettes.

There have also been numerous studies on state lotteries in United States. Cook and Clotfelter (1991) applied the effective price model to 14 state lotteries. Scoggins (1995) applied the model to the Florida Lotto and found that revenues could be increased by allocating a greater percentage of sales to the jackpot. Alm, Mckee & Skidmore(1993) examine the motives of states to introduce lotteries. Gulley and Scott(1993) evaluate whether state lottery agencies have structured their lotteries in such a way as to maximize tax revenue.

Gulley and Scott(1993) examine four US state lotteries. They find that in two cases, Kentucky and Ohio, the games are structured to maximize revenue. In the cases of the two Massachusetts lotteries, net revenue is not maximized. In both these cases, the authors find that the probabilities of winning can be changed to meet this goal.

There is little literature on lotteries other than the UK and the USA, although a study by Yu (2004) finds that the price elasticity of demand for the *Canadian* Lottery is -0.67. Beenstock, Golden & Haitovsky(1999) study only the jackpot payouts for the *Israeli* lottery to determine the optimal payout rate to maximize profits. Tzeng, Wang & Tain (2004) examines lotto demand in the *Taiwan* lottery to provide justification for a bettor to participate in an unfair lottery

4. The Mechanics of the Lottery

The lottery is pari-mutual which means that prize pool comes directly from ticket sales (Walker, 1998). The jackpot is the principal prize payout which is much greater than any of the subsequent prize divisions. It is won if all ticket numbers are matched to the numbers drawn in the lottery. The subsequent prize divisions are where smaller prizes are allocated to tickets in which fewer than 6 but more than 2 numbers are matched. Rollovers occur when the jackpot has not been won. The jackpot then gets added to the next lottery draw's jackpot (South African National Lottery, 2006).

The prize pool is determined by the take-out rate (τ) which is the proportion of sales that is not returned in the prize pool. The overall prize pool is therefore $(1- \tau)S$, where S is sales revenue. It is common for the take-out rate to be in the range 40-50% so that the pay-out rate becomes 60-50% (Walker and Young, 2001: F702).

In any organised gaming, the sales revenue needs to cover both the costs of the lottery and any promised fixed prizes. Therefore the "take-out" rate (i.e. the proportion of revenue retained by the operator, not distributed as prizes) needs to include a risk premium since there is no insurance market. The required risk premium and corresponding take-out rate could potentially be so high that very few would choose to play the lottery. In this situation the equilibrium could be where no games exist (Walker, 1998: 361).

As the national lottery has repeated draws, it enables the risk to be spread over time. The pari-mutual nature of the lottery is believed to promote sales and negates the risk of prizes exceeding the sales revenue. In the lottery game, the participants or ticket holders play against each other for the prize pool and the 'house' (lottery management company) takes risk-free commission. The game is risky for the players as the level of prizes is dependent on the overall sales and the number of players who have chosen the same winning combination of numbers. When the 'jackpot' prize pool has no winners, it is added to the jackpot pool of the following draw. This is known as a 'rollover' (Walker, 1998: 361).

Over time, sales behaviour is determined by the choice of *n* and *N* where players pick *n* numbers from a possible *N* available numbers. This choice determines the probability of winning the different prizes and the likelihood of a rollover. If the game is too easy to win and rollovers are infrequent, players may become bored with the uniformity of the game. Rollovers are important in lottery design as they enhance the attractiveness of the next draw so players are tempted to play more, return to the game or play for the first time. This is effect has greater longevity than games without rollovers. However, if the game is too difficult to win, it will also be detrimental to sales in the long run by creating the problem of intertemporal substitution. If, in an extreme case, the game was almost impossible to win it would rollover indefinitely since sales would be low relative to the possible combinations available. Only as the size of the rollover accumulates to become sufficiently large will the draw become attractive for players. At that point, players will play heavily. Lottery game design needs to find a balance between being hard enough to overcome the tedium but easy enough to avoid the problem of intertemporal substitution (Walker and Young, 2001: F701-F702).

The odds of matching fewer than *n* numbers are dependent on *N*. For example, the odds of matching 3 in a 6 from 49 game are 1 in 57 while in a 6 from 53 game is 1 in 71. Therefore, both n and N affect the number of prize winners for each prize pool. The UK Camelot game (and the South African game) has a more complex design with the addition of a 'bonus' ball which is used to define additional prize pools such as that for drawing 5 of the 6 numbers plus a bonus number (Walker and Young, 2001: F702-F703).

An important consideration of lottery design is the potential market size. A game which is suitable for the UK population is likely to be too difficult for the Israeli market which is a tenth of the size. Therefore the Israeli lottery was redesigned from a 6 from 49 game to a 6 from 45 game. In countries such as Ireland, they have redesigned the game twice to make it harder to win in order to induce more rollovers. The redesign follows organised attempts to 'buy the pot.' California, which has a population of 34 million, started their lottery with a 6 from 49 game. This then changed to 5 from 53, and then to 6 from 51 and eventually to a complex came of 5 from 47 plus 1 from 27 which has very long odds of 1 in 41.4 million. In Florida, where the population is 15 million, the game started as 6 from 49 and has now changed to 6 from 53 (Walker and Young, 2001: F702).

5. The South African National Lottery

The history of the South African National Lottery and the organisations responsible for the lottery provide insight as to how the lottery is a tool for public policy and how to ensure that the model is effectively modified to suit particular conditions that have evolved in the local lottery. The South African National Lottery (2006), the National Lotteries Board (2006) and Louw (2002) are used for this purpose.

The first SA National Lottery draw took place on 11th March 2000. It is designed so that the bettors choose 6 numbers out of a possible 49. The jackpot is allocated to the ticket that matches all six numbers drawn. The odds of matching the winning numbers are 1 in 13,989,816 and the odds of winning lowest prize (matching 3 numbers) are 1 in 57 which means that smaller prizes are commonly won (South African National Lottery, 2006).

There are two key organizations responsible for the National Lottery, Uthingo Management and the National Lotteries Board (NLB). The organization responsible for the running of the lottery is Uthingo Management. It is owned by a BEE companies (who own 50%), industry shareholders (30%) and the state (20%). National Lotteries Board (NLB) is responsible for regulation of lotteries in South Africa. It is also responsible for maximizing net proceeds and ensuring that the appropriate portion of ticket sales is transferred to the Distribution Trust Fund (Louw, 2002).

The proceeds of the lottery are allocated as follows (after 14% VAT has been levied):

- Prize pool 50%
- Good Causes 30%
- Uthingo Management 15% (who retain 1% for profits and the rest is for operating costs)
- Ticket retailers 5% (National Lotteries Board, 2006)

5.1 The Organisations Responsible for the South African National Lottery[3]

The primary responsibility for the National Lottery rests with two organisations, the licensed operator (Uthingo Management[4]) which is responsible for running the lottery and the National Lotteries Board which has the responsibility of overseeing the lottery and protecting the interests of all parties concerned. In addition to these two parties are distribution agencies which are appointed by the Minister of Trade and Industry but are run by the Lotteries board. The distribution agencies are responsible for the distribution of lottery funds to 'good causes.'

Uthingo Management (Pty) Ltd is a consortium composed of various South African black economic empowerment (BEE) partners, industry shareholders and state shareholders. The consortium was formed in 1996. Table 1 indicates the share of ownership for each member of the consortium.

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[3] (Louw, 2002: 1-7)

Table 1 Ownership of Uthingo Management (Pty) Ltd

Type of Investor	Companies and % Ownership	Share of Ownership
BEE	Black Management Forum Investment Co (Pty) Ltd 10% Disability Employment Concerns Trust 5% Motswedi Technology Group (Pty) Ltd 10% NAFCOC Investment Holding Co. Ltd 10% NUMSA Investment Co. Ltd 10% WDB Investment Holdings (Pty) Ltd 5%	50%
Industry Shareholders	Camelot International Tattersalls GTECH	30%
State shareholders	National Empowerment Fund 5% South African Post Office 15%	20%

Source: Louw (2002: 1-2)

Uthingo Management is responsible for the establishment and management of a national communications network; the selection, licensing and training of retailers; and associated marketing activities. The company is not responsible for the distribution of the proceeds from the lottery to good causes. However, Uthingo Management has established its own charity (the Uthingo Trust) which invests in small-scale community projects.

The National Lotteries Board is a statutory body which is responsible for the regulation of all lotteries conducted in South Africa. It reports annually to parliament but operates independently. The Lotteries Board has the following responsibilities:

- To ensure that the National Lottery and all other lotteries are conducted "with due propriety"
- To protect the interests of all participants
- To maximise the net proceeds of the National Lottery
- To ensure that a percentage of money from ticket sales is transferred to the National Lottery Distribution Trust Fund (NLDTF) and administered and invested in terms of the lotteries act.

The National Lotteries Distribution Trust Fund (NLDTF) was established and is monitored (although not directly administered) by the National Lotteries Board. Funds are transferred to the NLDTF weekly and the funds are distributed to good causes annually. No more than 10% of this money (i.e. 3% of the total proceeds) is allowed to be used for administration.

5.2 Allocation of National Lottery Funds[5]

The national lottery can be thought of as a voluntary tax as a portion of the proceeds is allocated to charities and other "good causes" that no longer receive government subsidies. In addition, the charitable portion is allocated to provinces in proportion to the provincial breakdown of sales. In South Africa, 50% of the total sales are allocated to prizes. This is the same as the United Kingdom (Forrest, Gulley and Simmons, 2000:854). In the USA, 35-45% of the total sales are allocated to the prize pool (Walker, 1998:370). The funds generated by ticket sales in South Africa are apportioned as follows. The prize pool comprises 50% of sales, good causes are allocated 30%, 15% is allocated to the operating costs of the lottery management Uthingo Management (who retain 1% of this as profit), and the remaining 5% is given to retailers of lottery tickets as commission.

A number of good causes and charities receive money from the national lottery. The portion of the sales figure is divided between different categories of charities and good causes as follows. The first category, Arts, Culture and National Heritage receives 22%, the second category (Charities) receives 36%, the Reconstruction and Development Programme (RDP)[6] is earmarked to receive 15%, Sport and Recreation receives 5% and the remaining 5% is given to miscellaneous good causes[7]. It should be noted that these figures are after 14% VAT has been levied on the proceeds from the lottery (Louw, 2002: 3).

The National Lottery operator is not expected to pay out 30% on all ticket sales immediately due to the roll out costs involved in establishing a national lottery. The percentage given to good causes is, instead, only meant to average at 30% during the seven year duration of the license. As such, contributions were expected to rise from 10.16% in the first year to 40.58% in the seventh year. Although the first and last years' percentages have been announced publicly, it is unclear whether the fixed percentages for each of the seven years have been determined in advance or whether the operator has discretion in choosing the percentages (Louw, 2002: 10-11).

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[5] National Lottery Board, www.nlb.co.za

[6] This category is problematic as the RDP has been abandoned. No decisions have been taken yet as to the allocation of the funds (Louw, 2002: 7)

[7] The 'miscellaneous' category is intended for emergency funding and the Minister of Trade and Industry (together with the Minister of Finance) has discretion over how the funds are to be used (Louw, 2002: 6)

6. The Rationality and Irrationality of Demand for the Lottery

Traditional economic theory is based on the idea that individuals are risk averse and therefore decline gambles that are actuarially 'unfair' (that the odds are not in the players' favour). However, lottery gambles are unfair gambles, yet there still exits demand for lottery tickets. The argument proposed is that a gamble generates an 'additional non-pecuniary pleasure.' Therefore, provided that the satisfaction or utility of the gamble offsets the monetary cost that is implied in the unfair odds, this type of gambling can exist in conjunction with insurance against large risks where risk aversion is important. Lottery tickets are generally widely available and the lottery stakes are small. The satisfaction derived from participation in the lottery may also extend to the knowledge that a portion of the revenues are used to support charitable causes or public works. Lotteries are often marketed to stress this particular feature of the game design. The explanation of lottery participation by the non-pecuniary satisfaction derived is compatible with empirical evidence that lottery participation takes place throughout the distribution of income (Walker, 1998:365).

Walker (1998:363-364) argues that, in spite of risk aversion and the low payout rate, players purchase lottery tickets because they derive satisfaction from participating, i.e. "non-pecuniary pleasure". Therefore players participate regularly, spending small amounts of money so that the satisfaction of the gamble outweighs the monetary cost. Players generally play in repeated draws, purchasing only few tickets in any one draw and can be thought of as risk neutral for this reason. The chief determinant of the number of tickets sold is game design. It is believed that these players are rational, playing the lottery for entertainment rather than in pursuit of an elusive financial gain. These rational players perceive the true odds and therefore lottery can ultimately bring about a social gain in terms of its pure entertainment value.

A gamble allows a consumer to obtain 'something for nothing,' which means that there is pleasure in gaining income without working for it. It is based on two fundamental concepts in economics. The first is that additional income increases utility at a diminishing rate. Secondly, the scarcity of economic resources means that for the average consumer additional income is costly to acquire. Therefore a prominent feature of a gamble is not that it allows the consumer to acquire additional income but that it means gaining additional income without working for it (Nyman, 2004: 1).

Rubner (1966:46-48) provides five explanations for the irrational act of gambling. The first reason given is that of the ‘pleasure of uncertainty’ in which the excitement of anticipating a windfall gives value to gambling. Secondly, there is entertainment value in gambling through either the place where bets are made or in watching for the results. In the case of the national lottery, the television program may provide this type of incentive. The third reason given is ‘charitable elation.’ Bettors are able to soothe their consciences for gambling when the proceeds go to charitable purposes. Fourthly, there is ‘psychological satisfaction’ in gambling. This can take the form of social admiration earned by the winner or even self-satisfaction from winning. The final reason given is actually attaining a large financial prize.

Kearney(2002) examines the consequences of gambling on the lottery for consumers. The micro-level gambling data on the US lotteries shows that lottery spending does not substitute for other forms of gambling. In addition, demand for lottery products has a positive relationship with the expected value of the gamble. This indicates that consumers of lottery products are not uninformed when making their purchase decisions. Instead they are partially or possibly fully informed on the wealth value of a bet.

*Cohen (2001) s*hows that playing the lottery is not economically irrational and uninformed. Instead, the purchase of lottery tickets is considered a valuable input in “creating a sense of open-minded possibility.” The lottery presents the individual with the possibility of escaping their current life through the acquisition of great wealth. Therefore playing the lottery is viewed as a part of rational utility maximization.

Walker (1998: 364) and Cook & Clotfelter (1990:101) also argue that the marketing of the lottery leads to misperception of the odds, which means that bettors are not aware of the true chances of winning the jackpot prize. Cook & Clotfelter (1990:102) add that the effect of lottery advertising is to create an impression that winning is easy.

In the survey undertaken on the US lotteries, it was found that when the advertisements gave information on the probabilities, they were the probabilities of winning any prize and not the jackpot prize. The survey found that amounts of prizes (especially the jackpot) were mentioned far more often than the probabilities in the advertisements. The survey also found that there exists a subversive message in the advertising that lottery success lies in picking the correct numbers (Cook & Clotfelter, 1990:102).

The marketing and game design of the lottery may encourage misperception of the odds. Lotteries generally feature smaller prizes for short-odds events such as matching three of the six numbers drawn. The probability of matching three (1 in 57 in a 6/49 design) is much higher than the probability of matching all six numbers. However many players may learn of someone who won this type of prize and may even win this themselves in a short period of time with a modest level of participation. These players may not even realise the vast difference in the odds of winning in these different prize categories (Walker, 1998:366).

Lotteries allow players to choose their own number combinations. This increases the demand for the lottery by giving players an 'illusion of control' which is the perceived ability to improve the odds in their favour by choosing the correct number combination. As the winning numbers are randomly generated, the decision for players to choose their own number combination indicates irrationality on their part. However, this feature also shows that the non-pecuniary aspect of lottery play is important as players can generate greater satisfaction from the conscious selection of number combinations (Walker, 1998:366).

The conscious selection of number combinations is highlighted by Thaler and Ziemba (1988:168-172) who argue that there are two features that make the lottery interesting for the rational investor. The first is that some numbers are more popular than others and the second is that when the jackpot prize is not won, the prize is carried over to the next week which means that the prize can be enormous. It is this prospect of winning a huge jackpot that is the primary driving force behind the interest and sales of lottery tickets. In economic theory, the existence of popular and unpopular numbers would appear to imply that no one should choose the more popular lottery numbers. However, allowing players to choose their own numbers provides them with an "illusion of control." Therefore, even when the game is pure chance, players are more confident of their chances of winning when they feel they can influence providence.

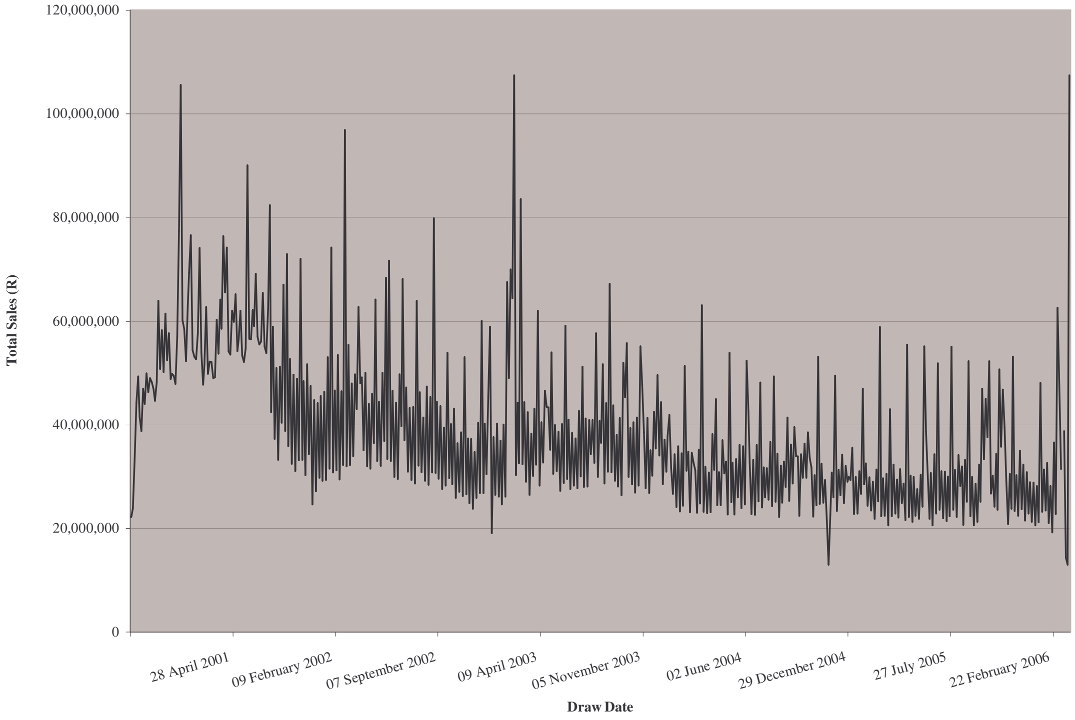
The model employed by Forrest, Simmons, and Chesters (2002:494-495) is based on the assumption that sales are related to the total prize payout, instead of the computed expected value of the prize associated with the purchase of a ticket. They find that jackpot considerations exert an influence over and above that of variations in lottery design. The most important motivation found is the headline prize figure. In addition, policy makers ought to guarantee the jackpot level should they wish to increase the take-out rate. In addition, should there be motivation to change the design of the lottery to a game of lower odds (such as from 6/49 to 5/53 or 6/51), then there will be an increase in the incidence of rollovers, creating greater headline prizes and ultimately increasing demand for lottery tickets.

7. The Effective Price Model – Methodology

The Effective Price Model has been used by Forrest, Gulley & Simmons (2000), Gulley and Scott (1993) and Scoggins (1995). The model will be modified slightly to accommodate characteristics particular to the South African lottery.

In order to establish whether the revenue collected from the national lottery is being maximised, data from the National Lottery which includes sales figures and prize payouts for each lottery division is used together with the model used by Forest, Gulley and Simmons (2000) on the UK lottery. In the model for the South African National lottery data for six years (from the first lottery on 11 March 2000 to 11 March 2006) is available from the South African National Lottery and will be used. The sample consists of 545 lottery draws. Figure 1 below shows the Sales data for the first six years of the lottery. After an initial leap, the lottery has settled into a fairly stable pattern of sales, with the exception of large guaranteed jackpots and rollovers which cause large spikes in the sales figures.

Figure 1 Sales of Lottery Tickets (11 March 2000 – 11 March 2006)



The model used by Forest, Gulley and Simmons (2000) provides an equation for the effective price of the lottery which is the actual ticket price (which is R2.50 in South Africa) less the expected value of the ticket. Intuitively, the expected value of the ticket is probability of winning multiplied by the jackpot multiplied by the expected share of jackpot if win i.e. *(probability of winning)* × *(value of the jackpot)* × *(expected share of a jackpot if won)* (Cook and Clotfelter, 1991).

Forest, Gulley and Simmons (2000) use the following formula for the effective price of the ticket for each lottery draw:

$$P = 1 - \left(\left(\frac{1}{Q} \right) (R + jQ)\left(1 - e^{-Qp}\right) + \sum EVs \right) \qquad \mathbf{1}$$

where P is effective price of the ticket, Q number (and value in pounds) of tickets sold in the draw, R is the amount added to the prize fund from a prior rollover or an ad hoc payment by the lottery management company, j is the proportion of the revenue from a draw that is allocated to the jackpot fund, p is the probability of holding the winning ticket and $\sum EVs$ is the sum of the expected value of the smaller prizes, which are calculated in a similar way.

The model adapted for the South African National Lottery is as follows:

$$P = 2.5 - \left(\left(\frac{1}{N} \right) (R + jQ)\left(1 - e^{-Np}\right) + \sum EVs \right) \qquad \mathbf{2}$$

Where R2.50 is the face price of a lottery ticket, P is effective price of the ticket, N is the number of tickets sold, Q value in Rands of tickets sold in the draw, R is the amount added to the prize fund from a prior rollover or an ad hoc payment by the lottery management company, j is the proportion of the revenue from a draw that is allocated to the jackpot fund, p is the probability of any ticket winning the jackpot, $\sum EVs$ is the expected value of the smaller prizes (Adapted from (Forrest, Gulley & Simmons, 2000))

The probability of a single combination of six figures winning a share in the jackpot is $\left(\frac{49!}{43!6!} \right)^{-1} = \frac{1}{13{,}989{,}816}$. The odds and probabilities of winning prizes in the different division are shown in Table 2 which implies that $\sum probability = 1.99 \times 10^{-2}$.

Table 2 Odds and Probabilities of Winning in the Different Divisions of the Lottery

Division	Numbers[1] Matched	Odds[2]	Probability[3]	% of Prize Pool Allocated to Division[4]
1	6	1 in 13,983,816	$7.15\text{x}10^{-8}$	18.25
2	5 + bonus	1 in 2,330,636	$4.29\text{x}10^{-7}$	4
3	5	1 in 54,201	$1.84\text{x}10^{-5}$	9
4	4 + bonus	1 in 22,197	$4.51\text{x}10^{-5}$	5
5	4	1 in 1,032	$9.69\text{x}10^{-4}$	16.75
6	3 + bonus	1 in 812	$1.23\text{x}10^{-3}$	11
7	3	1 in 57	$1.77\text{x}10^{-2}$	36

Sources: 1 The South African National Lottery;
2 Calculated using the formula n!/m!(n-m)! where is the number of possible choices (e.g. n=49) and m is the number to be matched (e.g. m=6) (Walker, 1998:368)
3 Probability = 1/odds
4 Uthingo Management (Note that this percentage is after VAT (Louw, 2002: 3))

Figure 2 Preliminary Graph - The Demand for Lottery Tickets (based on Effective Price)

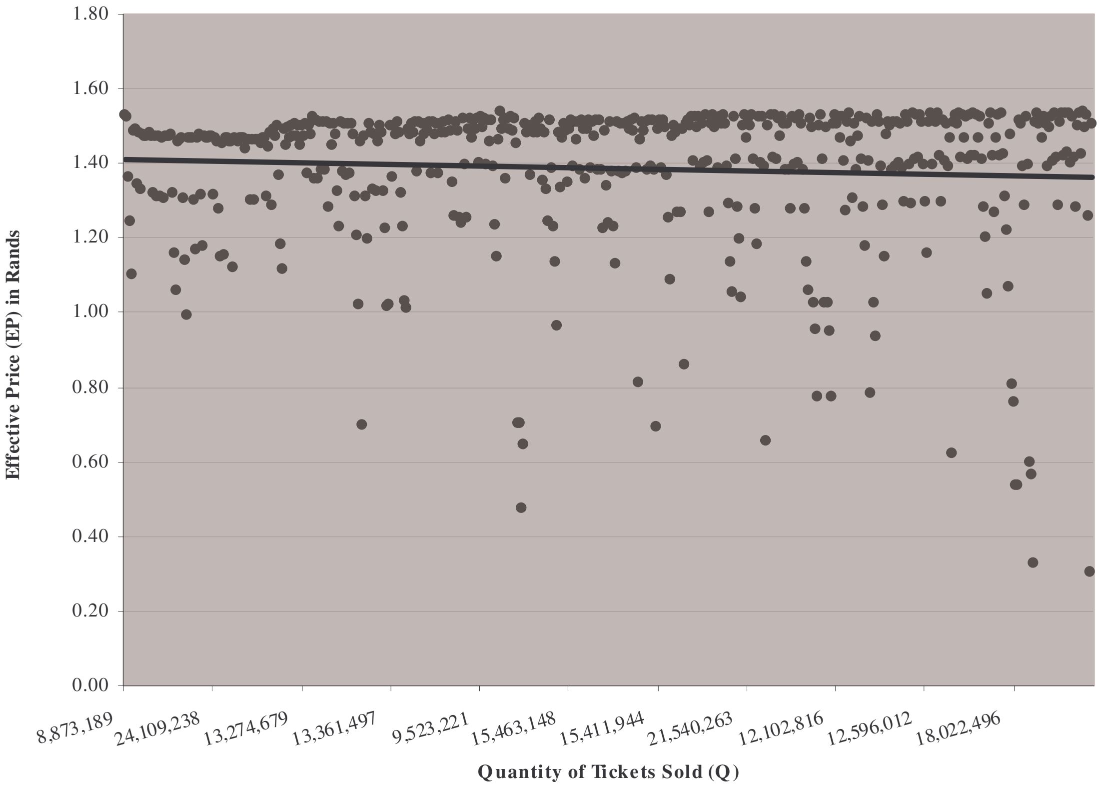


Figure 2 above shows a preliminary demand curve based on effective price only. There is a downward slope (as shown by the fitted line). The graph also shows that the effective price does not vary greatly for "normal" lottery draws in which there are no rollovers. The "outliers" (such as those below R1.20) occur when there are multiple rollovers and large guaranteed jackpots. These are necessary for the analysis of the demand function as guaranteed jackpots and rollovers (also multiple rollovers) are events that will continue to occur. The mean of effective price is R1.39 and its standard deviation is R0.20. The maximum effective price is fairly close to the mean at R1.54 while the minimum price is at outlier at R0.30. The number of tickets sold in the South African lottery varied from 5,202,426 to 42,988,236. The mean number of tickets sold was 15,520,657 and the standard deviation was 5,744,126.

The regression model to be used is two stage least squares since the effective price is not exogenous. The first stage estimates effective price based on the information that is publicly available (such as rollovers, guaranteed jackpots and estimated prize pool). The second stage is used to estimate number of tickets sold as a function of the effective price and dummy variables used to capture features such as the weekday of the draw and new draw features (Adapted from (Forrest, Gulley and Simmons, 2000)). A trend term will be included to capture the effects of the initial leap in the sales data. Meiers (1996) found that in the US, state lotteries had an initial experience of gaining momentum which was then followed by player boredom and disillusionment. Forrest, Gulley and Simmons (2000) found similar evidence of consumer satiation after a number of draws of the UK lottery. Time series tests will also be used to test for stationarity. Thereafter, the elasticity of demand with respect to effective price is calculated to determine whether or not revenue is maximised.

8. Results

8.1. Specifications of Equations[8]

Stage 1

$$EFFECTIVE \quad PRICE \quad (LEP)$$
$$= f\begin{pmatrix} CONSTANT; & TREND; & TREND2R100; & LROLLOVER; & LROLLOVER2; \\ & WEDDUM; & GTEEDUM; & ROLL4DUM; & LOTTOPLUS \end{pmatrix}$$

Stage 2

$$NUMBER \quad OF \quad TICKETS \quad SOLD \quad (LQ)$$
$$= g\begin{pmatrix} CONSTANT; & LQ_{-1}; & LQ_{-2}; & EXPECTEDPRICE; & TREND; \\ TREND2R100; & WEDDUM; & GTEEDUM; & ROLL4DUM; & LOTTOPLUS \end{pmatrix}$$

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[8] Adapted for South African lottery from Forrest, Gulley and Simmons (2000:857-858)

Logged variables are used for effective price, expected (predicted) price, sales and the size of rollovers. This is because the monotonic transformation of a demand function (such as that of a logarithm) exhibits constant elasticity (See Appendix 1). Without this transformation the elasticity of demand would change along the curve (Klein, 2002:190-191).

In the above equations, EP is the log of the effective price of a lottery ticket. Trend variables (TREND and TREND2R100) have been included to account for player boredom or disillusionment, as used by Forrest, Gulley and Simmons (2000:857). LROLLOVER is the log of the number of Rands carried over from the previous lottery draw/s. It has been included as it has a direct impact on the jackpot size. Non-linearity is allowed for with the inclusion of its square. The dummy variable WEDDUM has been included to show the impact of a Wednesday draw rather than a Saturday draw. Saturday draws are considered more popular with higher ticket sales than those on Wednesdays Forrest, Gulley and Simmons (2000:857). Another dummy variable GTEEDUM was included to show the effect of a jackpot that is guaranteed at a specific level by the lottery management company. The special case of a fourth rollover in which the funds will be distributed throughout all the prize categories if the jackpot is not won is represented by ROLL4DUM, while LOTTOPLUS indicates the start of an additional game to the lottery called Lotto plus. Lotto plus is an add-on to the lottery game in which players pay an additional rand on their R2.50 ticket to participate in a second draw which has no rollovers and lower prizes (South African National Lottery, 2006). A summary table of the variables and how they were calculated is provided in Appendix 2.

The dependent variable in the second stage (LQ) is the log of the number of tickets sold. Two lags on this variable were employed in the method of experimentation used by Forrest, Gulley and Simmons (2000:857). Additional lags failed to attract statistically significant coefficients. The expected price variable (EXPECTEDPRICE) is predicted from the first stage of the regression.

8.2. Results of Two Stage Least Squares Regression

Table 3 First Stage OLS Regression Dependent Variable is Log Effective Price (LEP)

Variable	*Coefficient*
TREND	-0.000
	(0.000)
TREND2R100	-0.000**
	(0.000)
LROLLOVER	0.007*
	(0.000)
LROLLOVER2	-0.009*
	(0.000)
WEDDUM	0.016**
	(0.007)
GTEEDUM	0.019
	(0.018)
ROLL4DUM	-0.025
	(0.025)
LOTTOPLUS	0.037*
	(0.013)
CONSTANT	2.328*
	(0.055)
Observations	545
R-squared	0.844

Standard errors in parentheses
+ significant at 10%; ** significant at 5%; * significant at 1%

The LROLLOVER and LROLLOVER2 variables are significant. The LROLLOVER variable is positive indicating the rollovers increase the effective price, while LROLLOVER2 is negative indicating that the impact of rollover increases the effective price at a negative rate. The turning point at which a rollover has a maximum contribution on the effective price occurs at R49.55[9] which is a very small percentage of an 'average' rollover. Therefore the figure is effectively zero and the increasing size of the rollover pushes down the price of lottery tickets throughout the range of feasible (non-negative) LROLLOVER values. The positive sign on LROLLOVER captures this curvature of the relationship (Farrell, Gulley and Simmons, 2000:860). WEDDUM is significant and positive, which implies that a Wednesday lottery has a higher effective price than a Saturday lottery, which is predicted by Forrest, Gulley and Simmons (2000:857). Neither GTEEDUM nor ROLL4DUM are significant in the model. LOTTOPLUS is significant and positive indicating that the introduction of the lotto plus game has increased the effective price.

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[9] Calculated by setting the first derivative with respect to LROLLOVER to zero (first order condition)

The Breusch-Pagan test ruled out heteroskedasticity in the model. The Portmanteau test ruled out autocorrelation in the regressions. The R^2 indicates that in the model 84% of the dependent variable is explained by the independent variables.

Table 4 Second Stage OLS Regression Dependent Variable is Log Number of Tickets Sold

Variables	*Coefficients*
EPHAT	-0.603*
	(0.040)
LQ1	0.214*
	(0.031)
LQ2	0.092*
	(0.033)
TREND	0.000
	(0.000)
TREND2R100	-0.000*
	(0.000)
WEDDUM	-0.433*
	(0.024)
GTEEDUM	0.341*
	(0.035)
ROLL4DUM	0.006
	(0.048)
LOTTOPLUS	-0.055**
	(0.026)
CONSTANT	11.953*
	(0.616)
Observations	543
R-squared	0.828

Standard errors in parentheses
** significant at 5%; * significant at 1%

The coefficient of EPHAT is negative and significant, indicating the downward slope of the demand curve and that an increase in the expected price will decrease lottery sales. The linear TREND variable is not significant, although the non-linear TREND2R100 variable is. As the TREND variable is not significant, it would appear that external effects such as inflation have not had a great effect on the model that would correspond to a linear trend in the series. The significance and negative sign of the TREND2R100 variable indicates that there is a non-linear (but decreasing) trend in the series. This is likely due to initial spike in sales shown in Figure 1. The negative coefficient of TREND2R100 indicates a turning point in demand for lottery tickets. In the model the turning point is at draw 45 which would be about 10 months into the lottery at which point there is an indication that there is consumer satiation or boredom, as expected (Farrell, Gulley and Simmons, 2000:860).

WEDDUM is significant and negative, which implies that a Wednesday lottery has lower ticket sales than a Saturday lottery. GTEEDUM is significant and positive in both models indicating that a guaranteed lottery sells more tickets. ROLL4DUM is not significant in either model indicating that the fourth (and final) rollover does not impact demand. LOTTOPLUS is significant and negative indicating that the introduction of the lotto plus game has actually decreased lottery sales. This may be due to the additional cost of entering the lotto plus draw being lower than that of an additional ticket. Therefore players may choose to enter the lotto plus draw rather than purchase additional tickets. The steady-state long-run elasticity of demand with respect to the effective price is -0.869[10] which is more inelastic than the revenue optimising elasticity of -1.

The Breusch-Pagan test ruled out heteroskedasticity and the Portmanteau test ruled out autocorrelation in both models. Two observations are lost due to the lagged LQ variables (LQ1 and LQ2). The R^2 indicates that in the model 83% of the dependent variable is explained by the independent variables.

The model employed by Forrest, Gulley and Simmons (2000:859) employed time series tests to avoid charges of spurious regression. Therefore time series tests were also carried out on the data from the South African National Lottery (see Appendix 3). Dickey-Fuller and augmented Dickey-Fuller Tests (two lags) were carried out to test for stationarity of number of tickets sold (Q), effective price and rollover. As was the case in the data for the UK lottery that after the game started an additional Wednesday draw was introduced; so to is the case in South Africa. Therefore the unit root tests were carried out on the data before the introduction of the additional draws and then afterwards. The null hypothesis of a unit root was rejected in each instance and therefore the continuous variables are considered stationary.

9. Alternative Lottery Design[11]

The results of the simulations on the data from the South African National Lottery where design changes were made are shown in

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[10] Coefficient of ephat/[1-(sum of coefficients of lq_is)] (Forrest, Gulley and Simmons, 2000)

[11] Simulation Results shown in Appendix 4

Table 5 below. The current design of 6 numbers from 49 is shown as a benchmark. Two types of changes were made, firstly to the actual lottery design which alters the odds of winning and secondly to the take-out rate which affects the prize pool directly.

Table 5 Simulation Results

Game Design	Coefficient of Effective Price	Elasticity of Demand	Minimum Effective Price	Maximum Effective Price	Effective Price Mean	Effective Price Standard Deviation
6 from 49[1]	*-0.603**	*-0.869*	*R0.30*	*R1.54*	*R1.39*	*R0.20*
6 from 51	-0.735*	-1.06	R0.46	R1.56	R1.42	R0.17
6 from 42	-0.366*	-0.526	-R0.19	R1.47	R1.29	R0.27
t = 45	-0.537*	-0.772	R0.20	R1.44	R1.29	R0.20
t = 40	-0.467*	-0.668	R0.10	R1.34	R1.19	R0.20

Note:
1. Current lottery design
* Significant at 1%

In altering the design of the lottery the odds of winning change considerably. Changing the design from 6 from 49 to the 6 from 51 design reduces the probability of winning the jackpot prize from 1 in 14 million to 1 in 18 million. However, changing the design to 6 from 42 improves the odds of winning the jackpot to 1 in 5 million. The lower prize categories are also affected. While the current game design gives players a 1 in 57 chance of winning the lowest prize category, the 6 from 51 game reduces this to 1 in 73 and the 6 from 42 game improves these odds to 1 in 21. This is shown in Table 6.

Table 6 Implications of Alternative Lottery Design (Changes to *N*)

Game Design	Odds of Winning Jackpot[1]	Odds of Winning Lowest Prize Category – Match 3 Numbers[1]
6 from 49[2]	1 in 13,983,816	1 in 57
6 from 51	1 in 18,009,460	1 in 73
6 from 42	1in 5,245,786	1 in 21

Source:
1. Calculated using the formula n!/m!(n-m)! where n is the number of possible choices (e.g. n=49) and m is the number to be matched (e.g. m=6) (Walker, 1998:368)
2. Current lottery design.

Simulations indicate that changing the design of the lottery has a greater effect on maximizing revenue than simply changing the take-out rate. Reducing the take-out rate increases the prize pool which implies that greater jackpots. However, when the take-out rate is reduced to 45% of the total sales rather than the 50% it is currently at, the elasticity of demand with respect to effective price actually becomes more inelastic and further away from revenue maximizing -1. When the take-out rate is further reduced to 40%, this problem is compounded.

The simulations show that changing the design of the game has a greater effect on the elasticity of demand. When the odds of winning are improved in the player's favour to a 6 from 42 game, the demand function is more inelastic with an elasticity of -0.525 which is significantly different from 1. If the odds of winning are reduced to a game of 6 from 51, the elasticity of demand with respect to effective price is -1.06 which is not significantly different to 1. This implies that when the odds of winning are lower, and there is a greater chance of a rollover occurring, that the revenue from the lottery will be maximized.

The 6 from 51 lottery design indicates that revenue will be maximised as the demand function is unit elastic. The design change increases the minimum, maximum and mean effective price while actually lowering the standard deviation. This means that there is lower variability of the effective prices as they are more clustered around the mean than for the simulations with a larger standard deviation (Clarke and Cooke, 1997:43:44).

10. Conclusion and Policy Recommendations

One of the goals set out for the National Lottery Board is to maximize revenues. An econometric model is employed to achieve this and indicates that demand for the South African National Lottery is inelastic with an elasticity of demand with respect to effective price equal to -0.869. This is significantly different from the revenue maximising level of -1.

In comparison to studies from other countries, the elasticity of demand for the South African lottery is marginally better than the Canadian lottery for which Yu (2004) finds that the price elasticity of demand is -0.67. Numerous studies, including Forrest, Gulley & Simmons (2000), Forrest, Simmons & Chesters (2002) and Walker (1998), find that the revenue from the UK lottery is maximized. The study by Gulley and Scott (1993) on four US state lotteries finds that only in two cases, Kentucky and Ohio, the games are structured to maximize revenue. In the remaining two cases, the authors find that changing the probabilities of winning can be changed to meet this goal, as is potentially the case in South Africa.

In South Africa, it would appear that adjusting the model to a 6 from 51 game may improve revenue maximization by increasing the minimum, maximum and mean effective prices and reducing the standard deviation. Through this alteration of game design the National Lottery Board can ensure that it will continue to meet its goal of revenue maximisation and thereby maximise the funds available to "good causes".

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Appendix 1 Monotonic Transformation of Demand Function[12]

Given the demand function:

$$q = \alpha - \beta p$$

The elasticity of the demand function with respect to price is:

$$\varepsilon_{q,p} = \frac{dq}{dp} \cdot \frac{p}{q} = -\beta \frac{p}{q}$$

Therefore, as p and q change in value, so too does the elasticity of demand with respect to price.

The monotonic transformation (logarithm) of this function:

$$\ln(Q) = \ln(\alpha) - \beta \ln(P)$$

Taking the differential of this log-linear demand function:

$$\frac{d\ln(Q)}{dQ} dQ = -\beta \frac{d\ln(P)}{dP} dP$$

Manipulating yields:

$$\frac{1}{Q} dQ = -\beta \frac{1}{P} dP$$

Or:

$$\frac{dQ/Q}{dP/P} = -\beta$$

Therefore the monotonic transformation of the demand function has constant elasticity -β.

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[12] Klein (1997:189-191)

Appendix 2 Variables

Variable	***Description***
TREND	Trend term equal to the draw number
TREND2R100	Square of trend term divided by 100.
LROLLOVER	Natural Logarithm of rollover amount
LROLLOVER2	Square of Natural Logarithm of rollover amount
WEDDUM	Dummy variable assigned the value of 1 if the draw took place on Wednesday
GTEEDUM	Dummy variable assigned value of 1 if the draw took place with a lottery jackpot guaranteed by the lottery management company
ROLL4DUM	Dummy variable assigned the value of 1 if the draw was the fourth rollover
LOTTOPLUS	Dummy variable to assigned the value of 1 for each draw in which there was an additional lottery plus game
EPHAT	Effective price predicted from the first stage of the draw, used as a dependent variable in the second stage
LQ1	Log of the number of tickets sold, lagged for one time period.
LQ2	Log of the number of tickets sold, lagged for two time periods.

Appendix 3 Time Series Test Results – Dickey-Fuller and Augmented Dickey-Fuller (two lags)

Variable	*Lags*	*Before (B) /After (A) Wednesday Draw*	*Test Statistic*	*1% Critical Value*	*Number of Observations*
Q	0	B	-5.401	-3.537	81
Q	0	A	-23.069	-3.443	462
Q	2	B	-4.455	-3.539	79
Q	2	A	-9.333	-3.443	460
EP	0	B	-7.645	-3.537	81
EP	0	A	-14.949	-3.443	462
EP	2	B	-6.402	-3.539	79
EP	2	A	-10.791	-3.443	460
ROLLOVER	0	B	-7.537	-3.537	81
ROLLOVER	0	A	-14.393	-3.443	462
ROLLOVER	2	B	-6.122	-3.539	79
ROLLOVER	2	A	-10.627	-3.443	460

Note: Q is number of tickets sold, and EP is the Effective Price

Appendix 4 Simulation Regression Results

Stage 1

	6from51	*6from42*	*t=45*	*t=40*
trend	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
trend2r100	-0.000	-0.000	-0.000**	-0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
lrollover	0.006*	0.012*	0.009*	0.010*
	(0.000)	(0.001)	(0.001)	(0.001)
lrollover2	-0.008*	-0.016*	-0.011*	-0.013*
	(0.000)	(0.001)	(0.000)	(0.000)
weddum	0.019*	-0.016	0.019**	0.023**
	(0.005)	(0.015)	(0.009)	(0.012)
gteedum	0.006	0.063+	0.021	0.029
	(0.013)	(0.038)	(0.022)	(0.030)
roll4dum	-0.022	0.146*	-0.032	-0.047
	(0.018)	(0.054)	(0.031)	(0.040)
quickpick	0.023**	0.015	0.035**	0.048**
	(0.010)	(0.027)	(0.016)	(0.021)
Constant	1.970*	3.599*	2.518*	2.811*
	(0.040)	(0.116)	(0.068)	(0.089)
Observations	545	543[13]	545	545
R-squared	0.871	0.763	0.822	0.780

Standard errors in parentheses
+ significant at 10%; ** significant at 5%; * significant at 1%

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[13] Two observations dropped due to the logarithm of negative effective prices on draws 512 and 544 in which there were large guaranteed jackpots that rolled over to these two draws.

Stage 2

	6from51	*6from42*	*t=45*	*t=40*
ep51hat	-0.735*			
	(0.048)			
ep42hat		-0.366*		
		(0.024)		
ept45hat			-0.537*	
			(0.035)	
ept40hat				-0.467*
				(0.031)
lq1	0.215*	0.213*	0.211*	0.209*
	(0.031)	(0.031)	(0.031)	(0.032)
lq2	0.092*	0.092*	0.092*	0.092*
	(0.033)	(0.033)	(0.033)	(0.033)
trend	0.000	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
trend2r100	-0.000*	-0.000*	-0.000*	-0.000*
	(0.000)	(0.000)	(0.000)	(0.000)
weddum	-0.429*	-0.449*	-0.432*	-0.433*
	(0.024)	(0.024)	(0.024)	(0.024)
gteedum	0.335*	0.353*	0.341*	0.342*
	(0.035)	(0.035)	(0.035)	(0.035)
roll4dum	0.005	0.074	0.003	-0.003
	(0.048)	(0.047)	(0.048)	(0.048)
lottoplus	-0.055**	-0.068*	-0.052**	-0.058**
	(0.026)	(0.026)	(0.026)	(0.026)
Constant	11.979*	11.879*	11.929*	11.917*
	(0.616)	(0.616)	(0.617)	(0.617)
Observations	543	543	543	543
R-squared	0.828	0.828	0.828	0.828

Standard errors in parentheses
+ significant at 10%; ** significant at 5%; * significant at 1%