14 Is the UK National Lottery experiencing lottery fatigue?

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In this chapter recent innovations to the UK National Lottery on-line lotto game are considered. We suggest that innovations are necessary to prevent players from becoming tired of the game and therefore to keep sales healthy. We also examine how the lottery operators have tried to stimulate the wider betting and gaming market and maintain interest in the on-line game, through the introduction of periphery games and products. In summary, we conclude that the UK lottery market *has* been stimulated and expanded in line with all the available evidence from lotteries elsewhere in the world.

Introduction

This chapter addresses the concept of lottery fatigue in the context of the UK National Lottery games, which were launched at the end of 1994. Creigh-Tyte (1997) provides an overview of the policy related to the UK National Lottery's introduction and Creigh-Tyte and Farrell (1998) give an initial overview of economic issues.

Lottery fatigue is the phenomenon experienced by many state/national lotteries whereby players have been found to tire of lottery games (reflected in a downward trend in sales) and so require continual stimulation to entice them to play (see Clotfelter and Cook, 1990, for a discussion of the US experience up to the late 1980s). This is the usual explanation given for the diversification of lottery products. As the US National Gambling Impact Study Commission (1999) comments: 'Revenues typically expand dramatically after the lottery's introduction, then level off, and even begin to decline. This "boredom" factor has led to the constant introduction of new games to maintain or increase revenues.'

In this chapter we will review the latest facts and figures pertaining to the sale of National Lottery games and the recent economic research on the lottery games. To date there has been no single empirical analysis of the impact of the launch of peripheral games on the main on-line game, so we draw what evidence we can from the available research.

We begin by looking at the performance of the on-line game since its launch in November 1994. Then we look at the Thunderball game, consider the impact of special one-off draws and give an introduction to the latest lottery game, Lottery

Extra. A brief introduction to the market for scratch cards is then provided, followed by the conclusions.

The on-line game

The on-line game is the central product in the National Lottery range. It was launched in November 1994 and has been running continually (on a once–weekly and more recently on a twice–weekly basis) ever since. Given that 2001 was the final year of operations under the initial license, it is an appropriate time to review the game's performance. The on-line game is the largest National Lottery product in terms of weekly sales figures, around £70–75 million in a normal week (i.e. a week with no rollover draws). Figure 14.1 shows the weekly sales figures by draw from the game's launch until 31 March, 2002. The spikes in the distribution represent weeks that contained at least one rollover or superdraw, and draw 117 is the first of the midweek draws. Whilst sales per draw have fallen since the introduction of the midweek draw, the weekly sales figures are higher than when there was just a Saturday single draw.

Conscious selection

One way to ensure the long-term success of the on-line game is to encourage players to use systems to select their numbers or to play the same number every week. This results in players getting locked into the game and makes them more likely to play regularly. Evidence that players do behave in this way can be seen from the startling feature of the on-line game that it exhibits many more rollovers than could have been generated by statistical chance, as can be seen from Figure 14.1. This can only arise from individuals choosing the numbers on the lottery tickets they buy in

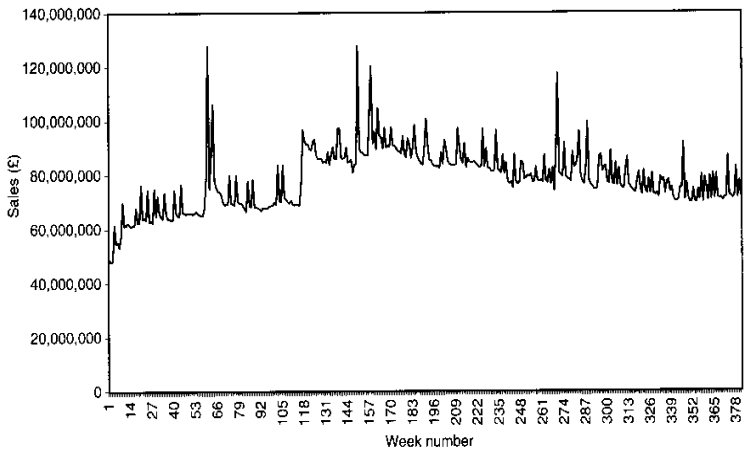

Figure 14.1 National lottery on-line weekly ticket sales.

a non-uniform way.[1] That is, many more individuals choose the same combinations of numbers than would occur by chance if individuals selected their numbers uniformly. The result is that the probability distribution of numbers chosen does not follow a uniform distribution, whereby the probability of each number being chosen is one in forty-nine.

Thus, the tickets sold cover a smaller set of possible combinations than would have been the case had individuals chosen their numbers in a uniform way – there will be more occasions when there are no jackpot prize winners.[2] The implications of this non-uniformity and (unintentional) co-ordination between players are important. If players realise that such non-uniformity is occurring then they will expect the return to holding a ticket to be smaller (for any given size of rollover) than it would be if individuals were choosing their numbers uniformly. Essentially, the non-uniformity increases the probability that there will be a rollover and this changes the behaviour of potential ticket purchasers (provided they are aware of it). Haigh (1996) presents evidence of conscious selection among players and Farrell *et al.* (2000a) show that whilst conscious selection can be detected it has little impact on estimates of the price elasticity of demand for lottery tickets.

In contrast most lotteries also offer a random number selector that players can use to pick their numbers. In the UK this is called 'Lucky Dip', but it is usually called 'Quick Pick' elsewhere. This is not, however, normally introduced until players have had a chance to develop a system for selecting their numbers and so it may simply attract marginal players who do not want to invest much time in the purchase of a ticket or those that have set numbers but who also try a Lucky Dip ticket. Simon (1999) argues that this is one reason why Camelot may have delayed introducing the Lucky Dip facility for a year, to 'entrap' players who feel they cannot stop buying tickets with a certain number combination because they have already played it for a long period. In the case of the UK game, the Lucky Dip was not introduced until March 1996 and represents the first innovation in the game intended to regenerate interest from players who might have been losing interest. It represents a new way for players to play the lottery.[3]

The importance of rollovers

Rollovers are good for the game stake for two reasons. First, they attract high levels of sales and second, successive draws also see increased sales. Farrell *et al.* (2000b) show that the effect of a rollover on sales lasts for up to five draws following the rollover. They use a dynamic model specification to estimate both the long- and short-run elasticity of the demand for tickets. The short-run elasticity simply tells us how demand changes in a single period following the price change, whereas the long-run elasticity tells us the dynamic response of demand to the price change after all responses and lags have worked through the system. The size of the long-run elasticity is of interest as it can signal addiction among players. The general hypothesis is that the demand for an addictive good will be higher the higher demand was in the recent past.[4] It is found that there is evidence of addiction among lottery players; the short-run (static) elasticity is smaller than the long-run

(dynamic) elasticity. The long-run elasticity takes account of the fact that price changes have more than a single period effect and is found to be approximately unity. Moreover since rollovers boost sales they may be a cause of addiction. Sales following a rollover are higher than the level of sales prior to the rollover and this is known in the industry as the 'halo' effect.

Thus, rollovers have a greater impact than just increasing sales in the week in which they occur; there is a knock-on effect in the following draws' sales. Players are attracted by the rollover and either new players enter or existing players play more, or both, and after the rollover those who entered remain and those who increased their purchases continue to purchase at the higher level. Shapira and Venezia (1992) find that demand for the Israeli lotto increased in rollover weeks, and this added enthusiasm for the lotto carried over to the following week's draw. In the UK, Farrell *et al.* (2000b) show that the halo decays within 5–6 draws by which point sales have returned to their post rollover level (Figure 14.2). However, a close succession of rollovers would have the effect of causing sales to ratchet upwards. The effect of rollovers on the game is, therefore, very important and complex. Were it not for the presence of rollovers, sales would have a strong negative trend. Players would soon tire of the game, experiencing lottery fatigue. Estimates by Farrell *et al.* (2000b) suggest that the half-life of the UK game would have been 150 draws (if there were no rollovers). That is sales would halve every three years (of weekly draws) if it was not for the presence of rollovers in the game. Mikesell (1994) found that in the case of US lotteries, sales tend to have peaked after about ten years of operation. Rollovers are therefore essential for stimulating interest in the game and this is reflected in the amount of advertising that the operators give to rollover draws and the fact that lottery operators even create artificial rollovers in the form of 'superdraws'.

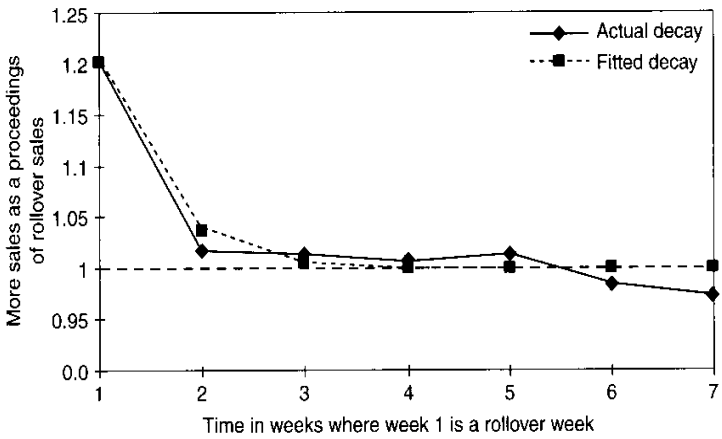

Figure 14.2 The halo effect for the case of the UK National Lottery.

The choice of take-out rate

The 'price' elasticity of demand for lottery tickets shows how demand varies with the expected value of the return from a ticket and it is this elasticity that is relevant in assessing the merits of the design of the lottery and the attractiveness of potential reforms to the design. That is, it tells us how demand would vary in response to changes in the design of the lottery – in particular, the tax rate on the lottery or the nature of the prizes. Lotteries are, typically, operated to maximise the resulting tax (or 'good causes') revenue that is typically a fixed proportion of sales. Thus, knowledge of the price elasticity is central to choosing an appropriate take-out rate (see Appendix).

The methodology to estimate the price elasticity of demand for lottery tickets is relatively simple. Price variation is derived from the fact that lottery tickets are a better bet in rollover than in normal weeks. The Appendix to this chapter shows how the expected value of a lottery ticket is derived. Previous work (outside of the UK) has attempted to estimate this elasticity by looking at how demand varies in response to actual changes in lottery design across time or differences across states.[5] However, these have been few and far between and limited attempts have been made to control for other changes and differences that may have occurred. An important exception is Clotfelter and Cook (1990), who estimate the elasticity of sales with respect to the expected value of holding a ticket.[6] The current estimates for the UK also exploit the changes in the return to a ticket induced by 'rollovers' that occurs when the major prize (the jackpot) in one draw is not won and gets added to the jackpot prize pool for the subsequent draw. This changes the expected return to a ticket in a very specific way. In particular, the expected return rises in a way that cannot be arbitraged away by the behaviour of agents.

The elasticity generated by this method is published in Farrell *et al.* (2000) and Forrest *et al.* (2000). Farrell *et al.* report estimates of -1.05 (in the short run) and -1.55 (in the long run).[7] Gulley and Scott (1989) report an estimate of -1.03.[8] Although Europe Economics (2000) argues that 'studies using American data typically find a lower elasticity than for the UK, with an estimated elasticity closer to one, which is the revenue maximising level of elasticity', in fact, the UK results are broadly similar to those found for the US state lotteries. Gulley and Scott (1989) also use price variation arising from changes in the expected value caused by rollovers. They report elasticity of -1.15 and -1.2 for the Kentucky and Ohio lotteries and elasticity of -1.92 for the multi-state Massmillions lotteries. The long-run elasticity given in Farrell *et al.* suggests that the take-out rate could be lowered to increase the sales revenue and thus the money going to good causes. However, the short-run elasticity and the estimate of Forrest *et al.* are not statistically significantly different from one, suggesting that the current take-out rate is right.

The introduction of the midweek draw

Over hundred lotteries worldwide run midweek draws and the majority of these are held on a Wednesday. In general, innovations to games are an endogenous response

to flagging sales. The midweek draw has seen lower sales than the Saturday draw but total weekly sales have risen (as can be seen from Figure 14.1). This second draw is a replica of the Saturday draw and therefore ensures that players, who 'own' a set of Saturday night numbers, will become locked into the midweek draw as well. An interesting question is whether the price elasticity of demand across the two draws is the same, as this determines if the optimal take-out rate across each draw should be the same.

Forrest *et al.* (2000) calculate that the Saturday elasticity is −1.04 and the Wednesday elasticity is −0.88 and find neither estimate to be statistically significantly different from one. Farrell *et al.* (1998) also test if players respond in the same way to price incentives across the lotto draws (i.e. Saturday and Wednesday). When considering the separate samples it appears that the demand on Wednesdays is less elastic than the demand on Saturdays. Examination of the associated standard errors reported in the paper, however, shows that the elasticity is not statistically significantly different from each other and this explains why none of the interaction terms in their model, indicating a change in the slope of the demand curve over the two types of draw for the full sample regression, are significant. The significance of the Wednesday dummy in the full sample regression implies that there is a change of intercept and sales are significantly lower on Wednesdays than Saturdays.

In general, the results suggest that the demand curve shifts backwards towards the origin on Wednesdays, but the elasticity of demand is unchanged. Furthermore, there is no evidence that players engage in inter-temporal substitution given that less people play on Wednesday rollovers than on Saturday rollovers despite the higher expected return. To date, lower sales on Wednesdays have been continually boosted through frequent topped up jackpot 'superdraws' but it is important to remember that the greater the frequency of the 'superdraw' the quicker the players will tire of this innovation.

It is, therefore, clear that less people play on Wednesdays than Saturdays but the introduction of the midweek draw has been successful in increasing the overall level of sales. The logical question that naturally occurs is whether there is an optimal frequency of draws? To date there is no research on how the frequency of draws affects participation in the game. However, logically, the closer the draws the easier it is to inter-temporally substitute play across the draws. This could result in low levels of play in normal draws as players wait for rollovers to occur. Whilst low levels of play in normal draws will increase the number of rollovers, the size of the rollover will be small and so the effect of a rollover in attracting high sales diminishes.

Thunderball

The third innovation to the current on-line game has been the introduction of the Thunderball game. This numbers game is different in that it has the format of a typical lottery but is not pari-mutuel.[9] An interesting feature of the paper by Forrest *et al.* (2000) is what the time trends reveal for the on-line game. The linear

trend in the model is positive, reflecting growing sales as the game was introduced and the boost to sales given by the introduction of the midweek draw. However, the quadratic trend term is more interesting (and is negative) and suggests that interest in the midweek draw fell around June 1998. Camelot's response to this falling interest was the introduction of the Thunderball game. Figure 14.3 shows the sales path for the Thunderball game since its first draw on Saturday 12th June, 1999 – initial sales of £6.4 million per game have trended downwards to £5.2 million in March 2002.

Whilst the odds of winning, Thunderball are much better than those for the on-line game, the former is still considerably less popular. This may in part be explained by the fact that the value of the top prize is relatively small compared to that offered by the on-line game. See Table 14.1. Current research by Walker and Young shows, in the context of the on-line game, that the skew in the prize distribution (that allows players to receive very large jackpots) is a key factor in

Figure 14.3 Thunderball sales.

Table 14.1 Ways to win at Thunderball

Winning selection	*Odds*	*Prize value* (£)
Match 5 and the Thunderball	1 : 3,895,584	250, 000
Match 5	1 : 299,661	5, 000
Match 4 and the Thunderball	1 : 26,866	250
Match 4	1 : 2,067	100
Match 3 and the Thunderball	1 : 960	20
Match 3	1 : 74	10
Match 2 and the Thunderball	1 : 107	10
Match 1 and the Thunderball	1 : 33	5

Source: http://www.national-lottery.co.uk

the game's success. Research in the context of other betting markets by Golec and Tamarkin (1998) for the case of racetrack bettors and Garrett and Sobel (1999) for the case of US lottery games also show that bettors like skewness in the distribution of prizes.

The Thunderball game does have a skewed prize distribution, but it appears that it is not sufficiently skewed as the value of the top prize is not sufficient to attract players to the game. One of the important lessons learnt from the US state lotteries is that single large games (such as the multi-state lotteries) generate greater amounts of revenue than numerous small games. It is, therefore, not surprising to find that the Thunderball game only attracts sales of around £5 million a week compared to the on-line game with sales of around £70–75 million.

Such games may pick up marginal sales, but it is important that care is taken not to allow them to simply divert resources away from the main game, as this would be detrimental to the long-term future of the main game.

Special one-off draws

Christmas 2000 and 2001 have seen further innovations to the format of the standard on-line game. These came in the form of a pari-mutuel game where players paid £5 for entry into two draws. The idea was to have two very large jackpots that would generate extra interest and revive a general interest in lottery play. Big Draw 2000 had two draws: one on 31st December, 1999 and one on 1st January, 2000. Big Draw 2001 had two draws on 1st January, 2001, one at 12.12 a.m. and the second at 12.31 a.m. These games are in part copies of Italy's Christmas lottery draw that attracts a huge number of players. Table 14.2 shows the number of winners and size of the prize for Big Draw 2001.

Table 14.2 Big Draw 2001

Category	*Prize* (£)	*Winners*	*Total* (£)	*Percentages*
Jackpot	0	0	0	0.0
4 + bonus	0	0	0	0.0
4 match	54,587	43	2,347,241	25.9
3 + bonus	2,650	103	272,950	3.0
3 match	260	3,212	835,120	9.2
2 + bonus	163	3,452	562,676	6.2
2 match	57	88,676	5,054,532	55.7
Total		95,486	9,072,519	100.0

Source: http://www.national-lottery.co.uk

Notes
Game 1
Winning years drawn at 12.12 a.m. GMT on Monday 1st January, 2001:
Sorted order: 1909 1920 1931 1982 1992 Bonus: 1911.
Game 2
Winning years drawn at 12.31 a.m. GMT on Monday 1st January, 2001:
First year: 1,620; Second year: 2,438.
Number of game 2 jackpot (£1 million) winners: 5.

It is interesting that for the Big Draw whilst the total sales were £24,739,425 (because each ticket cost £5) the total number of tickets sold was just less than 15 million. This is around the number of marginal tickets that are sold in the Thunderball game. Moreover, given the small number of tickets sold the probability of having no jackpot winners is large and not surprisingly the game did not generate any winners of the top two prizes. This game illustrates the points that have been made throughout this chapter that the design of the game must match the size of the playing population. As a one-off game it did generate a large amount of revenue but players are disheartened by games that are too hard to win (especially with such high prices), and this lack of enthusiasm may have dangerous effects on the main on-line game. Luckily draw 2 had a much higher probability of generating winners given the number of players, and successfully produced five millionaires.

Lottery Extra

This is the latest innovation to the on-line game. It exploits the fact that players like large jackpots by allowing a jackpot that is not won to rollover into the following weeks' jackpot prize pool. This continues until the jackpot grows to £50 million and is then shared by the second-prize winners. Tickets cost £1 and the draw uses the same numbers as the on-line game. Players simply choose whether or not to enter the extra draw and then whether to use the same numbers that they used for the main game or to use a lucky dip selection. Lottery Extra saw its first draw on Wednesday 15th November, 2000.

Figure 14.4 shows that the level of sales for this new game are currently around £1.2 million on a Saturday and £0.8 million on a Wednesday. Again the game does not appear to have a wide appeal but is picking up some sales. The key problem is

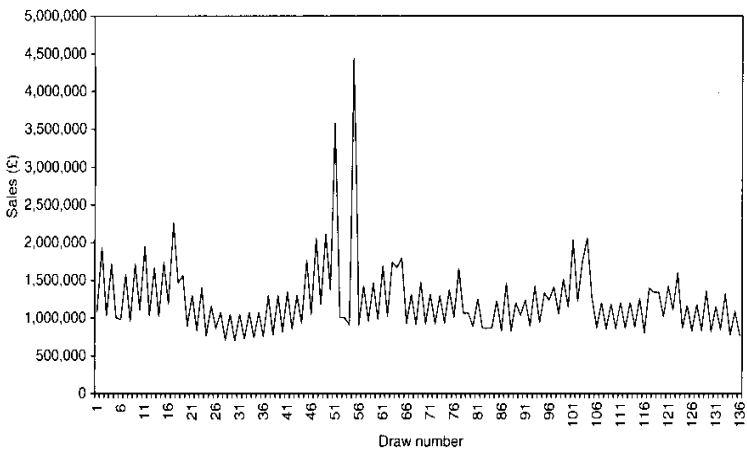

Figure 14.4 Lottery Extra sales.

whether these are new sales or simply expenditure that is substituted away from the main on-line game.

The potential impact of all the innovations that take the form of peripheral games is that if they simply direct expenditure from the main game then this will mean that total sales will not rise and the costs of launching the new game are lost, but more importantly we know there are economies of scale in lottery markets and competition is detrimental to total market sales (even if that competition comes from games operated by the same company). Large jackpots attract players so lots of small games effectively destroys the market. Innovation is necessary to stimulate interest but too many peripheral games are a dangerous means to try to regenerate interest.

Instants

National Lottery scratch cards called Instants were launched at the end of March 1995 and cost £1 or £2 depending on the card. Sales to date would tend to suggest that the UK market for Instants is quite small. Figure 14.5 shows the weekly sales figures for scratch cards. When they were first released sales peaked at just over £40 million per week in May 1995. Currently sales have fallen to as little as £10.5 million a week. We can see that this revenue is small compared to that generated by the on-line game (although greater than the sales that Thunderball or Lottery Extra have generated). The challenging question to answer is what is the potential to extend this market?

There is very little analysis on the market for scratch cards within the UK. This is mainly due to the poor quality of the available data. Surveys of scratch-card players persistently under record the level of activity. Analysis of the aggregate data is hindered by the fact that there are many games each offering different returns.

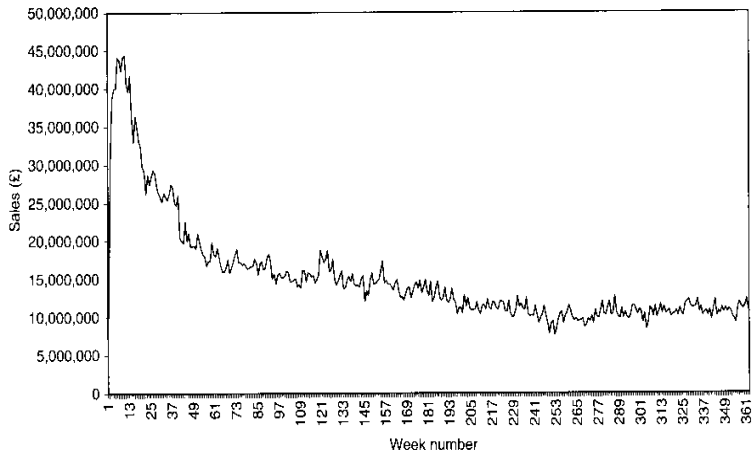

Figure 14.5 Instants sales.

Table 14.3 National Lottery stakes (£ million)

Financial year	*National Lottery lotto game sales (£)*	*Instant sales (£)*	*Easy Play sales (£)*	*Lottery Extra sales (£)*	*Thunderball sales (£)*	*Big Draw sales (£)*	*Gross stake (£)*
1994–95	1,156.8	33.9	0	0	0	0	1,190.6
1995–96	3,693.7	1,523.3	0	0	0	0	5,217.0
1996–97	3,846.6	876.5	0	0	0	0	4,723.2
1997–98	4,712.7	801.0	0	0	0	0	5,513.8
1998–99	4,535.9	668.7	23.1	0	0	0	5,227.8
1999–00	4,257.0	560.8	1.3	0	194.1	80.6	5,093.8
2000–01	4,124.2	546.1	0	48.1	240.2	24.7	4,983.3
Total to end 2000–01	26,326.9	5,010.3	24.4	48.1	434.3	105.3	31,949.3

Source: National Lottery Commission

New experiments in terms of offering cars and other goods, rather than money prizes, are currently being tested in the market place. Camelot remains diligent in its attempts to stimulate and expand this market.

This is important, as the innovations to the on-line game are limited, so over time sustaining the value of contributions to good causes will become increasingly focussed on expanding other areas of the lottery product range.

Conclusion

All the indicators show that since 1994 Camelot has followed the pre-existing models of lottery operation. They are continually innovating in order to stimulate demand to prevent lottery fatigue from impacting on sales and the revenue for good causes. However, potential dangers of too many peripheral games have been highlighted. Due to the downward trend in lottery sales we should expect to see a continued high level of innovation in the game. Camelot enjoys the advantage of a monopoly market, however; although J. R. Hicks once characterised a 'quiet life' as the greatest monopoly profit, the UK National Lottery is *not* an easy market. It is a demanding market with no room for complacency.

The Gambling Review Body (chaired by Sir Alan Budd) began work in April 2000 with the purpose of reviewing the 'current state' of the UK gambling industry – they published their findings in the *Gambling Review Report* in July 2001, including 176 recommendations.

While consideration of the National Lottery was expressly excluded from their brief, the Report has clear implications for the Lottery (and the rest of the gambling industry). The most significant recommendations for the Lottery are:

a that betting on the UK National Lottery be permitted;
b that limits on the size of prizes and the maximum annual proceeds should be removed for societies' lotteries, and that rollovers should be permitted; and

c that there should be no statutory limits on the stakes and prizes in bingo games, and that rollovers should be permitted.

The thrust of the Report is to 'extend choice for adult gamblers' and simplify gambling regulation, while ensuring that children and other vulnerable persons are protected, permitted forms of gambling are kept crime-free and that players know what to expect. As such, the Budd Report will (all else being equal) increase the level of competition within the various gambling and leisure sectors for consumers'

Table 14.4 Trends in betting and gaming expenditure

Net betting and gaming expenditure	*£ Million*	*% Change*
1991–92	3,181	—
1992–93	3,296	3.6
1993–94	3,517	6.7
1994–95	4,324	22.9
1995–96	6,034	39.5
1996–97	5,898	−2.3
1997–98	6,414	8.7
1998–99	6,550	2.1
1999–2000	6,587	0.6
2000–01	7,254	10.1
On lottery[a]		
1991–92	0	—
1992–93	0	—
1993–94	0	—
1994–95	660	—
1995–96	2,719	312.0
1996–97	2,425	−10.8
1997–98	2,785	14.8
1998–99	2,615	−6.1
1999–2000	2,547	−2.6
2000–01	2,492	−2.2
On other betting		
1991–92	3,181	—
1992–93	3,296	3.6
1993–94	3,517	6.7
1994–95	3,664	4.2
1995–96	3,315	−9.5
1996–97	3,473	4.8
1997–98	3,629	4.5
1998–99	3,935	8.4
1999–2000	4,040	2.7
2000–01	4,762	17.9

Source: ONS

Note

a Calculated as 50 per cent of the National Lottery stake.

Table 14.5 Trends in betting and gaming expenditure relative to total consumer spending

Net betting and gaming expenditure	£ *Million*	*Share of total consumer expenditure (%)*
On lottery[a]		
1991–92	0	0
1992–93	0	0
1993–94	0	0
1994–95	660	0.2
1995–96	2,719	0.6
1996–97	2,425	0.5
1997–98	2,785	0.6
1998–99	2,615	0.5
1999–2000	2,547	0.5
2000–01	2,492	0.5
On other betting		
1991–92	3,181	0.9
1992–93	3,296	0.9
1993–94	3,517	0.9
1994–95	3,664	0.9
1995–96	3,315	0.8
1996–97	3,473	0.7
1997–98	3,629	0.7
1998–99	3,935	0.7
1999–2000	4,040	0.7
2000–01	4,762	0.7

Source: ONS

Note
a Calculated as 50 per cent of the National Lottery stake.

discretionary spending, and also the competitiveness of the gambling industry as a whole, with other non-gambling sectors.

As shown in Table 14.3, since 1994 the total National Lottery ticket sales have reached almost £32 billion over the seven financial years to 2000–01. However, over 82 per cent of this total is attributable to the 6/49 lotto game, with over 15 per cent due to scratch cards. Preserving the core lotto game stake is clearly a priority in maintaining sales and hence the good causes funding streams.

Moreover, the National Lottery exists within an increasingly competitive UK betting and gaming sector. As shown in Table 14.4, consumer expenditure on non-lottery betting and gaming has risen (almost) continually between 1994–95 and 2000–01. Although the share of such non-lottery betting and gaming in total consumer spending has fallen from 0.9 per cent in the year of the National Lottery's launch to 0.7 per cent in 2000–01, the overall share of all betting and gaming in consumers' expenditure has risen from 0.9 per cent in 1993–94 to 1.2 per cent in 2000–01 per cent; see Table 14.5. Therefore the challenge facing the lottery in the near future is to learn to be adaptive and innovative in an increasingly competitive environment.

Appendix: the expected value of a lottery ticket

The formal expression for the expected value of a lottery ticket was first derived in the work of Sprowls (1970) and has subsequently been adopted and refined by Lim (1995) and Scoggins (1995). Here we will consider the case where players are assumed to select their numbers uniformly.[10] The size of the jackpot is equal to the sales revenue times the proportion of ticket sales in draw t going to the jackpot prize pool and plus any rolled over prize money from the previous draw. We denote C_t, as the sales revenue (aggregate consumption) and R_t as the amount rolled over; which for most draws will be zero. Finally π_{6t} is the proportion of ticket sales in week t going to the jackpot prize pool. The size of the jackpot in draw t, is thus expressed as

$$J_t(\pi_{6t}, R_t; C_t) = R_t + \pi_{6t} C_t \tag{1}$$

The probability that this jackpot is won, p_6, is determined by the characteristics of the game. For the UK National Lottery, players must select six numbers (x) from forty-nine (m) and the jackpot is shared among those players who selected the winning six number combination drawn at random without replacement.[11] The probability of there being a rollover is equal to the probability that none of the players win the jackpot $(1 - p_6)^{C_t}$. In the case of the UK National Lottery there are also smaller prizes awarded for matching any five, four or three of the main numbers and a further prize pool for matching any five main numbers plus a seventh bonus ball ($5 + b$). The expected value of holding a lottery ticket taking account of the smaller prizes is therefore[12]

$$V(R_t, \pi_{6t}, \pi_{jt}, p_6; C_t) = \left\{[1-(1-p_6)^{C_t}][\pi_{6t} C_t + R_t] + \sum_j \pi_{jt} C_t\right\}/C_t \tag{2}$$

where $j = 3, 4, 5, 5 + b$, p_6 is the probability of a single ticket winning the jackpot, p_j is the probability of correctly selecting any j numbers, π_{6t} is the proportion of ticket sales in draw t allocated to the jackpot prize pool and π_{jt} is the proportion of ticket sales going to the jth prize pool in draw t so that, $\sum_j \pi_{jt} + \pi_{6t} = (1 - \tau)$, $j = 3, 4, 5, 5 + b$, where τ represents the take-out. The take-out is the proportion of sales revenue not returned in the form of prizes, which covers the operator's costs, profits, tax, and in the UK, contributions to a number of good causes.[13] It is straightforward (see Farrell and Walker, 1996) to show that $V_R > 0$, $V_{p_6} > 0$ and $V_\tau < 0$ where subscripts indicate partial derivatives. The effects of the level of sales, C_t, is more difficult. In the case where $R = 0$ it is simple to show that $V_{C_t} > 0$ and $V_{C_t C_t} < 0$, but in general

$$V_{C_t} = (p_6 C_t (1 - p_6)^{C_t}((1 - \tau)C_t + R_t) - R_t(1 - (1 - p_6)^{C_t}))/C_t^2 \tag{3}$$

which is not necessarily monotonic and Figure 14.1 depicts the possibilities together with the relationship for $R = 0$. $V(\cdot)$ always asymptotes towards $(1 - \tau)$, but for $R > 0$ it is from above and at a slower rate than for $R = 0$ when it is faster

and from below. For $R > 0$ the relationship may attain a maximum for some finite C_t, but for sufficiently large R the relationship will be monotonically decreasing.

V is always higher in rollover draws than in regular draws, irrespective of the level of sales. Thus, it is impossible to arbitrage away the differences in V no matter what the variation in sales. This implies that there will always be some exogenous variation in V arising from the random incidence of rollovers. It is, indeed, possible in theory for the expected value to exceed unity, the cost of a ticket, so the net expected return becomes positive.

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Notes

1 Assuming that the mechanism employed to generate the winning numbers generates those numbers uniformly. Cook and Clotfelter (1993) refer to this non-uniformity as 'conscious selection'.
2 There will also be more occasions when there are a large number of jackpot winners. That is, the variance in the number of jackpot winners will be higher under non-uniform choice.
3 Allowing the Lucky Dip will of course reduce the frequency of rollovers as it increases the level of coverage of the possible combinations.
4 Explicit models of addiction stem from the work of Becker and Murphy (1988). They present and test empirically a theoretical model of addiction. The novelty of this approach is that the individual can behave rationally.
5 See Vrooman (1976) and DeBoer (1985).
6 Scott and Garen (1994) estimate a model of participation in a US scratch card game using micro-data, but could not estimate a price elasticity since there are no rollovers in such games.
7 See a later section for the difference between the long- and short-run elasticity.
8 These results are based on an analysis of the sales time series. Using micro-data also enables a more precise estimation of the price elasticity of demand. Given that richer people may choose to play only in rollover weeks when the return is higher we need to control for income variation between those individual who play in normal weeks compared to those who play in rollover weeks. Simple time series studies such as those mentioned above may obtain biased price elasticities due to the inability, within the time series data, to control for income effects. Therefore it is important to check for any bias by comparing these results to the corresponding elasticity estimated using micro-data when controlling for the effects of income. Farrell and Walker (1999) find estimates of -1.7 but this estimate was based on price variation arising due to a double rollover and this event attracted a lot of publicity that may have led to an unusually large response from players.
9 The other fixed-odds game that the lottery launched was called 'Easy Play' and was based on the football pools. Vernon's Easy Play ran from Saturday 15th August, 1998 to Saturday 8th May, 1999 (thirty-nine weeks), and was then shut down.
10 Cook and Clotfelter, 1993, pp. 636–7 speculate that the theoretical structure of the game is unchanged if individuals pick their numbers non-randomly (they call this 'conscious selection'). Farrell *et al.* (2000b) consider this more complex conscious-selection case

and prove that the most important theoretical properties of the game are indeed unaffected by this generalisation. They also show that conscious selection has a minimal impact on the estimated elasticity.

11 The probability of winning in this case is, then, 1/13983816.

12 It will be assumed, for expositional convenience, that the smaller prizes do not rollover. Whilst it is possible for them to do so, in practice they never have and the probability of them doing so is very small.

13 For the UK National Lottery Treasury the duty is 12 per cent of ticket sales, the retailer's commission is 5 per cent, operator's costs and profits are 5 per cent, and good causes get 28 per cent.

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