Drafts versus Auctions in the Indian Premier League

Tim B. Swartz *

Abstract

This paper examines the 2008 player auction used in the Indian Premier League (IPL). An argument is made that the auction was less than satisfactory and that future auctions be replaced by a draft where player salaries are determined by draft order. The salaries correspond to quantiles of a three-parameter lognormal distribution whose parameters are set according to team payroll constraints. The draft procedure is explored in the context of the IPL auction and in various sports including basketball, highland dance, golf, tennis, car racing and distance running.

Keywords: Auctions, Drafts, Lognormal distribution, Twenty20 cricket.

*Tim Swartz is Professor, Department of Statistics and Actuarial Science, Simon Fraser University, 8888 University Drive, Burnaby BC, Canada V5A1S6. Swartz has been partially supported by grants from the Natural Sciences and Engineering Research Council of Canada. He thanks Golnar Zokai for help in obtaining datasets. He also thanks the Associate Editor and an anonymous referee for detailed comments that helped improve the manuscript.

1 INTRODUCTION

In 2008, the Indian Premier League (IPL) was born. The 2008 IPL season involved 8 professional cricket teams, all based in India. In the IPL, teams play Twenty20 cricket, the most recent version of cricket which was introduced in 2003 in England. Twenty20 differs markedly from first class and one-day cricket in that matches are completed in roughly 3.5 hours, a duration more in keeping with many professional team sports. As a form of limited overs cricket, Twenty20 cricket has two innings, each consisting of 10 wickets and 20 overs. Compared to one-day cricket with 50 overs, the reduced number of overs encourages aggressive batting and an exciting style of play. Although the World Cup of Twenty20 has been established and contested between international sides in 2007, 2009 and 2010, the IPL deserves much credit for generating widespread interest in Twenty20.

To date, three successful IPL seasons have been completed (2008, 2009, 2010). Past IPL regular seasons have been short with two games played between each pair of teams, plus three playoff matches for a total of 59 scheduled games. An IPL season typically begins in the spring (March or April) and is completed within six weeks time. The accelerated pace of the IPL season allows international players to return to their home country to resume training with their home nation. The accelerated pace of the season is also believed to keep fans riveted. In 2011, the IPL is expected to expand from 8 to 10 teams with franchises awarded to both Pune and Kochi.

One of the fascinating features of the inaugural 2008 IPL season was the formation of the team rosters and the determination of player salaries. This was accomplished through a sequential English auction (Krishna 2010). Prior to the auction, players with an interest in playing in the IPL registered for the auction. Amongst the registrants, 77 were accepted by the IPL for inclusion on the auction list. In addition, the IPL set a base or reserve price for each player indicating the minimum salary for the player in the auction.

The 2008 auction imposed various constraints unique to the IPL. For example, five iconic players were identified and assigned to teams according to a regional affiliation. The idea was that regional connections of "star" players to teams would generate increased interest in the IPL. The five iconic players and their teams were Rahul Dravid (Bangalore), Sourav Ganguly

(Kolkata), Virender Sehwag (Delhi), Yuvraj Singh (Mohali) and Sachin Tendulkar (Mumbai). Further, the IPL required that each team with an iconic player must pay the iconic player a salary that is 15% higher than the highest auctioned salary on the team. Additionally, no team was allowed to exceed $5.0 million in total salary to players obtained in the auction including the iconic players. A lower bound of $3.5 million in salary was also required to help maintain a competitive balance in the league. A few other rules were imposed concerning the composition of teams based on players and their regional affiliations. The purpose of the 2008 IPL auction was therefore twofold:

- the assignment of players to teams
- the determination of player salaries

(1)

Now, it is well known that problems may exist with sequential auctions when there are dependencies between auction items (Krishna 2010). For example, suppose that a bidder has an interest in two adjacent lots that are auctioned sequentially where the bidder's intention is to build a large hotel encompassing the two lots. In this case, a successful bid on exactly one of the lots is of little value since a large hotel cannot be built on a single lot. For this participant, the bidding ceiling on the first lot depends on the unknown selling price of the second lot. Clearly, distortions in selling prices may exist with dependent auction items. In the 2008 IPL auction, dependencies existed amongst the auction items (ie. players). For example, a cricket team has complementary parts including bowlers, batsmen, wicketkeepers, and so on. And, there is a widespread feeling that distortions did exist in the 2008 IPL auction as players such as Mahendra Singh Doni was auctioned for $1.5 million in contrast to his reserve price of $400,000. On the other hand, Glenn McGrath surprisingly received no bid in the first round of the auction, and eventually settled for his reserve price of $350,000. During the 2008 season, McGrath had an economy rate of 6.61, the fifth best economy rate amongst players who had bowled at least 20 overs. Using regression techniques, Rastogi and Deodhar (2009) examine variables that may have played a role in determining the 2008 IPL auction prices. Karnik (2010) also considers the value of players using hedonic price models. Whereas simultaneous ascending auctions (Cramton 2006) and various combinatorial auctions (Krishna 2010) may be considered when multiple related objects are to be sold, these types of auctions tend to be far more complex than a sequential English auction.

With a full IPL auction again proposed for 2011, this paper argues for the use of a draft instead of an auction. The simplicity of a draft may be appealing to fans and the methods proposed here provide a theory-based approach for determining salaries. We note that there are no such general procedures in the various sports that utilize drafts. Suppose then that there are m teams and n eligible players where typically n is a multiple of m. A draft proceeds where the team drafting first selects a player from the list of n eligible players, the team drafting second then chooses one of the remaining $n-1$ players, and so on, until the team drafting m-th selects one of the remaining $n-m+1$ players. In the second round of the draft, it is often viewed as fair to reverse the draft order such that the team drafting m-th in the first round gets the next pick, the team drafting in position $m-1$ in the first round gets the subsequent pick, and so on, until all players have been selected. There is a precedence for using drafts in professional team sports. Every year, the National Hockey League (NHL), the National Football League (NFL), the National Basketball Association (NBA) and Major League Baseball (MLB) hold drafts to select players who have been deemed eligible. The initial order of drafting is often related to a team's performance in the previous season with weak teams given preferential early draft picks. For the IPL, a randomization of draft order may be appropriate.

Referring to the auction desiderata in (1), the assignment of players to teams in a draft is immediately accomplished. The question remains how to determine player salaries. In a draft, it is intuitive that salaries be assigned in a descending order according to draft position. In section 2, we propose a method of establishing salaries through the consideration of payroll constraints and the quantiles of lognormal distributions. In section 3, we explore the proposed draft procedure in the context of the IPL auction and the use of the three-parameter lognormal distribution in the various sports of basketball, highland dance, golf, tennis, car racing and distance running. For the IPL, we suggest that a simple draft procedure produces salaries that are in line with reality and that the approach is both conceptually and computationally simple. A discussion is provided in section 4.

As a new league, there has not been a great deal of quantitative research related to the IPL. Some notable exceptions include the consideration of player performance (van Staden 2009; Petersen et al. 2008) and optimal team selection in Twenty20 cricket (Sharp et al. 2010).

2 METHODOLOGY

In this section, we propose methodology based on a simple draft. We suggest that the draft provides an intuitive approach to assigning players to teams and provides salaries that are in line with true market values.

Consider a randomly chosen cricketer from the population of eligible players in a future IPL draft. We imagine that such a player has trained for years and that his overall skill level S may be represented as

$$S = a_S + \epsilon_1 \epsilon_2 \cdots \epsilon_N \tag{2}$$

where a_S is the baseline skill level of an IPL player and there are underlying components ϵ_i contributing to the cricketer's incremental skill level. For example, we may have a very long list of components relating to agility, strength, speed, fitness, throwing ability, health, etc. In (2), we have assumed that the effects are multiplicative. For example, a 1% increase in a particular component leads to a 1% increase in the cricketer's incremental skill level.

Referring to (2), for large N and under weak conditions involving the variances of the $\log(\epsilon_i)$, the Central Limit Theorem (CLT) suggests that the distribution of

$$\log(\epsilon_1 \epsilon_2 \cdots \epsilon_N) = \log(\epsilon_1) + \log(\epsilon_2) + \cdots + \log(\epsilon_N)$$

is approximately normally distributed (see chapter 27 of Billingsley (1995)). Expressed in an equivalent form, the distribution of $\epsilon_1 \epsilon_2 \cdots \epsilon_N$ is approximately lognormal according to the standard two-parameter lognormal definition. Since salary may be thought of as a proxy for overall skill level, we therefore propose that IPL cricketer's salaries arise from a three-parameter lognormal distribution. The three-parameter lognormal is of the form of a constant added to a two-parameter lognormal distribution. In fact, there is a long history of using lognormal distributions to successfully model incomes. Chapter 11 of Aitchison and Brown (1966) is devoted to the use of the lognormal distribution in a wide range of applications involving incomes.

Consider then a random variable $X \sim \text{Normal}(\mu, \sigma^2)$ such that $Y = a + \exp\{X\}$ has a three-parameter lognormal distribution with parameters a, μ and σ. Further, let $v(q)$ be the q-th quantile of the standard Normal$(0, 1)$ distribution (ie. $q = \Phi(v(q))$ where Φ is the distribution function of the standard normal). It follows that the q-th quantile of the three-parameter lognormal variable Y is

$$a + \exp\{\mu + \sigma v(q)\} \tag{3}$$

where $v(q)$ is readily available from statistical software packages.

Suppose that there are n players in an upcoming IPL draft involving m teams. Letting Y_i denote the salary of the i-th player selected in the draft, based on (3), we suggest that

$$Y_i = a + \exp\{\mu + \sigma v_i\} \tag{4}$$

where $v_i = v((n+1-i)/(n+1))$. In (4), the salaries are in decreasing order according to draft position and are spaced such that there is equal probability between adjacent salaries. Equation (5) therefore provides a simple formula for determining IPL salaries. The sole remaining problem is the determination of the parameters a, μ and σ which characterize the three-parameter lognormal distribution.

The determination of a, μ and σ ought to depend on the particular draft. For example, the salaries of iconic players need to be taken into account, and we note that the number of iconic players and their premium in salary (15% in 2008) may vary from draft to draft. The iconic players of 2008, Dravid, Ganguly, Sehwag, Singh and Tendulkar turn 37, 38, 33, 30 and 32 years of age respectively in 2011, and some of these cricketers may be reaching the end of their IPL careers. Also, there has been some discussion about teams retaining a few of their current players in 2011. If so, these players would be unavailable for drafting in 2011.

Despite the dependence of a, μ and σ on the particular draft, we propose a general strategy for the determination of the parameters that may be modified in a given context. It is reasonable to assume that the IPL (or any sporting league) has an idea or requirement of minimum player salary, and we denote this quantity by $s_{\min}$. The minimum salary is assigned to the last player drafted. Similarly, we fix the maximum salary $s_{\max}$ and it is assigned to the first player drafted. In the spirit of the IPL auction in 2008, it is also likely that the IPL impose a total salary obtained through a draft and we denote the salary limit by T. Using

(4), the three constraints are given by

$$\begin{aligned} s_{\min} &= a + \exp\left\{\mu + \sigma v_n\right\} \\ s_{\max} &= a + \exp\left\{\mu + \sigma v_1\right\} \\ T &= na + \textstyle\sum_{i=1}^{n} \exp\left\{\mu + \sigma v_i\right\}. \end{aligned} \tag{5}$$

In the Appendix, we show that the solution of (5) in terms of a, μ and σ is straightforward. We note that the estimation procedure implies that the largest salary $Y_1 = s_{\max}$ and the smallest salary $Y_n = s_{\min}$ are always fitted exactly.

3 ANALYSIS

In this section, we explore the use of the three-parameter lognormal distribution in various problems related to sport.

3.1 NBA Rookie Salaries

We first consider a league where salaries are determined by draft order. In the 2010 NBA draft held June 24/2010, there were 30 teams involved in two rounds of drafting where NBA salaries are only guaranteed to players drafted in the first round. Therefore, we consider only the first round, and using previous notation, we have $n = 30$ and $m = 30$. The NBA draft salaries were determined by the NBA's collective bargaining agreement (CBA), and although it is unknown to us how the salaries were determined, it is safe to say that the lognormal distribution was not utilized. However, we take the view that the NBA salaries are reasonable, and we are interested in the comparison of the NBA salaries with salaries obtained using the lognormal methodology. The salaries are provided at www.hoopsworld.com/Story.asp?story_id=9302.

Examining the NBA salaries, we let $X_1, \ldots, X_{30}$ be the salaries determined by the CBA. We observe that the first player selected was John Wall who was drafted by the Washington Wizards, and he received the maximum draft salary of $s_{\max} = X_1 = \$4,286,900$. The 30-th player selected was Lazar Hayward who through trades was also drafted by the Washington Wizards, and he received the minimum draft salary of $s_{\min} = X_{30} = \$850,800$. Using our methodology, we set $\$T = 51,942,000$ corresponding to the total salary assigned to first round players. Using the proposed approach in section 2, we solve for the parameters $a = 658,473.60$, $\mu = 13.6356$ and $\sigma = 0.7945$. Substituting the parameters into (4), we then obtain the salaries $Y_1, \ldots, Y_{30}$. In figure 1, we provide a Q-Q plot of (X_i, Y_i), $i = 1, \ldots, 30$ which allows a comparison of the actual NBA rookie salaries with our proposed salaries. We observe considerable disagreement between the two salary scales. In particular, the NBA seems to have a more egalitarian approach as the differences in salary between the early draft picks is not as great as with the lognormal quantiles. For example, the difference in rookie salary between the first and second draft pick is \$451,300 compared to a difference of \$838,308 using the lognormal quantiles. NBA rookie salaries appear contradictory to the popular sentiment that the "NBA is a league of stars", and that teams need superstars to succeed. With the exception of the Detroit Pistons in 2004, recent history in the NBA suggests that teams require star players in order to win championships.

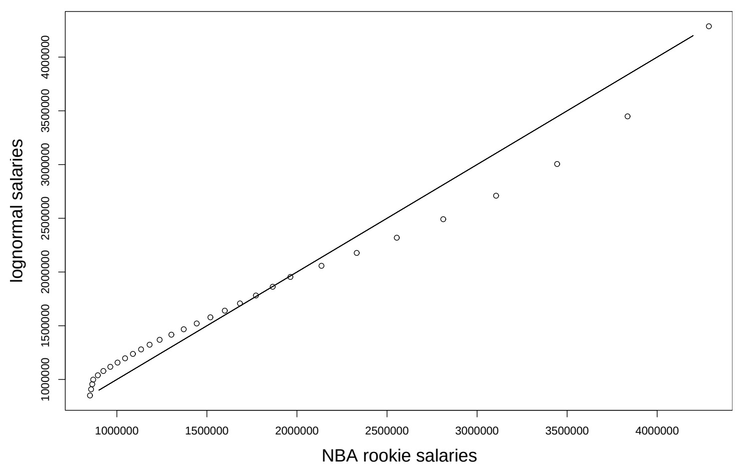

Figure 1: Q-Q plot of NBA rookie salaries and quantiles obtained from the lognormal distribution together with the line $y = x$.

3.2 Highland Dance Points

Highland dance is a competive sport which combines both athleticism and artistry (Swartz 2007). In highland dance, competitors are judged and the top six competitors are awarded points from first place to sixth place with the remaining competitors receiving zero points. The points from first through sixth are 88, 56, 38, 25, 16 and 10, respectively.

We wish to compare the points awarded in highland dance with points obtained via the methodology of section 2 using lognormal quantiles. Accordingly, we set $s_{\min} = 10$, $s_{\max} = 88$ and $T = 233$ which yields lognormal parameter estimates $a = -2.53$, $\mu = 3.5168$ and $\sigma = 0.9263$. Here, we might expect the fit to be good as six points are fit to a three-parameter family with the first and last points fitted exactly. In figure 2, we provide a Q-Q plot of the highland points with the lognormal quantiles and observe that the fit is indeed good.

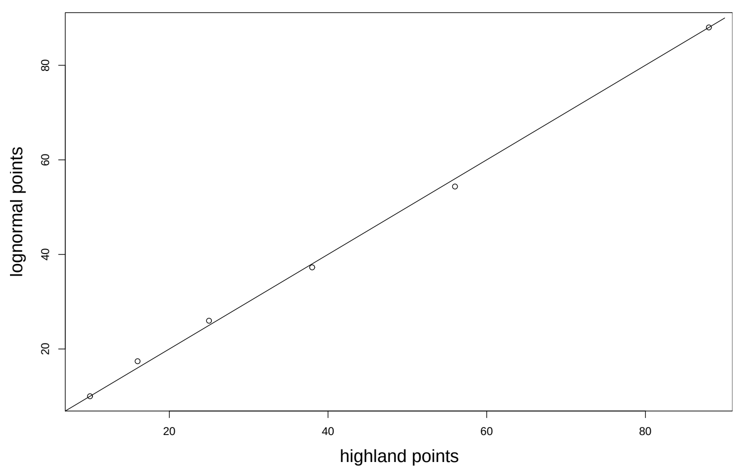

Figure 2: Q-Q plot of points awarded in highland dance and quantiles obtained from the lognormal distribution together with the line $y = x$.

3.3 PGA Prize Money

On the Professional Golfers' Association (PGA) tour, there exists a standard approach for the determination of prize money (www.frankosport.us/golf/Purse/index.html#PM01) which has been in effect since 1979. Apart from the four Major tournaments, there are only a handful of exceptions to the standard approach. Consider then a tournament with a total purse of $T = \$5,000,000$ and $n = 70$ corresponding to a 70-place purse. According to the standard approach for distributing prize money, we have $s_{\min} = \$10,000$ and a first place prize of

$s_{\max} = \$900,000$ for winning the tournament. Using the methodology of section 2, we obtain the corresponding lognormal parameter estimates $a = 9,737.94$, $\mu = 9.6339$ and $\sigma = 1.8522$. In figure 3, we provide a Q-Q plot of the PGA prize money with the lognormal quantiles. In this case, we see that the fit is reasonable. Unlike the NBA with guaranteed salaries, participation in the PGA tour is a cutthroat activity where players receive payment solely based on performance. In figure 3, the PGA recognizes the meaningful differences between high finishing positions, and rewards players as such. For example the difference in PGA prize money between first place and second place is $\$900,000 - \$540,000 = \$360,000$. With the lognormal quantiles, the difference is a comparable $\$900,000 - \$533,431 = \$366,569$.

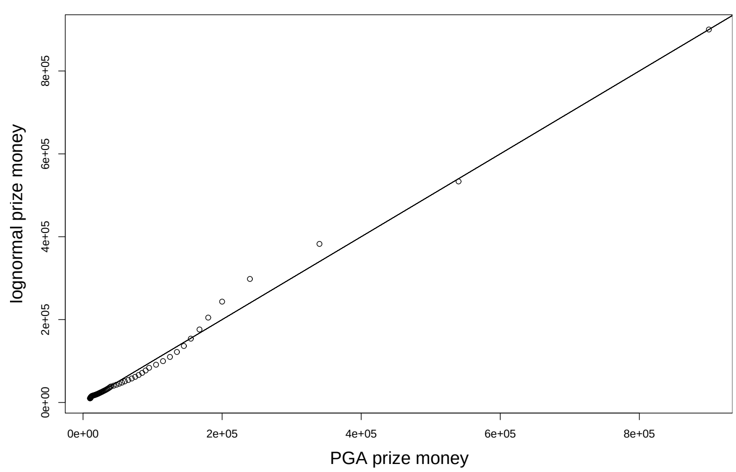

Figure 3: Q-Q plot of PGA prize money and quantiles obtained from the lognormal distribution together with the line $y = x$.

3.4 2011 Australian Open Tennis Prize Money

The Australian Open is one of the four prestigious "Grand Slam" tennis tournaments contested each year. We focus on the singles events for 2011 where the prize money is the same for the men and the women (www.australianopen.com/en_AU/event_guide/prize_money.html). In the singles events, there are $n = 128$ players who receive prize money. The winners receive $s_{\max}$ = \$Aus 2.2 million and those who compete but do not advance beyond the first round receive $s_{\min}$ = \$Aus 20,000. The total purse is T = \$Aus 8.9 million. A distinguishing feature of the distribution of the prize money compared to the previous examples is that the prize money is clumped as opposed to strictly decreasing. More specifically, set amounts are received for players eliminated in the first round (64), the second round (32), the third round (16), the fourth round (8), the quarterfinals (4), the semifinals (2), and for the runnerup (1) and the champion (1). In fitting the lognormal distribution as described in the Appendix, we obtain. $a = 19,998.80$, $\mu = 7.3879$ and $\sigma = 2.9776$. In figure 4, we provide a Q-Q plot of the singles prize money with the lognormal quantiles. In this case, we see that the fit is good, and this provides further evidence that the lognormal distribution is useful in the determination of awards in sport. The fit would be even better if the proposed methodology took into account the clumping structure of prize money.

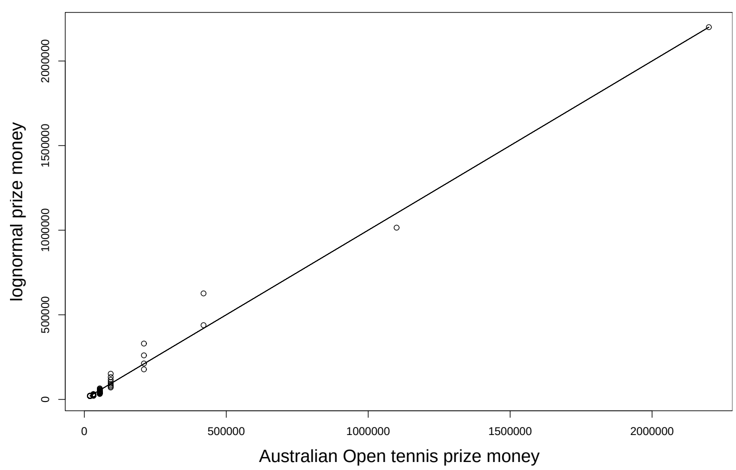

Figure 4: Q-Q plot of 2011 Australian Open prize money for singles and quantiles obtained from the lognormal distribution together with the line $y = x$.

3.5 Formula 1 Racing

Formula 1 (F1) car racing is the sport involving high performance cars travelling at speeds often in excess of 300 kilometres per hour. Formula 1 races are contested throughout the year in different international cities where the outcomes of races are of great importance to car manufacturers.

According to the 2010 Formula 1 rules, in a designated Grand Prix race, there may be 24 drivers where only the top $n = 10$ finishers receive Grand Prix points. The points are accumulated throughout the season and count towards the FIA (Fédération Internationale de l'Automobile) World Championships. From first to tenth place, points in a Grand Prix event are allotted as follows: 25, 18, 15, 12, 10, 8, 6, 4, 2, 1. To implement the fitting algorithm corresponding to the lognormal distribution, we therefore have $s_{\max} = 25$, $s_{\min} = 1$ and $T = 101$.

In fitting the three-parameter lognormal distribution, we obtained $a = -5.497$, $\mu = 2.6445$ and $\sigma = 0.5791$. In figure 5, we provide a Q-Q plot of the Formula 1 points with the resultant lognormal quantiles. We observe excellent fit.

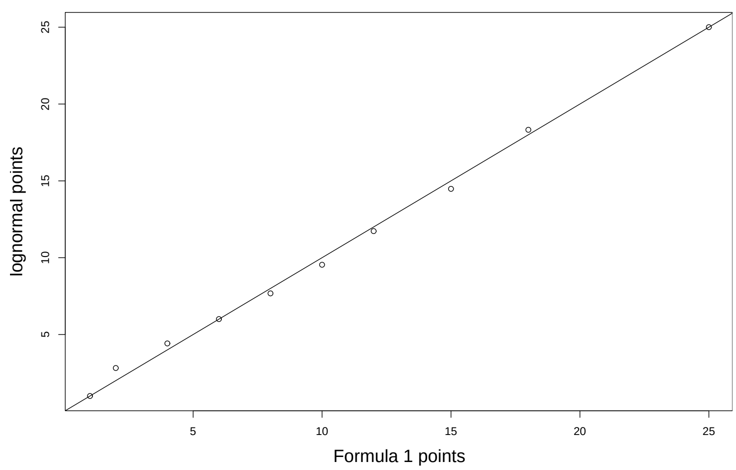

Figure 5: Q-Q plot of Formula 1 points and quantiles obtained from the lognormal distribution together with the line $y = x$.

3.6 2010 Boston Marathon Prize Money

The Boston Marathon is the world's oldest marathon which is held annually on the third monday in April. Prize money is awarded to the top $n = 15$ finishers in both the men's and women's divisions in a competition that attracts over 20,000 runners.

Beginning in 1986, cash prizes are relatively new to the Boston Marathon. The 2010 prize structure is given in table 1 where the total purse in both divisions is $T = \$353,000$ with $s_{\max} = \$150,000$ and $s_{\min} = \$1,500$. Clearly, it is more lucrative to be a first-round NBA rookie than a top-ranked marathon runner.

Finishing Position	Prize Money	Finishing Position	Prize Money	Finishing Position	Prize Money
1	\$150,000	6	\$12,000	11	\$2,600
2	\$75,000	7	\$9,000	12	\$2,100
3	\$40,000	8	\$7,400	13	\$1,800
4	\$25,000	9	\$5,700	14	\$1,700
5	\$15,000	10	\$4,200	15	\$1,500

Table 1: The prize structure for men and women in the 2010 Boston Marathon.

In fitting the three-parameter lognormal distribution, we obtained $a = 1147.02$, $\mu = 8.8886$ and $\sigma = 1.6479$. In figure 6, we provide a Q-Q plot of the 2010 cash prizes with the resultant lognormal quantiles. We observe reasonable fit suggesting that the Boston Marathon rewards its top finishers in a manner consistent with our theory.

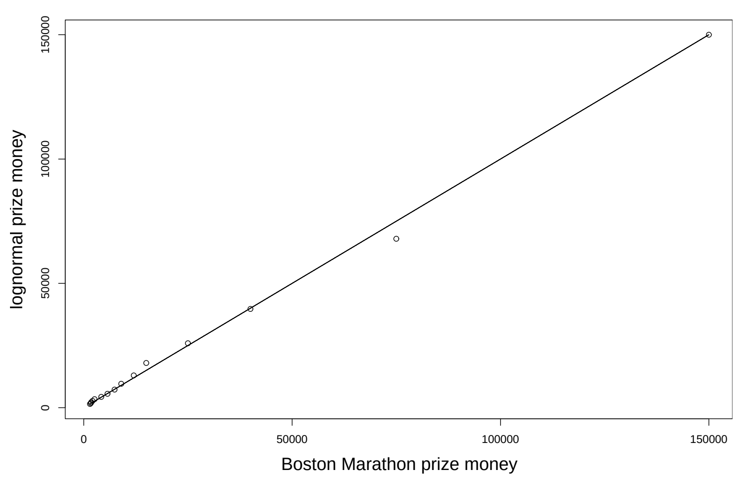

Figure 6: Q-Q plot of 2010 Boston Marathon prize money and quantiles obtained from the lognormal distribution together with the line $y = x$.

3.7 IPL Salaries

We now return to the original problem of determining salaries in an IPL draft. Referring to the 2008 IPL auction and ignoring the five iconic players, bids were received on 75 of the 77 registered players. The reserve prices and the winning auction bids are given in table 2. We therefore set $n = 75$. We also set $s_{\min} = \$100,000$ corresponding to the minimum auctioned salary bid on Chamara Silva (Hyderabad) and we set $s_{\max} = \$1,500,000$ corresponding to the maximum auctioned salary bid on Mahendra Singh Dhoni (Chennai). The determination of the total salary T is less straightforward. Earlier, it was stated that each team was constrained by a maximum payroll of \$5 million which might suggest $T = 8(\$5,000,000) = \$40,000,000$. However, the total auctioned salaries for the teams (excluding the iconic players) was \$36,780,000 and some of the teams exceeded the \$5 million limit. The reason why some of the team auction totals exceeded the limit is because some players played only a portion of the IPL season, and the team payrolls were reduced proportionately. We prefer to deal with the auctioned bids rather than the reduced salaries as they better represent player worth over an entire IPL season. We therefore set $T = \$36,780,000$ and obtain parameter estimates $a = -41,992.80$, $\mu = 13.0561$ and $\sigma = 0.5368$.

At this stage, it is difficult to compare the proposed IPL draft with the actual auction that took place. Although we know the proposed draft salaries (see table 3), we do not know the players to whom the salaries ought to be assigned. To facilitate a comparison, consider the total of the reserve prices \$15,255,000 assigned to the $n = 75$ cricketers in the 2008 IPL auction. The reserve prices greatly underestimate true market value as they are the minimum bidding prices for players. However, we do believe that there is information concerning player worth contained in the reserve prices, in the sense that the relative ordering of reserve prices provides insight into the relative ordering of player worth. We therefore calculate the correlation coefficient between the auction prices and the corresponding reserve prices. The correlation is low (0.36), and this provides some evidence of distortion in auction prices.

To provide some justification that the draft prices in table 3 are in line with market value, we calculate the correlation coefficient between the reserve prices and the draft prices sorted according to the ordering in the reserve prices. Although the sorting gives an unfair advantage to the draft procedure, we do note that the correlation is extremely high (0.98). To lessen the advantage, we take the sorted draft prices and mix them a little. Specifically, we take consecutive groups of five draft prices and reverse their order. The rationale is that the reserve prices exhibit roughly the correct ordering in market value but not exactly. In this case, the correlation is still reasonably high (0.67).

4 DISCUSSION

In theory, distorted bidding may arise in sequential English auctions involving complementary items. We have seen evidence of this phenomenom in the 2008 IPL auction, and we propose an alternative approach for the IPL in 2011. Specifically, we propose a simple draft where players are assigned to teams according to the teams which draft them, and where salaries are set according to the quantiles of a three-parameter lognormal distribution. The draft and the determination of lognormal parameters is straightforward, and the motivation for the approach is based on the supposition of multiplicative components of skill and the application of the CLT. Even if the CLT motivation is not found to be compelling, the flexibility of the three-parameter lognormal distribution facilitates modelling for a wide variety of distributional shapes. In various sports, we have demonstrated that the procedure produces results that are in line with current practice. Should the IPL wish to consider an auction, at the very least, the lognormal quantiles provide a starting point for assessing reasonable salaries.

There are several idiosyncrasies of the IPL that may be incorporated in the draft. With iconic players, they may again be assigned to teams with salaries determined by lognormal quantiles. With p iconic players, it may be seen as fair to give each iconic player the average salary of the top p lognormal quantiles. Constraints on total payroll may also allow teams to undertake various strategies that are intuitive to the public. For example, a team may trade draft picks to another team. This could be sensible when the next best available player is a player whose position on the team is already adequately filled. A team may also choose to skip a draft pick if its payroll is too high or if comparable undrafted players may be obtained at lower prices. This practice corresponds to a player who receives no bids in an auction.

Finally, there has been some dissatisfaction with rookie salaries in the NFL (Trotter 2010).

Whereas a rookie draft does exist in the NFL, the determination of salaries requires a negotiating process. It is clear that the methodology in this paper could be readily applied in the determination of a NFL rookie salary scale based on the existing NFL rookie draft. With the NFL collective bargaining agreement set to expire in March of 2011, the approach proposed in this paper may be worth investigating.

5 APPENDIX

We refer to the three constraints in (5) where our problem is to solve for a, μ and σ. Noting that $v_n = -v_1$, we rewrite the first two equations in (5) as

$$\begin{aligned} \log(s_{\min} - a) &= \mu - \sigma v_1 \\ \log(s_{\max} - a) &= \mu + \sigma v_1. \end{aligned} \tag{6}$$

From (6), we obtain

$$\begin{aligned} \mu &= \tfrac{1}{2}\log\left(s_{\min} - a\right) + \tfrac{1}{2}\log\left(s_{\max} - a\right) \\ \sigma &= \tfrac{1}{2v_1}\log\left(\tfrac{s_{\max}-a}{s_{\min}-a}\right). \end{aligned} \tag{7}$$

We then substitute the two expressions from (7) into the third equation in (5). This leads to

$$T = na + \sqrt{(s_{\max} - a)(s_{\min} - a)}\sum_{i=1}^{n}\left(\frac{s_{\max} - a}{s_{\min} - a}\right)^{\frac{v_i}{2v_1}}. \tag{8}$$

Since (8) is a decreasing function of a for $a < s_{\min}$, the determination of a is computationally straightforward. We then substitute a back into (7) to obtain μ and σ.

6 REFERENCES

Aitchison, J. and Brown, J.A.C. (1966). *The Lognormal Distribution*, Cambridge: Cambridge University Press.

Billingsley, P. (1995). *Probability and Measure, 3rd Edition*, New York: Wiley.

Cramton, P. (2006). "Simultaneous ascending auctions", In *Combinatorial Auctions* (editors P. Cramton, Y. Shoham and R. Steinberg), Cambridge: The MIT Press, 99-114.

Karnik, A. (2010). “Valuing cricketers using hedonic price models”, *Journal of Sports Economics*, 11, 456-469.

Krishna, V.J. (2010). *Auction Theory, Second Edition*, Burlington, MA: Academic Press/Elsevier.

Petersen, C., Pyne, P.D., Portus, M.J. and Dawson, B. (2008). “Analysis of Twenty20 Cricket performance during the 2008 Indian Premier League”, *International Journal of Performance Analysis in Sport*, 8(3), 63-69.

Rastogi, S.K. and Deodhar, S.Y. (2009). “Player pricing and valuation of cricketing attributes: Exploring the IPL Twenty20 vision”, *Vikalpa: the journal for decision makers*, 34(2), 15-23.

Sharp, G.D., Brettenny, W.J., Gonsalves, J.W., Lourens, M. and Stretch, R.A. (2010). “Integer optimisation for the selection of a Twenty20 cricket team”, *Journal of the Operational Research Society*, doi: 10/1057/jors2010.122.

Swartz, T.B. (2007). “Improved draws for highland dance”, *Journal of Quantitative Analysis in Sports*, 3(1), Article 2.

Trotter, J. (2010). “Mad money: Owners bemoan the massive deals for high picks, but a rookie salary scale might actually favor the players”. *Sports Illustrated*, August 2, 2010, page 38.

van Staden, P.J. (2009). “Comparison of bowlers, batsmen and all-rounders in cricket using graphical displays” *Current Science*, 96(6), 764-766.

Player	Reserve Price	Win Bid	Player	Reserve Price	Win Bid	Player	Reserve Price	Win Bid
MS Dhoni	400	1500	D Hussey	100	625	N Bracken	225	325
A Symonds	250	1350	M Muralitharan	250	600	D Steyn	150	325
S Jayasuriya	250	975	H Gibbs	250	575	P Patel	150	325
I Sharma	150	950	S Pollock	200	550	AB de Villiers	200	300
I Pathan	200	925	D Karthik	200	525	M Patel	100	275
B Lee	300	900	S Malik	300	500	T Dilshan	150	250
J Kallis	225	900	A Kumble	250	500	R Sarwan	225	225
RP Singh	200	875	C White	100	500	Y Khan	225	225
H Singh	250	850	G Smith	250	475	F Maharoof	150	225
C Gayle	250	800	M Jayawardene	250	475	J Sharma	100	225
R Uthappa	200	800	Y Pathan	100	475	S Chanderpaul	200	200
R Sharma	150	750	S Warne	450	450	J Langer	200	200
G Gambhir	220	725	M Boucher	200	450	S Katich	200	200
A Gilchrist	300	700	Z Khan	200	450	M Ntini	200	200
K Sangakkara	250	700	S Akhtar	250	425	C Vaas	200	200
B McCullum	175	700	M Kartik	200	425	S Styris	175	175
A Morkel	225	675	R Ponting	335	400	R Powar	150	170
S Afridi	225	675	P Chawla	125	400	K Akmal	150	150
J Oram	200	675	M Hayden	225	375	W Jaffer	150	150
M Kaif	125	675	VVS Laxman	150	375	U Gul	150	150
M Tiwari	100	675	G McGrath	350	350	D Fernando	150	150
M Asif	225	650	S Fleming	350	350	L Bosman	150	150
S Raina	125	650	M Hussey	250	350	T Taibu	125	125
D Vettori	250	625	A Agarkar	200	350	N Zoysa	100	110
S Sreesanth	200	625	L Malinga	200	350	C Silva	100	100

Table 2: Reserve prices and winning bids in thousands of dollars for the 75 players in the 2008 IPL auction.

Draft Order	Draft Salary	Draft Order	Draft Salary	Draft Order	Draft Salary
1	1,500,000	26	540,126	51	326,949
2	1,282,290	27	529,115	52	319,755
3	1,159,607	28	518,452	53	312,577
4	1,074,429	29	508,108	54	305,402
5	1,009,313	30	498,060	55	298,223
6	956,660	31	488,284	56	291,029
7	912,483	32	478,760	57	283,806
8	874,434	33	469,469	58	276,541
9	841,015	34	460,394	59	269,221
10	811,214	35	451,519	60	261,828
11	784,313	36	442,828	61	254,344
12	759,787	37	434,310	62	246,748
13	737,242	38	425,949	63	239,014
14	716,370	39	417,736	64	231,112
15	696,930	40	409,658	65	223,006
16	678,728	41	401,705	66	214,651
17	661,608	42	393,866	67	205,989
18	645,438	43	386,133	68	196,946
19	630,110	44	378,494	69	187,421
20	615,532	45	370,942	70	177,273
21	601,627	46	363,467	71	166,291
22	588,327	47	356,061	72	154,143
23	575,575	48	348,715	73	140,239
24	563,319	49	341,420	74	123,357
25	551,516	50	334,167	75	100,000

Table 3: Salaries in dollars based on a draft corresponding to the 2008 IPL auction and the fitting of the three-parameter lognormal distribution.