In this appendix we present an argument that may help explain why the point deficit that induces the underdog to go to a hurry-up offense is roughly equal to the spread times the fraction of the game that remains. The argument involves approximations that are most likely to be valid near the beginning of the game.

Let t denote the amount of time played. We will use a full game as our unit of measurement, so that $\Delta t = 1$ represents sixty minutes of playing time.

Let $X(t)$ be the point-differential process; i.e., $X(t)$ is the favored team's points minus the underdog's points, at time t. Let μ be the spread, the number of points by which the favorite is expected to win. Then for $t' > t$,

$$\mathcal{E}(X(t') - X(t)) \approx \mu(t' - t)$$

and in fact it's reasonable to suppose that the Central Limit Theorem applies when t' is substantially larger than t, so that for some σ,

$$\frac{X(t') - X(t) - \mu(t' - t)}{\sigma\sqrt{t' - t}} \tag{1}$$

is distributed approximately N(0,1). (Actually, the argument below requires only that the distribution of expression 1 converge to *something* for large t', but a normal distribution is the only possibility.)

Let t be given, and suppose that $X(t) > 0$, so that the favored team is in the lead. We wish to find the ending time t' that gives the underdog the best chance of winning. In other words, we want to find the t' that maximizes $\mathsf{P}(X(t') < 0)$.

Now $X(t') < 0$ is equivalent to

$$\frac{X(t') - X(t) - \mu(t' - t)}{\sigma\sqrt{t' - t}} < \frac{-X(t) - \mu(t' - t)}{\sigma\sqrt{t' - t}},$$

and the expression on the left side of this inequality is distributed approximately N(0,1). Hence

$$\mathsf{P}(X(t') < 0) \approx \Phi\left(\frac{-X(t) - \mu(t' - t)}{\sigma\sqrt{t' - t}}\right)$$

where Φ is the cumulative distribution function for the standard normal distribution. If we maximize

$$\Phi\left(\frac{-X(t) - \mu(t' - t)}{\sigma\sqrt{t' - t}}\right)$$

with respect to t' by taking the derivative, setting it equal to zero, and solving for $t' - t$, we find that

$$t' - t = \frac{X(t)}{\mu}. \tag{2}$$

This says that for an underdog who trails in the game, the "best" amount of remaining time (in units of full games) is the actual point differential divided by the spread.

As an example, suppose the spread is 14 points, and the underdog currently trails by 10. Then the underdog's probability of winning is maximized when 10/14 of a game, or 42:51, remains. If there is actually less time than this remaining, the underdog should be in hurry-up mode. Conversely, if there is more time than this remaining, the underdog should be in slowdown mode.

Notice that given the spread, the expected total points scored in the game — the "over-under" — can affect this analysis only through the value of σ that is required to normalize expression 1. Since σ doesn't enter into equation 2, it's not surprising that the results of the model are not sensitive to the expected total points scored.

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