Contest Efforts in Light of Behavioral Considerations♣

by

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Abstract

This study shows that distortion of probabilities is a possible reason for rent under-dissipation in contests with relatively small number of participants. Such distortion may also result, however, in over-dissipation of the contested rent. Focusing on contests with homogeneous contestants and the commonly studied contest success function, our main results clarify under what circumstances (i) rents are more under-dissipated relative to the standard situation where probabilities are not distorted (ii) rents are under-dissipated, yet less intensely relative to the standard situation where probabilities are not distorted (iii) rents are over-dissipated and (iv) the contest does not possess a symmetric interior equilibrium in pure strategies.

Key words: efforts in contests, rent dissipation.
JEL classification: D70, D72

♣ We are grateful to the participants in the conference on "Advances in the Theory of Contests and Tournaments", WZB, Berlin, October 2005 and, in particular, to two anonymous referees for their useful comments and suggestions.
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In the contest literature, a major theoretical and empirical effort has been made to clarify the reasons and extent of rent under-dissipation and to determine whether rent over-dissipation is possible. Whereas rent under-dissipation can be explained by different reasons (Baik and Shogren (1992), Che and Gale (1998), Cornes and Hartley (2003), Dixit (1987), Ellingsen (1991), Gradstein and Konrad (1999), Hirshleifer (1991), Kahana and Nitzan (1999), Konrad (2004), Konrad and Schlesinger (1997), Lockard and Tullock (2001), Nitzan (1994), Nti (1997), Posner (1975), Riley (2001)), it has been concluded that *over-dissipation is impossible* provided that the contestants are rational.[1] This impossibility result is obtained, regardless of the assumptions on the extent of competition among the contestants (their number, evaluations of the contested prize, income and their ability to affect the contest outcome) or the form of the contest success function (Baye et. al (1999), Lockard and Tullock (2001)).

When individuals are not perfectly rational and bidding behavior is subject to error, over-dissipation is possible as established by Anderson et. al (1998) for all-pay auctions. The main objective of the present study is to show that, in the context of the commonly studied generalized contest success functions of Tullock (1980), probability distortions, a so far unnoticed incentive for the reduction or expansion of wasteful resources in contests, may change the extent of rent under-dissipation and, furthermore, also result in over-dissipation of the contested rent. Probability distortions take the form advocated by a vast literature, namely, the distortion function is commonly assumed to have an inverse *S*-shape form, as in Tversky and Kahneman (1992), Camerer and Ho (1994), Gonzalez and Wu (1999), Bleichrodt and Pinto (2000), Abdellaoui (2002). These studies might suggest some different parametric estimation for the probability distortion function, which is inessential for our basic results. We illustrate our main arguments by assuming that probability distortions are given by the single-parameter inverse S-shaped distortion functions suggested by Tversky and Kahneman (1992) in their Cumulative Prospect Theory.[2]

Focusing on contests with relatively small number of n homogeneous contestants and on the most commonly studied contest success function that depends on a single parameter r, our main results clarify under what circumstances, namely, combinations of n and r, (i) rents are under-dissipated even more intensely relative to the standard situation where probabilities are not distorted (ii) rents are under-dissipated, yet less intensely relative to the standard situation where probabilities are not distorted (iii) rents are over-dissipated and (iv) the contest does not possess a symmetric interior equilibrium in pure strategies. The analysis focuses on probability distortions as a source of reduced or increased waste in contests. We illustrate the analysis for the case where r=1, assuming Tversky and Kahneman's parameter estimation, and show that when the number of contestants exceeds (is smaller than) 14, rents are over (under)-dissipated.

In the following section the standard benchmark rent-seeking contest is presented. In section 2 we introduce the more general contest that allows probability distortions and study the conditions for the existence of a symmetric interior pure-strategy equilibrium, rent under-dissipation and rent over-dissipation. We then compare under-dissipation in the extended model relative to under-dissipation in the benchmark model. The results are finally illustrated in the widely studied special cases of two-player and n-player contests, assuming that the contest success function is homogenous of degree zero. The last section contains a brief summary and concluding remarks.

1. The Standard Contest

Let us consider the standard contest (Lockard and Tullock (2001), Tullock (1980)), where n homogenous contestants compete over the same single prize, v.[3] With probability $0 \le Pr_i \le 1$, i=1,2,..,n, contestant i wins the contest. It is assumed that only one contestant wins the contest, $\sum_{i=1}^{n} \Pr_i = 1$. The expected net payoff of the risk neutral contestant i is equal to:

$$E(u_i) = \Pr_i v - x_i,\ i = 1,...,n \qquad (1)$$

where x_i denotes the resources invested by contestant *i*. The contest success function (CSF) $\Pr_i(x_1,...,x_n)$ specifies contestant *i's* probability of winning the contest, given the resources simultaneously invested by the contestants. It is assumed that the CSF is of the particular logit form, $\Pr_i(x_1,...,x_n)=\frac{x_i^r}{\sum_{i=1}^{n} x_i^r}$,[4] see Lockard and Tullock (2001). Each contestant determines his level of investment in the contests, x_i^*, so that he maximizes his expected net payoff. The first order conditions that determine the optimal level of resources invested in the contest, x_i^*, are given by $\frac{\partial E(u_i)}{\partial x_i}=0$, $\forall i=1,2,..,n$. The total amount of resources invested in the contest, *the rent dissipation of the contest,* is denoted by $X^*=\sum_{i=1}^{n} x_i^*$ (the dissipation notion is plausible, given that the prize is normalized to 1).

It has been shown that in this widely studied case of imperfectly discriminating contest success functions, the rent dissipation cannot exceed the prize, $X^* \leq v$. Specifically, see Perez- Castrillo and Verdier (1992)[5]:

Theorem 1: (i) If $r \leq 1$, then $X^*=\frac{(n-1)r}{n}v$

(ii) If $1<r\leq 2$ and $n\leq \frac{r}{r-1}$, then $X^*=\frac{(n-1)r}{n}v$.

(iii) If $1<r\leq 2$ and $n>\frac{r}{r-1}$, then $X^*=\frac{(n^*-1)r}{n^*}v$, where n^* is the highest integer that does not exceed $\frac{r}{r-1}$.

This under-dissipation result remains valid when entry to the contest is not restricted, the contestants differ in their evaluations of the prize, in their lobbying capabilities or in their budget constraints (Baye et. al. (1993), (1999), Che and Gale

(1998), Gradstein (1995), Nti (1997)). The impossibility of over-dissipation in equilibrium is also robust to various extensions of the standard Tullock (1980) contest that allow, for example:

- Bureaucratic friction (Kahana and Nitzan (2002)).
- Loss aversion (Cornes and Hartley (2003)).
- Risk aversion (Konrad and Schlesinger (1997)).
- Uncertainty regarding the award of the rent (Kahana and Nitzan (1999)).
- Various structural contest modifications (Gradstein and Konrad (1999) and Konrad (2004)).
- The introduction of opposition to the award of the prize (Baik (1999), Ellingsen (1991), Epstein and Nitzan (2003), (2006)).

The significance of establishing the extent of rent dissipation is due to the two main types of applications of contest theory. When dissipation is considered undesirable and investment in the contest is viewed, at least to some extent, as a social waste, it has direct efficiency implications that were of much concern in the rent-seeking literature. When dissipation is considered desirable, that is, efforts incurred in the contest enhance the welfare (profits) of some interest group, it also has direct efficiency and distributional implications that were of much concern in the patent races or auction literature. We therefore turn to the main undertaking of this study, namely, examining the effect of the behavioral considerations that play a central role in prospect theory (Kahneman and Tversky (1979) and Tversky and Kahneman (1992)), on the existence and extent of rent dissipation.

2. Equilibrium under distorted probabilities

We now allow for probability distortions that take the form that is commonly used in the literature allowing for such distortion, that is, an inverse S-shaped probability weighting function (Tversky and Kahneman (1992), Camerer and Ho (1994), Gonzalez and Wu (1999), Bleichrodt and Pinto (2000), Abdellaoui (2002) and others).[6] For the purpose of our analysis, we are only interested in the general form of the function, independent of the specific values of its parameters. Thus, we present here the simplest, one-parameter function, as in the Cumulative Prospect Theory (CPT) (Tversky and Kahneman (1992)).[7] According to this theory, individuals assign a value $w(p)$ to the objective probability p, where $w(p)$ is given by:

$$w(p) = \frac{p^{\beta}}{(p^{\beta} + (1-p)^{\beta})^{\left(1/\beta\right)}} \tag{2}$$

The following graph illustrates this distortion function, assuming β=0.61, as in CPT:

Figure 1 – Here

Facing relatively small probabilities (p<0.33), the individual can be conceived as optimistic; the subjective winning probability is higher than the objective probability p. Facing relatively large probabilities (p>0.33), the individual can be conceived as pessimistic; p is underestimated. Under such distorted probabilities, individual i's behavior is based on his belief that in a symmetric equilibrium his expected profit is given by:

$$E(u_i) = \frac{\left(\dfrac{x_i^r}{x_i^r + (n-1)x_j^r}\right)^{\beta}}{\left(\left(\dfrac{x_i^r}{x_i^r + (n-1)x_j^r}\right)^{\beta} + \left(1 - \left(\dfrac{x_i^r}{x_i^r + (n-1)x_j^r}\right)\right)^{\beta}\right)^{1/\beta}} v - x_i$$

In our strategic environment, the individual players have a systematic bias in the perception of their winning probabilities. Despite this unrecognized bias, the individual players are assumed to behave rationally, that is, choose a feasible action (strategy) that maximizes their expected utility, given their biased perception. Assuming that the players maximize expected utility does not contradict the fact that the players err in their probability assessments. Likewise, the use of Nash equilibrium as the notion on which the contest analysis is based does not prevent or contradict the assumption of biased probability perceptions. The resort to Nash equilibrium implies that the model predicts behavior, namely, choice of effort levels, that satisfies the appealing requirement of fulfilled expectations of rational players regarding the behavior of the other players. True, in Nash equilibrium the players can be conceived as sophisticated, because they analyze the game and anticipate correctly the actions of their opponents and such sophistication may seem inconsistent with their unsophisticated (biased) probability assessments. However, *the mere definition of Nash equilibrium does not require that agents are sophisticated* (in the same sense that the rationality principle does not require that real players are sophisticated in the sense of being able to solve maximization problems). Individual rationality and fulfilled anticipations of players' actions are simply the two defining elements of Nash equilibrium and both can coexist with our assumption of biased perceptions of the players' winning probabilities. In particular, notice that despite the unawareness of the individuals to their biased probabilistic perceptions, in equilibrium they anticipate correctly not only the efforts made by the other contestants, but also their winning probabilities.

The necessary condition for an interior, pure-strategy equilibrium is:

$$\frac{dE(u_i)}{dx_i} = 0 \qquad (3)$$

The explicit form of this condition appears in the Appendix. In a symmetric interior equilibrium, $x_i=x_j$, and, therefore, the explicit form of the necessary condition is considerably simplified (with no loss of generality, we let $v=1$) , see equation (4) in the Appendix. By (4), the symmetric equilibrium individual investment x^{**} is given by:

$$x^{**} = r\left(\frac{n-1}{n^{\beta}\left(1+(n-1)^{\beta}\right)^{(1/\beta)}}\left(\beta - \frac{1-(n-1)^{\beta-1}}{1+(n-1)^{\beta}}\right)\right) \tag{5}$$

We have verified that the second order conditions are satisfied for the relevant range of β, namely $0.28 \leq \beta \leq 1$. This range is referred to as relevant because it takes into account the values of β obtained in the experimental literature.[8] In other words, for the relevant range of β, at x^{**}, $\frac{d^2E(u_i)}{dx^2} < 0$. This implies that, if x^{**} is an interior equilibrium, then it is the unique equilibrium.

We now study the combination of n and r for which there exists a symmetric equilibrium in pure strategies. Note that, in addition to (4), a necessary condition for the existence of equilibrium is that, for every i, $E(u_i) \geq 0$. The reason is that passivity, that is $x_i = 0$, which is always a feasible strategy for contestant i, must be an inferior option. The additional necessary condition then is:

$$E(u_i) = \frac{\left(\frac{1}{n}\right)^{\beta}}{\left(\left(\frac{1}{n}\right)^{\beta} + \left(1-\left(\frac{1}{n}\right)\right)^{\beta}\right)^{1/\beta}} - r\left(\frac{n-1}{n^{\beta}\left(1+(n-1)^{\beta}\right)^{(1/\beta)}}\left(\beta - \frac{1-(n-1)^{\beta-1}}{1+(n-1)^{\beta}}\right)\right) > 0 \tag{6}$$

which requires that

$$r < \frac{1}{\left(\frac{n-1}{n}\right)\left(\beta - \frac{1-(n-1)^{\beta-1}}{1+(n-1)^{\beta}}\right)} = f(n) \tag{7}$$

In the above condition for the existence of a pure-strategy equilibrium, there is an inverse relationship between n and r. The economic intuition behind this relationship is the following: On one hand, an increase in r positively affects x^{**}. On the other hand, an increase in n reduces the equilibrium winning probability and, in turn, x^{**}. Hence, the simultaneous changes in r and n that do not affect x^{**} and, in turn, inequality (6), are of opposite signs. Assuming that β=0.61, as in CPT, the following table illustrates combinations of values of r, the parameter of the CSF and n, the number of players, for which there exists an equilibrium. Note that independent of n, for any $r > \frac{2}{\beta}$, there is no equilibrium, and for any $r < \frac{1}{\beta}$ there always exists an equilibrium.

Table 1 – Here

Utilizing (5) and (7) we can characterize X^{**}, rent dissipation in the extended setting.

Theorem 2:

(i) If $r \le \frac{1}{\beta}$, then $X^{**} = r\left(\frac{n-1}{n^{\beta}\left[1+(n-1)^{\beta}\right]^{(1/\beta)}}\left(\beta - \frac{1-(n-1)^{\beta-1}}{1+(n-1)^{\beta}}\right)\right)n$

(ii) If $\frac{1}{\beta} < r \le \frac{2}{\beta}$ and $n \le f^{-1}(r)$, then:

$$X^{**}=r\left(\frac{n-1}{n^{\beta}\left[1+(n-1)^{\beta}\right]^{(1/\beta)}}\left(\beta-\frac{1-(n-1)^{\beta-1}}{1+(n-1)^{\beta}}\right)\right)n$$

(iii) If $\frac{1}{\beta}<r\le\frac{2}{\beta}$ and $n>f^{-1}(r)$, then:

$$X^{**}=r\left(\frac{n^{*}-1}{\left(n^{*}\right)^{\beta}\left[1+\left(n^{*}-1\right)^{\beta}\right]^{(1/\beta)}}\left(\beta-\frac{1-\left(n^{*}-1\right)^{\beta-1}}{1+\left(n^{*}-1\right)^{\beta}}\right)\right)n^{*}$$

where n^* is the highest integer that does not exceed $f^{-1}(r)$.

Proof:

The proof is directly obtained from (5) and (7).

The individuals are, obviously, not aware of their perception bias. Consequently, despite their probabilistic bias, every player in the contest knows that, in equilibrium, her opponents choose the same effort level as she does and, therefore, have the same winning probability. The symmetric equilibrium total effort X**=nx** results from equally biased winning probabilities. As already noted, in equilibrium, although the players are unaware of the probability bias inducing their behavior, they do know that they share the same equal winning probability $1/n$. This means that despite the perception bias, the players behave rationally as well as anticipate correctly the actions of their opponents and their winning probabilities.

Let us complete the analysis by illustrating the conditions that ensure that rent under-dissipation with probability distortions is more or less intense relative to the standard case. The following table compares the two settings, assuming that v=1 and β=0.61, with few combinations of r and n values, such that $x^{**}>0$ (recall that X^{**} and X^* denote, respectively, rent-dissipation under distorted and undistorted probabilities:

Table 2 - Here

The following figure presents the dissipation level under distorted and undistorted probabilities, assuming that r=1 and β=0.61. Notice that in the former case the extent of over-dissipation is increasing in n.

Figure 2 –Here

Finally, let us illustrate our results in two special cases that were intensively examined in the contest literature.

2.1. *The special case of 2 homogeneous contestants, r =1 and CPT probability distortion.* Consider the widely studied case where n=2 and r=1. For illustration, we assume probability distortion as in CPT. By (5), in this case (recall that v=1)

$$x^{**} = 0.1283 \qquad (8)$$

and $X^{**} = x_1^{**} + x_2^{**} = 0.2566$. Hence, probability distortions reduce the dissipation from 0.5 in the standard case to 0.2566. The economic intuition behind this result is straightforward; with only two contestants, the relatively high winning probabilities are underestimated and this substantially reduces the incentive to expend resources in the contest. Notice that in this case, although the two players know that, in equilibrium, the winning probabilities resulting from the equal efforts of 0.1283 are equal, they are not aware of the fact that these efforts reflect their common bias regarding their winning probabilities (in this case, by (2), the distorted winning probabilities are equal to 0.42).

2.2. *The case of n homogeneous contestants and r =1*

When r=1, by (7), it can be shown that, for any n, there exists a pure-strategy symmetric equilibrium. By (5),

$$x^{**} = \frac{n-1}{n^{\beta}\left(1+(n-1)^{\beta}\right)^{(1/\beta)}}\left(\beta - \frac{1-(n-1)^{\beta-1}}{1+(n-1)^{\beta}}\right) \quad (9)$$

We can therefore directly derive the necessary and sufficient conditions for under and over rent dissipation, assuming probability distortions as in CPT.

Theorem 3: For r=1, β=0.61 and any $n \geq 14$ ($n < 14$), there is over (under) rent-dissipation.

Proof:

By (9), rent over-dissipation requires that $X^{**} = \tilde{n}\, x^{**} > 1$. That is,

$$\frac{n-1}{n^{0.61}\left(1+(n-1)^{0.61}\right)^{1.64}}\left(0.61 - \frac{1-(n-1)^{-0.39}}{1+(n-1)^{0.61}}\right)\tilde{n} > 1$$

from which we obtain that $\tilde{n} \geq 14$. **Q.E.D.**

When the number of contestants n is sufficiently small ($n < 14$), regardless of whether the individuals tend to be pessimistic (optimistic) and under- (over-) estimate the objective winning probability, their incentive to expand resources in the contest is relatively low. This results in rent under-dissipation which ensures their positive expected payoff.[9] This result which is valid for such small contests provides a modified explanation to Tullock's conundrum that theoretical models predict more rent seeking than observed in practice. When the number of contestants n is sufficiently large

($n \geq 14$), the individuals tend to be optimistic, that is, the conceived winning probability is higher than the objective probability and this induces them to sufficiently increase their effort, such that the contested rent is over-dissipated. Note that in our model over-dissipation is consistent with a pure-strategy equilibrium (it is not precluded by the existence condition (6) that requires a non-negative subjective expected payoffs), because in contests where the contestants are optimistic, their winning probabilities are over-estimated and, in turn, their subjective ex-ante expected payoffs are also over-estimated relative to the objective negative equilibrium expected payoffs.

Finally, it should be pointed out that assuming other values for β would quantitatively change Theorem 3. Nevertheless, qualitatively this result holds for *any* single parameter probability distortion function of the commonly assumed inverse S-shape form.

3. Conclusion

In small-number contests, where the contestants' winning probabilities are relatively high, distortion (underestimation) of probabilities is yet another possible reason for rent under-dissipation. In large-number contests, where the contestants' winning probabilities are relatively small, distortion (overestimation) of probabilities may, however, give rise to rent over-dissipation, which is in marked contrast to the standard, robust, under-dissipation result, namely, that total efforts of the contestants cannot exceed the contested prize. Focusing on contests with n homogeneous contestants and the most commonly studied generalized contest success function, $\Pr_i(x_1,...,x_n) = x_i^r / \sum_{i=1}^{n} x_i^r$, that depends on the single parameter r, and assuming that probability distortions take the form advocated by CPT, our main result specifies the extent of rent dissipation for different combinations of the parameters n and r (Theorem 2). By comparing rent dissipation in our case to dissipation in the standard case of undistorted probabilities (Theorem 1), we clarify under what circumstances (combinations of n and r) (i) rents are under-dissipated even more intensely relative to the standard situation where probabilities are not distorted (ii) rents are under-dissipated, yet less intensely relative to the standard situation and (iii) rents are over-dissipated. Our analysis has been carried out allowing the parameter r of the contest success function to be equal, larger or smaller to 1. When r=1, it was shown (Theorem 3) that, when the number of contestants exceeds (is smaller than) 14, rents are over (under)-dissipated.

The first necessary condition for the existence of a symmetric interior pure-strategy equilibrium, see (4), enables the derivation of the equilibrium effort of a contestant. The second necessary condition, see (7), implies that there is an inverse relationship between the number of contestants n and the parameter r that ensures the existence of such equilibria. It also implies that, independent of n, for any $r > \frac{2}{\beta}$, there is no equilibrium, and for any $r < \frac{1}{\beta}$ there always exists an equilibrium. This is in contrast to the standard situation of undistorted probabilities where, independent of n, $r \leq 2$ is a necessary condition for the existence of a symmetric interior pure-strategy equilibrium (see Theorem 1). Finally, we mention again the robustness of our results; that is, the basic findings presented in this paper are qualitatively valid under other probability distortion function that is of the inverse S-shape form.

Finally, given that the extent of over-dissipation is increasing in n, one may wonder why contests with distorted probabilities are not characterized by very large number of participants. The obvious answer is that usually participation in a contest is costly and a sufficiently large cost c serves as a barrier to entry to the contest. More precisely, there exist upper bounds of c corresponding to different values of n that are required for the existence of equilibrium. Large-number contests are not expected in our extended setting of distorted probabilities because equilibrium does not exist when the participation cost c is sufficiently large relative to the contested prize.

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Appendix

The first order condition is:

$$\frac{dE(u_i)}{dx_i} = -\frac{1}{\beta} v \frac{\left(\frac{x_i^r}{x_i^r + x_j^r(n-1)}\right)^{\beta}}{\left(\left(\frac{x_i^r}{x_i^r + x_j^r(n-1)}\right)^{\beta} + \left(1 - \frac{x_i^r}{x_i^r + x_j^r(n-1)}\right)^{\beta}\right)^{((\beta+1)/\beta)}} \cdot \tag{3}$$

$$\left(\begin{array}{l} \frac{\beta}{\left(\frac{x_i^r}{x_i^r + x_j^r(n-1)}\right)^{1-\beta}} \left(\frac{1}{x_i^r + x_j^r(n-1)}\left(rx_i^{r-1}\right) - \frac{x_i^r}{\left(x_i^r + x_j^r(n-1)\right)^2}\left(rx_i^{r-1}\right) \right) + \\ \frac{\beta}{\left(1 - \frac{x_i^r}{x_i^r + x_j^r(n-1)}\right)^{1-\beta}} \left(\frac{x_i^r}{\left(x_i^r + x_j^r(n-1)\right)^2}\left(rx_i^{r-1}\right) - \frac{1}{x_i^r + x_j^r(n-1)}\left(rx_i^{r-1}\right) \right) \end{array} \right) +$$

$$\beta \frac{v}{\left(\frac{x_i^r}{x_i^r + x_j^r(n-1)}\right)^{1-\beta}} \frac{\frac{1}{x_i^r + x_j^r(n-1)}\left(rx_i^{r-1}\right) - \frac{x_i^r}{\left(x_i^r + x_j^r(n-1)\right)^2}\left(rx_j^{r-1}\right)}{\left(\left(\frac{x_i^r}{x_i^r + x_j^r(n-1)}\right)^{\beta} + \left(1 - \frac{x_i^r}{x_i^r + x_j^r(n-1)}\right)^{\beta}\right)^{(1/\beta)}} - 1 = 0$$

In a symmetric equilibrium where $x_i = x_j$, the necessary condition for an interior equilibrium is:

$$\frac{dE(u_i)}{dx_i} = -\frac{1}{\beta}\frac{\left(\frac{1}{1+(n-1)}\right)^{\beta}}{\left(\left(\frac{1}{1+(n-1)}\right)^{\beta} + \left(1-\frac{1}{1+(n-1)}\right)^{\beta}\right)^{((\beta+1)/\beta)}} \tag{4}$$

$$\left(\frac{\beta}{\left(\frac{1}{1+(n-1)}\right)^{1-\beta}}\left(\frac{1}{nx_i}(r) - \frac{1}{x_i(n)^2}(r)\right) + \frac{\beta}{\left(1-\frac{1}{1+(n-1)}\right)^{1-\beta}}\left(\frac{1}{x_i(n)^2}r - \frac{1}{nx_i}(r)\right)\right) +$$

$$\beta\frac{1}{\left(\frac{1}{1+(n-1)}\right)^{1-\beta}}\frac{\frac{r}{nx_i}(1-\frac{1}{n})}{\left(\left(\frac{1}{1+(n-1)}\right)^{\beta} + \left(1-\frac{1}{1+(n-1)}\right)^{\beta}\right)^{(1/\beta)}} - 1 = 0$$

This yields the symmetric equilibrium effort:

$$x^{**} = r\left(\frac{n-1}{n^{\beta}\left[1+(n-1)^{\beta}\right]^{(1/\beta)}}\left(\beta - \frac{1-(n-1)^{\beta-1}}{1+(n-1)^{\beta}}\right)\right) \tag{5}$$

Footnotes

[1] There are two exceptions. First, under independent preferences, over-dissipation is impossible in pure-strategy equilibria, however, it is possible ex-post for particular realizations of players' mixed strategies, see Baye et. al. (1999). Second, in evolutionary equilibrium, negatively interdependent preferences may induce spiteful behavior (contestants behave as if they aim to maximize their relative payoff) that results in rent over-dissipation, see Guse and Hehenkamp (2005) and references therein.

[2] Qualitatively, our results remain valid under common alternative forms of the probability distortion function.

[3] This assumption can be easily generalized to *n* different evaluations of the same prize: v_i , i=1,2,...,n. Most of the contest literature studies single-prize contests, however, more recently several studies have focused on multiple-prize contests, see for example, Clark and Riis (1998).

[4] This logit form is commonly assumed in the rent-seeking literature.

[5] For $r > 2$, there is no pure strategy equilibrium, see Baye et. al. (1999).

[6] In our model the winning probability of the contestants are distorted. We could have assumed a different type of probability distortion that directly relates to the contest success function. In our case such a distortion could take the form of a distortion of the parameter *r*. Such a distortion pattern is less plausible because it has no support in the existing experimental literature.

[7] Clearly, supporting evidence generated in experimental work focusing on contests could increase the plausibility of our analysis.

[8] For example, $\beta = 0.674$ in Bleichrodt and Pinto (2000), $\beta = 0.56$ in Camerer and Ho (1994) and $\beta = 0.71$ in Wu and Gonzalez (1996).

[9] This implication of Theorem 3 is related to the effect of loss aversion on rent seeking that was recently studied by Cornes and Hartley (2003). Loss aversion is captured by the assumption that a gain in wealth is evaluated at φ times the same loss in wealth, where $0<\varphi<1$. Assuming that the reference level for wealth is zero, it can be shown that for r=1 and any n, $(n < 14)$, there exists a degree of loss aversion φ^* that yields the same extent of rent under-dissipation as in our case of distorted probabilities. The same is true for any r , r< 3.2787, see Theorem 2. Notice, however, that such equivalence between our setting and the loss aversion setting does not exist, when the rent is over-dissipated.