OVERCONFIDENCE AND VOTING DECISIONS IN “THE WEAKEST LINK”

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Abstract: This paper uses a natural laboratory of *The Weakest Link* television show to conduct a test for overconfidence. In *The Weakest Link* contestants are heterogeneous in their ability to answer general knowledge questions, which determines their rank in an ad hoc group. Contestants frequently assess their relative performance in a competitive group and have an opportunity to vote off any of their counterparts. We calculate expected prizes, necessary for individual voting decisions to constitute the Nash mixed-strategy equilibrium, and compare these prizes with the actual average earnings in the television show. We find that all contestants are miscalibrated: low ranked contestants are overconfident, while high ranked contestants are underconfident.

Key words: overconfidence, underconfidence, voting, television show, natural experiment, mixed strategy

JEL Classification codes: C72, C93, D72

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I. Introduction

Studies in economics and psychology accumulate compelling evidence that people are overconfident. When assessing their relative performance, overconfident individuals systematically overestimate their abilities or position themselves above the average standard. Early empirical evidence on overconfidence comes from psychological experiments based on subjective estimates without monetary incentives (e.g. Ola Svenson, 1981). In such experiments, the effect of overconfidence emerges when the experimental task is relatively difficult (Baruch Fischhoff et. al., 1977) and may disappear or reverse when the experimental task is relatively easy (Briony D. Pulford and Andrew M. Colman, 1997). People are also overconfident in domains, in which they consider themselves as knowledgeable (Chip Heath and Amos Tversky, 1991) but they rank themselves below average in domains, where they find themselves incompetent (Justin Kruger, 1999 and Don A. Moore and Tai Gyu Kim, 2003).

A growing body of economic research on overconfidence confirms and enhances robust evidence of overconfidence in the psychology of judgment (De Bondt and Thaler, 1995). Colin Camerer and Dan Lovallo (1999) find a strong evidence of overconfidence in the experiment based on a market entry game with monetary incentives. Analyzing nonexperimental data from a large brokerage company, Brad M. Barber and Terrance Odean (2001) show that men trade more excessively than women on financial markets and, therefore, exhibit a higher degree of overconfidence. Erich Kirchler and Boris Maciejovsky (2002) find that subjects are overconfident in experimental asset market when confidence is measured through subjective judgments, but find no evidence of systematic overconfidence when confidence is measured through choice decisions. Erik Hoelzl and Aldo Rustichini (2005) show that overconfidence changes to underconfidence when the task becomes less familiar and that this effect is stronger with monetary incentives.

A common explanation of overconfidence is that when comparing their performance with that of their peers, people often concentrate on their own abilities and skills, discarding the abilities and skills of their counterparts (Kruger, 1999). Notably, Yechiel Klar and Eilath E. Giladi (1999) and J. Richard Eiser et al. (2001) find that people are self-focused when assessing their performance relative to their peers. Camerer and Lovallo (1999) argue that in competitive environment people tend to suffer from 'reference group neglect', i.e. they fail to adjust when the composition of competitive group changes. However, in economic experiments the heterogeneity of subjects is often unobservable (e.g. Camerer and Lovallo, 1999), or subjects receive no feedback on the individual performance of their opponents (e.g. Hoelzl and Rustichini, 2005). Therefore, it also might be that without knowing their relative standing in the group, subjects mistakenly focus on their own abilities simply because the abilities of their counterparts are unknown. Moreover, it is still an open question whether overconfidence is a stable phenomenon, i.e. whether the confidence of a person changes if her relative standing in the group is altered.

In this paper, we test for overconfidence using a natural laboratory of British Broadcasting Corporation (BBC) television show *The Weakest Link*, where heterogeneity of contestants is observable. Natural experiments are real world situations, which can be exploited to investigate economic phenomena. Compared with conventional laboratory experiments, natural experiments have a disadvantage that the experimenter has little or no control over the treatment and have an advantage of a more representative subject pool and high monetary incentives.

Television shows have long represented an appealing material for economic researchers. Particularly, Andrew Metrick (1995) argues that a television show is a suitable empirical resource for economists, since many of them are structured as well-defined decision problems or strategic games. Randall W. Bennett and Kent A. Hickman (1993) and Jonathan B. Berk et al. (1996) use data from the television show *The Prize is Right* to test for the optimal information updating and rational bidding strategies correspondingly. Robert Gertner (1993), Andrew Metrick (1995), and Roel M. Beetsma and Peter C. Schotman (2001) use data from *Card Sharks*, *Jeopardy!* and *Lingo* respectively to measure individual risk attitudes.

BBC television show *The Weakest Link* offers a unique natural laboratory for the research on overconfidence. The monetary stakes are much higher than in standard laboratory experiments. Conducting a similar experiment in the laboratory would require a budget of at least £165,000. Contestants come from all geographical locations in the UK and belong to different age brackets in the interval from 18 to above 70. In addition, contestants are unambiguously ranked in terms of their observed ability to answer general knowledge questions.

The Weakest Link television show has attracted attention of several researchers. Notably, Steven D. Levitt (2004) and Kate Antonovics et al. (2004) examined discrimination in *The Weakest Link*. Philippe Fevrier and Laurent Linnemer (2002) studied behavioral strategies of the contestants. Marco Haan et al. (2004) calculated optimal banking decisions for the contestants of *The Weakest Link* and addressed signaling issues in the show.

In *The Weakest Link* contestants have a possibility to vote off any of their counterparts before proceeding to the next round. Having recorded individual voting decisions, we find expected prizes that are required to organize these individual voting strategies into the Nash mixed-strategy equilibrium. By comparing these inferred expected prizes with the actual average earnings in the show, we demonstrate that contestants with low ranks are overconfident and contestants with high ranks are underconfident in the following sense. Low ranked contestants systematically anticipate higher expected prizes than their actual average earnings when continuing the game with a team of strong opponents. In contrast, high ranked contestants anticipate lower expected prizes. This measure of overconfidence is based on actual voting decisions of the contestants rather than on their subjective judgments.

Obviously, our results depend on whether contestants *actually* play mixed strategies in Nash equilibrium. Experimental evidence is mixed. On the one hand, Barry O'Neill (1987) and Kevin A. McCabe et al. (2000) find that subjects generally follow Nash mixed strategies. On the other hand, Amnon Rapoport and Richard B. Boebel (1992), Dilip Mookherjee and Barry Sopher (1994) and Jack Ochs (1995) find no experimental evidence of resorting to mixed strategies in the Nash equilibrium. However, nonexperimental data from the real world are generally consistent with the Nash mixed-strategy equilibrium, though such investigations are quite rare due to the complexity of the real world situations (Pierre-Andre Chiappori et al., 2002). Mark Walker and John Wooders (2001) and Chiappori et al. (2002) find that data from tennis and soccer tournaments are consistent with the hypothesis that players adopt Nash equilibrium mixed strategies.

The remainder of the paper is organized as follows. Section II describes the rules of the television show *The Weakest Link*. It also contains basic statistics of the dataset as well as the details on the ranking of contestants and their voting decisions. Theoretical analysis of the television show is presented in Section III. The confidence of contestants is measured in Section IV. Section V concludes.

II. Description of the Television Show

A. *Rules of the Game*

In BBC television show *The Weakest Link* nine contestants participate in the game. Becoming a contestant requires applying by calling or sending an e-mail to the BBC. Thus, contestants self-select into the television show and have some familiarity with the rules of the game, when they apply for participation. Contestants come from different educational and professional backgrounds. They do not know the intellectual capabilities of each other before the game starts. There is, however, a preliminary two-hour session before the show when contestants are introduced to each other. The session is monitored and the chance of conspiracy among contestants is excluded.

The game consists of nine rounds. The first seven rounds are divided into two phases: accumulation and elimination phase (Fevrier and Linnemer, 2002). After a sequence of seven accumulation and seven elimination phases, two remaining contestants compete for the winner-take-all prize in a two-stage final.

During the accumulation phase contestants stand in a semi-circle in front of the host and sequentially answer general knowledge questions until either the time reserved for this phase runs out or the team reaches the money target of £1000. The first accumulation phase lasts three minutes. Every subsequent accumulation phase lasts 10 seconds less than the previous one. During the accumulation phase, each correct answer to the general knowledge question is awarded a monetary prize. The size of the monetary prize per correct answer depends on the number of correct answers given in a row up to this point. Depending on the number of correct consecutive answers in the chain, the prize grows progressively according to the rule, given in Table 1.

Table 1 – Prize Chain Rule in *The Weakest Link*

Number of correct answers in the chain	1	2	3	4	5	6	7	8	9
Prize awarded	£20	£50	£100	£200	£300	£450	£600	£800	£1000

Source: derived from BBC Prime *The Weakest Link* television show, 2005

The goal of the team is to create a chain of nine correct answers in order to reach the £1000 target. £1000 is the maximum prize that could be earned in every accumulation phase during the first seven rounds. Once the team has given nine correct answers in a row, further correct answers do not contribute any pound value to the total prize in the round. If the question is answered incorrectly, all money accumulated in the chain is lost and the team has to start a new chain from zero. Any contestant can secure the money already accumulated in the chain by saying “Bank” before she is asked a question. However, the team has to start a new chain from zero. Questions increase in difficulty as the game progresses.

During the elimination phase every contestant has an opportunity to vote off any of her *ad hoc* teammates. Contestants cannot communicate with each other while deciding on their votes. The contestant, eliminated as *the weakest link* after receiving the majority of votes, leaves the game without being able to claim her portion of the earned prize. If equal number of votes is cast for several contestants (in the event of a tie), the strongest contestant, who gave the most correct answers during the last accumulation phase and banked the largest amount of money for the team, casts the deciding vote, i.e. she can exogenously eliminate any of the tied contestants.

In the first accumulation phase, general knowledge quiz starts with the person, whose name is first alphabetically. In all consecutive accumulation phases, the quiz starts with the strongest contestant, unless she fails to survive the vote in the previous elimination phase. In this case, the second-strongest contestant starts the quiz.

The game is very intense as contestants not only have to answer the questions and keep track of the money accumulated in the chain, but they also have to pay attention to the performance of each other to make their voting decisions at the end of each of the seven rounds, until the number of contestants boils down to two. The tension is increased by the sarcastic remarks of the host, Anne Robinson, who reputably is "the rudest person on British television"[1].

Two finalists compete in rounds 8 and 9. Round 8 is an additional accumulation phase, which lasts 90 seconds. Money earned by the finalists during this phase is tripled, i.e. the finalists can earn up to £3000. In Round 9 the winner is determined through the head-to-head general knowledge quiz of five questions per contestant. If after ten questions both finalists have the same number of correct answers, the quiz continues until one contestant dominates the other by one correct answer. The winner receives the total prize accumulated in the game and the runner-up leaves with nothing.

Even though some contestants might have 'limelight' preferences, i.e. might derive utility from maximizing their time on the television (Berk et al., 1996), we assume that contestants maximize their expected prize. Note, that while two finalists remain on television until the end of the show, other contestants spend a relatively lower portion of time in the limelight. Therefore, limelight-preferring contestants have an incentive to maximize their expected prize.

B. *Basic Statistics*

The data for this paper were transcribed from BBC Prime *The Weakest Link* original broadcasts between January, 7 2005 and May, 11 2005, yielding a total of 74 television episodes. The resulting laboratory incorporated 20,720 voting decisions made by 666 subjects, including 3,700 decisions made in rounds 5, 6 and 7, that are analyzed in this paper. 60.06% of contestants were male and 39.94% female, with men winning in 64.86% of cases. Contestants usually reveal

[1] Quoted from official website of The Weakest Link television show http://www.bbc.co.uk/weakestlink.

their age and occupation at the beginning of the show and answer questions about their profession posed by the host during elimination phases of the game. However, it is difficult to deduce hard data on the characteristics of contestants based on this information.

One of the main advantages of *The Weakest Link* natural laboratory is that the stakes on the show are higher than in any standard experiment (Table 2). Notably, prizes in games, observed from January to May 2005 on BBC Prime, ranged in value from £990 to £5,420 with an average of £ 2,265.14, median of £2,100.00 and standard deviation of £855.78 across 74 episodes.

Table 2 –Number of Observations and Frequencies for Final Prize (*w*)

Final Prize *w* (£)	Number of observations	Occurrence frequency (percent)
w <1000	2	2.70
1000 < *w* < 1500	12	16.22
1501< *w* < 2000	21	28.38
2001< *w* <2500	15	20.27
2501 < *w* <3000	9	12.16
3001 < *w* < 3500	6	8.11
w >3501	9	12.16

C. *Ranking of Contestants*

Contestants in *The Weakest Link* are heterogeneous in their ability to answer general knowledge questions. This feature of the television show allows us to test for confidence of the contestants. Intuitively, overconfident contestants would prefer to play with higher ability counterparts in the later stages of the game. In contrast, underconfident contestants would prefer to continue the game with weaker counterparts. We measure the ability of contestants by constructing the following ranking system. In every round only contestants who participate in this round are ranked. Rank is determined after the accumulation phase and before the elimination phase in each round. The ranking is based on the percentage of correct answers given by a contestant in current and all previous rounds. Specifically, the rank of contestant $i \in \{1,...,10-j\}$ in round $j \in \{1,...,7\}$ is assigned based on the following index

(1) $$R_j^i = \frac{\sum_{k=1}^{j} \omega_k m_k^i}{\sum_{k=1}^{j} \omega_k n_k^i},$$

where m_k^i is the number of correct answers given by contestant i in round $k \in \{1,...,7\}$, n_k^i is the total number of questions that the contestant i was asked in round k and ω_k is the difficulty coefficient for questions asked in round k. The weights ω_k are used because the questions become progressively complex from round to round. Ranks are assigned in descending order, i.e. the contestant with the highest index R_j^i is assigned the highest rank (rank 1).

To estimate the difficulty of questions across rounds, we pool the data from all episodes and calculate ω_k as a fraction of incorrect answers given in round k by contestants, who participated in all rounds (finalists). Specifically,

(2) $$\omega_k = \frac{\sum_{i=1}^{74}(q_{ik}^1 + q_{ik}^2)}{\sum_{i=1}^{74}(t_{ik}^1 + t_{ik}^2)},$$

where q_{ik}^1 and q_{ik}^2 are the numbers of incorrect answers given by two finalists of television episode i in round k and t_{ik}^1 and t_{ik}^2 are the total numbers of questions that two finalists of television episode i were asked in round k. Since there are two finalists in each of 74 episodes, the coefficients ω_k are calculated based on 3,993 answers of 148 contestants (Table 3).

Table 3 –Difficulty Coefficient (ω_k) for Rounds 1 through 8

Round	1	2	3	4	5	6	7	8
Difficulty coefficient ω_k	0.089	0.182	0.293	0.302	0.326	0.336	0.371	0.451

After calculating the relative ranking of contestants in rounds 5, 6 and 7 according to equation (1), only one instance of shared ranking was observed. In Round 5 of one of the sample television episodes, two contestants shared the same rank. In order to differentiate between these two contestants, we used the amount of money banked as a tie-breaking rule, i.e. the higher rank was assigned to the contestant, who banked more money for the team than his tied counterpart.

D. *Voting Decisions*

In this paper, we analyze the voting decisions made in rounds 5, 6 and 7. Rounds 1-4 are not considered because the analysis of these rounds is complicated by both practical and theoretical considerations. On the practical side, in rounds 1-4 there is often not enough history of the game to discriminate among the abilities of the contestants. For example in Round 1 there are 126 instances of shared rankings, in Round 2 - 113 cases, in round 3 - 51, and in Round 4 - 17. Round 5 was chosen as a starting point of our analysis, because in this round we observe only one instance of shared ranking (Section II. C). Another practical limitation is dictated by the method of measuring overconfidence, used in this paper. This limitation is explained in detail in Section IV. On the theoretical side, one can argue that the ranking of opponents is imperfectly observed by the contestants in the early rounds of the game. Therefore, the contestants can differentiate among their relative abilities only as the game progresses to the later rounds.

Tables 4 present the voting decisions of the contestants in rounds 5-7. The aggregation across television episodes is based on the ability ranking of the contestants.

Table 4 - The Percentage of Episodes in which the Contestant with Row Rank Votes Against the Contestant with Column Rank in Rounds 5-7

Round	Rank \ Rank	1	2	3	4	5
Round 5	**1**	–	14.86	13.51	21.62	50.00
	2	10.81	–	20.27	25.68	43.24
	3	8.11	16.22	–	24.32	51.35
	4	6.76	17.57	24.32	–	51.35
	5	12.16	24.32	33.78	29.73	–
Round 6	**1**	–	17.57	29.73	52.70	
	2	13.51	–	29.73	56.76	
	3	18.92	28.38	–	52.70	
	4	28.38	31.08	40.54	–	
Round 7	**1**	–	51.35	48.65		
	2	45.95	–	54.05		
	3	43.24	56.76	–		

Since we model the elimination phase as a noncooperative game, we need to verify that the contestants *indeed* cast their votes independently of each other. Table 5 demonstrates two frequency distributions of the rank of the contestant who is voted off in rounds 5-7 respectively. The first frequency is a joint distribution of the outcomes of the actual majority voting, observed on the television show. The second frequency is a result of the hypothetical voting, when every contestant votes as detailed in Table 4 independently of the voting decisions of her counterparts. Chi-squared test for rounds 5-7 shows that the difference between these two frequencies is not statistically significant by conventional criteria, which supports our assumption that players cast their votes independently and do not vote jointly as a team.

Table 5 – Distribution of the Rank of a Contestant Who Is Voted Off in Rounds 5, 6 and 7

Round	Probability of being voted off (percent) for contestant with rank					Significance	
	1	2	3	4	5	χ^2	p value
Round 5	2.7 / 3.4	13.5 / 10.2	20.3 / 14.6	18.9 / 17.8	44.6 / 54.1	5.19	0.2687
Round 6	12.2 / 10.4	18.9 / 15.2	24.3 / 23.2	44.6 / 51.1		2.09	0.5537
Round 7	27.0 / 28.1	41.9 / 37.4	31.1 / 34.5			0.93	0.6281

Notes: The number in the left upper corner of every cell refers to the outcome of actual majority voting. The number in the right lower corner corresponds to the hypothetical independent voting.

One may argue that since the probabilities of being voted off for high ranked contestants increase as the game progresses (Table 5), high ranked contestants might have an incentive to answer questions incorrectly. In other words, high ranked contestants might try to deliberately lower their ranking in order to increase their chances of winning the game. However, low ranked contestants almost always have a higher probability of being voted off than their high ranked counterparts (Table 5). Therefore, contestants should have an incentive to answer questions honestly. Using the data from *The Weakest Link* television show broadcasted in France, Fevrier and Linnemer (2002) confirm that contestants tend to be honest in revealing their actual ability to answer general knowledge questions.

III. Theoretical Analysis

We first consider Round 5 of the game. Let $p_{ij} \in [0,1]$ denote the probability that the contestant with rank $i \in \{1,...,5\}$ votes against the contestant with rank $j \in \{1,...,5\}$ in Round 5 ($\sum_{j=1}^{5} p_{ij} = 1$). Notice that these probabilities are given in Table 4. Every row of Table 4 represents a randomizing voting strategy of one of the contestants in rounds 5, 6 and 7 respectively. We find next the expected prizes that are necessary for individual voting strategies in Round 5 to constitute the Nash mixed-strategy equilibrium. Let π_{ij} denote the expected prize for the contestant with rank $i \in \{1,...,5\}$ if the contestant with rank $j \in \{1,...,5\}$ is voted off in Round 5. To avoid confusion, we refer to the expected earnings of an individual conditional on the outcome of the majority voting as the *expected prize*. The expected earnings of an individual conditional on her voting decision are referred to as *expected payoff*.

Proposition 1: The expected payoff of the contestant with rank i when she votes against the contestant with rank $j \neq i$ is given by

(3) $$\Pi_{ij} = \sum_{a=1}^{5}\sum_{b=1}^{5}\sum_{c=1}^{5}\sum_{d=1}^{5} p_{ja} p_{kb} p_{lc} p_{md} \pi$$

where k, l and m are the ranks of the remaining three contestants and π is equal to:

a) π_{ij} when either two elements of the set $\{b, c, d\}$ are equal to j, or one element of the set $\{b, c, d\}$ is equal to j and the remaining two elements are distinct from each other and not equal to a.

b) π_{in} when either three elements of the set $\{a, b, c, d\}$ are equal to n, or two elements of the set $\{a, b, c, d\}$ are equal to n and the remaining two elements are distinct from each other and not equal to j, $n \in \{k, l, m\}$.

c) $\frac{1}{2}\pi_{ij} + \frac{1}{2}\pi_{in}$ when two elements of the set $\{a, b, c, d\}$ are equal to n, one element of the set $\{a, b, c, d\}$ is equal to j and the remaining element is not equal to n or j, $n \in \{k, l, m\}$

d) $\frac{1}{2}\pi_{in} + \frac{1}{2}\pi_{it}$ when two elements of the set $\{a, b, c, d\}$ are equal to $n \in \{k, l, m\}$ and the remaining two elements are equal to $t \in \{k, l, m\}$, $t \neq n$

e) $\frac{1}{5}(\pi_{i2} + \pi_{i3} + \pi_{i4} + \pi_{i5})$ when all elements of the set $\{a, b, c, d\}$ are distinct from each other and not equal to j (five-way tie).

Proof: The contestant with rank j is voted off with certainty if either three contestants vote against her or two contestants vote against her and the remaining contestants do not vote for the same person. The contestant with rank j is voted off with probability one half if two contestants vote against her and two of the remaining three contestants vote for the same person (two-way tie). The contestant with rank j is voted off with probability one fifth in case of a five-way tie.

It follows from Table 4 that in Round 5 every contestant votes against every other contestant with positive probability. In the Nash mixed-strategy equilibrium, the strategies that are played with non-zero probability should yield the same expected payoff. Therefore, the expected payoff of a contestant is the same regardless of her voting decision. Formally, for every contestant with rank i,

(4) $$\Pi_{ij} = \Pi_{ik} = \Pi_{il} = \Pi_{im}$$

This equation imposes three restrictions on the voting probabilities p_{ij} and expected prizes π_{ij} for every contestant with rank i. Since voting probabilities are observable, we can deduce the expected prizes from equation (4). For every contestant there are four expected prizes and only three restrictions in equation (4). Therefore, we can normalize one of the expected prizes to unity. We set $\pi_{i1} = 1$ for $i \in \{2, ..., 5\}$ and $\pi_{12} = 1$. This normalization implies that the expected prizes are measured relative to the expected earnings of a contestant given that her strongest opponent is voted off, i.e. she continues the game with the weakest possible set of opponents.

The theoretical analysis of two consecutive rounds (Round 6 and Round 7) is analogous to the theoretical analysis of Round 5. For example, Round 6 can be considered as a restricted Round 5 when $p_{i5} = 0$ for $i \in \{1,...,4\}$ and $p_{55} = 1$. Additionally, in the event of a five-way tie, contestant with rank $i \in \{1,...,4\}$ has a probability one fourth of being voted off and the contestant with rank $i = 5$ has a zero probability of being voted off. Similarly, Round 7 can be considered as a restricted Round 5 when $p_{i4} = p_{i5} = 0$ for $i \in \{1,2,3\}$ and $p_{44} = 1$ and $p_{55} = 1$. In the event of a five-way tie, contestant with rank $i \in \{1,2,3\}$ has a probability one third of being voted off and the contestant with rank $i = \{4,5\}$ has a zero probability of being voted off. As in Round 5, the expected prizes are measured relative to the earnings that a contestant expects to receive if her strongest opponent is voted off. Table 6 presents equilibrium expected prizes π_{ij} that are necessary for organizing the voting strategies from Table 4 into the Nash mixed-strategy equilibrium for rounds 5, 6 and 7 correspondingly. Calculations were conducted in the Matlab 6.5 package and the program files are available from the author on request.

Table 6 - Equilibrium Expected Prizes of the Contestant with Row Rank if the Contestant with Column Rank is Voted Off in Rounds 5-7

Round	Rank \ Rank	1	2	3	4	5
Round 5	**1**	–	1	0.9851	0.9849	0.9622
	2	1	–	0.8483	0.8412	0.7883
	3	1	0.8674	–	0.8228	0.7575
	4	1	0.8694	0.838	–	0.748
	5	1	0.7597	0.7084	0.6597	–
Round 6	**1**	–	1	0.977	0.9291	
	2	1	–	0.9299	0.8808	
	3	1	0.9659	–	0.8273	
	4	1	0.8762	0.813	–	
Round 7	**1**	–	1	1.0164		
	2	1	–	0.9615		
	3	1	0.9636	–		

Notice that in Table 6 the expected prizes are decreasing from left to right in every, but the first row in Round 7. This means that the expected prize π_{ij} decreases in j for every i (except when $i=1$ in Round 7). Thus, in equilibrium every contestant expects a lower prize when a low ranked opponent is voted off and she continues the game with a team of strong opponents. However, this observation alone is not an evidence of underconfidence. A contestant may expect a lower prize when playing against a high ranked opponent because either her probability of winning in the final is low or she underestimates her chances. To distinguish between these two explanations we need to compare the expected prizes from Table 6 with actual average earnings of the contestants.

Notice further, that in all columns of Table 6 the expected prizes are decreasing from top to bottom within each round. The only exception is the column when contestants vote against the second-strongest contestant in Round 5[2]. This means that the expected prize π_{ij} decreases in i for every j (except when $j = 2$ in Round 5). Thus, in equilibrium irrespective of who is voted off, a low ranked contestant expects a lower relative prize than a high ranked contestant. However, this observation also does not imply that low ranked contestants are less confident than high ranked contestants.

IV. Measurement of Overconfidence

A. *Average Earnings*

Using the whole sample of recorded episodes we calculate the average earnings of every contestant conditional on the outcome of the majority voting in rounds 5-7. These average earnings characterize a representative game that contestants actually play. Average earnings can be compared with the equilibrium expected prizes. This allows us to examine whether the actual average earnings correspond to the perception of the contestants about their expected prizes, which is required to organize individual voting strategies into the Nash mixed-strategy equilibrium. To make this comparison, we normalize the average earnings in the same way as the equilibrium expected prizes. For example, the earnings that a contestant with rank $i \in \{1,...,5\}$ receives on average in all episodes, when a contestant with rank $j \in \{1,...,5\}$ is voted off in Round 5, are divided by the earnings that the contestant with rank i receives on average in all episodes, when her strongest opponent is voted off in Round 5. These normalized average earnings for rounds 5-7 are presented in Tables 7.

Table 5 demonstrates that high ranked contestants have a low probability of being voted off in Round 5. This constitutes a practical problem for computing normalized average earnings. The sample of television episodes, used in this paper, does not contain enough information to

[2]All expected prizes in the column, when contestants vote against the strongest contestant, are normalized to unity by construction.

calculate normalized average earnings in Round 5 for every contestant conditional on every other contestant being voted off (Table 7). Particularly, the sample misses observations, when contestants ranked first and second in Round 5 are voted off in Round 5 and the contestant ranked fifth wins the game. Similarly, the sample fails to provide observations, when the contestant ranked first in Round 5 is voted off in Round 5 and the contestant ranked third in Round 5 becomes a winner and claims the total prize in the game. In the absence of these observations, the strongest competitor for the contestant ranked third in Round 5 becomes the contestant ranked second in Round 5, and for the contestant ranked fifth in Round 5 – the contestant ranked third in Round 5. Therefore, we normalize to unity the average earnings of contestants ranked third and fifth in Round 5, when, correspondingly, the second and the third ranked contestant is voted off. Intuitively, the instances of games, where the strongest ability player is voted off prior to Round 5 are very scarce. This is an additional practical limitation, which prevents us from calculating conditional actual earnings in rounds 1-4.

Table 7 - Normalized Average Earnings of the Contestant with Row Rank if the Contestant with Column Rank is voted off in Rounds 5-7 (average across all episodes)

Round	**Rank \ Rank**	**1**	**2**	**3**	**4**	**5**
Round 5	**1**	–	1	1.0080	1.1715	0.9720
	2	1	–	1.1782	1.2294	0.8444
	3	N/A	1	–	0.6188	0.2350
	4	1	0.3062	0.8309	–	0.6282
	5	N/A	N/A	1	0.8735	–
Round 6	**1**	–	1	1.9220	1.2963	
	2	1	–	1.1897	1.8895	
	3	1	0.8811	–	0.7394	
	4	1	0.5738	0.3299	–	
Round 7	**1**	–	1	1.1105		
	2	1	–	0.2683		
	3	1	0.7151	–		

The comparison of actual (normalized) average earnings with equilibrium expected prizes allows us to measure under- and overconfidence of the contestants. When the actual earnings that a contestant receives on average are exactly equal to the prize that she expects in equilibrium, the contestant is well-calibrated. If in equilibrium a contestant perceives a higher expected prize than her actual average earnings are, the contestant is overconfident about her chances to win. Otherwise, the contestant is underconfident. The intuition is the following.

Equilibrium expected prizes are measured relative to the expected earnings when the strongest opponent is voted off. If the strongest opponent is voted off, the contestant continues the game with the weakest possible pool of opponents. If any other opponent is voted off, the contestant continues the game with a stronger composition of the team. The contestant who is overconfident about her winning abilities systematically overestimates her chances of winning. Such an individual anticipates a higher expected prize than actual average earnings, when continuing the game with a team of strong opponents. Similarly, an underconfident contestant perceives the expected prize from continuing the game with a stronger group of contestants to be lower than her actual average earnings.

B. *Results*

Calculating the percentile difference between the equilibrium expected prizes (Table 6) and actual earnings of the contestants (Table 7) for rounds 5, 6 and 7 respectively yields the following discrepancy values.

Table 8 – Discrepancy between Expected Prizes and Average Earnings (in percent) for Contestant with Row Rank if the Contestant with Column Rank is voted off in Rounds 5-7

Round	Rank \ Rank	2	3	4	5
Round 5	1		-2.28	-15.93	-1.01
	2		-28.00	-31.58	-6.64
	3			53.29	271.62
	4	183.95	0.85		19.06
	5			6.61	
Round 6	1		-49.17	-28.32	
	2		-21.83	-53.38	
	3	9.63		11.88	
	4	52.71	146.41		
Round 7	1		-8.47		
	2		258.42		
	3	34.75			

Notes: The percentage in every cell of the table is calculated as a difference between the equilibrium expected prizes reported in Table 6 and corresponding actual earnings of the contestants shown in Table 7, divided by the actual earnings from Table 7

Low ranked contestants, i.e. contestants with rank $i > \text{int}\left\{\frac{(10-j)}{2}\right\}$ in round $j \in \{5,6,7\}$, expect much higher prizes than their actual average earnings. High ranked counterparts, i.e. contestants with rank $i \leq \text{int}\left\{\frac{(10-j)}{2}\right\}$ in round $j \in \{5,6,7\}$, appear to underestimate their earnings. Notably, in Round 5 contestants with third, fourth and fifth ranks exhibit a significant degree of overconfidence. However, contestants with ranks one and two are underconfident, though the second-strongest contestant is underconfident to a greater extent than the contestant with rank one. In Round 6 two stronger contestants are underconfident while two weaker contestants overestimate their prospective earnings. In Round 7 contestants with ranks two and three are overconfident, while the strongest contestant is underconfident.

Camerer and Lovallo (1999) found that the effect of overconfidence is stronger in the presence of self-selection than when subjects are recruited randomly. In *The Weakest Link* all contestants self-select into the show. However, we observe that not all contestants of *The Weakest Link* are prone to overconfidence. One can, therefore, argue that if contestants were chosen randomly, even more of them would exhibit underconfidence.

In *The Weakest Link* contestants' ranking is dynamic, i.e. a low ranked contestant may increase her relative standing in the team if she answers difficult questions in the later rounds of the game correctly. In contrast, high ranked contestant may jeopardize her standing. For example, a contestant ranked fourth in Round 5 may be ranked first in Round 6 if she gives a higher number of correct answers in Round 6 than her counterparts. In contrast, the strongest player in Round 6 may fail to provide any correct answer in Round 7 and receive a third rank in the team. Therefore, it is not possible to make any cross-round comparisons of our results. Notably, by referring to the contestant ranked second in rounds 5, 6 and 7 one may refer to three different people instead of one if the rankings in the team shifted several times.

Our results suggest two possible explanations of miscalibration, observed in the data. The first relates contestants' behavior to their perception of the median performance on the show, while the second provides an explanation in terms of benchmarking distortions, when contestants assess their relative performance.

On the one hand, when estimating their relative strength, contestants may suffer from the *reversion-to-the-median effect*. Even though contestants are heterogeneous in their ability to answer general knowledge questions, they might believe that their performance is equal or close to the group median performance. Therefore, contestants, whose performance is below the group median, constantly overestimate their abilities, while contestants, whose performance is above the group median, tend to underestimate their abilities.

On the other hand, it also might be that contestants of different ability have different benchmarks, which they use when assessing their relative performance. While low ranked contestants can use the ability of their high ranked counterparts as a benchmark to assess their own ability, high ranked contestants have to anchor their performance to the difficulty of questions asked in each round. Obviously, low ranked contestants have a subjective benchmark. They may believe that it is possible to outperform their counterparts in the later stages of the game. However, this should not suggest that low ranked contestants neglect the strength of their high ranked counterparts. On the contrary, low ranked contestants use their knowledge about the abilities of high ranked contestants to estimate the amount of effort that they need to exert in the future rounds of the game in order to reach the final. High ranked contestants have an objective benchmark. They know that questions will increase in difficulty and; therefore, are underconfident about their performance.

V. Conclusion

This paper represents one of the first attempts to test for overconfidence in the presence of observable heterogeneity. Using voting data from the BBC television show *The Weakest Link*, we find that dependent upon their relative standing in the team, contestants are characterized by miscalibration of different sign and magnitude. We show that high ranked contestants are underconfident, while their low ranked counterparts are overconfident in the later rounds of the television show.

Since contestants on *The Weakest Link* have to evaluate the performance of their counterparts in each round of the show, they are unlikely to suffer from the reference group neglect, proposed in the earlier experimental studies as an explanation of miscalibration (Camerer and Lovallo, 1999). Yet, our results suggest that over- and underconfidence can be observed even in the absence of reference group neglect. This observation opens the door to a new discussion on the possible causes of miscalibration.

The main contribution of this paper is the demonstration that individual self-confidence is related to the relative standing in the competitive group. It is left to further research to investigate if this relation is stable as well as to determine in which direction the causality goes, i.e. whether self-confidence affects the relative performance or the change in relative standing precipitates over- and underconfidence.

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