Testing the Predictions of Decision Theories in a Natural Experiment When Half a Million Is at Stake*

Pavlo Blavatskyy† and Ganna Pogrebna‡

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Abstract

In the television show *Deal or No Deal* an individual faces a sequence of binary choices between a risky lottery with prizes of up to half a million euros and a monetary amount for certain. The decisions of 500 contestants from Italian and British versions of the show are used to test the predictions of ten decision theories: risk neutrality, expected utility theory, the fanning-out hypothesis (weighted utility theory, transitive skew-symmetric bilinear utility theory), prospect theory, regret theory, rank-dependent expected utility theory, Yaari's dual model, prospective reference theory and disappointment aversion theory. Both Italian and British contestants violate assumptions of risk neutrality and loss aversion. We find evidence of simple nonlinear probability weighting but no evidence of rank-dependent probability weighting or disappointment aversion. Observed decisions are consistent with regret aversion and there is strong evidence for the fanning-out hypothesis. Nevertheless, we find no behavioral patterns that cannot be reconciled within the expected utility framework (or prospective reference theory that gives identical predictions).

Key words: decision theory, natural experiment, television show, expected utility, non-expected utility

JEL Classification codes: C93, D81

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† Corresponding author, Institute for Empirical Research in Economics, University of Zurich, Winterthurerstrasse 30, CH-8006 Zurich, Switzerland, tel.: +41(0)446343586, fax: +41(0)446344978, e-mail: pavlo.blavatskyy@iew.unizh.ch

‡ University of Bonn, Department of Economics, BWL I, Adenauerallee 24-42, 53113 Bonn, tel.:+49(0)228736740, fax: +49(0)228735924, email: ganna.pogrebna@uni-bonn.de

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1. Introduction

Well-known violations of expected utility theory such as the Allais paradox (Allais, 1953) motivated the development of numerous generalized non-expected utility theories (e.g. Starmer, 2000). The merits of these decision theories were largely assessed according to their goodness of fit to the behavioral patterns observed in the laboratory experiments (e.g. Harless and Camerer, 1994; Hey and Orme, 1994). In this paper we test the predictions of ten decisions theories in an experiment with a more diversified subject pool (drawn from the adult population of Italy and United Kingdom) and significantly higher monetary incentives (prizes of up to half a million euros) than in conventional laboratory experiments.

In the television show *Deal or No Deal* contestants make several choices between a risky lottery and an amount for certain. Risky lotteries, which contestants face in the show, are determined by chance events. This allows us to divide contestants across randomized treatments. Given an individual, whose preferences are described by a particular decision theory, we construct a treatment where she faces relatively unattractive lotteries (higher likelihood of choosing a sure amount) and a treatment where she faces relatively attractive lotteries (higher likelihood of choosing a risky lottery). By comparing behavioral patterns across two treatments, we test the predictions of decision theories without making any assumptions about their parametric forms.

Natural experiments, provided by television shows, are often used in economic research to draw conclusions about various aspects of human behavior.[1] Television shows

[1] The term "natural experiment" in application to the television show data was coined by Metrick (1995). In their classification of field experiments, Harrison and List (2004) also describe experiments in television shows as "natural experiments".

provide an appealing material for economists, because these shows are often structured as strategic games and well-defined decision problems (Metrick, 1995). For example, Bennett and Hickman (1993) and Berk, Hughson and Vandezande (1996) employ the natural laboratory of *The Prize is Right* to test for optimal information updating and rational bidding strategies correspondingly. Levitt (2004) and Antonovics, Arcidiancono and Walsh (2005) examine discrimination in *The Weakest Link*. Gertner (1993), Metrick (1995), and Beetsma and Schotman (2001) measure individual risk attitudes in the television shows *Card Sharks*, *Jeopardy!* and *Lingo* respectively.

Due to its simple design and high monetary incentives, the television show *Deal or No Deal* has attracted economists as a perfect laboratory for studying individual decision making under risk. Post et al. (2004) analyze risk attitudes of American, Dutch and German *Deal or No Deal* contestants. Bombardini and Trebbi (2005) elicit risk attitudes of contestants in the Italian version of the show (*Affari Tuoi*). De Roos and Sarafidis (2006) and Mulino et al. (2007a, 2007b) measure risk attitudes and study the endowment effect in the Australian version of *Deal or No Deal*. Andersen et al. (2006a, 2006b) analyze the behavior of British *Deal or No Deal* contestants. Botti et al. (2006) study risk attitudes and unobserved heterogeneity in *Affari Tuoi*. Deck et al. (2007) measure risk attitudes of contestants in the Mexican version of the show (*Vas o No Vas*).

All these studies conduct a *parametric* estimation by assuming specific functional forms of expected utility (e.g. constant relative or absolute risk aversion) and/or other generalized non-expected utility theories. In contrast, this paper concentrates on *non-parametric* analysis of contestants' decisions. The importance of this approach has been emphasized in Blavatskyy and Pogrebna (2006, 2007). Using a non-parametric technique, Blavatskyy and Pogrebna (2006) study the decisions of French, Italian and British *Deal or No Deal* contestants, when they can exchange two *ex ante* identical risky lotteries, and

find that contestants do not appear to be predominantly loss averse. Similarly, Blavatskyy and Pogrebna (2007) use a non-parametric test to show that, in contrast to numerous laboratory studies with low monetary incentives, British and Italian *Deal or No Deal* contestants do not exhibit lower risk aversion when facing gains of low probability.

The main findings of this paper can be summarized as follows. *Deal or No Deal* contestants are clearly not risk neutral, which is, probably, not surprising given high stakes of the show. The decisions of contestants are apparently not affected by foregone outcomes, which is consistent with expected utility theory (or prospective reference theory). We find that contestants are more likely to choose a monetary amount for sure when risky lotteries improve in the sense of first-order stochastic dominance. This confirms the fanning-out hypothesis of weighted utility theory and transitive skew symmetric bilinear utility theory.

At the end of the show, *Deal or No Deal* contestants experience *ex post* regret significantly less frequently than *ex post* rejoicing. This finding is consistent with the assumption of regret theory that individuals anticipate future regret and try to avoid it. We find evidence of nonlinear probability weighting in a simple form but not in a rank-dependent form. *Deal or No Deal* contestants also do not appear to be averse to receiving disappointingly low outcomes of a risky lottery. Finally, we find that Yaari's dual model cannot describe the behavior of Italian contestants in the last round of the show but it can rationalize the behavior of British contestants.

The remainder of this paper is organized as follows. Section 2 describes the rules of television shows *Affari Tuoi* and *Deal or No Deal UK*. Section 3 presents the data generated in this natural experiment and the demographic characteristics of contestants. The predictions of ten well-known decision theories are tested in section 4. Section 5 concludes.

2. Description of the Television Show

2.1. Format of Affari Tuoi Television Show

Affari Tuoi is the Italian version of the well-known Endemol television show *Deal or No Deal*. It is aired six days a week with an exception of Sunday on the first channel of Italian television RAI Uno. In order to become a contestant, interested candidates have to call a countrywide selection center. In other words, all contestants self-select into the show. According to Bombardini and Trebbi (2005), contestants are selected from the pool of interested candidates based on two criteria: entertaining appearance and income (wealthy candidates are discarded).

Twenty contestants, all representing different administrative regions of Italy, participate in every television episode. Contestants are randomly assigned sealed boxes, numbered consecutively from 1 to 20. Each box contains one of twenty monetary prizes ranging from €0.01 to €500,000. The list of possible prizes is presented on Figure 1. An independent notary company allocates prizes across the boxes and seals the boxes.

Figure 1 A typical screenshot with a list of possible prizes at the beginning of the game in *Affari Tuoi*[2]

[2] Prior to January 30, 2006 the first prize, appearing on the right hand side of Figure 1, was €5,000. Prize €5,000 was replaced with prize €30,000 starting from January 30, 2006

Contestants know the list of potential prizes (i.e. Figure 1) but they do not know the content of each box. In every episode four small monetary prizes, ranging from €0.01 to €500, are substituted with token gifts, such as, for example, an orange instead of €0.20 or a puppy instead of €100. This substitution is done primarily for entertainment purposes and any contestant can reject a token gift and opt for its monetary equivalent.

Every television episode consists of two phases – the selection phase and the game itself. During the selection phase, contestants receive one multiple-choice general knowledge question. The contestant, who is the first to answer this question correctly, is selected to play the game.[3] During the game, this contestant keeps her own box and opens the remaining boxes one by one. Once a box is opened, the prize sealed inside is publicly revealed and deleted from the list of possible prizes shown on Figure 1.

The more boxes the contestant opens, the more information she obtains about the distribution of possible prizes inside her own box. After opening several boxes the contestant receives an offer from the "bank". This offer can be either a monetary price for the content of her box or the possibility to exchange her box for any of the remaining sealed boxes.[4] Prior to February 9, 2006 in *Affari Tuoi* the "bank" made offers to the contestant when, respectively, 14, 11, 8, 5 and 2 boxes remained unopened (including contestant's own box). Starting from February 9, 2006 contestant received offers when, correspondingly, 17, 14, 11, 8, 5 and 2 boxed remained sealed.[5]

[3] The remaining 19 contestants (waiting contestants) continue to participate in the next television episode. The contestant who was selected to play the game is replaced by a new contestant from the same region. The new contestant is selected from a pool of volunteers who called the selection center.
[4] Official rules of *Affari Tuoi* require the "bank" to offer exchange option at least once in every television episode. Therefore, the first offer that the "bank" makes is always the exchange offer. Before February 9, 2006, the first offer was always made after the contestant opened six boxes. Starting from February 9, 2006, the first offer was made after the contestant opened three boxes.
[5] Bombardini and Trebbi (2005), Botti et al. (2006) and Blavatskyy and Pogrebna (2007) provide a detailed description of the timing of "bank" offers in the Italian version of *Deal or No Deal*.

Monetary offers are fairly predictable across episodes and follow a general pattern. In the early stages of the game, they are smaller than the expected value of possible prizes. As the game progresses, the gap between the expected value and monetary offer decreases and often disappears when there are two unopened boxes left. The game terminates when either the contestant accepts the price offered by the "bank" or when all boxes are opened. In the former case, the content of all remaining unopened boxes is revealed. In the latter case, the contestant leaves with the content of her box, which is opened last.

2.2. Format of Deal or No Deal UK Television Show

Twenty two contestants from various parts of the UK participate in each episode[6]. The prizes range from £0.01 to £250,000 (Figure 2)[7]. They are randomly assigned to 22 boxes by an independent adjudicator. However, an independent adjudicator does not assign boxes to contestants. After the prizes are distributed across boxes and boxes are sealed, contestants choose their boxes at random by drawing numbered ping-pong balls.

Figure 2 A typical screenshot with a list of possible prizes at the beginning of the game in *Deal or No Deal UK*

[6] Except for the British contestants, contestants from India, Italy and the United States appeared on the show. In contrast to *Affari Tuoi*, in the British version regional diversity is not strictly observed, i.e. several representatives of the same administrative region may appear on the show at one time.
[7] At the time of the broadcasts the exchange rate was £1= €1.48.

The British version of the show does not have a selection phase. The contestant is pre-selected by the producers and, therefore, it is quite rare for contestants to wait for more than 30 shows before they receive an opportunity to play the game. However, waiting contestants do not know in advance when they will be selected.

The game itself follows a similar procedure as *Affari Tuoi*. The "bank" makes offers to the contestant when there are, respectively, 17, 14, 11, 8, 5 and 2 unopened boxes left (including contestant's own box).[8] However, there are three major differences. First, the contestants in *Deal or No Deal UK* rarely receive exchange offers from the "bank". As a rule, the offer to exchange the box is made when there are two unopened boxed left and the contestant rejects the last monetary offer.

Second, in *Deal or No Deal UK* the contestant may take advice from waiting contestants or suggestions from the host on the next box to be opened or on whether to accept or reject the deal from the "bank". This is very different from the procedure in *Affari Tuoi*, where it is observed by the representative of the independent notary company, present on the show, that contestant's decision to open a certain box or to accept or reject the monetary offer of the "bank" is not precipitated by the suggestions of waiting contestants or the host. Moreover, while in *Deal or No Deal UK* the contestant is allowed to change her mind about opening a certain box after she has already called out its number, in *Affari Tuoi* the contestant does not have this opportunity.

Finally, in *Affari Tuoi* bank offers appear to be more generous than in *Deal or No Deal UK*. Notably, in the British version of the show, monetary offers are almost always significantly lower than the expected value of the remaining prizes. A detailed regression analysis of "bank" monetary offers in both versions of the show is presented in section 3.

[8] Andersen et al. (2006a, 2006b) and Blavatskyy and Pogrebna (2007) provide a detailed description of the timing of "bank" offers in the British version of *Deal or No Deal*.

3. Data

Data, analyzed in this paper, were derived from two sources. Data on Italian version of *Deal or No Deal* were transcribed from original RAI Uno broadcasts of *Affari Tuoi* from September 20, 2005 to March 4, 2006. To obtain the data from the British version of the show we used several Internet portals with description of the television episodes and game statistics[9]. This information was collected by the viewers of *Deal or No Deal* from Channel 4 broadcasts aired from October 31, 2005 to February 18, 2007.

The resulting natural laboratory contained 114 *Affari Tuoi* episodes and 386 *Deal or No Deal UK* episodes. Only one contestant played the game in every episode. In both versions of the show, the contestant, selected to play the game, had to decide on at least one monetary offer.[10] In the Italian version of the show the contestant also had to decide on at least one exchange offer. We recorded the distribution of all possible prizes that a contestant could potentially win at the moment when she made each decision as well as the prize sealed inside her own box (which was revealed only at the end of the show).

In the beginning of a television episode in both versions of the show, the contestant, selected to play the game, states her name, place of current residence, marital status and, less often, age and occupation. According to their self-reported data, contestants greatly varied in their age in both versions of the show. Minimum reported age was 23 (19) years and maximum reported age was 70 (83) years in the Italian (British) version of *Deal or No Deal*. Average age of *Affari Tuoi* contestants (46.3 years) was

[9] Particularly, a significant portion of the data was compiled from http://donduk.blogspot.com/ and the related Internet sources. We have also watched several episodes, available online, including the Hall of Fame editions of the show with *Deal or No Deal UK* highlights. We are grateful to Morten Lau, who generously provided the information on the personal characteristics of the British contestants.

[10] In our recorded sample only one *Affari Tuoi* contestant accepted the first monetary offer from the "bank" (€18,000). Ten contestants accepted the second monetary offer that they received from the "bank". 34 contestants accepted their third monetary offer. All remaining contestants received from 4 to 7 monetary offers. In *Deal or No Deal UK* all contestants rejected the first monetary offer, one contestant accepted the second monetary offer, 16 contestants accepted the third monetary offer, and all remaining contestants received from 4 to 7 monetary offers.

higher than that of *Deal or No Deal UK* contestants (41.2 years). In terms of the gender composition, the share of female contestants in *Affari Tuoi* sample (54.4%) was slightly greater than that of male contestants. In *Deal or No Deal UK* data set, men and women were selected to play the game almost equally frequently (in 50.5% and 49.5% of episodes respectively). The majority of contestants in the Italian version of the show were married (78.9%), while nearly one half of British contestants (45.4%) were single.

In our *Affari Tuoi* data set, representative of every Italian region played the game at least once. Contestants from Lombardia played the game most frequently (10 times), while a contestant from Campania played the game only once. In the British version of the show, representatives of 22 administrative regions of the United Kingdom appeared on the show in the "hot seat". Contestants from Yorkshire played the game most often—8 times (we collected data on administrative regions only for 18.4% of British contestants).

Therefore, the demographics, age and personal characteristics of *Affari Tuoi* and *Deal or No Deal UK* contestants make them a more diversified subject pool than standard pools, composed primarily of undergraduate students. Moreover, obtaining a similar data set in conventional laboratory conditions would be a highly ambitious project, since it would require a total budget of 13.26 million euros or 9 million British pounds (Table 1).

Description	***Affari Tuoi* contestants**			***Deal or No Deal UK* contestants**		
	All	**Male**	**Female**	**All**	**Male**	**Female**
Ex ante expected earnings	€52,295	€52,295	€52,295	£25,712	£25,712	£25,712
Total earnings	€3,364,852	€1,642,261	€1,722,591	£6,684,010	£3,195,407	£3,488,603
Minimum earnings	€0.01	€0.01	€0.01	£0.01	£0.01	£0.01
Maximum earnings	€250,000	€250,000	€200,000	£250,000	£110,000	£250,000
Average earnings	€29,516	€31,582	€27,784	£17,316	£16,387	£18,265
Median earnings	€19,000	€20,000	€17,000	£13,000	£13,000	£14,000
Standard deviation of earnings	€42,120	€48,271	€36,491	£21,244	£17,470	£24,517

Table 1 Summary statistics on contestants' earnings

Potentially, in *Affari Tuoi* and in *Deal or No Deal UK* any contestant, selected to play the game, can earn a maximum prize of €500,000 and £250,000 respectively. However, the actual earnings of contestants in both versions were significantly lower than the maximum. Table 1 presents summary statistics on earnings of the contestants in both versions of the show. Figure 4 and Figure 5 in the Appendix depict the distribution of final earnings in *Affari Tuoi* and *Deal or No Deal UK* correspondingly.

Across 114 episodes of *Affari Tuoi* and 386 episodes of *Deal or No Deal UK,* the distribution of monetary prizes in the initial boxes assigned to contestants is not significantly different from a uniform distribution (χ^2 = 22.49 and p=0.2605 in *Affari Tuoi* and χ^2 = 24.93 and p=0.2501 in *Deal or No Deal UK*). Therefore, contestants, who had large and small monetary prizes inside their initial boxes, were equally likely to be selected to play the game (see Figure 6 and Figure 7 in the Appendix).

3.1. "Bank" monetary offers

A precise mechanism of setting "bank" monetary offers is not revealed in the show regulations. Bombardini and Trebbi (2005) suggest that offers in *Affari Tuoi* can be modeled as informative signals about the prize sealed inside a contestant's box that the "bank" sends to the contestant. De Roos and Sarafidis (2006) conduct a regression analysis of "bank" offers in the Australian version of *Deal or No Deal* and find that the variability in "bank" offers is largely explained by the expected value of the remaining prizes but not by the prize hidden inside a contestant's briefcase. Given these different models of "bank" offers suggested in the literature, we investigate the determinants of "bank" offers in our recorded sample.

Table 2 and Table 3 present the results of ordinary least squares (OLS) regression $\mathbf{lnO} = \beta_0 + \beta_1 \mathbf{X_1} + ... + \beta_{20} \mathbf{X_{20}} + \boldsymbol{\varepsilon}$ of monetary amounts O that the "bank" offered in

exchange for risky lotteries in Italian and British versions of the show correspondingly. Explanatory variables $\mathbf{X}_1,...,\mathbf{X}_{20}$ consist of lottery specific variables (mean, median, and standard deviation of possible prizes etc.), socio-demographic characteristics of the contestants (gender, age, marital status and region) and treatment specific variables that are included to verify that the "bank" does not discriminate between different treatments that we consider in section 4.

When a *Deal or No Deal UK* contestant has already accepted one of the monetary offers, the "bank" informs this contestant about all monetary offers that would have been made in the game if the contestant rejected an earlier offer. In our OLS regression of "bank" offers in *Deal or No Deal UK* we added a dummy variable for hypothetical offers. This dummy variable takes a value of one if the "bank" makes an offer when another earlier offer has already been accepted by contestant so that the later offer is not binding.

The second column of Table 2 and Table 3 demonstrates that around 85% of total variability in monetary offers in *Affari Tuoi* and around 80% of total variability in monetary offers in *Deal or No Deal UK* is explained by the expected value and the number of possible prizes left. In both versions of the show the "bank" makes higher offers when the number of possible prizes decreases, i.e. the game approaches the end. Regression coefficient on the standard deviation of possible prizes is also significant (the more dispersed are the prizes, the lower is the offer). However, regression coefficient of the prize hidden inside a contestant's box is never statistically significant, i.e. there is no information content in the "bank" offers.

Description of explanatory variable	Regression coefficient (standard error)			
Lottery specific variables:				
Constant	-0.4982* (0.2078)	-0.7219*** (0.2085)	-0.6037* (0.2434)	-0.697* (0.3426)
Natural logarithm of expected value of possible prizes	0.9956*** (0.0205)	1.5026*** (0.1184)	1.5036*** (0.1189)	1.6057*** (0.1526)
Natural logarithm of a median possible prize		0.0132 (0.0160)	0.013 (0.0161)	0.0216 (0.0192)
Natural logarithm of standard deviation of possible prizes		-0.5073*** (0.1055)	-0.5091*** (0.1058)	-0.6087*** (0.1384)
Natural logarithm of the prize hidden inside a contestant's box		0.0044 (0.0063)	0.0032 (0.0064)	0.0065 (0.0065)
Number of possible prizes in a lottery	-0.0931*** (0.0098)	-0.051*** (0.0119)	-0.0515*** (0.0119)	-0.0221 (0.0252)
Individual specific variables:				
Gender dummy (0 – female, 1 – male)			0.0684 (0.0601)	0.0395 (0.0611)
Self-reported age (in years) or estimate based on physical appearance			-0.002 (0.0027)	-0.0021 (0.0027)
Marital status (0 – married, 1 – single, 2 – divorced, and 3 – widowed)			0.0324 (0.0477)	0.0383 (0.479)
Region dummy (0 for the region with the lowest income per capita (Calabria), 19 for the highest (Lombardia)			-0.0044 (0.0050)	-0.0073 (0.0051)
Treatment specific variables:				
Number of foregone prizes greater or equal to €5,000 (in the last three boxes)				-0.0351 (0.0470)
Number of foregone prizes that were among three highest ranked prizes				-0.0509 (0.0596)
Dummy for group 1				0.2525* (0.1187)
Dummy for group 2				-0.193 (0.1053)
Dummy for group 3				0.0645 (0.0959)
Dummy for group 4				-0.0866 (0.0937)
Dummy for group 5				0.0586 (0.1016)
Dummy for group 6				0.0601 (0.1013)
Chances of €500 or less				0.06 (0.2158)
Number of prizes less or equal to €5				-0.0596 (0.0395)
R^2	0.8567	0.8693	0.8703	0.8752
Adjusted R^2	0.8560	0.8676	0.8673	0.8690

* significant at 5% significance level
*** significant at 0.1% significance level

Table 2 OLS regression results for "bank" monetary offers in *Affari Tuoi* (dependent variable—natural logarithm of a price offered by the "bank"), N=402

Description of explanatory variable	Regression coefficient (standard error)			
Lottery specific variables:				
Constant	-0.4209*** (0.0999)	-0.3664*** (0.0986)	-0.5053*** (0.1193)	0.7088** (0.2294)
Natural logarithm of expected value of possible prizes	1.0412*** (0.0106)	1.5064*** (0.0823)	1.4996*** (0.0824)	1.2369*** (0.0927)
Natural logarithm of a median possible prize		0.0201 (0.0127)	0.0214 (0.0127)	0.0165 (0.0146)
Natural logarithm of standard deviation of possible prizes		-0.4754*** (0.0738)	-0.4690*** (0.0739)	-0.2724*** (0.0814)
Natural logarithm of the prize hidden inside a contestant's box		0.0025 (0.0034)	0.0031 (0.0034)	0.0032 (0.0033)
Number of possible prizes in a lottery	-0.1049*** (0.0037)	-0.0882*** (0.0041)	-0.0886*** (0.0041)	-0.1176*** (0.0057)
Dummy for hypothetical offers	0.0317 (0.0504)	-0.0456 (0.0504)	-0.0520 (0.0505)	-0.0085 (0.0561)
Individual specific variables:				
Gender dummy (0 – female, 1 – male)			0.0491 (0.0303)	-0.0578* (0.0292)
Self-reported age (in years) or estimate based on physical appearance			0.0024 (0.0014)	0.0026* (0.0013)
Marital status (0 – married, 1 – single, 2 – divorced, and 3 – widowed)			0.0099 (0.0434)	0.0273 (0.0419)
Treatment specific variables:				
Number of foregone prizes greater or equal to £1,000 (in the last three boxes)				-0.0687** (0.0219)
Number of foregone prizes that were among three highest ranked prizes				-0.2596*** (0.0293)
Dummy for group 1				-0.0473 (0.0730)
Dummy for group 2				-0.2569*** (0.0738)
Dummy for group 3				0.0413 (0.0814)
Dummy for group 4				-0.0527 (0.0731)
Dummy for group 5				-0.0457 (0.0424)
Dummy for group 6				0.0471 (0.0873)
Chances of £750 or less				-0.3192 (0.1521)
Number of prizes less or equal to £5				0.1402** (0.0489)
R^2	0.8089	0.8154	0.8159	0.8303
Adjusted R^2	0.8086	0.8149	0.8152	0.8288

* significant at 5% significance level
** significant at 1% significance level
*** significant at 0.1% significance level

Table 3 OLS regression results for "bank" monetary offers in *Deal or No Deal UK* (dependent variable—natural logarithm of a price offered by the "bank"), N=2,294

4. Testing Predictions of Decision Theories

The predictions of ten well-known decision theories are tested in the natural experiment provided by the television shows *Affari Tuoi* and *Deal or No Deal UK*. We selected a typical menu of decision theories that are usually considered in existing studies that investigate which model of risky choice describes the behavioral patterns observed in the conventional laboratory experiments best (Table 4). Since every contestant makes only few observed choice decisions, we use a between-subject design to test the predictions of the selected decision theories (except for risk neutrality and the assumption of loss aversion of prospect theory that can be tested for every contestant). This paper follows a non-parametric approach, i.e. we do not make any assumptions about specific functional forms for utility functions, probability weighting functions etc.

Decision theory	**Investigated in experimental study?**				
	Camerer (1989)	Starmer (1992)[11]	Harless & Camerer (1994)[11]	Hey and Orme (1994) [12]	Hey (2001)
Risk Neutrality			✔	✔	✔
Expected Utility Theory	✔	✔	✔	✔	✔
Weighted Utility Theory	✔	✔	✔	✔	✔
Skew-Symmetric Bilinear Utility	✔	✔	✔		
(Cumulative) Prospect Theory	✔	✔	✔		
Regret Theory				✔	
Rank-Dependent Expected Utility	✔	✔	✔	✔	✔
Yaari's Dual Model			✔	✔	
Prospective Reference Theory				✔	✔
Disappointment Aversion Theory			✔	✔	✔

Table 4 Decision theories investigated in the existing laboratory experiments

[11] Similar to our study, Starmer (1992) and Harless & Camerer (1994) tested fanning out hypothesis of weighted utility and skew-symmetric bilinear utility theory.

[12] Hey and Orme (1994) also considered the quadratic utility model of Chew et al. (1991) that is derived from a mixture symmetry axiom. However, there appears to be no testable implication of this theory in the context of this natural experiment.

We exploit the outcomes of random events to construct artifactual treatments. In every episode contestants face a distribution of monetary prizes, which is constructed by random elimination of prizes from the initial list of possible prizes (e.g. Figure 1 and Figure 2). For every decision theory (except for risk neutrality that is tested within subject) we identify two classes of prize distributions: those that yield relatively low utility and those that yield relatively high utility. Contestants are allocated across artifactual treatments based on the type of prize distribution that they face in the game. As usual in a between-subject design, the predictions of decision theories are tested by comparing contestants' behavior across two corresponding artifactual treatments.

Deal or No Deal contestants are confronted with random prize distributions but they do not receive random offers from the "bank". Therefore, we have to check that the "bank" does not discriminate between artifactual treatments. Table 2 and Table 3 show that the "bank" makes significantly higher offers when contestants face a distribution with a smaller number of possible prizes. Thus, we cannot pool contestants, who face a distribution with many possible prizes (at the beginning of the game), with contestants, who face a distribution with only few prizes (at the end of the game), in one treatment.

Monetary offers become relatively more attractive as the number of possible prizes decreases. Therefore, only those contestants, who are relatively less risk averse, are likely to remain in the game with a small number of possible prizes. Relatively more risk averse contestants are likely to face only distributions with a large number of prizes. Therefore, we test each decision theory separately for a subgroup of contestants, who face a distribution of two possible prizes, five possible prizes etc. Since we always compare behavior across two treatments constructed from the same subgroup, self-selection across different subgroups does not create any bias for our between-subject test.

4.1. Risk Neutrality

Risk neutrality is arguably the simplest decision theory. A risk neutral individual always prefers the lottery with the highest expected value of possible outcomes. Formally, utility of a risky lottery $L(x_1,1/n;...;x_n,1/n)$ that delivers outcome x_i, $i \in \{1,...,n\}$, with probability $1/n$ is given by $\sum_{i=1}^{n} x_i/n$.

Table 5 shows that an overwhelming majority of "bank" monetary offers (97.3% in *Affari Tuoi* and 99.4% in *Deal or No Deal UK*) is below the expected value of the prizes that a contestant is still able to win when the offer is made.[13] Contestants accepting such less than actuarially fair offers violate the assumption of risk neutrality. Contestants rejecting offers, which are higher than the expected value, violate risk neutrality if this is the last possible offer in the game (offer is made when only two boxes remain unopened). Contestants rejecting a more than actuarially fair offer, which is not the last possible offer in the game, do not necessarily violate risk neutrality—they may simply expect that future offers will be even more generous. Overall, 63 out of 114 Italian contestants (55.3%) and 278 out of 386 British contestants (72%) violated risk neutrality (overwhelming majority of these contestants accepted offers lower than the expected value of possible prizes).

Instances / **"Bank" offer**	*Affari Tuoi*			*Deal or No Deal UK*		
	Total	Accepted	Rejected	Total	Accepted	Rejected
Higher than expected value	2	1	1	6	2	4
Equal to expected value	9	4	5	6	2	4
Less than expected value[14]	391	62	329	1,944	277	1,667

Table 5 "Bank" monetary offers compared to the expected value of possible prizes

[13] It appears that several more than actuarially fair offers resulted from rounding of "bank" offers and they do not reflect a systematic policy of the "bank" to make occasional "kind" offers. For example, in *Affari Tuoi*, on one occasion, the "bank" offered €40 when the expected value of three prizes was €36.83 and on the second occasion the "bank" offered €17,000 when the expected value of eight prizes was €16,300. In *Deal or No Deal UK*, the "bank" made six more than actuarially fair offers: £800, £1,500, £2,500, £13,000, £15,001 and £28,000 when the expected value of remaining prizes was £761, £1,445, £2,476, £12,500, £14,719 and £23,211 respectively.

[14] Due to rounding of "bank" offers, several offers were just few pennies below the expected value of outstanding prizes. For example, seven offers in *Affari Tuoi* and thirteen offers in *Deal or No Deal UK* were less than 1% below the expected value and contestants accepted only one and seven of these offers respectively. Thus, a large number of accepted less than actuarially fair offers cannot be explained by the fact that some of these offers were just marginally lower than the expected value of possible prizes.

4.2. Expected Utility and Prospective Reference Theory

According to expected utility theory, an individual evaluates monetary outcomes by means of a subjective utility function and chooses the lottery with the highest expected utility of possible outcomes. Formally, utility of lottery $L(x_1,1/n;...;x_n,1/n)$ is given by $\frac{1}{n}\sum_{i=1}^{n}u(x_i)$, where $u:\mathrm{R}\to\mathrm{R}$ is a (Bernoulli) utility function over money. Utility function can be normalized for two outcomes without loss of generality, e.g. $u(€0.01)=0$ and $u(€500000)=1$ in *Affari Tuoi* or $u(£0.01)=0$ and $u(£250000)=1$ in *Deal or No Deal UK*.

According to prospective reference theory, an individual maximizes a weighted average of the expected utility of a lottery and the expected utility from receiving every possible outcome of the lottery with equal probability (Viscusi, 1989). Formally, utility of a risky lottery $L(x_1,1/n;...;x_n,1/n)$ is $\lambda\frac{1}{n}\sum_{i=1}^{n}u(x_i)+(1-\lambda)\frac{1}{n}\sum_{i=1}^{n}u(x_i)=\frac{1}{n}\sum_{i=1}^{n}u(x_i)$, where $u:\mathrm{R}\to\mathrm{R}$ is a (Bernoulli) utility function over money and $\lambda\in[0,1]$ is the weight of the relative information content. Television shows *Affari Tuoi* and *Deal or No Deal UK* employ only lotteries with equiprobable outcomes. Thus, in our data set the prediction of prospective reference theory is identical to the prediction of expected utility theory (for any possible weight of the relative information content).

Before February 9, 2006 every *Affari Tuoi* contestant received up to 4 monetary offers for a distribution of up to 11 possible prizes. Starting from February 9, 2006 *Affari Tuoi* contestants receive up to 7 monetary offers and the first offer is made when there are 14 prizes left in the game. In the British version of *Deal or No Deal* all contestants receive up to 6 monetary offers for a distribution of 17 possible prizes. Clearly, a non-parametric test of expected utility theory is not feasible on *Affari Tuoi* and *Deal or No Deal UK* data because every contestant makes only few observed decisions but faces lotteries with

many outcomes.[15] Instead of testing the prediction of expected utility theory, we look for patterns in the data that are difficult to reconcile within the expected utility framework.

Expected utility maximizers take into account only the distribution of possible prizes, a current offer and the expectation of future offers. Thus, their decisions are not influenced by monetary prizes that were already eliminated from the list of possible prizes. However, Post et al. (2004) find that American, German and Dutch *Deal or No Deal* contestants tend to exhibit a lower coefficient of relative risk aversion after the elimination of large prizes.[16] Given this finding, we test if *Deal or No Deal* contestants, who experienced recent elimination of large prizes, reject "bank" offers more often.

Since the "bank" typically makes the next monetary offer after a contestant opens another three boxes, we consider if contestant's decision to accept or reject the offer depends on the number of large prizes that were discovered in the last three boxes opened prior to the decision. We define a large prize both in absolute terms (any prize higher or equal to €5,000 in *Affari Tuoi* and higher or equal to £1,000 in *Deal or No Deal UK*[17]) and in relative terms (three largest prizes in the distribution of possible prizes that the contestant faced before opening three boxes).

Table 2 shows that "bank" monetary offers in *Affari Tuoi* do not depend on the number of foregone large prizes, both for large prizes in absolute and relative terms. Therefore, if *Affari Tuoi* contestants do not take foregone outcomes into account, we can expect similar rates of acceptance/rejection of "bank" offers when large prizes are

[15] For every contestant there are at most only 7 weak inequalities restricting individual utility function and at least 9 outcomes, for which utilities can be freely chosen (given that utility of 2 outcomes is normalized).
[16] Notice that this finding does not necessarily contradict to the expected utility theory. It rather shows that subjective utility function does not exhibit a constant coefficient of relative risk aversion. Instances, when a contestant rejects a more than actuarially fair offer only to accept later a less than actuarially fair offer, also do not necessarily contradict to the expected utility theory if utility function is concave over one range of outcomes and convex over another (e.g. Markowitz, 1952).
[17] Figure 1 offers a natural threshold for distinguishing between large and small prizes in *Affari Tuoi*. Prizes that are above or equal to €5,000 are significantly (at least 10 times) higher than all prizes below €5,000. In *Deal or No Deal UK* all prizes higher or equal to £1,000 are highlighted in red color (e.g. Figure 2) and are consistently framed in every episode as favorable outcomes (as opposed to prizes below £1,000).

eliminated and when they remain in the game. Table 3 shows that *Deal or No Deal UK* contestants receive systematically lower offers, if they eliminate large prizes. Thus, *Deal or No Deal UK* contestants, who open boxes with large prizes, may be expected to reject "bank" offers at least as frequently as the contestants, who open boxes with small prizes.

Table 6 shows how frequently *Affari Tuoi* and *Deal or No Deal UK* contestants accept "bank" offers depending on the number of large prizes that they discover in the last three opened boxes. In *Affari Tuoi* acceptance rate for "bank" offers does not depend on the number of foregone large prizes if they are defined in absolute terms. Generally, this also holds when large prizes are defined in relative terms. The only significant effect can be found in the behavior of Italian contestants, who face a distribution of five prizes. Contestants, who eliminated one of the highest ranked prizes, accept offers significantly more often than contestants, who were lucky not to eliminate any of large prizes.[18]

Number of foregone large prizes		**Number (percentage) of *Affari Tuoi* contestants who accepted "bank" offer when facing…**			**Number (percentage) of *Deal or No Deal UK* contestants who accepted "bank" offer when facing…**		
		8 prizes	**5 prizes**	**2 prizes**	**8 prizes**	**5 prizes**	**2 prizes**
Large prizes in absolute terms	**0**	3 (15.8%)	0 (0.0%)	3 (42.9%)	10 (23.3%)	18 (52.9%)	13 (54.2%)
	1	3 (5.8%)	18 (40.9%)	7 (41.2%)	34 (23.3%)	55 (51.9%)	15 (25.9%)
	2	4 (14.8%)	14 (34.1%)	4 (44.4%)	33 (22.9%)	48 (37.2%)	20 (32.3%)
	3	1 (7.7%)	2 (33.3%)	4 (50.0%)	9 (24.3%)	2 (13.3%)	9 (52.9%)
Large prizes in relative terms	**0**	6 (11.3%)	3 (18.8%)	-	47 (33.1%)	26 (52.0%)	-
	1	3 (6.5%)	25 (47.2%)	5 (29.4%)	35 (20.1%)	74 (50.7%)	23 (43.4%)
	2	2 (18.2%)	6 (24.0%)	12 (57.1%)	4 (7.7%)	23 (26.7%)	33 (34.7%)
	3	0 (0.0%)	0 (0.0%)	1 (33.3%)	0 (0.0%)	0 (0.0%)	1 (7.7%)

Table 6 Decisions of contestants depending on the number of large prizes discovered in the last three opened boxes. Large prizes in absolute terms are defined as prizes greater or equal to €5,000 in *Affari Tuoi* and £1,000 in *Deal or No Deal UK*. Large prizes in relative terms are defined as three highest ranked prizes.

[18] Interestingly, this is the opposite of the effect reported in Post et al. (2004).

Deal or No Deal UK contestants, who eliminated several large prizes, generally tend to accept "bank" offers significantly less often than contestants, who eliminated only one large prize or did not eliminate any of large prizes at all. This effect is especially strong when prizes are measured in relative terms. However, since British contestants receive less favorable offers after eliminating large prizes, this finding *per se* does not necessarily indicate that contestants' behavior is influenced by foregone outcomes. Convincing evidence of such path-dependence can be found only if contestants accept offers more frequently after eliminating large prizes. We find only one example of such behavior. Unlucky contestants, who face a distribution of two prizes after eliminating three prizes greater or equal to £1000, accept "bank" offers significantly more often than contestants, who eliminated only one large prize. Thus, in both versions of the show there is no strong evidence of path-dependence, which is consistent with expected utility theory.

4.3. Fanning-Out (Weighted Utility Theory, Transitive Skew-Symmetric Bilinear Utility Theory)

Machina (1982) proposed the fanning-out hypothesis that individuals do not become less risk averse when lotteries improve in the sense of the first-order stochastic dominance. Several decision theories such as weighted utility theory (e.g. Chew and McCrimmon, 1979, Chew, 1983) and transitive skew-symmetric bilinear utility theory (e.g. Fishburn, 1983, 1988) incorporate the fanning-out hypothesis by restricting their general utility functionals to explain well-know violations of the expected utility theory such as the Allais paradox (Allais, 1953) or common ratio effect (e.g. Starmer, 2000).

To test the fanning-out hypothesis, we consider all contestants who received a monetary offer for a distribution of eight, five and two possible prizes[19]. In each of these

[19] For the remaining offers, there is no sufficient variability in the data. Only one *Affari Tuoi* contestant and 15 *Deal or No Deal UK* contestants accepted an offer when 11 boxes remained unopened. Monetary offers for a distribution of 15 and 17 prizes, that are possible only in *Deal or No Deal UK*, were always rejected.

three cases, we select a separating lottery and compare the acceptance (rejection) rate for "bank" offers in two groups of contestants. In the first group, contestants face a distribution of possible prizes, which is stochastically dominated by the separating lottery. In the second group, contestants face a distribution of possible prizes, which stochastically dominates the separating lottery. The separating lottery is selected to maximize the minimum number of observations in two groups[20].

Contestants are allocated across the two groups at random (as a result of chance events). Table 2 shows that the "bank" does not make higher offers to *Affari Tuoi* contestants in group 2. In fact, at 5% significance level we cannot reject the hypothesis that the "bank" makes higher offers to group 1 of *Affari Tuoi* contestants. Table 3 shows that the "bank" offers significantly lower amounts to *Deal or No Deal UK* contestants in group 2. Thus, both *Affari Tuoi* and *Deal or No Deal UK* contestants receive relatively less favorable offers in group 2 compared to group 1 and they have no *a priori* reason for accepting "bank" offers more frequently in group 2. This allows us to formulate our testing hypothesis as follows:

Hypothesis I Contestants in both groups accept "bank" offers equally often.

Hypothesis II (fanning out) Contestants in the second group accept monetary offers from the "bank" more often than contestants in the first group.

Table 7 shows that the fraction of contestants who accept "bank" offers is always higher in the second group than in the first group. This difference is also statistically significant for contestants who face a distribution of five and two possible prizes. Thus,

[20] Lotteries $(€10,1/2;€20000,1/2)$, $(€0.5,1/5;€50,1/5;€500,1/5;€20000,1/5;€100000,1/5)$ and $(€0.01,1/8;€1,1/8;€50,1/8;€250,1/8;€5000,1/8;€15000,1/8;€50000,1/8;€250000,1/8)$ are used as separating lotteries for *Affari Tuoi* contestants who received an offer for a distribution of two, five and eight prizes respectively. Corresponding separating lotteries for British *Deal or No Deal* contestants are $(£10,1/2;£5000,1/2)$, $(£0.5,1/5;£50,1/5;£750,1/5;£10000,1/5;£50000,1/5)$ and $(£0.01,1/8;£5,1/8;£100,1/8;£750,1/8;£5000,1/8;£15000,1/8;£35000,1/8;£75000,1/8)$.

the data from our natural experiment strongly support the fanning-out hypothesis. Although this finding may cast doubt on the descriptive validity of expected utility theory, it does not necessarily contradict the expected utility framework. The reason is that contestants in groups 1 and 2 generally face lotteries over *different* monetary prizes. Thus, expected utility maximizers with convex (or linear) utility function over small outcomes and concave utility function over large outcomes may also exhibit this type of fanning-out. Note that evidence of fanning-out that invalidates expected utility theory comes from conventional laboratory experiments where subjects face lotteries over the *same* outcomes (usually, three-outcome lotteries located inside the probability triangle).

	Affari Tuoi			*Deal or No Deal UK*		
		YES	**NO**		**YES**	**NO**
Contestants facing a distribution of eight prizes	**G1**	1	12	**G1**	3	35
	G2	3	12	**G2**	8	28
		N=28			*N*=74	
	Fisher's exact test (one sided) p=0.3831			Fisher's exact test (one sided) p=0.0794		
		YES	**NO**		**YES**	**NO**
Contestants facing a distribution of five prizes	**G1**	3	16	**G1**	7	48
	G2	10	9	**G2**	32	21
		N=38			*N*=108	
	Fisher's exact test (one sided) p=0.0191			Fisher's exact test (one sided) p=0.0000		
		YES	**NO**		**YES**	**NO**
Contestants facing a distribution of two prizes	**G1**	2	11	**G1**	6	51
	G2	7	6	**G2**	30	28
		N=26			*N*=115	
	Fisher's exact test (one sided) p=0.0484			Fisher's exact test (one sided) p=0.0000		

Table 7 Number of contestants accepting ("YES") and rejecting ("NO") "bank" offers in group 1 (G1) and group 2 (G2). All contestants in G2 face distributions that stochastically dominate distributions faced by contestants in G1.

4.4. Prospect Theory

According to prospect theory, an individual obtains a simplified representation of a decision problem in the editing phase and subsequently evaluates edited lotteries in the evaluation phase (e.g. Kahneman and Tversky, 1979). Two editing operations that are relevant in the context of this experiment are simplification (monetary outcomes are rounded up) and combination (probabilities associated with identical outcomes are added together). In the evaluation phase, edited lotteries are evaluates by means of an S-shaped value function and inverse-S shaped probability weighting function. The probability weighting function overvalues small probabilities and undervalues medium and high probabilities. Note that in cumulative prospect theory (Tversky and Kahneman, 1992) this effect holds only for extreme outcomes (highest ranked and lowest ranked gains and losses). We will test rank-dependent nonlinear probability weighting in section 4.6 below.

A rather natural implication of the editing phase in the contest of this natural experiment is that *Affari Tuoi* and *Deal or No Deal UK* contestants round up numerous small outcomes in the left section of Figure 1 and Figure 2 respectively and combine their probabilities in one joint probability.[21] This joint probability is overweighted, if small, and underweighted otherwise. Thus, prospect theory predicts that *Affari Tuoi* and *Deal or No Deal UK* contestants facing a low chance of receiving a small prize (less or equal than €500 and £750 respectively) are likely to accept "bank" offers more frequently than the contestants facing a high chance of ending up with a small prize.

To test this prediction of prospect theory, we consider the decisions of *Affari Tuoi* contestants, who received an offer for a distribution of eight and five possible prizes.[22]

[21] Figure 1 and Figure 2 also show that prizes are framed in a way that encourages such editing. All small prizes on the left hand side are highlighted in one color (blue).

[22] We do not consider the decisions of contestants who received a monetary offer for a distribution of eleven and two prizes because there is no sufficient variability of the data in the first case (only one

Table 8 shows no evidence that low chances of a small prize are overweighted (leading to a higher acceptance rate) and high chances of a small prize are underweighted (leading to a lower acceptance rate).[23] Only contestants, who face a ¼ chance of receiving €500 or less, are marginally more likely to accept "bank" offers than contestants, who face a corresponding chance of 3/8 (*p*-value for one sided Fisher's exact test is 0.0587).

Monetary offers for a distribution of eight possible prizes

Chance of €500 or less	Number (percentage) of contestants who …	
	Accept offer	Reject offer
1/4	2 (28.57%)	5 (71.43%)
3/8	1 (2.63%)	37 (97.37%)
1/2	4 (12.12%)	29 (87.88%)
5/8	3 (11.54%)	23 (88.46%)
3/4	0 (0.00%)	3 (100.00%)

Monetary offers for a distribution of five possible prizes

Chance of €500 or less	Number (percentage) of contestants who …	
	Accept offer	Reject offer
0	1 (33.33%)	2 (66.67%)
1/5	7 (35.00%)	13 (65.00%)
2/5	10 (35.71%)	18 (64.29%)
3/5	12 (37.50%)	20 (62.50%)
4/5	4 (30.77%)	9 (69.23%)

Table 8 Decisions of *Affari Tuoi* contestants depending on their chances of receiving a small prize (≤€500)

We conduct a similar test for British *Deal or No Deal* contestants. Table 9 shows how many of them accepted and rejected monetary offers for a distribution of eight and five possible prizes depending on their chances of receiving a small prize (defined as £750 or less). Contestants, who face a low chance of receiving a small prize, appear to be significantly more likely to accept a monetary offer from the "bank". For instance, British contestants, who are confronted with a probability of 1/5 or 2/5 of receiving £750 or less, accept "bank" offers significantly more frequently than contestants for whom the corresponding probability is 3/5 or 4/5. At the same time contestants, who face five to eight odds of receiving £750 or less, tend to accept monetary offers significantly less often than contestants for who the respective chances are 3/8 and 1/2.

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contestant accepted a monetary offer for a distribution of eleven prizes) and contestants do not face outcomes of low probability in the second case.

[23] Similar results hold when only the probabilities of prizes below or equal to €250, €100 etc. are combined.

Monetary offers for a distribution of eight possible prizes

Chance of £750 or less	Number (percentage) of contestants who …	
	Accept offer	Reject offer
1/8	2 (50.00%)	2 (50.00%)
1/4	7 (25.00%)	21 (75.00%)
3/8	21 (24.42%)	65 (75.58%)
1/2	36 (26.67%)	99 (73.33%)
5/8	14 (15.22%)	78 (84.78%)
3/4	6 (25.00%)	18 (75.00%)

Monetary offers for a distribution of five possible prizes

Chance of £750 or less	Number (percentage) of contestants who …	
	Accept offer	Reject offer
0	2 (40.00%)	3 (60.00%)
1/5	20 (50.00%)	20 (50.00%)
2/5	54 (53.47%)	47 (46.53%)
3/5	39 (39.39%)	60 (60.61%)
4/5	8 (21.62%)	29 (78.38%)
1	0 (0.00%)	2 (100.00%)

Table 9 Decisions of *Deal or No Deal UK* contestants depending on their chances of receiving a small prize (≤£750)

Natural laboratory of *Affari Tuoi* and *Deal or No Deal UK* can be also used for testing the assumption of loss aversion of prospect theory by considering the decisions of contestants, who received an exchange offer. Particularly, Blavatskyy and Pogrebna (2006) show that loss averse contestants should always reject the exchange offer and keep the box that they are initially endowed with. However, 47% of *Affari Tuoi* contestants violated the assumption of loss aversion (40% accepted the first exchange offer and 7% rejected the first exchange offer but accepted the second exchange offer). Among 63 British *Deal or No Deal* contestants who received an exchange offer from the "bank", 27 (43%) contestants exchanged their initial endowment for a new box in violation of the assumption of loss aversion.

4.5. Regret Theory (Non-Transitive Skew-Symmetric Bilinear Utility Theory)

According to regret theory, an individual experiences regret (rejoicing) when a lottery that she has chosen delivers lower (higher) outcome than the *ex post* outcome of the lottery that she did not choose. *Ex ante*, an individual anticipates future regret or rejoicing and attempts to minimize *ex post* regret (e.g. Loomes and Sugden, 1987).

Formally, an individual chooses a risky lottery $L(x_1,1/n;...;x_n,1/n)$ over a sure amount y if $\sum_{i=1}^{n}\psi(x_i,y)\geq 0$, where $\psi(\cdot,\cdot)$ is a skew-symmetric function satisfying the assumption of regret aversion: $\psi(a,c)>\psi(a,b)+\psi(b,c),\ \forall a>b>c$ (e.g. Loomes *et al.*, 1992). Since contestants always choose between one risky and one degenerate lottery, i.e. between two statistically independent lotteries, regret theory also coincides with (non-transitive) skew-symmetric bilinear utility theory (e.g. Loomes and Sugden, 1987).

To test the prediction of regret theory, we compare the difference between final earnings of contestants and the outcome that they would have received if they had reached a different decision when the "bank" made them an offer. For example, a contestant, who rejected "bank" offer *A* and ended up earning *B*, could have received amount *A* if she reversed her decision and accepted the offer. We look at the difference between actual earnings (*B*) and hypothetical earnings (*A*) if a different decision were made. A positive difference signifies rejoicing and a negative difference denotes regret. If the assumption of regret aversion holds, instances of *ex post* regret are likely to be infrequent and/or of a smaller absolute magnitude compared to *ex post* rejoicing.

Figure 3 shows that the cumulative distribution function of *ex post* rejoicing often (first order) stochastically dominates the distribution function of *ex post* regret. Both *Affari Tuoi* and *Deal or No Deal UK* contestants experienced *ex post* regret for their decisions less often than they experienced rejoicing. Non-parametric Mann-Whitney test indicates that median experienced regret is significantly lower than median experienced rejoicing for decisions that contestants make when eight boxes remain unopened (and for decisions that British contestants make when five boxes remain unopened). Thus, contestants are quite successful in avoiding *ex post* regret, which is consistent with the assumption of regret aversion (convexity of a skew-symmetric utility function).

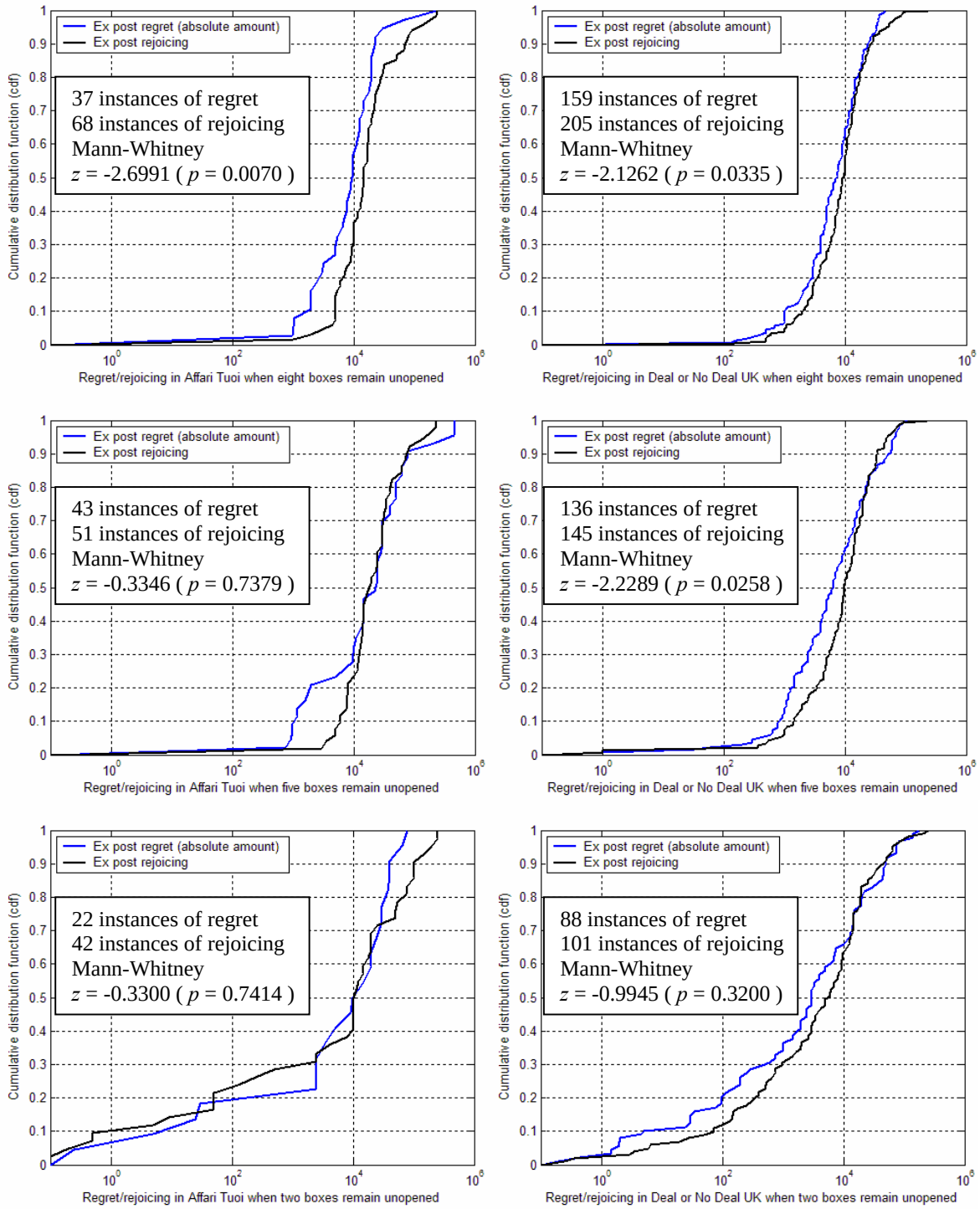

Figure 3 Cumulative distribution functions of *ex post* regret (absolute amount) and *ex post* rejoicing in *Affari Tuoi* (left panels) and *Deal or No Deal UK* (right panels). Vertical axis shows the probability that a contestant regretted for or rejoiced in an amount not higher than shown on the horizontal axis (€ in *Affari Tuoi*, £ in *Deal or No Deal UK*).

4.6. Rank-Dependent Expected Utility Theory

According to rank-dependent expected utility theory (RDEU), utility of a risky lottery $L(x_1,1/n;...;x_n,1/n)$, $x_1 > x_2 > ... > x_n$, is given by $\sum_{i=1}^{n}\left[w\left(\frac{i}{n}\right) - w\left(\frac{i-1}{n}\right)\right]\cdot u(x_i)$, where $w:[0,1]\to[0,1]$ is a probability weighting function and $u:\mathrm{R}\to\mathrm{R}$ is utility function (e.g. Quiggin, 1982). Probability weighting function is strictly increasing and satisfies boundary conditions $w(0)=0$ and $w(1)=1$. Additionally, it has a characteristic inverse-S shape being concave for low probabilities ($p<1/3$) and convex for medium and high probabilities ($p>1/3$). If all lottery outcomes $x_1 > x_2 > ... > x_n$ are above the reference point of an individual, the prediction of RDEU is identical to the prediction of cumulative prospect theory (e.g. Tversky and Kahneman, 1992).

The inverse-S shape of the probability weighting function implies that individuals overvalue small probabilities of extreme outcomes (i.e. highest ranked and lowest ranked outcomes) and undervalue medium and high probabilities of extreme outcomes. Consider an individual facing a risky lottery that delivers the highest possible outcome with a small probability and this outcome is significantly higher (in terms of utility) than the second highest possible outcome. RDEU predicts that an individual overvalues such a lottery, i.e. she is likely to exhibit risk-seeking behavior. Similarly, an individual undervalues a risky lottery that yields the lowest possible outcome with a small probability if this outcome is significantly lower (in terms of utility) than the second lowest possible outcome of a lottery. In this case an individual is more likely to exhibit risk-averse behavior.

To test the predictions of RDEU, we consider the decisions of *Affari Tuoi* and *Deal or No Deal* contestants, who received a monetary offer for a distribution of eight and five possible prizes (see footnote 22). These contestants face risky lotteries that yield

every possible prize with probability 0.2 and 0.125, respectively. We consider the acceptance/rejection rate for "bank" monetary offers across four groups of contestants. Contestants are divided across four groups depending on the risky lottery that they face:

Group 3 The highest possible prize of a lottery is at least ten times higher than the second highest prize of the lottery.

Group 4 Two highest possible prizes of a lottery are adjacent prizes (e.g. in Figure 1 or Figure 2). If lottery has eight possible prizes, the three highest ranked prizes are adjacent.

Group 5 The second lowest possible prize of a lottery is at least ten times higher than the lowest prize of the lottery.

Group 6 Two lowest possible prizes of a lottery are adjacent prizes (e.g. in Figure 1 or Figure 2). If lottery has eight possible prizes, the three lowest ranked prizes are adjacent.[24]

Table 2 and Table 3 show that the "bank" does not discriminate between members of groups 3-6 when making offers. RDEU then predicts that offers are rejected more frequently in group 3 than in group 4. Probability of receiving a large prize is 20% or 12.5% in group 3 and 40% or 37.5% in group 4. This probability is overweighted to a stronger extent in group 3 than in group 4,[25] leading to a higher rejection of "bank" offers. Similarly, RDEU predicts that "bank" offers are accepted more frequently in group 5 than in group 6.

Table 10 shows that there is no systematic difference in acceptance/rejection of "bank" monetary offers across groups 3 and 4 and across groups 5 and 6 of *Affari Tuoi* contestants. Table 11 shows that there is also no significant difference in acceptance of

[24] For identification of groups 5 and 6, five lowest prizes from Figure 1 or Figure 2 are treated as identical.

[25] For example a 1/5 chance of a large prize x_1 is valued as $w(1/5)\cdot u(x_1)$, which can be higher than utility of an actuarially fair offer $u(x_1/5)$ if $w(1/5)>1/5$. However a 1/5 chance of x_1 and a 1/5 chance of a similar large prize $x_2<x_1$, $u(x_2)\approx u(x_1)$, is valued as $w(1/5)\cdot u(x_1)+[w(2/5)-w(1/5)]\cdot u(x_2)\approx w(2/5)\cdot u(x_1)$, which is likely to be lower than utility of an actuarially fair offer $u((x_1+x_2)/5)$ if $w(2/5)\le 2/5$.

"bank" offers across groups 3 and 4 and across groups 5 and 6 of British *Deal or No Deal* contestants. Thus, the decisions of *Affari Tuoi* and *Deal or No Deal* contestants do not reveal any manifestable effect of nonlinear probability weighting when the highest and the lowest ranked outcomes of a risky lottery are systematically overweighted.

Monetary offers for a distribution of eight possible prizes:

	Accepted	Rejected
Group 3	1	11
Group 4	0	14

Fisher's exact test (one sided) p=0.9999

	Accepted	Rejected
Group 5	2	16
Group 6	4	49

Fisher's exact test (one sided) p=0.4790

Monetary offers for a distribution of five possible prizes:

	Accepted	Rejected
Group 3	14	20
Group 4	7	17

Fisher's exact test (one sided) p=0.8883

	Accepted	Rejected
Group 5	15	27
Group 6	19	35

Fisher's exact test (one sided) p=0.5629

Table 10 Number of monetary offers for a distribution of five/eight possible prizes that were accepted/rejected by *Affari Tuoi* contestants in groups 3-6.

Monetary offers for a distribution of eight possible prizes:

	Accepted	Rejected
Group 3	10	27
Group 4	13	36

Fisher's exact test (one sided) p=0.6186

	Accepted	Rejected
Group 5	65	211
Group 6	3	16

Fisher's exact test (one sided) p=0.3235

Monetary offers for a distribution of five possible prizes:

	Accepted	Rejected
Group 3	17	27
Group 4	21	44

Fisher's exact test (one sided) p=0.8121

	Accepted	Rejected
Group 5	96	133
Group 6	14	21

Fisher's exact test (one sided) p=0.4908

Table 11 Number of monetary offers for a distribution of five/eight possible prizes that were accepted/rejected by *Deal or No Deal UK* contestants in groups 3-6.

4.7. Yaari's Dual Model

According to Yaari's dual model, utility of a risky lottery $L(x_1,1/n;...;x_n,1/n)$, $x_1 > x_2 > ... > x_n$, is given by $\sum_{i=1}^{n}\left[w\left(\frac{i}{n}\right)-w\left(\frac{i-1}{n}\right)\right]\cdot x_i \geq y$, where $w:[0,1]\rightarrow[0,1]$ is a probability weighting function (e.g. Yaari, 1987). The probability weighting function is strictly increasing and $w(0)=0$, $w(1)=1$. Note that this model is a special case of rank-dependent expected utility theory where the utility function is linear.

To test Yaari's dual model, we consider the decisions of *Affari Tuoi* and *Deal or No Deal UK* contestants who receive monetary offer y for a 50%-50% chance to win either prize x_1 or prize x_2. According to Yaari's model, contestants reject "bank" offer if $x_2 + w(1/2)\cdot(x_1 - x_2) \geq y$, which is equivalent to $w(1/2) \geq (y - x_2)/(x_1 - x_2)$. Thus, the higher is the ratio $z = (y - x_2)/(x_1 - x_2)$, the more likely is a contestant to accept a "bank" offer for a given probability weight $w(1/2)$.

Affari Tuoi and *Deal or No Deal UK* contestants face two-outcome lotteries in the last stage of the game. "Bank" monetary offers steadily improve towards the end of the show when less and less boxes remain unopened (e.g. Table 2 and Table 3). Thus, risk-averse contestants may accept one of "bank" offers in the early rounds of the show (when many boxes still remain unopened). In this case, only relatively less risk-averse contestants (with high probability weight $w(1/2)$) are likely to face a choice between a 50%-50% gamble and a monetary outcome for sure. Thus, the estimation of a probability weight $w(1/2)$ based on data from the last round of the game is affected by serious selection bias.

However, this selection bias does not affect our test of the prediction of Yaari's dual model. Yaari's dual model predicts that in any population of contestants with

heterogeneous probability weights, the fraction of accepted monetary offers is higher when contestants face two-outcome lotteries with high ratio $z = (y - x_2)/(x_1 - x_2)$. This prediction holds for a sample of contestants, who have relatively high probability weights $w(1/2)$, just as it holds for a sample of contestants, who, on average, have low probability weights $w(1/2)$.

For 41 *Affari Tuoi* contestants who received a monetary offer for a distribution of two prizes, a simple logit regression $\Pr(\text{"accept"}) = \exp(\beta_0 + \beta_1 \mathbf{z})/(1 + \exp(\beta_0 + \beta_1 \mathbf{z}))$ yields an estimate of regression coefficients, with standard errors in parenthesis, of $\beta_0 = -0.9509\,(1.0104)$ and $\beta_1 = 1.9588\,(2.5522)$. Thus, there is no statistically significant relationship between the ratio $z = (y - x_2)/(x_1 - x_2)$ and the likelihood that contestants accept "bank" offers. Apparently, *Affari Tuoi* contestants facing a decision problem with high ratio z, are also more likely to possess a higher probability weight $w(1/2)$. It is difficult to reconcile this finding within the framework of Yaari's dual model, because probability weights are assumed to be independent of the monetary outcomes.

In contrast, for 161 British *Deal or No Deal* contestants, who received a monetary offer when only two boxes remained unopened, the same logit regression yields an estimate of regression coefficients $\beta_0 = -2.3639\,(0.7110)$ and $\beta_1 = 5.1837\,(1.9319)$. Thus, *Deal or No Deal UK* contestants are significantly more likely to accept "bank" offer when facing lotteries with high ratio $z = (y - x_2)/(x_1 - x_2)$ and their behavior is consistent with the prediction of Yaari's dual model.

4.8. Disappointment Aversion Theory

According to disappointment aversion theory, an individual experiences disappointment (elation) when a realized outcome of a lottery is below (above) its certainty equivalent. *Ex ante*, an individual anticipates future disappointment or elation and attempts to minimize *ex post* disappointment (Gul, 1991). Formally, utility of a risky lottery $L(x_1,1/n;...;x_n,1/n)$, $x_1 > x_2 > ... > x_n$, is $\frac{1}{1+m\beta}\frac{1}{n}\sum_{i=1}^{n-m}u(x_i)+\frac{1+\beta}{1+m\beta}\frac{1}{n}\sum_{i=n-m+1}^{n}u(x_i)$, where $m \in \{1,...,n-1\}$ is a number of disappointing outcomes in lottery L and $\beta \geq 0$ is a subjective parameter that captures disappointment averse preferences.

To test the prediction of disappointment aversion theory, we analyze the decisions of *Affari Tuoi* and *Deal and No Deal UK* contestants who received a monetary offer for a distribution of eight, five and two prizes. Consider the five lowest prizes from Figure 1 or Figure 2. Given that the other prizes are significantly higher monetary amounts, we assume, for simplicity, that these five lowest prizes yield the same utility. Without loss of generality, this utility can be normalized to zero. In our recorded sample, five lowest prizes are always disappointing prizes.[26] Utility of a risky lottery L is then given by $\frac{1}{1+(m+k)\beta}\frac{1}{n}\sum_{i=1}^{n-m}u(x_i)+\frac{1+\beta}{1+(m+k)\beta}\frac{1}{n}\sum_{i=n-m+1}^{n-k}u(x_i) \geq u(y)$, where $k \in \{1,...,5\}$ is the number of prizes of lottery L that are below or equal to €5 in *Affari Tuoi* and £5 in *Deal and No Deal UK* and m is the number of disappointing prizes of lottery L that are higher than

[26] When contestants receive a monetary offer for a distribution of eight (five) equiprobable prizes, at least two (one) of these prizes are (is) at least 1,000 times higher than €5 in *Affari Tuoi* or £5 in *Deal or No Deal UK*. Thus, for any plausible level of risk aversion, the certainty equivalent of such lotteries is significantly above €5 or £5 i.e. five lowest prizes are disappointing outcomes. When contestants receive a monetary offer for a distribution of two prizes, one of which is below or equal to €5 or £5, the low prize is obviously a disappointing prize. In *Affari Tuoi* there are also two instances when a contestant received an offer for lotteries (€1,0.5;€0.50,0.5) and (€1,0.5;€0.20,0.5). In *Deal or No Deal UK* there are eight episodes when the "bank" made a monetary offer for a distribution of two prizes, both of which were less or equal to £5. We excluded these cases from current analysis.

€5 or £5 respectively. According to disappointment aversion theory, the higher is k, the lower is subjective utility of a risky lottery and the more likely is a contestant to accept a monetary offer from the "bank".[27]

Contrary to the theoretical prediction, Table 12 shows that *Affari Tuoi* contestants tend to accept "bank" offers less frequently when they face lotteries with a high number of small disappointing prizes. However, this tendency is not statistically significant. Results are more mixed for *Deal or No Deal UK* contestants. On the one hand, there is evidence of disappointment aversion among contestants who face a distribution of eight possible prizes. Specifically, contestants confronted with one disappointing prize accept "bank" offers significantly less frequently than contestants for whom two or three out of eight prizes are disappointingly low. On the other hand, British contestants facing two to five odds of receiving £5 or less tend to accept "bank" offers less often than contestants, who face only one or no disappointing prizes at all (among five possible prizes). Thus, contestants do not appear to be systematically averse to small disappointing prizes.

Number of small prizes	**Number (percentage) of *Affari Tuoi* contestants who accepted "bank" offer when facing…**			**Number (percentage) of *Deal or No Deal UK* contestants who accepted "bank" offer when facing…**		
	8 prizes	**5 prizes**	**2 prizes**	**8 prizes**	**5 prizes**	**2 prizes**
0	1 (16.67%)	12 (54.55%)	12 (50.00%)	7 (25.93%)	38 (52.05%)	7 (25.00%)
1	4 (12.90%)	12 (30.00%)	6 (40.00%)	18 (15.79%)	60 (44.78%)	19 (16.38%)
2	5 (11.90%)	9 (32.14%)	-	39 (25.32%)	22 (33.33%)	-
3	1 (3.57%)	1 (20.00%)	-	20 (29.85%)	3 (30.00%)	-
4	0 (0.00%)	0 (0.00%)	-	2 (28.57%)	0 (0.00%)	-

Table 12 Decisions of contestants in relation to the number of small disappointing prizes (≤€5 for *Affari Tuoi* and ≤£5 for *Deal or No Deal UK*) that they face in the game

[27] Moreover, Table 3 shows that British contestants, who face many prizes less or equal to £5, receive more favorable offers from the "bank", which reinforces a relative disadvantage of a risky lottery.

5. Conclusion

Television shows *Affari Tuoi* and *Deal or No Deal UK* provide an interesting natural experiment that allows testing the predictions of different decision theories. Contestants representing the adult population of Italy and United Kingdom face a sequence of binary choices between a risky lottery and a monetary amount for certain. The show provides very high real incentives with prizes ranging from one cent to half a million euros. This allows us to investigate decision making in a domain that is not feasible in conventional laboratory experiments. However, we observe only few choices made by each contestant, which mostly restricts our analysis to a between-subject design.

Random events play a crucial role in this natural experiment, because they determine the distribution of possible prizes that a contestant is facing. This enables us to allocate contestants across randomized treatments. Assuming that a particular decision theory correctly represents contestants' preferences, we allocate contestants across two groups. In the first group, contestants face probability distributions that are relatively unfavorable according to the selected theory, while contestants in the second group are confronted with relatively attractive gambles (according to the same theory). The selected theory is tested by comparing behavior across these two artifactual treatments. This research methodology allows using data from natural experiments in television shows for testing virtually any research hypothesis even though the experimenter does not have any control over the course of such shows.

We test the predictions of ten well-known decision theories that are usually contested against each other for the best explanation of behavioral patterns observed in laboratory experiments. The main findings of this natural experiment can be summarized as follows. On the one hand, *Deal or No Deal* contestants clearly violate the assumption

of risk neutrality and the assumption of loss aversion of prospect theory. On the other hand, contestants' behavior supports the assumption of regret aversion of regret theory and the fanning-out hypothesis of weighted utility and skew-symmetric bilinear utility theories. We find evidence of simple non-linear probability weighting but no evidence of rank-dependent probability weighting or disappointment aversion to low prizes.

It is important to emphasize that none of contestants actually violated expected utility theory or any of the generalized non-expected utility theories that incorporate the former as a special case. However, contestants managed to avoid *ex post* regret, which is difficult to reconcile with any other decision theory but regret theory, and revealed significantly higher risk aversion when facing stochastically dominating lotteries, which is predicted by decision theories that incorporate the fanning-out hypothesis. Obviously, these results have important implications for future theoretical work.

In contrast to numerous laboratory experiments that document rank-dependent probability weighting, our natural experiment provides no support for this phenomenon. This somewhat surprising lack of evidence suggests that more empirical work has to be done outside the laboratory. Interestingly, the results of our natural experiment are nearly identical for *Affari Tuoi* and *Deal or No Deal UK* contestants, which suggests that certain aspects of individual decision making under risk can be generalized across different cultural, social and economic environments. However, for one decision theory—Yaari's dual model—we find that the behavior of *Affari Tuoi* contestants is inconsistent with the theoretical prediction but the decisions of *Deal or No Deal UK* contestants confirm the prediction of the model.

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Appendix

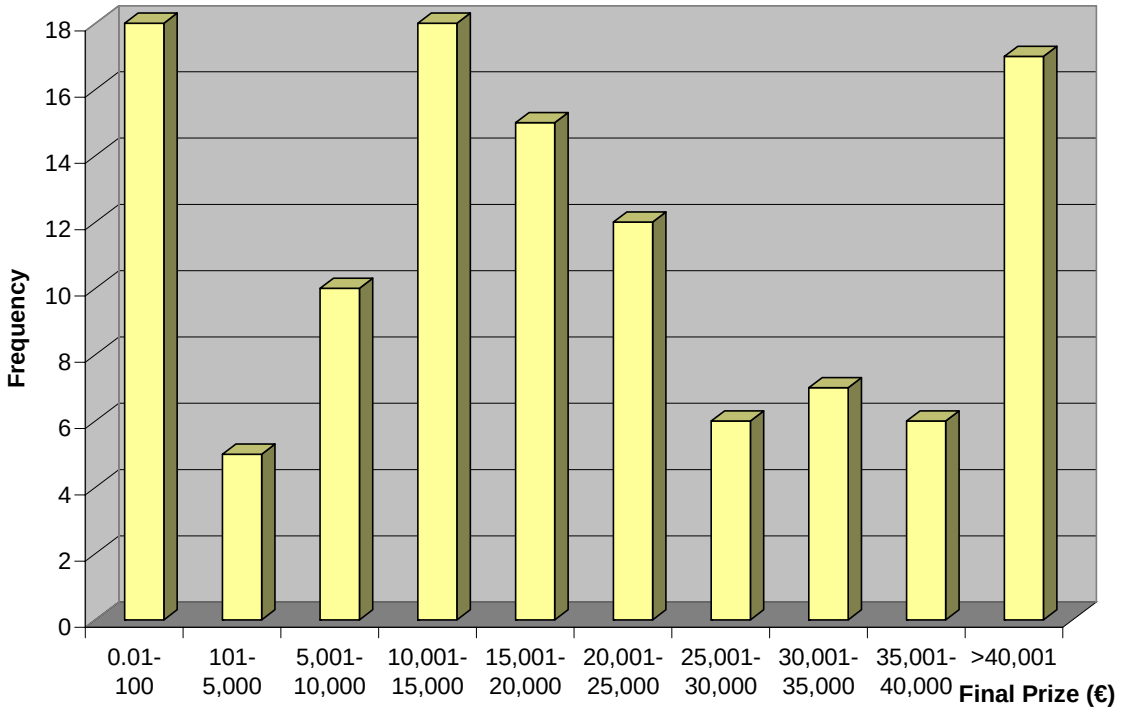

Figure 4 Distribution of final earnings in *Affari Tuoi* (114 episodes)

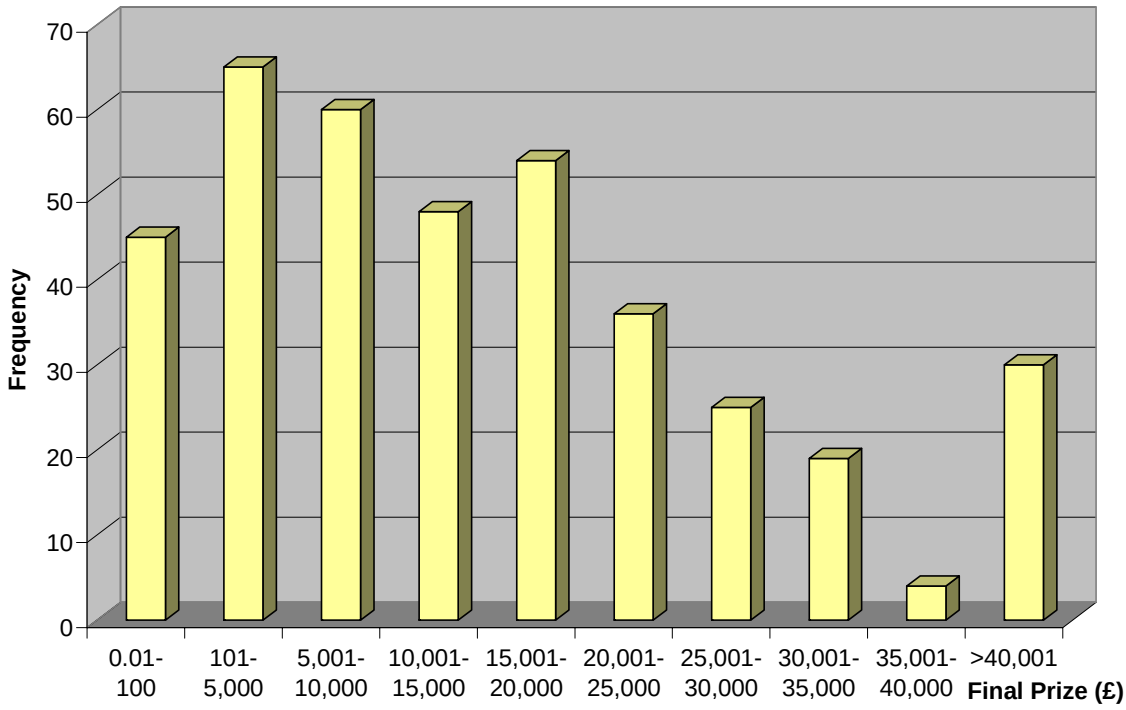

Figure 5 Distribution of final earnings in *Deal or No Deal UK* (386 episodes)

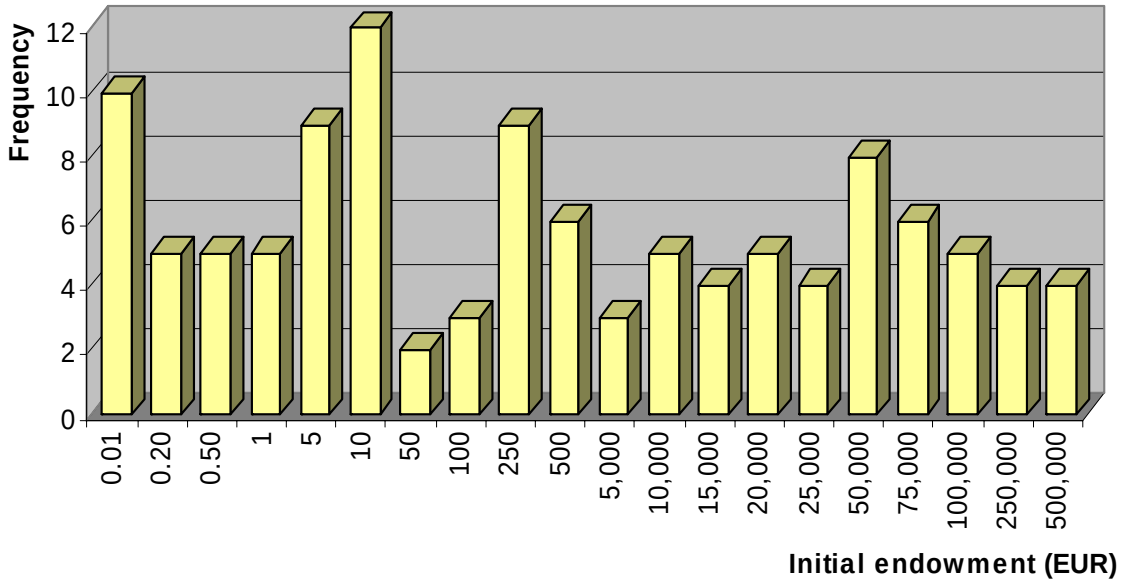

Figure 6 Distribution of initial endowments across 114 episodes in *Affari Tuoi*

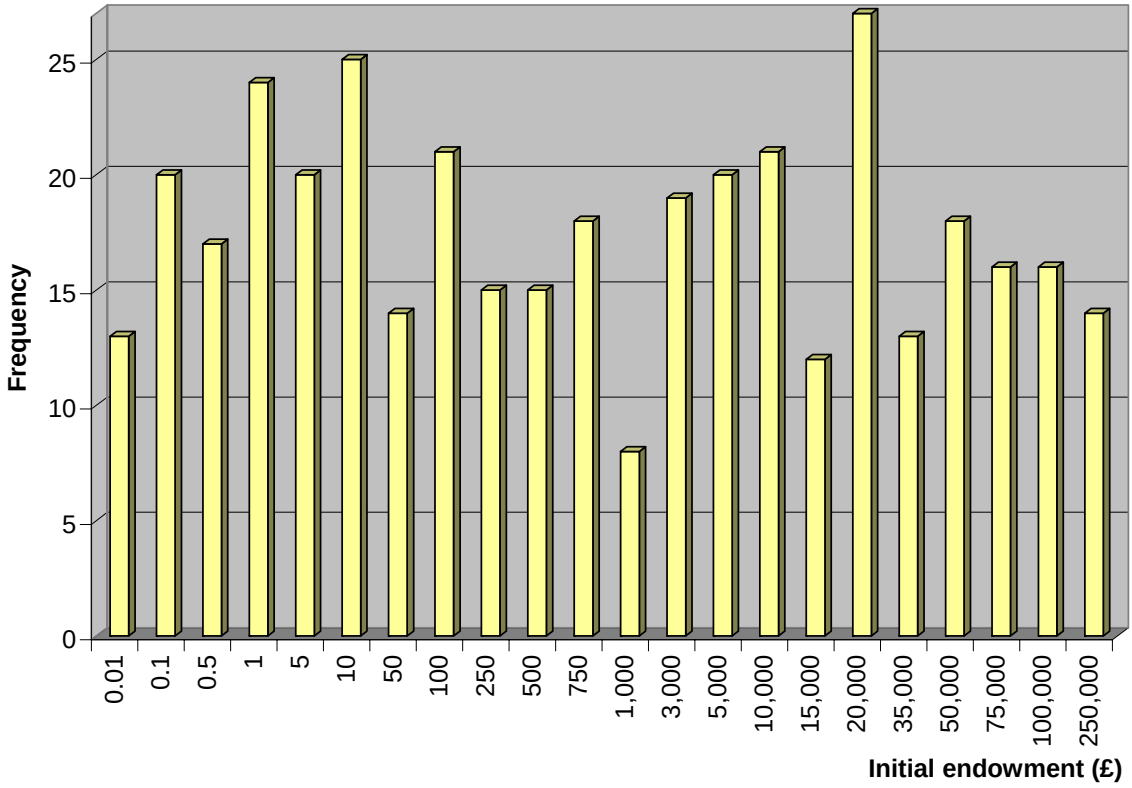

Figure 7 Distribution of initial endowments across 386 episodes in *Deal or No Deal UK*