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May 2011

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Escalation Bargaining:
Theoretical Analysis and Experimental Test

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11 May 2011

Abstract

The standard chicken game is a popular model of certain important real scenarios but does not allow for the escalation behaviour these are typically associated with. This is problematic if the critical, final decisions in these scenarios are sensitive to previous escalation. We introduce and analyse, theoretically and by experiment, a new game which permits escalation behaviour. Compared with an equivalent chicken game, Pareto-suboptimal outcomes are significantly more frequent. This result is inconsistent with our rational choice analysis and possible psychological roots are explored.

Key words: escalation; brinkmanship; chicken game; experiments
JEL classification: C72, C78, C91

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1 Introduction

Suppose you observe two players gambling over a pot of eight chips in a casino. They can either fold or raise using the one chip each of them holds. If both players raise, the pot goes to the house. If one raises and the other does not, the former gains the pot while the latter keeps one chip. If neither raises, the pot is split equally. Players decide simultaneously, i.e. under imperfect information. What would you predict to be the outcome? What would you advise players to do?

Now suppose you are told the situation is actually the final stage in a game which began with each player holding four chips with two in the pot. In each stage, players decide simultaneously whether to raise by placing one chip in the pot or to fold. The game ends as soon as a player folds (the pot goes to the raising player or is shared equally if both fold) or otherwise when the players have no chips left to bet (the house wins the pot). Would knowledge of the existence of three preceding stages change your analysis, and if so, how?

The interactions in both scenarios belong to a important type [1] where participants make claims in dividing a joint benefit which is lost if they cannot agree. What makes such situations interesting is that in pursuing their individually maximal payoffs, participants jockey for position and risk the individually and collectively most harmful outcome. Consequently, there is an important role for prediction and advice in situations of this kind (e.g. Hargreaves-Heap and Varoufakis 2002). Towards this end, the standard (i.e. one-shot 2×2) chicken game has been used in both theoretical and experimental analysis. However, in their real settings, these situations vary in complexity and most are likely to be more complex than our first scenario, which mirrors the standard chicken game. As a result, it has been argued that while its simple structure elegantly captures the essence of these situations and renders them amenable to rigorous examination, it by the same token fails to adequately allow for some of their material aspects (Kahn 1965, pp 10-15, Snyder 1971, p. 87, Brams 1993, p. 106, O'Neil 1994, p. 997, Field 2008, p. 6).

One such aspect in which we are interested here consists of brinkmanship and escalation, important characteristics of many of the real phenomena the chicken game is used to model. *Brinkmanship* entails players incrementally and irreversibly raising the risk they take in order to get others to accede, in turn generating increasing *escalation* of the situation (Kahn, 1965; Schelling, 1966; Pruitt and Kim, 2003). In this sense, the chicken game captures only the final stage of an escalating interaction that unfolds progressively over suc-

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[1] Applications include market entry under natural monopoly conditions (Ghemawat, 1997, chapter 7), industrial or international trade disputes (Carpenter and Rudisill, 2003), superpower conflicts (O'Neil, 1994; Zagare, 1996) as well as animal contests over food sources (Maynard Smith, 1982).

cessive stages. In such interactions, players initially do not choose between backing down or risking immediate disaster as in the standard chicken game. Rather, they initially choose between backing down and further escalating, with the possibility of the disaster only arising finally after some periods of mutual brinkmanship behaviour. The second scenario described above incorporates the possibility of such previous escalation into the first: because the collectively harmful outcome results from players' decisions in the final stage of such scenarios, and to the extent that it arose through prior gradual escalation among players, modelling needs to account for the escalation process. In short, if prediction and advice differ between the two scenarios described above, the standard chicken game is not an appropriate model to shed light on real scenarios and an alternative 'escalation game' is needed.

We approach this question by comparing players' *critical* choices, i.e. the final ones capable of bringing about disaster, in both scenarios described above. To the extent that the two available actions in the final stage are associated with the *same* consequences irrespective of previous escalation, no difference in behaviour should be observed, supporting the use of the standard chicken game. However, there are good reasons to suspect previous escalation may lead to greater likelihood of disaster. First, one might suspect that the final stage of escalation and the one-shot chicken game do represent substantively different situations even if actions and payoffs are the same: as early stages provide opportunities for backing down, it may be the case that players in later stages of escalation situations are typically less risk averse than those in the one-shot game. However, it is not clear what effect this would have on player behaviour. While all players' lesser risk averseness suggests more risky play, common knowledge of it might conversely suggest greater caution and cancel out any effect of a changing risk profile among typical players. Second, irrespective of the level of their risk averseness, players may be subject to habituation to the increasing level of risk or other potential psychological effects of escalation such as sunk cost fallacies, overconfidence or spite.

It is this latter possibility that forms our central interest in this paper. Our intuition is that previous escalation can indeed influence decisions towards the greater possibility of disaster through psychological processes. In particular, we hypothesise this effect between the critical stage of escalation situations compared with the one-shot game with otherwise identical game parameters, even if relevant player characteristics such as risk attitudes are controlled for. Such a finding would have practical significance as well as implications for the use of the one-shot chicken game in generating better understanding of these important situations. We examine this issue theoretically and by experiment. In the following, we introduce a new game designed to capture the possibility of escalation through minimal modifications to the standard chicken game. We present theoretical analysis before reporting our experiment designed to compare critical behaviour in it with the standard chicken game. The rest of

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the paper is structured as follows. Section 2 contains the theoretical analysis. We first appraise the chicken game as a model of escalation before presenting and analysing the escalation game we propose as an alternative. The experiment we conducted is reported in section 3. Section 4 concludes this paper with a discussion of our results and their implications.

2 Theoretical analysis

We begin by assessing the effect of previous escalation on critical decisions theoretically. For this purpose, we examine the standard chicken game and its drawbacks as a model before outlining the escalation game we propose as an alternative. We then ascertain any theoretical differences between critical decisions in both games allowing for differing risk attitudes in players. These findings can then be used as a benchmark for our experimental exploration of the hypothesised psychological effects that our theoretical model based on rational decisions cannot capture.

2.1 The standard chicken game

In the standard form commonly used in game theory, the chicken game is a symmetric 2×2 game with the action set {A,B} and symbolic payoffs shown in figure 1, which obey the condition $T > R > S > P$. Without loss of generality[2], we additionally consider versions with a fixed benefit of 100 to be divided, i.e. where $2R = T + S$, with $R = 50$ and $P = 0$. Each player's best action is the opposite of the co-player's. In particular, the game has multiple Nash Equilibria in the two inequitable divisions [A,B] and [B,A] as well as in mixed strategies where each player adopts action A with probability $p^*(A) = (P - S)/(R - S - T + P)$, which, under our conditions, is $S/50$. All outcomes are Pareto-efficient bar [B,B]. In the mixed strategy equilibrium, players' expected values of playing either action or any probability mix between them are equal, and, in our case, yield the expected value of playing the game as $T(p^*)$ given by $TS/50 = 2S - S^2/50$. Since $0 < S < 50$, this increases in S and decreases in T. To wit, the smaller is the disparity between players in unequal divisions, the greater the value of the game to them as action A associated with equitable division becomes relatively more attractive. Players in such games have more reason to choose action A the smaller T/S, the less likely the co-player is deemed to choose A and the more risk averse he or she is. The latter is due to the greater variance in the payoffs associated with B compared with A (e.g. de Heus et al. 2010). The specific payoffs for the game we used in the experiment are also shown in figure 1 and yield the mixed Nash Equilibrium where players adopt action A with probability $p^*(A) = 0.4$, giving

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[2] Rapoport and Chammah (1966) define the chicken game as having payoffs that additionally satisfy $2R > T + S$ to avoid the possibility of cooperative play by alternating between the asymmetric outcomes in repeated one-shot games, which we do not consider here.
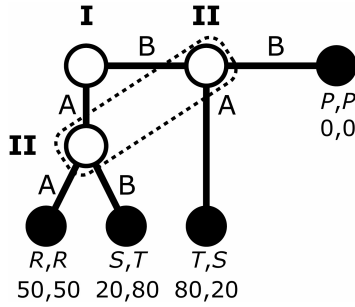
Fig. 1. The standard chicken game in extensive form. Players I and II decide between an acquiescing (A) and a bold (B) action for the symbolic payoffs shown. The actual payoffs used in the experiment are also given.

an equilibrium expected value of the game of 32.

The chicken game, as game theory generally, provides a powerful way to explore strategic behaviour using a simplified model designed to capture the essence of real situations while making these amenable to rigorous examination. However, the cost of simplicity arises to the extent that crucial aspects of real phenomena are not accounted for. In their use to explore real phenomena, models are useful partly to the extent that they capture those factors thought to be responsible for the observed effects. This kind of case has been made repeatedly against the standard chicken game as a model for the study of escalation behaviour. It can be illustrated by comparing chicken to the well-known dare involving two cars on a collision course on a highway it is based on and to which it owes its name, which can be thought of

> as a *stage game with discrete time intervals* as the vehicles approach each other. During each interval players can swerve, threaten to discard the steering wheel, actually throw it out, or *irrevocably commit* to a device which [...] will lock the wheel (Field (2008), p. 5, italics added).

Highway chicken is often thought to capture the essence of escalation behaviour in real contexts such as superpower relations "because of the scope it offers for exploring the attraction and perils of competitive risk taking, of brinksmanship, of committing to a course of action that leaves some part of the outcome to chance" (Field (2008), p. 6). However, the abstraction of the situation into the one-shot chicken game does not allow for this kind of strategising associated with real scenarios. Poundstone (1993) argues that the standard chicken represents

> the *last possible moment* of a game of highway chicken. Each driver has calculated his reaction time and his car's turning radius [and] there comes a moment of truth in which each must decide whether or not to swerve. This decision is *irrevocable* and must be made in ignorance of the other driver's decision. There is no time for one driver's last-minute decision to influence
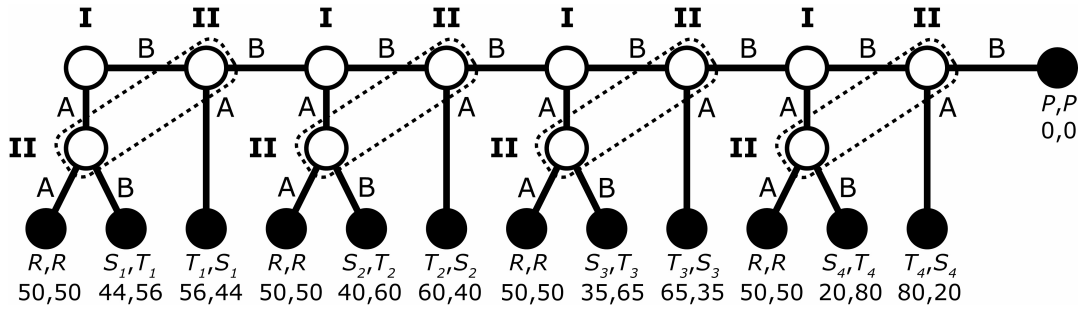
Fig. 2. An escalation game with four stages. Players are denoted by Roman numerals.

the other driver's decision (Poundstone (1993), p. 197, italics added).

A similar argument is made by Dixit and Skeath (1999, p. 457). The standard chicken game therefore does not allow for brinkmanship behaviour, i.e. (a) a *series* of mutual decisions whether to (b) incrementally and *irreversibly* raise the level of risk in order to get the other player to accede (Kahn 1965, p.3; Staw 1981, p. 578; Pruitt and Kim 2003, p. 89). This is problematic to the extent that the possibility of previous escalation moderates player behaviour in the critical stage of the game in which researchers are interested.

2.2 The escalation game

In order to assess the effect of previous escalation on critical behaviour, we now introduce the *escalation game* which makes those minimal adjustments to the standard chicken game necessary to allow for brinkmanship behaviour. It is designed to permit us to compare behaviour in the critical stage of chicken-type situations with and without previous escalation. The escalation game preserves a number of the desirable features of the standard chicken game, such as its basic structure of players, payoffs and imperfect information in every stage. However, it is based more closely on highway chicken and involves the two following modifications: first, the disastrous outcome becomes possible only after the basic choice between the two actions is repeated some number of stages. Secondly, each subsequent stage is accompanied by increasing levels of risk in the payoff function inherent in the variance of potential payoffs. The intuition behind our design is the following: players' irreversible commitment of resources in escalation processes *incrementally* generates the increasingly risky and polarised payoffs between the player who backs down and the one who does not.

For the purposes of this paper, we consider a four-stage escalation game as depicted in figure 2. In every stage, players face simultaneous decisions between A and B, and mutual decisions of A end the game in an even split. If in any stage one player chooses A while the other chooses B, the game ends in an increasingly favourable division for the latter player. If no player chooses A at any point, the game ends in the final stage with zero payoffs for both players.

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		Player II			
	A1	A2	A3	A4	ALL-B
A1	50,50	44,56	44,56	44,56	**44,56**
A2	56,44	50,50	40,60	40,60	40,60
A3	56,44	60,40	50,50	35,65	35,65
A4	56,44	60,40	65,35	50,50	20,80
ALL-B	**56,44**	60,40	65,35	80,20	0,0

(Player I labels the rows; Player II labels the columns.)

Fig. 3. An escalation game in strategic form. The payoffs are those used in our experiment. Pure Nash Equilibria indicated by boldface payoffs.

In general, the escalation game involves simultaneous decisions over stages i where the payoffs obey $T_i > R > S_i > P$. Additionally, $T_i < T_{i+1}$ and $S_i > S_{i+1}$. Also, as before, in our analysis we assume $2R = T_i + S_i$ as well as $R = 50$ and $P = 0$. The game has five possible pure strategies (see figure 3). The first four strategies (A1 to A4) respectively correspond to the number of the stage in which a player chooses A. The fifth, ALL-B, involves never choosing A. In the resulting two pure Nash Equilibria, one player plays A in stage one, while the other plays B throughout.

Within these conditions, we consider, for the purposes of further analysis and experiment, the escalation game with the specific numerical payoffs in figure 2. To provide the opportunity to examine the impact of differing risk attitudes and previous escalation on critical decisions, its fourth and final stage is, in terms of actions and payoffs, identical to the one-shot game in figure 1 with the same mixed Nash equilibrium $p^*(A)_{i=4}=0.4$. When we substitute the resulting equilibrium expected value of 32 for that stage as the payoff for the subgame following mutual B-decisions in stage three of the escalation game, calculate the resulting mixed Nash Equilibrium for that stage and repeat this process until the first stage, we obtain the proportions of players adopting each of the five pure strategies as the overall mixed Nash Equilibrium for our escalation game with risk-neutral players (see the top panel in table 1 where $r=0$).

2.3 Risk preferences in the chicken and escalation games

As discussed, players' appetite for risk may influence decisions in both the chicken and the escalation game. We now examine the effects of different parametric assumptions about risk attitudes in a population of players on equilibrium behaviour. In particular, we assess the notion that a typical player in the last stage of the escalation game may be less risk averse, i.e. values high payoffs relatively more than in the chicken scenario. While in both games action A is associated with a lower variance in available payoffs than B, this is increasingly the case over the successive stages of the escalation game. As a result, decisions may be sensitive to risk attitudes in the population (Engelmann and Steiner, 2007; de Heus et al., 2010). We therefore expect more risk averse players to exit earlier, typically leaving more risk seeking ones in its

critical stage compared with the chicken game, where no player can exit the game before this point.

To work out equilibria for players with varying degrees of risk averseness for both games, we assume agents have utility functions U as the payoff x received from a particular game adjusted for individual risk preferences as r obeying constant relative risk aversion. They are given by the functional form [3] $U(x) = x^{1-r}$. We use this formula to transform the payoffs of both games for different values of r and repeated the analyses above. [4] The mixed strategy equilibria we obtained for both games assuming players' (homogeneous) risk preferences of different levels r are shown in the top panel of table 1.

In real populations, risk attitudes are unlikely to be homogeneous. As a result, we also determined mixed Nash Equilibria for heterogeneous risk preferences of different levels. In particular, we performed a computer simulation of changes in the representation of the games' different possible pure strategies among a population of learning and interacting agents. [5] The proportions of the pure strategies within the population adjust according to their success and, when convergence is reached, can be interpreted as the equilibrium mixed strategy (Aumann, 1987, p. 41).

We consider populations with normally-distributed heterogeneous values for r using the utility transformation above. While the transformation of payoffs into utilities using different values for r is intuitively realistic, it means we cannot use utilities to compare the success of agents with unequal r-values in order to implement learning. As a result, for simulations with heterogeneous risk preferences between agents, we segment the population into nine sub-populations each with different respective values of r shared by all their members. The sizes of sub-populations were chosen to generate a discretised normal distribution of risk in the overall population with a standard deviation of 0.1 and remain constant throughout a simulation. In each sub-population, the five possible pure strategies are equally represented initially. Agents are matched for game play across the whole population, but their strategies' suc-

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[3] Our approach follows Holt and Laury (2002, p. 1646). In order to preserve positive marginal utility of wealth, for $r > 1$, we use their formula $U(x) = x^{1-r}/(1-r)$. For $r = 1$, $U(x) = ln(x)$ is used.

[4] For the specific payoffs and risk preferences (i.e. $-1 \leq r \leq 1$) we use, these transformations never violate the conditions of either game.

[5] The application of standard analytical techniques would require solving an exponentially increasing number of simultaneous equations which cannot feasibly be done through matrix inversion. The computer simulation technique provides an alternative approach when mathematical analysis is impractical or impossible due to model or dynamic complexity. It also permits the observation of the model's behaviour under alternative initial parametric assumptions (Simon, 1981, e.g.). The Python programming code we used is available on request.

cess is evaluated within their respective sub-populations of agents who share the same risk attitudes.

A typical simulation proceeded as follows. First, a population is generated either homogeneously (i.e. with a single sub-population) or consisting of nine sub-populations with their respective sizes and values of r chosen. The program then determines the total utility received by each pure strategy in each sub-population as the payoffs it would receive in a round-robin tournament among the entire population, transformed for each game according to the utility function above. This calculation is based on the game's payoffs in figure 3 as well as the representation of all pure strategies in the population and agents' risk attitudes. Strategies are then propagated using a standard replicator dynamic (e.g. Hofbauer and Sigmund 2003). After each generation of the simulation, the proportion of each pure strategy within each sub-population in the next generation is determined by its relative success compared with other strategies in that sub-population. This is repeated until the proportions in every sub-population have stabilised. This basic process was repeated for different mean values of r for heterogeneous normally-distributed populations.

The lower panel in table 1 reports simulation results as the final representations of the five pure strategies in the population as a whole upon convergence, which we interpret as the mixed strategy equilibrium.[6] Critical chicken and escalation game decisions in mixed strategy equilibrium are reported as respective values for B*, the proportion of players choosing B in the critical stage in equilibrium for each of the games. This rises for both games with falling r irrespective of its distribution, i.e. with populations that are more risk seeking on average. Following intuition, more risk seeking agents value higher game payoffs more and therefore are more likely to opt for B in the critical stage of both games. While we might expect the falling average risk averseness of co-players from stage to stage might instil caution, as commented earlier, all players' greater valuation of larger payoffs more than countervails such an effect.

The last column in the table shows δB*, the difference in critical decisions between the two games for different values and distributions of risk preferences we are interested in. There are no differences between critical chicken and escalation game behaviour for populations with homogenous risk preferences of any level. Conversely, modest differences do arise with normally-distributed heterogeneous risk preferences. They are greatest for the interval r $-0.5 \leq r \leq 0$. For populations with the average risk attitudes ($-0.15 \leq r \leq 1$)

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[6] We checked the program by comparing the mixed Nash equilibria it generates for the homogeneous populations with different values for r with the analytically-derived results which matched perfectly. In addition, in a series of robustness tests, our results were not found to be sensitive to initial conditions such as population size and composition.

r	Chicken		Escalation game						δB^*
Ave.	A	B*	A1	A2	A3	A4	All-B	B*	
Homogeneous risk preferences									
-1.00	0.093	0.907	0.327	0.020	0.175	0.044	0.434	0.907	0.000
-0.50	0.198	0.802	0.343	0.030	0.173	0.090	0.364	0.802	0.000
0.00	0.400	0.600	0.250	0.150	0.100	0.200	0.300	0.600	0.000
0.50	0.705	0.295	0.410	0.018	0.000	0.403	0.169	0.295	0.000
1.00	0.973	0.027	0.000	0.000	0.000	0.973	0.027	0.027	0.000
Normally-distributed risk preferences									
-1.00	0.126	0.874	0.329	0.024	0.173	0.044	0.430	0.907	0.033
-0.50	0.229	0.771	0.366	0.012	0.186	0.075	0.361	0.828	0.057
0.00	0.400	0.600	0.313	0.092	0.137	0.160	0.298	0.651	0.051
0.50	0.639	0.361	0.265	0.162	0.000	0.366	0.207	0.361	0.000
1.00	0.891	0.109	0.000	0.000	0.000	0.891	0.109	0.109	0.000

Table 1

Theoretical results of mixed strategy equilibria as the proportion of agents adopting the available pure strategies in the chicken (obtained by analysis) and the escalation game (by simulation) under different averages and distributions of risk attitudes in the population. B* represents critical B-decisions. The final column shows the difference in this between the two games.

representing about 90% of subjects in the experiments by Holt and Laury (2002), we would expect an increase in B-decisions between the critical stages of the two games in the region of 5% caused by risk preferences alone. It arises as differences in risk attitudes among players cause more risk averse ones to exit the game earlier. The psychological factors we hypothesise may add to this modest effect and will be examined next.

3   Experiment

While our theoretical analysis demonstrates the role of differing risk preferences in contributing to critical B-decisions, it is not suited for the examination of what we loosely term 'psychological' influences to which we now turn using an experimental approach. We begin by considering what motivations, other than their own risk preferences, final-stage escalation game players may have that do not apply to chicken, despite the same available actions and payoffs in both. We use this discussion to formulate hypotheses for experimental examination. We then report our experiment and its results which we compare with the benchmark established theoretically.

In both of our games, we can think of players choosing between actions based on their respective expected utility, i.e. are motivated by the available payoffs as well as their beliefs concerning the likely behaviour of the co-player. Both motivations may be sensitive to a number of well-known psychological effects triggered by previous escalation that make risky behaviour more likely. We consider three plausible such factors.

To begin with, escalation game players may continue to choose B in the last stage as an 'escalating commitment to a course of action'. There are several possible reasons for this type of effect established in a management literature relating to investment decisions (Staw, 1976). First, they include self-justification and norms for consistency (Staw, 1981). On this account, a final B-decision has an added attraction in retrospectively lending apparent rationality to all previous ones. Another way to look at the same issue is in terms of overconfidence or misperception (e.g. Camerer and Weber 1999, p. 78; Bazerman 2005, p. 88). Players might systematically underestimate the likelihood of co-players choosing B also to resolve cognitive dissonance between a desire to be consistent in continuing with action B and a realistic assessment of the likelihood of the co-player choosing similarly. This type of considerations is also related to the sunk cost fallacy Camerer and Weber 1999, p. 75). Escalation game players may interpret the increasing, irreversible level of risk they accept in subsequent stages of the game as an irrecoverable investment which they may wish to continue pursuing. Second, an ongoing escalation situation may be accompanied by changes in the protagonists' motivations from initially pure self-regard to fairness concerns and finally spite (Glasl, 1982; Fisher and Keashly, 1989; Camerer and Weber, 1999). Increasing ill will towards each other develops as neither compromises. Action B provides more scope for avoiding a 'loss' against or harming the co-player. The third factor, which forms our central interest in this paper, has to our knowledge not been examined in relation to escalation bargaining situations: players may be subject to a phenomenon metaphorically called the *boiling frog.*[7] Here, decision makers continuously adjust rather than react to small, incremental changes in their environment that together amount to conditions that would have provoked a reaction had they materialised in one step. While the phenomenon was originally studied in reflexes, it has been demonstrated experimentally to affect risk perception of animals (Rodriguez-Prieto et al., 2009) and human cognitive valuations (Fetherstonehaugh et al., 1997). It has been put forward as an

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[7] In the (apparently inaccurate) metaphor, a frog fails to flee when the temperature of the water is raised sufficiently slowly. We use this term to describe a family of phenomena known under different terms which has habituation, an organism's decreasing response to a repeated stimulus, as a possible root. The salami tactic can be deployed to exploit this tendency in others.

explanation for the lack of public response to environmental or political risks through 'creeping normalcy' (Diamond, 1995; Krugman, 2009, e.g.). Applied to the escalation game, players who repeatedly choose B over its course may become gradually accustomed to the greater level of risk involved in successive stages. A de-sensitivisation to greater risk may most naturally be interpreted as a decreasing value for the parameter r in players as the game unfolds and a concomitant greater tendency to play B. Taken together, our theoretical analysis including the influence of risk and discussion of the possible psychological factors generate the following nested hypotheses for experimental testing:

Hypothesis 1: There will be relatively more B-decisions in the critical stage of the escalation game compared with chicken.

Hypothesis 1a: Heterogeneous risk attitudes cause relatively more B-decisions in the critical stage of the escalation game compared with chicken.

Hypothesis 1b: Psychological factors cause relatively more B-decisions in the critical stage of the escalation game compared with chicken.

As both sub-hypotheses contribute positively towards an overall effect of hypothesis 1, we need a way to separate their respective influences. The psychological factors of hypothesis 1b operate differently to players' risk attitudes in hypothesis 1a we examined theoretically. They are likely to be the result of particular cognitions that accompany successive stages of play in the escalation game as it unfolds. Risk considerations, in contrast, can more plausibly influence decisions even *a priori*, i.e. be undertaken before it starts. If so, we may use different methods of experimental decision elicitation to isolate the impact of risk attitudes and psychological factors respectively. In particular, we perform an experiment with both games using the 'hot' direct response method as well as the 'cold' strategy method. In the former, decisions are made and recorded in real time as subjects interact. In the latter, subjects are asked to supply full descriptions of their strategies, i.e. decisions for any possible game history, which are subsequently used in determining their choices when matched with other subjects (Selten, 1967). Theoretically, both methods should yield the same results for rational players. However, the point has been made that differences may arise to the extent that, in hot situations, subjects may think about decisions differently (Roth 1995, p. 323) and respond more emotionally (Brandts and Charness 2000, p. 228). In particular, some psychological processes like self-justification are retrospective (Staw, 1981, p. 583), making the strategy method unsuitable for their measurement. As a result, we use the hot condition to elicit the psychological effects we hypothesise.

Our experiment was designed to test whether subjects' critical decisions in the standard chicken game [8] and escalation game differ and to what extent any difference can be explained with reference to risk attitudes or psychological factors. The game task was conducted using a 2×2 experimental design (see table 2). The first dimension concerns the possibility of escalation. In the *chicken* condition, subjects faced the standard chicken game with payoffs as shown in figure 1. Under *escalation*, subjects played the escalation game depicted in figure 2. For the experimental task, our payoff choices within the conditions of the two games were guided by considerations of generating sufficient observations. We chose payoffs for the experimental escalation game so that enough subjects proceeded to the final stage to allow reliable observation of critical behaviour. In addition, we ensured that every individual stage i constituted a chicken game in its own right in that the equilibrium expected value of the subgame following mutual B-decisions remained strictly less than S_i. The second dimension of the game task involves the elicitation method of subject decisions for both games. In the cold version, decisions were recorded using the strategy method. Cold escalation subjects were asked to specify decisions for every stage of the task before being matched but told that if an A-decision was recorded, all decisions made for later stages would be void. For cold chicken, decisions were recorded for the one stage only. The hot condition describes the use of the direct response method. Subjects knew they were matched with another subject prior to making decisions, and that all decisions would be recorded simultaneously during a set period of one minute per decision shown on the screen. For hot chicken, subjects made one decision, whereas in the hot escalation game, decisions were made for up to four stages or until an A-decision was recorded. In addition to the game task, we measured subjects' risk attitudes as possible moderators of behaviour. In particular, we administered the risk preference elicitation task introduced by Holt and Laury (2002) following their binary choice lottery procedure with the exception that payoffs were multiplied by a factor of twenty. In the task, subjects face ten binary choices between safe and increasingly risky gambles. The task was designed as a measurement of individuals' risk preferences as the number of safe gambles chosen out of the ten, from which corresponding values for r can be imputed.

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[8] To date, the chicken game has received relatively modest attention by experimentalists (Camerer and Thaler 2003, p. 164; de Heus et al. 2010, p. 737). Variables shown to affect behaviour include variations in the payoffs (Rapoport and Chammah, 1966; Ells and Sermat, 1968), communication (Swingle and Santi, 1972), beliefs about other players based on their characteristics such as labels (Hargreaves-Heap and Varoufakis, 2002), status and gender (Grant and Sermat, 1969; Conrath, 1972), as well as subjects' own characteristics including mood (Hertel et al., 2000) and values (Liebrand et al., 1986).

The experiment took place at a private, English-spoken university in the People's Republic of China in May 2010. A total of 286 volunteers were recruited via e-mail invitation from the undergraduate student population and participated in ten sessions conducted in a campus computer laboratory. Subjects were mostly Chinese nationals with a mean age of 20 of whom about three quarters were female. Each session was devoted to one of the four task conditions and subjects were allocated in such a way as to generate sufficient sample size for each (see table 2). In particular, to afford a statistically meaningful comparison between decisions in the last stage of the chicken and escalation games, more subjects were allocated towards sessions with the latter to compensate for early-stage exits due to A-decisions. Sessions began with an announcement in Chinese explaining experimental discipline, subject anonymity and privacy as well as monetary incentives and their delivery. The experimental tasks were conducted subsequently using a computerised interface with complete English instructions programmed using z-Tree (Fischbacher, 2007). Subjects additionally received paper copies of the instructions in both Chinese and English.[9] The program included a comprehension quiz for each task. Subjects with incorrect answers were individually instructed until correct answers were elicited before proceeding. Subjects were randomly matched for game play at the session level and co-players remained anonymous to each other throughout. The risk elicitation task followed the game task in every session. After their completion, subjects filled in a pen-and-paper questionnaire in Chinese containing demographic questions. At the end of each session, which typically lasted about one hour, subjects received a show-up fee of 10 Chinese Renminbi (RMB) as well as the pay-out for one of the tasks chosen at random in cash, on average about 38 RMB.[10]

3.4   Results

The experiment generated a dataset with observations for subjects' demographics as well as decisions for the game and binary choice lottery tasks.[11] We now report the effect of the experimental variables on critical decisions in the two games.

The experimental results for the game tasks are summarised in table 2. In the chicken game, about a third of subjects opted for B. There was no effect of using the hot or cold elicitation method on chicken behaviour, confirming

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[9] Copies of our instructions and the program are available upon request.

[10] At the time of the experiment, 1 RMB traded at 0.146 U.S. $. In the area of China where the experiment was performed, students typically earn around RMB 8 an hour for casual work.

[11] In one session, a computer crash caused loss of some data for the binary choice lottery task for 18 subjects.

	Escalation game			
Stage	Hot	n	Cold	n
1	0.680 (83)	122	0.750 (75)	100
2	0.793 (46)	58	0.813 (61)	75
3	0.868 (33)	38	0.689 (42)	61
4	0.786 (22)	28	0.548 (23)	42
	Chicken game			
1	0.367 (11)	30	0.382 (13)	34

Table 2

Proportion (and number) of B-decisions across experimental conditions and game stages. Note that in the hot condition of the escalation game, some subjects who choose B fail to proceed to the next stage due to their co-player's decision for A which ends the game.

the same result in Brandts and Charness (2000). Compared with chicken, we observe a much larger proportion of B-decisions in the critical stage of the escalation game. In cold escalation, more than half of subjects in the last stage chose B, and more than three quarters did so in hot escalation. The difference between critical escalation and chicken game behaviour is marginally insignificant for the cold (one-tail Fisher exact $p = 0.114$), and significant ($p < 0.001$) for the hot condition. Both tests yield significant differences if we pool all chicken game observations due to non-difference within them by elicitation method ($p = 0.061$ for cold and 0.000 for hot escalation). We interpret these main findings as support for hypothesis 1, that previous escalation overall generates more critical B-decisions. In addition, the marginal (in)significance obtained for cold escalation is suggestive of the relatively greater role of psychological factors compared with risk preferences in contributing to this overall effect. This is further supported by a significant difference ($p = 0.036$) in critical B-decisions between cold and hot escalation. While risk attitudes caused a small increase in B-decisions after escalation, an additional jump can be detected using the hot method designed to elicit psychological factors as discussed.

We now examine to what extent risk preferences contributed towards the effects we observe, and, in particular, whether risk played the role in subject behaviour suggested by the theoretical analysis. The distribution of risk preferences in our entire subject group based on the lottery task compared with subjects in Holt and Laury (2002) is presented in figure 4. They are measured as each subject's number of choices (between 1 and 10) of safe alternatives in the task. There were no differences in these choices between our four experimental conditions (Kruskal-Wallis $p=0.91$). Our subjects' choices roughly follow a normal distribution and seem somewhat more risk seeking on average
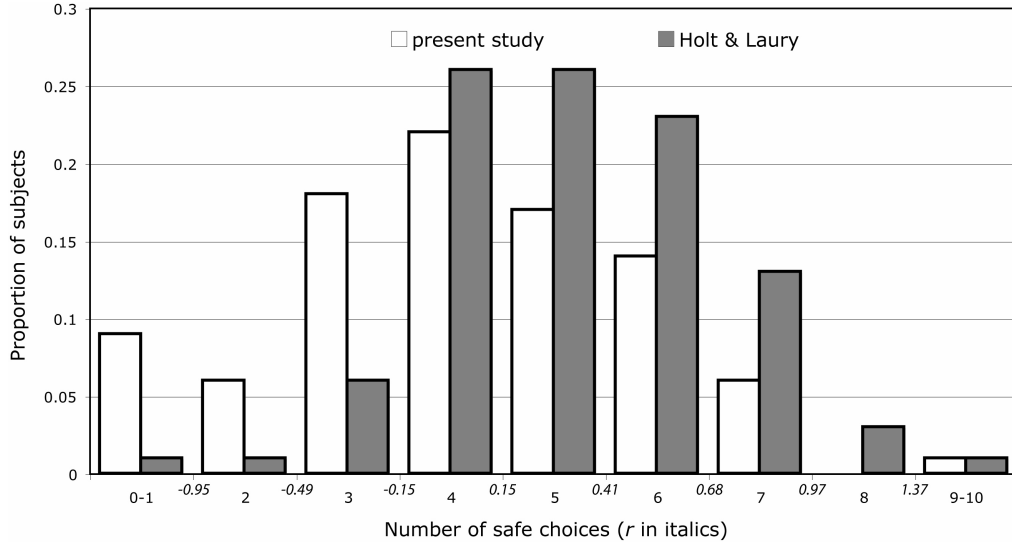
Fig. 4. The distribution of risk attitudes as the number of safe choices (and associated r values) in our subject group as well as in Holt and Laury's (2002) low real payoff condition.

than Holt and Laury's, with a noticeable tail of high-risk preference subjects. The average number of safe choices was 3.88, with a corresponding r of between 0.15 and -0.49. Theoretically, given this value, we would have expected more B-behaviour in the chicken game (see table 1) than we observed, possibly suggesting the limitations of the Holt and Laury (2002) technique to capture strategic, rather than parametric risk (see section 4). There was no difference in the number of safe choices between subjects who chose A and B respectively in the hot, cold and pooled chicken game data (Mann-Whitney $p > 0.45$ for all three tests). This latter result runs counter to de Heus et al.'s (2010) finding that in the chicken game, lesser risk aversion as measured by a 12-item questionnaire was associated with more B-decisions.

Given these risk preferences we expect, from the theoretical results, to observe slightly more critical B-decisions in the escalation than in the chicken game by virtue of risk preferences (hypothesis 1a): as discussed, subjects with greater risk aversion exit earlier. To find evidence for this in our experimental data, we tested for changes in risk attitudes among subjects over the stages of the escalation game. We regressed subjects' risk preference measures on game decisions using the ordered logistic regression technique. In the model we estimated, the dependent variable was the number of safe options subjects chose out of the ten binary gambles in the lottery task (following Holt and Laury 2002, p. 1648). For the single independent variable coded 1-5, the pure strategy specified out of the five possibilities was used for a regression using cold treatment data. For the hot condition, we used the number of the stage where a subject chose A. This led to a loss in observations from stage to stage

as subjects exited the game due to co-player's, rather than own choice of A. We obtained insignificant coefficients both for the cold (p=0.111) and the hot (p=0.355) condition. We also performed Mann-Whitney tests comparing the number of safe choices of subjects in the first and last stage of the escalation game. There was a significant difference for the cold condition (p=0.038) and an insignificant one for the hot condition (p=0.357). Despite the theoretical findings, there seems to be mixed evidence at best for hypothesis 1a or the role of risk attitudes in contributing to the large observed differences in critical B-behaviour between the chicken and escalation games. One interpretation is that this lends support to an independent, and perhaps greater role of the psychological factors (hypothesis 1b). However, this result warrants caution to the extent that the Holt and Laury (2002) lottery was designed as a measure of risk in parametric and not strategic situations. We return to this issue in the next and final section.

4   Discussion and conclusions

Escalation has been studied both in parametric and strategic contexts, i.e. when the source of the uncertainty is either random or reactive and deliberate. Our results are a contribution to the latter agenda. There have been other approaches to use game theory to model strategic escalation and brinkmanship behaviour. One is explored in Shubik's (1971) dollar auction [12] and Maynard Smith's (1974) related war of attrition model. Both depict escalation somewhat differently to us in that it becomes increasingly ruinous for all players, whereas ours may secure the highest available payoff only through continuing brinkmanship. The difference lies in the issue of whether an increasing cost is incurred by both parties as the escalation unfolds. Also, the dollar auction does not involve the kinds of risk considerations we examine here as an important feature of realistic scenarios. A number of other models consider escalation with reversible commitment to a course of action and associated scope for strategic moves and cheap talk (Rubinstein, 1982; Brams and Kilgour, 1987), which again is different to what we consider here.

For the type of situation we study, our main finding is that, through psychological effects, previous escalation makes the Pareto-dominated outcome of certain kinds of bargaining situations more likely irrespective of the risk attitudes of participants. We now discuss some of the implications of our work before commenting on its limitations and scope for further research in this area. First, our findings provide empirical support for the suggestion that the chicken game is not a suitable model for the study of those bargaining situations we described at the outset as they occur in real contexts. To be sure,

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[12] In this game, both the highest and second highest bid for a dollar note must be paid, leading to the possibility of an escalating bidding war as bidders try to avoid increasing losses.

the game's properties make it a useful tool for theory development. However, in taking issue with the standard chicken game as a model of escalation and proposing an alternative, we interpret them not merely as models for the 'conceptual exploration' of their internal workings, but rather for 'empirical theorising', i.e. generating insight into the real phenomenon by virtue of their ability to capture those realities we are interested in, albeit in a simplified way that facilitates analysis (see Hausman, 1992; Sugden, 2000). Similarly, when used by us as an experimental task, we perceive of the escalation game as representing the structure of choices real actors face. Second, to this extent, our findings have potential implications for policy designed to reduce the possibility of disastrous outcomes in relevant real bargaining scenarios, such as international or industrial disputes. We tentatively suggest that long-winded, escalating bargaining processes may trigger psychological phenomena such as frog boiling that make mutually harmful outcomes more likely. Third, our results contribute to the issue of what effects cold and hot elicitation methods may have on experimental behaviour. The survey of Brandts and Charness (2009) finds mixed evidence of a difference for a given task, and no evidence for particular treatment effects being sensitive to elicitation method. In contrast, we find evidence that elicitation moderates task behaviour as well as treatment effects. Hot escalation game subjects chose B more frequently than ones in the cold condition. The difference in critical behaviour between the two games is significant for hot, but not for cold elicitation. While we attribute this to the psychological factors involved in escalation, Brandts and Charness (2009) do not find their meta-result moderated by whether an experimental task offers scope for emotions. Alternatively, there is some evidence that more complex and, in particular, stage games offer more scope for elicitation effects (Schotter et al., 1994; Brandts and Charness, 2000).

Our findings also require qualification and provide scope for further work. To advance the study of strategic escalation with irreversibility, the nature both of subjects' risk preferences and the accompanying psychological effects need to be better established. First, the Holt and Laury (2002) lottery tasks we and other studies on game behaviour use (e.g. Goeree et al. 2003) was designed to measure attitudes towards parametric, rather than strategic risk. While this distinction may be less important in games with mixed strategy equilibria, a dedicated measurement for strategic risk attitudes may be a useful tool (e.g. Aumann 2009) for analysing behaviours such as escalation . Second, our work was designed to test for the existence of psychological effects generally, but not to distinguish between different types. There is scope for future research on this issue to better formulate practical implications. Finally, a related issue that merits further exploration is the relationship between brinkmanship behaviour and the psychological processes that accompany it. The direction of any causation between the two and the possibility of their mutual self-reinforcement as the basis of escalation processes generally are promising areas.

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