

# The Rationality of Irrationality for Managers: Returns-Based Beliefs and The Traveler's Dilemma

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## Abstract

This paper discusses the importance of paradoxes of irrationality for managers by elaborating upon the rational basis for the adoption of non-equilibrium strategies in game theory. It does so by revisiting the one-shot Traveler's Dilemma game, proposing a solution which reconciles the anomaly between the empirical findings and the theoretical predictions of the Nash equilibrium suggested by the game. We contend that this seeming irrationality may be based upon the subjective probabilities of the players. We proffer an alternative basis upon which beliefs in game theory might be formed - 'returns-based beliefs' - and we present the corresponding numerical results for the Traveler's Dilemma game. We show that as long as the penalty is not too severe, then players are likely to play a high claim strategy. Our results correspond very closely to other empirical studies of the Traveler's Dilemma. Therefore, we argue that understanding the rational basis for game-theoretic paradoxes of irrationality

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might have important and practical uses for managerial decision-making.

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# 1 Introduction

Economists and management scholars have highlighted the inherent contradictions and paradoxes of many different games in which the reality of individual decision-making is at odds with what is predicted on the basis of economic reasoning driven by game theory (Bicchieri 1989, Binmore 1987, Goeree and Holt 2001, Luce and Raiffa 1957, Petit and Sugden 2001, Reny 1993, Rosenthal 1981, Rubinstein 2007, Rubinstein 2006, Selten 1978). In their articulation of the game-theoretic rationale underlying how subjects determine their optimal strategy, economists are routinely confronted with both experimental and survey evidence which depict subjects who do not choose voluntarily a strategy that is predicted by a Nash equilibrium (Camerer, Ho and Chong 2004, Kadane and Larkey 1983, Rubinstein 2007, Rubinstein 2006). In the scholarly writing of earlier decades, some even went so far as to argue that the traditional result of an equilibrium in economics could be overturned (Kaldor 1985, Robinson 1974). For example, the Cambridge economist Joan Robinson argued that ‘A model applicable to actual history has to be capable of getting out of equilibrium; indeed, it must normally not be in it’(Robinson, 1962, p. 25). In the corporate world, there are numerous examples of firms choosing to adopt seemingly non-optimal strategies for example in choosing whether or not to implement innovations (Chesbrough and Rosenbloom 2002, Kaplan and Henderson 2005). Understanding therefore the rational basis for game-theoretic paradoxes of irrationality might have practical use for managerial and corporate decision-making. The purpose of this paper is to show the rationale for why managers might choose a non-equilibrium strategy that is ostensibly irrational. We argue that the rationality of subjective probabilities and what we term ‘*returns-based beliefs*’ might explain the adoption of non-equilibrium strategies in game theory, and that this might have wide implications for firms and managers. Therefore, the rationality of irrationality warrants our collective consideration.

To provide support for this argument, we revisit a curious paradox in game theory - the one shot Traveler's Dilemma game (Basu 1994 and 2007). We propose a solution which reconciles the anomaly found in empirical studies of the paradox, because the empirical findings do not correspond to the theoretical predictions of the Nash equilibrium suggested by the game, when the penalty is low. We argue that given the importance of subjective probabilities, even in a fully specified game, there is strategic uncertainty when players try to coordinate their actions. Therefore, we show that when players play a mixed strategy over the possible claims, we may plausibly reconcile the empirical evidence on the Traveler's Dilemma game. We maintain that the value of investigating the seeming irrationality of the economic theory of the Traveler's Dilemma with empirical studies of it, casts light on individual- and on firm-level decision-making. For example, every firm has its own particular set of past experiences. Institutional theorists have long argued the importance of 'sociocultural embeddedness' in influencing institutional decision making (DiMaggio and Powell 1983, March and Olsen 1984). These institutional factors have managerial implications in areas as diverse as, for example, organizational knowledge, pricing policy and innovation strategy (Conner 1991, Conner and Prahalad 1996, Phillips 2004). And an analysis of these areas suggests that the past might yet influence decision-making in the present. For example, in the case of organizational knowledge it is important to factor in both individual and organization memory in deciding upon the optimal strategy (e.g., Argote 1999, Benkard 2000). Second, the past might have profound strategic implications for pricing policy if past interactions have an influence on current pricing. For example, Basu (1994) proposed that the case of pricing policy for a differentiated duopoly market might have some analogy to the Traveler's Dilemma game. In such a game the pricing adopted might be different from the equilibrium strategy as defined by the Nash equilibrium. Third, past experience might also have bearing on innovation strategy as an organization's past could affect the cognitive frames which might encourage or impede the

implementation of innovations (Chesbrough and Rosenbloom 2002, Kaplan and Henderson 2005). Therefore it is important to comprehend not only the possible game-theoretic Nash solutions in formulating strategy (which frequently act as benchmarks for managers) but equally to understand the institutional aspects that could potentially influence decisions that concern strategic choice. These institutional aspects might well cause managerial decision making to deviate from the conventional rationality associated with game theory.

Game theory has been motivated, in the main, by an interest to understand systematically human behavior when strategic interactions exist. Conventional game theory assumes that players are rational and that rationality is a common belief i.e. it is not only known by the players but known to be known, and so forth (for a discussion see Brandenburger 2007). In such a case, the solution concept such as a Nash equilibrium, is critical in forming the basis for the prior distribution of beliefs that players hold. Therefore, in determining the outcome of the game these prior beliefs held by the players are fulfilled in equilibrium. However, game theory is unable to describe how a player might behave should an opponent not choose strategies that are rational in the spirit of the solution concept being used (Basu 1990). In this sense, game theory is a normative theory that describes how people *ought to behave* rather than a descriptive theory about how people *actually behave* (Kadane and Larkey 1983). Harsanyi (1982) contended that ‘in deciding on the best strategy against an actually or potentially irrational opponent or opponents, normative game theory can provide only indirect help. Rather, what we need is an empirically supported psychological theory making at least probabilistic predictions about the strategies people are likely to use, . . . given the nature of the game and given their own psychological makeup’ (p.122). We argue that such a psychological makeup might be conditioned by the past experience of the individual. Therefore, this experience might influence how individuals form beliefs about an opponent’s play. This is termed the ‘*subjective*’ or personal interpretation of probability which is the probability that a

person assigns to a possible outcome, or some process based on his own judgement, the likelihood that the outcome will be obtained (DeGroot 1975, pp. 4). In an influential paper, Kadane and Larkey (1983) argued that the subjective view of probabilities clarifies the important distinction between normative and descriptive aspects of theorizing about behavior in games. Moreover, the authors argue that the disparity between the empirical findings and the predictions provided by game theory supports the conclusion that players might appear at least at first to be ‘actually or potentially irrational’.

Herbert Simon (1957) articulated the concept of rationality by distinguishing between subjective and objective rationality. In particular, subjective rationality is behavior that is rational given the perceptual and evaluational premises of the subject. This is termed the rationality of perception. Whilst objective rationality is behavior that is rational as viewed by the experimenter. This is termed the rationality of choice. Therefore, it is important to distinguish between rationality of perception and rationality of choice, given the perception (Simon 1957). The key point here is that human behavior is likely to be subjectively rational but not necessarily objectively rational. This implies that the experiences of the individual might feed into the so-called perceptive and evaluational premises of the individual and influence thereby the subjective probabilities. The subjective probabilities thus formed may then influence the strategies chosen. An implication of the subjective probability approach is that the chosen strategy might not be consistent with the equilibrium predictions of an objectively rational outcome. For example, Roth and Schoumaker (1983b) have shown that the expectation of bargainers might influence the outcome of the game. They show via experiments of a repeated bargaining game that a player that has been allowed to obtain consistently a larger share in the initial games than a Nash outcome would predict, has every reason to continue to and does expect this outcome in subsequent games. Therefore, the players’ experience is an important determinant of the expectations of the player which then influences the outcome of the

game. The authors show that this outcome might not be the Nash equilibrium prediction (Roth and Schoumaker 1983a). Thus, managers who try to work out what the strategy of their competitors might be, need to take into account how their competitors might form subjective probabilities, in order to determine an optimal response. As a consequence, we might find managers even going so far as to play non-equilibrium strategies. This is true of the evidence for several games in game theory more generally but especially pertinent to the example of the one-shot Traveler's Dilemma game that has much fascinated economists and other scholars (Basu 1994 and 2007).

The one-shot Traveler's Dilemma game was illustrated first in a classic paper by Kaushik Basu (Basu 1994), and analyzed progressively by other economists (Capra et al 1999, Colombo 2003, Goeree and Holt 2001, Rubinstein 2006, Rubinstein 2007). The dilemma is important because it concerns 'iterated elimination of dominated strategies' (Kolhberg and Mertens 1986, Luce and Raifa 1957) and the 'Nash equilibrium' (Aumann and Brandenburger 1995, Nash 1951), two concepts that lie at the heart of game theoretic models and other contemporary research in the social sciences. We argue in this paper that the links between subjective probabilities and non-equilibrium strategies alluded to above, might have important consequences for the outcome of this game and for its empirical testing. In so doing, we also proffer an alternative basis upon which beliefs in game theory might be formed - returns-based beliefs - and we present the corresponding numerical results. We show that as long as the penalty is not too severe, then players are likely to play a high claim strategy. Our results correspond very closely to empirical studies of the Traveler's Dilemma, and we discuss the managerial implications of our findings. Section 2 revisits the Traveler's Dilemma. Section 3 provides an explanation for the reconciliation of the empirical findings and the theoretical predictions of the Traveler's Dilemma using returns based beliefs. Section 4 discusses the managerial implications and concludes.

## 2 The Traveler's Dilemma Revisited

Basu's (1994) Traveler's Dilemma game is based on a story about two travelers who holiday on a tropical island and then return having purchased identical antiques. Whilst returning, the airline that they have flown back on damages their antiques irreparably, but promises them adequate compensation, requesting them to make claims for that compensation independently. The airline manager, who is unaware of the true cost of the antiques, makes the following proposition to the two travelers: Each traveler has to write down the cost of the antique  $n_i (i = 1, 2)$ , which can take a value between 80 and 200<sup>1</sup>. If traveler 1 and traveler 2 write down the same number ( $n_1 = n_2$ ), then the manager assumes that they are telling the truth and both travelers are paid the sum of money written down. If traveler 1 writes down a number larger than traveler 2 ( $n_1 > n_2$ ) then it is assumed that traveler 1 is lying relative to traveler 2. In this case, the airline manager regards  $n_2$  as the cost of the antique and pays traveler 1 the sum of  $(n_2 - 2)$ , while traveler 2 gets the sum of  $(n_2 + 2)$ . Traveler 1 thus receives a penalty for inflating the cost of the antique, while traveler 2 is suitably rewarded for his honesty. The Traveler's Dilemma game thus involves choosing the amount to claim,  $(n_1, n_2)$  to maximize the travelers' respective payoffs.

The nature of the 'paradox' arises from the anomalous behavior of both players in this situation. Each player will not write '200'; instead they realize that if they wrote '199' assuming the other player writes 200 then the player who wrote 199 would receive 201. But if both write '199' then they will receive 199, so one can do better by writing '198', and so forth. The two travelers iteratively eliminate dominated claims until the pair (80, 80). (80, 80) in the travelers dilemma game is a unique Nash equilibrium; yet in a real-world situation, it is highly unlikely that either player is likely to put down (80, 80). Rather,

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<sup>1</sup>In the original paper (Basu 1994), the cost of the antique can take a value between 2 and 100. However, to avoid negative payoffs we have altered the payoff to conform with the examples in empirical studies (Capra et al 1999, Goeree and Holt 2001).



both are likely to play a large number, and both are likely to reject (80, 80) based upon their rational interpretation of the others' behavior. And, as Basu points out, it is this paradox which lies at the heart of the Traveler's Dilemma.

The paradox in the theoretical literature is reflected in the evidence from empirical testing of the Traveler's Dilemma game. Recent studies of the Traveler's Dilemma have asserted that when the dilemma is tested in empirical laboratory situations, when the penalty is small, the Nash outcome does not obtain and when the penalty is large, the outcome is very near to the Nash outcome of (80, 80) (Capra et al 1999, Goeree and Holt 2001). One of the most striking features of these studies is that the anomalous result for the low penalty case does not disappear even when subjects play the game repeatedly and so have the benefit of learning from past experience. As Goeree and Holt argue, '*Since the treatment change does not alter the unique Nash (and rationalizable) prediction, standard game theory simply cannot explain the most salient feature of the data i.e. the effect of the penalty/reward parameter on average claims*' (Goeree and Holt, 2001, p. 1406). The authors of the Capra et al study concur, '*To summarize: the Nash equilibrium prediction of 80 (equivalent to 2 in Basu's example) for all treatments fails to account for the most salient feature of the data, the intuitive inverse relationship between average claims and the parameter that determines the relative cost of having the higher claim*' (Capra et al, 1999, p. 680; emphasis in the original). The paper also examines a logit equilibrium learning model, which is shown to perform well in explaining the Traveler's Dilemma game. Even here though the authors do acknowledge that the model does not explain all aspects of the data (Capra et al 1999, p. 686).

In the sections which follow we attempt to show why the empirical testing of the Traveler's Dilemma game does not always accord with the theory. We argue that even when the game is fully specified, there is strategic uncertainty when players attempt to coordinate their actions. We argue that this uncertainty induces players to play mixed strategies.

Although the common practice is to eliminate strictly dominated strategies from normal form games in formulating equilibria in mixed strategies, empirical studies have shown that dominated cooperative strategies might be played with positive probabilities (Cooper et al 1990). Based on the findings of the study by Cooper et al, we hypothesize that when agents form subjective probabilities about the strategies of the other players, it is not appropriate to delete strategies that were eliminated using the process of iterated deletion because these strategies might be played with positive probabilities. Moreover, it turns out that the use of mixed strategies might result in better returns for the players than the Nash equilibrium strategy of playing 80. We show that using mixed strategies (including the strictly dominated strategies) allows us to provide a plausible explanation for the empirical evidence discussed in previous studies of the Traveler's Dilemma. We also suggest a formulation upon which beliefs are formed which we term 'returns-based beliefs' and present the corresponding numerical results. In so doing, we argue that the rationality of the players that is based upon their subjective probabilities, might explain the seeming irrationality of their adopting non-equilibrium strategies, as witnessed in the economic testing of the paradox. The remainder of our paper elaborates upon these arguments further.

### **3 An Explanation for the Anomalous Behavior in the Traveler's Dilemma Game**

This section provides an explanation for the anomalous behavior in the Traveler's Dilemma. We show that a plausible explanation for the empirical evidence conducted on this game may be based upon agents playing mixed strategies. We discuss a possible way in which agents may form beliefs that is based upon expected returns. We discuss how this forms the

subjective probabilities, and show how the numerical results obtained correspond closely with the evidence presented in previous empirical research on this issue.

### **3.1 Strategic uncertainty and the formation of beliefs**

In the Traveler's Dilemma game, the iterated elimination of dominated strategies is used to derive the Nash equilibrium of (80, 80). However, clearly the agents are not using a method based upon the iterated elimination of dominated strategies in arriving at their outcomes, because the empirical evidence is at odds with the theoretical outcome of a Nash equilibrium. This is what leads us to believe that there must be an alternative explanation in terms of how agents think about the game and the manner in which they are choosing their strategies. Other economists have argued that perhaps we need to examine psychological motives more to understand behavior in the Traveler's Dilemma game and have suggested examining the process of cognitive reasoning (Rubinstein 2006 and 2007). In this section, and in keeping with this line of thought, we propose an explanation that is based on players wanting to co-operate on their strategies, as such co-operation provides better returns than non-cooperation.

In the case of the Traveler's Dilemma, ideally, the agents would like to co-operate by co-ordinating their actions on the joint claims that will maximize their returns, which is (200,200), or indeed on any other coordinated claims such as (199, 199), (198, 198), and so forth. Intrinsically, each player knows the value of the antique - or has a view about it - and hence he or she may actually be providing a bid, with positive probabilities, that coordinates with the other player. However, since they are unable to communicate their actions, they are unable to co-ordinate their actions. This does not imply however that the players may not want to cooperate on their actions. For example, there is significant evidence that has shown that human beings are prone to cooperative behavior based on

reciprocity (Axelrod 1984, Axelrod and Dion 1988). Therefore, the history of human interactions are likely to influence the general disposition of players to want to co-operate. For example, many economists have argued that history matters in determining how people behave and that this has implications for issues as diverse as economic growth, technology, trade, parliamentary democracy, demography, financial systems and business strategy (Anderson and Smith 2007, Aumann and Dreze 2008, Guinnane, Sundstrom and Whatley 2004, Jones and Khanna 2006, Monnet and Quintin 2007, Roberts 2005). To this line of argument, Nicholas Kaldor contributed ‘The only truly exogenous factor is whatever exists at a given moment of time, as a heritage of the past...the heritage of all past history, determine what can be produced or created in the immediate future’ (Kaldor 1985, p. 61). Based on this argument that history matters in studying economic incentives, we should factor this cooperative bias into our decision making framework in order to predict how players should behave in a competitive situation where cooperation is possible and does result in better outcomes<sup>2</sup> (Friedman 1996).

In this paper we argue that the willingness to cooperate might be influenced by the past experiences of the individuals, generating what we term ‘*strategic uncertainty*’. We define strategic uncertainty as uncertainty concerning the actions and beliefs (and beliefs about the beliefs) of others (Brandenberger 1996, Morris and Shin 2002). Strategic uncertainty can arise even when all possible actions and returns are completely specified and are common knowledge (Van Huyck et al 1990). Due to strategic uncertainty, the rational decision-maker has to form beliefs about the strategy that the other decision maker will use. Consequently, the agents create their beliefs about the probabilities that other agents

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<sup>2</sup>In addition, psychologists argue that cooperation may be prompted by altruism, by the desire to conform to social norms, or by adhering to the dictates of one’s conscience (Dawes 1980). Economists point out that the ‘people’s natural tendency to cooperate’ is an important element that subjects bring to experimental situations from the outside (Andreoni and Miller 1993, p. 571).

play in order to determine in turn their best-response strategy. This best response strategy is likely to be based upon the mixed strategy of the other player. The mixture is due to uncertainty regarding the conjecture about the choice by the other players<sup>3</sup> (Brandenburger and Dekel 1989).

The issue of mixed strategies is relevant also when we consider the concept of the iterated deletion of dominated strategies. The concept of iterated elimination of dominated strategies assumes that a strategy that is dominated will never be played. However, empirical analysis shows that dominated co-operative strategies might be played with positive probabilities which could change the results in a significant way (Cooper et al 1990). Cooper et al (1990) show that variation in a player's payoff from an opponent's play of a co-operative dominated strategy influences equilibrium selection. Although the subject of that paper demonstrates the change in equilibrium selection between multiple Nash equilibrium outcomes, we use a similar concept to illustrate why the results might even go so far as to move away from Nash equilibrium outcomes to a non-equilibrium outcome. In so doing we provide plausible theoretical support for the empirical evidence conducted on the Traveler's Dilemma paradox. The formation of beliefs about the strategies that the other decision maker might use is a subjective assessment based on the previous experiences of the player. Therefore, it is possible for the player to expect the opponent to play all possible strategies, including strictly dominated strategies, with positive probabilities. For example, Roth and Schoumaker (1983b) showed that more than one outcome that is not the Nash bargaining solution, could be considered as consistent with perfect rationality when the 'outcome depends on subjective expectations of the players which are not deter-

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<sup>3</sup>It is not assumed that the opponent is using a randomized strategy but merely reflects the representation of player 1's belief about player 2 (Wilson 1986). Wilson (1986, pp.47) points out that conceptually this distinction between randomization and subjective beliefs to explain the mixed strategies is an important one, although it makes little difference to the mathematics.

mined by the data of the game' (p. 1338). Such a subjective expectation could be created by the experience of the player which might or might not be unusual. If the experience of the individual has been to get a share of a bargain that is not a Nash bargaining solution, then it is reasonable to assume that the player will continue to expect the non-Nash bargaining solution in the next game (Roth and Schoumaker 1983a, 1983b). Therefore, a player who knows that this belief is held by the opponent could be deemed to be rational when forming a subjective assessment of the opponent's play by taking this factor into account (Basu 1990). If one were to look at this game purely from the perspective of objective rationality, then this might constitute an error by the player. In this situation, there would be a rationality of perception which might not necessarily correspond to the objective probabilities that would result if the dominated strategies were to be deleted iteratively (as in the case of the Traveler's Dilemma). Correspondingly, we argue that there may be 'subjective' rationality coexisting with the rationality of perception driven by the historical experiences of the individuals. Given such a perception, what would be the rational choice of strategies to choose? In order to answer this question, we need to re-examine the process of iterated deletion of dominated strategies.

The deletion of dominated strategies assumes that these strategies are not expected to occur and hence the probability of playing them is zero. The question arises as to whether one could delete dominated strategies when subjective probabilities are held so much so that dominated strategies could be played with positive probabilities. We illustrate this argument better in Figure 1. The figure shows the payoff for player 1 for various strategies of player 2. In the case of iterated elimination of dominant strategies, player 1 would not play 200 as player 2 could trump him by playing 199. Therefore, player 2 would be better off playing 198 and so on until we reach (80, 80) by iteratively eliminating all strategies between 200 and 81. However, if we assume that player 1 holds the belief that player 2 is likely to play 200 even with a very small probability because of some historical experience

of player 2 (for example, the need to want to coordinate the strategy with player 1 and earn the same payoff, or to want to target a specific amount that is the actual price of the antique) then it would be rational for player 1 to also choose the strategy 200 with a positive probability. A similar reasoning could be applied to all claims between 199 and 81. Now it is easy to see that it is no longer the case that strategy 200 is dominated. This is because if player 2 were to play any strategies between 200 and 80 with some positive probability, player 1 could do better by mixing between 200 and 81 than to play 80. This result is shown using the example of the numerical model in the next section. The common practice is to eliminate strictly dominated strategies from a normal form game in formulating equilibria in mixed strategies (Kohlberg and Mertens 1986). However, the practice of eliminating strategies between 200 and 81 via a process of iterated deletion of dominated strategies is not appropriate, because playing a mixed strategy between 200 and 81 could yield a better payoff than playing the Nash equilibrium strategy of 80 when the other player plays all strategies with some positive probability<sup>4</sup>.

In order to illustrate our results we need some plausible set of assumptions about how agents form beliefs with respect to the probability of the opponent's strategy. Let us call the agents, players 1 and 2 respectively. In this paper, we formulate a possible way in which agents' might form beliefs. In this method, player 2 plays strategies based on the probabilities of the proportion of returns over the total returns for each possible claim by player 1. The next section describes the approach and results associated with this method

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<sup>4</sup>Conventionally, any mixed strategy will have a support in pure strategies. However, the pure strategies between 200 and 81 will get eliminated by an iterated deletion of dominated strategies which suggests that the play of a mixed strategy based upon a support in pure strategies would not be apposite in this context. However, due to our argument that invokes subjective probabilities, all the strategies are played with positive probabilities. Consequently we argue that the iterated deletion of dominated strategies is no longer appropriate. Hence a mixed strategy can exist if one player experiences uncertainty with respect to his conjecture about the choice of the other player.

		Player 2													
		200	199	198	197	196	195	194	193	192	191	→	82	81	80
Player 1	200	200	194	193	192	191	190	189	188	187	186	→	77	76	75
	199	204	199	193	192	191	190	189	188	186	186	→	77	76	75
	198	203	203	198	192	191	190	189	188	186	185	→	77	76	75
	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	82	87	87	87	87	87	87	87	87	87	87	→	82	76	75
	81	86	86	86	86	86	86	86	86	86	86	→	86	81	75
	80	85	85	85	85	85	85	85	85	85	85	→	85	85	80

Reward/Penalty = 5

Figure 1: Dominated Claims

of belief formation.

### 3.2 Returns-based beliefs

In this section we describe a possible subjective probability formation based on returns based beliefs. In order to understand why this method of forming beliefs might be reasonable, we discuss the concept of subjective probabilities and its implications for the Nash equilibrium. We assume that players are expected utility maximizers<sup>5</sup>. The conventional approach in game theory when mixed strategies are required is for a player to choose probabilities (over their own strategies) in such a manner as to make the other player indifferent between the different strategies. This implies that each person's equilibrium strategy must depend only on the other players' payoff and not their own in order to make the other player indifferent (Amaldos and Jain 2001). However, this would not be the case when non-equilibrium strategies are chosen. In such non-equilibrium outcomes each player maximizes their own expected values based on their conjecture of what the opponent is

<sup>5</sup>The players derive one unit of utility from each dollar that they gain.



likely to do. Therefore, the probabilities are chosen to maximize this expected utility rather than to make the opponent indifferent to the different strategies. As discussed earlier, due to a bias towards cooperation, for example in the Traveler's Dilemma game, there is uncertainty regarding the conjecture about the choice of the other player. Therefore the player holds a subjective probability opinion with respect to all of the unknown contingencies affecting his payoffs. In particular the player is assumed to have *'an opinion about the major contingency faced, namely what the opposing player is likely to do'* (Kadane and Larkey 1982, pp. 115). Kadane and Larkey (1982, pp. 115) put the implications of this line of reasoning very neatly as follows: *'If I think my opponent will choose strategy  $i$  ( $i = 1, \dots, I$ ) with probability  $p_i$ , I will choose any strategy  $j$  maximizing  $\sum_{i=1}^I p_i u_{ij}$ , where  $u_{ij}$ , is the utility to me of the situation in which my opponent has chosen  $i$  and I have chosen  $j$ .....the opponent's utilities are important only in that they affect my views  $\{p_i\}$  of what my opponent may do....'*

Therefore, it follows that if player 2 is not expected to play the Nash equilibrium strategy than it might be optimal for player 1 also not to play the Nash equilibrium strategy as this would give player 1 a larger payoff. In effect, the Nash equilibrium becomes the special case when each player is assumed to believe that the other is sure to play the Nash equilibrium strategy. We come back again to the concept of objective and subjective probabilities to help clarify the context of this discussion: the Nash equilibrium solution concept assumes rationality from the perspective of an outside observer. However, at the level of the individual player, assumptions about the opponent's beliefs may be conditioned by the past and therefore may diverge from the priors held by the rational outside observer. In situations of strategic interaction such as in a Traveler's Dilemma game, the individuals might hold subjective probabilities that might differ from the objective probabilities demanded by the Nash equilibrium solution concept. When these probabilities coincide we get the special case of the Nash equilibrium. However, there is no compelling

reason a priori for these definitely to coincide. Although any possible subjective probabilities could be a possibility, we shall try to propose a reasonable subjective probability belief that the players might use when they do not know each other. We call this ‘*returns-based beliefs*’, which we describe in more detail below.

We posit that the players would prefer to cooperate based on the premise that historical experience tells them that this might provide a better return. However, due to the strategic uncertainty about what the opponent is going to play, the rational decision maker has to form beliefs about the opponent’s play. Since the decision maker is trying to maximize expected returns based on these beliefs, it is reasonable to assume that the decision maker would assign probabilities based on the expected returns from playing the different strategies. In turn, it would be reasonable to assume that the opponent will also assign probabilities based on the opponent’s expected returns given the probabilities of the focal decision maker. Following this line of thought, our analysis will be based on a model for which the decision probabilities are proportional to the expected returns. We assume that agents form beliefs based upon the expected returns for a particular claim over the total expected returns of all claims, if the opponent were to play all possible claims. Our proposed approach has both theoretical merit and empirical support. Luce (1959) showed by using probability axioms that if the ratio of probabilities associated with any two decisions is independent of the payoff of any other decisions, then the choice probabilities for decision  $i$  can be expressed as a ratio of the expected payoff for that decision over the total expected payoff for all decisions:  $\frac{\pi_i^e}{\sum_j \pi_j^e}$  where  $\pi_i^e$  is the expected returns associated with decision  $i$ . This method of arriving at decision probabilities has been supported by empirical work for paired comparison data which supports the model such that the probability for choosing  $x$  over  $y$ ,  $P(x, y) = \frac{v(x)}{[v(x)+v(y)]}$  where  $v(x)$  and  $v(y)$  are the scale values of choosing  $x$  and  $y$  respectively (Abelson and Bradley 1954, Bradley and Terry 1952). We operationalize our model as follows. Let us assume that the feasible range of claims

between 80 and 200 is divided into  $n = 121$  intervals. Therefore, a strategy in category  $j$  corresponds to a claim of  $80 + j - 1$ . In this model, each player chooses among  $n$  possible categories and the expected payoffs are given by the summation below:

$$\pi_i^e(j) = \sum_{m=1}^n \pi(j, m) p_i(m), \quad j = 1, \dots, n \quad (1)$$

where  $\pi(j, m)$  is player  $i$ 's payoff from choosing a claim equal to  $j$  when the other player claims  $m$  and  $p_i(m)$  is the belief probabilities held by player  $i$  about player  $j$  playing strategy  $m$ . The decision probabilities in turn follow the specification outlined above which is proportional to the expected returns as follows,

$$D_i(j) = \frac{\pi_i^e(j)}{\sum_{m=1}^n \pi_i^e(m)} \quad (2)$$

In our model we assume a Nash-like equilibrium in beliefs whereby the belief probabilities matches the decision probabilities for both players 1 and 2 respectively. This is achieved by iterating between the expected payoff in equation (1) and the decision probabilities in equation (2). For example, Figure 2 shows the claim values and the associated rewards for player 1 (the first number in parenthesis) and player 2 (the second number in parenthesis) respectively when the penalty is 5. To begin the analysis, let us assume that player 2 believes that player 1 plays each of the claims with equal probabilities i.e.  $0.083 = \frac{1}{121}$ . We then multiply 0.083 with the rewards of player 2 (as per Figure 2) to get the expected returns as shown in Figure 3. For example, the number 1.6529 (row one and column one in Figure 3) is obtained by multiplying 0.083 by 200 (the second number in parentheses in row one and column one in Figure 2). The second last row labelled ‘Total’ shows the total rewards for a particular claim for player 2 for all possible claims by player

		Player 2					
		200	199	198	-->	81	80
Player 1	200	(200, 200)	(194, 204)	(193, 203)	-->	(76, 86)	(75, 85)
	199	(204, 194)	(199, 199)	(193, 203)	-->	(76, 86)	(75, 85)
	198	(203, 193)	(203, 193)	(198, 198)	-->	(76, 86)	(75, 85)
	↓	↓	↓	↓	-->	↓	↓
	81	(86, 76)	(86, 76)	(86, 76)	-->	(81, 81)	(75, 85)
	80	(85, 75)	(85, 75)	(85, 75)	-->	(85, 75)	(80, 80)

Reward/Penalty = 5

Figure 2: Returns for players 1 and 2

1. For example, 135.04 is the sum of all the rewards ( $1.6529 + 1.6033 + 1.5950 + \dots + 0.6281 + 0.6198$ ) for a claim of 200 by player 2 when player 1 plays all possible claims between 200 and 80.

We would now need to calculate the probabilities that player 2 will play the various claim strategies. As discussed above, player 2 is concerned about his opponent's returns only to the extent that he wants to maximize his own returns subject to the opponent's play. Therefore, it might be reasonable to assume that player 2 assigns probabilities to each of the claim strategies proportional to the expected returns of playing that strategy. The last row in Figure 3 depicts the probabilities that player 2 would play a particular claim in response to the various claim strategies for player 1. This is the same as the conjecture that player 1 has about player 2's probabilities. This is derived by dividing the reward player 2 gets for a particular claim strategy by the total rewards for all possible claims of player 1. For example, the number in the last row and first column of Figure 3 - 0.0093 - is obtained by dividing 135.04 (the number in the first column of the row labelled

		Player 2					
		200	199	198	-->	81	80
Player 1	200	1.6529	1.6860	1.6777	-->	0.7107	0.7025
	199	1.6033	1.6446	1.6777	-->	0.7107	0.7025
	198	1.5950	1.5950	1.6364	-->	0.7107	0.7025
	↓	↓	↓	↓	-->	↓	↓
	81	0.6281	0.6281	0.6281	-->	0.6694	0.7025
	80	0.6198	0.6198	0.6198	-->	0.6198	0.6612
Total	135.04	135.12	135.18	-->	85.87	84.96	14,500
Probability	0.0093	0.0093	0.0093	-->	0.0059	0.0059	1.0

Reward/Penalty = 5

Figure 3: Player 2's probabilities

'Total' in Figure 3) by the total of 14,500 (the number in the far right column in the row labelled 'Total' in Figure 3).

However, so far player 1 and player 2 have different beliefs about each other's probabilities of playing a claim. Player 1's expected returns can be calculated by applying the probabilities that player 2 will play each of the strategies as calculated from Figure 3 above. In a similar way, player 1's revised probabilities for each of the claim strategies can be calculated based on the returns based method described for player 2 above. We now revise the expected returns in Figure 3 with the new probabilities (as compared to the equal probabilities that we started out with). This process provides updated probabilities for player 2 for each claim strategy, shown by the revised numbers for the last row of Figure 3. This process can be repeated until the probabilities for players 1 and 2 converge. Conducting this iterative process shows that these probabilities do actually converge after about four to five iterations. Since the players are symmetric, it is not unreasonable to

		Player 2						
		200	199	198	-->	81	80	Total
Player 1	200	1.8812	1.8258	1.8174	-->	0.4399	0.4294	139.63
	199	1.9188	1.8729	1.8174	-->	0.4399	0.4294	139.72
	198	1.9094	1.9105	1.8645	-->	0.4399	0.4294	139.79
	↓	↓	↓	↓	-->	↓	↓	↓
	81	0.8089	0.8094	0.8098	-->	0.4688	0.4294	85.91
	80	0.7995	0.8000	0.8004	-->	0.4920	0.4580	84.97

Reward/Penalty = 5

Figure 4: Expected values for player 1

assume without any further information about history or preferences that they would have the same subjective beliefs about each other.

We then apply the converged probabilities to the returns of player 1 to calculate the expected values of player 1 for each of the claim strategies and the corresponding claims for player 2. This is shown in Figure 4. The column at the far right of Figure 3 gives the total by summing the expected values for each row. Player 1 will play the claim strategy that maximizes this expected value. Figure 5 shows the expected values for different penalties such as 5, 30, 40 and 60. The expected value is maximized at claim 190 for penalty value 5, 138 for penalty value 30, 114 for penalty value 40, and 80 for penalty value 60. The claim strategy decreases from close to 200 for small penalty values to fall sharply to the Nash equilibrium value at about penalty level 55, and remains at this level thereafter for higher penalty values. Figure 6 shows the claims for the game based on returns-based beliefs (Column 1), game one in Capra et al (Column 2) and the average for game 8-10 in Capra et al (Column 3) which incorporates the ability of players to learn. As shown in Figure 6 this feature of the data conforms closely to the empirical observation of the Traveler's

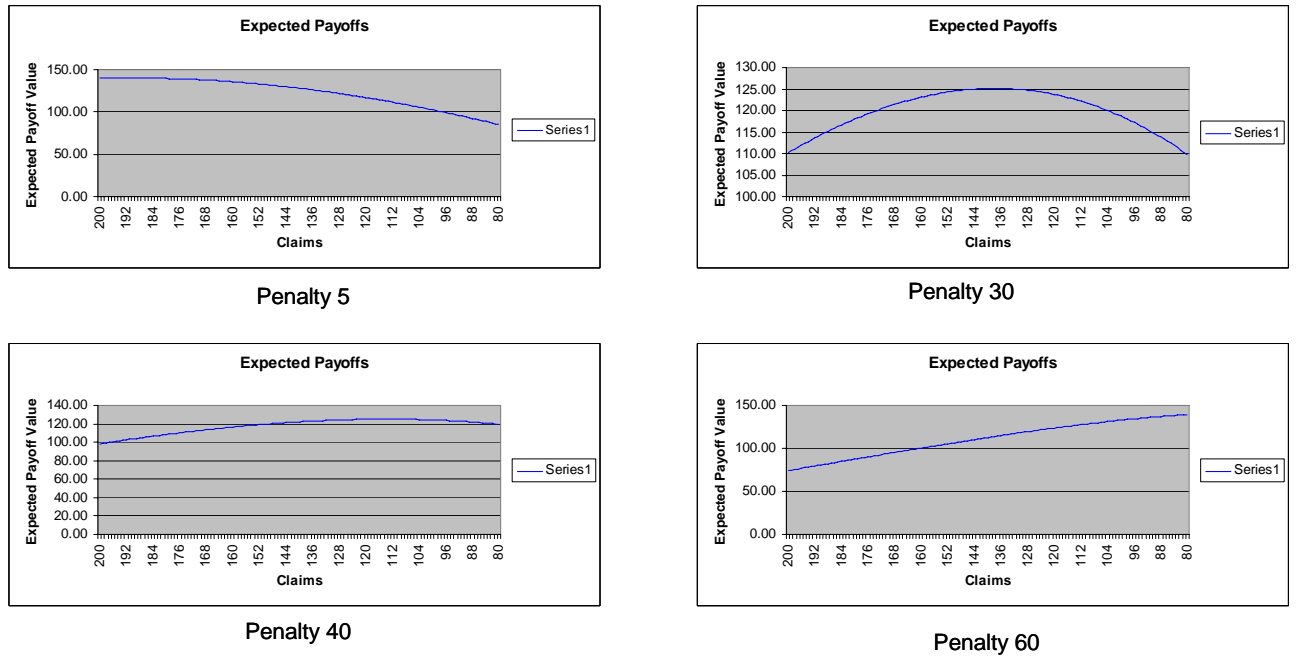


Figure 5: Penalty and expected value

Dilemma in studies by Capra et al (1999) and Goeree and Holt (2001) which show the *‘intuitive inverse relationship between average claims and the parameter that determines the relative cost of having the higher claim’*(Capra et al 1999, p.680).

Our explanation for the reconciliation between the theoretical Nash equilibrium outcome and the empirical findings are different to the ones provided by Capra et al (1999) in several ways. First, the Capra model has a time element whereby there is learning taking place over time between the actual play and the predicted claims based on the model. Therefore, their model has an error parameter and a learning parameter to allow for this adjustment to take place. Since our model does not assume learning over time, these parameters are not relevant for our analysis. Second, the Capra model assumes that the decision probabilities are proportional to an exponential function of the expected payoff<sup>6</sup>.

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<sup>6</sup>Decision probabilities that are exponential functions of expected payoffs implies that the choice probabilities are unaffected by adding a constant to all expected payoffs (Capra et al 1999, pp. 683). The equivalent of the Capra model for decision probabilities without a time element and error parameter is

Penalty	Maximum Claim Returns Based Beliefs (Column 1)	Capra et al Game 1 (Column 2)	Capra et al Average for Game 8-10 (Column 3)
5	190	178	195
10	180	180	186
20	160	160	119
25	149	150	138
50	86	130	85
80	80	120	81

Source: Capra et al 1999, Goree and Holt 2001

Figure 6: Penalty and maximum claim

The next section discusses some of the managerial implications of our study and concludes.

## 4 Managerial Implications and Conclusion

The one-shot Traveler's Dilemma game (Basu 1994) is a curious paradox in game theory which is important because it affects concepts that lie at the heart of game theory - iterated elimination of dominated strategies (Kolhberg and Mertens 1986, Luce and Raiffa 1957) and the Nash equilibrium (Aumann and Brandenburger 1995, Nash 1951). The testing of the game in empirical laboratory experiments has shown that when the penalty is low, players do not play the Nash equilibrium outcome as suggested by the game. However,

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$$D_i(j) = \frac{\exp(\pi_i^e(j))}{\sum_{m=1}^n \exp(\pi_i^e(m))}.$$



it must be emphasized that this divergence is not unique to the Traveler's Dilemma. For example, as other economists have pointed out recently, '*Increasingly, economists have come to accept that decision-making behavior, as observed in laboratory environments, diverges systematically from the predictions of standard theory...*' (Bruni and Sugden, 2007: p.162). To this end, the illustration of the Traveler's Dilemma is an important example in which the economist's observation of the experimental outcome needs to take this insight on board.

In this paper, we show that even when the game is fully specified, there is strategic uncertainty when players try to coordinate their actions (based on an intrinsic understanding of the value of the antique). We argue that this uncertainty induces players to play mixed strategies. Although the common practice is to eliminate strictly dominated strategies from normal form games in formulating equilibria in mixed strategies, empirical studies have shown that dominated co-operative strategies might be played with positive probabilities (Cooper et al 1990). Based on the findings of the study by Cooper et al, we hypothesized that when agents form subjective probabilities about the strategies of the other players, strategies that were previously eliminated via iterated deletion cannot be eliminated any longer. This is because the use of mixed strategies might result in better returns than the Nash equilibrium strategy of playing 180. We show that using mixed strategies (including the dominated strategies) allows us to provide a plausible explanation for the empirical evidence discussed in previous studies of the Traveler's Dilemma. We show that as long as the penalty is not too severe, then players are likely to play a high claim strategy. We believe that if returns-based belief formation is in fact the explanation for the experimental observations, then this might open up the possibility of testing other observable anomalies in game theory.

Accepting this line of argument also has several clear managerial implications for our study. First, past experience of the firm matters in determining optimal strategy. Often,

scholars are keen to emphasize the rational strategy that a firm should follow. However, it must be remembered that a firm has its peculiar history and particular set of past experiences. For example, institutional theorists have long argued the importance of ‘sociocultural embeddedness’ in influencing institutional decision making (DiMaggio and Powell 1983, March and Olsen 1984). Decision making institutions are often guided by the norms and traditions which in turn are shaped by historical events. This has various managerial implications. We discuss three areas, namely organizational knowledge, pricing policy and innovation strategy to provide an illustration of the issues. First, it has been shown that past experience has an influence over an organization’s knowledge repository (Phillips 2004). The concept of organizational knowledge is a powerful tool in understanding organizations (e.g., Conner 1991, Conner and Prahalad 1996). Organizational knowledge is the collection of assets, rules (Levitt and March 1988; Schulz 1998, 2001), routines (Nelson and Winter 1982) and standard operating procedures (Cyert and March 1963) which could shape the behavior of the organization. Organizational knowledge resides within the organization and is distinct from the knowledge of the individuals within that organization (Phillips 2004). In addition to organizational knowledge, the knowledge of individuals within an organization could also influence the behavior of organizations. Although it has been shown that memory decays over time, the past might yet have a considerable influence on the decisions of the current period. Therefore, it is important to factor in both individual and organization memory in deciding upon the optimal strategy (e.g., Argote 1999, Benkard 2000). Second, memory might have profound strategic implications for pricing policy. For example, Basu (1994) proposed that the case of pricing policy for a differentiated duopoly market might have some analogy to the Traveler’s Dilemma game. In such a game the pricing adopted might be different from the equilibrium strategy as defined by the Nash equilibrium. An example of this type of game in practice is the pricing of securities by dealers in the equity or bond markets. It is very possible

that for differentiated financial instruments (such as corporate bonds, treasury bonds and other securities) the history of interactions between institutions or traders could determine the optimal spread charged. And our example shows that this could be substantially different from the Nash solution depending upon the elasticity of the pricing schedule (which corresponds to the penalty of the Traveler's Dilemma game). For example, in cases where the elasticity is very low (which corresponds to the low penalty of the Traveler's Dilemma game) the pricing could diverge significantly from the Nash equilibrium prediction. Third, the knowledge and experience of the organization could also affect the innovation strategy as the cognitive frames could impede the implementation of innovations (Chesbrough and Rosenbloom 2002, Kaplan and Henderson 2005). For example, it has been argued in other research that Xerox did not commercialize many of its inventions from its research lab PARC, because the new business model that was required to commercialize these inventions did not conform to the historical business model of Xerox (Chesbrough and Rosenbloom 2002). Therefore we argue that it is important not only to understand the possible Nash solutions in formulating strategy (which frequently act as benchmarks) but equally that it is also of fundamental importance to understand the institutional aspects that could potentially influence decisions that concern strategic choice. We contend therefore that the seeming objective irrationality of the economic theory of the Traveler's Dilemma with empirical studies of it, may be based upon the subjective rationality of the players participating in this game, and that by taking this on board, we can provide a rationale both theoretically for the choice of the non-equilibrium strategies in the game, and consider more practically its implications for the actual behavior of individuals and firms.

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