Dragon Slaying with Ambiguity:Theory and Experiments

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Introduction

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- In contrast the present paper presents an experimental test of whether ambiguity affects behaviour in games.
- In games ambiguity arises from the behaviour of other people. This is more like actual economic behaviour than experiments on ball and urn problems.
- In games subjects create ambiguity for one another rather than the experimenter creating ambiguity.

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    - Introduce ambiguity; the equilibrium should move in the opposite direction in the two games;
    - The pair of games which we use are the weakest link and best shot models of public goods. Sometimes known as dyke building and dragon slaying.

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- Kilka and Weber (2001) show that subjects perceive more ambiguity about the returns on foreign (specifically Japanese) securities than comparable domestic (i.e. German) securities
- We conjectured that players in a game might likewise view a foreign opponent as being more ambiguous than a domestic opponent.

The Neo-additive Model of Ambiguity

We use the neo-additive model of ambiguity, axiomatised by Chateauneuf, Eichberger, and Grant (2007). They represent preferences by:

$$\alpha\delta M(a) + \delta(1-\alpha)\, m(a) + (1-\delta)\mathbf{E}_\pi u(a)\,, \tag{1}$$

- $M(a)$ denotes the maximum utility of act a,
- $m(a)$ denotes the minimum utility of act a,
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- This is a special case of the Choquet expected utility model, Schmeidler (1989), which represents beliefs as capacities.

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- δ is a measure of perceived ambiguity;
- α measures ambiguity-attitude, $\alpha = 1$ (resp. $\alpha = 0$) corresponding to pure optimism (resp. pessimism).
- Only 2 additional parameters needed compared to expected utility.

Definition of Equilibrium Under Ambiguity (EUA)

Definition

A pair of capacities ν^A, ν^B is an equilibrium under ambiguity if:

1. *for all x^A in the support of ν^A, x^A maximises the expected utility of player A given that ν^B represents player A's beliefs about the strategy of player B.*

Each players "believes" his/her opponent will play a best response. However it is an ambiguous belief. As a result the best and worst outcomes are given positive weight in decision-making in addition to best responses.

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2. *for all* x^B *in the support of* ν^B, x^B *maximises the expected utility of player* B *given that* ν^A *represents player* B*'s beliefs about the strategy of player* A.

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The Games

Weakest Link Public Goods Model

- Public good available = *minimum contribution* made by any individual.
- $u_i\left(x_i, x_{-i}\right) = \min\left\{x_1, ..., x_n\right\} - cx_i$, where x_i = contribution of individual i and c = the marginal cost of a contribution.
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- For instance a medieval village that is besieged by a dragon.

Nash Equilibria

The pure strategy equilibria of the public goods games are as follows:
Weakest Link

- Any situation where all players choose the same effort level is a Nash equilibrium.

Best Shot

- Any profile where one player chooses the highest action $\bar{x}$, and all other players choose the lowest possible action $\underline{x}$.

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Both games have multiple Nash equilibria which could be a source of ambiguity.

Proposition

The equilibria under ambiguity of the Best-Shot game are as follows:

1. *if* $(1-\delta_1)+\delta_1\alpha_1 < c$ *and* $(1-\delta_2)+\delta_2\alpha_2 < c$, *the equilibrium strategies are unique and are equal to* $\langle \underline{x}, \underline{x} \rangle$.
2. *if* $(1-\delta_1)+\delta_1\alpha_1 < c$ *and* $(1-\delta_2)+\delta_2\alpha_2 > c$, *the equilibrium strategies are unique and are equal to* $\langle \underline{x}, \bar{x} \rangle$.
3. *if* $(1-\delta_1)+\delta_1\alpha_1 > c$ *and* $(1-\delta_2)+\delta_2\alpha_2 < c$, *the equilibrium strategies are unique and are equal to* $\langle \bar{x}, \underline{x} \rangle$.
4. *if* $(1-\delta_1)+\delta_1\alpha_1 > c > \delta_1\alpha_1$ *and* $(1-\delta_2)+\delta_2\alpha_2 > c > \delta_2\alpha_2$, *there are two possible pairs of equilibrium strategies* $\langle \bar{x}, \underline{x} \rangle$ *and* $\langle \underline{x}, \bar{x} \rangle$.
5. *if* $\delta_1\alpha_1 > c$ *and* $\delta_2\alpha_2 > c$, *the equilibrium strategies are unique and are equal to* $\langle \bar{x}, \bar{x} \rangle$.
6. *if* $\delta_1\alpha_1 < c$ *and* $\delta_2\alpha_2 > c$, *the equilibrium strategies are unique and are equal to* $\langle \underline{x}, \bar{x} \rangle$.
7. *if* $\delta_1\alpha_1 > c$ *and* $\delta_2\alpha_2 < c$, *the equilibrium strategies are unique and*

Equilibria of the Weakest Link Game

Proposition

Assume that both players have neo-additive preferences. The equilibria under ambiguity of the weakest link model are as follows:

1. *if either* $c > 1 - \delta_1\alpha_1$ *or* $c > 1 - \delta_2\alpha_2$, *the equilibrium strategies are unique and are equal to* $\langle \underline{x}, \underline{x} \rangle$;
2. *if* $1 - \delta_1\alpha_1 > c > \delta_1(1-\alpha_1)$ *and* $1 - \delta_2\alpha_2 > c > \delta_2(1-\alpha_2)$, *then* $\langle \hat{x}_1, \hat{x}_2 \rangle$ *is a pair of EUA strategies if and only if* $\hat{x}_1 = \hat{x}_2$;
3. *if* $\delta_1(1-\alpha_1) > c$ *and* $1 - \delta_2\alpha_2 > c$, *the equilibrium strategies are unique and are equal to* $\langle \bar{x}, \bar{x} \rangle$;
4. *if* $1 - \delta_1\alpha_1 > c$ *and* $\delta_2(1-\alpha_2) > c$, *the equilibrium strategies are unique and are equal to* $\langle \bar{x}, \bar{x} \rangle$.

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  - *decrease* contributions in the weakest-link game (range $100 - 120$).
  - *increase* contributions in the best-shot game (range $130 - 150$).
  - We test whether subjects perceive more ambiguity when dealing with foreign opponents.

Weakest-link Game: Nash Predictions & Equilibrium under Ambiguity (EUA)

		Column Player					
		100	110	120	130	140	150
Row Player	100	50, 50	50, 45	50, 40	50,35	50, 30	50, 25
	110	45, 50	55, 55	55, 50	55, 45	55, 40	55, 35
	120	40, 50	50, 55	60, 60	60, 55	60, 50	60, 45
	130	35, 50	45, 55	55, 60	65, 65	65, 60	65, 55
	140	30, 50	40, 55	50, 60	60, 65	70, 70	70, 65
	150	25, 50	35, 55	45, 60	55, 65	65, 70	75, 75

- Nash equilibrium: both players to coordinate on any one of the six effort levels available.

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- Nash equilibrium: both players to coordinate on any one of the six effort levels available.
- Multiple Nash equilibria possible - ambiguity!!
- High ambiguity-aversion causes a player to choose an effort level of 100, which gives definite or ambiguity-safe payoff.

Best-shot Game: Nash Predictions & EUA

		Column Player					
Row Player		100	110	120	130	140	150
	100	50, 50	60, 55	70, 60	80, 65	90, 70	100, 75
	110	55, 60	55, 55	65, 60	75, 65	85, 70	95, 75
	120	60, 70	60, 65	60, 60	70, 65	80, 70	90, 75
	130	65, 80	65, 75	65, 70	65, 65	75, 70	85, 75
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- Two pure Nash equilibria: $\{(e_1^*, e_2^*) = ((100, 150), \ (150, 100)\}$. One player free-rides.

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- Two pure Nash equilibria: $\{(e_1^*, e_2^*) = ((100, 150), \ (150, 100)\}$. One player free-rides.
- Multiple Nash equilibria - ambiguity!!
- EUA: choose the highest effort level, i.e., 150− provides a constant/ambiguity-safe payoff.

Experimental Design I

- Paper-based experiment   Short, comprehensive set of instructions.
- Sessions conducted at St. Stephen's College, India, and in FEELE, University of Exeter.
- Three different treatments -
  - Treatment 1– locally recruited subjects - 60 subjects.

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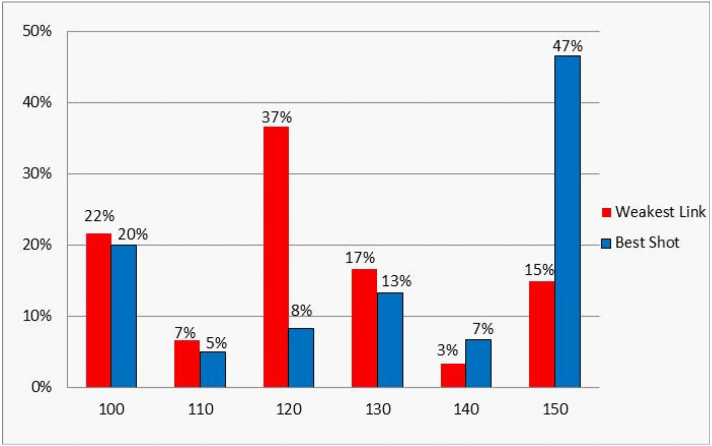
- Throw of dice determined *one* round for payment.
- Predetermined matching, and pay-offs announced.

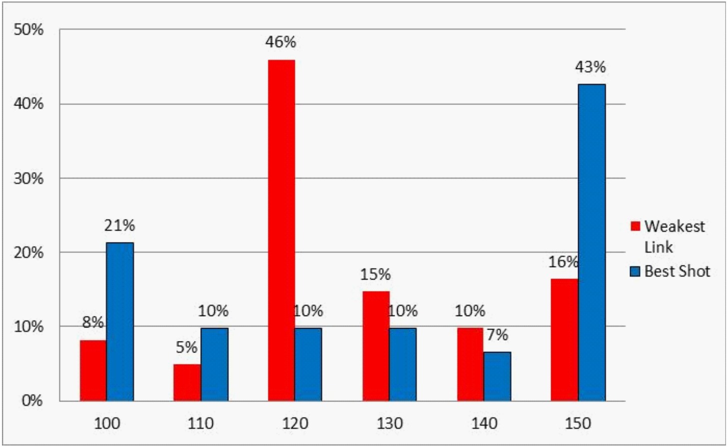
Data Analysis and Results I

Figure: Treatment I - Effort Level vs. Local Opponent



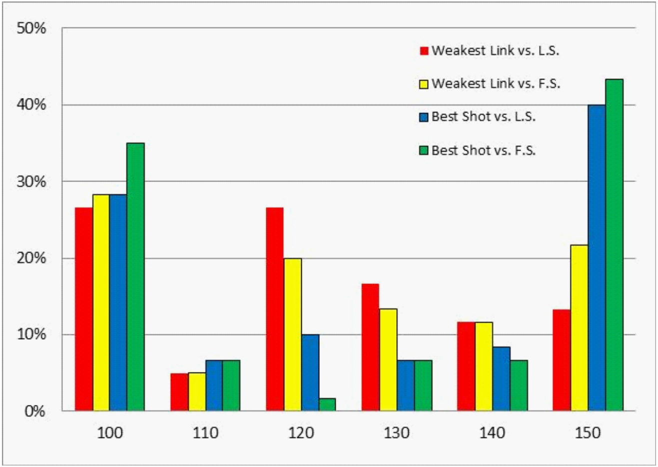
Data Analysis and Results II

Figure: Treatment II - Effort Levels vs. Foreign Opponent



Data Analysis and Results III

Figure: Treatment III - Effort Levels vs. Both Local & Foreign Subjects



Data Analysis and Results IV

Table: Switching Effort Levels between Weakest Link and Best Shot Game

	Treatment I		Treatment II		
Low to High	33	55%	28	46%	Ambiguity-averse
High to Low	15	25%	20	33%	Ambiguity-loving
Constant	12	20%	13	21%	
$\sum$	60		61		

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- For earlier experimental tests of ambiguity in games see, Eichberger, Kelsey, and Schipper (2008), Ivanov (2011), Di Mauro and Castro (2011) or Kelsey and le Roux (2015).

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