Distributional Equity in Climate Change Policy: Responsibility, Capacity, and Vulnerability[1]

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Abstract

Bargaining over the allocation of climate change mitigation costs has proven difficult, as evidenced by repeated failures to reach an international agreement. We argue that any such allocation must take into account a number of important distributional equity factors, especially those related to the distribution of capacities, vulnerabilities and causal responsibilities. Moreover, this bargaining takes place against the backdrop of ever increasing likelihood that failure to reach an agreement will impose significant costs on the parties involved. We introduce a novel and flexible bargaining game that is capable of incorporating all of these factors. Experimental applications of the bargaining game, employing the novel framework, suggest that states with greater relative vulnerability to the effects of climate change have lower bargaining power than their counterparts, and that states with lower capacity to pay for change mitigation correctly anticipate that those with higher capacity to bear a greater share of the costs will do so. The results related to causal responsibility are less clear-cut. More studies are needed to better understand how distributional equity considerations shape climate change negotiations.

Keywords. Climate Change, Equity, Laboratory Experiment, Bargaining

1 Introduction

There is little doubt that global climate negotiations have thus far failed to achieve an effective international agreement on how the burden of climate change mitigation will be shared across countries. This is in large part because negotiating positions are characterized by a number of distinct but interrelated equity considerations that complicate its resolution. Furthermore, this bargaining takes place against the backdrop of ever increasing likelihood that failure to reach an agreement will make catastrophic climate change more likely and therefore will impose significant costs on the parties involved. Thus, current bargaining models cannot adequately capture bargaining in this context.

Broadly speaking, with respect to bearing the costs of climate change mitigation efforts, three general equity principles emerge: "ability to pay," "polluter pays," and "beneficiary pays" (Hayward 2012). The three principles differ in their implied distributional criterion for cost-sharing in climate change mitigation. These criteria are, respectively, concerned with the distribution of resources to pay for climate change mitigation (*capacity*), the distribution of causal *responsibility* for climate change, and the distribution of effects of climate change (*vulnerability*). Because of the direct link between historical emissions, current wealth levels and the severity of anthropogenic climate change, the distributional criteria are all endogenous to one another, and therefore it is difficult to estimate their effects using observational data, even if such data were available.

Any attempt to behaviorally measure distributional preferences in climate change mitigation policy must be able to disentangle the interdependent nature of these criteria. In this paper, we introduce a novel bargaining game framework that is flexible enough to take into account the interdependencies and operationalize the notion of increasing loss probabilities associated with failed bargaining attempts. The framework allows us to operationalize and behaviorally measure norms that relate to these three important distributional equity factors surrounding anthropogenic climate change and its mitigation. We investigate how changes in the parameter values of these three important distributional factors lead to behavioral changes in an incentivized laboratory experiment.

The structure of the paper is as follows. Section 2 presents out theoretical framework and how it builds on previous research. Section 3 presents our experimental design and Section 4 presents our initial results. Section 5 concludes by highlighting the core contributions of the paper and suggests extensions for future work.

2 Theory

2.1 Collective risk social dilemma

The collective risk social dilemma (CRSD) has traditionally been used in behavioral economics to model climate change mitigation behavior (Milinski et al. 2008, Dreber & Nowak 2008). It is a threshold public goods game of loss avoidance: players are randomly assigned to small groups and exogenously endowed with an initial wealth level, portions of which can be contributed—over multiple periods—toward an exogenously given threshold value. If the group's collective contributions meet or exceed this threshold, the group avoids a collective loss of earnings and each member retains the un-contributed remainder of their endowment. If the group's collective contributions fail to reach the threshold value, the members face some exogenous and known probability of climate change-induced "catastrophic loss" (loss of the entirety of their retained earnings). The social dilemma arises, as in all public goods games, from the incentive to free-ride on the contributions of others in hopes that one's group will meet the threshold through the contributions of others.

Capacity, in the form of wealth inequalities, has been explored in a CRSD framework, using both behavioral game theory and computational simulation Wang et al. (2010), Milinski et al. (2011), Tavoni et al. (2011), Burton-Chellew et al. (2013), Vasconcelos et al. (2014), Abou Chakra & Traulsen (2014). Kline et al. (2014) introduce endogenous (causal) responsibility into the CRSD by making the wealth and the probability of loss endogenous to group extraction levels in a preceding common pool resource game. Differential vulnerability, however, has not yet been incorporated into the CRSD framework.

While these studies have yielded important insights, it is not an ideal model of international climate negotiations as it fails to take into account the offers and counteroffers that underlie international negotiations, including those related to the climate, and therefore makes it difficult to extract revealed preferences over these distinct distributional equity factors. To better model this aspect of climate negotiations, we introduce an alternating offers bargaining model that is akin to a Rubinstein bargaining game. In the standard Rubinstein bargaining game, two players make alternating take-it-or-leave-it offers to split a given amount of money, with the total amount available to split decreasing with each rejected offer. In our variant, pairs of players must bargain over how to split the cost of climate change mitigation between them, with the costs to be paid out of their respective endowments. We incorporate the probability of loss concept from the CRSD into the Rubinstein framework by modeling it as monotonically increasing in the number of rejected offers. We then introduce the three distributional equity criteria—capacity, vulnerability, and responsibility—outlined above into this basic barganing framework. Table 1 describes each of these more explicitly.

Table 1: **Distributional considerations in climate change policy**

Capacity: some countries and populations have more resources with which to combat climate change
Vulnerability: some countries and populations are more vulnerable to the effects of climate change
Responsibility: some countries and populations have a greater responsibility for causing climate change

2.2 Motivations for a new model

To capture the endogeneity of the important distributional considerations of responsibility, capacity and vulnerability, we introduce a new bargaining framework, building on Kline et al. (2014). Crucially, this framework allows us to endogenize the probability of catastrophic economic loss due to anthropogenic climate change that is inherent in international climate negotiations. The possibility of economic loss, though uncertain, casts a shadow over these negotiations, making any related bargaining process fundamentally different than traditional bargaining scenarios. As in real-world climate negotiations, the ever-increasing probability of catastrophic economic loss plays a fundamental role in our model.

2.3 Climate Bargaining Game

The Climate Bargaining Game (CBG) introduced in this paper is a modified version of Rubinstein bargaining. In our variation of the game, players begin the bargaining phase with an initial endowment (which may differ in its source) and they must bargain over how to split the cost of climate change mitigation. If they fail to reach an agreement, then both players may suffer a catastrophic economic loss, i.e., they lose their entire endowments, with some probability. This probability is increasing in the number of rejected offers (the rate of increase is in some cases asymmetric). The CBG allows us to capture the distributional considerations outlined above with just a few parameters, which can be manipulated to shed light on distributional concerns. We implement this new bargaining framework in an incentivized laboratory experiment.

3 Experimental Design and Treatments

A sample of subjects, consisting of students recruited from the general undergraduate population, played variants of the CBG, described in the following sections. Administered over the course of four months, experimental sessions were fully computerized and held at the Center for Behavioral Political Economy at Stony Brook University. Participants were paid a show-up fee in addition to payments from the experiment itself. A summary of subject demographics is provided in Appendix A.[1]

3.1 General Model

The CBG has three parts: the distribution of initial wealth; the determination of the cost of climate change mitigation; and the bargaining phase with alternating offers and uncertainty with respect to catastrophic loss. We are able to isolate each of the key distributional equity factors by manipulating parameters across a number of distinct treatment conditions.

All treatments begin with two randomly and anonymously matched subjects, Player A and Player B. Each player is either exogenously or endogenously endowed (depending on the treatment) with initial endowment levels, π. The players' initial endowment levels are common knowl-

[1] Across treatments, the distributions of subjects' gender, age, and political affiliations are similar. Additionally, subjects hold similar opinions on direction and magnitude of the effects of global warming.

edge. After the initial endowment is awarded, the cost of mitigation, $\Omega = \delta(\pi_A + \pi_B)$ is determined, and the players then bargain, using alternating offers, over how to split this cost between them. In all treatments, players are randomly re-matched for a total of 8 matches. After each rejection, there is some positive probability–p–that each player in the pair loses the entirety of their endowment. p is increasing after each rejection.

In all treatments, Player A makes the first offer, $\theta_1 = \{\omega_{A_1}, \omega_{B_1}\}$, where ω_i is the cost borne by player i, $i = \{A, B\}$. The strategy space is all non-negative integers such that $\omega_{A,\theta_1} + \omega_{B,\theta_1} = \Omega$. B can either accept or reject θ_1. In case of acceptance, each player pays their respectively agreed upon portions of the costs of climate change mitigation—ω_{i,θ_1}—and each player's payoff is $\gamma_i = \pi_i - \omega_{i,\theta_1}$.

In the event of rejection, the game will continue with a probability of q (in all conditions, $q = 0.75$). If the first draw from the continuation probability distribution dictates that the game ends, then each player's expected payoff is $\gamma_i = p_t * \pi_i$, where p_t is the probability of catastrophic economic loss after the t'th rejection.

If the game continues, Player B is then able to make a counter-offer, $\theta_2 = \{\omega_{A_2},\ \omega_{B_2}\}$, and then A is given the opportunity to accept or reject θ_2. The procedures for and consequences of acceptance and rejection are the same as in the first round, with the exception of the value of p_t. This parameter, p_t, where t is the tally of rejected offers, is a key feature of our design. This is the potential catastrophic economic loss that is projected to result from unmitigated climate change. Thus, such a loss is possible in the CBG as long as no agreement has been reached on splitting the costs of climate change mitigation efforts that would have prevented it. The longer agreement on the distribution of costs to climate change mitigation is delayed, the greater the probability of catastrophic economic loss. Therefore, p_t is a function of the bargaining history. In a particular match, as the tally, t, of rejected offers increases, so does p_t, in that $p_{t+1} = p_t + \varepsilon$. In all conditions, we allow a maximum of eight rejected offers, so $t = [1, 2, 3, 4, 5, 6, 7, 8]$. This monotonically though ε can change across conditions and players, it is always positive, and therefore the probability of loss is always monotonically increasing in the number of rejected offers, which captures a crucial feature of real-world climate negotiations.

With manipulations of π_i, such that $\pi_A > \pi_B$ we operationalize differential **capacity**, whereas manipulations of p_{1A}, p_{1A}, ε_A and ε_B such that $p_{1A} < p_{1B}$ and $\varepsilon_A < \varepsilon_B$ represents increased **vulner-**

ability for Player B. We incorporate causal **responsibility** by allowing Players A and B to choose their own endowments, π_i, with the cost of mitigation increasing in $\pi_A + \pi_B$. Next we describe each of these manipulations in detail.

3.2 Treatments

3.2.1 Baseline

We are interested in the effects of our manipulations of p, ε, Ω and π, which result in asymmetries in capacity, vulnerability and responsibility between Players A and B. The baseline (*BL*) treatment gives us a point of comparison in which each of these factors is symmetric and exogenous.

In the case of the **baseline** (*BL*) condition, initial endowments are exogenously determined, such that $\pi_A = \pi_B = 100$. Similarly, δ is also exogenous and equal to 0.5, so the cost, $\Omega = 0.5(100 + 100)$. Under the *BL* condition, Ω is simply stated as an absolute quantity 100. This is necessary because we want to ensure that responsibility and capacity are, in the minds of the players, independent from one another in the *BL* condition and thus we do not want subjects to construe that the level of initial endowments is *causing* an increase in Ω.

The *BL* value for p_1 is exogenous and equal to 0.2. If, for example, all eight possible offers were made and rejected, then $p_8 = 0.9$, and the expected payoffs would be $\gamma_i = 0.9 * \pi_i$. A vector of the probability of catastrophic loss over time for each player under *BL* is $(0.2, 0.3, ...0.9)$. Recall, however, that even if the offer θ_t is rejected in round t, p_t is only activated, if the end of the game is reached, which occurs with probability $1 - q = 0.25$ if an offer is rejected, and probability 1 if θ_t is accepted. If the end of the game is reached due to rejection in round t, the payoffs are $\gamma_i = p_{i,t} * \pi_i$. If the end of the game is reached due to an accepted offer, the payoffs are $\gamma_i = \pi_i - \omega_{i,\theta_1}$.

Next, we describe treatments in which, in which various aspects of the baseline scenario are manipulated in order to isolate these remaining three considerations. All treatments are between-subjects.

3.2.2 Capacity Treatment

The basic **capacity** (*CP*) conditions described here are identical to the *BL* treatments, but we incorporate *capacity* considerations by introducing heterogeneity in π_i such that $\pi_A > \pi_B$. This gives A greater capacity to contribute to climate change mitigation than B. In this case, $\pi_A = 150$ and $\pi_B = 50$. Comparing results from *BL* with *CP* allows us to isolate and measure the effect of *capacity* considerations in climate change mitigation, without being contaminated with the effects of vulnerability or responsibility. This manipulation allows us to isolate the effect of "ability to pay" considerations on bargaining.

3.2.3 Vulnerability Treatment

The basic **vulnerability** (*VN*) conditions described here are similar to the *BL* treatments. Like the *BL* treatment and unlike the *CP* treatments, $\pi_A = \pi_B = 100$. Unlike the previously described treatments, we incorporate *vulnerability* considerations by introducing heterogeneity in p: $p_A > p_B$, implying that A is more vulnerable to the effects of climate change (catastrophic economic loss) than B, and the vulnerability of A increases over time.

In the *VN* conditions, p_{A_1} and p_{B_1} are exogenous and equal to 0.05 and 0.2 respectively. Additionally p_A increases at a faster rate than p_B, such that $p_{A_{t+1}} = p_{A_t} + 0.05$ and $p_{B_{t+1}} = p_{A_t} + 0.1$. Under *VN*, the vectors of the probability of catastrophic loss over time for Player A and Player B respectively are $(0.05, 0.10, ...0.4)$ and $(0.2, 0.3, ...0.9)$. By comparing the *VN* conditions to *BL*, we can determine what weight the subjects place on the distribution of *vulnerability* to the impacts of climate change. This manipulation allows us to isolate the effect of the "beneficiary pays" principle on bargaining.

3.2.4 Capacity - Vulnerability Treatment

To assess the relative impacts of the *CP* treatment and the *VN* treatment, we designed a capacity - vulnerability *CP-VN* condition, which combines the endowments parameters of *CP* with the loss probability parameters of *VN*. As in the case of the *CP* treatment, $\pi_A = 150$ and $\pi_B = 50$ such that $\pi_A > \pi_B$. Additionally, as in the case of the *VN* treatment, the vectors of the probability of catastrophic loss over time for Player A and Player B respectively are $(0.05, 0.10, ...0.4)$ and $(0.2, 0.3, ...0.9)$. Combining the capacity and vulnerability conditions in this way allows us to observe interactions between the capacity and vulnerability treatments (*CP-VN*) when compared against the *BL* conditions. Subjects' reactions to both treatments and the relative weights of each treatment are compared with both *BL* conditions and the individual administration of each treatment.

3.2.5 Responsibility Treatment

To capture *responsibility* considerations in the CBG framework, we allow π_i to be endogenously created, therefore affecting Ω because $\Omega = \delta(\pi_A + \pi_B)$. As in the *BL* conditions, $\delta = 0.5$. In these **responsibility** *RS* conditions, the subjects, with full knowledge of the the function that determines Ω, will be allowed to each extract an amount from a common pool resource, Π. The strategy space is: $\pi_i \in [\pi_i^{min}, \pi_i^{max}]$, where $\pi_i^{min} = 0$ and $\pi_i^{max} = \frac{\Pi}{2}$. The *RS* parameters were $\Pi = 200$. In all other respects, *RS* conditions are identical to *BL*. This single manipulation allows us to compare the results of the *RS* conditions with the *BL* conditions therefore isolating the role of responsibility, and allowing us to investigate the effect of the "causal responsibility" factor on bargaining strategies.

3.2.6 Responsibility - Vulnerability Treatment

To further understand the effects of *RS*, we combine it with *VN*. The **responsibility - vulnerability** *RS-VN* treatment has an endogenously created π_i [2] alongside *VN* conditions, wherein the vectors of the probability of catastrophic loss over time for Player A and Player B respectively are $(0.05\ 0.04\ ...0.4)$ and $(0.2\ 0.3\ ...0.9)$. A summary of the treatments and the dates on which they were administered is provided in Table 2.

[2] Subjects still have full knowledge of extraction amounts and the function determining the cost.

Table 2: Treatments and Dates Administered

Treatment	**Date Administered (2015)**	π	**p**
BL	April 15 April 28 April 29	$100/100$	$p_A =$ (0.2, 0.3, ...0.9) $p_B =$ (0.2, 0.3, ...0.9)
CP	June 9 June 11	$150/50$	$p_A =$ (0.2, 0.3, ...0.9) $p_B =$ (0.2, 0.3, ...0.9)
VN	June 11 June 17	$100/100$	$p_A =$ (0.05, 0.1, ...0.4) $p_B =$ (0.2, 0.3, ...0.9)
CP-VN	June 17 June 18	$150/50$	$p_A =$ (0.05, 0.1, ...0.4) $p_B =$ (0.2, 0.3, ...0.9)
RS	June 30 July 8 July 9	$\pi \in [1:100]$	$p_A =$ (0.2, 0.3, ...0.9) $p_B =$ (0.2, 0.3, ...0.9)
RS-VN	June 30 July 21 July 22	$\pi \in [1:100]$	$p_A =$ (0.05, 0.1, ...0.4) $p_B =$ (0.2, 0.3, ...0.9)

3.3 Hypotheses

We expect subjects to make and accept offers based on the manipulated values of a given treatment's parameters. Generally speaking, given the symmetry of the scenario under *BL*, we expect more successful bargaining outcomes and less divergence between the offers of Players A and B. When asymmetries are introduced—as in *CP*, *VN*, etc.—bargaining should become more contentious as the bargaining focal point is no longer salient. This should result in fewer successfully concluded cost-splits. This asymmetry should also result in greater divergence between the offers and Player A and Player *B*.

We consider the following hypotheses regarding each player's behavior in individual rounds (i.e., unconditional on previous round offers):

H.**1.** Successful bargaining outcomes:

H.1*a*) The symmetric nature of the scenario creates a focal point for what a "fair" offer would be, and as a result, aside from *RS*, *BL* will have the highest levels of successful bargaining outcomes. Similarly, due to this symmetry and resultant focal point, agreement should be achieved more quickly in *BL*.

H.1*b*) Due to asymmetric capacity and the resulting asymmetric focal point, there will be less success in *CP* relative to *BL*. We expect the player with the greater endowment to cover a higher proportion of the costs. This could occur out of a general sense of fairness, or because opportunity costs for Player A in the event of a loss are greater than opportunity costs for Player B, and since the probability of loss increases across rounds, Player A would be incentivized to reach an agreement as quickly as possible.

H.1*c*) As a result of asymmetric vulnerability and the strategic advantage it confers to Player A, there will be less success in *VN* as we expect Player A to push this advantage by offering smaller-than-acceptable offers to Player B. In other words, though we expect Player B, because of their more rapidly increasing probability of loss, to cover a higher proportion of the costs, we also expect that Player A might exploit Player B's vulnerability and low-ball the initial offer.

H.1*d*) We expect that when total costs are an explicit and increasing function of endowments, both players will be more willing to pay their share of the costs they created, following the "polluter pays" principle. Thus, relative to *BL*, there will be more success in *RS*.

H.1*e*) Success in the hybrid treatments—*CP-VN* and *RS-VN*—will be a mixture of their constituent treatments. We do not have a prediction as to which factor will predominate.

H.**2.** Divergence in offers between Player A and PlayerB:

H.2*a*) There will be the least divergence in the offers of Player A and Player B in *BL* due to symmetry discussed above. This does not necessarily imply that the offers will be in terms of equal (50-50) splits, but there will be less divergence between offers from the two players.

H.2*b*) The "ability to pay" principle would imply that in *CP*, relative to *BL*, Player A should make larger offers. This could occur, however, not just out of a general sense of fairness, but also because opportunity costs for Player A in the event of a loss are greater than opportunity costs for Player B, and since the probability of loss increases across rounds, Player A would be incentivized to reach an agreement as quickly as possible.

H.2*c*) Relative to *BL*, in *VN* offers by Player A will be lower and offers by Player B higher. We expect this since Player A may anticipate Player B's incentives to accept a comparatively lower offer. Given their vulnerability, B benefits more from any agreement, and therefore could be expected to pay more under the "beneficiary pays" principle.

H.2*d*) Consistent with the "causal responsibility" principle, and relative to *BL*, *RS* offers by Player A and by Player B should be more proportional to the size of their endowment.

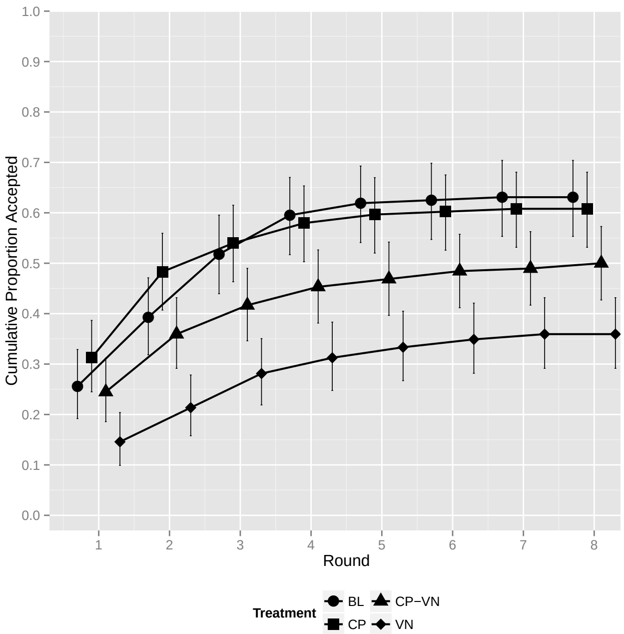
H.2*e*) Offer divergence in the hybrid treatments—*CP-VN* and *RS-VN*—will be a mixture of their constituent treatments. Based on the discussion above, we would expect two competing effects. In *CP-VN*, Player A, having a greater endowment, may offer to cover a greater proportion of the costs; however, since Player A's probability of loss increases only gradually, we may expect Player A to make less generous offers than in *CP*, since Player B may be more willing to accept a lower offer given his/her increasing probability of loss as the game continues. In *RS-VN*, Player B, whose probability of total loss increases over rounds, may choose a lower endowment to incentivize Player A to end the game earlier and make a more generous offer concerning costs.

H.**3.** Under *RS*, players may both choose the maximum possible endowments. In the cases where both select similar levels of endowments, players may extend the game to a greater number of rounds than if the players choose different levels of endowments. In cases where one player selects a lower endowment, his/her opponent may agree to cover a relatively higher proportion of the cost – perhaps an even greater proportion than in the case with both players exogenously assigned different initial endowments.

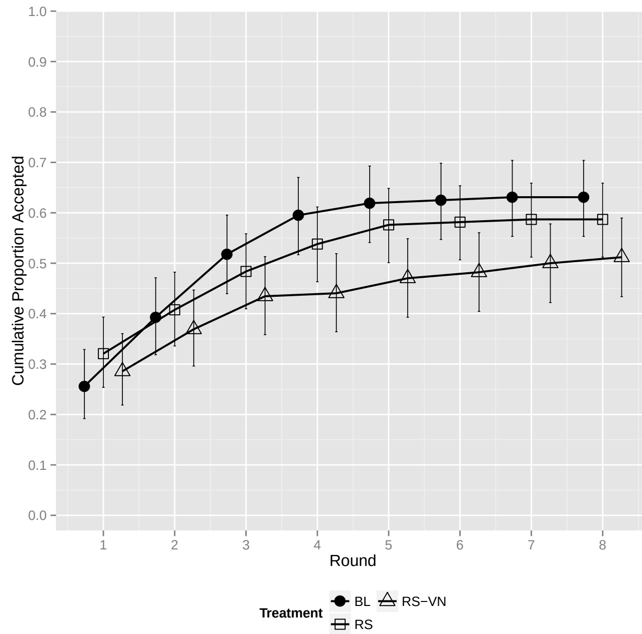
4 Results

4.1 Successful Negotiation of Cost-Splitting

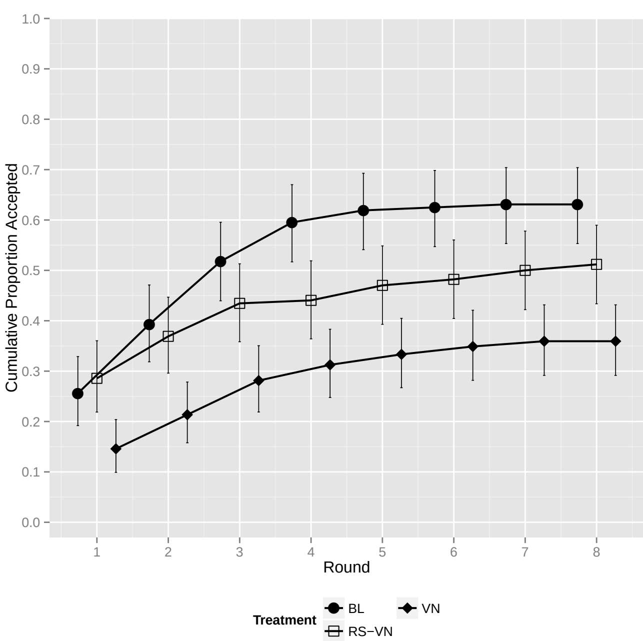
We first investigate the conditions under which successful negotiation (i.e. cost-splitting) is most likely. Figure 1 below summarizes the proportion of cumulative offers accepted over rounds under each treatment.



(a) Exogenous Endowments - Plot of Cumulative Acceptance per Round



(b) Endogenous Endowments - Plot of Cumulative Acceptance per Round



(c) Uneven Probability Treatments - Plot of Cumulative Acceptance per Round

Figure 1: Cumulative Proportion of Acceptances Across Rounds

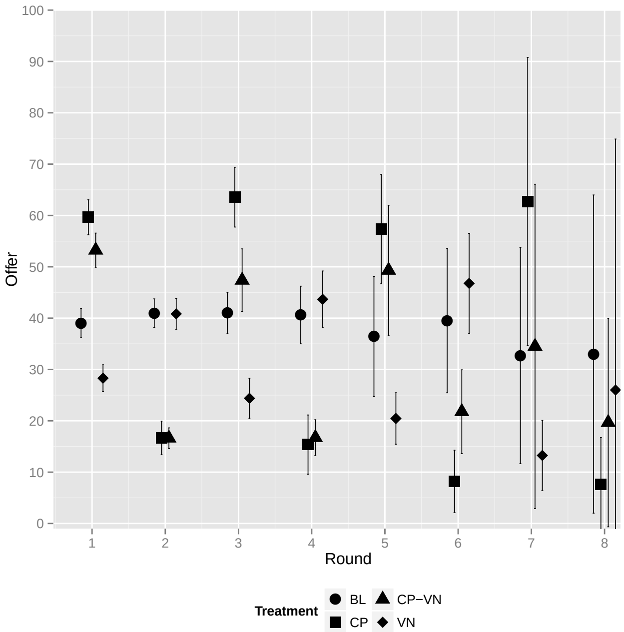
The cumulative success rates in figure 1a are consistent with H.1*a*), with *BL* demonstrating the highest proportion of successful bargaining outcomes, a roughly 60% success rate. Contrary to H.1*b*), *CP* is characterized by a virtually identical overall success rate compared to *BL*. Consistent with H.1*c*), the *VN* treatment results in the lowest proportion of cumulative acceptances over rounds. Consistent with H.1*e*), the *CP-VN* treatment results in a cumulative acceptance rate that falls almost exactly at the midpoint between those of the *CP* and *VN* treatments.

Figure 1b highlights the similarities between the *BL* and the *RS* treatments. In most matches in the *RS* treatment, both participants selected endowments of 100 (see figure 3), so the relative similarity between cumulative acceptance rates under the *BL* and *RS* treatments is expected and consistent with hypothesis H.1*d*). In cases where one player selects an endowment lower than the other, we would expect patterns similar to those exhibited under the *CP* treatment. Consequently, we find that *RS* appears to incorporate players behaving in a manner predominantly consistent with the *BL* treatment but moderated by some pairs exhibiting behavior associated with the *CP* treatment. The *RS-VN* treatment incorporates elements of the *VN* treatment, and therefore results in a lower proportion of successful negotiations as rounds progress. Per Figure 1c, the effect is not as pronounced under the *RS-VN* treatment as it is under the *VN* treatment, but the patterns and changes in the proportion of accepted offers per round is similar nonetheless.

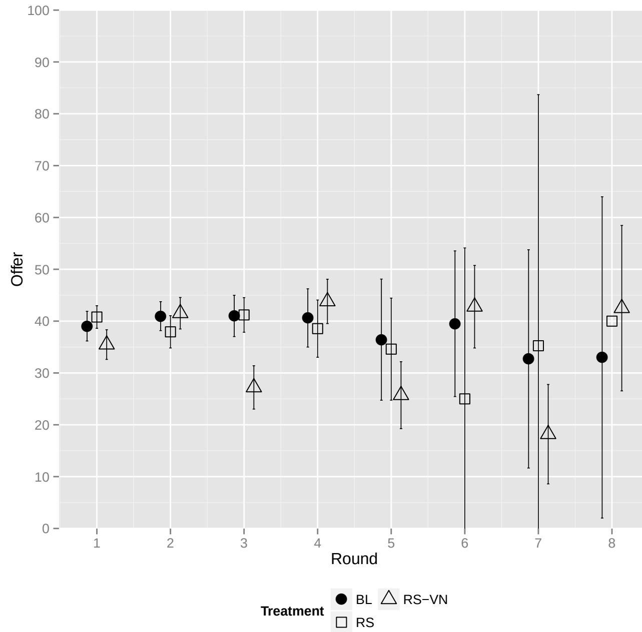
Next, we provide a summary of observed trends in offers and counteroffers for Players A and B. When considering the treatments, for the sake of simplicity, we first evaluate each player's behavior in rounds, unconditional on the opponent's behavior in previous rounds. In this context, we begin to assess the theoretical predictions outlined in Section 3.3. Then, we consider subject behavior conditional on opponent offers and counteroffers in previous rounds. This consideration allows us some preliminary measurements on subjects' reactions to opponent offers. It also helps us explain differences in successful negotiation across treatments.

4.2 Trends in Offers

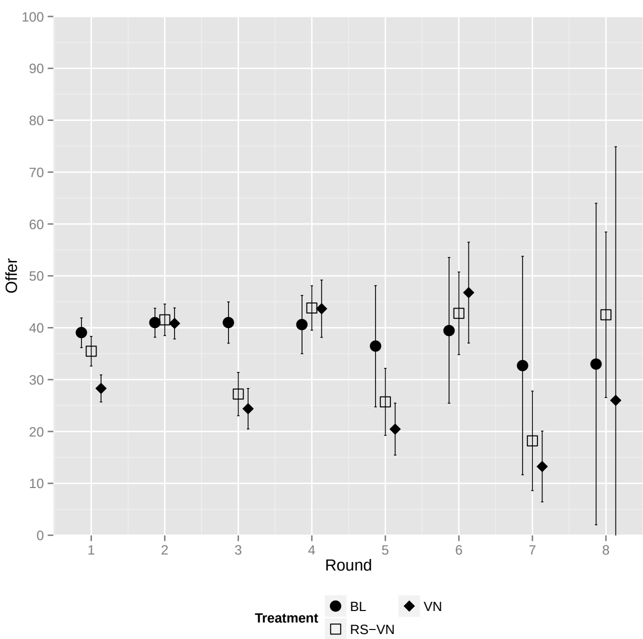
Figure 2 considers average offers made by Players across rounds and matches, distinguishing between treatments.



(a) Exogenous Endowments - Mean Plot of Offers per Round



(b) Endogenous Endowments - Mean Plot of Offers per Round



(c) Uneven Probability Treatments - Mean Plot of Offers per Round

Figure 2: Average Offers Across Rounds

Figure 2a considers cases in which endowments were exogenously determined (i.e., *BL*, *CP*, *VN*, *CP*-*VN*).[3] Focusing on the offers made by Players A and B *BL*, we find that both players make offers that begin around 40 and slightly decrease over rounds. There is, however, little divergence between offers from *A* and *B*, which is consistent with H.2*a*).

Second, focusing only on Player A's first proposed offer to Player B (i.e., the offer in round 1) and Player B's first proposed offer to Player A (i.e., the offer in round 2), we find that, compared to *BL*, in *CP* Player A makes greater average offers, and B makes smaller average offers. This greater divergence between the two offers supports H.2*b*). Conversely, in *VN*, when less vulnerable to losing her endowment, Player A makes relatively low offers compared to offers under the *BL* treatment, whereas *B* makes relatively greater offers. This divergence between the offers is consistent with hypothesis H.2*c*).

With respect to the *CP*-*VN* treatment, we expect two competing effects, with the vulnerability element of the treatment suggesting that Player A would make comparatively lower offers than the *BL* case, and the capacity element of the treatment suggesting that Player A would make comparatively higher offers. As shown in Figure 2a, the *CP*-*VN* case more closely resembles the outcomes associated with *CP*, though the variation in means across rounds is somewhat attenuated. The tendency of the *CP*-*VN* treatment to resemble a muted version of the *CP* treatment suggests that the treatment incorporates both the *CP* effect wherein Player A makes comparatively higher offers to Player B, and the *VN* effect wherein Player A makes comparatively lower offers to Player B. This shows that while the behavior in this hybrid treatment is a convex combination of its two constituent factors, and therefore consistent with H.2*e*), the data clearly show that the effect of *CP* predominates.

Next we provide a similar set of results for the endogenous endowment treatments in Figure 2b (*RS* and *RS*-*VN*). Examining trends in offers under *RS* and *RS*-*VN* allows us to detect any effects that occur when endowments are endogenously selected. The endogenous responsibility treatments explicitly model the link between the wealth of nations and the cost of climate change mitigation. In addition to further understanding the impact of responsibility on bargaining, we consider whether *VN* effects interact with the *RS* treatment.

[3] As expected, 95% confidence intervals for the mean become wider over the progression of rounds, due to pairs reaching a successful agreement.

Though, compared to *BL*, in *RS* there is somewhat greater divergence between the offers of *A* and *B*, the divergence is not pronounced. This is consistent with hypothesis H.2*d*). In the *RS-VN* treatment, Player A makes lower offers to Player B, but the differentiation is less pronounced than offers made by Player A to Player B in the *VN* case. The comparison can be discerned more easily in Figure 2c. Regardless of the source of the endowments in the the asymmetric vulnerability treatments, the pattern of offers is zig-zagging and nearly identical: the less vulnerable participant offers to pay a small share of the cost, and the more vulnerable participant responds with a more generous offer. Average offers by the less vulnerable are slightly decreasing over time, whereas offers by the more vulnerable are increasing. This reflects the increasing vulnerability of Player B compared to Player A.

As mentioned above, we find that the effects of *VN* on Players A and B are moderated in cases where players select their own endowments. This suggests that *RS* cases and its variants decrease Player A's leverage over the more vulnerable Player B. Whereas it is also possible that Player B may make lower endogenous selections as an alternative mechanism to "concede" to Player A in exchange for its vulnerability, this does not appear to be the case, as shown in Section 4.3.

4.3 Additional Evaluation of *RS* and *RS-VN* Conditions

The *RS* and *RS-VN* cases differ from the other four treatments in that each player in each match can choose their own endowment – from 0 to 100 units – and this choice, in turn, affects the cost of mitigation.

As an additional analysis , we consider the endowments selected by both players across *matches*. Whereas previous plots differentiated between offers across rounds, the following plot segments offers across matches. Evaluating offers across matches may illustrate players' behavior as they "adapt" or "practice" strategies. Such adaptation has practical relevance. As the salience of climate change mitigation increases, states are likely to repeatedly bargain with one another over mitigation costs. If the frequency of negotiations increases, the characteristics of states (in our model, the parameters) are likely to remain between negotiations. Consequently, the short-run adaptation that is likely to occur can be observed by analyzing strategies across matches under the same treatments. Under the *RS* and *RS-VN* conditions, the only difference between subjects' selection of initial endowments across matches is their level of experience. Both cases therefore offer a measure of comparison across matches that is affected only by previous experience.

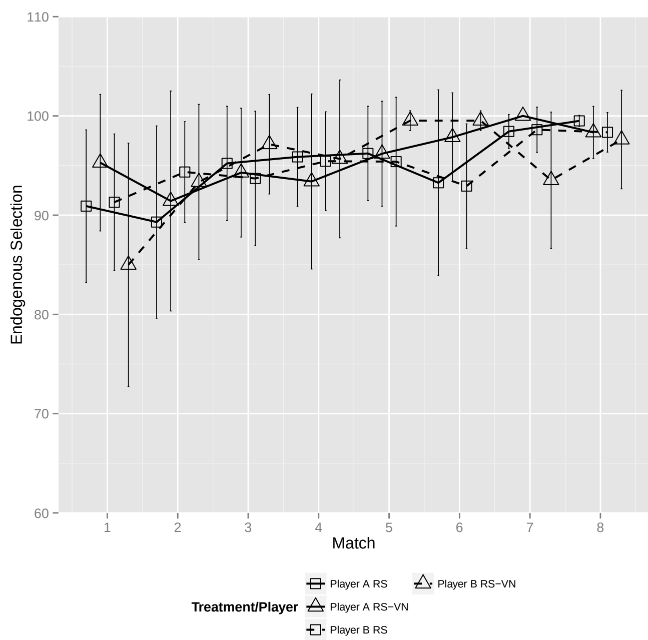


Figure 3: Endogenous Endowment Selections Across Matches

As shown in Figure 3, Player B does not appear to select lower endowments than Player A under the *RS-VN*. This suggests that Player B does not take any steps to appease Player A through the selection of a lower endowment, even when Player B is relatively vulnerable. This is surprising because Player A appears to exercise less leverage over Player B under *RS-VN* as compared to *VN*, as shown in Figure 2c. Additionally, we observe that the standard errors of the mean endowments selected in Figure 3 seem to be high in early matches but then narrow as matches continue, suggesting that players converge around choosing close to 100 as the matches progress.

4.4 Trends in Offers Conditional on Previous Round's Offer

In previous sections, we considered offers and responses aggregated and summarized by round or by match. In this section, we differentiate each interaction between players. Bargaining is not conducted in isolation, and counteroffers are likely conditional on initial offers. In this subsection, we consider: (i) the relationship between offers made by players in consecutive rounds; and (ii) the relationship between an offer made by a player in a particular round, and his/her opponent's tendency to accept or reject the offer.

To capture the relationship between the size of an offer and the likelihood of acceptance, we estimate a series of logistical regressions and conduct simulations plots of the probability of rejection, given a particular offer, under various treatments / cases. Below, we present the results of a regression of the probability of rejection on the amount offered by an opponent in a particular round (round *n*) and treatment dummy variables.

The benefit of using regressions is threefold. First, regressions allow us to more precisely and easily identify treatment effects, how the treatment effects differ across rounds, and the statistical significance of any treatment effects. Second, the regression provides insights on the interaction between treatments and the incremental effect of a one-unit change in offers on the probability of rejecting the offer. Bargaining under certain treatments may be more sensitive than under others. Finally, the regression provides the basis for simulating the probability of rejecting offers under different treatment conditions. The simulation more intuitively outlines the differences across treatments in players' sensitivities to offers. The following table presents results of the regression for the first three rounds.

Table 3: Case 1: Simple Regression of Rejection on Conditions Across Rounds

	Probability Rejected		
	Round 1	Round 2	Round 3
	(1)	(2)	(3)
Offer	-0.105^{***}	-0.246^{***}	-0.297^{***}
	(0.030)	(0.080)	(0.107)
CP	-1.578	-10.840^{***}	-4.983
	(1.640)	(3.877)	(5.953)
VN	5.044^{**}	-7.704^{*}	-9.982^{*}
	(2.510)	(4.166)	(5.234)
CP-VN	-0.938	-9.406^{**}	-10.075^{*}
	(1.635)	(3.908)	(5.330)
RS	-2.298	-7.556^{*}	-10.259^{*}
	(1.607)	(4.267)	(5.593)
RS-VN	-0.119	-7.738^{*}	-9.250^{*}
	(1.776)	(4.203)	(5.410)
Offer x CP	0.054^{*}	0.185^{**}	0.180
	(0.033)	(0.082)	(0.114)
Offer x VN	-0.111^{**}	0.187^{**}	0.211^{*}
	(0.054)	(0.086)	(0.110)
Offer x CP-VN	0.045	0.153^{*}	0.248^{**}
	(0.033)	(0.085)	(0.109)
Offer x RS	0.044	0.164^{*}	0.226^{*}
	(0.035)	(0.090)	(0.117)
Offer x RS-VN	-0.010	0.176^{**}	0.190^{*}
	(0.039)	(0.087)	(0.115)
Constant	5.693^{***}	12.505^{***}	14.498^{***}
	(1.407)	(3.856)	(5.136)
N	1,080	579	378

$^{*}p < .1$; $^{**}p < .05$; $^{***}p < .01$

We find statistically significant coefficients that align with the conclusions from the figures above. The negative coefficient on *Offer* reflects the expected lower probability of rejecting an offer as it increases in value. The negative *Offer* × *VN* coefficient in round 1 suggests that Player B is more sensitive to Player A's offers under *VN* conditions which, as we noted earlier, is likely due to lower initial offers made by Player A. Conversely, the coefficient in round 2 is positive, suggesting that Player A is less sensitive to Player B's offers under this condition compared to the *BL* conditions.

The *CP* condition appears to make Player B mildly more sensitive to Player A's offer, but Player A significantly more sensitive to Player B's offer. This is in accordance with our observation that Player B likely makes smaller concessions to Player A, and so incremental changes in the concessions have a greater impact on Player A's probability of accepting / rejecting offers. The *Offer* × *RS* and *Offer* × *RS-VN* coefficients also suggest that both the *RS* and *RS-VN* treatments decreases sensitivity to offers.

Using the logistic regression presented above, we simulated probabilities of rejection for each treatment in rounds 1 and 2, shown in Figure 4. The most noticeable difference between Player B behavior in relation to the *BL* case under the *CP* and *VN* cases is for offers greater than 40. When Player A holds a greater endowment under *CP* conditions, Player B's probability of rejecting offers remains higher than the baseline, even when Player A makes offers between 50 and 100. Conversely, the probability of Player B rejecting Player A's offer in the under *VN* conditions substantially decreases by around 80 percentage points between offers of 40 and 60.

Under *CP-VN*, the behavior associated with differences in *capacity* appears to overwhelm behavior associated with differences in *vulnerability*. This may, however, simply be due to the comparative degree by which we chose to vary our parameters under the *VN* and *CP* cases compared to the *BL* case.

Whereas, under *BL* conditions, Player B is more sensitive to changes in Player A offers between 40 and 60, the simulation of the endogenous *RS* case suggests that the Player B reacts more consistently to changes in Player A's offers, regardless of the value of Player A's offer. This is reflected in the more linear pattern of the treatment in the fourth panel. Under *RS-VN*, simulated in the fifth panel, changes in sensitivity based on the initial offer reemerge. The simulation under the *RS-VN* treatment is similar to that under *BL*. As Player B becomes more vulnerable, he/she also becomes more sensitive to changes in Player A's offers when Player A's initial offer falls between 40 and 60.

We recognize, however the limitations we face when making inferences with respect to the responsibility conditions. In these conditions, as opposed to the others, there is a prior step whereby each subject is selecting their responsibility level which obviously could be signalling any number of things about the subject's likely negotiation strategy. The virtues of clean identification through randomization in this particular set of designs is thus lessened. Nevertheless, substantively, this is obviously a key component of behavior and hence worth investigating.

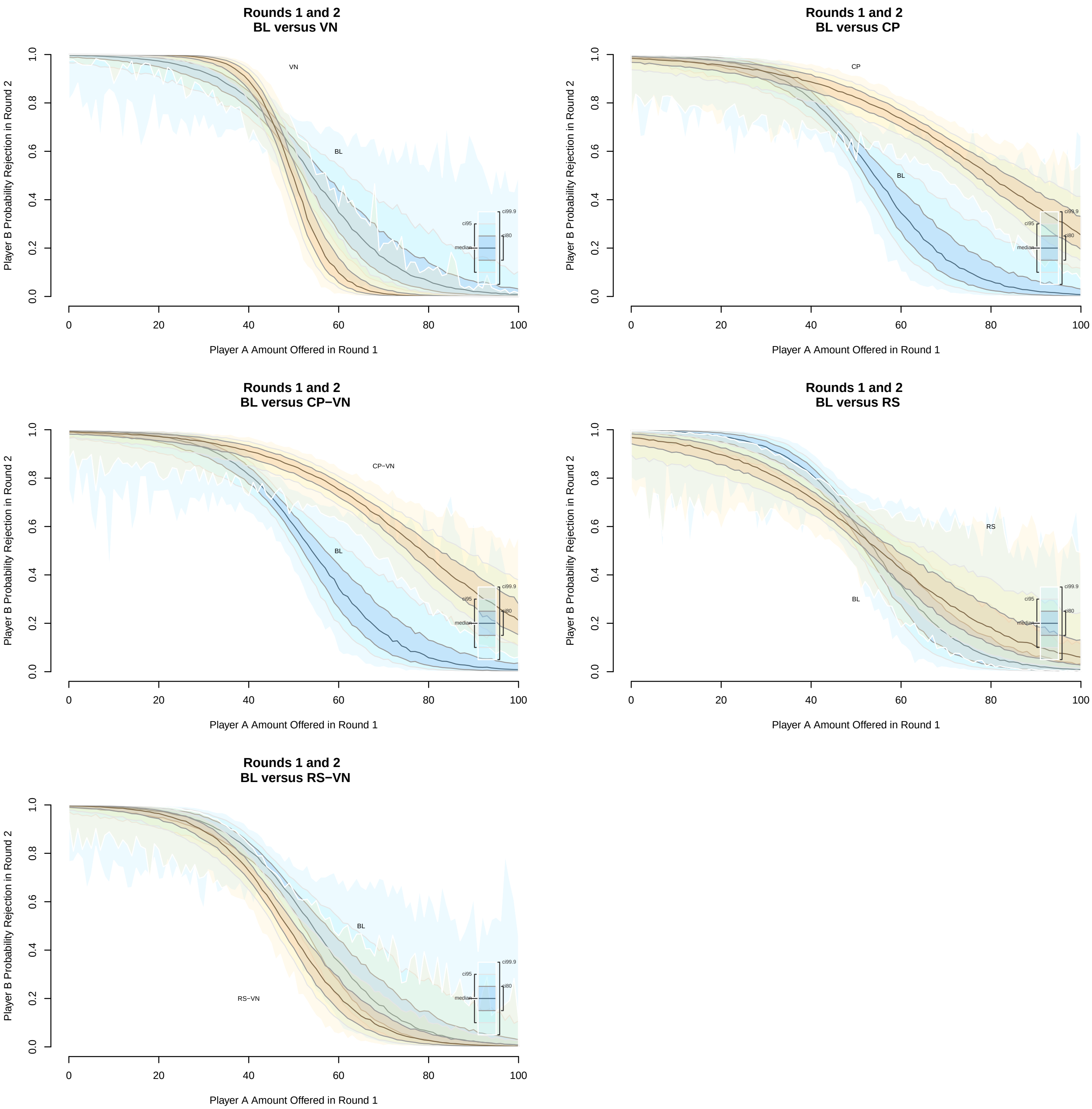


Figure 4: Simulated Probability of Rejecting *A*'s Offer

4.5 Summary of Results

We have investigated three important distributional equity factors within the context of bargaining over paying the costs of climate change: capacity, responsibility and vulnerability. In particular, we analyzed their effects on bargaining success and the relative size of offers.

In terms of successful bargaining outcomes, we observe the most success in the *BL*, *CP* and *RS* treatments, with each ultimately resulting in about 60% of the matches successfully splitting the mitigation costs. The *VN* treatment is characterized by the least amount of success with bargaining success occurring in roughly 35% of all matches. The two treatments that mix *VN* with another factor—*CP-VN* and *RS-VN*—fall in between these two extremes, with about 50% success rates.

Thus, overall, it appears that differential vulnerability makes the bargaining process more contentious, with the less vulnerable party attempting to leverage their advantage, and the more vulnerable party refusing to be taken advantage of to such a great extent, but still willing to make larger offers than in *BL*. This can be seen in figure 1a in the zig-zagging patterns of offers, with Player A's offers always below the baseline from *BL* and Player B's offers always above. On the other hand, the introduction of asymmetric endowments (capacity) seems to have little effect on bargaining success, with success rates in *BL* and *CP* virtually identical.

In terms of average offers—where we focus mostly on the first four rounds given the small number of observed offers after that point—Player A's offers seem to be driven up by the *CP* factor, driven down by the *VN* factor, and mostly unaffected by the *RS* factor. As a result, *A*'s offers are highest in *CP*, somewhat lower in *CP-VN*, and lower again in *BL*. Offers in *RS*, however are not lower than those in *BL*, but are larger than in both *RS-VN* and *VN*. Player B's offer levels are mostly unaffected by the treatments. The average offers in *BL*, *VN*, *RS*, and *RS/VN* are largely the same. Not surprisingly, given *B*'s smaller endowment in the *CP* and *CP-VN* treatments, it is in those that *B*'s offers are substantially lower relative to the other four treatments.

5 Discussion

The experiment outlined in this paper provides "public" preferences for distributional equity in climate change mitigation. The model's framework and conclusions could also be applied to understanding the effect of such preferences on the behavior of elites involved in climate change negotiations. One way is through the bottom up institutions of public opinion affecting elites Bechtel & Scheve (2013), Tingley & Tomz (2014). Further studies could combine representative survey experiments with behavioral games, as suggested in Mutz (2011, , chapter 5). Even to the extent that the elite act without consideration of public preferences, there is some evidence that behavior in student samples does not substantially differ from that in samples of elites (Hafner-Burton et al. 2014).

The experiment also provides a basis for endogenously incorporating distributional criteria in a bargaining model. Whereas capacity has been explored independently the context of the CRSD (Wang et al. 2010, Milinski et al. 2011), this model builds on the work of Kline et al. (2014), partially capturing the endogenous effects of capacity, vulnerability, and responsibility. Additional experiments could build upon this model to assess the effects of other endogenous variables, such as interaction between countries through trade restrictions and/or sanctions on high-carbon energy sources. Of course, fully characterizing standard equilibrium behavior analytically remains a goal in order to establish a benchmark. This could help enable extensions that admit of behavioral considerations like fairness that may be relevant both in our experiment and in the context of actual international negotiations. Finally, an additional research trajectory is understanding subject behavior when the bargaining problem is a) framed explicitly in terms of climate change (the experiment presented here was framed in an abstract way), b) admits the role of moderating variables that may generate heterogenous treatment effects and/or c) an interaction between (a) and (b).

Though we have explored three key equity factors in the context of climate change negotiations, another factor in terms of distributional equity in climate change mitigation is that of intergenerational responsibility. This has been explored in the context of a CRSD Jacquet et al. (2013). This factor could be especially interesting when combined with those that we have explored here. For example, much of the causal responsibility for climate change in the developed world is "inherited" from previous generations, and the benefits from any agreement, in terms of reduced vulnerability, will mostly accrue to future generations. Inter-generational concerns are difficult to operationalize in an experimental context, but doing so within the context of our bargaining framework could yield additional insights into the impasse we observe in international climate negotiations.

An important policy implication of our data is that negotiations could be more successful if the media and negotiators highlighted the difference in economic capacity across countries and downplayed the differences in vulnerability in climate change. Our results indicate that differences in vulnerability cause the less vulnerable parties to attempt to exploit the more vulnerable parties by lowballing their offers. Rather than being nudged toward cooperation by their greater vulnerability, the more vulnerable parties reject offers that they perceive to be unfair.

it is a little difficult for our us to reach any strong conclusions about our *RS* and *RS-VN* treatments. Due to an artifact of our design, choosing the maximal endowment is a dominant strategy in these treatments, so the effective endowments in these treatments are virtually identical to those in *BL*, especially in the latter half of the matches. Despite virtually identical endowments and the same asymmetries in the probability of loss, we do observe greater success in the *RS-VN* treatment compared to the basic *VN* treatment. This implies, perhaps, that greater salience of the role that wealth plays in terms of responsibility for climate change could result is in a higher likelihood of reaching agreement in international negotiations. In round 1, we do observe significantly higher offers by Player A in *RS-VN* compared to *VN*. This initial generosity may make the subsequent bargaining less contentious.

We believe that the general bargaining framework we introduce here is as important as any specific finding in this study. The element of bargaining under increasing probability of loss is crucially important in this context, and our study is the first to incorporate this aspect of international climate negotiations into a behavioral model. Still much work remains to be done to fully exploit the flexibility of this general framework.

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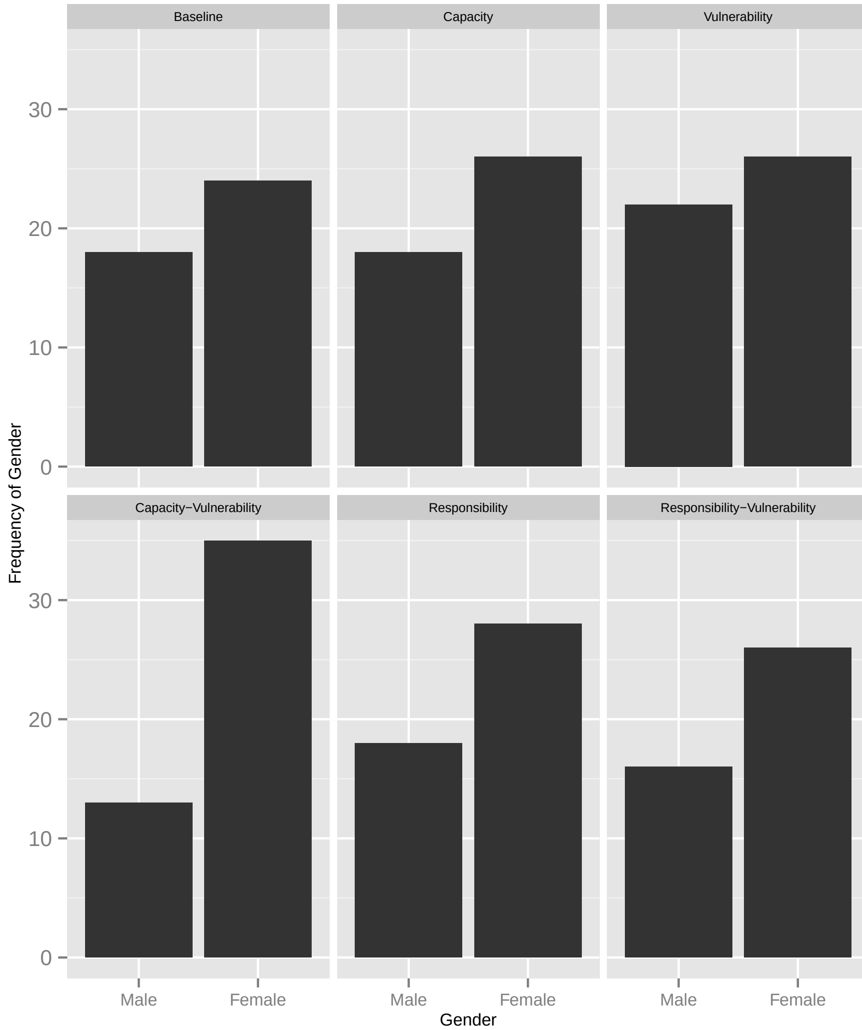

Figure 5: Distribution of Subject Gender

Appendices

A Distribution of Subject Demographics and Opinions

As shown in Figures 5 through 9, the distribution of subject demographics across treatments was similar. Overall, more women than men participated in the experiments, particularly for the uneven probability and endowment treatment. The distribution across ages was also similar. As expected in the case of average undergraduates, most subjects across the treatments were concentrated between ages 20 and 22. Per Figures 7 through 9, subjects were generally twice as likely to affiliate with the Democratic party as the Republican party (in the case of the uneven probability endowment, nearly three-times as likely) and found global warming to be a realistic threat.

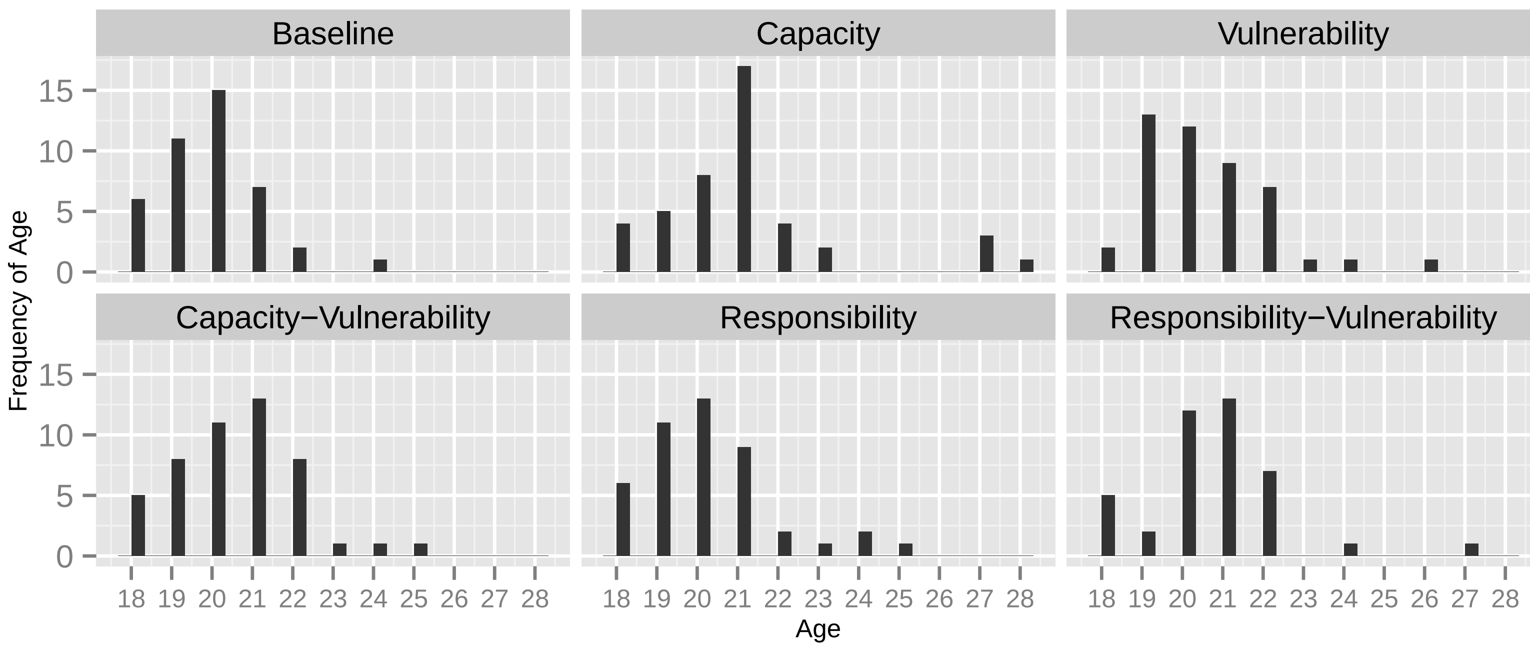

Figure 6: Distribution of Subject Ages

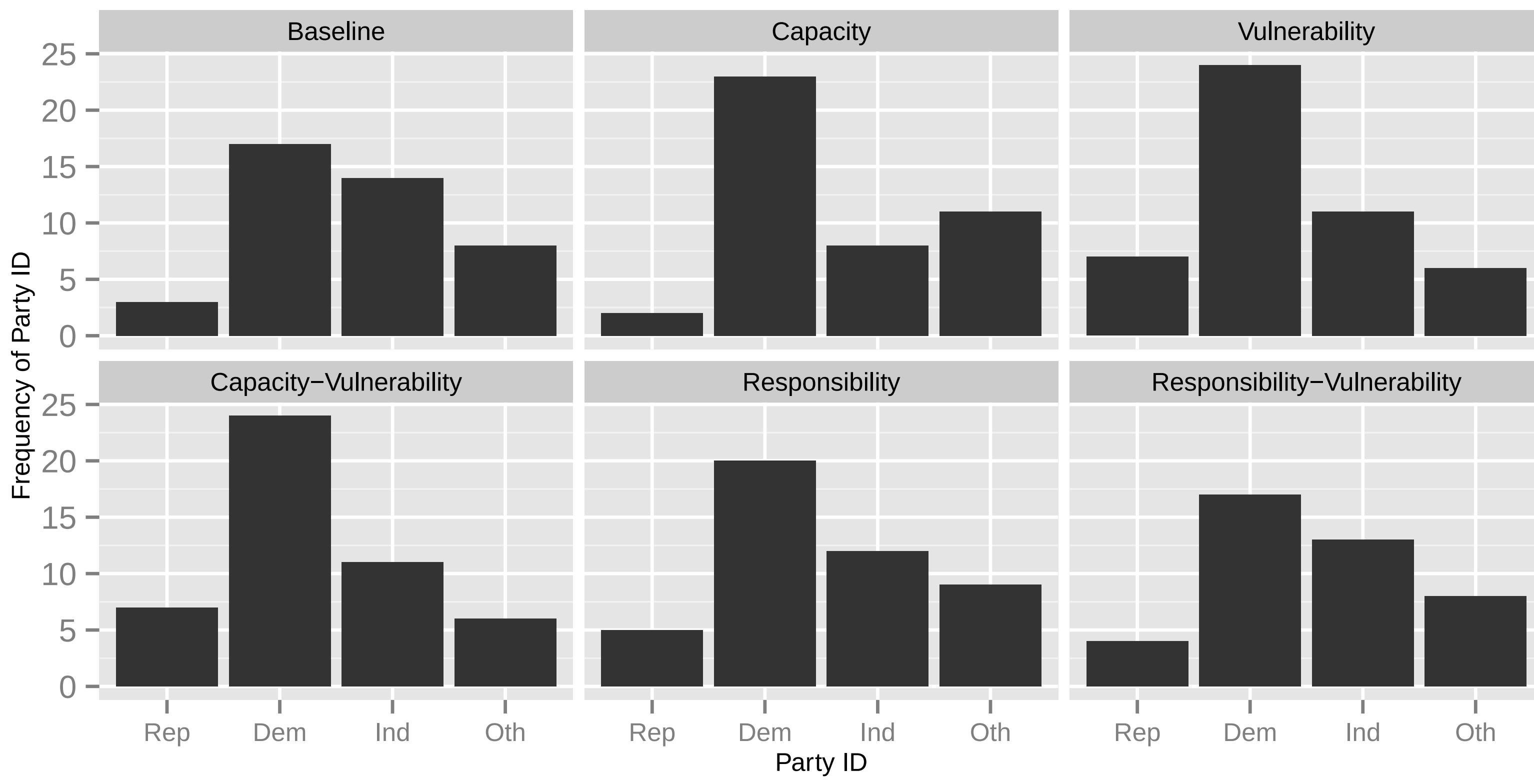

Figure 7: Distribution of Subject Party

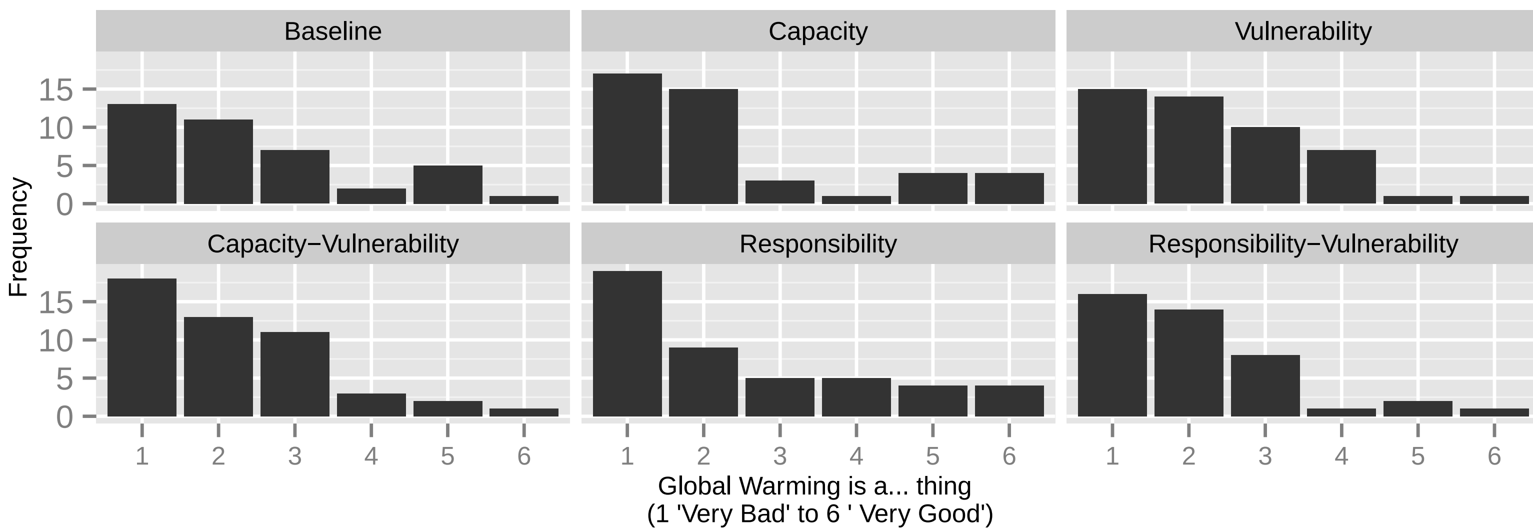

Figure 8: Distribution of Effects of Global Warming

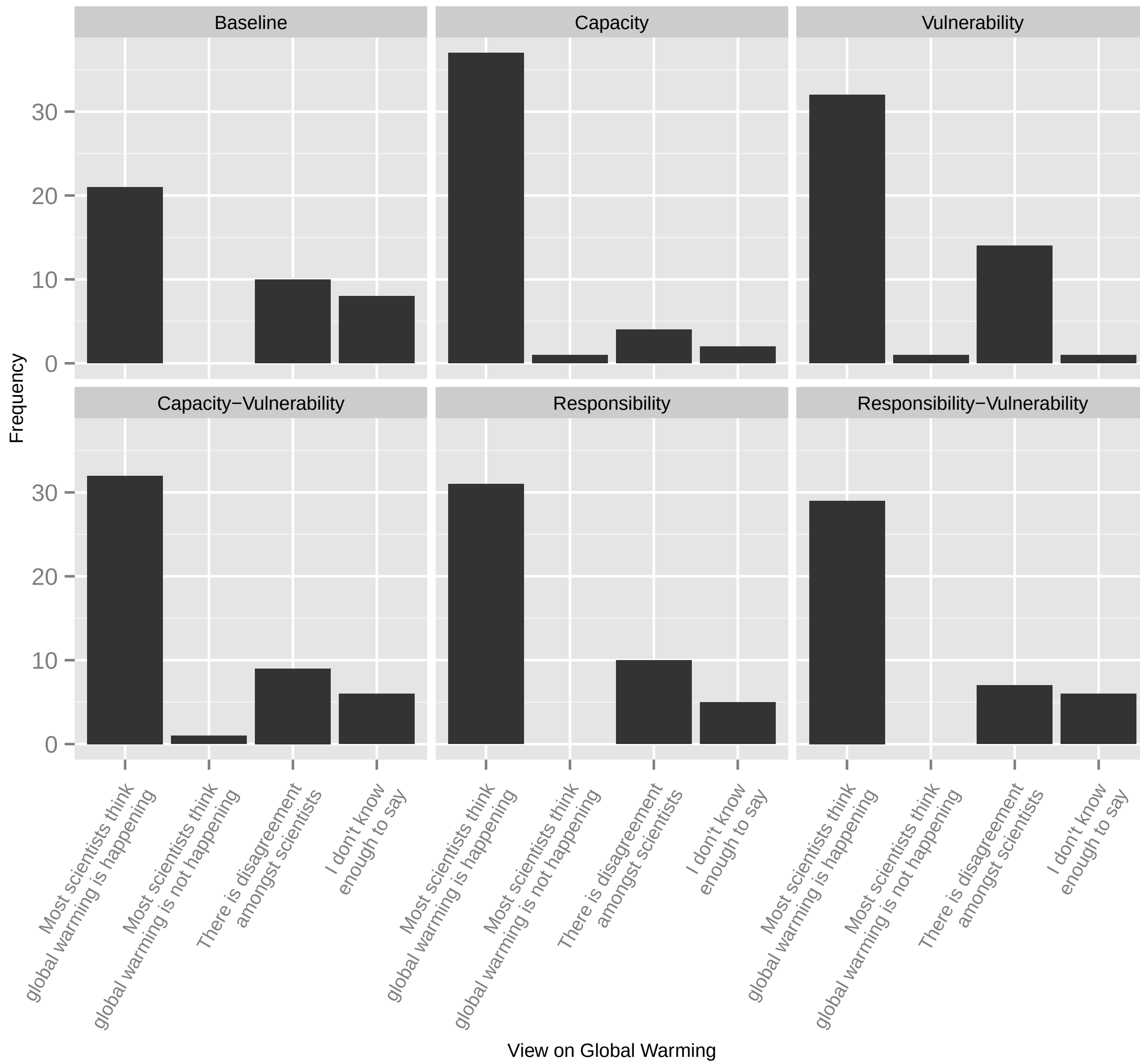

Figure 9: Distribution of Opinion of Evidence of Global Warming

B Offer/Counter-offer analysis

In this appendix we present several analyses of offer/counter-offer dynamics. Figures 10 and 11 reflect patterns in Player B's reaction to Player A's offers.

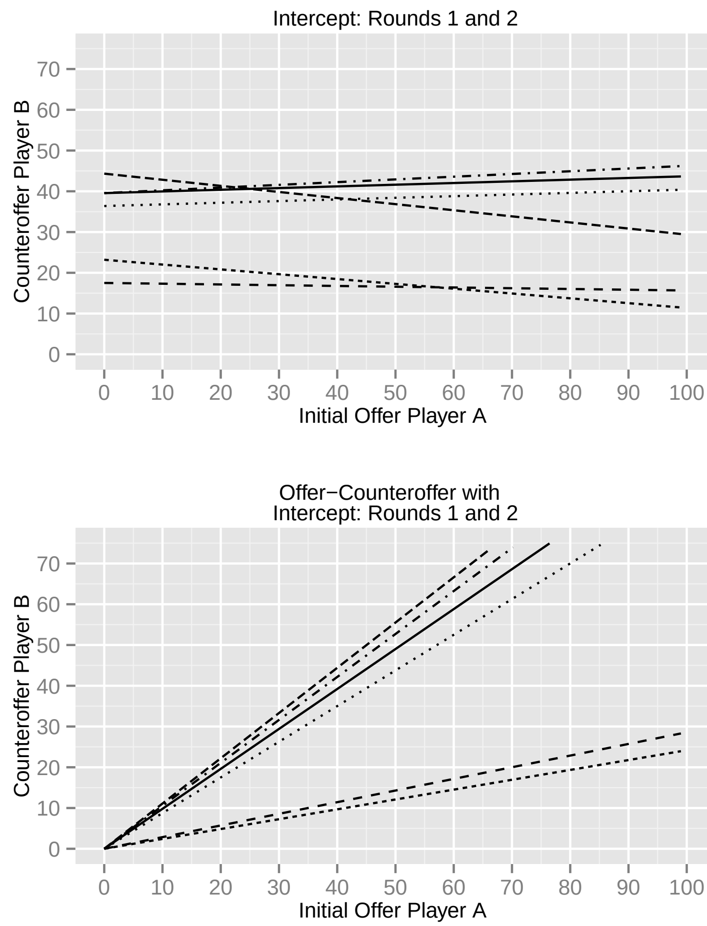

Figure 10: Offer v Counteroffer (Rounds 1 and 2)

The first panel of each figure shows Player B's counteroffers regressed onto Player A's corresponding initial offers with an intercept. We find that Player B counteroffers are consistently lower than Player A offers in round 1 under the *CP* and *CP-VN* treatments, which has been borne out by earlier results. Additionally, given an intercept, Player B's counteroffer decreases in Player A's initial offer, though this may be due to extremely low incidence of Player A offering less than 50.

The second panel removes the intercept, and therefore provides a better idea of each player's sensitivity to the other's offer under various treatments. Player B appears to be most sensitive to Player A's under the *RS-VN* and the *VN* treatments. If Player A offers Player B greater amounts under the *CP* and *CP-VN* treatments, incremental increases in offer comprise a smaller percentage of the total initial offer, and so Player B may be less sensitive to changes. Since Player A tends to give Player B lower offers under the *VN* and *RS-VN* conditions, each incremental increase or decrease in the offer more drastically affects Player B's response. Additionally, examining the *BL* case in the figure, we find that Player B generally adjusts his or her counteroffer to match Player

A's initial offer. Although 2a suggested that players were offering one another less than 50, this would likely have been due to Player A's initial offers below 50, in response to which Player B would respond with a similar counteroffer under *BL* conditions.

Figure 11 similarly summarizes Player A's response to Player B's offer in round 2. In an analogous case to Figure 10, we find that Player A is relatively sensitive to changes in Player B's offer under the *CP-VN* and *CP* cases, under which Player B contributes a relatively lower share of the cost. Alternatively, when Player A is expropriating greater offers from a vulnerable Player B under *VN* and *RS-VN*, incremental changes in Player B's offer have a lower effect on Player A's counteroffer.

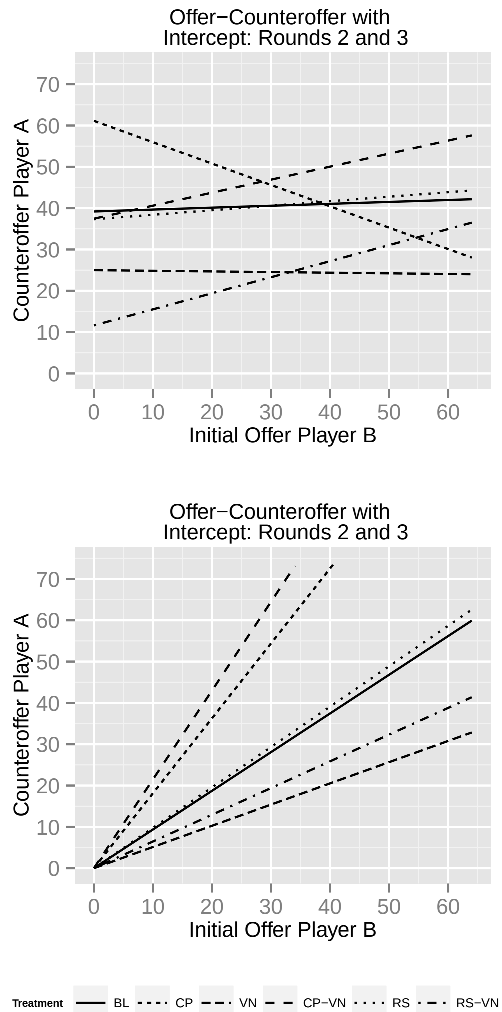

Figure 11: Offer v Counteroffer (Rounds 2 and 3)

As an additional observation, both sets of plots in Figure 11 select cases in which the initial offer was not accepted. Consequently, counteroffers are being made by players who were not willing to accept the initial offer, and so some the plots may be selecting for more demanding players, resulting in overstated slopes in the plots without intercepts, and overstated slopes and/or understated intercepts in plots with intercepts or local regressions.