Gerrymandering in the Laboratory

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Abstract

Gerrymandering, the act of drawing political boundaries for electoral advantage, remains a hot button political topic. Previous theoretical work has treated gerrymandering as a one-stage strategic game against nature, but this paper treats drawing districts as the first stage in a two stage game in which the two parties compete within districts for undecided voters. In a controlled laboratory experiment, subjects overwhelmingly engage in gerrymandering, which is optimal in terms of maximizing the probability of winning a majority of the districts and maximizing the expected payoff of the party drawing the districts. Engaging in gerrymandering occurs despite the fact that subjects report being opposed to the practice and regardless of their own political views. However, when forced to select the electoral map behind a veil of ignorance, our subjects indicate a clear preference for fair maps although not the theoretically socially efficient map. Additionally, consistent with past Tullock contest experiments, the subjects overspend at the second stage although average spending across electoral maps is largely consistent with the theoretical comparative static predictions.

1 Introduction

Gerrymandering is the act of strategically determining the boundaries of an electoral district in an attempt to influence the outcome of an election. The term was introduced in 1812 to criticise Massachusetts Governor Elbridge Gerry, who authorized a state senate district thought by some to resemble a salamander. Today, gerrymandering is perhaps most associated with the United States House of Representatives with districts know as the earmuffs (Illinois' 4^{th} District), the duck (Ohio's 4^{th} District), and Goofy kicking Donald (Pennsylvania's 7^{th} District) all based on their geographic shape. Redrawing Congressional districts has become a data science driven endeavor (Newkirk 2017), so it is little wonder that the practice continues to receive considerable political attention. For example, in September 2021 Democrats in Indiana accused Republican lawmakers of cracking apart democratic voters in the state to create districts that favor Republicans. That same month, Oregon's state legislature put forward a plan that Republicans claim favors Democrats in five of the state's six Congressional districts. Also in September 2021, a case was filed in federal court claiming that Alabama's congressional districts are racially motivated and pack many black voters into one district to minimize the impact of that community in other districts. Concern with gerrymandering has led some states to form non-partisan groups to draw Congressional Districts; in September 2021, Michigan's Independent Citizens Redistricting Commission provided a draft map of its proposed districts. However, in the 2019 case Rucho, et al v. Common Cause, the United States Supreme Court ruled that claims of partisan gerrymadering are not justiciable leaving the practice in play.[1]

Previous economic research on gerrymandering has primarily fallen into two categories. The first examines the effects of redistricting on voter participation (Hayes and McKee 2009), policy choices (Shots 2002, Besley and Preston 2007), and polarization (McCarty, et al. 2009). The second category focuses on gerrymandering as a strategic problem (from the perspective of the gerrymanderer). Owen and Grofman (1988) introduce a model where the party drawing districts has an aggregate level of support but can partition that support among a fixed number of districts. They show that a gerrymanderer who wishes to either maximize the expected number of districts won or to maximize the chance of winning a majority of districts should pack rival's supporters into some districts and fragment own supporters across the other districts. Known as packing and cracking, respectively, these two strategies have become a cornerstone of partisans seeking to gain a political advantage. Gilligan and Matsusaka (1999) consider a setting in which the preferences of each voter are observable and show that constructing districts that maximize homogeneity within districts can effectively eliminate bias whereas randomly generated districts will not eliminate bias in general. More recent work by Friedman and Holden (2008), Gul and Pseendorfer (2010) and Kolotilin and Wolitzky (2020) has focused on voters with unobservable types.

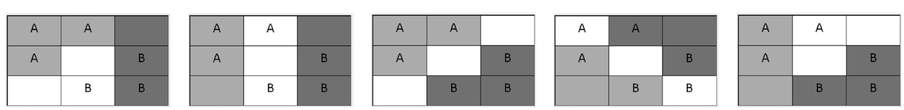
Our paper contributes to the strategic gerrymandering literature in two ways. First, the prior papers in this area have treated districting as a one stage game against nature, whereas in practice districting is only the first stage in a two stage game against another party. Therefore, we combine the notion of districting with a second stage Tullock style electoral competition within each district. Specifically, we assume that there are two types of voters: partisan voters who will vote for their favored party and undecided voters who can be influenced by the campaign efforts of the candidates. In our setting, optimal gerrymandering involves packing (rival partisans) and cracking (own partisans and undecided voters). Theoretically, gerrymandering yields a higher expected payoff and a greater probability of winning than the other possible ways district maps could be drawn. Second, we conduct a controlled laboratory experiment to examine not only what districts are chosen, but also how people compete in those districts. We find that conditional on the electoral map, subjects tend to overspend relative to the theoretical predictions, but spending across electoral maps

[1] Cases involving racial discrimination, such as that alleged against the State of Alabama, can be reviewed by the courts and are subject to the Voting Rights Act of 1965.

is largely consistent with the predicted comparative statics of the model. Additionally, we find that subjects overwhelmingly engage in self-interested gerrymandering when given the opportunity to do so and this pattern holds regardless of the subjects own political leanings. This pattern also holds despite the nearly unanimous claim among the subjects that they do not support gerrymandering. However, when our subjects are forced to draw electoral boundaries behind a veil of ignorance, they are far more likely to choose an unbiased map although not the one that theoretically yields the greatest expected profit.

2 Theory

We consider an election game with two players (A and B) and 9 zones arranged in a 3x3 grid. The players compete for a fixed a prize, V. To win the prize, a player must win at least two of the three districts. For simplicity we refer to the districts as (W)hite, (L)ight Gray, and Dark (G)Gray. Each district is comprised of 3 zones and to win a district a player must claim at least two of the three zones in the district. The players represent political parties competing for majority control of a representative legislature and the zones represent individual voters. To capture the notion that some voters are party loyalists while others are influenced by political campaign, some zones are preassigned to a specific player while other zones are not. We assume that one-third of zones are preassigned to A, one-third are preassigned to B, and one third are not preassigned. We refer to a specific assignment of the 9 zones to three equally sized districts as a map. Figure 1 shows five distinct maps. Any other map that could be constructed with three zones of three districts each where one third of the zones are not preassigned and the other districts are equally split between the two players is strategically equivalent to one of these five maps.



(a) $Gerry_B$ (b) $Sym_{1,1}$ (c) $Sym_{1,3}$ (d) $Sym_{3,1}$ (e) $Gerry_A$

Figure 1: Map Structures

The players compete via simultaneous independent Tullock contests for each non-preassigned zone; however, investment decisions are made at the district level reflecting the practical reality of electioneering. Specifically, given Map M, Player $i \in \{A, B\}$ selects an expenditure triple $(e_{i,W|M}, e_{i,L|M}, e_{i,G|M})$ where $e_{i,d|M}$ denotes the player's investment in district $d \in \{W, L, G\}$. When there is no ambiguity with regard to the map being referenced, we drop $|M$ from the notation. The probability that player i wins a non-preassigned zone in district d of map M is $\frac{(e_{i,d|M})}{(e_{i,d|M})+(e_{j,d|M})}$ with $i \neq j$. Player i's expected payoff is $E\pi_i = \rho_i V - \sum_d e_{i,d|M}$ where ρ_i is the probability that player i claims a majority of the zones in a majority of the districts given the choices of both players.

We now consider each Map shown in Figure 1. Three of these maps are symmetric in the sense that the objective function of the two players are symmetric and the resulting equilibrium strategy is symmetric. We refer to these the maps as $Sym_{D,Z}$ as there are D districts in the map that either player could win and there are Z zones in each of those competitive districts that are not preassigned. For example, in $Sym_{1,1}$ there is only one district that is competitive and there is a single zone in that district that is in play. The other two districts each have 2 zones preassigned to a single player and thus that player is guaranteed to win those districts. Specifically, player $A(B)$ is guaranteed to win district $L(G)$. Therefore $e^*_{A,L} = e^*_{B,L} = e^*_{A,G} = e^*_{B,G} = 0$ as expenditures in these districts cannot influence which player wins those districts. For $Sym_{1,1}$, whichever player claims the non-preassigned zone in district W wins the map. Thus, $\rho_i = \frac{e_{i,W}}{(e_{i,W}+e_{j,W})}$ for $Sym_{1,1}$ and the competition reduces to a standard Tullock contest with the optimal expenditure from both players being $e^*_{A,W} = e^*_{B,W} = \frac{V}{4}$, giving each player a 50% chance of wining and an expected profit of $\frac{V}{4}$.

In $Sym_{3,1}$, no player has a guaranteed victory in any district. Further, because each player has one preassigned zone in each district the player who wins the non-preassigned zone in a district will win that district. Thus, the two parties are playing a simultaneous best of three Tullock contest, where each contest is independent. For $Sym_{3,1}$,

$$\rho_i = \frac{e_{i,W}}{e_{i,W}+e_{j,W}}\frac{e_{i,L}}{e_{i,L}+e_{j,L}}\frac{e_{i,G}}{e_{i,G}+e_{j,G}} + \frac{e_{i,W}}{e_{i,W}+e_{j,W}}\frac{e_{i,L}}{e_{i,L}+e_{j,L}}\frac{e_{j,G}}{e_{i,G}+e_{j,G}} + \frac{e_{i,W}}{e_{i,W}+e_{j,W}}\frac{e_{j,L}}{e_{i,L}+e_{j,L}}\frac{e_{i,G}}{e_{i,G}+e_{j,G}} + \frac{e_{j,W}}{e_{i,W}+e_{j,W}}\frac{e_{i,L}}{e_{i,L}+e_{j,L}}\frac{e_{i,G}}{e_{i,G}+e_{j,G}} \tag{1}$$

The equilibrium investment for each district for Player i is $(e^*_{i,W}, e^*_{i,L}, e^*_{i,G}) = (\frac{V}{8}, \frac{V}{8}, \frac{V}{8})$. Each player wins with a 50% chance and has an expected profit of $\frac{V}{8}$.

In $Sym_{1,3}$, Player $A(B)$ is guaranteed to win district $L(G)$ and thus both players should spend zero in these two districts. District W has three zones that are in play and whichever player wins at least two of those zones will win the overall contest. Again, the contest reduces to a best of three competition, but for this map both players are constrained to make a single investment that applies to all three competitive zones. Thus, for $Sym_{1,3}$

$$\rho_i = \left(\frac{e_{i,W}}{e_{i,W}+e_{j,W}}\right)^3 + 3\frac{e^2_{i,W}e_{j,W}}{(e_{i,W}+e_{j,W})^3} \tag{2}$$

The equilibrium investment for District W for player i is $e^*_{i,W} = \frac{3V}{8}$ and the expected profit is $\frac{V}{8}$. Thus, of the three symmetric maps $Sym_{1,1}$ is socially optimal and yields the greatest expected profit to the players.

We now turn to the two asymmetric maps. In $Gerry_A$, all of the zones preassigned to Player B are packed into District G. However, the zones preassigned to Player A are cracked and split between Districts L and W in such a way that Player A is guaranteed to win District L and that Player A has a one zone advantage in District W. Because the outcomes in Districts L and G are guaranteed, $e^*_{A,L} = e^*_{B,L} = e^*_{A,G} = e^*_{B,G} = 0$. While either player can win the contest, Player A only needs to win one of the two non-preassigned zones in District W while Player B must win both non-preassigned zones in District W. Thus, the game effectively becomes a weak-link contest. In $Gerry_A$,

$$\rho_A = 1 - \left(\frac{e_{B,W}}{e_{A,W} + e_{B,W}} \right)^2 \tag{3}$$

In equilibrium, $e^*_{A,W} = e^*_{B,W} = \frac{V}{4}$, giving Player A 75% chance of winning the contest and an expected profit of $\frac{V}{2}$ while Player B has a 25% chance of winning the contest and en expected profit of 0. $Gerry_B$ is similar to $Gerry_A$ except that the advantage and equilibrium favor Player B.

Table 1 summarizes the equilibrium predictions for each of the 5 maps in Figure 1. From this table it is clear that Player A would prefer to compete on $Gerry_A$ while Player B would prefer to compete on $Gerry_B$. That is, both players find it optimal to engage in gerrymandering if given the opportunity.

Table 1: Summary of theoretic results

	$Sym_{1,1}$	$Sym_{3,1}$	$Sym_{1,3}$	$Gerry_A$	$Gerry_B$
$(e^*_{A,W}, e^*_{A,L}, e^*_{A,G})$	$(\frac{V}{4}, 0, 0)$	$(\frac{V}{8}, \frac{V}{8}, \frac{V}{8})$	$(\frac{3V}{8}, 0, 0)$	$(\frac{V}{4}, 0, 0)$	$(\frac{V}{4}, 0, 0)$
$(e^*_{B,W}, e^*_{B,L}, e^*_{B,G})$	$(\frac{V}{4}, 0, 0)$	$(\frac{V}{8}, \frac{V}{8}, \frac{V}{8})$	$(\frac{3V}{8}, 0, 0)$	$(\frac{V}{4}, 0, 0)$	$(\frac{V}{4}, 0, 0)$
ρ_A	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{4}$
ρ_B	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{4}$
$E\pi_A$	$\frac{V}{4}$	$\frac{V}{8}$	$\frac{V}{8}$	$\frac{V}{2}$	0
$E\pi_B$	$\frac{V}{4}$	$\frac{V}{8}$	$\frac{V}{8}$	0	$\frac{V}{2}$

3 Experimental Design

To test the theoretical predictions developed in the previous section we conducted a controlled laboratory experiment using a within subjects design. While the choice of V is somewhat arbitrary, given the predictions in Table 1 we set $V = 80$. The experiment progressed in 3 main stages.

Stage 1 consisted of ten decision periods with random and anonymous rematching each period. Participants were informed of their role as Player A or

Player B and shown all 5 maps simultaneously. As explained to the participants, one map would be selected at random after both players made all of their decisions and it was the result for the randomly selected map that would determine the actual outcome for that period. That is, the strategy method was used so that participants had an incentive to faithfully report their preferred choices for all 3 district on all 5 maps each period. After both players made their decisions, participants received feedback that included the other player's choices, the probability they themselves would win each district, the probability they would win the map, a realization of the outcome for the map and the resulting payoff. The map that was randomly selected to determine the outcome was highlighted on the participant's screen. Figure 2 provides an example of the period end feedback.

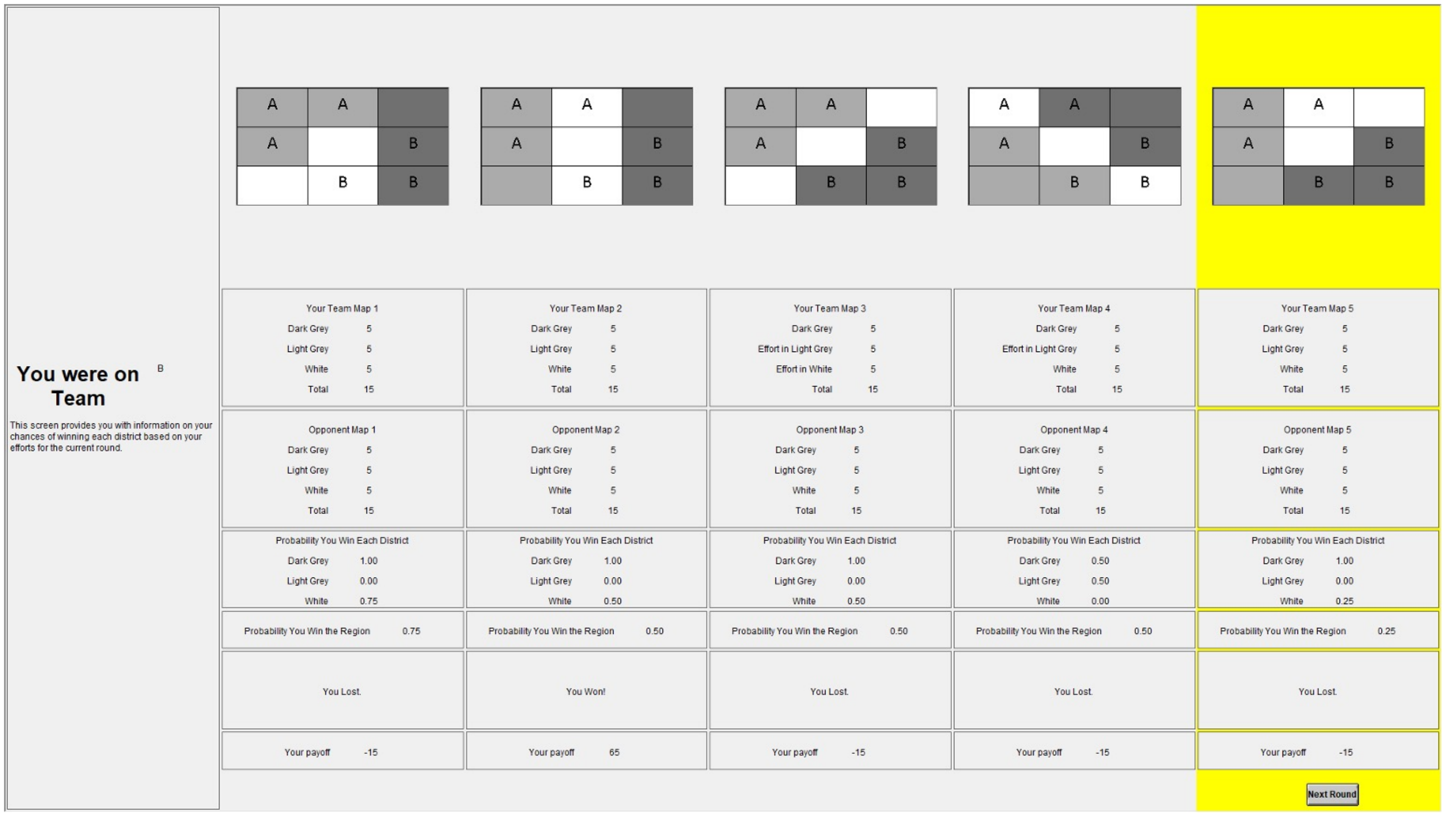


Figure 2: Information presented to subjects at the end of each round

Stage 2 consisted of three decision periods with random and anonymous rematching each period. The only distinction between Stage 2 and Stage 1 is that in Stage 2 participants were first asked what map they would prefer to use to determine the outcome for that period. Both Player A and Player B privately indicated their preferred maps, but this information was not revealed until after the period was over. What participants did know was that the computer would randomly pick one of the maps selected by the two players. But because a player did not know which map would be selected, both players had an incentive to make choices on each map as though it would be the one that determined the outcome. The feedback received in Stage 2 was the same as the feedback received in Stage 1.

Stage 3 consisted of a single decision period with random and anonymous rematching. The only difference between Stage 3 and Stage 2 is that a participant was asked to select the map that he or she preferred to use prior to learning if the subject would be in the role of Player A or Player B. That is, in Stage 3 each participant selected a map behind a veil of ignorance. Once both people in the contest made their selections, roles were revealed. But which map would be used that period was not revealed and thus both players again had to make choices on each map as if it were the map that would determine the outcome. The feedback received in Stage 3 was the same as the feedback received in the other two stages.

In each session, participants entered the laboratory. Each person each was seated at a private workstation where they read instructions and went through several practice contests. To minimize experimenter demand effects or other implications of loaded language, no mention of elections or gerrymandering were used in the instructions or during the three stages of the experiment. Copies of the instructions are available in Appendix A. After everyone completed the initial set of instructions, Stage 1 of the study was conducted. After Stage 1 was completed, instructions regarding Stage 2 were displayed and then Stage 2 was completed. After Stage 2 was completed, instructions for Stage 3 were displayed and then Stage 3 was completed. After Stage 3 was completed, an anonymous survey that collected information about gender, political leaning, and attitude towards gerrymandering was administered. The entire experiment was programmed using ztree (Fischbacher, 2007). Once everyone in the session completed the experiment, a die was rolled in front of the participants to determine which single period from across all 3 stages would determine the participants' actual payments.

A total of 8 sessions were conducted at The University of Alabama's TIDE Lab. All of the participants were undergraduate students at that university who had registered in the lab's standing pool of volunteers. Each participant received $5 plus their salient earnings, which averaged $XXX. As explained to participants in the instructions, all monetary amounts in the experiment were denoted in Lab Dollars that were converted at the rate 4 Lab Dollars = 1$US. To avoid the loss of experimenter control associated with negative earnings, each participant received an endowment of 80 Lab Dollars and was not allowed to spend more than this on any map in any period.

4 Results

We present the analysis separately for each stage. In our analysis, we combine data for Player A and Player B in equivalent strategic positions. That is, for $Sym_{1,1}$,$Sym_{1,3}$, and $Sym_{3,1}$ we combine Player A and Player B data from district d on a given map as player roles are interchangeable. For the maps with gerrymandering, we combine Player A data from District d in $Gerry_A$ with Player B data from district d in $Gerry_B$ and refer to this as Gerrymander-Advantaged-d and we combine Player A data from District d in $Gerry_B$ with Player B data from District d in $Gerry_A$ and refer to this as Gerrymander-Disadvantaged-d. In Appendix B we show that role labels do not impact behavior between these various strategically equivalent situations. ¡¡¡ This appendix should have the cdfs by player role and tests that they do not differ. It should also have information about whether map bidding differs between stages 1 and 2. ¿¿¿

4.1 Stage 1

Our data includes 9,600 Stage 1 decisions with 640 decisions per district. Table XXXX provides a summary of the observed behavior. Several patterns are readily apparent from this table. First, the participants are far more likely to make positive expenditures in districts where the the equilibrium prediction is positive than in districts where the equilibrium prediction is zero. However, some participants do make positive expenditures in districts that have no strategic value, a common pattern in the experimental contest literature (see for example XXXX and XXXX). On the other hand, participants do not always make positive expenditures in districts when they are predicted to do so. This is most notable in $Symm_{3,1}$, something we return to later. Another pattern readily apparent from Table XXXX is that on average participants expend more than the predicted level. Of the seven situations in which the equilibrium expenditure is positive, the average expenditure exceeded the predicted level in each of them. This overbidding is typical in the experimental contest literature (see for XXXX for a survey). ¡¡¡Here we need to work in some comparisons with prior work¿¿¿

1) Insert summary Table XXXX - see Map and District Summary Table.docx. This is similar to Table 6

Figure XXXX plots average bid by district by period. Behavior in districts with positive equilibrium expenditures is fairly stable across Stage 1. However, the amount expended in districts that have no strategic value does fall over the first part of the study. Therefore, to compare behavior across treatments we do so using all of the Stage 1 data as well as only using data from the last half of the stage. Specifically, to compare total expenditures we rely on the regression analysis in Table XXXX that includes subject fixed effects and standard errors clustered at the session level. The omitted treatment is $Sym_{1,1}$, which is theoretically equivalent to a standard Tullock game, and thus the coefficients for the other treatments can be viewed as deviations from that baseline.

2) we go with something like Figure 3 but lets have separate plots for each district in sym1,1 syms1,3m sym3,1 GerryAdv and GerryDisadv

3) we compare total expenditure by treatment and use something like Table 4 but with only the data for stage 1 (two specifications: one with periods 1-10 and one with periods 6-10).

Theoretically, both the advantaged and the disadvantaged player in a gerrymandered map should exert the same total effort as each other and that level should equal that of a player in $Sym_{1,1}$. The lack of significance for Advantaged in Table XXXX is consistent with the theoretical prediction. But the negative and significant coefficient for Disadvantaged is not consistent with the prediction. Further, as shown in the lower portion of Table XXXX, the coefficients on Advantaged and Disadvantaged are statistically different; contrary to the theoretical predication of equal expenditures, disadvantaged players expend less than advantaged players on average. The coefficient on $Sym_{1,3}$ is predicted to be ten, but it is not statistically different from zero and is statistically different from ten. Thus, while $Sym_{1,3}$ is predicted to lead to greater expenditure than $Sym_{1,1}$, it does not. $Sym_{3,1}$ is also predicted to lead to an increase in expenditure relative to $Sym_{1,1}$, which it does as evidence by the positive and significant coefficient in Table XXXX. However, the effect is less than the predicted change of ten, as shown in the lower portion of the table. We also note that, although $Sym_{1,3}$ and $Sym_{3,1}$ are predicted to generate equal expenditures, they do not as shown in the lower portion of Table XXXX.

Before continuing to Stage 2, we provide additional analysis of behavior in two settings. First, Table XXXX shows that participants are less likely to make positive expenditures in districts where the equilibrium is positive when competing on $Sym_{3,1}$ than when competing on other maps. One difference between this maps and the others is that here players should make positive expenditures on all three districts whereas for the other maps the players should focus on a single district. Further, on $Sym_{3,1}$ the benefit of winning a district depends on the outcome for the other districts. Deck, et al. (XXXX) report that participants in a related situation focus on forming a minimum winning combination. In our setting, a minimum winning combination would consist of two of three districts. Further, Deck, et al. (XXXX) report that participants often make nearly equal expenditures across the components of a given minimum winning combination. Our participants exhibit similar behavior. In only 3% of observations do our participants place a positive bid in only one of ht three districts in $Sym_{3,1}$ and in

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To introduce our analysis of Stage 1, consider this brief qualitative summary of bidding behavior throughout the study. Figure 3 highlights two key features of bidding behavior. The first is that salience is achieved. Participants bid much higher in competitive districts than noncompetitive districts with average bids being higher than theoretical predictions. The second feature of the time series plots is that a slight learning effect is present in a few of the noncompetitive districts. In $Gerry_B$ ELG, $Symm_{1,1}$ ELG, and $Symm_{1,3}$ ELG bidding during the first two periods is relatively high and falls as the experiment continues. Another feature of Figure 3 is that the panels displaying average bids in districts of $Symm_{3,1}$ look as expected relative to all other panels. That is, bidding in each

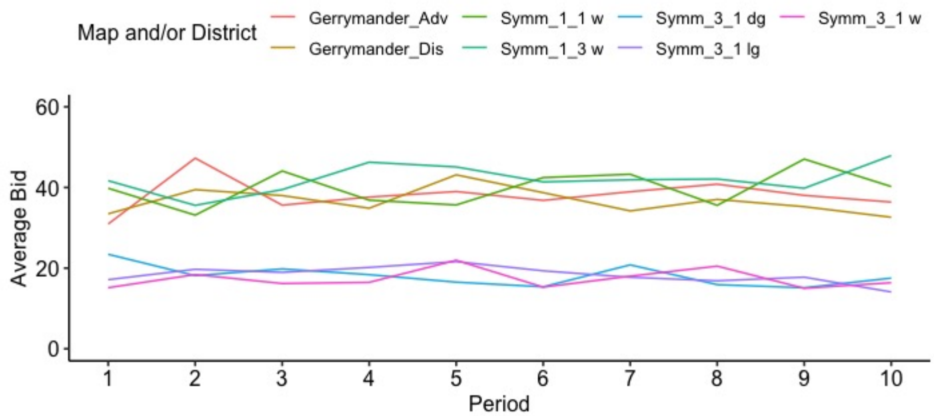


Figure 3: Average bidding in each session and period for competitive districts

Percent of Participants Bidding in $Symm_{3,1}$			
Zero Districts	One District	Two Districts	Three Districts
8	3	17	72

Table 2: Bidding behavior in $Symm_{3,1}$ with multiple, competitive districts

of the three competitive districts of $Symm_{3,1}$ is less than bids in the singularly competitive, white districts of the other four maps. However, our theoretical prediction of equal bids in each district of $Symm_{3,1}$ appears to be slightly lower than the realized average bids.

Though the averages appear somewhat similar across $Symm_{3,1}$ districts, it is possible that participants only bid in one or two districts rather than bidding in all three. Table 2 and Figure 4 offer a more granular window into $Symm_{3,1}$ bidding. We see that 72% of participants partially follow the equilibrium bidding strategy and bid in all three districts. Figure 4 displays the difference between the maximum and minimum bids for participants who bid in only two districts and those who bid in all three. The inclusion of Figure 4 helps emphasize that participants mostly bid equal amounts in the districts for which they compete, especially when bidding in only two districts.

As Section {insert theory section here} explains, there should be no distinction between bids of Player A and that of Player B. Figure 5 allows us to visualize the influence, if any, of player role. A fairly clear difference between advantaged and disadvantaged players exists, but this only implies bidding varies in gerrymandered maps, not across Player A and Player B participants. A K-S test confirms that the distribution from which advantaged players select their bids is different than that of disadvantaged players. Aligning with our theoretical predictions, it is more difficult to distinguish an effect of player role on bids

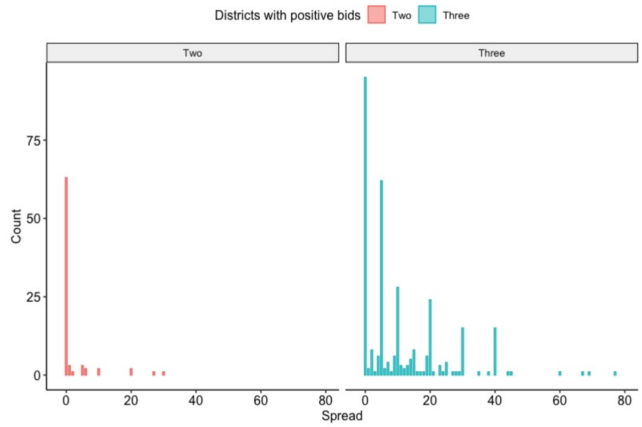


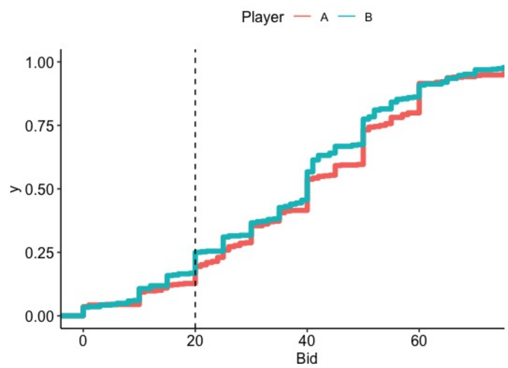
Figure 4: Difference between maximum and minimum positive bids

in Figure 5.

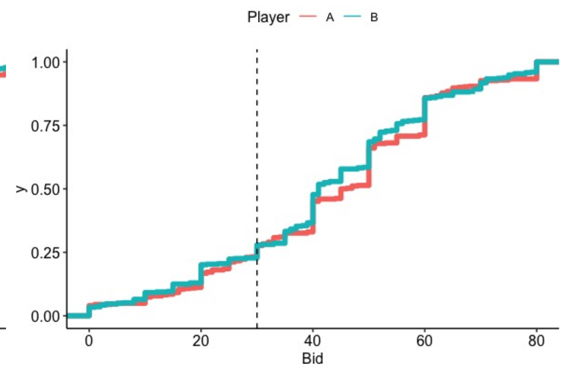
To better determine whether a player role effect exists, we begin our quantitative analysis with a linear model including player role effect, map effect, and the interaction of player role and each map. Specifically,

$$\begin{aligned} Bid = \alpha + \beta_1 Player_B + \beta_2 Gerry_B + \beta_3 Gerry_B Player_B + \beta_4 Symm_{1,3} + \beta_5 Symm_{1,3} Player_B \\ + \beta_6 Symm_{3,1} + \beta_7 Symm_{3,1} Player_B + \beta_8 Gerry_A + \beta_9 Gerry_A Player_B + \varepsilon \end{aligned} \tag{4}$$

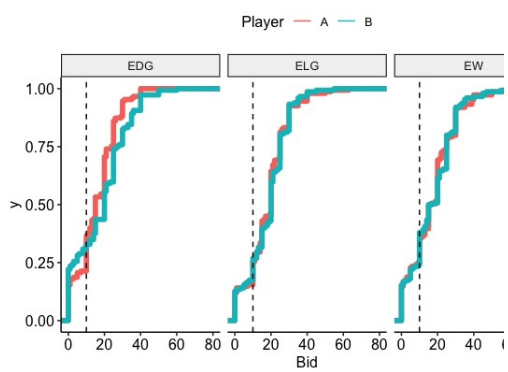
where α captures bidding of Player A on $Symm_{1,1}$ and $\varepsilon \sim N(0, \sigma^2)$. The choice of $Symm_{1,1}$ as the baseline map allows us to interpret changes in bidding relative to a socially optimal, non-gerrymandered map. If participants follow the equilibrium bidding strategies, there should be no effect of moving from $Symm_{1,1}$ to $Gerry_A$ or $Gerry_B$. From our theoretical predictions, we expect positive changes when moving from $Symm_{1,1}$ to either $Symm_{1,3}$ or $Symm_{3,1}$. Coefficient estimates presented in Table {insert first regression} support our expectation for player role in that there is no significant effect of moving from bidding on $Symm_{1,1}$ as Player A to bidding as Player B in the same map. Linear hypothesis testing of each possible combination of Player B effects and map level effects provides further support that player role does not impact bidding behavior. Unlike our prediction, we do not find statistically significant support for increased bidding in $Symm_{1,3}$ relative to $Symm_{1,1}$. However, the coefficient on $Symm_{3,1}$ is both positive and significant ($\hat{\beta}_6 = 7.33$, *p-value* $=$ 0.000). Though Table 3 provides estimates for the effects of gerrymandered maps, we have shown player role does not change bidding behavior. Therefore, interpreting the effects of gerrymandered maps is best done in the context of an



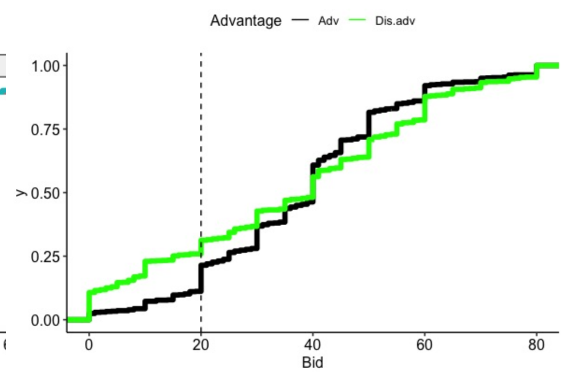
(a) $Symm_{1,1}$



(b) $Symm_{1,3}$



(c) $Symm_{3,1}$



(d) *Gerrymandered*

Figure 5: Cumulative distribution functions of bidding in each map by player role

Table 3: Model 1 Regression Results

	Dependent variable:	
	Effort	
	w/out learning	w/ learning
	(1)	(2)
Player_B	1.219 (2.345)	1.219 (2.345)
Gerry_B	-4.325^{*} (2.345)	-4.325^{*} (2.345)
Symm_1_3	0.575 (2.345)	0.575 (2.345)
Symm_3_1	7.431^{***} (2.345)	7.431^{***} (2.345)
Gerry_A	-1.331 (2.345)	-1.331 (2.345)
Player_B:Gerry_B	2.563 (3.317)	2.563 (3.317)
Player_B:Symm_1_3	1.194 (3.317)	1.194 (3.317)
Player_B:Symm_3_1	-1.531 (3.317)	-1.531 (3.317)
Player_B:Gerry_A	-3.194 (3.317)	-3.194 (3.317)
Constant	45.656^{***} (1.658)	45.656^{***} (1.658)
Observations	1,600	1,600
R^2	0.031	0.031
Adjusted R^2	0.025	0.025
Residual Std. Error (df = 1590)	20.978	20.978
F Statistic (df = 9; 1590)	5.603^{***}	5.603^{***}
Note:		*p<0.1; **p<0.05; ***p<0.01

advantaged or disadvantaged map. That is, we estimate

$$Bid = \alpha + \beta_1 Advantage + \beta_2 Disadvantage + \beta_3 Symm_{1,3} + \beta_4 Symm_{3,1} + \beta_5 Stage^{II} + \beta_6 AdvantageStage^{II} + \beta_7 DisadvantageStage^{II} + \beta_8 Symm_{1,3} Stage^{II} + \beta_9 Symm_{3,1} Stage^{II} + \varepsilon \tag{5}$$

where $Stage^{II}$ is an indicator variable which captures the effect of map selection, discussed further in section 4.2. These estimates, reported in Table 4, rely on all data up to and including the last period of Stage 2. In

Table 4: Model 2 Regression Results

	Dependent variable:	
	Effort	
	w/out learning	w/ learning
	(1)	(2)
Adv	−1.470 (1.219)	−1.547 (1.705)
Disadv	−3.656*** (1.219)	−4.425*** (1.705)
Symm_1_3	1.417 (1.219)	1.172 (1.705)
Symm_3_1	7.189*** (1.219)	6.666*** (1.705)
Stage_2_indicator	−5.405*** (1.795)	−4.271** (1.969)
Adv:Stage_2_indicator	2.215 (2.538)	2.292 (2.784)
Disadv:Stage_2_indicator	0.224 (2.538)	0.993 (2.784)
Symm_1_3:Stage_2_indicator	0.822 (2.538)	1.068 (2.784)
Symm_3_1:Stage_2_indicator	−2.408 (2.538)	−1.884 (2.784)
Constant	47.400*** (0.862)	46.266*** (1.206)
Observations	4,160	2,560
R^2	0.034	0.030
Adjusted R^2	0.032	0.027
Residual Std. Error	21.813 (df = 4150)	21.568 (df = 2550)
F Statistic	16.343*** (df = 9; 4150)	8.844*** (df = 9; 2550)
Note:		*p<0.1; **p<0.05; ***p<0.01

this setting, the coefficients of Advantage and Disadvantage both indicate that bids for any gerrymandered map are less than those in $Symm_{1,1}$, but only in the case of a Disadvantaged map is the coefficient statistically significant ($\hat{\beta}_2 = -3.66$,*p-value* $= 0.0027$). From this regression we again report positive changes in bid amounts for $Symm_{1,3}$ and $Symm_{3,1}$ and as with the previous regression, only the map with three open districts has a statistically significant coefficient ($\hat{\beta}_4 = 7.19$, *p-value* $= 0.000$). To explain our inclusion of a Stage 2 indicator in our section devoted to Stage 1 we draw attention to the negative coefficient of the indicator covariate itself ($\hat{\beta}_5 = -5.41$, *p-value* $= 0.0026$). Given that there is no apparent reason for participants to change their bidding strategies simply because they are able to select a map, which is not guaranteed to be the map from which payment is determined, this decline in bidding is perplexing. As a possible explanation for this behavioral shift, we model bidding as a function of map and period (or time) to account for learning effects during Stage 1. Table 5 presents the estimates of the model

$$Bid = \alpha + \beta_1 Advantage + \beta_2 Disadvantage + \beta_3 Symm_{1,3} + \beta_4 Symm_{3,1} + \beta_5 Period$$
$$+ \beta_6 AdvantagePeriod + \beta_7 DisadvantagePeriod + \beta_8 Symm_{1,3} Period + \beta_9 Symm_{3,1} Period + \varepsilon \quad (6)$$

for which we run a joint linear hypothesis test on each effect of *Period*. The estimate of the *Period* coefficient is negative and statistically significant ($\hat{\beta_5} = -0.67$, $p\text{-}value = 0.0235$), indicating that as participants advance through Stage 1 they reduce their bids, albeit by fairly small amounts. As a robustness check, we evaluate each of the previous models under the assumption that learning happens during the first half of Stage 1 and, after five periods of the same environment and institution, participants have converge on their individual strategies. Tables 3, 4, and 5 report the estimates for the previous models under the constraint that periods 15 through 19 are not included in the second column of each table. We draw the same conclusion, that player role does not effect bidding, with the abbreviated data. The same is true for model 5 under the abbreviated data. We again observe negative coefficients for the gerrymandered maps with only the Disadvantaged covariate having a statistically significant result ($\hat{\beta_2} = -4.43$,$p\text{-}value = 0.0095$). The Stage 2 indicator also maintains a significant, negative effect ($\hat{\beta_5} = -4.27$, $p\text{-}value = 0.0302$). The impact of the *Period* estimate for model (6) is no longer significant, but remains negative ($\hat{\beta_5} = -0.99$, $p\text{-}value = 0.2333$) as shown in Table 5.

To close out our analysis of Stage 1 consider the effects we have shown. First, participants over bid relative to equilibrium on every map. On socially inefficient maps bidding does not increase at much as predicted relative to socially efficient maps. Socially inefficient maps are also not equivalent in realized bids, as theory suggests, with $Symm_{3,1}$ extracting higher bids than $Symm_{1,3}$. Secondly, when participants see themselves as advantaged or disadvantaged they bid less, but being disadvantaged augments this downward effect. Third, while learning occurs throughout Stage 1 and dampens bids, the effect is quite small. The fourth and final observation from the preceding results is the effect of Stage 2. When able to influence, to some degree, the map on which they will compete for the prize, bidding declines relative to Stage 1 bids.

4.2 Stage 2

As mentioned, our theoretical predictions suggest that bidding on any map is not impacted by the ability to select a map on which to compete. The reason for this is that any map *could* be the map for which the competition actually translate to a payout and participants should therefore maintain the same bidding strategies they implemented in Stage 1. In practice this is not the case. Later

Table 5: Model 3 Regression Results

	Dependent variable:	
	Effort	
	w/out learning	w/ learning
	(1)	(2)
Adv	−1.299 (8.253)	−9.522 (25.821)
Disadv	−1.595 (8.253)	−0.988 (25.821)
Symm_1_3	−1.126 (8.253)	−10.516 (25.821)
Symm_3_1	8.598 (8.253)	6.116 (25.821)
Period	-0.671^{**} (0.296)	−0.988 (0.828)
Adv:Period	−0.009 (0.419)	0.363 (1.171)
Disadv:Period	−0.106 (0.419)	−0.156 (1.171)
Symm_1_3:Period	0.130 (0.419)	0.531 (1.171)
Symm_3_1:Period	−0.072 (0.419)	0.025 (1.171)
Constant	60.489^{***} (5.836)	67.991^{***} (18.258)
Observations	3,200	1,600
R^2	0.036	0.033
Adjusted R^2	0.033	0.028
Residual Std. Error	21.514 (df = 3190)	20.952 (df = 1590)
F Statistic	13.257^{***} (df = 9; 3190)	6.050^{***} (df = 9; 1590)
Note:		*p<0.1; **p<0.05; ***p<0.01

in this section we offer possible explanations for this deviation from theory, but we must address which maps participants actually select. We report the modal

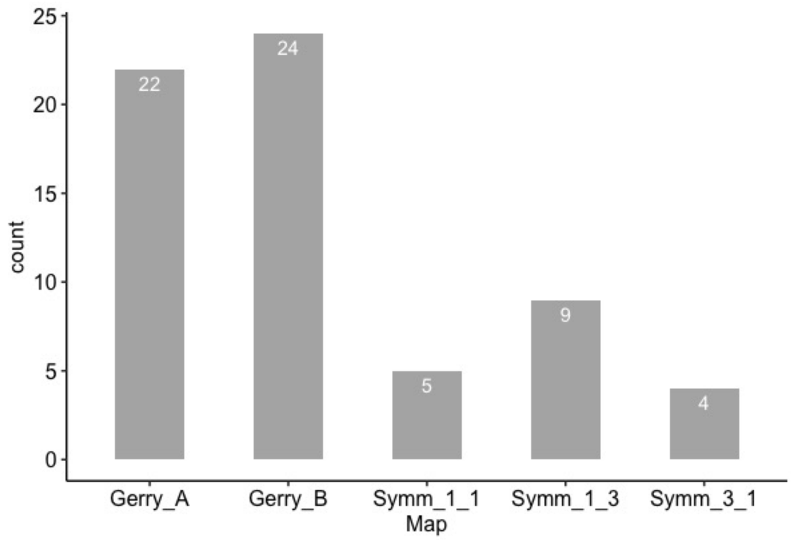


Figure 6: Modal choice of map for each participant

choice of participants when asked to select a map. The reason for using modal map selection is to identify on which map a participant converges[2]. Figure 6 illustrates that the majority of participants engage in gerrymandering. We find that 43 of 64 participants, or about 67%, prefer the gerrymandered map that provides them with an advantage. The high prevalence of gerrymandering is interesting when compared with the responses to a post-experiment questionnaire. Figure 7 displays histograms of participant responses to the question: "On a scale of 1 to 9, how would you describe your political views with 1 being extremely liberal (i.e. to the left of the Democratic Party), 5 being centrist (i.e. falling between the Democratic Party and the Republican Party), and 9 being extremely conservative (i.e. to the right of the Republican party)." The color identifies participants who responded to a separate question: "Do you support gerrymandering (the manipulation of the boundaries of electoral constituencies to favor one election outcome over another)." Clearly, an overwhelming majority of participants, about 95%, claim to not support gerrymandering. Of those 61 participants, 41 engage in gerrymandering. That is, 41 of 43 gerrymandering participants claim to disapprove of the practice in which they themselves engage.

[2]For participants that choose three different maps we use their map choice in the last period of Stage 2. If we remove the 11 individuals who did not choose the same map at least twice, then we find that 40 of 53 participants gerrymander, which is a little over 75%.

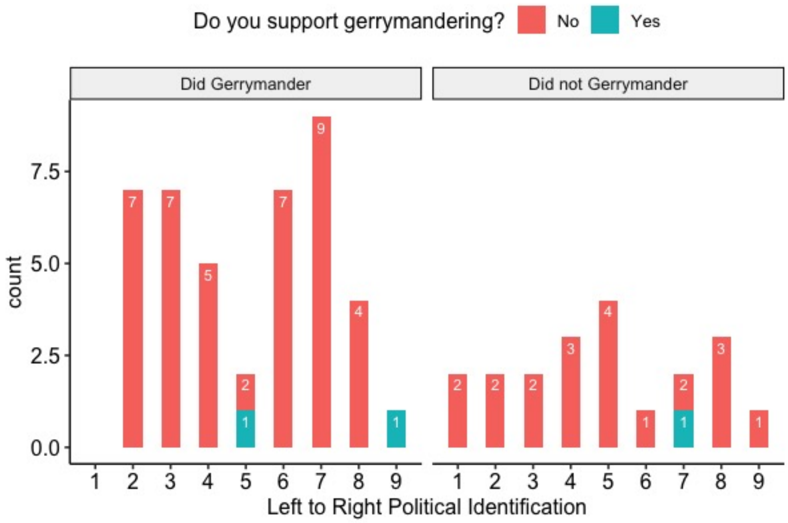


Figure 7: Political leaning and decision to gerrymander

4.3 Stage 3

Our analysis of Stage 3 is largely qualitative. The additional treatment in Stage 3 is map selection under a veil of ignorance. While theory suggests participants maximize expected earnings by choosing $Symm_{1,1}$ and bidding 20, Figure 8 paints a much different picture. In fact, over half of all participants choose socially inefficient maps when unaware of the role they will have in the competition. Further, just under 30% of participants select gerrymandered maps. This leads to the question: are subjects picking gerrymandered maps because they believe they are going to be in the same role as in previous periods, or are they willing to take the 50/50 chance of ending up in an advantaged map? To answer this question we depict a ”spillover” effect in Figure 9 where spillover occurs when a participant gerrymandered in Stage 2 and picks that same map in Stage 3. We report 18% of participants are impacted by this spillover effect and 9% of participants are simply choosing a gerrymandered map without having chosen the same one in the pervious stage.

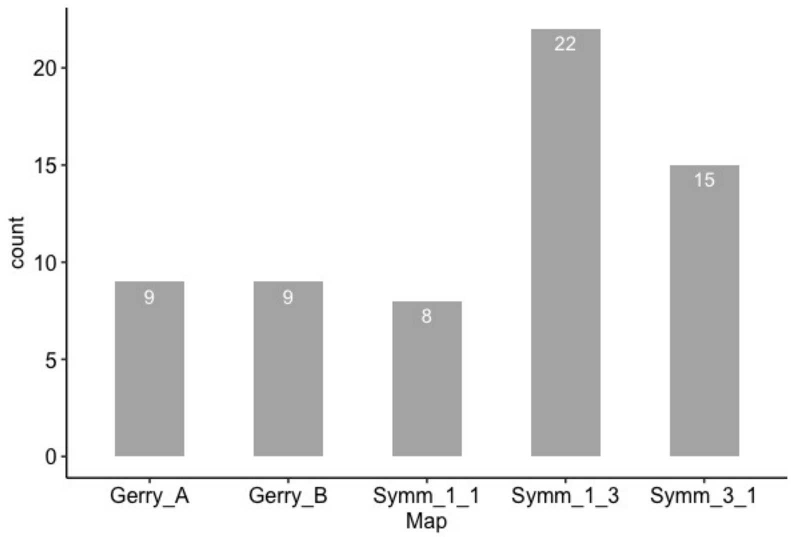


Figure 8: Modal choice of map for each participant in Stage 3

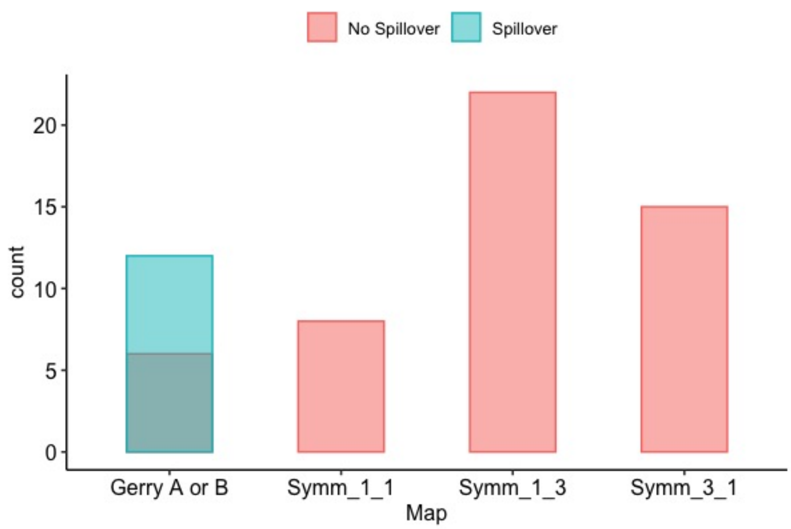


Figure 9: Map choice in Stage 3 by spillover identifier

Table 6 provides the percentage of participants who bid zero in any given district, the average bid conditional on not bidding zero, and the unconditional average bid for each district.

Table 6: District Statistics

Map and District	Percent Bidding Zero	Average Positive Bid	Unconditional Average Bid
$Gerrymandered_B$ W	6	40.05	37.73
$Gerrymandered_B$ LG	85	17.45	2.59
$Gerrymandered_B$ DG	77	19.84	4.59
$Symm_{1,1}$ W	3	40.35	39.35
$Symm_{1,1}$ LG	80	16.03	3.26
$Symm_{1,1}$ DG	76	19.94	4.80
$Symm_{1,3}$ W	3	44.51	43.40
$Symm_{1,3}$ LG	87	14.98	1.99
$Symm_{1,3}$ DG	84	21.10	3.43
$Symm_{3,1}$ W	13	20.38	17.73
$Symm_{3,1}$ LG	12	21.56	18.94
$Symm_{3,1}$ DG	16	21.24	17.92
$Gerrymandered_A$ W	6	39.95	37.57
$Gerrymandered_A$ LG	80	18.32	3.75
$Gerrymandered_A$ DG	84	20.96	3.44

Table 7 provides the percentage of participants who bid zero in any given district, the average bid conditional on not bidding zero, and the unconditional average bid for each district, but here we only look at the last half of Stage 1 (or periods 6-10)

Model 8 presents the results of

$$Bid = \alpha + \beta_1 Advantage + \beta_2 Disadvantage + \beta_3 Symm_{1,3} + \beta_4 Symm_{3,1} + \varepsilon \tag{7}$$

with subject level fixed effects and standard errors clustered at the session level. We are able to reject the null that Adv = Disadv and $Symm_{1,3} = Symm_{3,1}$ with both p-values being less than 0.001.

Table 7: District Statistics: second half of Stage 1

Map and District	Percent Bidding Zero	Average Positive Bid	Unconditional Average Bid
$Gerrymandered_B$ W	6	40.21	37.95
$Gerrymandered_B$ LG	91	17.62	1.60
$Gerrymandered_B$ DG	83	21.40	3.68
$Symm_{1,1}$ W	3	41.26	40.23
$Symm_{1,1}$ LG	85	15.00	2.25
$Symm_{1,1}$ DG	82	20.56	3.79
$Symm_{1,3}$ W	2	44.37	43.40
$Symm_{1,3}$ LG	92	16.73	1.36
$Symm_{1,3}$ DG	89	23.81	2.68
$Symm_{3,1}$ W	12	19.99	17.68
$Symm_{3,1}$ LG	13	21.14	18.36
$Symm_{3,1}$ DG	18	20.63	16.89
$Gerrymandered_A$ W	6	39.88	37.52
$Gerrymandered_A$ LG	84	20.50	3.20
$Gerrymandered_A$ DG	88	22.05	2.62

Table 8: Model 4 Regression Results

	Dependent variable:
	Effort
Adv	-1.547 (1.030)
Disadv	-4.425^{***} (1.030)
Symm_1_3	1.172 (1.030)
Symm_3_1	6.666^{***} (1.030)
Observations	1,600
R^2	0.076
Adjusted R^2	0.036
F Statistic	31.602^{***} (df = 4; 1532)
Note:	*p<0.1; **p<0.05; ***p<0.01

The average [total] bid by an advantaged player on a gerrymandered map in the last 5 periods of stage 1 is 44.7

The average [total] bid by a disadvantaged player on a gerrymandered map in the last 5 periods of stage 1 is 41.8

The percentage of wins by an advantaged player on a gerrymandered map for the entire stage 1 is 55%

The percentage of wins by an advantaged player on a gerrymandered map for the last 5 periods of stage 1 is 59%