Durable Majority Gerrymanders: Where Partisan Gerrymandering can Display Democracy *

Maxwell Palmer† Benjamin Schneer‡

September 2025

Short title: Durable Majority Gerrymanders

Keywords: Redistricting, Gerrymandering, Voting Rights, Representation

*We would like to thank Shiro Kuriwaki, Lali Madduri, Nolan McCarty, Pablo Montagnes, Jonathan Rodden, Daniel Thompson and Richard Zeckhauser and audiences at APSA, HKS, MPSA, and PolMeth for constructive feedback. We also thank three anonymous reviewers and the Editors for their helpful suggestions.

†Associate Professor, Department of Political Science, Boston University, 232 Bay State Road, Boston, MA 02215. mbpalmer@bu.edu

‡Assistant Professor, Harvard Kennedy School, 79 John F. Kennedy Street, Cambridge, MA 02138. benjamin_schneer@hks.harvard.edu

Durable Majority Gerrymanders: Where Partisan Gerrymandering can Displace Democracy

Abstract

We develop the concept of, and estimation tools for, *durable majority gerrymanders*: electoral district maps drawn to reduce an opposing political party's probability of winning a majority in a legislative chamber. Directly interpretable, forward-looking, and motivated by the democratic principle that a party in power should have some chance of losing it, this measure provides new insights into the role of redistricting in state legislative elections. We show that, when map drawers are unconstrained, the ability to create durable majorities is so widespread that at least one party in every state can draw a map where a majority of legislative districts withstand almost any likely future electoral swing. Enacted maps are less durable, due to a combination of underlying geography, voter partisanship, and state-level guidelines. This paper provides the theoretical framework and empirical tools to understand which gerrymandered maps enable state-level majorities to emerge and to endure.

Verification Statement: The data, code, and any additional materials required to replicate all analyses in this article are available on the *American Journal of Political Science* Dataverse within the Harvard Dataverse Network, at: https://doi.org/10.7910/DVN/XMZSSY.

The Cornell Center for Social Sciences verified that the data and code submitted to the AJPS Dataverse replicates the numerical results reported in the main text of this article.

Word Count: 10,030

Partisan gerrymandering is a persistent problem in America's congressional and state legislative districts. Gerrymandering reduces the need for legislators to be responsive to their constituents (Caughey, Tausanovitch, and Warshaw, 2017; Stephanopoulos and Warshaw, 2020) and distorts public policy (Grumbach, 2022). When taken to an extreme, partisan gerrymanders can even lock in a majority of seats in a state legislature for a political party that may not receive a majority of the vote. In Wisconsin, North Carolina and Nevada, for example, the 2022 statewide elections were extremely close toss-ups, with Democratic and Republican candidates each earning about half of all votes. Yet in each of these states, despite razor-thin victory margins in statewide elections, one party held at or near supermajority control in the state legislature (in 2022 Republicans in Wisconsin and North Carolina had supermajorities, and Democrats in Nevada were a seat away). Gerrymanders allowed the Republican state legislatures in Wisconsin and North Carolina to alter and reduce the power of the states' Democratic governors, in spite of voter preferences. Map drawers in these states may have begun to approach the limits of extreme gerrymandering, but in most states the true bounds of what may be accomplished through extreme gerrymanders remains unexplored and generally unknown.

Parties have strong incentives to seek out electoral advantages when drawing new district maps—whether maximizing seats won, achieving a super majority, or ensuring continued control of the legislature in spite of a bad election year—and these incentives can come into conflict with bedrock democratic principles. A prominent, minimalist definition of a democracy "is a regime in which those who govern are selected through contested elections," meaning that the opposition "has some chance of winning and taking office" (Przeworski et al., 1996; Przeworski, 2000). By this definition, assessing the prospects of anti-democratic political regimes in state legislatures requires understanding if political parties can eliminate meaningful competition for a majority. If extreme gerrymandering forecloses the possibility of an opposition party ever winning office, then it may threaten a key democratic principle in some parts of the United States. Of course, single parties already effectively dominate many states' electoral landscapes and not due to gerrymandering; the critical question, in our view, hinges not on one party control per se but rather on whether existing electoral institutions permit future shifts in political power in response to changing voter preferences.[1]

Understanding the limits of gerrymandering—what extreme maps *could* look like, rather than what maps *should* look like—is also critical for understanding ongoing threats to key principles of representative government in the current legal context. Redistricting rules at both the federal level (e.g., *Merrill v. Caster* and *Moore v. Harper*) and state level are in flux, and there is potential for changes to the interpretation of the Voting Rights Act, state constitutions, and other laws that will open the doors to further partisan gerrymandering. Recent Supreme Court rulings such as *Alexander v. South Carolina NAACP* have affirmed the right of state legislators to engage in partisan gerrymandering and added barriers to making some racial gerrymandering claims. Appendix Section C discusses the current legal context and enumerates reasons why a future of gerrymandering unconstrained by federal law is becoming increasingly plausible. Yet, even in such a scenario, the different redistricting guidelines, political characteristics, and geographic characteristics of the fifty states will translate into meaningfully different impacts for state legislatures. In this paper, we identify the states most susceptible to the potentially anti-democratic threats posed by gerrymandering. We ask: what are the most extreme state legislative maps that a party could draw in every state? Where is it possible for a party to draw a legislative map ensuring a continued,

[1]Furthermore, on its own, single party control does not necessarily preclude all forms of democratic representation; even in extreme cases of one-party dominance, intra-party competition may still induce politician responsiveness to voters. For example, Caughey (2018) describes the meaningful representation of a range of white voter interests in the one-party South.

durable hold on power (e.g., a partisan majority in the state legislature) across multiple election cycles? How much of this ability can be attributed specifically to gerrymandering? How do states' current, enacted legislative district maps compare to these counterfactual extreme gerrymanders, and what might explain key differences?

To answer these questions, we develop the concept of a "durable majority gerrymander." While partisan gerrymandering has received significant scholarly, political, and legal attention in recent years, we add a new dimension to the issue by focusing on the *future* effects of gerrymandering on the prospects of a party holding a legislative majority. Durable majority gerrymandering occurs *when a state's districting plan, rather than its other political or geographic characteristics, meaningfully reduces one party's ability to win a majority and increases another party's probability of maintaining majority control relative to a neutral baseline map.* By forecasting future elections, we can evaluate whether gerrymandered plans enable parties to maintain power, even when electoral swings lead them to receive a minority of the statewide vote. When a neutral plan cannot withstand the same electoral swings, it provides strong evidence that partisan gerrymandering itself has contributed to a durable majority.

Measuring the durability of a gerrymandered map requires that we identify maps that best fulfill partisan objectives and then assess their sensitivity to electoral shocks. Our focus on extreme maps means we cannot rely on standard approaches for assessing partisanship of redistricting plans. In recent years, political scientists have used simulated distributions of redistricting maps to identify partisan gerrymanders in both academic work (e.g., Chen and Rodden, 2013; Magleby and Mosesson, 2018) and in court cases. Most work using these simulations focuses on generating representative ensembles of maps—a large set of maps meant to be representative of the set of all possible redistricting maps in a state (DeFord, Duchin, and Solomon, 2021; McCartan et al., 2022; Chen and Rodden, 2015; Chen and Cottrell, 2016). Since we seek to find the most extreme possible maps instead of a representative sample, we instead employ the *shortburst* algorithm (Cannon et al., 2023), which iteratively generates maps seeking to maximize a specified objective function. We combine this approach to identifying the most extreme counterfactual gerrymanders with election forecasting models in order to predict future electoral outcomes under these maps. For each party in each state, we estimate the probability that the map gerrymandered optimally to lock in a permanent majority will withstand electoral swings in the next election as well as for a full redistricting cycle. We construct a non-gerrymandered counterfactual baseline by identifying a map that minimizes distance to the state's average partisan skew in a randomly generated ensemble of plans.[2] Finally, we evaluate the durability of states' enacted maps, comparing to both the "optimal" gerrymander and the neutral baseline map.

We find that the ability to enact durable redistricting plans in the states is widespread. Through a combination of gerrymandering and existing partisan imbalances (e.g., lop-sided support for one party or the other), every state has at least one party that can enact a map ensuring a high probability of victory in the next election and better than even chances of maintaining a majority for a full redistricting cycle.

In states where one party holds a lopsided electoral advantage, such as Massachusetts or Wyoming, no gerrymandering is necessary to enact such durable majorities. However, in states with meaningful electoral competition, gerrymandering itself explains much of this ability: on average, durable Democratic party gerrymanders can increase the probability of winning a legislative majority in an upcoming election by 32 percentage points in state senates and by 23.9 percentage points in state houses as compared to a neutral map; durable Republican party gerrymanders can on average increase the probability of winning a legislative majority by 21.5 percentage points in

[2]Specifically, we identify maps closest to the average mean-median difference (e.g., the difference in vote shares between the mean and median district in a plan).

state Senates and by 20.6 percentage points in state Houses as compared to a neutral map.

In a narrower set of high-profile states including Arizona, Georgia, Michigan, North Carolina and Texas, *either* party can in theory enact maps offering even odds or better of locking in legislative majorities durable enough to last a full redistricting cycle. These results are surprising as they suggest that if either political party happened to win a legislative majority coinciding with a redistricting year, that party might ensure legislative control for a decade. Measures to limit gerrymandering in such states might prove particularly impactful. Absent such reforms, both parties have strong incentives to gerrymander, given the potential losses suffered if the opposing party gains a majority in a redistricting year. States where mid-cycle redistricting is feasible can further increase the probability of ongoing durable majority gerrymanders, since any year where a party controls all necessary veto points can become a redistricting year.

While academics have developed many approaches to measuring partisan gerrymandering, this paper adds to this literature in a new way. From calculations like the seats-votes curve (Tufte, 1973), partisan symmetry (Gelman and King, 1990), mean-median difference (Erikson, 1972), or the efficiency gap (Stephanopoulos and McGhee, 2015), to the use of distributions of simulated district maps (Chen and Rodden, 2013), these approaches calculate theoretical quantities of interest around notions of *fairness*: what does a fair map look like, and how far from a given fairness target is an adopted map? Motivated by the principle that representative democracies benefit from meaningfully contested elections, this paper develops a new quantity of interest: a gerrymandered map's *durability*.[3] In addition to identifying the states most susceptible to anti-democratic threats posed by unconstrained gerrymandering, this approach allows for assessing complex counterfactuals useful for understanding enacted maps. Benchmarking enacted maps against the most durable maps

[3]While related to responsiveness (e.g., the slope in a seats-votes curve) durability more directly captures the probability of maintaining a party majority, a key quantity of interest.

possible offers an important and directly interpretable measure of gerrymandering.

Comparing *enacted* maps to these *counterfactual* durable majority gerrymanders, a striking finding is that most map drawers in competitive states, where durable majority gerrymanders might meaningfully improve the odds of maintaining a majority, do not actually enact the most durable maps. Texas, a state with few meaningful state-level rules constraining gerrymandering, stands out as having enacted maps that come closest to approaching the limits of what can be achieved when seeking to secure the most durable party majorities.[4]

Map drawers have a range of objectives beyond gerrymandering and face a variety of geographic constraints and state-level rules and procedures (McCartan et al., 2024). We identify the main factors explaining variation in the durability of enacted maps. First, state-level geography and partisanship of voters are by far the most important factors, outweighing the explanatory power of state-level rules and guidelines. Yet, to understand marginal increases or decreases in durability of enacted maps, state-level rules and guidelines also play a meaningful role. In particular, among state-level rules, compactness requirements appear most strongly associated with meaningful reductions in the durability of enacted maps; among redistricting methods, commission-based approaches are also associated with reductions in durability.

Finally, this paper illustrates how durable majority gerrymandering exists both in tandem and in tension with existing, practical restraints. On the one hand, state-level constraints in combination with geographic distributions of voters appear to help limit some of the most extreme gerrymanders possible. Even so, many enacted maps still provide favor to the party controlling redistricting, and, as this paper highlights, extreme maps locking in durable majorities are potentially in reach if map drawers and courts choose to disregard or reinterpret certain state-level guidelines.

[4]Georgia also comes close, but its gerrymandered maps do not need to diverge as dramatically from neutral maps in order to enact durable gerrymanders.

How this tension is resolved in the coming decades will have implications for democracy in the states as well as ongoing debates about the underlying causes of political polarization. While scholars have generally found relatively weak support for partisan gerrymandering itself as a factor contributing to political polarization (McCarty, 2019), that may change under ongoing and durable single-party majorities.

Durable Majority Gerrymanders

Political parties have a mix of objectives when drawing new state legislative district lines, including maintaining or building a political majority in the state legislature, protecting incumbent politicians, respecting communities of interest, and many others. We seek to identify maps that a political party would draw given the sole objective of creating a durable majority in the state legislature.

Objective Functions

A political party seeking to draw a map to maintain a durable majority in a state legislature faces a problem of choice under uncertainty. The party seeks to ensure an ongoing political majority and knows the probability distribution, but not the realized values, of electoral swings in future elections. To capture these dynamics, we consider an objective function directly maximizing the probability of maintaining an electoral majority. The approach (1) incorporates an election forecast for each district and (2) solves for the most durable gerrymander based on the range of forecast year-to-year electoral swings (whether uniform swings or not). Specifically, the redistricting party seeks to solve:

$$\max \Pr\left(\sum_{i}^{N}(\mathbb{1}[\nu_i > 0.5]) \geq \frac{N}{2}\right) \tag{1}$$

where, for a map m with N electoral districts, ν_i denotes the vote share in each district i.[5] In order to maximize this function, the redistricting party (or an analyst) will need some means of forecasting future vote shares for each hypothetical district. We discuss forecasting approaches later in the paper.

In the case of statewide uniform swings (e.g., election swings that are roughly the same throughout a state), the problem above reduces to a simpler objective of maximizing the margin of victory for the redistricting party in the pivotal district. For example, in a state with five districts, the pivotal district has the median Republican vote share (e.g., the third district if ranked in ascending order). Thus, for districts 1,...,p,...N where p is the pivotal district in map m with statewide vote v, the redistricting party solves:

$$\max \nu_p - 0.5 \quad (2)$$

where ν_p is the redistricting party's two party vote share in the pivotal district (e.g., the district the party must win for a majority in the legislature). Under the assumption of uniform swing (e.g., that year-to-year electoral swings occur at the same rate across different parts of the same state), maximizing this objective for the pivotal district will be the optimal approach to creating a durable

[5]In practice, we have found that an approach that produces an optimal map for several different objective functions based on normal vote and then evaluates each optimal map on the forecast vote is computationally more tractable and produces similar results to the approach directly optimizing over the election forecasts. For this paper we use this first order approximation for two reasons: (1) it requires substantially less computing time, and (2) we fear that, if made available in the public domain, tools facilitating optimizing directly over an election forecast could be an innovation prone to misuse by partisan mapmakers. Note further that this approach can be extended to maximize the minimum probability of maintaining a majority across any number of future elections.

gerrymander. As a result, we use it as our primary objective when considering statewide electoral swings.[6]

Shortburst Algorithm

In order to model the map-drawing process given these objectives, we use the "shortburst" algorithm developed in Cannon et al. (2023) and Kenny et al. (2022) to simulate redistricting. This algorithm takes an initial map, permutes its district lines, calculates a numerical score based on the objective function, and then repeats the process. For each iteration, the algorithm we implement generates a set of 20 permutations, or bursts, from the initial map. Of this set of 20 new maps, the map with the highest score is then used to replace the previous starting map. We repeat this process 10,000 times and we run 30 separate chains. Thus, for each combination of state, party, map (e.g., state Senate or state House) and objective function, we run 30 chains with a burst size of 20 for 10,000 iterations (evaluating a total of 6 million maps for each chamber-state-objective combination).[7]

[6]Objective functions maximizing vote margin in a district other than the pivotal one, such as the 55th percentile district, also represent plausible rules of thumb for a gerrymandering party. We also consider other objective functions including maximizing the number of "safe" districts (e.g., 55+ or 65+) for a party and maximizing total seats won. As a neutral baseline map for comparison, we simulate an ensemble of maps without regard to partisan intent and identify the map in this ensemble that minimizes the distance to the mean value of the mean-median differences calculated across the ensemble of maps. Appendix E reports the objective function of these alternatives and describes them in detail. Appendix I discusses the construction of neutral maps and considers alternatives to the mean-median difference as a partisan bias metric.

[7]We use the precinct-level shapefiles and 2020 election data available from Voting and Election Science Team (2022). Our main approach features only minimal constraints—population deviations

From this set, we find the map with the highest score based on the pre-specified objective function. While this approach does not guarantee that we find the global maximum, it proves more effective than distribution-based approaches (Cannon et al., 2023) and, for applications such as partisan gerrymanders, appears to identify maps whose extremeness equals or surpasses levels known to practitioners.[8] Appendix Figure D1 reports diagnostics that illustrate the effective performance of the shortburst algorithm applied to the problem of maximizing vote shares in pivotal districts. The maximum values across the 30 chains are not widely dispersed, suggesting that running additional chains would not yield dramatically different results than attained through this simulation process.[9]

To estimate vote share ν_i for district i we identify the voting tabulation districts (VTDs)

---

of 2.5% or less across districts, contiguity, and a mild compactness encouragement. We discuss stronger constraints in Appendix H. We did not run simulations for Alaska, Maine, and West Virginia due to data limitations. We exclude both chambers of the Vermont legislature and the lower chamber for New Hampshire because these chambers use a mixed districting system where some districts are single-member districts and others are multi-member districts of varying sizes.

[8]Cannon et al. (2023, p.36) note: "While we demonstrate the effectiveness of this method for the problem of maximizing majority-minority districts in the context of the Voting Rights Act, the idea itself is much more general. In any application where biased random walks are currently used to find outlying elements, short bursts has the potential to provide a significant improvement." Indeed, the shortburst algorithm has been applied to maximize other, redistricting related objective functions: McCartan (2024) employs a shortburst approach to find Pareto efficient maps maximized over multiple objectives; Palmer, Schneer, and DeLuca (2024) uses shortburst algorithms to identify maps that maximize the number of seats won for a party to analyze partisan gerrymandering.

[9]Additionally, as Appendix Figure D2 illustrates, across different chains the early bursts tend to exhibit some meaningful variability, consistent with exploring a broad space of possible maps and improvements, though after roughly 2,500 bursts the chains tend to converge to a limit. Finally,

composing a legislative district, and we aggregate from the level of VTDs to districts. Because drawing new districts requires permuting existing district lines, any measure of partisanship should be exogenous to changing district lines, ruling out the use of historical state legislative elections that occurred under one specific set of district lines. As a result, we employ historical national and statewide elections. The objective in Equation 1 requires an election forecast based on historical election results. For the objective in Equation 2, we measure partisanship with district-level "normal vote" in the form of 2020 presidential election vote share, a widely adopted practice in the literature on elections and political representation (Erickson, 1971).

Describing Effectiveness of Gerrymanders

We now assess the ability of a redistricting party to maintain a majority in the state legislature. Our initial results are based upon each party seeking the largest possible margin in the pivotal district, consistent with maximizing the chances of winning and maintaining a majority under uniform electoral swings. Figure 1 presents results for competitive state house and senate districts (2020 US presidential election vote margins of ten percentage points or less). The black upside-down triangle indicates the Republican vote share in the pivotal district in each chamber under the baseline neutral map, and the white triangle indicates the same quantity for the enacted map. The blue and red points to the left and right of this line, respectively, indicate the Republican vote share in the pivotal district in the maximal Democratic and Republican gerrymanders. The

---

as Appendix Figure D3 reports for an example state (North Carolina), use of shortburst applied to maximizing the margin of victory in a pivotal district appears to dramatically surpass distribution-based approaches in which an analyst simulates a random ensemble of maps. In the case of minimal constraints and when facing stronger map-drawing constraints, shortburst identifies maps with safer majorities (e.g., larger margins of victory in the pivotal district) than the ensemble approaches.

distance between each gerrymandered map and the 50% threshold is the magnitude of the swing that the gerrymander could withstand, while the distance to the baseline map is the additional vote share gained through gerrymandering (e.g., accounting for other underlying political factors in the state that advantage or disadvantage each party).[10]

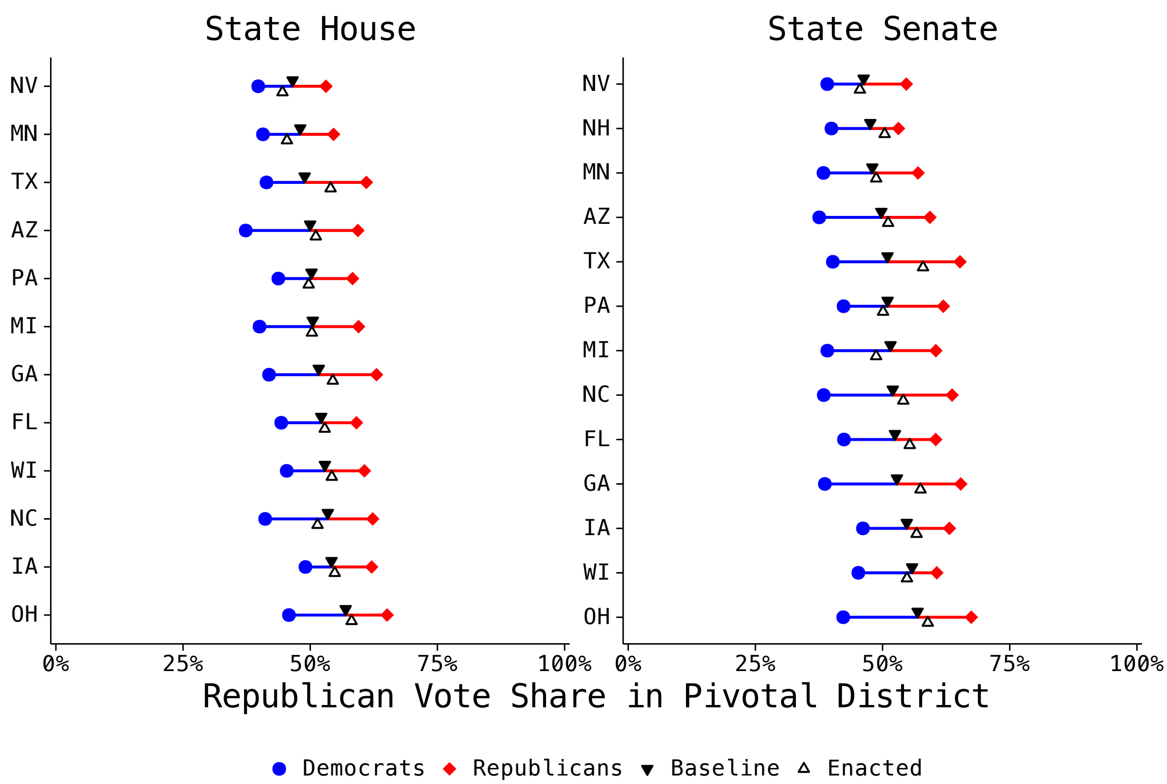


Figure 1: Maximizing Votes in Pivotal Districts: Gerrymanders vs Baseline Maps. **Notes:** This figure presents the size of the electoral swing that a majority gerrymander can withstand. The black upside-down triangle indicates the vote share in the pivotal district in the baseline simulation. The white triangle indicates the vote share in the pivotal district in the enacted map. The blue circle to the left of the bar indicates the Republican vote share in the pivotal district in the maximal Democratic gerrymander, and the red circle to the right of the bar indicates the Republican vote share in the pivotal district in the maximal Republican gerrymander.

To illustrate the results, consider the state of Texas House maps. The statewide vote share in the 2020 presidential election was around 47% for the Democratic candidate, Joe Biden. The

[10]Appendix Tables B1 and B2 present summary statistics for each state House and state Senate map that maximizes this objective for each of the two major parties.

shortburst algorithm produced a map maximizing Democratic vote share in the pivotal district and a second map maximizing Republican vote share in the pivotal district. For the Democratic map, based on 2020 presidential election totals, we estimate that Democratic candidates would have won roughly 53% of legislative district seats; similarly, if Republicans drew a map designed to maintain a majority, we estimate that Republican candidates would have won roughly 52% of seats. The key statistic is the vote share in the pivotal district. For the Democratic map, the pivotal district has a Democratic vote share of 58.6%, suggesting that the gerrymandered Democratic map would allow the party to maintain a majority in the legislature even with a statewide swing of over 8 percentage points in favor of the Republicans. In other words, even if the Democratic vote share swings from 47% to 39%, the Democratic gerrymander could still produce a Democratic majority in the Texas State House. For the Republican map, the pivotal district has a Republican vote share of 61%, meaning the party could maintain a majority in spite of an 11 percentage point statewide swing in favor of the opposing party. Considering that the Democratic vote share was 47%, it suggests that Republicans could maintain a safe majority in the legislature until statewide Democratic vote share begins to approach almost 60% under the assumption of uniform vote swing. Furthermore, as the figure illustrates, almost all of this vote swing withstood in the gerrymandered maps can be attributed to gerrymandering itself, as the neutral baseline maps withstand very little vote swing.

The state Senate maps for Texas reveal a similar story. The most notable departure from the House maps is that a Republican gerrymander proves to be even more durable. The gerrymandered Republican map for Texas state Senate has a Republican vote share of 65.2% in the pivotal district, suggesting the map can withstand a 15 percentage point electoral swing and still maintain a Republican legislative majority. As before, most of this can be attributed to the gerrymandering itself rather than the underlying political geography of the state. For reference, Appendix Figure J1 illustrates the Texas SD maps that maximize vote margin in the pivotal district for both Democrats and for Republicans. The differences between the Republican-drawn and Democratic-drawn Senate maps provide some intuition for the strategy that optimally gerrymanders the state for a durable majority. The Republican map creates a number of districts that combine rural areas with suburban and exurban parts of Dallas, Houston, Austin and San Antonio—effectively creating safe but not overly packed Republican-leaning districts, while packing Democrats in cities. In contrast, the Democratic gerrymander sees Democratic districts extending from urban cores in Austin, Dallas and Houston into suburbs and exurbs.

Returning to Figure 1, several other states stand out for the remarkable maps possible through unconstrained gerrymandering. Both Arizona and Georgia were essentially toss-ups in the 2020 presidential election, but legislative districts in each state can be drawn to lock in a party majority for either party. In Arizona, the Democratic map can withstand a 12.7 percentage point statewide swing without losing control of the chamber, and the Republican map can withstand a 9.4 percentage point swing. In Georgia, the Democratic map can withstand an 8.1 percentage point swing, and the Republican map can withstand a 13 percentage point swing. In North Carolina, a state with a 49.3% Democratic vote share in the 2020 presidential election, the gerrymandered Democratic map can withstand an 8.9 percentage point statewide swing in vote, while the gerrymandered Republican map can withstand a 12.3 percentage point statewide swing. Instructively, in all three of these states a neutral redistricting plan can only withstand a swing of a few percentage points while maintaining a legislative majority.

Forecasting for Durability

Assessing whether a map maintains a majority for a party while withstanding a given vote swing provides one angle on assessing the durability of a gerrymander. However, a more comprehensive approach requires directly assessing the probability of maintaining a party majority given election forecasts. To this end, we now explicitly define our measurement of a durable majority gerrymander, conceptualized as the probability that a gerrymandering political party will win a legislative majority in their state in an upcoming election, net of the probability of winning a majority under a neutral map. To calculate this quantity of interest for a given legislative district map, we must forecast the number of legislative districts a political party will win for each map and then (based on the posterior distribution) determine how often that party wins a legislative majority in a state legislative chamber.

Following previous notation, the probability of winning a majority for a given map m and statewide vote share v can be expressed as:

$$d(m,v) = \Pr\left(\sum_{i \in m}^{N} (\mathbb{1}[\nu_i > 0.5]) \geq \frac{N}{2}\right) \tag{3}$$

where $\mathbb{1}$ is an indicator function equal to one if the vote for the redistricting party in district i surpasses 50% and zero otherwise. Thus, the extent of a durable majority gerrymander for map m is:

$$d(m,v) - d(b,v) \tag{4}$$

where b refers to the baseline map. The metric is in the interval $[-1,1]$ but in practice will take a positive value as long as the map m provides as much or more durability than the neutral baseline map. Under an assumption of uniform swing (e.g., future electoral shocks occur uniformly across districts in a state), the measure of a durable majority gerrymander simplifies to the probability that the gerrymandering party wins the pivotal district in the gerrymandered map m minus the probability of winning the pivotal district in the baseline map b.

Identifying Durable Majority Gerrymanders through Simulated Elections

Estimating the quantities of interest defined in Equations 3 and 4 allows us to assess sensitivity to electoral swings of the maps drawn to enact durable gerrymanders. We simulate election swings based on historical elections data from presidential (Leip, 2016), senatorial (Leip, 2018a), and gubernatorial (Leip, 2018b) elections.

The most straightforward simulation approach employs statewide uniform swings. We use a multi-level model for forecasting elections, accounting for lagged vote share, group-level year, office and state random effects, and allowing for shocks to vary systematically depending on these features. Appendix Fdescribes the multi-level election forecasting model in full detail and reports validation exercises illustrating its effectiveness at predicting out of sample elections.

Under statewide uniform swings, the year-to-year changes have the same magnitude across all legislative districts in a state. This forecasting approach aligns with the objective function specified in Equation 2 that maximizes margin of victory in the pivotal district.[11] We pair the statewide election forecasts with the maps optimizing the objective function in Equation 2. Our quantity of interest is the share of total simulated elections where the redistricting party maintains a simple majority in the state legislature. To determine this quantity given a statewide uniform swing, the vote share in the pivotal district (and all other districts) shifts based on the size of each simulated swing, and we then determine which party wins a majority given the simulated election totals.

A limitation of the approach is that different areas of a state may swing more or less from election to election. Thus, we also relax the assumption of uniform swing and model district-specific electoral swings. We again implement a multi-level election forecast model to simulate heterogeneous electoral swings within a state. As compared to the model for statewide electoral

[11]Note that uniform swings mean an analyst knows the pivotal district *ex ante*.

swings, this new model replaces state random effects with county random effects. The residual variance in this model incorporates these effects as well, capturing correlations in random shocks between counties based on historical election data. For example, in an election where a shock diminished Democratic vote share in rural parts of a state but increased Democratic vote share in urban parts, the model can capture such heterogeneity. The county-level forecasts are then disaggregated to the precinct level. Appendix F provides further details.

This forecasting approach pairs with the objective function maximized in Equation 1, where we maximize the probability of maintaining a majority directly. To calculate the probability of winning a subsequent election we tally the share of simulations for which the redistricting party maintains a simple majority in the state legislative chamber.

We validate both forecasting models by using them to predict results for the 2020 elections. For the state-level model, we predict state-level 2020 presidential election results after fitting the model on past election data; the exercise confirms the model performs well (see Appendix Figure F1(a)). For the district-level model, we predict 2020 state legislative results (by chamber and district) in two ways: using lagged district-level presidential vote as a predictor and then, separately, using the lagged state legislative election result as a predictor. Again, both models perform well; the true outcomes fall outside of the prediction intervals 5% of the time or less (see Appendix Figure F1(b)). This validation exercise shows that national elections effectively predicted state legislative elections in 2020, but of course some potential sources of measurement error remain.

Redistricting parties may have unique knowledge of local political trends that we cannot observe or incorporate in a forecasting model. An on-the-ground expert may be able to harness knowledge of local candidates, local political conditions, and changing trends in ideology and population growth to produce a more accurate forecast—incorporating these factors may allow for a more durable gerrymander that our forecasting approach would not detect. However, as elections continue to nationalize (Hopkins, 2018), local idiosyncrasies and variation not captured by national partisan forces appear relatively less frequent. Furthermore, factors such as progressive ambition (and, in some states, term limits) produce considerable turnover in state legislatures so that local knowledge of particular candidates is unlikely to alter the ability to enact durable gerrymanders over the long-term.

Election Simulations to Assess Durable Gerrymanders

For states where the underlying composition of voters favors one party in a lopsided manner, a map gerrymandered to lock in a durable party majority can only add modestly to the probability of maintaining a majority for the dominant party. For example, for legislative districts in Massachusetts (where 2020 statewide Biden vote share was 67%), we estimate that a neutral baseline map still offers Democrats a near certain chance of maintaining a party majority. Ceiling effects therefore necessarily limit the impact of gerrymandering for a durable majority. On the other hand, in states with electoral competition as well as for minority parties in lopsided states, a gerrymander designed to create a durable majority has a larger effect when compared to a neutral baseline map. Figure 2 presents results for competitive states (where 2020 two-party vote share was between 45% and 55%) and we report the full set of results across states in Appendix Figure A4. The red points (diamonds) report the probability of winning a majority in the next election when Republicans are the gerrymandering party; the blue points (circles) depict the probabilities when Democrats are the gerrymandering party. We also report the probability of a Republican victory under the neutral baseline map and for the current, enacted maps. The difference between the estimates for the party-controlled gerrymanders and the baseline map is the additional probability of winning attributable to a gerrymander. We analyze map data and district lines current to the conclusion of the 2022 mid-term elections U.S. Census Bureau (2021, 2022).

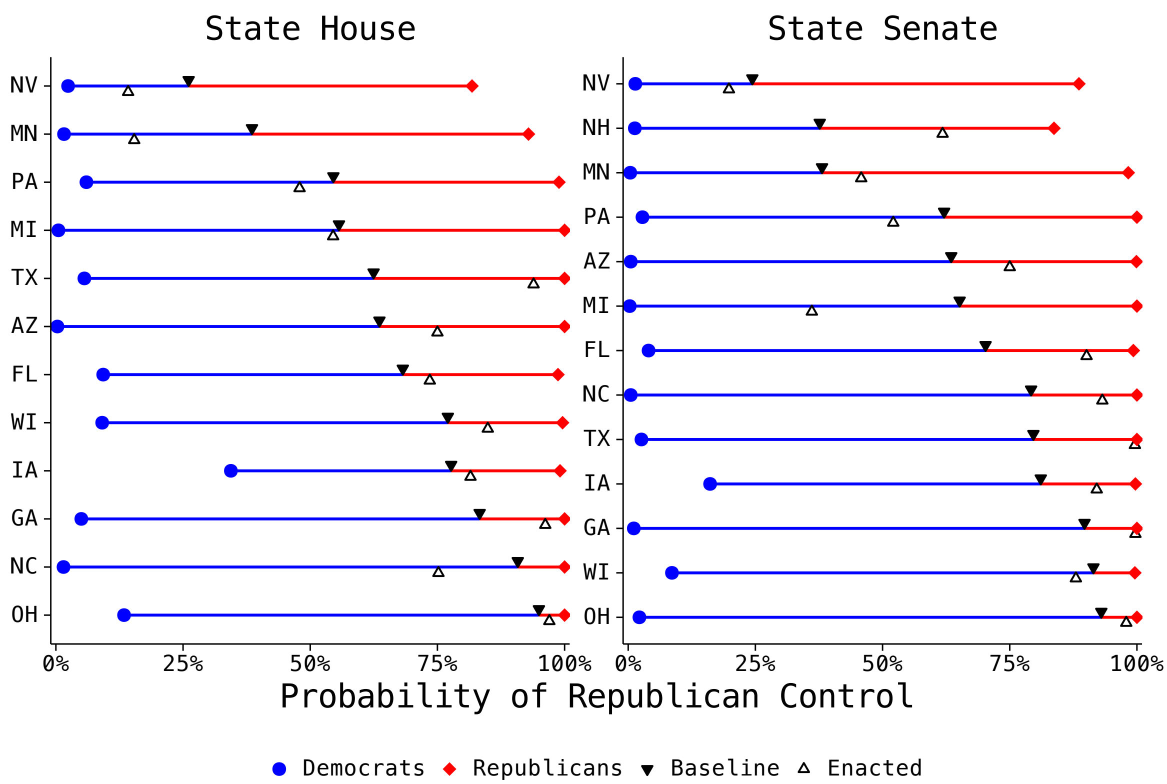


Figure 2: Probability of Winning Next Election for Redistricting Party Under Optimal Gerrymander, Simulated Statewide Election Swings from Multi-Level Election Forecast Model. **Notes:** This figure presents, for State House and State Senate district maps, the probability that each redistricting party will win a majority in their respective chamber, based on simulations from past elections. The black upside-down triangle indicates the probability of Republican control of the chamber under the baseline simulations. The white triangle indicates the probability of Republican control of the chamber in the enacted map. The blue circle to the left of the bar indicates the probability of Republican control under the maximal Democratic gerrymander, and the red circle to the right of the bar indicates the probability of Republican control under the maximal Republican gerrymander.

This figure illustrates several surprising findings about durably gerrymandered maps. For states with competitive balance between the parties, either party can come close to locking in a legislative majority if given the opportunity to gerrymander. Based on these forecasts, in almost every case either party in the competitive states can ensure a better than 3 in 4 chance of winning a legislative majority, even when facing a statewide electoral disadvantage.

When allowing for a more complicated model of elections where vote swings do not occur uniformly (reported in Appendix Figure A1), the results are largely similar, but parties without strongly lopsided statewide advantages have lower chances of maintaining majorities, consistent with higher variability due to heterogeneous swings across districts. Even with this greater variability, in some states either party can essentially ensure a majority in a legislative chamber if given the opportunity to gerrymander; these states include Arizona, Michigan, North Carolina and Texas, particularly for the State Senate maps.

Second, in the competitive states, a large part of the ability to ensure a legislative majority arises from gerrymandering itself. Comparing the probability of a majority under the gerrymandered map to the neutral baseline reveals this finding. This ability appears most pronounced in states such as Georgia and North Carolina, where in some cases Democrats can add 70 percentage points to their probability of winning a legislative majority as compared to the neutral baseline map.[12]

[12] Comparing maps gerrymandered for a durable majority to a neutral baseline also helps illustrate the strategies adopted by a gerrymandering party. Appendix Figure A3 illustrates a visualization of the district-by-district changes in 2020 presidential election vote share when seeking to maximize vote margin in the pivotal district (e.g., optimal strategy for uniform swings) and when seeking to maximize the odds of maintaining a majority under non-uniform vote swings. The example used in the figure is for Republicans in the North Carolina state Senate. In each case, the optimal strategy involves packing more Democrats into existing majority-Democratic districts and reducing

Election Simulations for a Full Redistricting Cycle

Since a redistricting cycle typically spans five separate general elections (e.g., the current cycle includes general elections in 2022, 2024, 2026, 2028 and 2030), we also estimate the probability that a party with a majority in a state legislative chamber will maintain a majority for a full redistricting cycle. Most state Houses have 2-year term lengths, with Alabama, Louisiana, Maryland, Mississippi, and North Dakota as the only exceptions. Some state Senates also have two year terms, but a majority have other term lengths, including some with 2-4-4 terms (e.g., three elections every ten years). Many state Senates have elections every two years, but with only a subset of state Senators facing reelection. Our simulations incorporate these varying electoral schedules for each state (Ballotpedia, 2025a,b).

---

the margins in lopsided Republican districts in order to add to the vote margins in the more competitive Republican-leaning districts.

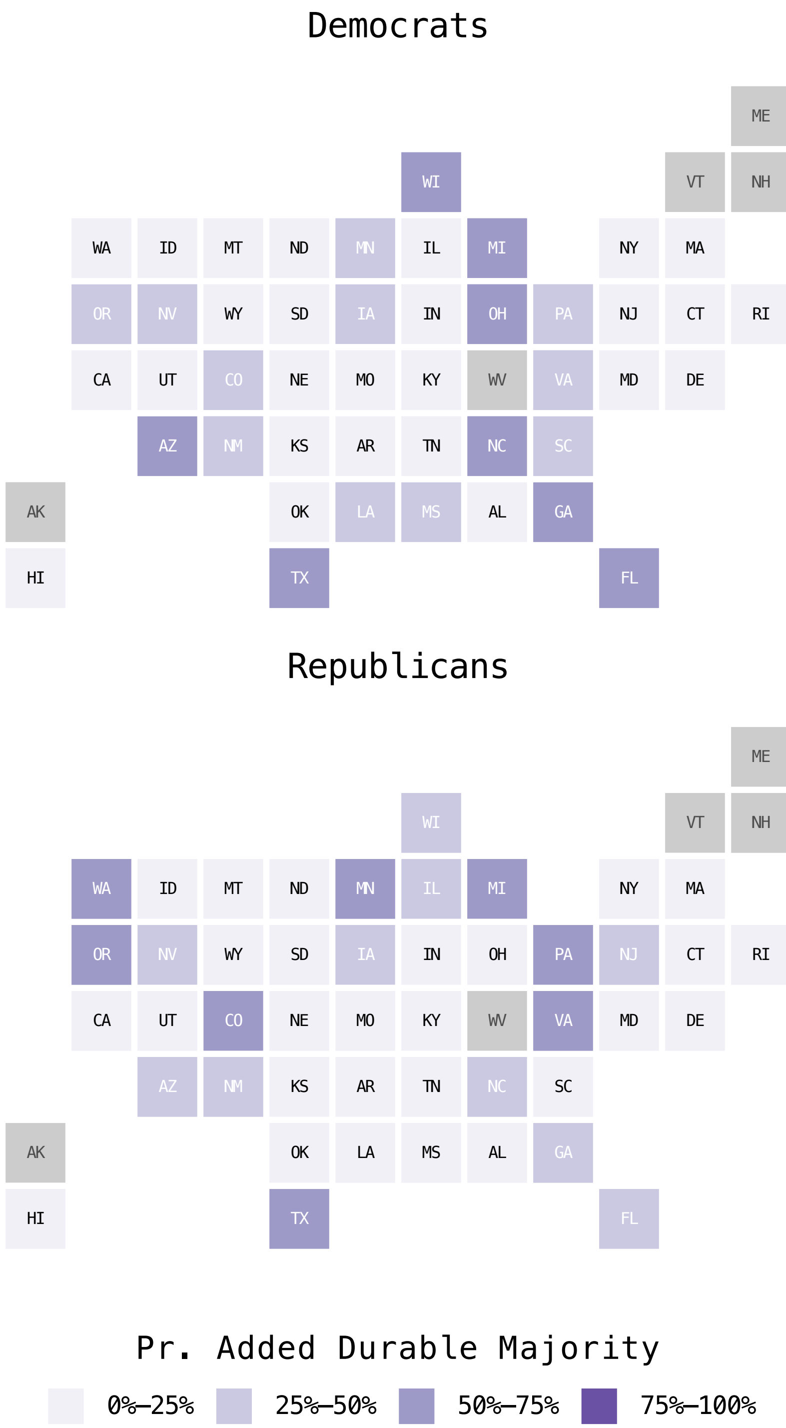


Figure 3: Durable Majorities in Both Legislative Chambers by State, Upcoming Hypothetical Full Redistricting Cycle. **Notes:** This figure illustrates for Democrats and Republicans the probability that optimal gerrymandering adds to the chances of maintaining a majority in both chambers of the state legislature for a full decade. We calculate this quantity by comparing the chances for a party's gerrymandered map with the objective of maximizing chances of maintaining party control for a decade to the chances under a neutral baseline map. The states in gray were omitted from our calculations due to either lack of data or a unicameral legislature. For New Hampshire, we perform this calculation only for the state Senate.

To estimate the probability of a party maintaining a durable majority for a full redistricting cycle, we implement step-ahead forecasts, simulate a decade of future elections, and then determine the share of simulations for which a single party maintains a majority throughout the sequence of elections. Appendix G provides additional details. Note that if each election was independent across years (which is not the case), then a party with a 75% chance of winning a majority would maintain partisan control through a sequence of five elections with a probability of just 24%. A party with even odds would have just a 3% chance of maintaining partisan control through a full cycle. As a result, we view our assessments of gerrymanders for a full redistricting cycle as a very strict test of durability. In practice, as courts eliminate restrictions on gerrymandering some states may redraw state legislative district lines after a single election in response to shifts in the distribution of voters.[13] If mid-decade redistricting grows commonplace for state legislative districts, then simulations forecasting the next hypothetical election would serve as the most informative measure of durable partisan gerrymandering.

Figure 3 reports for each state and party the additional probability of maintaining a durable majority attainable through gerrymandering *in both state legislative chambers* for a full redistricting cycle.[14] Arizona, Florida, Georgia, Michigan, North Carolina, Ohio, Texas and Wisconsin stand out as states where Democrats could employ gerrymandering to add between 50 and 75 percentage points to the chances of locking in a decade-long legislative majority in both chambers, as compared to a neutral baseline. Republicans in Colorado, Michigan, Minnesota, Oregon, Pennsylvania, Texas, Virginia, and Washington can similarly make such gains through gerrymandering. Michigan and Texas stand out as states where either party can make such dramatic gains. Table 1 reports the

[13]In 2025, Texas redrew congressional districts mid-decade and additional states may follow.

[14]As before, we calculate probability of control gained through gerrymandering by comparing to a neutral baseline map and using the assumption of uniform swings.

raw probabilities for each state.[15]

Moving from durability attained through gerrymandering to an assessment of overall durability, we estimate that in a bit more than one in five states, *both* parties have the ability to construct maps offering more than even odds (e.g., greater than 50% chance) to maintain partisan control of both legislative chambers throughout the decade. In state Houses, states where both parties have a 75% chance or greater of maintaining a decade-long durable majority include Arizona, Michigan, North Carolina and Virginia. In state Senates, this list expands further. See Appendix Figure A7 for the full accounting.[16] The threat of either party locking in a permanent majority creates clear incentives to expend extensive resources to block such efforts. Consistent with this notion, many of the states identified in Figure 3 and Appendix Figure A7 have witnessed fierce contests over redistricting, including ongoing attempts to gerrymander and to litigate existing maps.

Locking in a party majority for a full redistricting cycle bears directly on prospects for a democracy offering more than one party a non-zero chance to govern. In the redistricting cycle from 2012 to 2021, 35states had unified control of both chambers of the state legislature for the full decade (Klarner, 2013; National Conference of State Legislatures, 2025). To evaluate prospects for the next decade given current maps and given the counterfactual of extreme gerrymandered

[15]Making forecasts far into the future by necessity will yield results somewhat sensitive to forecasting assumptions. When we forecast under the assumption of non-uniform swings, we find that Democrats could increase the chances of a decade-long majority by more than 25% in Arizona, Colorado, Oregon, Virginia and Washington; Republicans could do the same in Arizona, North Carolina, Texas and Virginia. To provide an alternate forecast, we made forecasts based upon observed sequences of historical elections (and hence election swings) rather than step-ahead forecasts. Appendix Figure A6 reports the results and provides additional details on the method.

[16]Appendix Figure A8 disaggregates the results by party and legislative chamber.

Table 1: Durable Majorities by State (Pr. Added to Chances of Majority in Both Legislative Chambers), Upcoming Hypothetical Full Redistricting Cycle

State	Dems. Draw	Reps. Draw	State	Dems. Draw	Reps. Draw
AL	0.07	0.00	MT	0.06	0.08
AR	0.04	0.06	NC	0.74	0.31
AZ	0.67	0.48	ND	0.01	0.02
CA	0.15	0.07	NE	0.19	0.01
CO	0.42	0.66	NJ	0.09	0.26
CT	0.12	0.04	NM	0.29	0.34
DE	0.06	0.02	NV	0.38	0.46
FL	0.53	0.39	NY	0.13	0.17
GA	0.63	0.34	OH	0.61	0.23
HI	0.04	0.00	OK	0.00	0.01
IA	0.31	0.37	OR	0.43	0.62
ID	0.00	0.00	PA	0.48	0.54
IL	0.19	0.26	RI	0.12	0.05
IN	0.21	0.09	SC	0.27	0.12
KS	0.09	0.08	SD	0.01	0.06
KY	0.00	0.02	TN	0.04	0.03
LA	0.34	0.04	TX	0.56	0.53
MA	0.10	0.01	UT	0.00	0.01
MD	0.01	0.19	VA	0.45	0.73
MI	0.72	0.58	WA	0.22	0.65
MN	0.48	0.51	WI	0.61	0.43
MO	0.02	0.08	WY	0.00	0.00
MS	0.46	0.05			

Notes: This table shows the probability that optimal gerrymandering adds to the chances of maintaining a majority in both chambers of the state legislature for a full decade. We calculate this quantity by comparing the chances for a party's gerrymandered map with the objective of maximizing chances of maintaining party control for a decade to the chances under a neutral baseline map. The color codes correspond to those for Figure 3.

maps, we directly calculated the posterior distribution of the number of states forecast to have a single party maintain unified control for the next decade. Figure 4 reports the results. The forecast for the next decade under the enacted district maps is centered closely around the actual result from the previous cycle. The forecast has a mean of 37.1states with a party maintaining uninterrupted majority control for a full decade. Under the counterfactual of each majority party drawing a durable gerrymander, the forecast distribution shifts substantially rightward, with a mean of 43.4states. The posterior draws for the optimal maps almost exclusively fall at or above the result for the previous decade of 35 states with a unified majority.

Unconstrained, optimal gerrymandering would further reduce party competition in state legislatures in the United States based on these findings. While we forecast that under the current, enacted maps a substantial majority of states will have single-party unified control for the full decade, our findings suggest unconstrained gerrymandering could add roughly six states to that number.

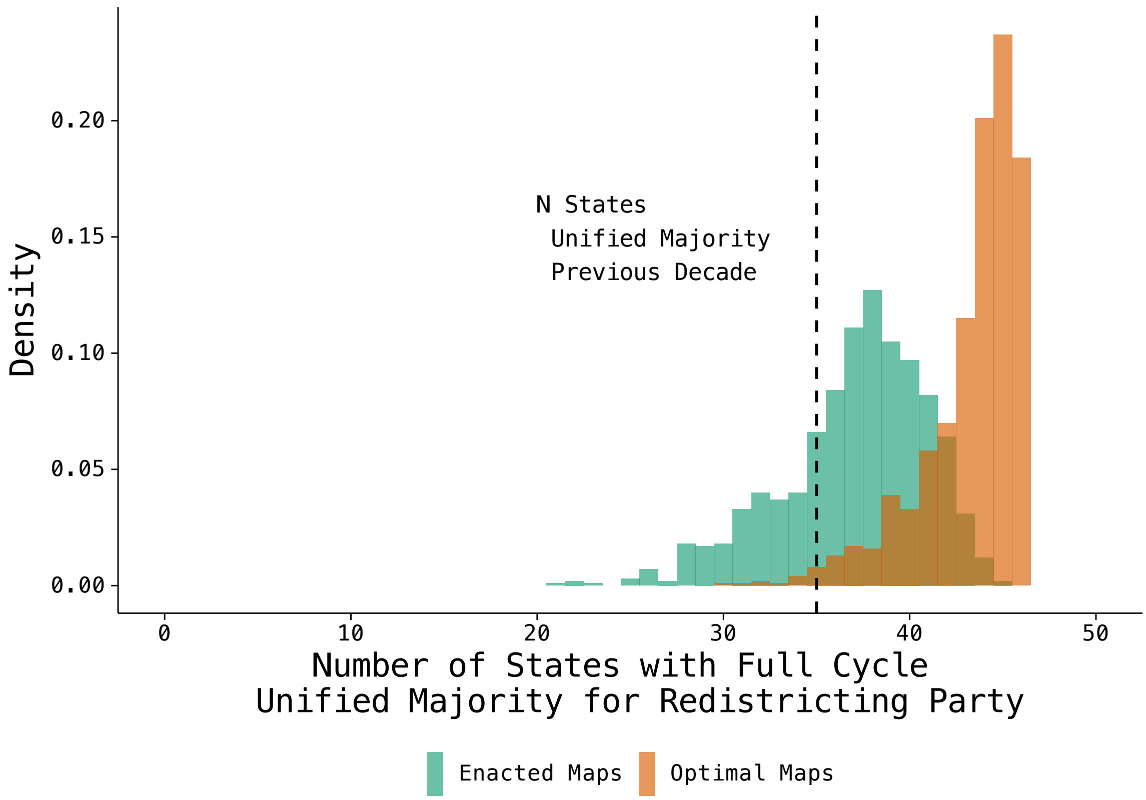


Figure 4: Forecast of Number of States with One-Party Rule in State Legislature for Full Decade. **Notes:** This figure illustrates the forecasts for the number of states where a single party maintains a majority in each chamber of the legislature for the full decade of the 2022–2031 redistricting cycle. The green histogram plot illustrates the forecast for the currently enacted maps while the orange histogram plot illustrates the forecast under the counterfactual of the majority party enacting a durable majority gerrymander.

Enacted Maps

Enacted maps in the competitive states generally do not approach the limits possible under unconstrained partisan gerrymandering. For instance, in the Michigan state House the parties have roughly even odds of winning a majority under the enacted map, but under gerrymandered maps either party could dramatically improve their chances at a majority. Arizona represents another case where the enacted map does not lock in a result with certainty. Notably, a commission draws the district maps in each of these states.

In states where enacted maps offer a high probability of maintaining a majority, much of that can be attributed to underlying geographic and partisan characteristics of the state. For example, in the Ohio state House, Republicans have high chances of maintaining a majority in the next election in each chamber of the legislature, but the neutral baseline maps offer similarly favorable odds for Republicans. Figure 5 summarizes these findings across competitive states, displaying the additional probability of maintaining a majority in a future election over a neutral baseline for a state's enacted map and for a counterfactual durable majority gerrymander. A handful of enacted maps exhibit modest advantages for durability won through redistricting. In both chambers of the Georgia legislatures and in the Florida and New Hampshire state Senates (among others), enacted maps drawn by Republican state legislatures considerably increase the odds of maintaining a durable majority. In Nevada, enacted maps drawn by the Democratic state legislature increase the odds of maintaining a durable majority. The enacted map for the Minnesota state House, but not the Senate, similarly increases Democratic chances at holding a majority.[17]

[17] Furthermore, across more than half of the competitive states enacted maps suggest a level of sophistication that goes substantially beyond simply maximizing the number of seats won. Appendix Figure A2 illustrates cases where a map maximizing seats won offers a *lower* probability of maintaining a durable majority than a state's enacted map).

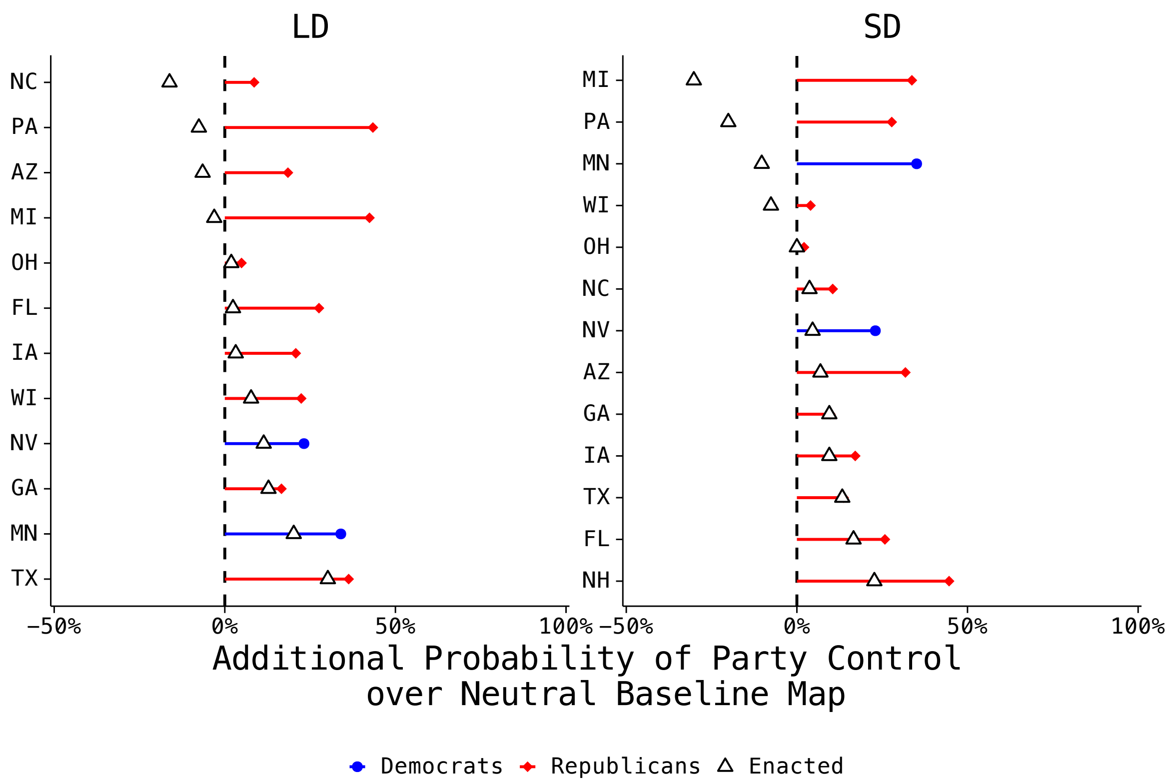


Figure 5: Comparing Enacted Maps to Durable Majority Gerrymanders, Both Net of Baseline, Simulated Statewide Election Swings from Multi-Level Election Forecast Model. **Notes:** This figure presents, for State House and State Senate district maps, the additional probability (net of the neutral baseline maps) garnered for Enacted maps (triangles) and for the Durable Majority Gerrymander map possible for the majority party in the state (red/blue circle).

As Figure 5 illustrates, Texas stands out most as a state where the enacted map approaches the limits of an optimal durable majority and where this appears attributable in considerable part due to map drawing itself. In the lower chamber of the Texas state legislature, a neutral baseline map would only modestly advantage Republicans yet in the enacted map Republicans had well over a very strong chance of winning a majority. Even so, there is still some room to improve the durability of the lower chamber's majority. In the upper chamber of the Texas state legislature, the enacted map again increases the chances of maintaining a majority dramatically as compared to the neutral baseline, and it essentially ensures future Republican majorities.

These comparisons raise the issue that the optimally gerrymandered maps account for only minimal constraints (contiguity, equal population, and mild compactness constraints) and otherwise have the sole objective of creating a durable majority. Yet, many states impose additional constraints on map drawers. We view the measure of a durable majority gerrymander as a theoretical quantity representing an estimate of the most extreme gerrymander possible for the purposes of enacting a durable majority (1) subject to minimal constraints and (2) setting aside details about how state-level redistricting guidelines are interpreted. As legislatures can endogenously choose their own redistricting constraints, and judicial interpretations of constraints are quickly evolving, these theoretical limits for each state represent the extremes possible for map drawers.[18]

Nonetheless, we sought to check whether imposing constraints similar to those faced by current map drawers would alter the possibilities for durable majority gerrymanders. We gathered information on the practical and legal redistricting constraints faced by map drawers in four states—Colorado, Nebraska, North Carolina and Texas—and set about re-implementing our simulation-based approach while explicitly accounting for the constraints in each state. The mix of states represents variation in state population size, level of competitiveness, and the constraints faced my map drawers. Appendix Table H1 describes these constraints and their implementation for each state.

When imposing constraints accounting for legal redistricting criteria in these four states, the resulting durable majority gerrymander maps match or exceed enacted maps on key legal redistricting criteria (compactness, county splits, and population equality) while sacrificing only very small durability advantages. Appendix Figure H2 illustrates that when imposing the legal redistricting constraints the durable majority maps and baseline maps match the enacted maps in terms of compactness (and substantially exceed compactness in Texas); in terms of county splits and

[18]As a useful point of reference, we compare the minimally constrained maps to enacted maps along several key redistricting criteria in Appendix H.

population deviations, the simulated maps again match the enacted maps, with only the North Carolina enacted districts exhibiting noticeably fewer county splits than the simulated maps. Finally, the figure indicates that the probability of maintaining a party majority for the constrained durable majority maps continues to exceed the enacted and baseline maps. Furthermore, when recalculating the additional probability of party control over a neutral baseline map for enacted and constrained durable gerrymander maps, the relative positions of enacted maps to the most durable gerrymanders possible remain unchanged (see Appendix Figure H3).

Explaining Durable Gerrymanders

Analysis of the enacted maps raises the question of why a greater number of state parties (beyond Republicans in Texas and, to a slightly lesser extent, Georgia) do not explicitly seek to optimize maps for durable majorities. For one, parties have multiple objectives when redistricting, and so parties in other states may place more weight on alternative goals beyond creating a durable majority. Other explanations include constraints brought about by legal action (including the Voting Rights Act), the threat of legal action, or map-drawing constraints specified in state constitutions. McCartan et al. (2024) provides a detailed analysis of how a range of reforms may affect the partisan bias of enacted maps. Analyzing variation in the durability of enacted maps, we seek to understand (1) how it relates to the underlying geographic and partisan factors captured by a state's neutral baseline map and a state's most durable map, and (2) what state-level redistricting rules and institutions best explain increases and decreases in durability.

To start, we measure geographic and partisan factors using (a) the durability of the majority party's *optimal* map and the durability of the neutral *baseline* map, (b) the majority party in the state, and (c) the district type (e.g., state House or Senate).[19] To capture state-level redistricting

[19]The durability measures summarize how geography and the partisan leanings of the electorate

guidelines, we gathered data from the National Conference of State Legislatures and All About Redistricting (National Conference of State Legislatures, 2021; All About Redistricting, 2024). We record the method used to draw a map (legislature-drawn, advisory commission, independent commission, backup commission, or politician commission) along with a range of rules and guidelines, primarily in state constitutions, that place constraints on map drawers. These rules and guidelines require map drawers to take into account constraints based upon (1) compactness of districts, (2) not favoring incumbents (e.g., explicitly preventing incumbent pairing or allowing it), (3) no use of partisan data, (4) not favoring parties, and (5) preserving communities of interest, previous district cores and/or political subdivisions.[20] Each of these guidelines can be thought of as restricting or expanding some part of the space of possible maps in a state, and different state constitutions impose different sets of guidelines upon map drawers. Appendix Table B3 summarizes the variables captured and how they are coded.

Redistricting is a policy context with many nonlinearities and plausible interactions between variables. Parties may, for example, respond differently to a rule or constraint based on the spatial distribution of their voters (e.g., consider that compactness requirements could either limit or boost the drawing of maps that deliver a partisan advantage based on different configurations of voters). To account for such possibilities, we assess variable importance with a method that does not require strong assumptions about the form of the relationship between the extent of durable gerrymandering and our set of explanatory variables. Specifically, we estimate random forest models to predict durability of enacted maps. We then use a standard importance measure for Random Forest models, the mean decrease impurity (MDI), to assess variable importance. MDI

combine to produce gerrymandered or neutral maps. The underlying structure of the data in the analysis is a state-district cross-section, with state characteristics current as of 2024.

[20]In addition, all states other than Nevada require contiguity of districts.

measures the reduction in variance at each node attributable to including or excluding a variable in a tree and then is summed across trees (Breiman, 2001).[21] It captures how much each predictor reduces unexplained variance in the durability of a map while also allowing for nonlinearities and interactions. Higher values denote more important variables.

Figure 6 Panel A presents the results for the full sample of states and reveals two key points. First, the durability measures, which capture underlying geographic and partisan factors, have the largest variable importance scores by a considerable margin—consistent with geography and partisan composition of the state electorate playing by far the largest role in explaining durability of a state's enacted map. Indeed, geographic and partisan factors explain more of the variation in durability of enacted maps than all of the state-level guidelines and rules combined. Second, the variable importance exercise identifies method of redistricting and rules related to not favoring incumbents as the most important state-level rules and guidelines. These rules and guidelines may help explain whether an enacted map's durability falls closer to the upper bound represented by the optimal gerrymander or closer to the neutral baseline.

Next, we focus on whether each variable in the importance analysis is positively or negatively associated with the durability of a party's majority. We fit a linear regression of the probability of a party majority under each enacted map on the same set of covariates capturing state-level geography, partisan composition, and rules.

Figure 6 Panel B reports that state-level rules related to compactness and not favoring incumbents appear associated with constraining map drawers. Among redistricting methods, independent commissions appear most associated with a reduction in durability of enacted maps. Compactness and method of redistricting may impose particularly biting constraints on the range of possible

[21]We adjust this measure by setting the most important explanatory variable to a value of 1 and all other variables to reflect importance relative to the most important variable.

maps. A strong enough compactness constraint eliminates a range of possible maps that could enable more durable gerrymanders. Similarly, while there are ongoing debates on the extent to which independent commissions limit gerrymandering (Henderson, Hamel, and Goldzimer, 2018), they can likely provide constraints pulling enacted maps away from the most extreme durable gerrymanders that legislature-drawn maps do not face.

Finally, several state-level guidelines and rules were associated with higher chances of approaching a durable gerrymander. Rules prohibiting encouraging competitiveness, prohibiting the use of partisan data, and requiring backup commissions stand out as having the most positive associations with map durability. One possibility is that competitiveness guidelines may "put in play" (e.g., make competitive) districts that would otherwise be safely won by the minority party, further reducing minority party chances of winning a legislative majority.

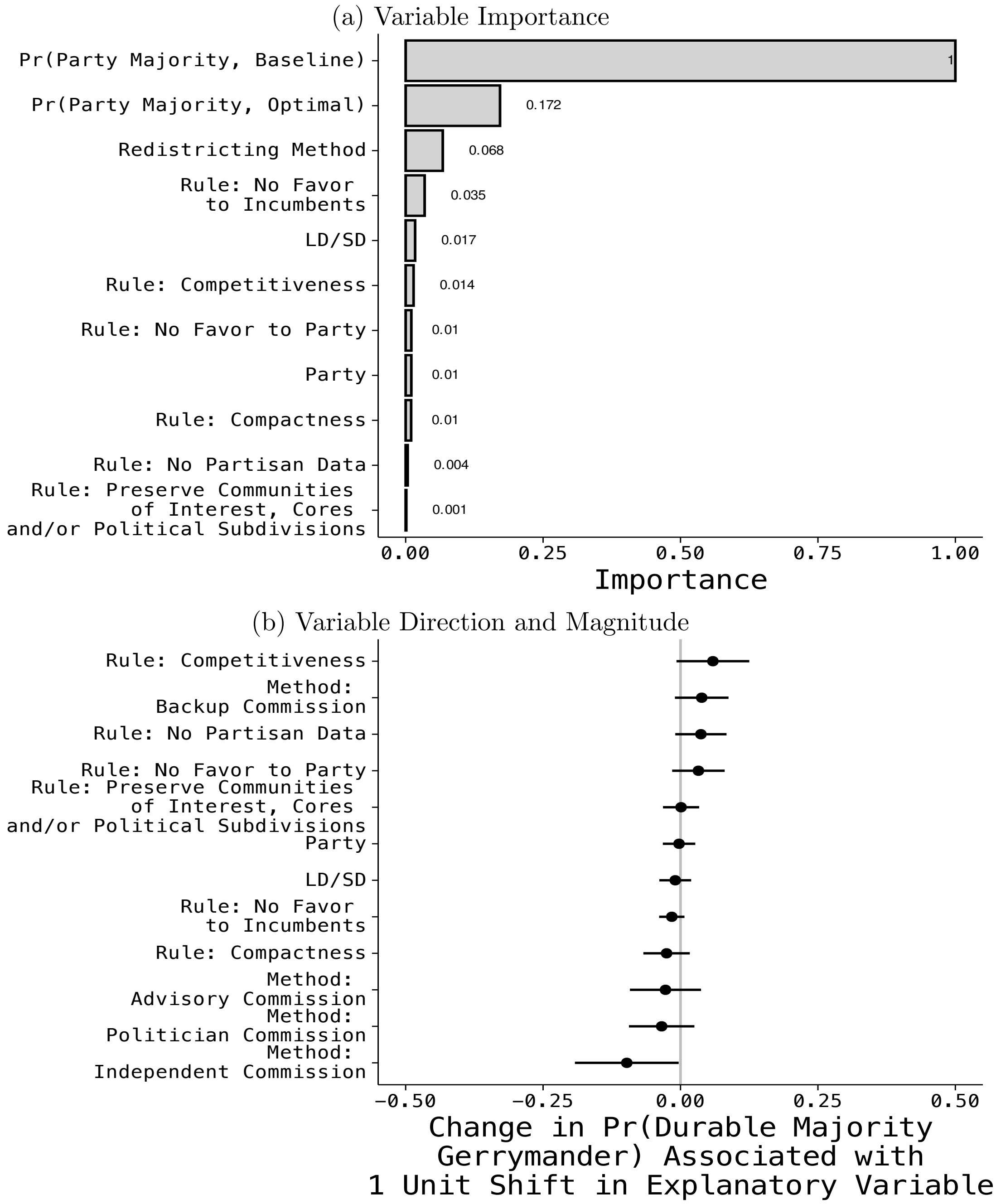


Figure 6: State Characteristics and Extent of Durable Majority Gerrymanders in Enacted Maps. **Notes:** This figure presents estimates of the relationship between state geographic and population characteristics and the extent of enacted durable majority gerrymanders. Panel (a) uses a random forest model to examine the durability of enacted maps as a function of durability of neutral baseline maps and optimally gerrymandered maps, party control, district type, and state-level rules. Variable importance is determined based on reductions in unexplained variance attributable to each variable. Panel (b) examines the magnitude and direction for factors predicting whether an enacted map has higher durability. The model is a linear regression with robust standard errors. The 95% confidence intervals reflect the uncertainty around each point estimate. The estimates for "Method" are reported in contrast to the excluded category of legislature-drawn districts. In Panel (b) we control for the baseline and optimal map but omit them from the figure to focus on state-level rules and redistricting methods.

Conclusion

The landscape of redistricting and election law may look dramatically different in just a few years. Even if state legislatures do not maximize partisan advantage as ruthlessly as the short-burst algorithm—and surely other factors and priorities will continue to matter in the redistricting process—map drawers can enact durable partisan gerrymanders in many states without much difficulty, even in states where party identification splits relatively evenly among voters. Through gerrymandering alone, political parties can dramatically increase their chances of maintaining a legislative majority, an effect that we estimate is more than 20 percentage points on average and can reach triple that magnitude in states with specific political geographies such as North Carolina and Texas. Furthermore, we illustrate how durable gerrymanders may yield substantial increases in the chances of a party to enact maps that lock in a unified legislative majority for a full decade.

Our primary contribution is developing a theoretical framework and empirical basis for estimating durable majority gerrymanders. By doing so, we can report directly interpretable measures of the chances of a party locking in state-level majorities in extreme counterfactual maps, in current enacted maps, and in neutral baseline maps. These estimation tools reveal both the extreme anti-democratic possibilities of durable majority gerrymanders along with the more modest, but still meaningful, biases present in currently enacted state legislative maps.

Our findings also point to the factors that best explain variation in the maps actually enacted in each state. Underlying state characteristics—including geography and partisanship—matter by far the most, as one might expect, in explaining variation in enacted maps. But conditional on these factors, state-level guidelines also appear to play a meaningful role, with factors such as compactness constraints and independent commissions correlated with enacted maps falling closer to neutral baselines than to extreme durable gerrymanders. At the same time, as the states that do enact extreme durable gerrymanders illustrate, this state of affairs may be relatively fragile, and a swing election that threatens a party's long-held majority may be all it takes for map drawers to explore maps that are even less responsive to partisan swings.

Increasing numbers of durable majority gerrymanders would have meaningful implications for democratic governance and majority representation. Once locked into a durable majority, a motivated state legislature may be able to make further legal changes to maintain political power, including changes to election administration and ballot access, campaign regulations, and other policies. With more limited accountability to voters, state legislatures can make increasingly unpopular policy decisions when their own preferences deviate from their constituents' preferences. While unpopular policy choices may lead to electoral swings in the future, durable partisan gerrymanders may diminish or even prevent electoral change and partisan turnover despite such swings.

Though written and conceived before the mid-decade congressional redistrictings of 2025, this paper anticipated the possibility that partisans could seek out increasingly extreme maps, even in the middle of a redistricting cycle. Given the opportunities available to lock in political power at the state level, even more extreme legislative redistricting may come next. If frequent mid-decade redistrictings for purely partisan ends become the norm, the harms of partisan representation may grow and there may be an even greater need for nation-wide reform.

National-level legislative solutions appear the most direct way to protect against durable majority gerrymanders and the accompanying threats to democratic principles, considering how widespread the potential is for such gerrymandering. Past attempts at a remedy such as the "For the People Act" (H.R. 1)—an effort to pass sweeping electoral reforms including mandated independent redistricting commissions in each state—met with fierce political opposition and never came close to passing through Congress. Given institutional barriers in Congress to such action, such an approach appears unlikely for the foreseeable future.

Reforms further tying parties' hands or preventing single parties from determining district maps appear most essential. Independent commissions, delegating map drawing to independent experts, or solutions that involve structured bargaining between both parties (Palmer, Schneer, and DeLuca, 2024) would all limit the chances for redistricting plans that upend the will of a majority of voters. This paper has provided a road map of where to target such reforms by developing the concept of durable majority gerrymanders and estimating its prevalence in the states.

References

All About Redistricting. 2024. "All About Redistricting: National Overview." `https://redistricting.lls.edu/national-overview`. Accessed August 28, 2024.

Ballotpedia. 2025a. "Length of Terms of State Representatives." `https://ballotpedia.org/Length_of_terms_of_state_representatives`. Accessed August 28, 2025.

Ballotpedia. 2025b. "Length of Terms of State Senators." `https://ballotpedia.org/Length_of_terms_of_state_senators`. Accessed August 28, 2025.

Breiman, Leo. 2001. "Random Forests." *Machine learning* 45: 5–32.

Cannon, Sarah, Ari Goldbloom-Helzner, Varun Gupta, JN Matthews, and Bhushan Suwal. 2023. "Voting Rights, Markov Chains, and Optimization by Short Bursts." *Methodology and Computing in Applied Probability* 25 (1): 36.

Caughey, Devin. 2018. *The Unsolid South: Mass Politics and National Representation in a One-Party Enclave*. Princeton University Press.

Caughey, Devin, Chris Tausanovitch, and Christopher Warshaw. 2017. "Partisan Gerrymandering and the Political Process: Effects on Roll-Call Voting and State Policies." *Election Law Journal: Rules, Politics, and Policy* 16 (4): 453–469.

Chen, Jowei, and David Cottrell. 2016. "Evaluating Partisan Gains from Congressional Gerrymandering: Using Computer Simulations to Estimate the Effect of Gerrymandering in the U.S. House." *Electoral Studies* 44: 329-340.

Chen, Jowei, and Jonathan Rodden. 2013. "Unintentional Gerrymandering: Political Geography and Electoral Bias in Legislatures." *Quarterly Journal of Political Science* 8: 239-269.

Chen, Jowei, and Jonathan Rodden. 2015. "Cutting Through the Thicket: Redistricting Simulations and the Detection of Partisan Gerrymanders." *Election Law Journal* 14 (4): 331-345.

DeFord, Daryl, Moon Duchin, and Justin Solomon. 2021. "Recombination: A Family of Markov Chains for Redistricting." *Harvard Data Science Review* 3 (1): 1-67.

Erickson, Robert S. 1971. "The Electoral Impact of Congressional Roll Call Voting." *American Political Science Review* 65 (4): 1018–1032.

Erikson, Robert S. 1972. "Malapportionment, Gerrymandering, and Party Fortunes in Congressional Elections." *American Political Science Review* 66 (4): 1234–1245.

Gelman, Andrew, and Gary King. 1990. "Estimating the Electoral Consequences of Legislative Redistricting." *Journal of the American statistical Association* 85 (410): 274–282.

Grumbach, Jacob. 2022. *Laboratories Against Democracy: How National Parties Transformed State Politics*. Vol. 184 Princeton University Press.

Henderson, John A., Brian T. Hamel, and Aaron M. Goldzimer. 2018. "Gerrymandering Incumbency: Does Nonpartisan Redistricting Increase Electoral Competition?" *The Journal of Politics* 80 (3): 1011-1016.

Hopkins, Daniel J. 2018. *The Increasingly United States: How and Why American Political Behavior Nationalized*. University of Chicago Press.

Kenny, Christopher T., Cory McCartan, Ben Fifield, and Kosuke Imai. 2022. *redist: Simulation Methods for Legislative Redistricting.* ALARM. R package. https://alarm-redist.org/redist/.

Klarner, Carl. 2013. "State Partisan Balance Data, 1937 - 2011." https://doi.org/10.7910/DVN/LZHMG3.

Leip, Dave. 2016. "Dave Leip U.S. Presidential General County Election Results." https://doi.org/10.7910/DVN/SUCQ52.

Leip, Dave. 2018a. "Dave Leip Detailed General Election Data for U.S. Senate." https://doi.org/10.7910/DVN/IZQWRO.

Leip, Dave. 2018b. "Dave Leip Governor General County Election Data." https://doi.org/10.7910/DVN/LTFVBG.

Magleby, Daniel, and Daniel Mosesson. 2018. "A New Approach for Developing Neutral Redistricting Plans." *Political Analysis* 26 (2): 147-167.

McCartan, Cory. 2024. "Finding Pareto Efficient Redistricting Plans with Short Bursts.". https://arxiv.org/abs/2304.00427.

McCartan, Cory, Christopher T Kenny, Tyler Simko, Emma Ebowe, Michael Y Zhao, and Kosuke Imai. 2024. "Redistricting Reforms Reduce Gerrymandering by Constraining Partisan Actors." arXiv preprint arXiv:2407.11336.

McCartan, Cory, Christopher T Kenny, Tyler Simko, George Garcia III, Kevin Wang, Melissa Wu, Shiro Kuriwaki, and Kosuke Imai. 2022. "Simulated Redistricting Plans for the Analysis and Evaluation of Redistricting in the United States." *Scientific Data* 9 (1): 689.

McCarty, Nolan. 2019. *Polarization: What Everyone Needs to Know.* Oxford University Press.

National Conference of State Legislatures. 2021. "2020 Redistricting Criteria." https://www.ncsl.org/elections-and-campaigns/2020-redistricting-criteria. Accessed August 28, 2024.

National Conference of State Legislatures. 2025. "State Partisan Composition." https://www.ncsl.org/about-state-legislatures/state-partisan-composition. Accessed August 28, 2025.

Palmer, Maxwell, Benjamin Schneer, and Kevin DeLuca. 2024. "A Partisan Solution to Partisan Gerrymandering: The Define–Combine Procedure." *Political Analysis* 32 (3): 295–310.

Przeworski, Adam. 2000. *Democracy and Development: Political Institutions and Well-Being in the World, 1950-1990.* Cambridge University Press.

Przeworski, Adam, Michael Alvarez, José Antonio Cheibub, and Fernando Limongi. 1996. "What Makes Democracies Endure?" *J. Democracy* 7: 39.

Stephanopoulos, Nicholas O, and Christopher Warshaw. 2020. "The Impact of Partisan Gerrymandering on Political Parties." *Legislative Studies Quarterly* 45 (4): 609–643.

Stephanopoulos, Nicholas O., and Eric M. McGhee. 2015. "Partisan Gerrymandering and the Efficiency Gap." *The University of Chicago Law Review* 82 (2): 831–900.

Tufte, Edward R. 1973. "The Relationship Between Seats and Votes in Two-Party Systems." *American Political Science Review* 67 (2): 540–554.

U.S. Census Bureau. 2021. "2020 Census Redistricting Data (Public Law 94-171) Summary File." `https://api.census.gov/data/2020/dec/pl`. Accessed August 15, 2025.

U.S. Census Bureau. 2022. "TIGER/Line Shapefiles, 2022, state, U.S., State Legislative Districts (SLD), Upper and Lower Chambers." `https://www2.census.gov/geo/tiger/TIGER2022/`. Accessed August 28, 2025.

Voting and Election Science Team. 2022. "Precinct-Level Election Results, 2016–2020." Dataset, Harvard Dataverse.

Supplementary Material for

Durable Majority Gerrymanders

Contents

A Figures

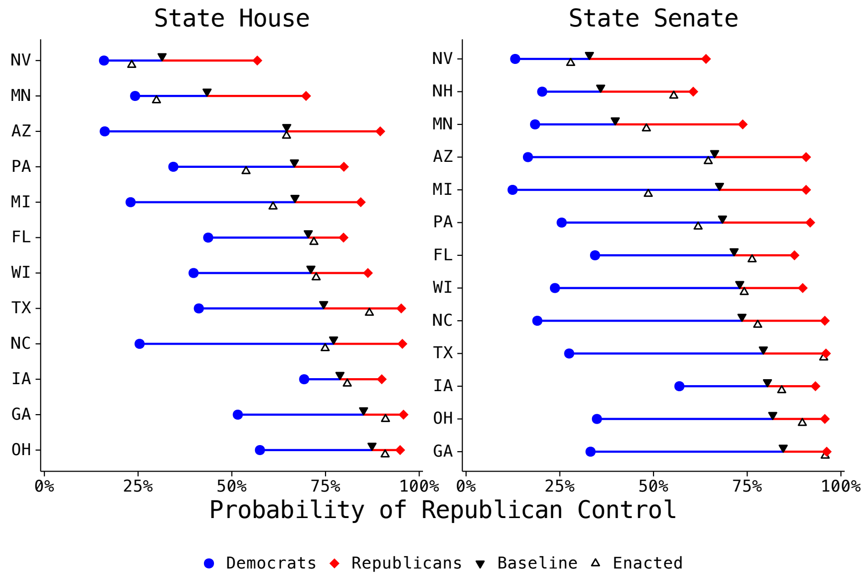


Figure A1: Probability of Winning Next Election for Redistricting Party Under Optimal Gerrymander, Simulated Precinct-Level Election Swings from Multi-Level Election Forecast Model. **Notes:** This figure presents, for State Legislative (LD) and State Senate (SD) district maps, the probability that each redistricting party will win a majority in their respective chamber, based on simulations from past elections. The approach in this figure in particular accounts for non-uniform swings within each state. The black upside-down triangle indicates the probability of Republican control of the chamber under the baseline simulations. The white triangle indicates the probability of Republican control of the chamber in the enacted map. The blue circle to the left of the bar indicates the probability of Republican control under the maximal Democratic gerrymander, and the red circle to the right of the bar indicates the probability of Republican control under the maximal Republican gerrymander. Appendix Figure A5 reports the results for the full set of states in our sample.

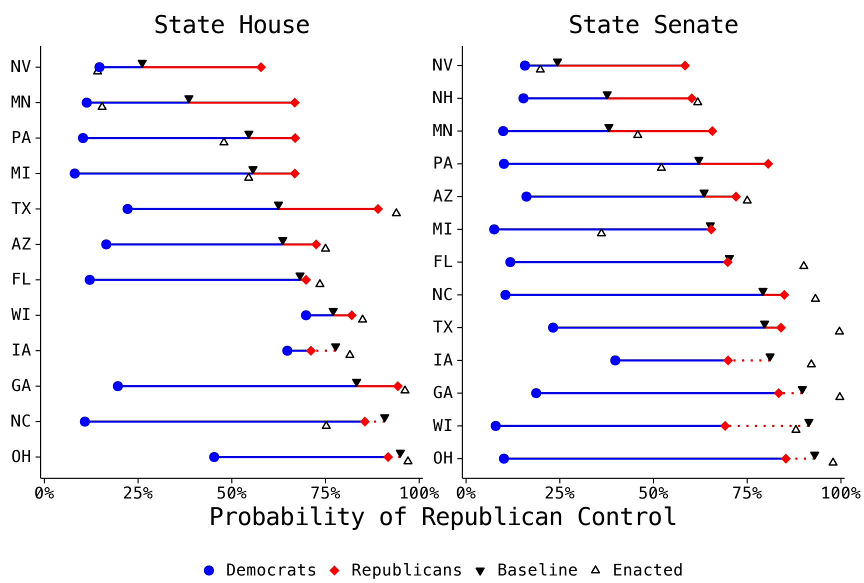
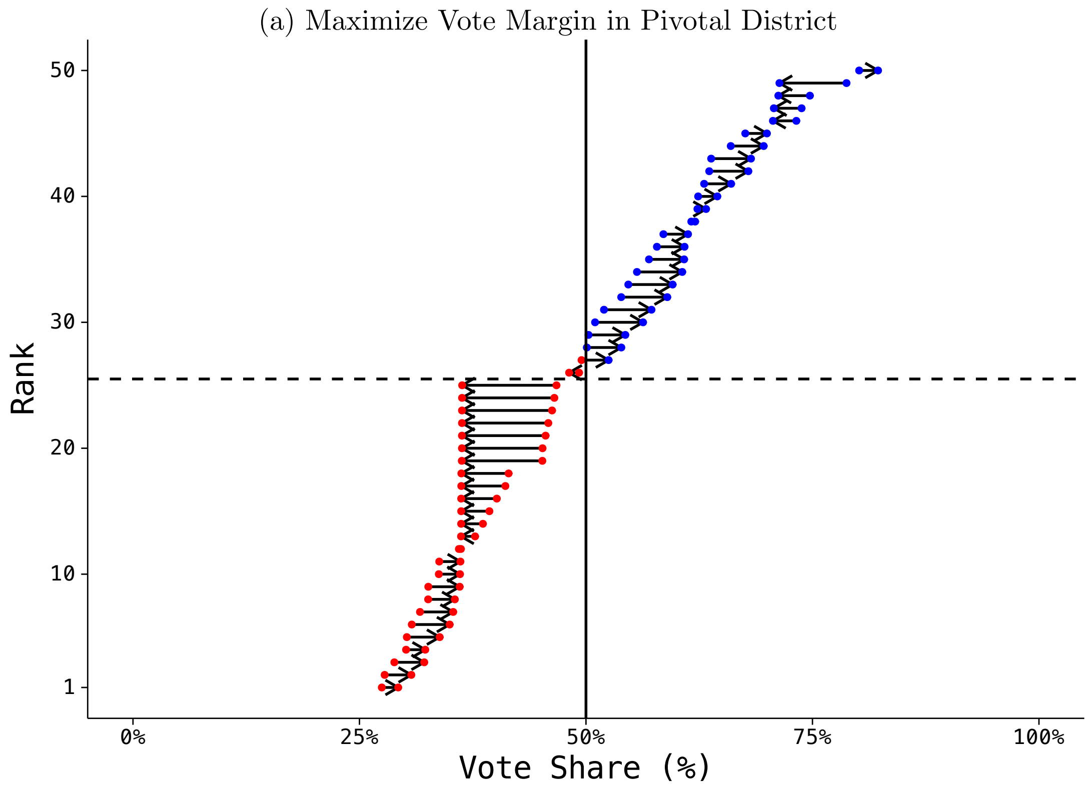


Figure A2: Probability of Winning Next Election for Redistricting Party Under Gerrymander Optimizing Number of Seats Won, Simulated State-Level Election Swings from Multi-Level Election Forecast Model. **Notes:** This figure presents, for State Legislative (LD) and State Senate (SD) district maps, the probability that each redistricting party will win a majority in their respective chamber, based on simulations from past elections. The simulations maximize the number of districts won by the gerrymandering party. Because this is not an optimal approach for maximizing the odds of maintaining a majority, several baseline maps actually offer better odds than the map winning the most possible districts. Dotted lines extending from the baseline to the party-majority map illustrate these cases. The black upside-down triangle indicates the probability of Republican control of the chamber under the baseline simulations. The white triangle indicates the probability of Republican control of the chamber in the enacted map. The blue circle to the left of the bar indicates the probability of Republican control under the maximal Democratic gerrymander, and the red circle to the right of the bar indicates the probability of Republican control under the maximal Republican gerrymander.



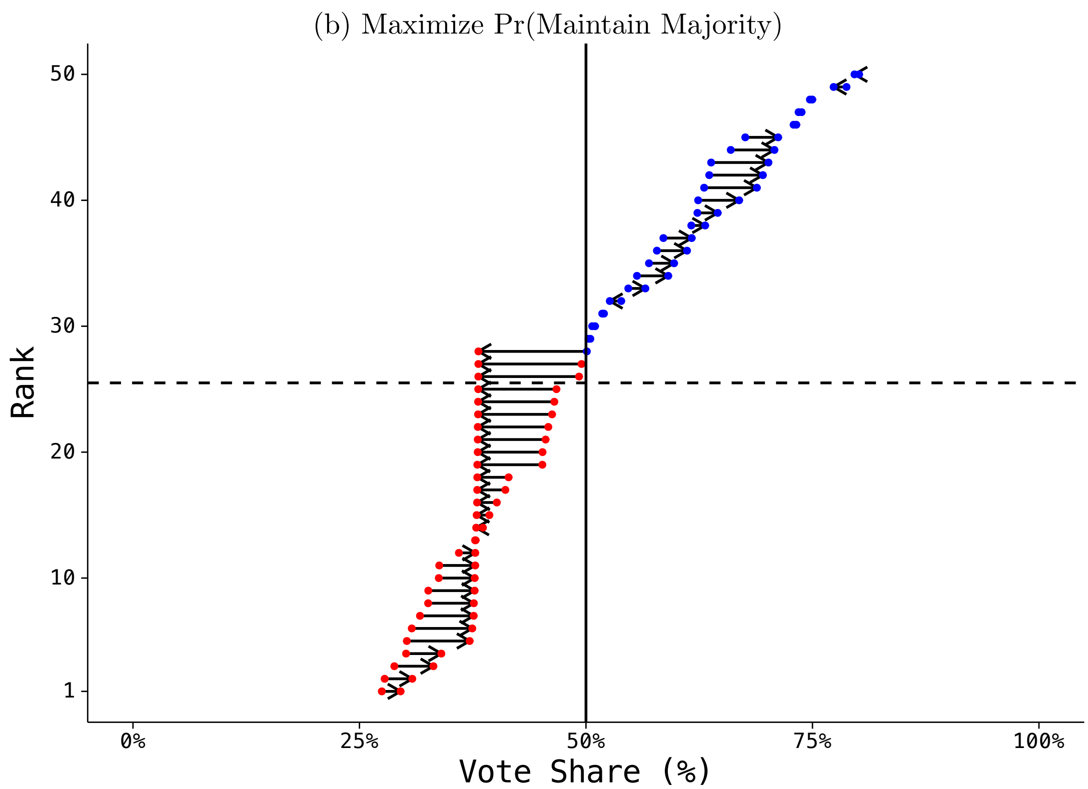


Figure A3: Visualizing Changes in District Composition for Each District, North Carolina SD, Republican Gerrymander. **Notes:** This figure illustrates how the vote shares in a rank-ordered set of senate districts change due to gerrymandering when comparing a neutral baseline map to a Republican gerrymander. This example is for the state Senate in North Carolina under a Republican gerrymander. We present two gerrymandering approaches. Panel (a) presents a gerrymander where the objective is to maximize the vote margin in the pivotal district under uniform swings. Panel (b) presents a gerrymander where the objective is to maximize the probability of maintaining a majority under non-uniform swings.

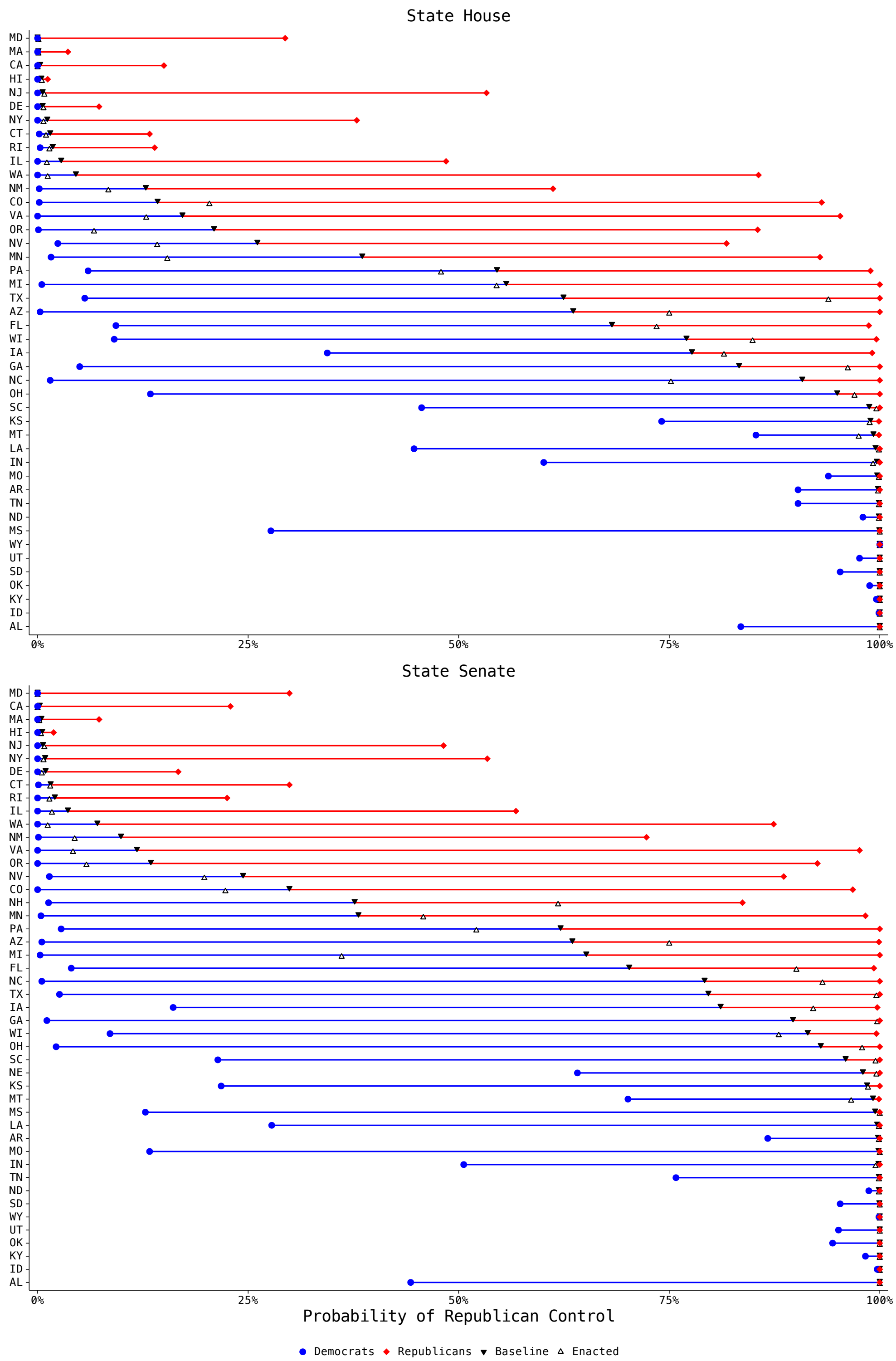


Figure A4: Probability of Winning Next Election for Redistricting Party, Maximize Vote Margin in Pivotal District, Simulated Statewide Election Swings from Multi-Level Election Forecast Model. **Notes:** This figure presents, for State Legislative (LD) and State Senate (SD) district maps, the probability that each redistricting party will win a majority in their respective chamber, based on simulations from past elections. This figure expands beyond the data reported in Figure 2 by including all states rather than just competitive states. The black upside-down triangle indicates the probability of Republican control of the chamber under the baseline simulations. The white triangle indicates the probability of Republican control of the chamber in the enacted map. The blue circle to the left of the bar indicates the probability of Republican control under the maximal Democratic gerrymander, and the red circle to the right of the bar indicates the probability of Republican control under the maximal Republican gerrymander.

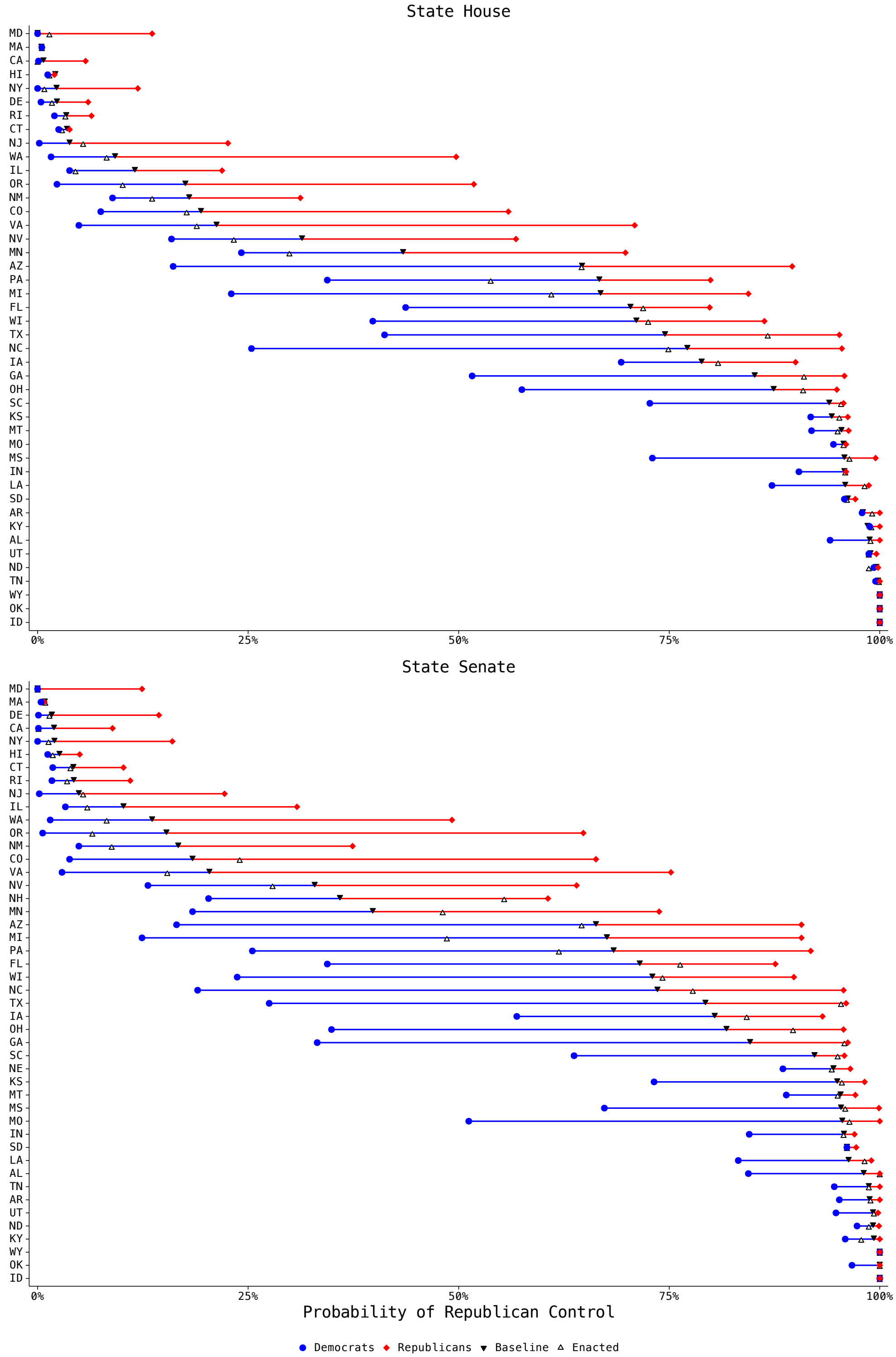


Figure A5: Probability of Winning Next Election for Redistricting Party, Maximize Share of Wins in Simulated Elections, Swings Varying by District from Multi-Level Election Forecast Model. **Notes:** This figure presents, for State Legislative (LD) and State Senate (SD) district maps, the probability that each redistricting party will win a majority in their respective chamber, based on simulations from past elections. This figure incorporates an approach accounting for non-uniform swings within states, and it expands beyond the data reported in Appendix Figure A1 by including all states rather than just competitive states. The black upside-down triangle indicates the probability of Republican control of the chamber under the baseline simulations. The white triangle indicates the probability of Republican control of the chamber in the enacted map. The blue circle to the left of the bar indicates the probability of Republican control under the maximal Democratic gerrymander, and the red circle to the right of the bar indicates the probability of Republican control under the maximal Republican gerrymander.

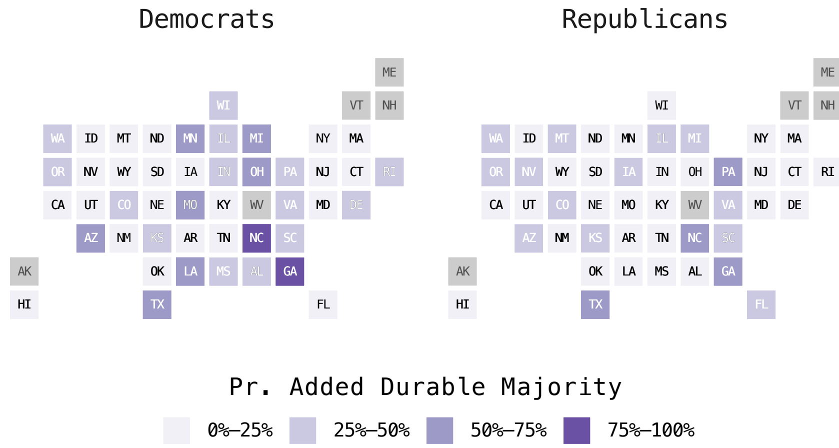


Figure A6: Alternative Simulation Approach, Durable Majorities in Both Legislative Chambers by State, Upcoming Hypothetical Full Redistricting Cycle. **Notes:** This figure considers an alternative forecasting approach when making step-ahead forecasts. Rather than making out-of-sample predictions about future years, instead we make in-sample predictions based on five year sequences of actual observed election data. We then randomly draw decade-long sequences of elections from these in-sample predictions. This approach is similar to using observed historical election data to generate vote swings but accounts for the fact that we need to account for electoral swings every two years when in practice not all states held one of the statewide elections we use in our model (President, Governor or Senator) in every election year. The figure illustrates for Democrats and Republicans the probability that optimal gerrymandering adds to the chances of maintaining a majority in both chambers of the state legislature for a full decade. We calculate this quantity by comparing the chances for a party's gerrymandered map with the objective of maximizing chances of maintaining party control for a decade to the chances under a neutral baseline map. The states in gray were omitted from our calculations due to either lack of data or a unicameral legislature. For New Hampshire, we perform this calculation only for the state Senate.

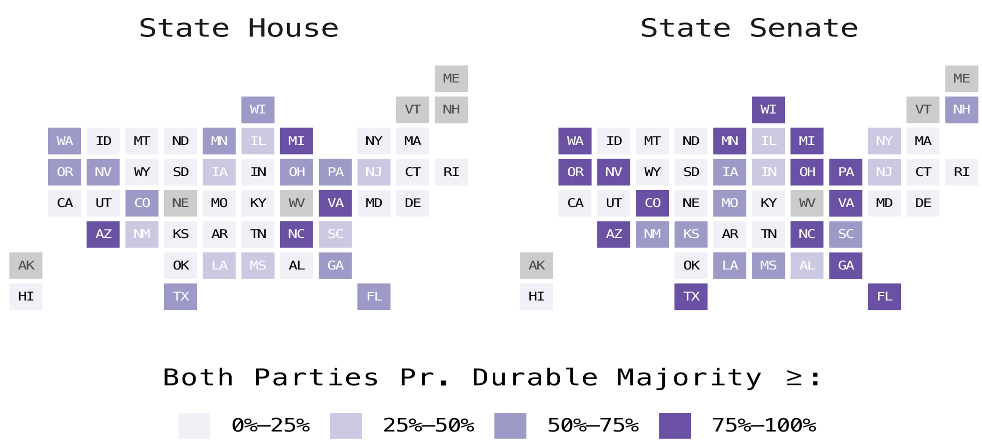


Figure A7: Durable Majorities by Chamber, Upcoming Hypothetical Full Redistricting Cycle. **Notes:** This figure illustrates for state House (LD) and state Senate (SD) districts, the ability of both parties to enact a durable gerrymander. Each bin (e.g., probability quantiles) represents the range for which both parties have a probability in a given quartile of maintaining a party majority for a full decade. The states in gray were omitted from our calculations due to either lack of data or a unicameral legislature.

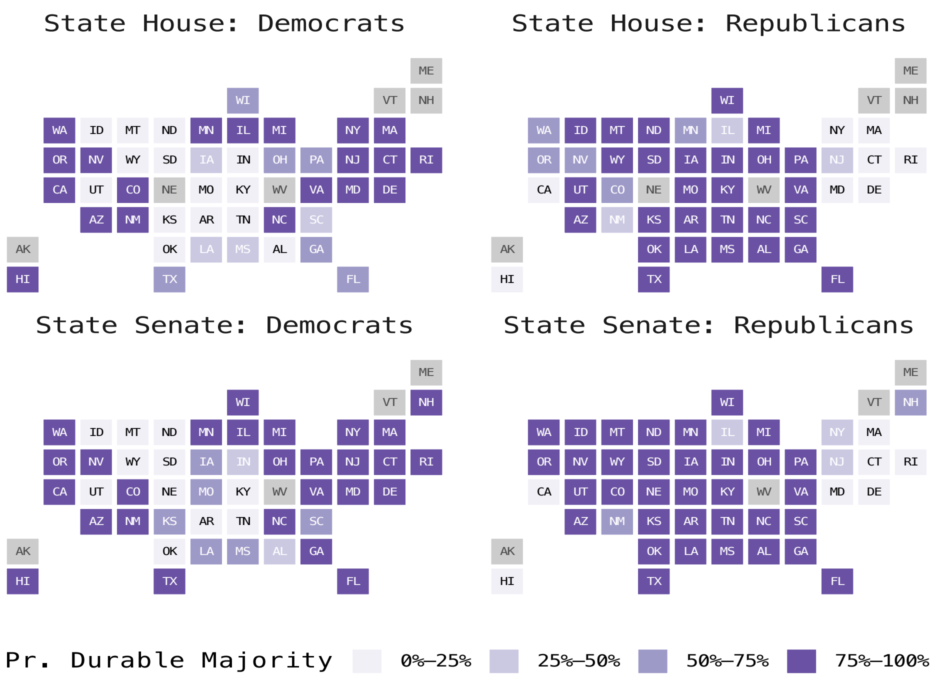


Figure A8: Durable Majorities by State and by Party, Upcoming Hypothetical Full Redistricting Cycle. **Notes:** This figure illustrates for each party and for each chamber in a state, the unconditional probabilities of enacting a durable gerrymander for a full decade. The states in gray were omitted from our calculations due to either lack of data or a unicameral legislature.

B Tables

Table B1: Safe State Majority Map Summary Statistics with Objective to Maximize Vote Margin Pivotal District, LDs

	Statewide Voteshare		Statewide Winshare		Voteshare Pivotal District		Voteshare 55th Pctile District		No. Safe 55+ Districts		No. Safe 65+ Districts		Efficiency Gap	
State	D	R	D	R	D	R	D	R	D	R	D	R	D	R
AL	37.1%	62.9%	19.0%	77.1%	46.3%	75.9%	46.7%	75.9%	12.4%	69.5%	7.6%	53.3%	-6.0%	2.1%
AR	35.8%	64.2%	13.0%	80.0%	43.0%	75.3%	43.2%	75.4%	7.0%	72.0%	5.0%	55.0%	-9.3%	3.2%
AZ	50.2%	49.8%	50.0%	50.0%	62.7%	59.4%	62.7%	59.5%	50.0%	50.0%	0.0%	3.3%	-6.3%	3.6%
CA	64.9%	35.1%	87.5%	6.2%	72.2%	44.1%	72.7%	44.2%	71.2%	0.0%	52.5%	0.0%	7.3%	-14.1%
CO	56.9%	43.1%	66.2%	50.8%	65.9%	53.5%	66.1%	53.5%	53.8%	15.4%	50.8%	1.5%	2.3%	14.6%
CT	60.2%	39.8%	84.1%	10.6%	65.4%	44.8%	65.5%	44.9%	66.2%	4.0%	50.3%	0.0%	12.3%	-18.5%
DE	59.6%	40.4%	73.2%	22.0%	68.0%	43.5%	68.1%	43.6%	63.4%	22.0%	51.2%	2.4%	3.6%	-9.0%
FL	48.3%	51.7%	50.8%	53.3%	55.7%	59.1%	55.8%	59.1%	50.0%	50.8%	5.8%	6.7%	0.3%	2.7%
GA	50.1%	49.9%	50.6%	51.1%	58.1%	63.0%	58.3%	63.2%	50.0%	50.6%	20.0%	26.1%	-1.1%	2.8%
HI	65.0%	35.0%	98.0%	2.0%	68.4%	37.6%	68.4%	37.7%	88.2%	0.0%	54.9%	0.0%	18.6%	-18.5%
IA	45.8%	54.2%	50.0%	63.0%	50.9%	62.1%	51.1%	62.1%	22.0%	50.0%	6.0%	14.0%	7.7%	5.2%
ID	34.1%	65.9%	8.6%	85.7%	38.5%	77.0%	39.1%	77.0%	5.7%	80.0%	2.9%	62.9%	-8.8%	3.1%
IL	58.7%	41.3%	69.5%	30.5%	64.8%	49.0%	64.9%	49.2%	59.3%	17.8%	43.2%	7.6%	0.0%	-0.4%
IN	41.8%	58.2%	45.0%	72.0%	49.4%	69.9%	49.9%	70.0%	13.0%	59.0%	7.0%	50.0%	9.6%	7.3%
KS	42.5%	57.5%	36.8%	65.6%	49.2%	66.8%	49.5%	66.9%	22.4%	54.4%	8.0%	50.4%	1.1%	0.8%
KY	36.8%	63.2%	17.0%	82.0%	37.5%	72.8%	37.8%	72.9%	15.0%	78.0%	8.0%	55.0%	-6.9%	5.4%
LA	40.5%	59.5%	50.5%	71.4%	50.7%	74.5%	50.8%	74.6%	17.1%	62.9%	9.5%	53.3%	17.1%	3.7%
MA	67.1%	32.9%	98.1%	1.2%	72.2%	39.0%	72.4%	39.1%	85.6%	0.0%	53.8%	0.0%	13.7%	-14.4%
MD	67.0%	33.0%	76.6%	12.8%	82.1%	45.8%	82.5%	45.8%	68.1%	6.4%	53.2%	2.1%	-8.5%	-3.2%
MI	51.4%	48.6%	51.8%	51.8%	60.0%	59.5%	60.1%	59.5%	50.0%	50.0%	11.8%	6.4%	-3.5%	6.7%
MN	53.6%	46.4%	54.5%	50.0%	59.3%	54.6%	59.4%	54.8%	50.7%	38.8%	21.6%	12.7%	-3.2%	7.1%
MO	42.2%	57.8%	27.6%	69.3%	44.1%	69.9%	45.2%	70.0%	23.3%	59.5%	16.6%	50.3%	-7.9%	4.8%
MS	41.6%	58.4%	50.0%	63.1%	52.5%	71.0%	52.7%	71.2%	22.1%	56.6%	7.4%	50.0%	14.7%	-2.2%
MT	41.6%	58.4%	23.0%	73.0%	45.5%	68.2%	45.7%	68.4%	17.0%	64.0%	7.0%	50.0%	-9.9%	5.3%
NC	49.3%	50.7%	50.0%	54.2%	58.9%	62.3%	59.0%	62.4%	50.0%	50.8%	10.8%	15.8%	0.8%	3.0%
ND	32.8%	67.2%	12.8%	83.0%	37.5%	75.4%	37.6%	75.7%	4.3%	74.5%	0.0%	59.6%	-3.6%	0.1%
NJ	58.1%	41.9%	72.5%	22.5%	68.9%	49.9%	69.1%	49.9%	55.0%	5.0%	50.0%	0.0%	2.1%	-8.8%
NM	55.5%	44.5%	67.1%	48.6%	64.5%	50.0%	64.8%	50.1%	52.9%	20.0%	34.3%	15.7%	8.5%	6.4%
NV	51.2%	48.8%	64.3%	50.0%	60.2%	53.1%	60.3%	53.1%	50.0%	19.0%	4.8%	4.8%	4.6%	10.2%
NY	61.6%	38.4%	69.3%	24.7%	71.0%	48.7%	71.2%	48.8%	57.3%	11.3%	50.7%	1.3%	-7.5%	0.2%
OH	45.9%	54.1%	51.5%	59.6%	54.2%	65.1%	54.2%	65.1%	26.3%	53.5%	7.1%	50.5%	8.6%	2.5%
OK	33.1%	66.9%	10.9%	82.2%	40.2%	76.9%	40.3%	76.9%	7.9%	75.2%	2.0%	59.4%	-6.8%	-0.3%
OR	58.3%	41.7%	65.0%	50.0%	67.1%	53.2%	67.3%	53.3%	53.3%	21.7%	50.0%	8.3%	-2.1%	16.3%
PA	50.6%	49.4%	52.2%	53.7%	56.3%	58.3%	56.4%	58.5%	50.2%	50.7%	15.3%	18.2%	0.3%	5.2%
RI	60.6%	39.4%	85.3%	12.0%	66.9%	44.3%	67.0%	44.3%	66.7%	5.3%	50.7%	0.0%	11.1%	-14.4%
SC	44.1%	55.9%	50.0%	66.1%	50.9%	64.5%	51.1%	64.7%	14.5%	56.5%	5.6%	31.5%	10.2%	5.2%
SD	36.3%	63.7%	2.9%	91.4%	41.9%	71.0%	42.0%	71.0%	2.9%	77.1%	0.0%	51.4%	-20.0%	15.7%
TN	38.2%	61.8%	18.2%	75.8%	44.5%	75.0%	44.5%	75.1%	17.2%	65.7%	9.1%	52.5%	-10.3%	4.5%
TX	47.2%	52.8%	52.7%	52.0%	58.6%	61.0%	58.8%	61.1%	51.3%	50.0%	12.7%	20.0%	3.6%	0.1%
UT	39.3%	60.7%	21.3%	72.0%	43.8%	71.0%	43.9%	71.0%	14.7%	68.0%	8.0%	50.7%	-7.0%	0.5%
VA	55.2%	44.8%	58.0%	50.0%	67.2%	54.6%	67.4%	54.6%	51.0%	29.0%	50.0%	8.0%	-4.2%	12.1%
WA	59.9%	40.1%	65.3%	51.0%	68.2%	52.3%	68.4%	52.3%	57.1%	8.2%	51.0%	0.0%	-4.2%	19.0%
WI	50.3%	49.7%	50.5%	55.6%	54.6%	60.6%	54.8%	60.7%	38.4%	51.5%	14.1%	4.0%	-2.5%	8.1%
WY	27.5%	72.5%	6.7%	93.3%	29.3%	81.3%	29.4%	81.4%	3.3%	88.3%	1.7%	71.7%	1.5%	-2.5%

Note: This table reports key summary statistics for the simulated map produced when each party has the objective of maintaining a durable majority. The first two columns report the name of the state and the statewide 2020 presidential election vote share. The subsequent columns report key statistics for the map maximizing Democratic vote share in the pivotal district (indicated with a "D" in each column), and for the map maximizing Republican vote share in the pivotal district (indicated with an "R" in each column). Note that the efficiency gap metric takes a positive value when the minority party wastes more votes and a negative value when the majority party wastes more votes.

Table B2: Safe State Majority Map Summary Statistics with Objective to Maximize Vote Margin Pivotal District, SDs

	Statewide Voteshare		Statewide Winshare		Voteshare Pivotal District		Voteshare 55th Pctile District		No. Safe 55+ Districts		No. Safe 65+ Districts		Efficiency Gap	
State	D	R	D	R	D	R	D	R	D	R	D	R	D	R
AL	37.1%	62.9%	51.4%	71.4%	50.5%	77.2%	50.5%	77.2%	0.0%	65.7%	0.0%	54.3%	26.7%	-3.9%
AR	35.8%	64.2%	5.7%	80.0%	43.8%	75.7%	44.6%	75.7%	2.9%	74.3%	2.9%	54.3%	-15.4%	1.8%
AZ	50.2%	49.8%	50.0%	50.0%	62.5%	59.3%	62.5%	59.4%	50.0%	50.0%	0.0%	3.3%	-6.1%	3.9%
CA	64.9%	35.1%	90.0%	0.0%	73.8%	45.1%	73.8%	45.2%	72.5%	0.0%	50.0%	0.0%	11.2%	-20.2%
CO	56.9%	43.1%	68.6%	51.4%	68.9%	55.0%	68.9%	55.0%	51.4%	40.0%	51.4%	0.0%	4.4%	15.3%
CT	60.2%	39.8%	86.1%	0.0%	67.5%	47.3%	67.5%	47.3%	69.4%	0.0%	50.0%	0.0%	14.9%	-29.6%
DE	59.6%	40.4%	81.0%	19.0%	69.6%	45.7%	69.6%	45.8%	66.7%	14.3%	52.4%	0.0%	12.0%	-11.0%
FL	48.3%	51.7%	52.5%	55.0%	57.6%	60.4%	57.6%	60.5%	50.0%	50.0%	0.0%	0.0%	1.8%	4.2%
GA	50.1%	49.9%	50.0%	53.6%	61.3%	65.4%	62.0%	65.4%	50.0%	50.0%	17.9%	50.0%	-1.6%	4.4%
HI	65.0%	35.0%	100.0%	0.0%	68.8%	38.9%	68.8%	39.0%	80.0%	0.0%	52.0%	0.0%	19.9%	-19.9%
IA	45.8%	54.2%	50.0%	64.0%	53.9%	63.1%	53.9%	63.3%	16.0%	50.0%	4.0%	12.0%	7.7%	6.2%
ID	34.1%	65.9%	8.6%	88.6%	39.3%	77.0%	39.4%	77.0%	8.6%	77.1%	2.9%	62.9%	-8.9%	5.3%
IL	58.7%	41.3%	69.5%	37.3%	65.4%	49.8%	65.5%	49.8%	55.9%	15.3%	50.8%	6.8%	0.3%	5.6%
IN	41.8%	58.2%	50.0%	70.0%	50.3%	70.6%	50.7%	70.6%	10.0%	56.0%	6.0%	50.0%	14.8%	4.8%
KS	42.5%	57.5%	50.0%	57.5%	54.9%	69.8%	54.9%	69.9%	35.0%	52.5%	2.5%	50.0%	13.9%	-8.7%
KY	36.8%	63.2%	13.2%	81.6%	40.3%	74.3%	40.3%	74.3%	10.5%	73.7%	7.9%	57.9%	-9.6%	5.4%
LA	40.5%	59.5%	51.3%	64.1%	52.8%	75.0%	52.9%	75.0%	10.3%	61.5%	2.6%	51.3%	18.9%	-4.4%
MA	67.1%	32.9%	100.0%	0.0%	73.8%	41.1%	73.8%	41.1%	90.0%	0.0%	55.0%	0.0%	15.8%	-15.8%
MD	67.0%	33.0%	74.5%	12.8%	82.3%	45.9%	82.4%	45.9%	68.1%	6.4%	57.4%	2.1%	-11.0%	-2.9%
MI	51.4%	48.6%	55.3%	52.6%	60.9%	60.5%	61.2%	60.5%	50.0%	52.6%	7.9%	0.0%	0.5%	6.7%
MN	53.6%	46.4%	53.7%	50.7%	61.6%	57.0%	61.7%	57.0%	50.7%	50.7%	17.9%	9.0%	-3.6%	7.5%
MO	42.2%	57.8%	50.0%	73.5%	53.7%	74.3%	53.9%	74.3%	17.6%	55.9%	8.8%	50.0%	15.7%	8.8%
MS	41.6%	58.4%	50.0%	61.5%	54.2%	71.6%	54.3%	71.7%	17.3%	57.7%	3.8%	50.0%	15.5%	-4.6%
MT	41.6%	58.4%	20.0%	76.0%	47.9%	69.8%	48.1%	69.8%	12.0%	66.0%	4.0%	50.0%	-13.0%	7.6%
NC	49.3%	50.7%	50.0%	52.0%	61.6%	63.7%	61.9%	63.7%	50.0%	50.0%	4.0%	12.0%	0.9%	0.4%
ND	32.8%	67.2%	8.5%	85.1%	36.9%	74.9%	37.2%	75.0%	4.3%	74.5%	0.0%	57.4%	-7.3%	1.6%
NE	40.2%	59.8%	34.7%	63.3%	49.6%	68.4%	49.6%	68.4%	16.3%	57.1%	10.2%	51.0%	1.8%	-4.2%
NH	53.7%	46.3%	62.5%	50.0%	60.1%	53.1%	60.1%	53.3%	54.2%	4.2%	0.0%	0.0%	4.2%	7.4%
NJ	58.1%	41.9%	72.5%	17.5%	68.8%	49.5%	68.8%	49.6%	57.5%	7.5%	50.0%	2.5%	2.2%	-15.7%
NM	55.5%	44.5%	66.7%	50.0%	66.7%	51.3%	66.8%	51.3%	54.8%	21.4%	50.0%	11.9%	7.5%	8.7%
NV	51.2%	48.8%	66.7%	52.4%	60.9%	54.7%	60.9%	54.7%	52.4%	4.8%	4.8%	0.0%	7.3%	12.4%
NY	61.6%	38.4%	74.6%	50.8%	71.2%	50.1%	73.5%	50.1%	57.1%	1.6%	52.4%	0.0%	-2.3%	29.3%
OH	45.9%	54.1%	51.5%	54.5%	57.7%	67.4%	57.8%	67.5%	51.5%	51.5%	0.0%	51.5%	8.7%	-2.9%
OK	33.1%	66.9%	2.1%	85.4%	43.3%	77.7%	43.3%	77.7%	0.0%	81.2%	0.0%	56.2%	-14.6%	2.3%
OR	58.3%	41.7%	73.3%	50.0%	70.2%	54.7%	70.2%	54.7%	53.3%	20.0%	50.0%	3.3%	5.9%	15.8%
PA	50.6%	49.4%	54.0%	52.0%	57.7%	61.9%	57.7%	62.0%	50.0%	50.0%	14.0%	10.0%	3.3%	2.8%
RI	60.6%	39.4%	84.2%	2.6%	69.4%	45.9%	69.5%	45.9%	68.4%	2.6%	50.0%	0.0%	10.0%	-25.5%
SC	44.1%	55.9%	50.0%	63.0%	53.4%	65.2%	53.4%	65.2%	6.5%	56.5%	2.2%	50.0%	10.3%	2.2%
SD	36.3%	63.7%	2.9%	91.4%	41.9%	71.2%	41.9%	71.2%	2.9%	80.0%	0.0%	51.4%	-20.0%	15.9%
TN	38.2%	61.8%	15.2%	75.8%	47.1%	76.4%	47.3%	76.4%	6.1%	63.6%	6.1%	51.5%	-12.2%	3.3%
TX	47.2%	52.8%	54.8%	51.6%	59.8%	65.2%	60.5%	65.2%	51.6%	51.6%	0.0%	51.6%	5.8%	-1.1%
UT	39.3%	60.7%	13.8%	75.9%	45.6%	72.6%	45.7%	72.6%	10.3%	69.0%	3.4%	51.7%	-15.1%	3.5%
VA	55.2%	44.8%	52.5%	50.0%	68.4%	55.8%	68.7%	55.8%	50.0%	50.0%	50.0%	5.0%	-10.1%	11.4%
WA	59.9%	40.1%	65.3%	51.0%	67.8%	52.5%	67.9%	52.5%	57.1%	14.3%	51.0%	0.0%	-3.4%	19.3%
WI	50.3%	49.7%	54.5%	57.6%	54.8%	60.7%	55.7%	60.7%	48.5%	51.5%	12.1%	0.0%	2.9%	10.0%
WY	27.5%	72.5%	0.0%	93.3%	35.3%	82.5%	35.3%	82.5%	0.0%	90.0%	0.0%	70.0%	-5.0%	-2.3%

Note: This table reports key summary statistics for the simulated map produced when each party has the objective of maintaining a durable majority. The first two columns report the name of the state and the statewide 2020 presidential election vote share. The subsequent columns report key statistics for the map maximizing Democratic vote share in the pivotal district (indicated with a "D" in each column), and for the map maximizing Republican vote share in the pivotal district (indicated with an "R" in each column). Note that the efficiency gap metric takes a positive value when the minority party wastes more votes and a negative value when the majority party wastes more votes.

Table B3: Description and coding of variables used in Figure 6

Variable	Meaning / construction	Coding (unit)
Map characteristic predictors		
Pr(Party Majority, Baseline)	Multilevel-model estimate of the probability the redistricting party wins a chamber majority under the neutral baseline plan.	Continuous [0,1]
Pr(Party Majority, Optimal)	Multilevel-model estimate of the probability the redistricting party wins a chamber majority under optimal durable majority plan.	Continuous [0,1]
State institutional predictors		
Redistricting Method	Institution that enacted the current map: Advisory, Backup, Independent, or Politician commission (Legislature is reference category).	Binary indicators for each
LD/SD	Observation is a state senate or upper chamber district (lower chamber = 0; upper chamber = 1).	Binary
Party	Observation represents map drawn by Republican majority (Democrats or mixed = 0; Republicans = 1).	Binary
Substantive redistricting rules		
Rule: Compactness	State constitution/statute mentions compact district requirement	Binary
Rule: Preserve Communities of Interest, Cores and/or Political Subdivisions	State constitution/statute mentions requirement of preserving communities of interest, district cores, or political subdivisions.	Binary
Rule: Competitiveness	State constitution/statute explicitly directs map-drawers to promote electoral competitiveness.	Binary
Rule: No Favor to Incumbents	Language prohibiting maps that advantage/disadvantage incumbents (Explicit protection of incumbents is required = -1; Neutrality toward incumbents or soft guidance = 0; No guardrails on treatment of incumbents) = 1	−1, 0, or 1
Rule: No Favor to Party	Language prohibiting partisan advantage in district design.	Binary
Rule: No Partisan Data	Language that bans the use of past election returns or other partisan data when drawing districts.	Binary

Notes: Institutional variables drawn primarily from the Loyola Law School Redistricting Project's "National Overview" (2020 cycle). Redistricting-rule indicators drawn from the National Conference of State Legislatures' 2020 redistricting-criteria database.

C Current Legal Context and How It Relates to Extreme Partisan Gerrymanders

In June 2023, the Supreme Court unexpectedly affirmed an Alabama district court's ruling that the state's congressional map violated Section 2 of the Voting Rights Act. Alabama's initial congressional district map included only one majority-Black district (of 7 congressional districts) despite black voters comprising more than a quarter of the state's population. The Court's decision in *Allen v. Milligan*, written by Chief Justice John Roberts and joined by Justices Brett Kavanaugh, Sonia Sotomayor, Elena Kagan, and Ketanji Brown Jackson, reaffirmed the three Gingles pre-conditions used to assess when vote dilution has occurred under Section 2. Legal challenges in states such as Georgia and Louisiana have subsequently followed the road map affirmed in this decision. Though challenges based upon Section 2 are often viewed as a boost to the fortunes of Democratic candidates, this decision may not translate straightforwardly into more widespread limits on partisan gerrymanders.

First, the affected states appear likely to continue to challenge the logic of Section 2 in the courts. Despite Alabama's map being struck down, the state refused to add an additional majority-minority district. Even after a three-judge federal court enjoined the state's revised map and appointed a special master to draw a remedial map, Alabama's Attorney General signaled the state would continue to defend their previous map.

Second, at the federal level, openings for challenges to Section 2 remain. Justice Kavanaugh, likely the pivotal vote in future Section 2 cases, did not sign a portion of the Roberts opinion and his concurrence invites Section 2 defendants, including Alabama, to question the court's authority in mandating additional minority opportunity districts. The Supreme Court is scheduled to hear a case challenging the constitutionality of Section 2, *Louisiana v. Callais*, in October, 2025.

Third, challenges to gerrymandered maps under state constitutions appear sensitive to partisan pressures in the state courts. In North Carolina, a Democratic majority State Supreme Court threw out the state's initial map, deciding that it was a partisan gerrymander violating the state's constitution. However, after the majority in the State Supreme Court shifted from Democratic to Republican, the state legislature simply drew a new set of gerrymandered maps to replace the old ones.

Fourth, the mid-decade Congressional redistricting in several states, prompted by President Trump, highlights the increasingly partisan nature of redistricting and the potential to use mid-decade redistricting to ensure durable gerrymanders. They may open the door to future redistrictings and to majorities in state legislatures redrawing maps whenever necessary to preserve majorities at the state or federal levels.

Finally, as map-drawing technology improves (or becomes more widely used by practitioners), partisan gerrymanders may be drawn in even more sophisticated ways that will allow map drawers to ruthlessly adhere to maximizing a clear partisan objective or objectives.

D Validating Shortburst

There are many approaches and algorithms for simulating redistricting maps. In this article we use the shortburst algorithm. Here, we provide additional information about how shortburst works and diagnostic plots demonstrating how the algorithm is used to effectively find the most extreme maps.

One concern when seeking to maximize an objective function when using simulations is that the algorithm may get stuck at a local optima. To ensure that we are not finding only local optima, we perform multiple runs of each shortburst chain for each state, chamber, and target quantity, using different starting maps for each. We then combine all of the results and use only the most extreme final map. This helps guard against getting stuck at local optima. Appendix Figure D1 illustrates the spread of shortburst maps we identified for a handful of states to help illustrate this point.

In Figure D2 we highlight an example from North Carolina illustrating how each chain progresses in the course of shortburst each run. As D2 illustrates, across different chains the early bursts tend to exhibit some meaningful variability, consistent with exploring a broad space of possible maps and improvements, though after roughly 2,500 bursts the chains tend to converge to a limit. Finally, as D3 reports, use of shortburst applied to maximizing the margin of victory in a pivotal district appears to dramatically surpass distribution-based approaches in which an analyst simulates a random ensemble of maps and identifies the map in this set with the largest margin of victory in the pivotal district both with minimal constraints and stronger constraints.

To illustrate the dramatic improvement that shortburst represents compared to some other methods of identifying extreme maps and to give readers a sense of how shortburst compares to a typical ensemble of maps with and without constraints we compare the result from our shortburst runs (which have a population deviation constraint, a contiguity constraint, and a moderate compactness constraint) to the results of taking the extreme cases from (a) a randomly generated ensemble distribution via SMC algorithm with the same minimal constraints, (b) a randomly generated ensemble subject to realistic legal redistricting constraints, and (c) shortburst subject to the same legal redistricting constraints.

As Appendix Figure D3 illustrates, the improvements from shortburst are dramatic in terms of finding extreme maps. Compared to minimally constrained ensemble SMC algorithms, for Democratic maps, it identifies maps with 10 percentage point larger margins of victory in a pivotal district, and the gap is roughly 7-8 percentage points for Republican maps. The margins are even larger compared to the constrained ensemble.

Interestingly, the difference between minimally constrained shortburst and shortburst with constraints is considerably smaller.

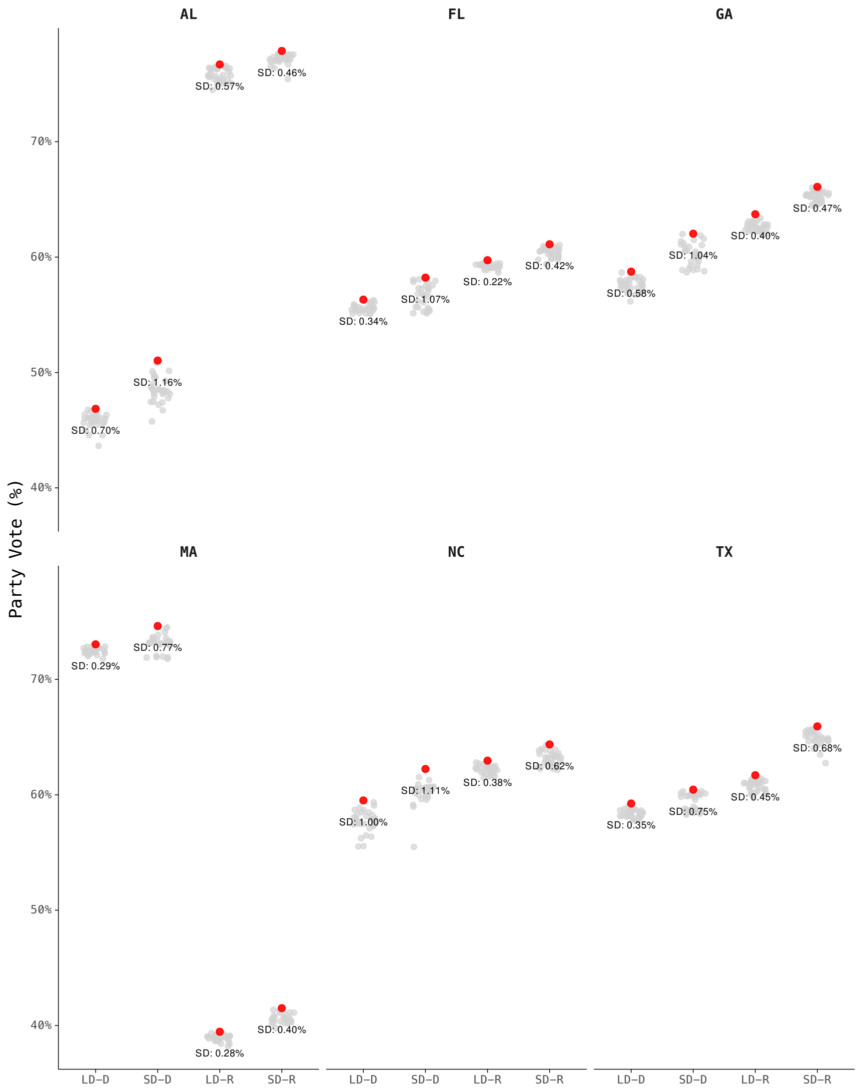


Figure D1: Simulation Diagnostics Displaying Range of Optimal Map Scores Across 30 Chains. **Notes:** This figure presents diagnostics to assess the performance of the shortburst algorithm applied to the problem of maximizing the vote margin in the pivotal district across six example states, for each party and each district type. The algorithm maximizes a score (in this case specified as the vote margin in the pivotal district for each of 30 chains). We then select the chain with the highest score (e.g., the maximum among the maximized scores across chains), indicated by the red dot. The gray dots report the maximum attained from each other chain. We also report the standard deviation for each party and district calculated across the maximums from the chains. If large variations existed across the chains, we might worry that running additional chains could yield a solution substantially closer to the optimal one than what has been attained.

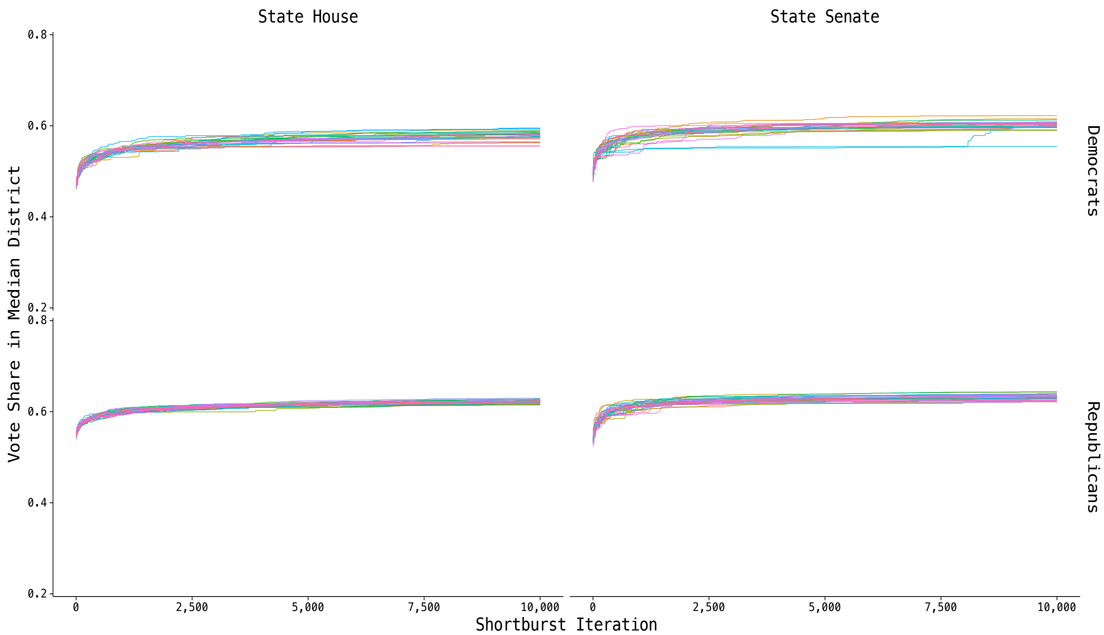


Figure D2: Simulation Diagnostics Displaying Path of Shortburst across 10,000 Bursts. **Notes:** This figure presents additional diagnostics to assess the performance of the shortburst algorithm applied to the problem of maximizing the vote margin in the pivotal district for North Carolina, for each party and each district type. We run 30 separate chains (with different randomly generated starting maps) for each party and district, and the algorithm performs 10,000 "bursts" searching across a range of 20 map permutations per burst to assess whether a given permutation better maximizes the objective function. The figure illustrates that: (1) different chains exhibit meaningful variability in the early bursts, with some making more rapid improvements than others; (2) over the course of 10,000 bursts, the separate chains tend to converge towards some limit and in most cases the improvements level off after roughly 2,500 bursts; (3) there is meaningful, but not enormous, variation in final maps reached across chains.

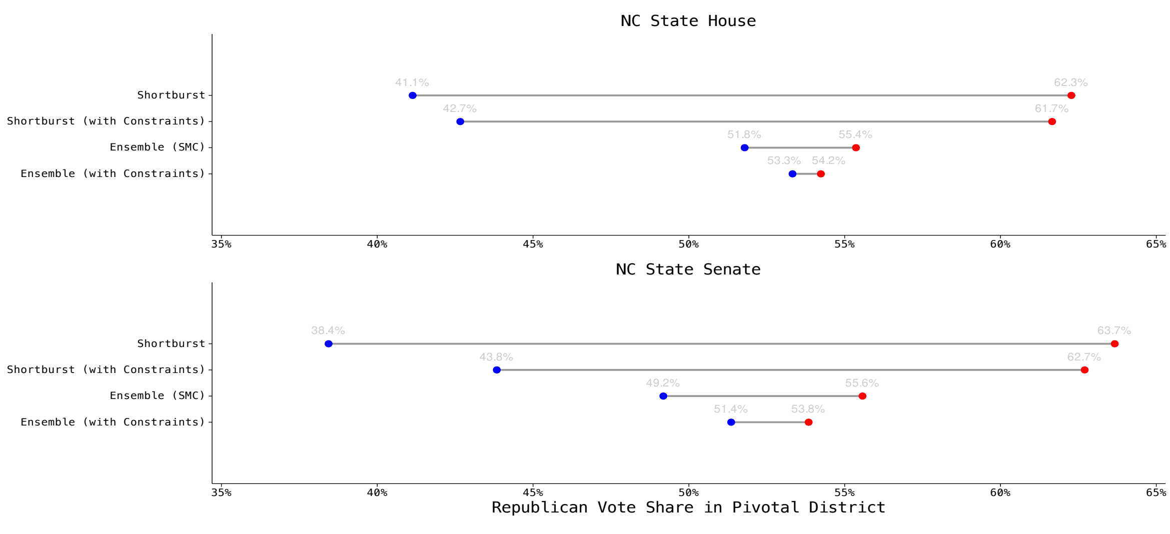


Figure D3: Comparison of Shortburst Maps to Extremes from Ensemble. **Notes:** This figure compares the performance of a shortburst function maximizing margin of victory in the pivotal district to the results from alternative optimization approaches. We implement these approaches with minimal constraints (contiguity, equal population and mild compactness) and with stronger constraints (see Figure H1). The shortburst functions perform dramatically better in terms of finding a map with a large margin of victory in the pivotal district.

E Alternative Objective Functions

We discuss additional objective functions a redistricting party might seek to maximize. First we consider an objective function maximizing the number of "safe" districts for a party, where we define a "safe" district as one with a vote share greater than c for the redistricting party. In practice, we classify safe districts as those with a margin of victory of either (a) 55%-45% or (b) 65%-35%. Parties' exact objectives may vary depending on their sensitivity to electoral risk, with the larger vote margin representing an effort to trade a smaller number of seats won in exchange for more electoral safety.

For a district i, let the two-party vote share in a district be ν_i; the number of districts with vote shares over c can be represented by $\sum_i^N \mathbb{1}(\nu_i > c)$. The redistricting party solves:

$$\max \sum_i^N \mathbb{1}(\nu_i > c)$$

where for each district i the function takes a value of one if the vote share for the redistricting party is over c and takes a value of zero otherwise.

We also consider a neutral objective designed to create maps that can serve as a counterfactual against which to compare the most durable gerrymandered maps. Specifically, we construct counterfactual neutral maps (which we will denote as a baseline map b) by using sequential Monte Carlo (SMC) methods to generate an ensemble of maps without regard to partisan intent (McCartan and Imai, 2023). We then compute the mean-median difference (MMD) for each map in the ensemble and across the full set of generated maps we calculate the mean of this statistic. A large absolute value for the mean-median difference denotes a redistricting plan where the mean district vote share is much higher or lower than the median, with the mean being pulled away from the median likely due to packing of a party's voters into a given district.

We then identify the map whose value for mean-median difference is closest to the mean of the ensemble distribution of MMDs, following other political science work focused on identifying map characteristics isolated from the intentional effects of partisan gerrymandering (Chen and Rodden, 2013).

F Election Forecasting Model

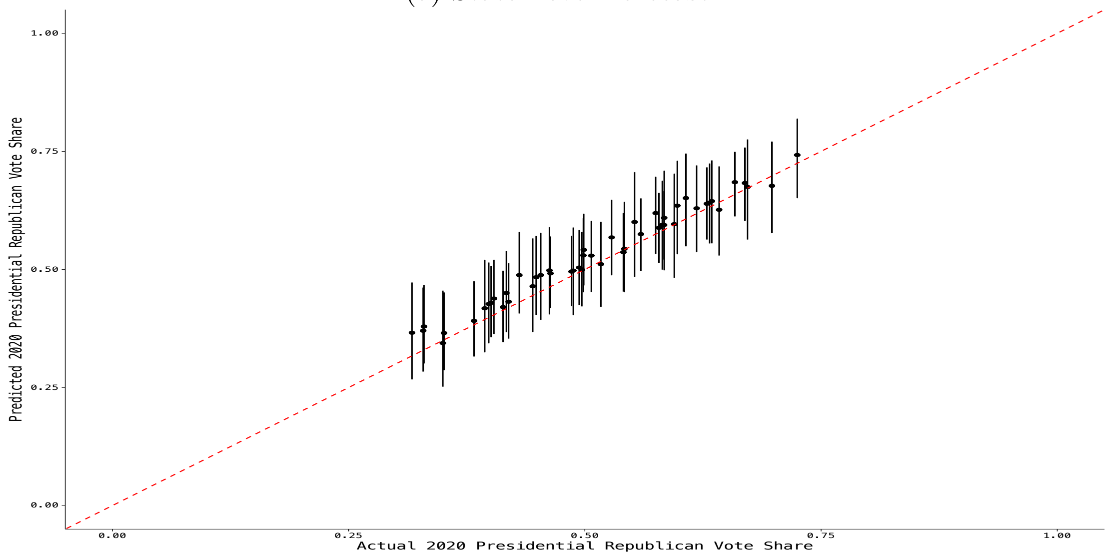
We develop a multi-level model of elections to estimate the durability of redistricting plans. Specifically, we aim to simulate election swings at both the state and district level, calculating the probability of a gerrymandering party maintaining a legislative majority from election to election.

The first version of the model is based on state-level election data. State-level vote shares since 1990 are observed for president, senate and governor elections. We model the process as:

$$\begin{aligned}
v_i &\sim t(\mu_i, \phi_i^2, \xi_i) \\
\mu_i &= \alpha + \beta v_{t-1[i]} + \alpha^{(t)}_{t[i]} + \alpha^{(o)}_{o[i]} + \alpha^{(s)}_{s[i]} \\
\phi_i &= \exp(\alpha^{(o)}_{o[i]} + \alpha^{(s)}_{s[i]} + \delta_\phi |v_{t-1[i]}|)
\end{aligned}$$

where $s[i]$ indexes state observations, $t[i]$ indexes year, $o[i]$ indexes office of the observed statewide election (e.g., presidential, senator or governor). The outcome v_i is a random variable that fits a t-distribution, where the mean is a function of an intercept (α), the previous observed vote share for a state ($v_{t-1[i]}$), and group-level random effects for year, office, and state. This choice of distributional approach has the well-known, advantageous property of fatter tails at the extremes of the distribution, so as not to underestimate the probability of more extreme electoral shocks (Katz and King, 1999). All vote shares are logit transformed, restricting them to be in the interval $[0,1]$. The variance of the outcome v_i is modelled as a function of office random effects, state random effects, and lagged competitiveness (e.g., allowing variance to possibly be higher when there was previously a lopsided historical election). Priors on the group-level random effects are meant to be weakly informative and so are modeled as $t_3(0,2.5)$; we place a more informative prior for the coefficient on lagged vote share, centering it around one. We estimate the model using the Hamiltonian Monte Carlo algorithm implemented via the `brms` and `stan` R packages.

(a) State-Level Forecast



(b) District-Level Forecasts

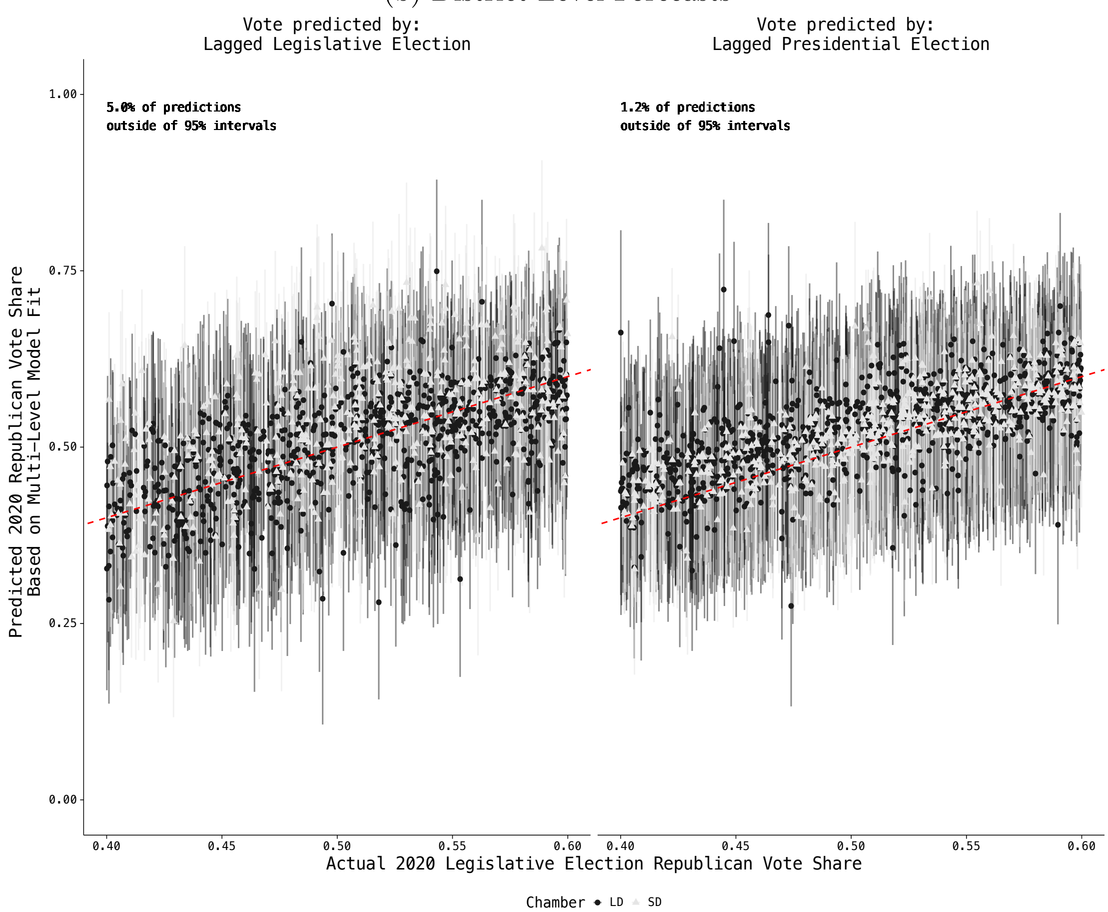


Figure F1: Validating Multi-Level Model Forecasts. **Notes:** Panel (a) presents a comparison of state-level 2020 election forecasts on the x-axis to the actual vote share on the y-axis. The actual value tends to be close to the forecast and is always contained within the 95% interval. Panel (b) presents a comparison of district-level 2020 election forecasts on the x-axis to actual district-level vote shares on the y-axis. Forecasts are broken out by state House and Senate districts. The plot on the left uses lagged legislative election vote share as the key lagged predictor variable. The plot on the right uses 2016 presidential election vote share as the key lagged predictor variable.

When making predictions from the model in order to yield a posterior distribution, there are several additional issues to keep in mind with respect to incorporation of group-level effects. First, we allow for uncertainty from unobserved group-level effects to be incorporated into the predictions. In our case, this is most relevant for properly allowing for uncertainty based on year-to-year electoral tides; in a future year, there will likely be an electoral tide and so the fact that the direction of the tide is unknown should be incorporated into the uncertainty estimates. Second, we make predictions for presidential vote shares (equivalent to setting the office term to the presidential election group), as this is a standard metric used for assessing district partisan lean. Overall, the approach accounts for year-level shocks and state-level averages along with a state-level variance/covariance matrix incorporating correlations across states in the error term.

To validate the model, first we fit it based upon pre-2020 election data and then predict outcomes for the 2020 presidential election in each state. Appendix Figure F1 (a) displays the results and illustrates that the actual state-level election outcomes are always contained within the 95% prediction intervals, suggesting good predictive performance.

Using a near-identical approach, we also model county-level vote shares. Most changes to the model revolve around the change of unit of observation from state-level election returns to county-level election returns. Specifically, for county-level returns we model the mean of the vote share variable v_i to include group-level random effects for counties instead of states. Second, we include group-level county random effects when modeling the variance to capture correlations between counties within a given state.

While we model county-level elections, our primary interest is in vote swings occurring in legislative districts. To translate between these levels of geography, we estimate district-level swings by disaggregating the forecasts to the precinct level and then reaggregating precinct estimates to the district level (U.S. Census Bureau, 2021; Kenny, 2024). In practice, this amounts to estimating district-level swings based on a weighted average of county swings, depending on the share of the district's total geography that each precinct comprises.

To validate this approach, we forecast legislative district-level 2020 vote shares based on the district-level swings from the multi-level model. We focus on competitive elections with ± 0.10 vote shares. In Appendix Figure F1 (b), we report the results in two ways, using as the lagged predictor (1) actual legislative district vote share from the previous election (left panel), and (2) actual 2016 presidential election vote share at the legislative district level (right panel).[1] For both methods, the model generally performs well with 5% or less of predictions seeing the true outcome falling outside of the prediction interval.

G Step-Ahead Election Forecasts

To predict elections more than one election into the future, we implement a one-step-ahead forecasting procedure making predictions for an upcoming election and then plugging in each of the simulated election outcomes as predictors to iterate election by election into the future. We follow this procedure up to five elections into the future to capture the range of possible outcomes for a full redistricting cycle. Such a process by definition leads to greater forecast uncertainty the further into the future the predictions. Appendix Figure G1 illustrates this pattern by reporting the density plot of simulated future election forecasts based on the multi-level model for the state of Texas. For 2022, the height of the density plot is greatest, reflecting relatively less uncertainty for the election. For 2030, several elections into the future, the height at the mean of the density plot is relatively less and the tails are fatter, reflecting greater uncertainty since the election is occurring several years away.

For a sequence of elections, we calculate if the redistricting party ever loses control of the majority. These simulations are applied to maps optimizing over the chances of maintaining a majority throughout a full redistricting cycle.

[1]We draw upon state legislative election results, presidential election results at the state legislative district level and geographic crosswalks (Klarner, 2024; The Downballot, 2020; Missouri Census Data Center, 2022) to make these comparisons.

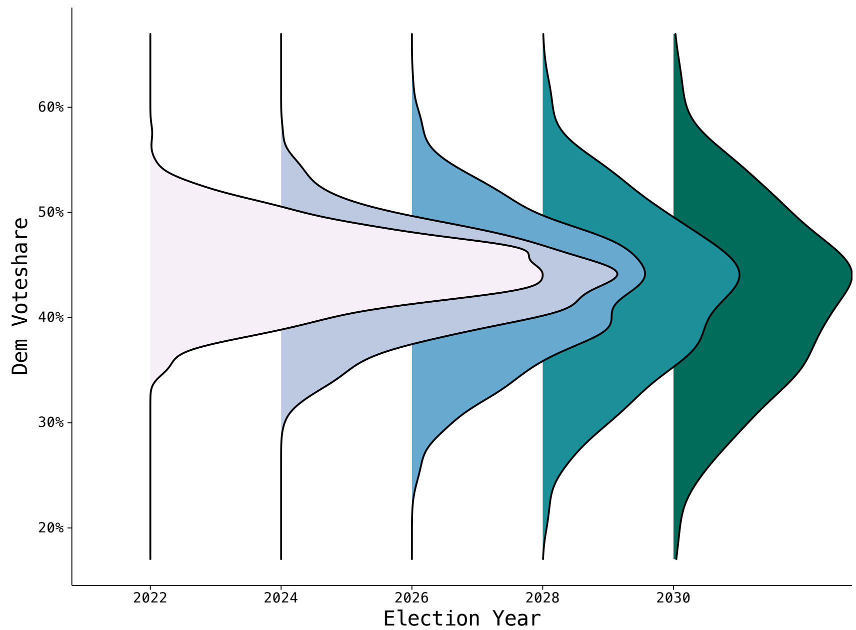


Figure G1: Multi-Level Model Forecasts Year by Year, Texas 2022–2030. **Notes:** This figure presents year-by-year forecasts for the state of Texas based on the fit of the state-level multi-level model. As the forecast moves further into the future, the prediction intervals grow wider to reflect increasing uncertainty about the predicted two-party vote share.

H Redistricting Constraints and Legal Redistricting Criteria

To evaluate how (minimally constrained) durable majority plans compare with enacted and baseline maps, we scored each map on key legal redistricting metrics: compactness, county splits, and population equality. Appendix Figure H1 compares each competitive state's durable-majority plan with its enacted plan and neutral baseline plan for these measures.[2] Across the board, the results align with expectations. Enacted maps tend to have significantly higher compactness and fewer county splits—since our simulations (1) impose only a mild compactness constraint without tuning the maps explicitly to increase compactness and (2) do not impose any constraints on county splits whatsoever. On the other hand, across the board the simulation-based maps have smaller population deviations than the enacted maps because we use a hard population deviation constraint of 2.5% whereas those drawing enacted maps may have more discretion.[3]

We chose four states to assess the sensitivity of our key results on durable majority gerrymanders to realistic map-drawing constraints. Table H1 reports specifics on the constraints imposed for each state.

To illustrate the extent of the robustness of these results, we imposed the redistricting criteria constraints and then re-calculated their performance for (1) legal redistricting criteria in Table H2 (discussed in the main draft) and for (2) the additional probability of party control over a neutral baseline map for enacted and durable gerrymander maps. Appendix Figure H3 illustrates that the changes on this dimension are minimal. While slightly more extreme durable majority gerrymanders are possible without constraints, the fact that the baseline map is also constrained means that the additional probability of a durable majority gerrymander (over and above a neutral baseline) remains very similar to the unconstrained case.

[2] County shapes come from U.S. Census Bureau (2020); Walker (2024)

[3] Also, enacted map drawers may sometimes split census blocks, which would not be reflected in our population calculations.

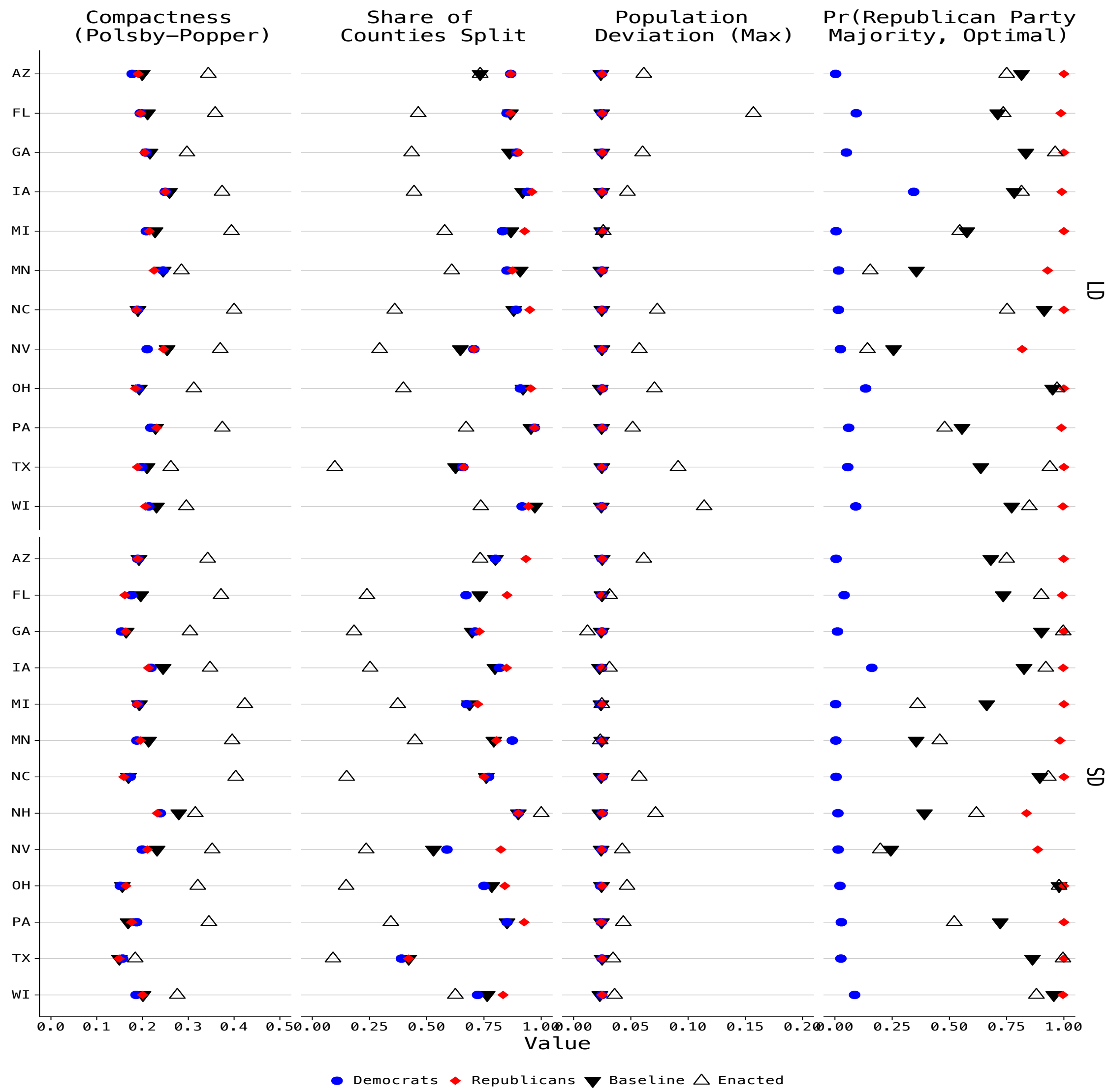


Figure H1: Comparison of Redistricting Legal Criteria Between Durable Majority Gerrymandered Maps, Baseline Maps, and Enacted Maps. **Notes:** This figure presents a comparison of Republican and Democratic durable majority gerrymander maps to enacted and baseline maps. The first column measures compactness using the Polsby-Popper metric. Higher values indicate more compact district maps and values can range from 0 to 1. The second column reports the share of counties int he state that are split by a district. The third column reports the maximum population deviation in percentage terms of a district from parity (where parity is district population when population is split evenly among all districts). Higher values indicate greater population deviations. The fourth column re-reports the estimated chances of maintaining a Republican Majority for each map, as a point of reference.

Table H1: Statutory Redistricting Rules and Implementation in Simulations

State	Rule	Requirement	In practice
Colorado			
	Compactness	Required	Add stronger compactness constraint; tune toward enacted-map compactness
	Competitive	Required	Add constraint encouraging competitiveness
	Contiguity	Required	Contiguity required
	Favor / disfavor incumbent, person or party	Prohibited	—
	Preserve communities of interest	Required	Add constraint penalizing splits
	Preserve political subdivisions	Required	Add constraint penalizing splits
Nebraska			
	Compactness	Required	Tune toward enacted-map compactness
	Contiguity	Required	Contiguity required
	Favor / disfavor party, group or person	Prohibited	—
	Preserve communities of interest	Required	Add constraint penalizing splits; maintain district cores
	Preserve cores of prior districts	Required	Add constraint maintaining district cores
	Preserve political subdivisions	Required	Add constraint penalizing splits; maintain district cores
	Use partisan data	Prohibited	—
North Carolina			
	Avoid pairing incumbents	Allowed	—
	Compactness	Required	Add stronger compactness constraint; tune toward enacted-map compactness
	Contiguity	Required	Contiguity required
	Preserve communities of interest	Required	Add constraint penalizing splits
	Preserve political subdivisions	Required	Add constraint penalizing splits
	Use partisan data	Allowed	—
	Use racial data	Prohibited	—
Texas			
	Contiguity	Required	Contiguity required
	Preserve political subdivisions	Required	Add constraint penalizing splits
	House only: preserve county lines "as nearly as may be"	Required	Add constraint penalizing splits, multi-splits, and total splits

Notes: Dashes indicate no added constraint to simulations for a requirement. All map simulations included weighting to encourage additional compactness and discourage county splits in the shortbust function. Data for historical district cores in Nebraska is drawn from Warshaw, McGhee, and Migurski (2022).

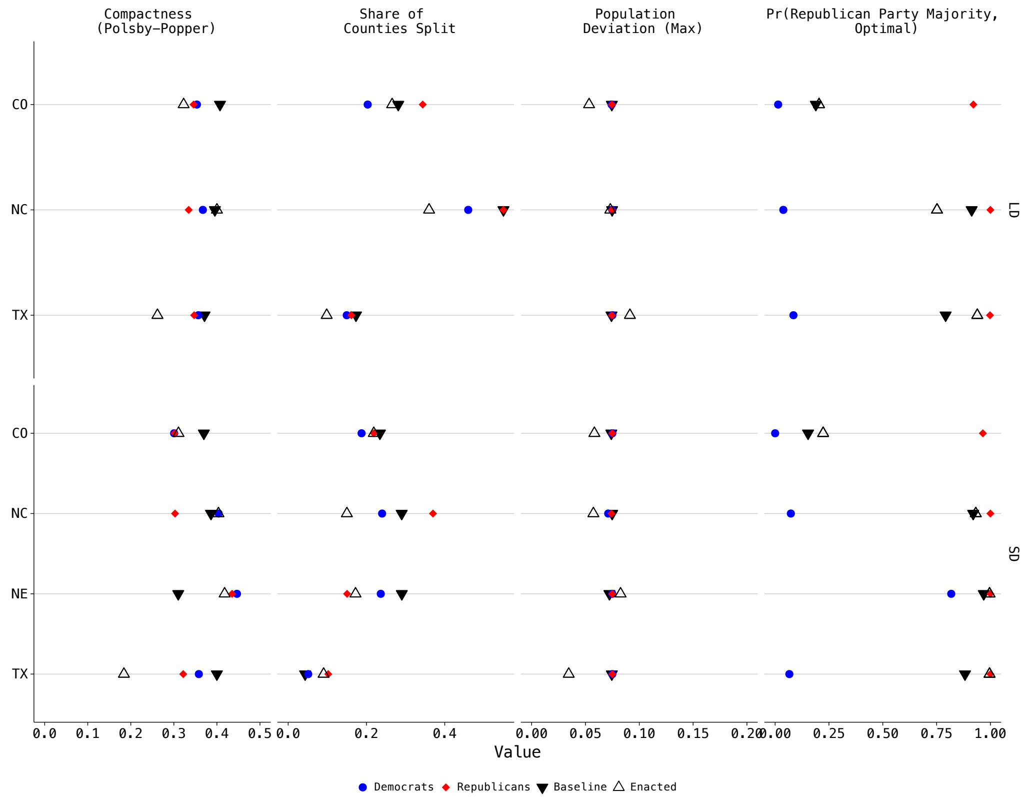


Figure H2: Comparison of Redistricting Legal Criteria Between Constrained Durable Majority Gerrymandered Maps, Constrained Baseline Maps, and Enacted Maps. **Notes:** This figure presents a comparison of Republican and Democratic *constrained* durable majority gerrymander maps and *constrained* baseline maps to enacted maps. The first column measures compactness using the Polsby-Popper metric. Higher values indicate more compact district maps and values can range from 0 to 1. The second column reports the share of counties split by a district. The third column reports the maximum district population deviation from parity, in percentage terms. The fourth column re-reports the estimated chances of maintaining a Republican Majority for each map, as a point of reference.

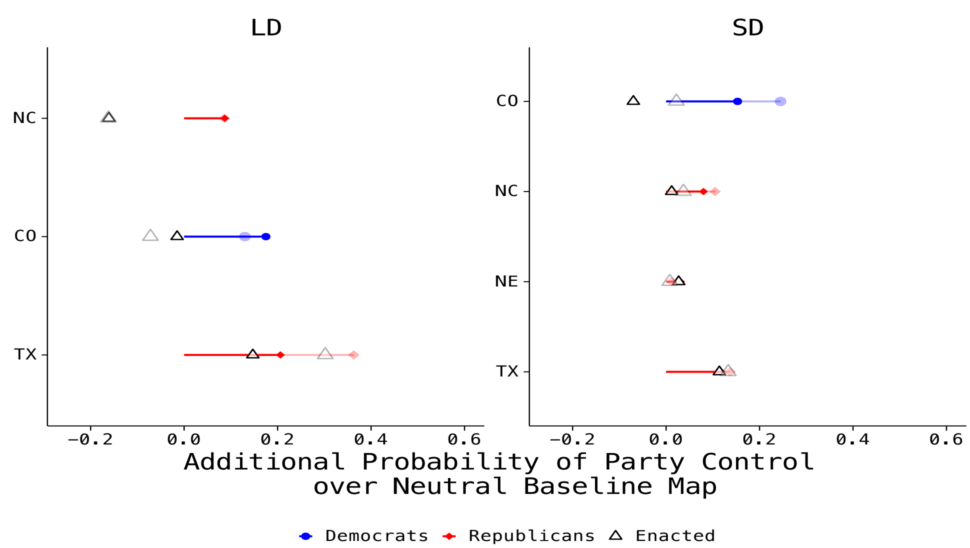


Figure H3: Additional Pr(Majority) Using Alternative Simulation Constraints. **Notes:** This figure replicates Figure 5 imposing realistic map drawing constraints for four states. The points and line segments with reduced opacity illustrate the results without imposing constraints, allowing for a comparison across simulation approaches. The figure illustrates the additional probability (net of the neutral baseline maps) garnered for Enacted maps (triangles) and for the Durable Majority/Gerrymander map possible for the majority party in the state (red/blue circle). Because the additional constraints operate on the baseline maps as well as the durable gerrymander maps, any shifts downward in the additional probability of party control due to constraints are accompanied by similar shifts for the enacted map; as a result, the enacted maps' relative positions to extreme durable gerrymanders does not change.

I Robustness of Neutral Maps

We test the robustness of our primary results to using alternative measures of partisan bias when constructing neutral baseline maps. We consider two alternatives to mean-median difference: (1) the efficiency gap and (2) the vote margin in a plan's pivotal district.

To construct alternative neutral baseline maps, we then followed the same approach as with mean-median difference to identify maps that are neutral with respect to these additional partisan bias measures.

When we plot the pivotal district vote shares for neutral baseline maps constructed via mean-median difference as compared to neutral baseline maps constructed using (1) Efficiency Gap or (2) Pivotal district vote margin, we find that the key map characteristics remain very similar. The figure below presents a scatterplot illustrating the substantive similarities.

Furthermore, when we use these alternatives to reconstruct Figure 5, which is a primary figure making use of the neutral baselines, we find that the estimates and conclusions remain very similar as when using our original approach. For example, the possible additional probability of party control over a neutral baseline does not differ meaningfully, and Texas remains the state that stands out most in terms of having enacted maps close to maximizing the chances of ongoing durable majorities.

(a) Efficiency Gap (b) Vote Margin in Pivotal District

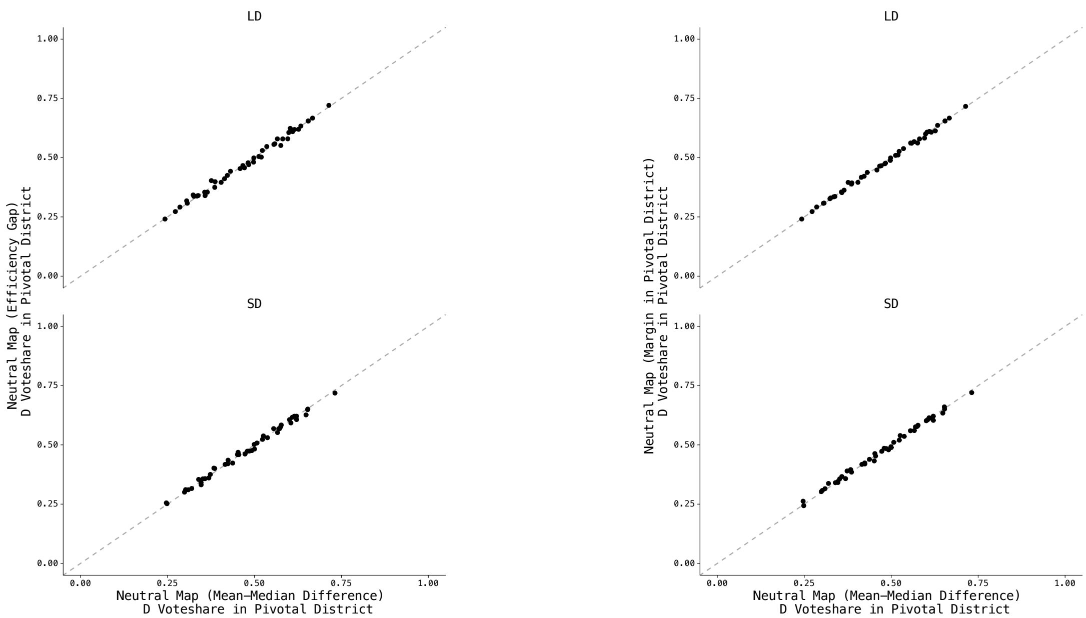


Figure I1: Alternative Measures of Partisan Bias for Determining Neutral Baseline Maps. **Notes:** This figure presents, for State House and State Senate district maps, the additional probability (net of the neutral baseline maps) garnered for Enacted maps (triangles) and for the Durable Majority/Gerrymander map possible for the majority party in the state (red/blue circle).

(a) Efficiency Gap (b) Vote Margin in Pivotal District

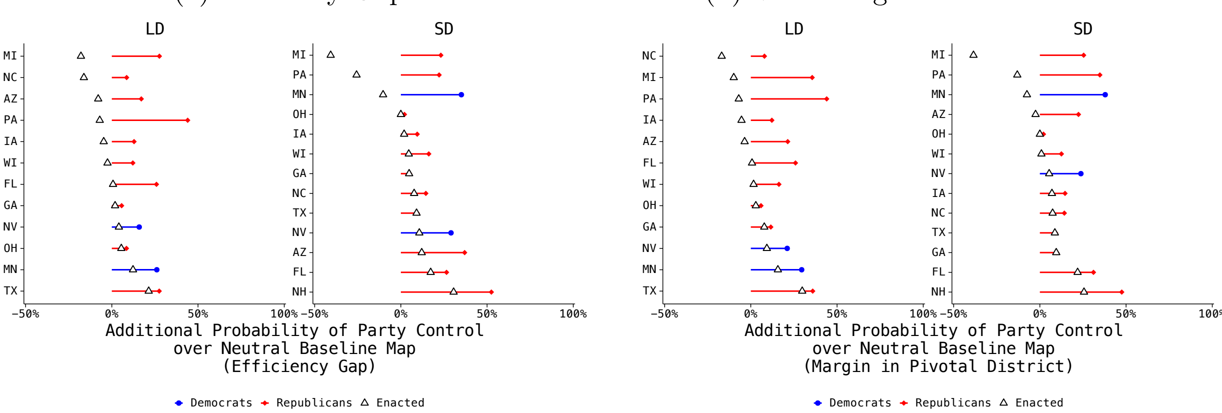
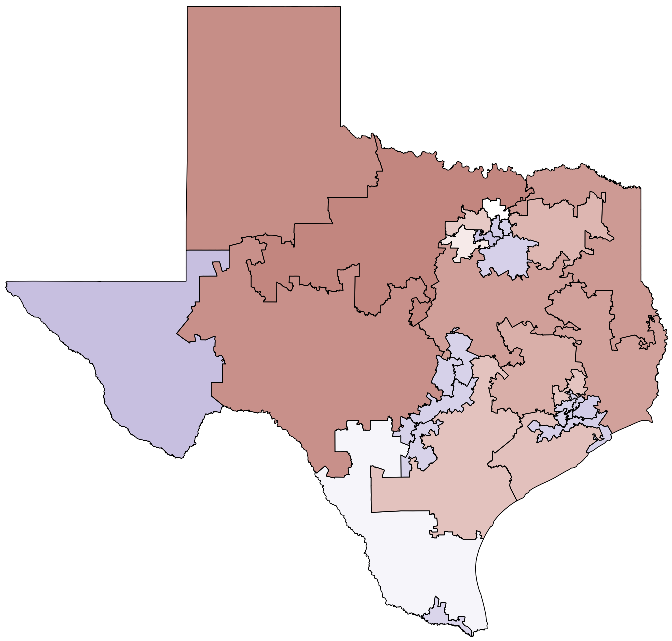


Figure I2: Additional Pr(Majority) Using Alternative Measures of Partisan Bias for Determining Neutral Baseline Maps. **Notes:** This figure replicates Figure 5 but using alternative baseline maps. The first alternative uses the Efficiency Gap to determine a neutral alternative. The second alternative uses the vote margin in the pivotal district to determine a neutral alternative. Neither approach substantively alters our core results for the additional probability added due to durable majority gerrymandering. The figure illustrates the additional probability (net of the neutral baseline maps) garnered for Enacted maps (triangles) and for the Durable Majority/Gerrymander map possible for the majority party in the state (red/blue circle).

J Example Maps

(a) Democratic Map



(b) Republican Map

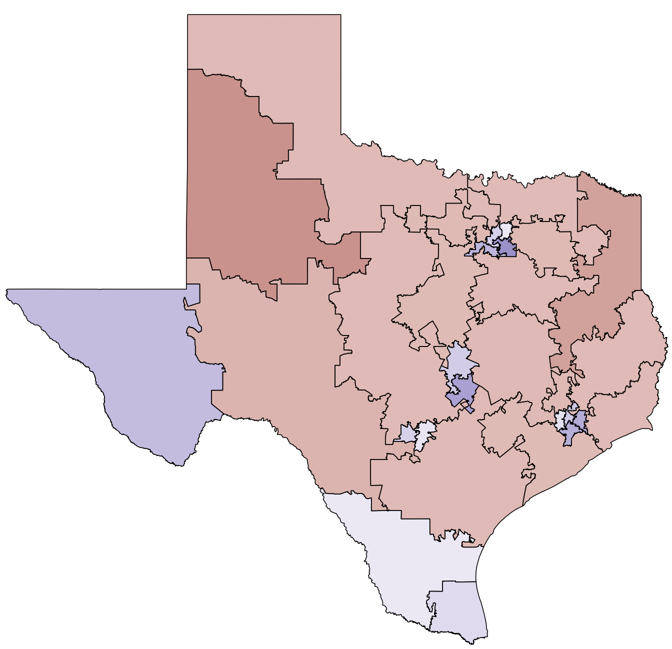


Figure J1: Texas Senate District (SD) Map, Maximizing Vote Margin in Pivotal District. **Notes:** This figure presents the Democratic (panel a) and Republican (panel b) maps that maximize the vote margin in the pivotal district for Texas Senate. Darker blue denotes more Democratic-leaning districts and darker red denotes more Republican-leaning districts, according to 2020 presidential election vote share.

References

Chen, Jowei, and Jonathan Rodden. 2013. “Unintentional Gerrymandering: Political Geography and Electoral Bias in Legislatures.” *Quarterly Journal of Political Science* 8: 239-269.

Katz, Jonathan N, and Gary King. 1999. “A Statistical Model for Multiparty Electoral Data.” *American Political Science Review* 93 (1): 15–32.

Kenny, Christopher T. 2024. “censable: Making Census Data More Usable.”. R package version 0.0.7, `https://github.com/christopherkenny/censable`.

Klarner, Carl. 2024. “State Legislative Election Returns, 1967-2022.” `https://doi.org/10.7910/DVN/FJOGJB`.

McCartan, Cory, and Kosuke Imai. 2023. “Sequential Monte Carlo for Sampling Balanced and Compact Redistricting Plans.” *The Annals of Applied Statistics* 17 (4): 3300–3323.

Missouri Census Data Center. 2022. “Geocorr 2022: Geographic Correspondence Engine.” `https://mcdc.missouri.edu/applications/geocorr2022.html`. Accessed August 28, 2025.

The Downballot. 2020. “Presidential and Statewide Election Results by Legislative District, 2020.” `https://www.the-downballot.com/p/data`. Accessed August 28, 2025.

U.S. Census Bureau. 2020. “TIGER/Line Shapefiles.” `https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html`. Accessed August 15, 2025.

U.S. Census Bureau. 2021. “2020 Census Redistricting Data (Public Law 94-171) Summary File.” `https://api.census.gov/data/2020/dec/pl`. Accessed August 15, 2025.

Walker, Kyle E. 2024. “tigris: Load TIGER/Line Shapefiles.” `https://CRAN.R-project.org/package=tigris`. R package version 2.1.

Warshaw, Christopher, Eric McGhee, and Michal Migurski. 2022. “Districts for a New Decade—Partisan Outcomes and Racial Representation in the 2021–22 Redistricting Cycle.” *Publius: The Journal of Federalism* 52 (3): 428–451. `https://planscore.org/2022-redistricting-review`.