Using computer simulations to measure the effect of gerrymandering on electoral competition in the U.S. Congress

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Abstract

Recent research has leveraged computer simulations to identify the effect of gerrymandering on partisan bias in U.S. legislatures. As a result of this method, researchers are able to distinguish between the intentional partisan bias caused by gerrymandering and the natural partisan bias that stems from the geographic sorting of partisan voters. However, this research has yet to explore the effect of gerrymandering on other biases like reduced electoral competition and incumbency protection. Using a computer algorithm to design a set of districts without political intent, I measure the extent to which the current districts have been gerrymandered to produce safer seats in Congress. I find that gerrymandering only has a minor effect on the average district, but does produce a number of safe seats for both Democrats and Republicans. Moreover, these safe seats tend to be located in states where a single party controls the districting process.

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1 Introduction

In recent decades, House elections have resulted in a near-even partisan split of the popular vote. Yet despite partisan parity at the national-level, elections at the district-level are relatively uncompetitive. Reelection rates in the House have dropped below 90% only twice in the past forty years and electoral competition has been in decline since the 1970’s (Abramowitz, Alexander and Gunning, 2006). In 2016, 97% of incumbents who ran for reelection were reelected. The average margin of victory across all districts was nearly 40%. And only 4% of elections were classified as tossups according to the Cook Political Report.¹

Given that national elections are so close, why then are seats so safe? While there are a number of factors that potentially explain the lack of electoral competition across districts, one particularly concerning explanation is that the lack of competition is a byproduct of gerrymandering. Through gerrymandering, parties work to pack and crack districts during the redistricting process in an effort to gain an electoral advantage. This packing and cracking alters the electoral landscape and inevitably leads to changes in the level of electoral competition in districts across the country. These changes potentially result in more uncompetitive districts than there otherwise would be.

Yet, empirical evidence that gerrymandering results in safer seats in the House has been mixed. Tufte (1973), for example, finds that competition in the House declined in the 1960’s and attributes at least some of the decline to a series of gerrymanders that occurred during the reapportionment revolution following Baker v. Carr (369 U.S. 186, 1962). Others have similarly found a link between the reduction in competition and gerrymandering (Lyons and Galderisi, 1995; King, 1989; Niemi and Jackman, 1991; McDonald, 2004). However, the effect is usually isolated to states where parties share control over the redistricting process and protect incumbents through bipartisan gerrymandering. Yet, not all studies agree that gerrymandering leads to reduced electoral competition. There is also evidence that gerrymandering has little to no effect on electoral competition in the House (Glazer,
Grofman and Robbins, 1987; Abramowitz, Alexander and Gunning, 2006) or on second-order outcomes like polarization (McCarty, Poole and Rosenthal, 2009). There is even evidence that gerrymandering works to enhance electoral competition rather than reduce it (Gelman and King, 1994).

One potential reason for the lack of consensus surrounding the effect of gerrymandering is that isolating the effect is hard to do. Researchers must attempt to separate the effect of gerrymandering from that of various alternative explanations. There are two alternative explanations that are commonly used to explain the abundance of safe seats. The predominant explanation is that safe seats are a result of incumbency advantage (Erikson, 1971; Gelman and King, 1990; Cox and Katz, 1996; Levitt and Wolfram, 1997). This explanation suggests that seats are safe not because they are designed to be that way, but because incumbents who run for reelection have a natural advantage over their competition. They have name recognition, government resources, better funding, and other privileges that the challenger does not. As a result, incumbents receive an electoral bump that increases their margin of victory and ensures that they are reelected.\(^2\)

The other explanation is that the lack of electoral competition is an unintended consequence of partisan geography. It is well-known to political scientists that the geographic distribution of partisanship plays an important role in biasing electoral outcomes in legislative elections (Erikson, 1972; Abramowitz, Alexander and Gunning, 2006; Chen and Rodden, 2013; Goedert, 2014). Because districts are designed to adhere to certain geographic principles like contiguity and compactness, electoral outcomes will inherently be a function of the residential patterns of voter preferences.\(^3\) As Republicans and Democrats increasingly segregate, they will increasingly be sorted into separate districts (Gimpel and Schuknecht, 2014).

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\(^2\)Some estimates suggest that incumbents receive a vote advantage of about 5 to 10 percentage points, holding all else equal (Gelman and Huang, 2008). However, Jacobson (2015) has observed that incumbency advantage is on the decline. He provides more recent estimates of the effect that are between 2 and 4 percentage points.

\(^3\)For example, compact districts contain individuals who live near each other. Therefore, these districts will be less competitive if the people who live near each other tend to share partisanship. Partisan geography interacts with district compactness to alter electoral competition.
2009; Bishop, 2009) that are homogeneously partisan and uncompetitive. For example, the concentration of Democrats in Southern states prior to partisan realignment resulted in safe and often uncontested Democratic seats in the South. And the tendency for Democrats to disproportionately reside in densely-populated metropolitan and urban centers continues to result in uncompetitive Democratic districts in those areas.

These alternative explanations suggest that districts would lack electoral competition even in the absence of gerrymandering. Therefore, to properly measure the causal effect of gerrymandering on electoral competition, one must attempt to control for the level of electoral competition that would have occurred if districts were not gerrymandered. One must find the difference between the gerrymandered outcome and the non-gerrymandered counterfactual outcome, holding confounding factors like voter geography and incumbency advantage constant.

In this study, I establish the non-gerrymandered counterfactual outcome by simulating it. Leveraging a computer-automated districting algorithm to redraw the current congressional districts without political intent and using precinct-level presidential votes to estimate the electoral outcome in these districts, I am able to simulate the level of electoral competition that would have resulted in a hypothetical election where districts were not subject to gerrymandering. By comparing the actual level of electoral competition to the simulated level of competition, I effectively isolate the extent to which gerrymandering has made seats safer in the United States. Because the simulations replicate the districting process with the same underlying partisan geography and because presidential votes are unaffected by incumbency advantage, this design successfully isolates the effect of gerrymandering on seat safety holding confounding factors like partisan geography and incumbency advantage constant.
2 Measuring the effect of gerrymandering by establishing the non-gerrymandered counterfactual

To make claims about the effect of gerrymandering on electoral competition, we need to compare the electoral competition in the current districts to the electoral competition that would have occurred if the current districts were not exposed to gerrymandering. While it is easy to determine electoral competition in the current districts, it is difficult to estimate what the electoral competition would have been if the districts were not exposed to gerrymandering. Ideally, we would observe the results of a similar election consisting of the same voters in the same location choosing between the same incumbent and challenger, where the only difference is that the districts in this election would be unaffected by gerrymandering. However, observing such a case is unlikely. Not only is it challenging to find two legislative elections that are held under the same conditions, but it is also challenging to find elections where gerrymandering can be completely ruled out. There often exists at least some suspicion that a state’s districts have been gerrymandered in some way, even in states with bipartisan or non-partisan commissions or in states where map-makers proclaim to be neutral.

Since it is difficult to estimate the non-gerrymandered counterfactual using comparable elections, researchers have recently turned to simulating it using computer-automated districting algorithms (Magleby and Mosesson, 2018; Chen and Cottrell, 2016; Krasno et al., 2016; Fifield et al., 2015; Cirincione, Darling and O’Rourke, 2000; Fryer Jr and Holden, 2011).\(^4\) These algorithms are designed to reproduce the districting process by aggregating Census blocks into a predetermined number of contiguous and equally-populated geographic jurisdictions. The advantage of a computer-automated districting algorithm is that the com-

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\(^4\)The Supreme Court recently considered the constitutionality of partisan gerrymandering in \textit{Gill vs. Whitford}. The plaintiffs argued that a large efficiency gap produced by the enacted districting plans in Wisconsin’s state legislature indicated that the plans had been gerrymandered to favor Republicans. However, as pointed out by Chen (2017), such a gap could occur naturally as a result of partisan geography. Hence, computer simulations are necessary to account for these confounding effects. Although the Court ruled against the plaintiffs on account of standing, further proceedings have integrated the simulations-based approach.
puter can be tasked with generating a large number of these districts without political intent. These alternative districting plans can then be used as a non-gerrymandered baseline against which the actual maps can be compared. Assuming that the only difference between the computer-generated districts and the actual districts is that the computer-generated districts are designed without political intent, then the expected difference in outcomes between the maps can be attributed specifically to gerrymandering alone. Because non-gerrymandered election outcomes can be simulated for a given election in a given state, cross-state and cross-election confounders are effectively eliminated.

Still, this method is not without its limitations. For one, it relies on an important assumption that the districting algorithm is randomly sampling from the true distribution of all potential non-gerrymandered districts (Altman et al., 2015). Specifically, it is assumed that the algorithm successfully replicates the districting process by crafting districts using the same politically-neutral criteria that would have been used in the absence of gerrymandering. If this assumption is satisfied, we can then attribute the difference in outcomes between the simulated and the actual districts to partisan intent. However, if the assumption is not satisfied and the algorithm systematically fails to capture a particular outcome that might result in the absence of gerrymandering, then we may falsely attribute that outcome to being a product of gerrymandering when it is actually a result of a neutral process.\footnote{Similarly, this method may be susceptible to more Type II errors than expected if map-makers somehow know the true distribution of potential maps and systematically select favorable maps that are just moderate enough to go undetected.}

To satisfy this assumption, districting algorithms attempt to replicate the districting process by aggregating Census blocks into larger, contiguous, and equally-populated geographic jurisdictions in the same way that the actual map-makers do. However, these algorithms can only follow a set of basic procedures for designing districts and might not fully capture the districting process in its entirety. For example, they generally build districts without considering race, ethnicity, communities of interest, existing political boundaries, or existing geographic landmarks, which are factors that might be considered in the actual districting
process. Hence, they are unable to replicate the more complex considerations that might occur in real-world districting.

There are additional limitations to using computer-automated districting algorithms to detect gerrymandering. For example, conducting a single districting simulation in a single state often requires randomly merging together combinations of hundreds of thousands of Census blocks in an iterative process until relatively compact, contiguous and equally-populated districts emerge. This can be computationally taxing and, for some algorithms under some conditions, it can be simply infeasible. Moreover, once the hypothetical districts are designed, one needs to estimate the electoral outcomes in those districts, which requires using geocoded voting data at the most granular level - usually at the precinct-level - to determine how voters in the districts have voted. Unlike Census data, geocoded voting data at the precinct-level is not always accessible and for some states the data might not exist at all.

For these reasons, studies have generally focused their gerrymandering analysis on just a handful of states. Cirincione, Darling and O’Rourke (2000), for example, look only at redistricting in South Carolina, Chen (2017) and Krasno et al. (2016) focus on the state legislature in Wisconsin, Fryer Jr and Holden (2011) limit their analysis to congressional districts in only four states, and Fifield et al. (2015) limit their analysis to districts in only two states. Moreover, up until recently, geographically-precise data on partisanship spanning all states had not yet been compiled. As a result, the analysis of partisan gerrymandering though simulations had been a state-by-state endeavor. This changed, however, when precinct-level election returns for the 2008 election were collected for the entire country and mapped to geocoded shape files of voting tabulation districts (VTDs) provided by the Census (Ansolabehere and Rodden, 2011). As a result, Chen and Cottrell (2016) were able to move beyond a few states and apply a computer-automated districting algorithm across all states with multiple congressional districts, assessing the effect of gerrymandering on the partisan seat share of Congress in its entirety.
Still, simulations have not been used to assess the effect of gerrymandering on electoral competition across the country. Districting algorithms have primarily been used to analyze the effect of gerrymandering on a party’s seat share rather than the degree of electoral competition across districts. Yet, parties are not only concerned with maximizing their seat share, they are also concerned with making their members’ seats safer. Computer simulations can be used to detect how votes get redistributed across districts in order to create safer seats. Therefore, I use computer-simulated districts to measure the extent to which gerrymandering makes seats safer.

I proceed in the following way. First, I employ an algorithm that generates a random set of districts that are equally apportioned, contiguous, and as compact as the enacted districts of the 113th Congress. These districts have been drawn by a computer and are therefore designed without political intent. Next, I estimate the likelihood of a partisan victory in each district (including the enacted districts) using precinct-level election returns for the 2008 presidential elections. I then analyze the difference in seat safety between the actual districts and the simulated counterfactual, breaking the results down by redistricting regimes at the state level to assess the effect of partisan gerrymandering and bipartisan gerrymandering.

3 Producing computer-generated districts

In order to establish the non-gerrymandered counterfactual, election results are simulated in hypothetical districts generated without political intent by a computer-automated districting algorithm. Unlike the actual map-makers whose decisions can be influenced by politics, the algorithm is independent of such influence. It uses a random process to combine small geographic units into larger ones until a set of districts that comply with basic districting standards are achieved. It repeats this process until hundreds of hypothetical districting plans have been produced for each of the multi-district states. The estimated electoral out-

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6 Basic districting standards require districts to be equally-populated, contiguous, and reasonably compact. Although some states use additional criteria, the computer-generated districts are designed to comply with these basic standards.
comes of these hypothetical districting plans can then be compared to the actual outcomes to assess the effect of gerrymandering.

There are a variety of computer algorithms that can be used to automate this process. Most of these algorithms use a random process to first partition the state into a predetermined number of contiguous districts. Some algorithms start with small geographic units like Census blocks and iteratively combine these blocks with adjacent ones until they grow into a predetermined number of contiguous districts. Some algorithms start with a predetermined number of seeds randomly located across the state and build the districts by assigning each geographic unit to its nearest seed. Other algorithms start with the entire state and then repeatedly divide the geographies into sub-geographies until a predetermined number of districts form. Because these districts usually aren’t equally-populated, the algorithms will often engage in an extra step where small adjustments are made to the boundaries of the districts until they are equally-populated.\(^7\)

For the purposes of this study, I leverage a particular districting algorithm developed by Fryer Jr and Holden (2011), which employs a weighted Voronoi diagram to partition the population of a given state into equally populated districts just as other algorithms do. The benefit of this algorithm, however, is that it can be used to search for districts that are at least as compact as the current set of districts. In fact, Fryer Jr and Holden (2011) developed this algorithm specifically to search for the maximally compact district in each state. This means that districts will tend to contain dense clusters of the population. By instructing the algorithm to contain dense clusters of the population, the simulations will effectively account for uncompetitive districts that might have resulted unintentionally from drawing compact districts in states where partisans cluster.

To build the districts, the algorithm begins with a contiguous spatial grid of the state’s geography as its input. This grid aggregates block-level population data from the 2010

\(^7\)While the districting algorithms differ in their procedure, it is hard to say whether they differ with respect to their outcome. To my knowledge, there has yet to be a formal comparison of the various districting algorithms in order to analyze differences in their outcomes.
Census' P.L 94-171 summary file into larger, more manageable rectangular subunits. Each subunit has around 1,200 residents on average, while a Census block has around 28 residents on average. Along with details about the resident population, these subunits also contain estimates of the 2008 McCain-Obama vote which were calculated by projecting precinct-level votes down to Census blocks and then aggregating up to each subunit in the grid. Counts for the number of blocks, precincts, and subunits are listed in Table A.1. Because all of these subunits are geographically contiguous, they have the effect of “smoothing” the population and vote density across geographic space. To design a feasible districting map, one simply needs to partition these units into relatively compact, contiguous, and equally apportioned districts.

To partition the units into districts for any given state, the algorithm begins by randomly selecting a subset of units on the grid equal to the number of desired districts using the K-means++ seeding method described in step 1 below. These units will be used as starting points or seeds for building districts. Once the seeds have been selected, every unit on the grid is assigned to the nearest seed. This effectively partitions the state into a set of contiguous districts of varying populations. Because the districts need to be equally-populated, the

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8These subunits are created by first dividing each congressional district into two contiguous halves and assigning the Census blocks to their nearest half. Then those halves and their corresponding Census blocks are subdivided into halves, which are subdivided into halves, and this process is repeated until the resulting subdivisions contain fewer than 2,000 residents each. This is the same grid technique used for the simulations in Chen and Cottrell (2016).

9Building districts with these larger subunits significantly reduces the computational burden associated with building districts directly from Census blocks.

10The McCain-Obama vote is projected down to the underlying Census blocks according to the fraction of the precinct population that resides within each block, so the projection assumes that McCain’s vote and Obama’s votes are similarly distributed across the blocks within a precinct according to population. The votes at the precinct-level come from the Harvard Election Data Archive http://projects.iq.harvard.edu/eda/home.

11Because votes have been projected onto smaller units and then aggregated upward into hypothetical districts that don’t correspond with precinct boundaries, there will be some degree of error in estimating the true McCain-Obama vote in these hypothetical districts. However, it is assumed that any noise in the projection process will be minor and unsystematic. Unfortunately, it is challenging to verify this assumption because presidential election results are not officially aggregated in these districts. As an alternative, I use the grid to predict the presidential vote at the county-level as a way to test the accuracy of the projections. I overlay county boundaries onto the grid for each state and aggregate upward to estimate Obama’s vote share in the county. Comparing it to the official vote share reported by the county, I am able to show that there is a near perfect correlation. In fact, the estimated vote share explains about 98.5% of Obama’s variation in the vote share across the counties. The degree of noise is minor.
algorithm iteratively adjusts the boundaries of the districts so that in each iteration the less-populated districts expand to acquire additional residents and the more-populated districts contract so as to remove excess residents. These expansions and contractions continue until the districts are relatively equal in population. This process results in a set of contiguous and equally-populated districts that tend to be reasonably compact. If the districts are not as compact as the actual districts, the algorithm moves the original seeds to the centroids of the equally-populated districts and repeats the procedure until the districts are at least as compact as the actual districts. In the 9-district state of Tennessee, for example, the algorithm works as follows:12

**Step 1** Select a unit on the grid at random with uniform probability. This is the first seed. Then select another unit on the grid with a probability that is inversely proportional to each unit’s distance from the first seed. This is the second seed. Then select another unit on the grid with a probability that is inversely proportional to each unit’s distance from its nearest seed. This is the third seed. This process repeats until all nine seeds have been set. See Figure 1(a).

**Step 2** Draw straight-line borders that divide the population into nine districts such that every unit is assigned to its closest seed. At this point the nine districts are guaranteed to be contiguous, but not equally apportioned.

**Step 3** Iteratively, shift the borders of the districts in a direction that improves population parity between the districts, continuing only if any district’s population is more or less than 1% of the mean population. (Figure 1(b) displays the path of the district centroids as the borders iteratively adjust.)

**Step 4** Calculate the total sum of squares (TSS) for each district by summing the squared distances between every person in the district - whose location is defined by the geographic unit in which they reside - and the district’s centroid. Total this sum over the

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12The formal details of the algorithm can be found in the appendix.
nine districts as a measure of compactness. If the districts are as compact as the actual districts, stop. The districting is complete. Otherwise continue to step five.

**Step 5** Move the original seeds to the centroids of the districts. Repeat Steps 1-5 until districting is complete.\(^{13}\) (A completed districting plan is displayed in Figure 1(C))

These steps are repeated 1,000 times generating 1,000 different randomly drawn districting plans. Therefore, the computer generates 1,000 partitions of the underlying grid in Tennessee. Each of the districts in those partitions are roughly equal in size. Moreover, they are as compact as the actual set of districts. In other words, the total sum of squared distances between every person and the district’s population center is just as small in the simulated districts as it is in the actual districts. The minimum, maximum, and average simulated TSS for each state is listed as a percent of the TSS of the actual districts in Table A.1.\(^{14}\)

After the simulations are run, I am left with the McCain and Obama votes for a set of hypothetical districts in the 113th Congress that can be compared to the McCain and Obama votes for the actual districts. Since the simulated districts were not designed with political intent, they represent a non-gerrymandered counterfactual to the actual districts of the 113th Congress.

The results for Tennessee are presented in Figure 2. The figure ranks the nine districts in the state according to Obama’s share of the two-party vote in 2008. Then it does the same for each of the simulated districts, plotting the mean and middle 95% of the 1,000 simulated results. Where the red dot extends above the black error bar, the districts are more Democratic than at least 97.5% of the non-political, computer-drawn plans. And where the red dot extends below the black error bar, the district is more Republican than at least 97.5% of the non-political, computer-drawn plans. The difference between the actual

\(^{13}\)If the algorithm continually fails to discover a set of districts that are at least as compact as the actual set of districts, the seeds are redrawn.

\(^{14}\)The algorithm’s output tends to converge on a distribution of vote-shares across the districts pretty quickly. This convergence occurs well before a 1,000 simulations. In fact, the results do not change even if I were to use half as many simulations.
Figure 1: Simulating congressional districts in Tennessee

(a) Nine seeds - one for each congressional district in Tennessee - are randomly dispersed across the state using the K-means++ seeding method. People within the state are assigned to each district according their nearest seed. (b) Using gradient descent, borders of the districts slightly expand or contract toward more equally-populated districts until each are within 1% of their target population. To visualize this, I’ve plotted the movement of the centroid of each district as the borders iteratively adjust to improve population parity. (c) The simulated boundaries of Tennessee’s nine districts. (d) The actual post-2010 boundaries of Tennessee’s nine districts.

and simulated result is the difference due to gerrymandering - holding the concentration of Democratic voters constant.

Tennessee presents an example of how gerrymandering is used to improve seat safety. The simulations imply that the 4th, 7th, 5th and 9th districts should be more moderate than they are. In fact, the 5th district should be a tossup. Instead it is eight points more Democratic than a tossup district. The outcome of the Republican-controlled districting process was seven equally strong Republican districts with around 65% McCain support. Had the plan been made without political intent, there would only be four districts that were strongly Republican. To achieve this, the 5th and 9th districts were packed with Democratic voters. As a result, the Republican districts in Tennessee are more Republican while the Democratic districts are more Democratic.

These results reflect the intention of this paper - to measure the extent to which gerry-
Figure 2: Simulated vs actual: Tennessee's 9 congressional districts

The above plot orders Tennessee’s 9 congressional districts along the x-axis by Obama’s share of the two-party presidential vote, which is indicated by the red dot. The black dot and error-bar represent the mean and middle 95% of the results produced by 1,000 simulated districts in Tennessee. The difference between the actual and simulated results reflect the effect due to gerrymandering. Marginal districts are more extreme than the simulated counterfactual, suggesting that gerrymandering in Tennessee promotes seat safety.

Gerrymandering reduces competition in congressional districts across the United States. In the next section, I transform Obama’s share of the two-party presidential vote into a probability that a Democrat wins a congressional seat. Then I compare those probabilities against the simulated probabilities to determine the degree to which gerrymandering alters the likelihood of a victory.
4  Measuring the net effect of gerrymandering on seat safety

Just as I did for Tennessee, I perform the same simulation procedure for all multi-district states other than Oregon and Georgia.\textsuperscript{15} Therefore, simulations are conducted for 41 of the 43 multi-district states, comprising 409 of the 435 congressional districts. A measure of electoral competition is then calculated for each of the simulated districts and compared to the districts of the 113th Congress.\textsuperscript{16}

One way to measure how competitive a seat will be is to calculate the degree to which Obama’s share of the 2-party vote approaches a 50-50 split. Competitive districts should contain roughly the same number of Obama voters as McCain voters. However, a 50-50 split in the 2-party presidential vote may not map directly onto a 50-50 split in the congressional vote. For example, Obama’s presidential vote share tends to uniformly overestimate the Democratic vote share in congressional elections. Therefore, it is important to adjust the presidential vote so that it is defined relative to the congressional vote.

4.1 The effect on the Partisan Vote Index

One way to make this adjustment is to follow the method that the Cook Political Report uses for their Partisan Vote Index (PVI)(Wasserman, 2013). The PVI has commonly been employed as a way to identify competitive seats in congressional elections using presidential votes. Because presidential votes are often biased toward the winning president’s party, it assumes that a tossup congressional election will have a presidential vote share equal to the national share of the 2-party vote. Hence, the index measures the percentage point difference between Obama’s 2-party vote share nationally and Obama’s 2-party vote share in a district. For example, a district where Obama received 58.7% of the 2-party vote is 5 points higher

\textsuperscript{15}I exclude Oregon because voters in the state vote exclusively by mail, which means precinct-level data is unavailable. I exclude Georgia because the precinct-level votes acquired from the Harvard Election Data Archive for Georgia’s 2008 presidential election do not perfectly match the official 2008 votes reported at the County-level. There is a correlation, but it is weak enough that I’ve chosen to remove the state from this analysis.

\textsuperscript{16}The 113th Congress is the first Congress to be elected using districts from the 2011-2012 redistricting cycle.
than the national Obama vote share, which is 53.7%. Therefore, the PVI in this district would be +5 in favor of Democrats. Likewise, the PVI in a district where Obama received 48.7% of the 2-party vote would be +5 in favor of Republicans. The greater the absolute PVI, the safer the seat.

To estimate how gerrymandering has affected seat safety, I simply compare the average absolute PVI across the enacted set of districts to the average absolute PVI of each of the simulated set of districts. I display the results in the left plot of Figure 3. The 1,000 simulated results are presented as a density histogram. The average of the simulations is approximately +10.5, which means that in an election where gerrymandering was absent and incumbents were no longer advantaged, we would expect the presidential vote share of the majority party in the district to deviate from Obama’s national vote share by 10.5 points. This is 1.4 points less than the deviation that we observe in the current Congress. Hence, on average, gerrymandering has the effect of increasing the majority party’s vote by 1.4 percentage points.

4.2 The effect on the probability of winning

While this result suggests that gerrymandering significantly increases seat safety, it is difficult to know how meaningful 1.4 percentage points in presidential votes is in terms of winning elections. Therefore, I translate the presidential vote into the likelihood that a district’s majority party candidate wins the Congressional election in his district. To do this, I match Obama’s 2008 district-level vote share to a dummy variable that indicates whether a Democrat won the congressional election in that district in each year from 2002 to 2012. I then conduct a simple logit transformation where I regress the outcome dummy on the 2008 Obama vote share in each district. This transforms the Obama vote share into the likelihood that a Democrat wins a congressional election. Then, I transform this likelihood ($p$) into the likelihood that a district’s majority party candidate wins the congressional election in his district ($0.5 + \left| p - 0.5 \right|$).
Figure 3: The aggregate effect of gerrymandering on safe seats

The two figures compare the partisan electoral competition of the average congressional district to that of the 1,000 simulated districts. A district’s Partisan Vote Index is the absolute point difference between Obama’s share of the national vote and Obama’s share of the district vote. The probability of a victory is the probability that the majority party in a district will win the election. The distribution of the 1,000 simulated results is represented by a density histogram and the mean simulated result is represented by a black triangle. The average result for the 113th Congress is represented by a red triangle.

By translating presidential votes into this likelihood, I can now estimate the meaning of a 1.4 point increase in PVI. The right plot of Figure 3 displays the results of this transformation. The plot on the right is the same as the plot on the left except that the x-axis indicates the average probability that the most likely partisan candidate will win the election in his district. We can see from the outcomes of the simulations that in the absence of gerrymandering the average probability that the favored party wins an election is 81.3%. This is 2.8 points less than the average probability under the enacted plans, which is a significant but small effect. Therefore, the results of Figure 3 suggest that gerrymandering - on average - makes seats safer.

However, the results also suggest that gerrymandering is responsible for only a small fraction of a district’s partisan advantage. Gerrymandering might increase a favored party’s likelihood of victory by 2.8 percentage points, but that party’s likelihood of victory is expected to be above 80% without gerrymandering. This suggests that safe seats are largely
an unintended consequence of districting and that partisan geography is more to blame for the lack of competition in congressional elections than partisan gerrymandering.

4.3 The effect on the number of marginal and safe seats

One problem with the measures displayed in Figure 3 is that they fail to show how gerrymandering might affect the parties in different ways. For example, gerrymandering may increase the number of safe seats for one party but not the other. We can potentially gain some insight into this differential effect on parties by dividing the districts into marginal and safe seats for Republicans and Democrats. Then we can observe how districts are distributed across this categorization and compare this distribution to the simulated distribution.

Therefore, I divide the districts into four categories and plot the number of districts in those categories in Figure 4. Those districts where Democrats have more than a 75% chance of winning are labeled “Safe Democrat.” Those districts where Democrats have between a 75% and 50% chance of winning are labeled “Marginal Democrat.” Those districts where Democrats have between a 50% and 25% chance of winning are labeled “Marginal Republican.” And those districts where Democrats have less than a 25% chance of winning are labeled “Safe Republican.”17 The red dot corresponds with the number of seats under the enacted plan for the 113th Congress. The height of the grey bars represents the mean number of seats produced by the simulated districting plans in each category. The black error bar represents the middle 95% percent of the simulations.

From this figure, we can easily see that the simulated non-gerrymandered districts produced just under 17 fewer safe Republican seats and just over 18 fewer safe Democratic seats than the enacted plans. Therefore gerrymandering appears to increase the number of safe seats for both Democrats and Republicans equally. However, what is interesting about this distribution is that these additional safe seats seem to come at the expense of marginally marginal districts.

17 For reference, a Marginal Republican district is defined as having an Obama vote share between 47.1% and 52.6% while a Marginal Democratic district is defined as having an Obama vote share between 52.6% and 58.1%. Therefore, marginal districts cover a 11 point spread, which is conventional. See Figure A.1 which displays how Obama’s vote share is categorized.
The red dot corresponds with the number of seats under the enacted plan. The grey bar represents the mean number of seats produced by the simulated plans and the black error bar represents the middle 95% percent of the results produced by the simulations. There are 41 states and 409 districts.

Democratic districts. In fact, there are nearly 35 fewer marginally Democratic districts than the simulations predict there should be. Therefore marginally Democratic seats are being intentionally swapped for both safe Democratic seats and safe Republican seats as a result of gerrymandering.

This is consistent with a Republican partisan gerrymander, where Republicans capture vulnerable Democratic seats at the expense of making some Democratic districts safer. However, it is possible that Republican gerrymandering is not the only explanation for this pattern. Some of these safer seats might also be explained by Democratic gerrymandering or by incumbent protection strategies. We are unable to tell from this plot. However we might be able to gain some insight into the different types of gerrymandering by separating the states by its redistricting regime.
Figure 5: Simulated vs actual: Republican and Democrat redistricting regimes

(a) Republican-controlled
(14 States, 144 Districts)

(b) Democrat-controlled
(7 States, 97 Districts)

5 Analyzing redistricting regimes

Using Justin Levitt’s classification of each state’s redistricting process during the 2011-2012 redistricting cycle, I separate the states into four categories: “Republican-controlled”, “Democrat-controlled”, “Split-controlled,” or “VRA.” Republican-controlled” and “Democrat-controlled” refer to states where a single party controlled the districting process. Conversely, “Split-controlled” refers to states where no single party controlled the districting process. This includes cases where there is divided government or split legislatures, as well as cases where there are bipartisan or independent redistricting commissions. And “VRA” refers to states that require pre-clearance under the Voting Right Act.

Figure 5 displays the result for Republican-controlled states on the left and Democrat-controlled states on the right. Compared to the actual districting plans in Republican-controlled states, the simulated plans produce a similar number of safe Democratic districts.

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18Levitt’s classification can be found at http://redistricting.lls.edu/who-partyfed.php.
and marginally Republican districts. However, they also produce fewer safe Republican districts and more marginally Democratic districts than the actual districting plans. This result implies an optimal partisan gerrymander, where marginally Democratic districts are replaced with safe Republican districts so that Republicans not only gain additional seats, but they also gain safer seats as well. In fact, most of the safe Republican seats gained by gerrymandering in the House can be explained by gains in these Republican-controlled states.

In Democrat-controlled states, the simulations produce fewer safe Democratic districts and more marginally Democratic districts than the actual districting plans. Therefore, it appears that Democrats are using gerrymandering to make a handful of marginally Democratic districts safer. On average, Democrats do not seem to be engaging in the type of partisan gerrymandering that would transform Republican seats into Democratic ones. One reason for this is that states where Democrats control the districting process tend to be saturated with Democratic voters. Therefore, districts drawn in those states are not likely to produce Republican seats even in the absence of gerrymandering. And it may be challenging for Democrats to design the districts in a way that produces fewer Republican seats while maintaining safe Democratic seats.

Just as we might expect to see partisan gerrymandering in states where parties have full control over the districting process, we might also expect to see incumbency protection in states where no single party controls the districting process. In these states, map-makers have the incentive to reduce the electoral competition for both parties as a way to strike a bipartisan compromise. Therefore, where the districting authority is split between the two parties, one might expect the map-makers to resort to incumbency protection. The first plot in Figure 6 tests this hypothesis. If these states are engaging in incumbency protection, we would expect there to be safer seats than the counterfactual simulations predict.

Yet, Figure 6 shows that the actual districts deviate only slightly from the simulated districts. To the extent that there is a significant deviation, it is that there are fewer
marginally Democratic districts and slightly more safe Democratic districts than there are in the simulations. While this might suggest that Democrats are protecting their members in Split-controlled states, this effect is mostly driven by the bipartisan redistricting commission in California. If you take out California, significant differences no longer exist. Hence, outside of California, districts in Split-controlled states produce outcomes that are no different from a computer-drawn map. Contrary to the incumbency protection hypothesis, it does not appear that gerrymandering is responsible for creating safer seats in these states.19

Lastly, the second plot in Figure 6 shows how the districts in pre-clearance states compare to the simulations. These pre-clearance states are states where map-makers are under special scrutiny to design districts that do not dilute minority representation. While not necessarily

19Generally, the incumbency protection hypothesis involves states where there is divided government rather than states where some bipartisan redistricting commission controls the process. Therefore, it might be useful to separate those states with divided government from those states with bipartisan commissions. You can see the distributions of each redistricting regime separately in Figure A.2 in the Appendix. Still, the results suggest that gerrymandering does not increase the number of safe seats in states with divided government, which is contrary to the incumbency protection hypothesis.
partisan in nature, these states may draw some districts to have more minority voters than they would have otherwise if the map-makers did not consider race in the redistricting process. By intentionally drawing districts with more minority voters, these voters are better able to elect a candidate of their choice. This will likely create plans that deviate from the non-gerrymandered simulations, even if no partisan gerrymandering took place. In fact, the VRA plot in Figure 6 shows that pre-clearance states have fewer marginally Democratic seats and more safe Democratic seats than the non-gerrymandered simulations. This is unlikely a result of Democratic gerrymandering since most of the states subject to pre-clearance are uniformly controlled by Republicans. Rather, these safer Democratic seats are more likely a result of race-conscious efforts to design districts that comply with the Voting Rights Act.

6 Conclusion

Gerrymandering is commonly blamed for the prevalence of safe seats in Congress. The conventional wisdom is that legislators take advantage of the districting process to bolster their party’s electoral fortunes by packing districts with partisans in order to make seats safer. However, I have shown that on average, gerrymandering does little to improve seat safety for most representatives in Congress. Using computer simulations to isolate the effect of gerrymandering on electoral competition, I show that gerrymandering increases the probability of winning a Congressional election by less than 3 percentage points on average. This suggests that the national-level effect of gerrymandering on increasing the safety of seats is quite small. Instead, much of the variation in seat safety in the aggregate is caused by factors other than gerrymandering, like incumbency advantage and partisan geography.

While gerrymandering may not play a large role in shifting electoral competition in the average district, it does produce a number of safe seats for both Democrats and Republicans that would not have otherwise existed. In fact, around 35 marginally Democratic seats are replaced with approximately 17 safe Republican seats and 18 safe Democratic as a result of gerrymandering. While both Democrats and Republicans gain safer seats, these safer seats
come at the expense of Democratic leaning districts. Hence, Democrats are at a net loss.

Moreover, I find that Republicans and Democrats gain safe seats from gerrymandering primarily in states where the districting process was uniformly controlled by their party. For example, in Republican-controlled states, Republicans gain safer seats by swapping marginally Democratic seats with safer Republican seats. And in Democrat-controlled states, Democrats gain safer seats by swapping marginally Democratic seats with safe Democratic seats. Partisan control of the districting process accounts for most of the effect of gerrymandering.

Lastly, while it is often asserted that safe seats tend to result from bipartisan gerrymandering (King, 1989; Niemi and Jackman, 1991; McDonald, 2004), the results of this analysis appear to suggest otherwise. In states where the parties split control of the districting process, there are no more safe seats than there would be if the districts were designed by a computer. The simulated results are no different from the actual results in those states, suggesting that the effect of gerrymandering is neutralized by bipartisanship.
A Appendix

A.1 Districting algorithm: weighted Voronoi diagram

To randomly generate contiguous and equally apportioned districts, I employ a districting algorithm used by Fryer Jr and Holden (2011). The algorithm is designed to solve an equipartitioning problem where a state’s population is partitioned into a set of equally populated and contiguous districts. Therefore, $N$ residents in state $S$ are partitioned into one of $d$ districts denoted $D_i \in D_1, \ldots, D_d$ so that each district is of equal size $n = N/d$. To do this, the algorithm uses a power diagram (or weighted Voronoi diagram) to separate the state into $d$ contiguous partitions defined by linear borders according to a set of generator points $z_1, \ldots, z_d \in \mathbb{R}^2$ and a set of weights $\lambda_1, \ldots, \lambda_d \in \mathbb{R}$. The districts $D_1, \ldots, D_d$ divide the state’s euclidean space so that,

$$D_i = \{ q \in \mathbb{R}^2 : i = \arg \min_j [||q - z_j||^2 - \lambda_j] \},$$

where $||.||$ indicates the euclidean distance.

The algorithm begins by selecting a set of seeds $z_1, \ldots, z_d \in \mathbb{R}^2$ arbitrarily and setting the weights at $\lambda_i = 0$. It then assigns each resident in the state, defined as a point $x \in \mathbb{R}^2$, to the district in which she resides according to the borders defined by the argument above. Therefore, each resident is assigned to the seed $z_i$ if and only if $||x - z_i||^2 - \lambda_i > (||x - z_k||^2 - \lambda_k)$ for all $k \neq i$. Since $\lambda_i = 0$, every resident $x$ is assigned to her nearest seed $z_i$.

Next the algorithm adjusts the borders of the districts until the districts are equally apportioned. It does this by choosing the vector $\lambda_i$ such that $|D_i| = n$. At this point, the residents have been divided into a set of equally apportioned and contiguous districts.

While the districts may be equally apportioned and contiguous, they are not necessarily compact. Therefore, the next step is to measure the compactness of the district. To do this, the algorithm computes the centroid of each districts $c_i = \frac{1}{n} \sum_{x \in D_i} x$ and then calculates the
distances from each resident to their district’s centroid. The compactness of the districting plan is defined as the combined total sum of squared distances (TSS) such that,

\[
TSS = \sum_{i=1}^{d} \sum_{x \in D_i} ||x - z_i||^2.
\]

If the TSS is less than the TSS of the actual district, then the process is complete. Every resident has successfully been partitioned into districts that are equally apportioned, contiguous, and sufficiently compact. However, if the TSS is greater than the TSS of the actual districts, then the districts are not sufficiently compact. Therefore, the algorithm continues in order to improve the districts’ compactness. It does this by moving the seeds to the district centroids and repeating the previous steps with these new points as starting values. Fryer Jr and Holden (2011) show that this step has the property of improving the district’s compactness. The process repeats until the districts are equally apportioned, contiguous, and sufficiently compact.
Table A.1: Summary of data and the relative compactness of the simulations

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| Total | -      | -        | 409      | 177,662 | 10,041,845 | 245,056 | 41,000 | -     | -     |
| Median | -      | -        | 7       | 2,525   | 210,227    | 4,287   | 1,000  | 84    | 92    |

To calculate %TSS, I identify the location of every person within a given simulated district and sum over their squared distances from the district’s center. I then total this sum across the districts in the state for each simulation and present the number as a percent of the TSS for the actual plans.

**Regime:** DEM: Democrat controlled; REP: Republican controlled; DIV: Divided government; BIP: Bipartisan commission.
Figure A.1: Estimated transformation of Obama’s vote share into the probability of a Democratic victory for a given district.

Figure A.2: Simulated vs Actual: Divided Government and Bipartisan commission

(a) Divided Government
(10 States, 74 Districts)

(b) Bipartisan commission
(5 States, 79 Districts)
References


Altman, Micah, Brian Amos, Michael P McDonald and Daniel A Smith. 2015. “Revealing Preferences: Why Gerrymanders are Hard to Prove, and What to Do about It.”. URL: http://dx.doi.org/10.2139/ssrn.2583528


Krasno, Jonathan S, Daniel Magleby, Michael D McDonald, Shawn Donahue and Robin E Best. 2016. “Can Gerrymanders Be Measured? An Examination of Wisconsin’s State Assembly.” *An Examination of Wisconsin’s State Assembly (May 22, 2016)*.


