EXPERT REPORT OF JOWEI CHEN, Ph.D.

I am an Associate Professor in the Department of Political Science at the University of Michigan, Ann Arbor. I am also a Faculty Associate at the Center for Political Studies of the Institute for Social Research at the University of Michigan as well as a Research Associate at the Spatial Social Science Laboratory at Stanford University. In 2007, I received a M.S. in Statistics from Stanford University, and in 2009, I received a Ph.D. in political science from Stanford University. I have published academic papers on political geography and districting in top political science journals, including *The American Journal of Political Science* and *The American Political Science Review*, and *The Quarterly Journal of Political Science*. My academic areas of expertise include spatial statistics, redistricting, gerrymandering, the Voting Rights Act, legislatures, elections, and political geography. I have unique expertise in the use of computer algorithms and geographic information systems (GIS) to study questions related to political and economic geography and redistricting.

I have provided expert reports in the following redistricting court cases: Missouri National Association for the Advancement of Colored People v. Ferguson-Florissant School District and St. Louis County Board of Election Commissioners (E.D. Mo. 2014); Rene Romo et al. v. Ken Detzner et al. (Fla. 2d Judicial Cir. Leon Cnty. 2013); The League of Women Voters of Florida et al. v. Ken Detzner et al. (Fla. 2d Judicial Cir. Leon Cnty. 2012); Raleigh Wake Citizens Association et al. v. Wake County Board of Elections (E.D.N.C. 2015); Corrine Brown et al. v. Ken Detzner et al. (N.D. Fla. 2015); City of Greensboro et al. v. Guilford County Board of Elections, (M.D.N.C. 2015). I have testified at trial in the following cases: Raleigh Wake Citizens Association et al. v. Wake County Board of Elections (E.D.N.C. 2015); City of Greensboro et al. v. Guilford County Board of Elections (M.D.N.C. 2015). I am being compensated $500 per hour for my work in this case.

Research Question and Summary of Findings

The attorneys for the plaintiffs in this case have asked me to analyze North Carolina's current congressional districting plan, as created by Session Law 2016-1 (Senate Bill 2). Specifically, I was asked to analyze: 1) Whether partisan considerations were the predominant factor in the drawing of the 2016 enacted Senate Bill 2 (SB 2) districting plan; and 2) The extent

to which the enacted SB 2 plan conforms to the February 16, 2016 Adopted Criteria of the Joint Select Committee on Congressional Redistricting (The "Adopted Criteria").

In conducting my academic research on legislative districting, partisan and racial gerrymandering, and electoral bias, I have developed various computer simulation programming techniques that allow me to produce a large number of valid, non-partisan districting plans in any given state, county, or municipality using either Voting Districts ("VTDs") or census blocks as building blocks. This simulation process is non-partisan in the sense that the computer ignores all partisan and racial considerations when drawing districts. Instead, the computer simulations are programmed to optimize districts with respect to various traditional districting goals, such as equalizing population, maximizing geographic compactness, and preserving county boundaries and VTD boundaries. By generating a large number of drawn districting plans that closely follow and optimize on these traditional districting criteria, I am able to assess an enacted plan drawn by a state legislature and determine whether partisan goals may have motivated the legislature to deviate from these traditional districting criteria.

More specifically, by holding constant the application of non-partisan, traditional districting criteria through the simulations, I am able to determine whether the enacted plan could have been the product of something other than the explicit pursuit of partisan advantage. I determined that it could not.

I use this simulation approach to analyze the North Carolina General Assembly's enacted SB 2 congressional districting plan in several ways. First, I conduct 1,000 independent simulations, instructing the computer to generate valid congressional districting plans that strictly follow all of the non-partisan criteria enumerated in the Adopted Criteria. I then measure the extent to which the enacted SB 2 plan deviates from these simulated plans with respect to the Adopted Criteria. The simulation results demonstrate that the enacted plan failed to minimize county splits and was significantly less geographically compact than every single one of the 1,000 simulated districting plans. By deviating from these traditional districting criteria, the SB 2 plan also managed to create a total of 10 Republican-leaning districts out of 13 total districts. By contrast, the simulation results demonstrate that a map-drawing process respecting non-partisan, traditional districting criteria generally creates either 6 or 7 Republican districts. Thus, the enacted plan represents an extreme statistical outlier, creating a level of partisan bias never observed in any of the 1,000 computer simulated plans. The enacted plan creates 3 to 4 more

Republican seats than what is generally achievable under a map-drawing process respecting non-partisan, traditional districting criteria. The simulation results thus warrant the conclusion that partisan considerations predominated over other non-partisan criteria, particularly minimizing county splits and maximizing compactness, in the drawing of the General Assembly's enacted plan.

Having found that partisan considerations predominated over the General Assembly's drawing of its enacted plan, I then consider a series of possible alternative explanations for the extreme partisan bias in the enacted plan. The Adopted Criteria calls for the drawing of congressional districts in a manner that avoids double-pairing of any of the incumbent members of Congress. I thus conduct a second set of 1,000 simulations to see if following this mandate would somehow alter the partisan composition of valid districting plans.

This second set of simulation results demonstrates that the Adopted Criteria's provision for protecting House incumbents does not explain the extreme partisan bias of the enacted plan. Among the 1,000 simulated plans protecting all 13 of North Carolina's House incumbents, not a single simulation creates 10 Republican-leaning districts; once again, most of the simulations contain either 7 or 8 Republican districts. These simulation results clearly reject any notion that an effort to protect incumbents might have warranted the extreme partisan bias observed in the General Assembly's enacted plan. I also found that the enacted plan did not succeed entirely in protecting incumbents, as two congressional incumbents were in fact paired under the enacted plan.

Additionally, even though the enacted plan failed to fully minimize county splits and protect incumbents, I evaluated whether the General Assembly's specific decision to split 13 counties and to protect exactly 11 incumbent House members under the enacted plan could have possibly explained the extreme partisan bias of the plan. Hence, I conducted a third set of 1,000 simulations in which the computer intentionally split 13 counties and protected only 11 incumbents, while otherwise optimizing on the other non-partisan criteria set forth in the Adopted Criteria. Once again, the simulation results demonstrate that even with these particular benchmarks for county splits and protected incumbents, a non-partisan simulated districting process never achieves the outcome of 10 Republican districts that is produced by the enacted plan. Hence, the drawing of the enacted SB 2 plan can only be explained as a process in which

partisan goals were predominant and subordinated the non-partisan, traditional districting criteria included in the Adopted Criteria.

This report proceeds as follows. First, I explain the logic of using computer-generated districting simulations to evaluate the partisan bias of a districting plan. I then present three sets of computer simulations of valid districting plans, as described above. Next, I explain how the results of these districting simulations demonstrate that partisan concerns predominated significantly over other factors in the drawing of the General Assembly's enacted map. Finally, I present additional robustness checks of my calculations of the enacted and simulated plans' partisanship using alternative measures of partisan electoral bias.

The Logic of Redistricting Simulations

Once a districting plan has been drawn, academics and judges face a difficult challenge in assessing the intent of the map-drawers, especially regarding partisan motivations. The central problem is that the mere presence of partisan bias may tell us very little about the intentions of those drawing the districts. Whenever political representation is based on winner-take-all districts, asymmetries between votes and seats can emerge merely because one party's supporters are more clustered in space than those of the other party. When this happens, the party with a more concentrated support base achieves a smaller seat share because it racks up large numbers of "surplus" votes in the districts it wins, while falling just short of the winning threshold in many of the districts it loses. This can happen quite naturally in cities due to such factors as racial segregation, housing and labor markets, transportation infrastructure, and residential sorting by income and lifestyle.

When tallying votes in recent statewide races such as those for U.S. President, U.S. Senator, or Governor, it is clear that North Carolina's statewide electorate is roughly evenly divided between Democratic and Republican voters. Yet Republicans currently hold a very significant 10-3 advantage over Democrats in control over North Carolina's U.S. congressional seats.

The crucial question is whether, due to underlying patterns of political geography, the distribution of partisan outcomes created by the General Assembly's enacted districting plan could have plausibly emerged from a non-partisan districting process. In order to make informed and precise inferences about the presence or absence of partisan intent during the redistricting

process, it is necessary to compare the General Assembly's enacted districting plan against a standard that is based on a non-partisan districting process following the traditional redistricting criteria outlined in the Adopted Criteria.

The computer simulations I conducted for this report have been created expressly for the purpose of developing such a standard. Conducting computer simulations of the districting process is the most statistically accurate strategy for generating a baseline against which to compare an enacted districting plan, such as the SB 2 plan. The computer simulation process leaves aside any data about partisanship or demographic characteristics other than population counts, and the computer algorithm generates complete and legally compliant districting plans based purely on the traditional districting criteria outlined in the Adopted Criteria.

After a simulated districting map has been created in complete ignorance of partisanship, I then overlay past results from recent elections, sum them over the simulated districts, and then calculate the number of seats that would be won by Democrats and Republicans under this districting plan, using two different sets of political data to measure partisan performance. Instead of generating only one such plan, the algorithm allows for the generation of thousands of such plans. Each plan combines North Carolina's census blocks together in a different way, but always in compliance with the non-partisan portion of the Adopted Criteria. The simulations thus produce a large distribution of valid non-partisan districting plans. For each simulated plan, I sum up recent past election results across the 13 districts and calculate the number of seats that would have been won by Democrats and Republicans.

I also perform the same calculations for the enacted SB 2 plan drawn by the General Assembly. One should expect that if the SB 2 plan had been drawn without partisanship as its predominant consideration, the enacted plan's partisan breakdown of seats will fall somewhere roughly within the normal range of the distribution of simulated, valid non-partisan plans. If the plan produced by the legislature is far in the tail of the distribution, or lies outside the distribution altogether—meaning that it favors one party more than the vast majority or all of the simulated plans—then such a finding provides strong indication that the enacted plan was drawn with an overriding partisan intent to favor that political party, rather than to follow non-partisan, traditional districting criteria.

By randomly drawing districting plans with a process designed to optimize on traditional districting criteria, the computer simulation process thus gives us a precise indication of the

range of districting plans that plausibly and likely emerge when map-drawers are not motivated primarily by partisan goals. By comparing the enacted plans against the range of simulated plans with respect to various partisan measurements, I am able to precisely determine the extent to which a map-drawer's deviations from traditional districting criteria, such as geographic compactness and county splits, was motivated by partisan goals.

In simulating plans for North Carolina's congressional districts, the computer algorithm follows five traditional districting criteria, all of which are mandated by the Adopted Criteria.

1) ***Population Equality:*** North Carolina's 2010 Census population was 9,535,483, so districts in the 13-member plan have an ideal population of 733,498.7. Specifically, then, the computer simulation algorithm is designed to populate each districting plan such that precisely nine districts have a population of 733,499, while the remaining four districts have a population of 733,498.

2) ***Contiguity***: The computer simulations require districts to be geographically contiguous. As described in the Adopted Criteria, water contiguity is permissible.

3) ***Minimizing County Splits:*** The simulation process attempts to avoid splitting any of North Carolina's 100 counties, except when doing so is necessary to avoid violating one of the aforementioned criteria. Furthermore, as mandated by the Adopted Criteria, the computer always avoids splitting a county into more than two simulated districts. In practice, the simulation process is able to always create valid districting plans by splitting only 12 counties, in contrast to the 13 counties split by the enacted SB 2 plan.

4) ***Minimizing VTD Splits***: North Carolina is divided into 2,692 VTDs. The computer simulation algorithm attempts to keep these VTDs intact and not split them into multiple districts, except when doing so is necessary for creating equally-populated districts. In practice, the simulated plans always split either 11 or 12 VTDs into two districts.

5) ***Geographic Compactness***: The simulation algorithm prioritizes the drawing of geographically compact districts whenever doing so does not violate any of the aforementioned criteria. After completing the computer simulations, I then compare the compactness of the simulated plans and the enacted plans using two different measures:

First, I calculate the average Reock score of the districts within each plan. The Reock score for each individual district is calculated as the ratio of the district's area to the area of the smallest bounding circle that can be drawn to completely contain the district. The General

Assembly's enacted districting plan has an average Reock score of 0.3373 across its 13 districts. As described later, the computer simulation process is able to always generate plans that are significantly more compact than the enacted SB 2 plan, as measured by average Reock score.

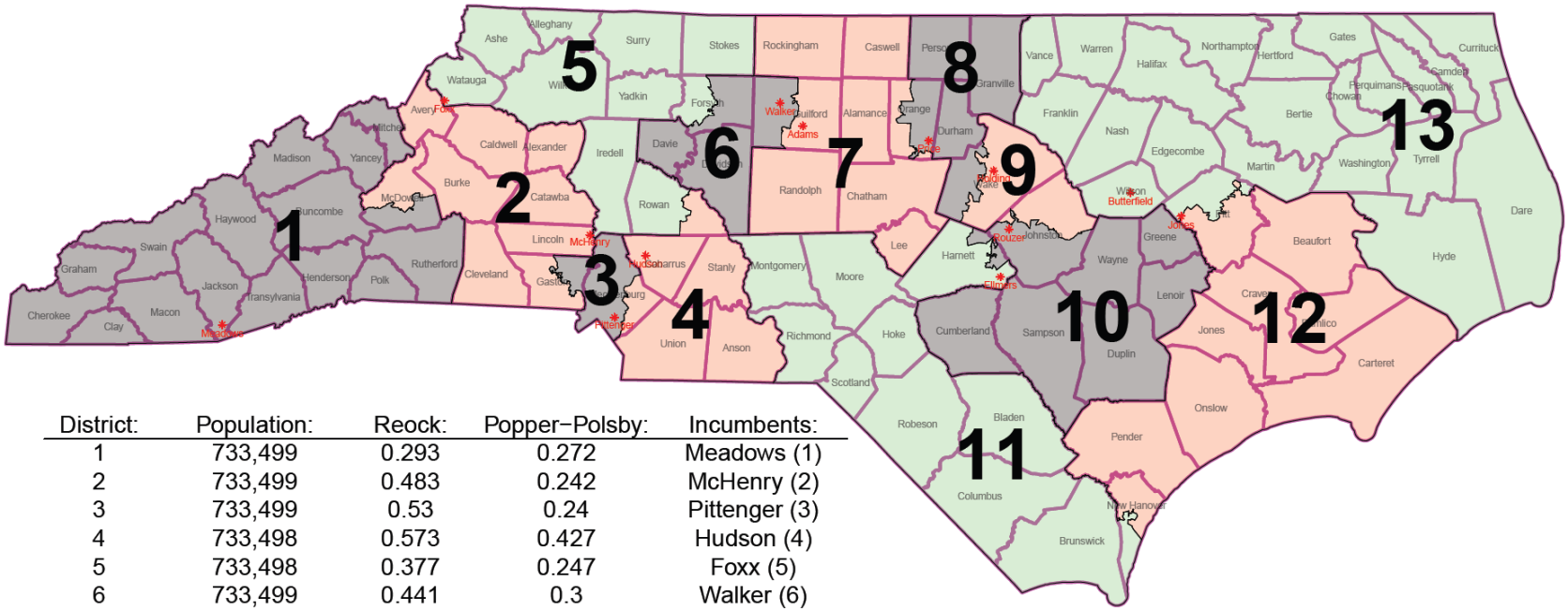
Second, I calculate the average Popper-Polsby score of each plan's districts. The Popper-Polsby score for each individual district is calculated as the ratio of the district's area to the area of a hypothetical circle whose circumference is identical to the length of the district's perimeter. The General Assembly's enacted districting plan has an average Popper-Polsby score of 0.2418 across its 13 districts. As described later, the computer simulation process is able to always generate plans that are significantly more compact than the enacted SB 2 plan, as measured by average Popper-Polsby score.

Beyond these five traditional districting criteria, the Adopted Criteria also call for the congressional plan to protect incumbents by requiring "reasonable efforts…to ensure that incumbent members of Congress are not paired with another incumbent in one of the new districts constructed." Although such incumbency protection may not be explicitly partisan, this criterion may nevertheless potentially cause indirect partisan electoral consequences. Thus, I address this criterion in two ways: One set of 1,000 simulations pays no attention to the protection of incumbents, while a second, separate set of 1,000 simulations deliberately protects incumbents by assigning each of North Carolina's 13 incumbents from the 114th Congress to a separate district with no pairing of incumbents. I then evaluate these two sets of simulations separately.

Figure 1 illustrates an example of one of the simulated districting plans produced by this computer algorithm. The simulated map in Figure 1 was produced within this second set of simulations, in which the computer sought to adhere as closely as possible to the non-partisan traditional criteria in the Adopted Criteria. Thus, it was able to split fewer counties, protect more incumbents, and draw significantly more geographically compact districts than the enacted SB 2 plan.

Figure 1:

Example of a Computer−Simulated Districting Plan
Drawn to Optimize Geographic Compactness and Protect All 13 Incumbents



District:	Population:	Reock:	Popper−Polsby:	Incumbents:
1	733,499	0.293	0.272	Meadows (1)
2	733,499	0.483	0.242	McHenry (2)
3	733,499	0.53	0.24	Pittenger (3)
4	733,498	0.573	0.427	Hudson (4)
5	733,498	0.377	0.247	Foxx (5)
6	733,499	0.441	0.3	Walker (6)
7	733,499	0.547	0.345	Adams (7)
8	733,498	0.467	0.259	Price (8)
9	733,499	0.43	0.243	Holding (9)
10	733,499	0.451	0.243	Rouzer (10)
11	733,499	0.273	0.2	Ellmers (11)
12	733,499	0.39	0.263	Jones (12)
13	733,498	0.357	0.41	Butterfield (13)
Plan Average:	733,498.7	0.432	0.284	

12 Split Counties:	12 Split VTD's:
Forsyth (Districts 5 and 6)	37111GLENWD
Gaston (Districts 2 and 3)	3707141
Guilford (Districts 6 and 7)	37119045
Harnett (Districts 10 and 11)	3715913
Johnston (Districts 10 and 9)	37067052
McDowell (Districts 1 and 2)	37081G26
Mecklenburg (Districts 3 and 4)	37135SJ
New Hanover (Districts 11 and 12)	3718308−05
Orange (Districts 7 and 8)	37101PR12
Pitt (Districts 12 and 13)	37085PR24
Rowan (Districts 4 and 5)	37129W18
Wake (Districts 8 and 9)	371470501

Measuring the Partisanship of Districting Plans

I use two different sets of political data to measure the partisan performance of the simulated and enacted districting plans in this report. Each of these two measures enables me to calculate the number of Republican and Democratic-leaning districts within each plan, thus allowing me to determine whether or not the partisan distribution of seats in the enacted plan could reasonably have arisen from a districting process respecting the various traditional criteria set forth in the Adopted Criteria.

The Hofeller Formula: Attorneys for the plaintiffs shared with me a document which describes in detail the formula for measuring voter partisanship employed by Tom Hofeller, whom plaintiffs' counsel described as being involved in the General Assembly's drawing of the SB 2 plan. The Hofeller formula describes the partisanship of any given constituency of North Carolina voters by aggregating together, with equal weights, the partisan results from seven recent elections: The 2008 Gubernatorial, US Senate, and Commissioner of Insurance elections; the 2010 US Senate election; the 2012 Gubernatorial and Commissioner of Labor elections; and the 2014 US Senate election.

Applying the Hofeller formula to the SB 2 districting plan reveals that the enacted plan contained 10 Republican-majority districts and 3 Democratic-leaning districts. Throughout this report, I also apply the Hofeller formula to all simulated districting plans, allowing for a direct comparison of the partisanship of the enacted and the simulated districting plans.

The Adopted Criteria Elections: The Joint Select Committee's Adopted Criteria state that when evaluating the political composition of congressional districts, the General Assembly shall consider "election results in statewide contests since January 1, 2008, not including the last two presidential contests." Since this set of elections is significantly broader than the election results considered in the Hofeller formula, I use this broader set of elections as a second measure for evaluating the partisanship of the enacted and simulated districts in this report.

Specifically, I evaluate districts by counting up the total number of Republican and Democratic votes cast in the 20 statewide, non-presidential elections held from November 2008 to November 2014, as described by the Adopted Criteria. Much like the Hofeller formula, I weight each election equally and count whether each district contains more Republican than Democratic voters, aggregated over all 20 elections. I find that, using the results of these 20 elections, total Republican voters outnumbered total Democratic voters in 10 of 13 districts in

the enacted plan. Throughout this report, I apply the same formula for evaluating all of the simulated plans, allowing for yet another direct comparison of the partisanship of the enacted and the simulated districting plans.

Simulation Set 1:
Optimizing on Traditional Districting Criteria with No Incumbent Protection

I conducted a first set of 1,000 computer simulations in which plans were drawn to optimize on the five non-partisan, traditional districting criteria described previously: population equality, contiguity, minimizing county splits, minimizing VTD splits, and geographic compactness. Table 1 details how the simulated plans perform with respect to these various districting criteria.

Figure 2 compares the partisan breakdown of the simulated plans to the partisanship of the enacted SB 2 plan. The left diagram in Figure 2 illustrates the number of Republican-leaning districts created by the 1,000 simulated plans, while the right diagram illustrates the same quantity using the 20 statewide elections described in the Adopted Criteria. Applying the Hofeller formula (left diagram in Figure 2), the simulated plans all create from 5 to 9 Republican districts out of 13 total districts. Moreover, the vast majority of simulations create 6, 7, or 8 Republican districts; even 9 Republican districts are created in only 1% of the simulations. Hence, the enacted SB 2 plan's creation of 10 Republican districts is an extreme statistical outlier, as it is an outcome never achieved by a single one of the 1,000 simulations. We are thus able to conclude with overwhelmingly high statistical certainty that the enacted plan created a pro-Republican partisan outcome that would never have been possible under a districting process adhering to the non-partisan traditional criteria mandated by the Adopted Criteria.

Analysis of the simulations and the enacted plan using the 20 statewide elections (right diagram in Figure 2) yields similarly strong conclusions. The enacted plan creates 10 districts in which Republican votes outnumbered Democratic votes across these 20 statewide elections. Yet the simulated plans all create only 3 to 8 Republican-leaning districts, with most simulations resulting in 5, 6, or 7 Republican districts. Hence, it is clear that not only is the enacted plan an extreme partisan outlier when compared to valid, computer-simulated districting plans, but the net effect of the enacted plan's partisan efforts was the creation of at least 2 or 3 additional

Republican seats beyond what would normally have been achievable under a non-partisan, legally complaint districting process.

Did the enacted SB 2 plan comply with the non-partisan districting criteria mandated by the Adopted Criteria? Once again, the computer simulations are illuminating because they offer insight into the type and range of plans that would have emerged had reasonable efforts been made to adhere to the Adopted Criteria. First, as detailed in Table 1, each of the 1,000 simulated plans in this first set splits 12 counties; hence, it is clear that drawing a valid plan with only 12 counties split can be easily accomplished without difficulty and without sacrificing other non-partisan districting criteria, such as equal population. By contrast, the enacted SB 2 plan split 13 counties, thus falling short of the 12-county benchmark that the computer simulations found to be very reasonably attainable in all 1,000 of the simulated plans. Hence, it is clear that the SB 2 plan failed to adhere to the Adopted Criteria's mandate of reasonably minimizing split counties.

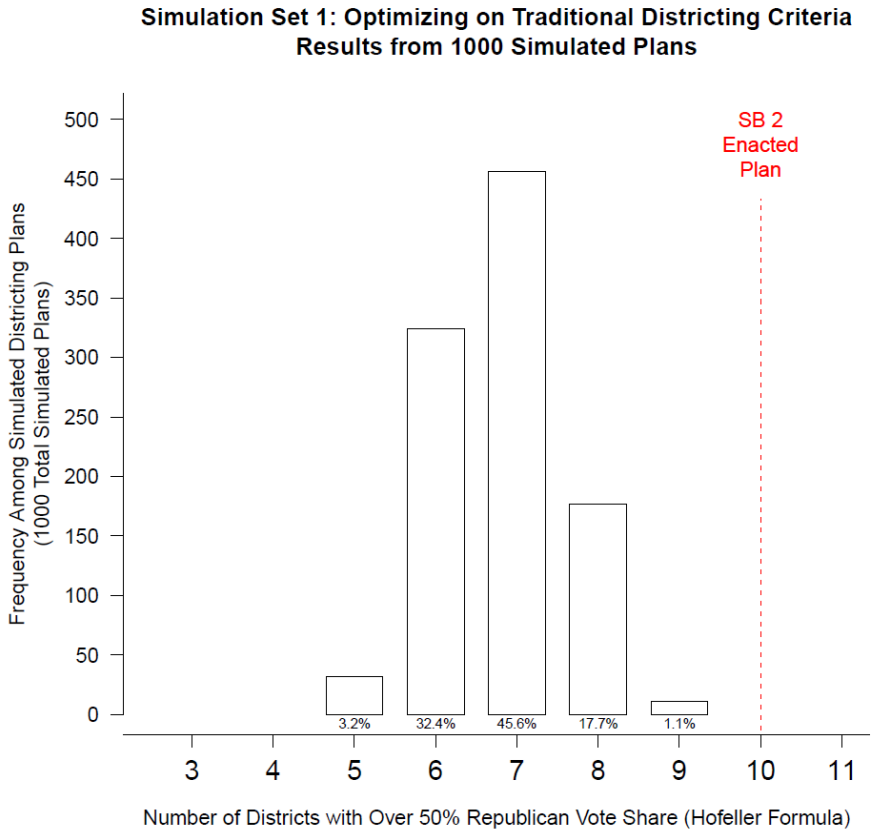
Did the enacted plan make reasonable efforts to draw compact districts? In Figure 3, the left diagram illustrates the compactness of the 1,000 simulated plans, compared against the compactness of the enacted SB 2 plan. In this diagram, the horizontal axis depicts the average Reock score of the districts within each plan, while the vertical axis depicts the average Popper-Polsby score. Each black circle in this diagram represents one of the 1,000 simulated plans, while the red star denotes the enacted SB 2 plan. Figure 3 illustrates that all of the simulated plans are more geographically compact than the SB 2 plan, as measured both by average Reock and average Popper-Polsby scores. Hence, it is clear that the SB 2 plan did not seek to draw districts that were as geographically compact as reasonably possible.

Why did the enacted SB 2 plan fall short of the Adopted Criteria's mandates on geographic compactness and minimizing county splits? As the right diagram in Figure 3 illustrates, the SB 2 plan was entirely outside the range of the simulated maps with respect to both geographic compactness and the partisan distribution of seats, in addition to splitting one additional county than was necessary. Collectively, these findings suggest that the SB 2 plan was drawn under a process in which a partisan goal – the creation of 10 Republican districts – predominated over adherence to traditional districting criteria, The predominance of this extreme partisan goal thus subordinated the two non-partisan, traditional districting considerations of minimizing county splits and achieving geographic compactness.

Table 1: Summary of Three Sets of Simulated Districting Plans and Enacted SB 2 Plan

	Senate Bill 2:	**Simulation Set 1:**	**Simulation Set 2:**	**Simulation Set 3:**
Description:	General Assembly's Enacted Plan	Simulated maps only follow traditional districting criteria	Maps protect all 13 incumbents and otherwise follow traditional districting criteria	Maps intentionally match SB 2 plan on 13 county splits and 11 protected incumbents
Total Number of Simulated Plans:		1,000 simulations	1,000 simulations	1,000 simulations
Number of Split Counties:	13	12 (1,000 simulations)	12 (1,000 simulations)	13 (1,000 simulations)
Number of Split VTDs:	12	12 (1,000 simulations)	12 (1,000 simulations)	12 (1,000 simulations)
Incumbents Protected:	11	2 to 11	13 (1,000 simulations)	11 (1,000 simulations)
Average Reock Score (Compactness):	0.3373	0.372 to 0.480	0.371 to 0.466	0.347 to 0.453
Average Popper-Polsby Score (Compactness):	0.2418	0.253 to 0.332	0.250 to 0.316	0.244 to 0.313
Number of Republican Districts (Hofeller Formula):	10	5 (32 simulations) 6 (324 simulations) 7 (456 simulations) 8 (177 simulations) 9 (11 simulations)	5 (9 simulations) 6 (194 simulations) 7 (529 simulations) 8 (258 simulations) 9 (10 simulations)	4 (1 simulation) 5 (33 simulations) 6 (267 simulations) 7 (530 simulations) 8 (160 simulations) 9 (9 simulations)

Figure 2:


Simulation Set 1: Optimizing on Traditional Districting Criteria
Results from 1000 Simulated Plans
Frequency Among Simulated Districting Plans
(1000 Total Simulated Plans)
SB 2
Enacted
Plan
3.2%
32.4%
45.6%
17.7%
1.1%
Number of Districts with Over 50% Republican Vote Share (Hofeller Formula)

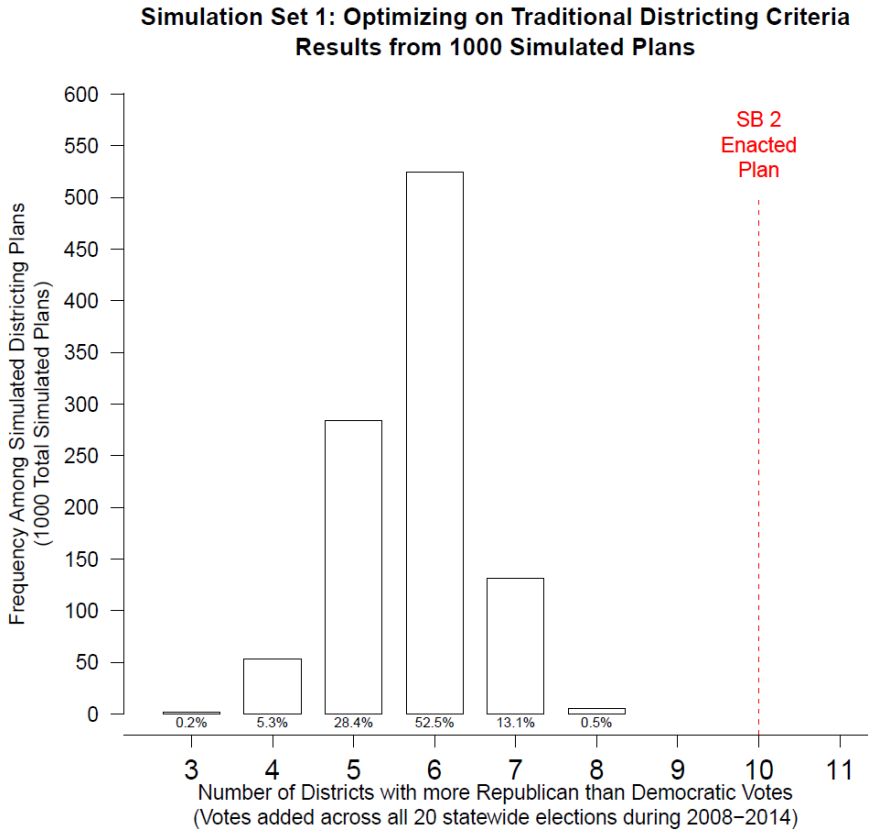
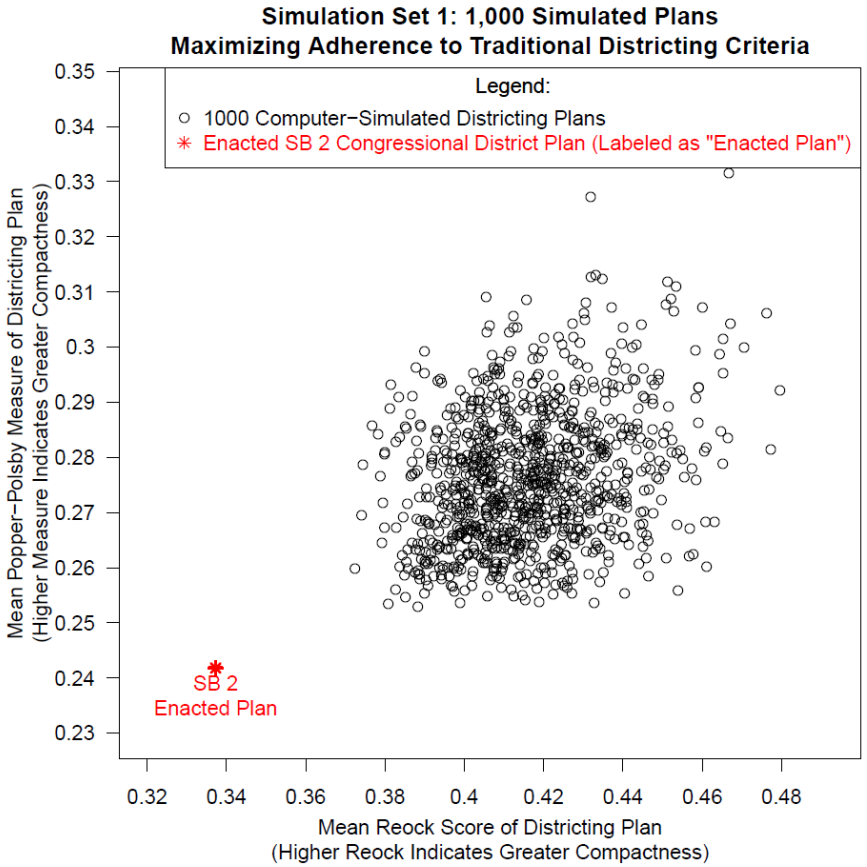
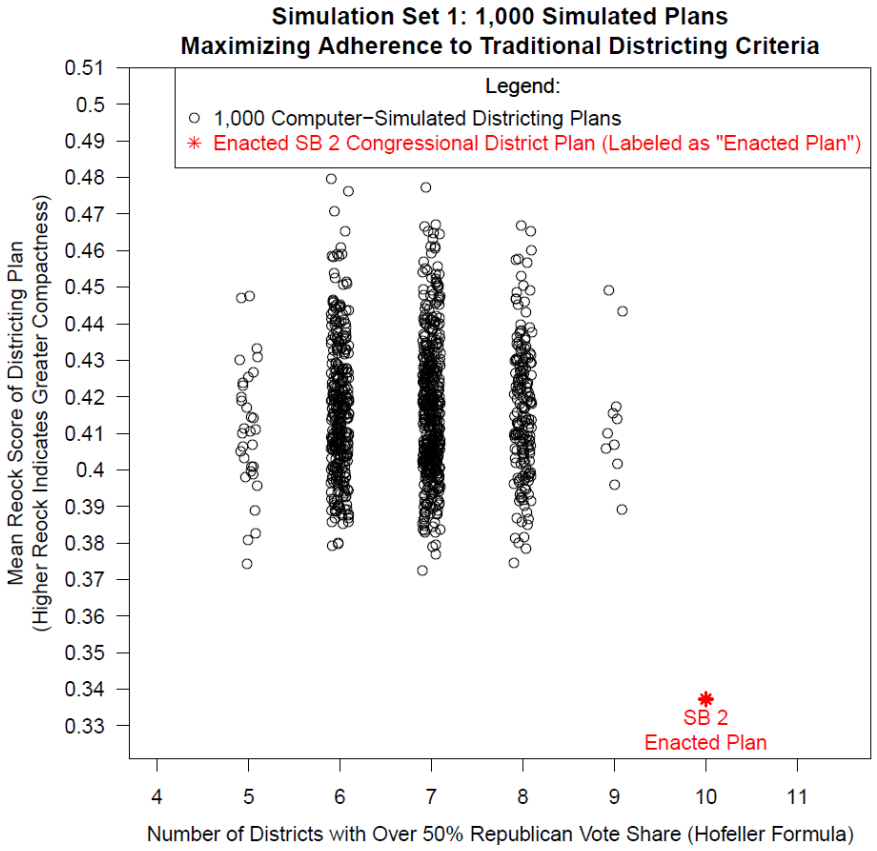

Simulation Set 1: Optimizing on Traditional Districting Criteria
Results from 1000 Simulated Plans
Frequency Among Simulated Districting Plans
(1000 Total Simulated Plans)
SB 2
Enacted
Plan
0.2%
5.3%
28.4%
52.5%
13.1%
0.5%
Number of Districts with more Republican than Democratic Votes
(Votes added across all 20 statewide elections during 2008−2014)

Figure 3:


Simulation Set 1: 1,000 Simulated Plans
Maximizing Adherence to Traditional Districting Criteria
Legend:
1000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Popper−Polsby Measure of Districting Plan
(Higher Measure Indicates Greater Compactness)
SB 2
Enacted Plan
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)


Simulation Set 1: 1,000 Simulated Plans
Maximizing Adherence to Traditional Districting Criteria
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
SB 2
Enacted Plan
Number of Districts with Over 50% Republican Vote Share (Hofeller Formula)

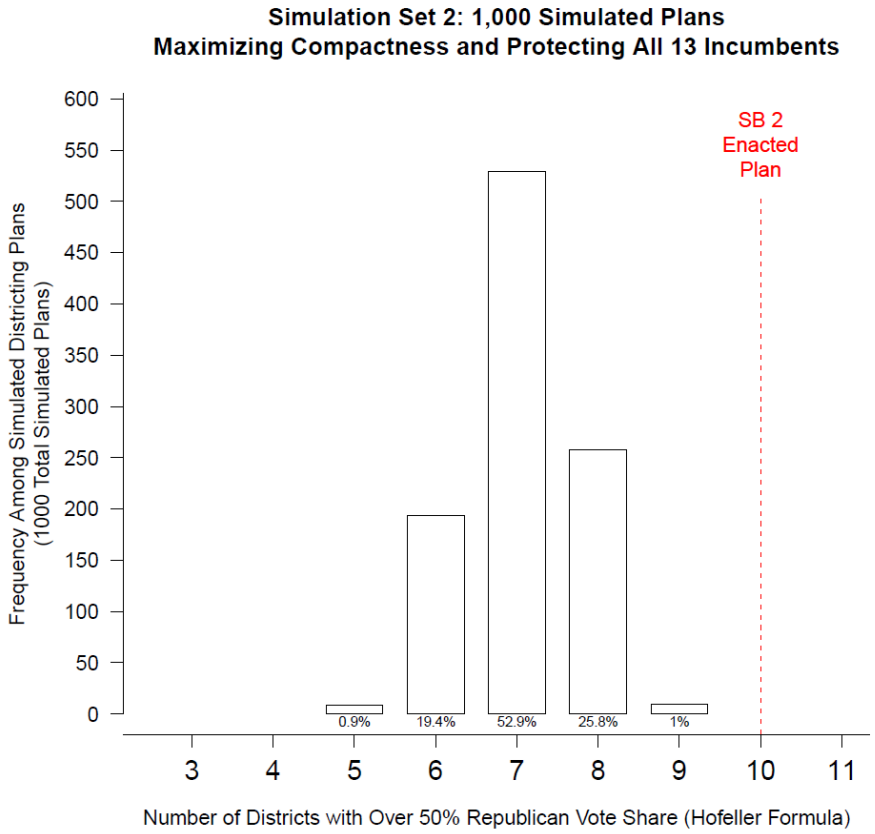
Simulation Set 2: Maximizing the Protection of Incumbents

The first set of 1,000 simulations ignored any considerations regarding the protection of incumbent House members or the pairing of incumbents within the same district. I initially ignored this portion of the Adopted Criteria because even though incumbency protection is not an overtly partisan goal, the protection of North Carolina's 13 incumbents as of November 2016 could have indirect partisan electoral consequences.

Ten of North Carolina's thirteen incumbents in November 2016 were Republicans. These incumbents were elected from the previously partisan-gerrymandered 2011 congressional districting map. Thus, making efforts to place each of the 13 incumbents into separate districts would, in general, encourage the drawing of a plan with districts that geographically overlap with and share borders similar to the districts from the previous 2011 plan. In this sense, attempts to protect incumbents in the new congressional plan could indirectly distort the partisan distribution of voters across districts. Hence, I conducted the first set of simulations with no efforts at incumbency protection in order to analyze the range of plans that could emerge from strict adherence to the apolitical portion of the Adopted Criteria.

Moreover, I analyzed the SB 2 plan and found that the enacted congressional districts do not protect all 13 of North Carolina's incumbents as of the November 2014 election. Eleven of the 13 incumbents are placed into separate districts, but the remaining two incumbents – David Price (Democrat) and George Holding (Republican) – are paired into a single district. This particular outcome of protecting only 11 of 13 incumbents was within the range observed among the first 1,000 of computer-simulated plans. Thus, I did not detect any extreme efforts by the General Assembly to protect incumbents at the expense of other traditional districting criteria.

Figure 4:


Simulation Set 2: 1,000 Simulated Plans
Maximizing Compactness and Protecting All 13 Incumbents
Frequency Among Simulated Districting Plans
(1000 Total Simulated Plans)
600
550
500
450
400
350
300
250
200
150
100
50
0
SB 2
Enacted
Plan
0.9%
19.4%
52.9%
25.8%
1%
3
4
5
6
7
8
9
10
11
Number of Districts with Over 50% Republican Vote Share (Hofeller Formula)

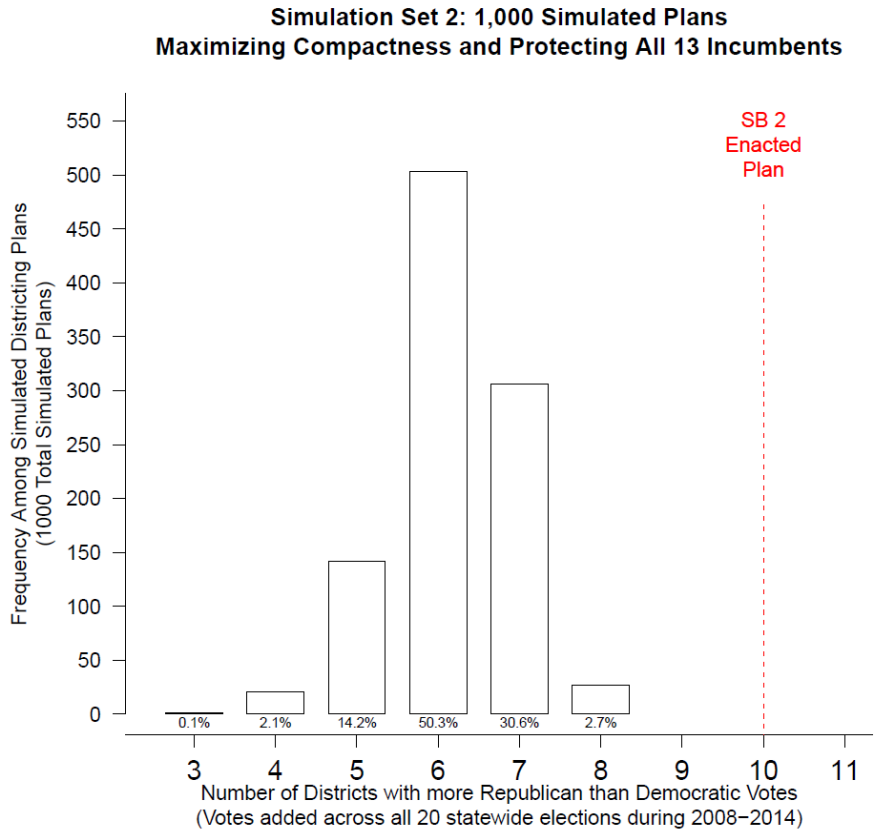
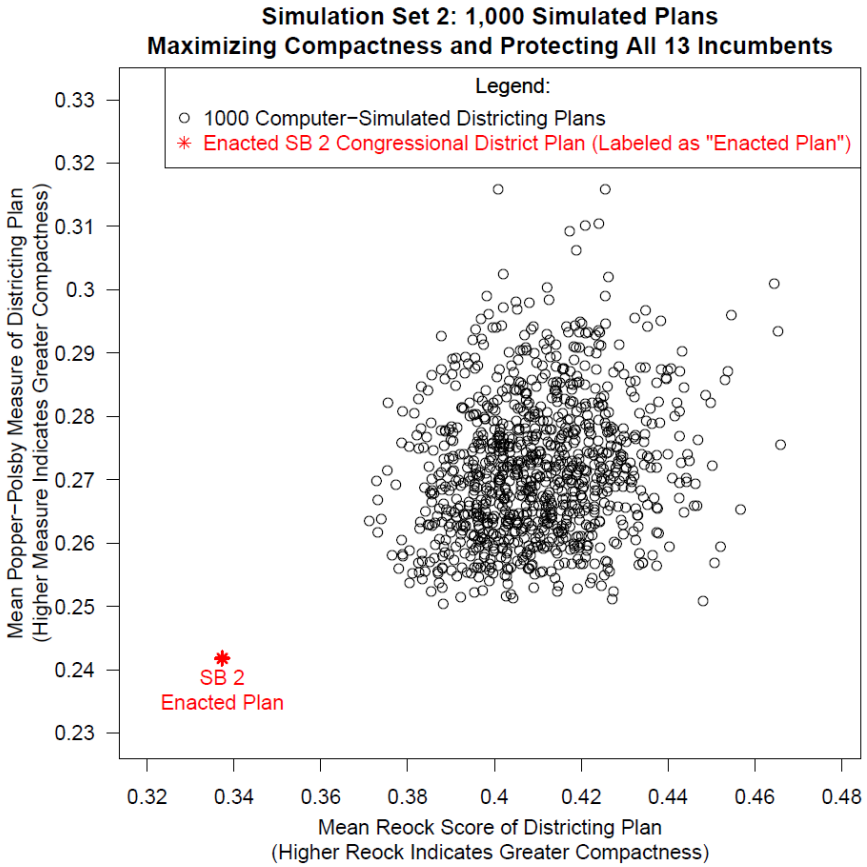
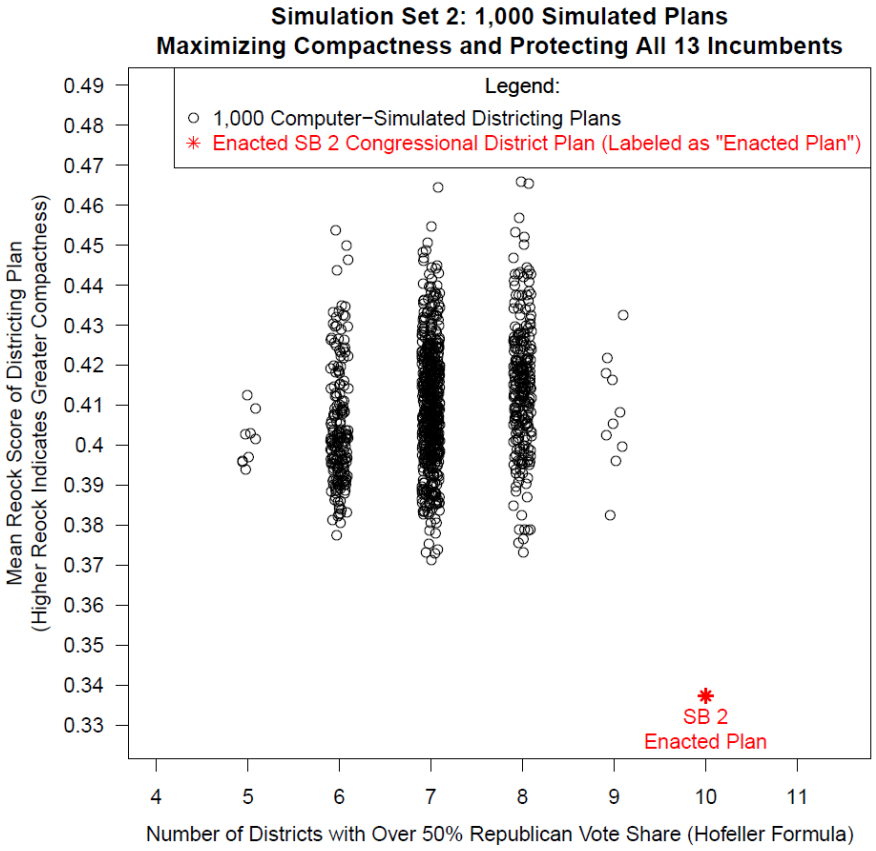

Simulation Set 2: 1,000 Simulated Plans
Maximizing Compactness and Protecting All 13 Incumbents
Frequency Among Simulated Districting Plans
(1000 Total Simulated Plans)
550
500
450
400
350
300
250
200
150
100
50
0
SB 2
Enacted
Plan
0.1%
2.1%
14.2%
50.3%
30.6%
2.7%
3
4
5
6
7
8
9
10
11
Number of Districts with more Republican than Democratic Votes
(Votes added across all 20 statewide elections during 2008−2014)

Figure 5:


Simulation Set 2: 1,000 Simulated Plans
Maximizing Compactness and Protecting All 13 Incumbents
Legend:
1000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Popper−Polsby Measure of Districting Plan
(Higher Measure Indicates Greater Compactness)
0.33
0.32
0.31
0.3
0.29
0.28
0.27
0.26
0.25
0.24
0.23
SB 2
Enacted Plan
0.32
0.34
0.36
0.38
0.4
0.42
0.44
0.46
0.48
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)


Simulation Set 2: 1,000 Simulated Plans
Maximizing Compactness and Protecting All 13 Incumbents
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
0.39
0.38
0.37
0.36
0.35
0.34
0.33
SB 2
Enacted Plan
4
5
6
7
8
9
10
11
Number of Districts with Over 50% Republican Vote Share (Hofeller Formula)

Nevertheless, it is worth exploring whether reasonable efforts *could* have been made to avoid pairing any of the 13 incumbent House members, and whether such efforts could somehow be a valid explanation for the extreme outcome of creating a 10-3 Republican advantage in North Carolina's congressional districts. To answer these questions, I conducted a second, separate set of 1,000 simulations in which the computer algorithm was programmed to intentionally guarantee that each of the 13 incumbents resided in a separate district, thus avoiding any pairing of incumbents. Beyond this intentional incumbent protection, the simulation procedure otherwise prioritized the same five non-partisan traditional districting criteria followed in the first set of simulations and ignored other political considerations.

Descriptions of this second set of 1,000 simulated congressional plans appear in the third column of Table 1. All 1,000 of these simulated plans were able to separate all 13 of the incumbents into 13 separate districts, thus avoiding pairing any incumbents. Moreover, this complete level of incumbency protection was achieved without any increase in the number of split counties or VTDs and with only slight decreases in the geographic compactness of the simulated districts. As illustrated in Figure 5, all 1,000 of the simulations in this second set are still significantly more compact than the enacted SB 2 plan on both the Reock and Popper-Polsby measures. Hence, these simulation results suggest that the Adopted Criteria mandate of not pairing multiple incumbents in districts can be achieved with very reasonable effort and without noticeably subordinating any of the non-partisan traditional districting criteria listed in the Adopted Criteria.

Does the protection of all 13 House incumbents make the creation of a 10-3 Republican advantage in the congressional districting plan a plausible outcome? Figure 4 illustrates the distribution of partisan seats across the 1,000 simulated plans, with partisanship measured using the Hofeller formula (left diagram of Figure 4) and using the 20 elections specified in the Adopted Criteria (right diagram). This Figure illustrates that the partisan distribution of seats under these simulations is nearly identical to the first set of simulations, which ignored incumbency protection. When all 13 incumbents are protected in separate districts, the simulation procedure almost always produces a plan with 6, 7, or 8 Republican districts, as measured by the Hofeller formula. The enacted plan's creation of 10 Republican districts is an outcome never achieved in a single one of the 1,000 simulations. Hence, we are able to conclude with overwhelmingly high statistical certainty that even the strictest adherence to the Adopted

Criteria's mandate of protecting incumbents, combined with adherence to the other non-partisan portions of the Adopted Criteria, would not explain the creation of a congressional map with a 10-3 Republican advantage.

Simulation Set 3:
Matching the Enacted Plan's County Splits and Protected Incumbents

The first two sets of simulations thus far have intentionally produced districting maps optimized for adherence to various requirements specified in the Adopted Criteria. However, the General Assembly's enacted SB 2 plan failed to adhere quite as strictly to these various criteria, splitting 13 counties instead of 12 achieved in the simulations and protecting only 11 incumbents rather than 13.

Hence, one might wonder whether the General Assembly's choice to draw a less-than-optimal plan with respect to these two criteria might somehow account for the creation of a 10-3 Republican advantage in the partisan control of districts. To address this possibility, I conduct a third set of 1,000 simulations in which the computer algorithm is instructed to specifically match, but not exceed, the enacted plan's achievement of 13 county splits and 11 protected incumbents. Beyond these two criteria, the simulation algorithm otherwise seeks to achieve optimal compliance with respect to all of the other traditional districting criteria described earlier, including minimizing VTD splits and maximizing geographic compactness.

If the General Assembly's choice to split exactly 13 counties and protect exactly 11 incumbents were the cause of the enacted plan's pro-Republican partisan advantage, then we would expect that a partisan-neutral districting algorithm requiring 13 split counties and 11 protected incumbents would also sometimes create a similar level of Republican partisan advantage. If such a districting algorithm does not frequently create plans similar level of Republican partisan advantage, then we may reject the notion that the General Assembly's specific goals with respect to county splits and protected incumbents was responsible for the extreme pro-Republican partisanship of the enacted plan. As noted previously, the enacted plan achieves suboptimal level of incumbency protection and county preservation, as the first two set of simulations in this report demonstrate that splitting as few as 12 counties and protecting all 13 incumbents is quite easily achievable while still drawing a more compact plan than the SB 2 plan. Hence, the purpose of this set of simulations is to determine whether we can accept or

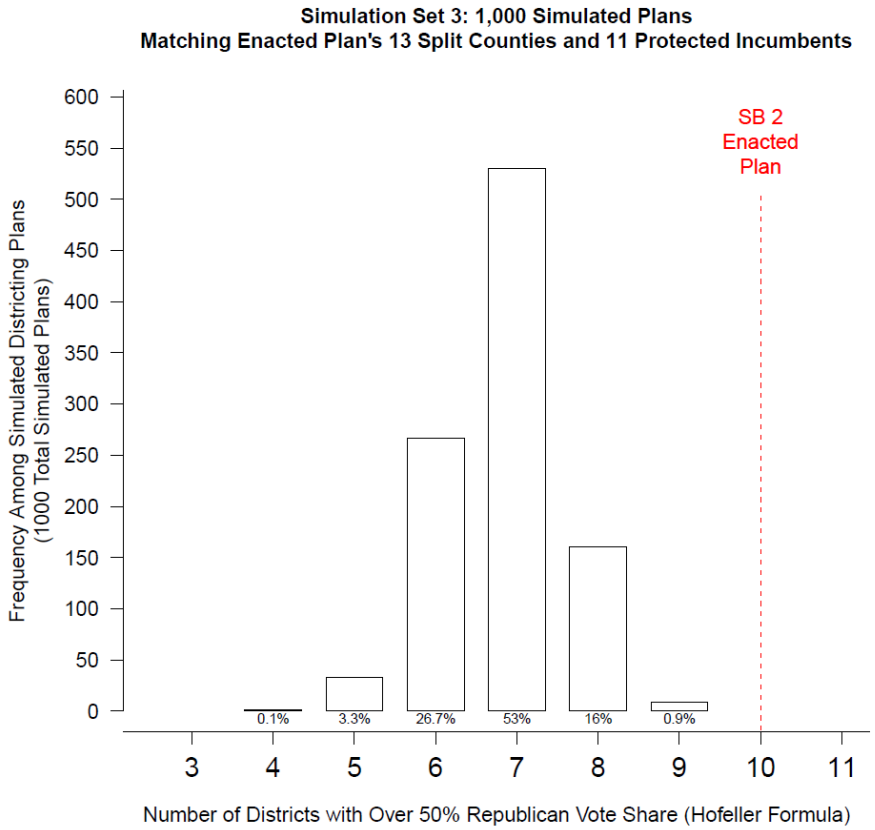
reject the possibility that the unusual partisan performance of the enacted plan can somehow be attributed to the plan's failure to fully minimize county splits and maximize incumbency protection.

The fourth column of Table 1 presents descriptions of this third set of 1,000 simulated congressional plans. All 1,000 of these simulated plans were able to split exactly 13 counties and protect exactly 11 incumbents, thus matching the enacted SB 2 plan on these criteria. Figure 7 illustrates the geographic compactness of this third set of simulated plans, showing that the intentional splitting of a 13th county comes at only a minimal cost to overall plan compactness.

Does the unique combination of splitting 13 counties and protecting 11 incumbents explain the creation of a plan with 10 Republican districts? The simulation results displayed in Figure 6 clearly reject this notion. This set of simulated districting plans contain anywhere from 4 to 9 Republican districts, and the simulated plans most commonly contain 6, 7, or 8 Republican districts, as measured by the Hofeller formula. Hence, it is clear that merely an effort to create a map with 13 county splits and 11 protected incumbents alone would not naturally result in a plan with a 10-3 Republican partisan advantage. Instead, the simulation results demonstrate that a 10-3 Republican advantage could have resulted only from a deliberate attempt to draw a map with partisan advantage as the predominant goal.

Furthermore, as the Reock compactness measurements in Figure 7 illustrate, such a deliberate attempt would have also required the subordination of district compactness, in addition to splitting more counties and protecting fewer incumbents than was reasonably possible. The diagrams in Figure 7 illustrate that all 1,000 of the simulations in this set, which matched the enacted plan's splitting of 13 counties and protection of 11 incumbents, were significantly more geographically compact than the enacted plan. Together, these findings demonstrate that none of the enacted plan's unique characteristics with respect to non-partisan districting criteria could have justified the plan's creation of a 10-3 Republican advantage. Instead, such an extreme level of pro-Republican advantage in congressional seats could not have emerged from following these districting criteria, if not for the General Assembly's explicit pursuit of Republican partisan advantage.

Figure 6:


Simulation Set 3: 1,000 Simulated Plans
Matching Enacted Plan's 13 Split Counties and 11 Protected Incumbents
Frequency Among Simulated Districting Plans
(1000 Total Simulated Plans)
600
550
500
450
400
350
300
250
200
150
100
50
0
SB 2
Enacted
Plan
0.1%
3.3%
26.7%
53%
16%
0.9%
3
4
5
6
7
8
9
10
11
Number of Districts with Over 50% Republican Vote Share (Hofeller Formula)

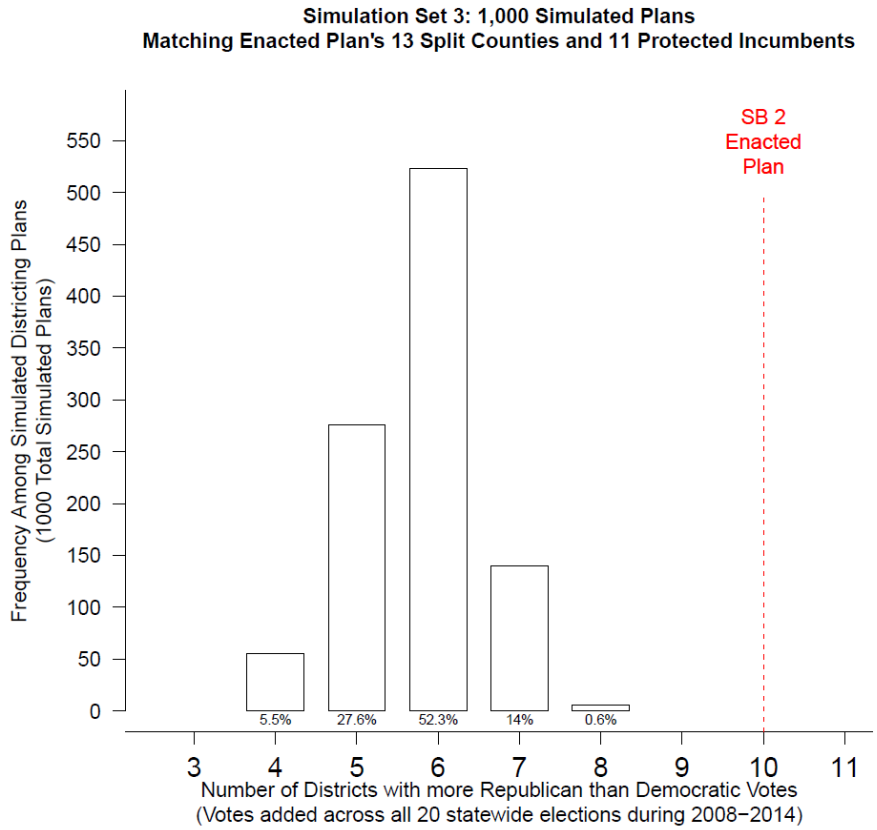
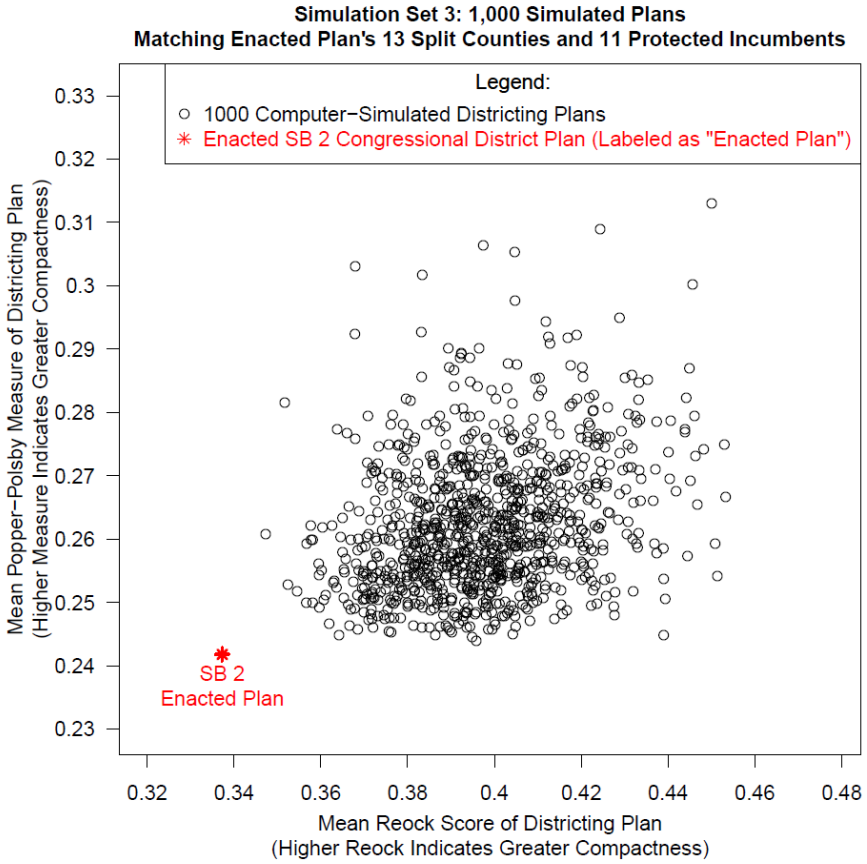

Simulation Set 3: 1,000 Simulated Plans
Matching Enacted Plan's 13 Split Counties and 11 Protected Incumbents
Frequency Among Simulated Districting Plans
(1000 Total Simulated Plans)
550
500
450
400
350
300
250
200
150
100
50
0
SB 2
Enacted
Plan
5.5%
27.6%
52.3%
14%
0.6%
3
4
5
6
7
8
9
10
11
Number of Districts with more Republican than Democratic Votes
(Votes added across all 20 statewide elections during 2008−2014)

Figure 7:


Simulation Set 3: 1,000 Simulated Plans
Matching Enacted Plan's 13 Split Counties and 11 Protected Incumbents
Legend:
1000 Computer−Simulated Districting Plans
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(Higher Measure Indicates Greater Compactness)
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0.28
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0.26
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0.24
0.23
SB 2
Enacted Plan
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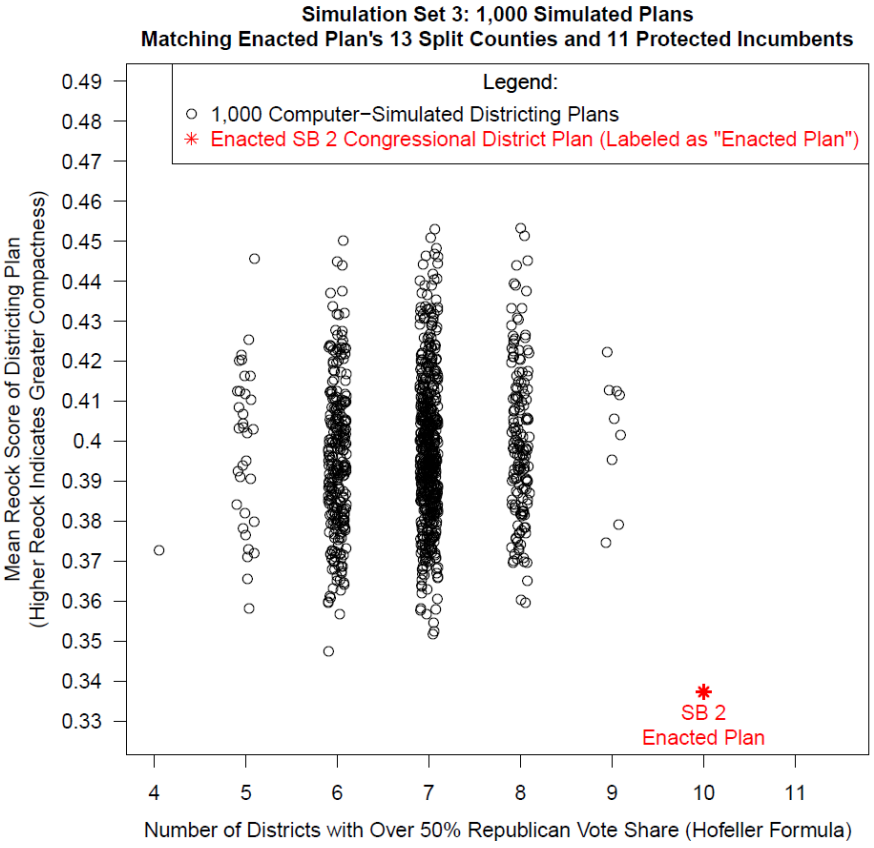
0.34
0.36
0.38
0.4
0.42
0.44
0.46
0.48
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)


Simulation Set 3: 1,000 Simulated Plans
Matching Enacted Plan's 13 Split Counties and 11 Protected Incumbents
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
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0.42
0.41
0.4
0.39
0.38
0.37
0.36
0.35
0.34
0.33
SB 2
Enacted Plan
4
5
6
7
8
9
10
11
Number of Districts with Over 50% Republican Vote Share (Hofeller Formula)

Robustness Checks Using Alternative Measures of Partisanship

The previous section of this report has laid out the main simulation analysis and comprehensive, statistically valid measures of the partisanship of the simulated and enacted districting plans. In particular, the Hofeller formula and the 20 elections from 2008-2014 identified in the Adopted Criteria are broad, durable, and sufficient measurements of districting plan partisanship, particularly given that these measurements represent the General Assembly's actual and stated efforts to measure the partisanship of constituencies in North Carolina.

What follows in the remainder of the report, then, is a completely separate set of analyses in which I examine the simulated plans and the enacted SB 2 plan using alternative measures of partisanship and electoral bias that other scholars of redistricting have proposed. These alternative measures are presented as robustness checks, and the conclusions reached in the previous sections do not depend on these robustness checks. Nevertheless, I introduce these alternative measures of districting plan partisanship in order to illustrate the findings of my simulation analysis in more relatable ways and to demonstrate the robustness of these findings.

Specifically, in this section, I re-analyze the simulated plans and the enacted SB 2 plan using two types of alternative measures of partisan electoral bias. These two measures – efficiency gap analysis and analysis of predicted election results using regression modeling – have been increasingly used by political scientists and other academics in studying redistricting, and they provide a robustness check for the partisan calculations presented thus far in this report.

Efficiency Gap of the Enacted and Simulated Plans:

To calculate the efficiency gap of the enacted SB 2 plan and of each simulated plan, I first determine the partisan leaning of each simulated district and each SB 2 district, as measured by the Hofeller formula. Using the Hofeller formula as a simple measure of district partisanship, I then calculate each districting plan's efficiency gap using the method outlined in *Partisan Gerrymandering and the Efficiency Gap*[1]. Districts are classified as Democratic victories if, across the seven elections included in the Hofeller formula, the sum total of Democratic votes in the district during these elections exceeds the sum total of Republican votes; otherwise, the district is classified as Republican. For each party, I then calculate the total sum of surplus votes

[1] Nicholas O. Stephanopoulos & Eric M. McGhee, *Partisan Gerrymandering and the Efficiency Gap,* 82 University of Chicago Law Review 831 (2015).

in districts the party won and lost votes in districts where the party lost. Specifically, in a district lost by a given party, all of the party's votes are considered lost votes; in a district won by a party, only the party's votes exceeding the 50% threshold necessary for victory are considered surplus votes. A party's total wasted votes for an entire districting plan is the sum of its surplus votes in districts won by the party and its lost votes in districts lost by the party. The efficiency gap is then calculated as total wasted Republican votes minus total wasted Democratic votes, divided by the total number of two-party votes cast statewide across all seven elections.

Thus, the theoretical importance of the efficiency gap is that it tells us the degree to which more Democratic or Republican votes are wasted across an entire districting plan. An extremely positive efficiency gap indicates far more Republican wasted votes, while an extremely negative efficiency gap indicates far more Democratic wasted votes.

In addition to calculating the efficiency gap using each district's votes from the Hofeller formula, as described above, I also separately calculate the efficiency gap using the combined results from the 20 statewide 2008-2014 elections, as identified by the Adopted Criteria. As before, I sum up the total Democratic votes and total Republican votes from across the 20 elections and calculate a single efficiency gap for each simulated and enacted districting plan using these combined partisan vote counts.

Figure 10 illustrates the efficiency gap, using both sets of election results, of the 1,000 districting plans from Simulation Set 2. This is the set of plans produced under a districting algorithm that guarantees incumbents are never paired with one another within the same district while otherwise maximizing compliance with the five traditional districting criteria in the Adopted Criteria. Each black circle in Figure 10 represents a simulated districting plan, with its efficiency gap measured along the horizontal axis. The red star in each diagram represents the enacted SB 2 plan. The vertical axis measures the compactness of each districting plan, as measured by the plan's average Reock score.

The left diagram in Figure 10 shows the efficiency gap calculations using the Hofeller formula, while the right diagram in Figure 10 shows the efficiency gap calculations using the 20 statewide elections from 2008-2014. Using either formula, the two diagrams in Figure 10 both illustrate three important findings.

First, both diagrams reveal that the simulated districting plans are reasonably neutral with respect to electoral bias. Specifically, 53% of the simulated plans (529 of the 1,000 simulations)

exhibit an efficiency gap within 2% of zero, indicating de minimis electoral bias in favor of either party. In fact, 31% of the simulations produce an efficiency gap between -1.0% and +1.0%. These simulated plans with nearly zero efficiency gap are all plans that contain exactly seven Republican and six Democratic-leaning districts. These patterns illustrate that a non-partisan districting process strictly following the traditional districting criteria mandated by the Adopted Criteria very commonly produces a neutral congressional plan in North Carolina with minimal electoral bias as measured by efficiency gap.

Second, it is also important to note that the simulations produce plans with both slightly positive and negative efficiency gaps. But the broader, more striking finding in this analysis is that over one-half of the simulated plans produced by the partisan-neutral simulation algorithm strictly following traditional districting criteria are within 2% of a zero efficiency gap. Hence, it is clearly not difficult to create an electorally unbiased map when one strictly follows the non-partisan criteria from the Adopted Criteria. To produce a map with significant electoral bias deviating by over 10% from a zero efficiency gap, however, would require more extraordinary and deliberate map-drawing efforts beyond following the non-partisan guidelines set forth in the Adopted Criteria.

Third, the enacted SB 2 plan, denoted in each Figure 10 diagram as a red star, produces an efficiency gap that is extremely inconsistent with and outside of the entire range of the 1,000 computer-simulated plans. The enacted plan creates an efficiency gap of -24.2% using the Hofeller Formula and -30.4% using the 20 statewide elections from 2008-2014, indicating that the plan results in significantly more wasted Democratic votes than wasted Republican votes. As Figures 9 and 11 show, results are similar when we analyze the efficiency gap of plans in Simulation Sets 1 and 3 as well. Thus, the level of electoral bias in the SB 2 enacted plan is not only entirely outside of the range produced by the simulated plans, the enacted plan's efficiency gap is far more biased than even most biased of the 1,000 simulated plans. The improbable nature of the enacted plan's efficiency gap allows us to conclude with overwhelmingly high statistical certainty that neutral, non-partisan districting criteria, combined with North Carolina's natural political geography, could not have produced a districting plan as electorally skewed as the enacted SB 2 plan.

Predicted Election Results Using Regression Modeling:

An additional method commonly used by political scientists for analyzing the partisan performance of districting plans involves using regression modeling to estimate the partisan election results for any given congressional district. The underlying statistical intuition behind this approach is that analyzing a districting plan using the results from any legislative election contest inherently introduces some degree of error. The results from any given legislative election may deviate from the long-term partisan voting trends of the district's voters due to such factors as incumbency advantage, the presence or absence of a quality challenger, anomalous difference between the candidates in campaign efforts or campaign finances, candidate scandals, and coattail effects. These factors can even differ across different districts within the state of North Carolina, thus making it statistically unreliable to combine and directly compare election results from different congressional districts when evaluating a new districting plan.

Thus, a more robust approach is to statistically model the congressional elections voting patterns of any given constituency – such as a VTD, county, or congressional district – using the results from a statewide, federal election contest, such as a US presidential election. I then apply this statistical model to predict the likely level of future partisan voting in congressional elections for an enacted congressional district or a computer-simulated congressional district. Applying this model to an enacted district, for example, can give us a statistical prediction of the likely level of electoral support for a future Democratic congressional candidate. This prediction also allows me to account for the presence of either a Democratic or Republican incumbent in the district. I am thus able to compare the predicted partisan breakdown of districts within the simulated districting plans and the enacted SB 2 districting plan, and these predictions are able to account for the presence of the various 13 congressional incumbents (as of November 2016) across North Carolina.

The first statistical model I use is a VTD-level regression analysis that predicts Republican candidates' vote share in the November 2012 congressional elections. The regression model predicts Republican vote share using Mitt Romney's (Republican) vote share in each VTD in November 2012. As Figure 12 demonstrates, at the VTD-level in North Carolina, presidential election votes for Obama and Romney were extremely highly correlated with partisan votes in the November 2012 congressional elections. Thus, presidential voting is a quite accurate and useful predictor for this regression model. Additionally, the model includes control

variables accounting for the presence of a Democratic incumbent or a Republican incumbent House member in the district and the voter turnout in the 2012 presidential election, expressed as the number of presidential votes cast, divided by the voting age population (VAP) of the VTD.

The second statistical model I estimate is a VTD-level regression predicting the voter turnout rate in the 2012 congressional elections, expressed as the number of congressional votes cast divided by VAP. This model predicts congressional election turnout using 2012 presidential election turnout as a predictor, in addition to all of the predictors from the first model. Hence, there are two separate models with the following full regression model specifications:

$$\textit{Republican Congressional Vote Share}_i = \alpha + \beta_1 * \text{Republican Presidential Vote Share}_i + \beta_3 * \text{Republican Incumbent}_i + \beta_4 * \text{Democratic Incumbent}_i + \beta_5 * \text{VAP}_i + \beta_6 * \text{Presidential Election Turnout} + \varepsilon_i$$

$$\textit{Congressional Election Turnout Rate}_i = \alpha + \beta_1 * \text{Republican Presidential Vote Share}_i + \beta_3 * \text{Republican Incumbent}_i + \beta_4 * \text{Democratic Incumbent}_i + \beta_5 * \text{VAP}_i + \beta_6 * \text{Presidential Election Turnout} + \varepsilon_i$$

These two models explain the partisan results in the 2012 congressional elections in each VTD of North Carolina as a function of three factors: The underlying partisanship of the VTD, as measured by presidential voting, the presence of Democratic or Republican incumbents in the district in which the VTD is located, and the presidential election turnout in the VTD. Table 2 presents both full estimated regression models.

The two models have an R-squared of 0.985 and 0.992, indicating that the models are able to predict the results of the November 2012 congressional elections with very high statistical accuracy. In particular, the estimated model coefficients reveal that partisan support for congressional candidates in 2012 was largely explained by voters' underlying partisanship, as measured by their presidential voting behavior: In general, Obama voters also supported Democratic congressional candidates, while Romney voters supported Republican congressional candidates. Additionally, the presence of incumbents has a small effect on election results as well: The presence of a Republican incumbent in a VTD's district increases electoral support for the Republican congressional candidate by about 3.1%, while the presence of a Democratic incumbent boosts the Democratic congressional candidate's vote totals by approximately 3.2%. The presence of an incumbent of either party also boosts the overall voter turnout rate.

Next, I apply these two regression models to each of the simulated plans and the enacted plan in order to calculate the predicted partisanship of each district within each plan and the overall efficiency gap of each plan. As before, the motivation of this analysis is to determine whether the enacted plan's partisanship could possibly have arisen from a non-partisan map-drawing process respecting traditional districting criteria. I conduct this analysis using two different approaches:

Predicted Congressional Election Results with Incumbency Advantage: First, I used the regression model to evaluate the partisanship of the simulated and enacted plans, accounting for all 13 House incumbents in North Carolina as of the November 2016 congressional elections. Specifically, I geocoded the residential locations of North Carolina's 13 incumbent House members from the 114th Congress. I then overlaid the incumbents' locations onto the enacted map and each of the 1,000 simulated maps, thus identifying which district each incumbent resides in within each of these plans. I use this information to apply the appropriate incumbency advantage adjustment, as estimated in the two regression models in Table 2, for each districting plan. This incumbency advantage adjustment, as estimated in the regression models, effectively boosts Republican vote share by 3.1% when the district contains a Republican incumbent. Meanwhile, Democratic vote share increases by 3.2% when the district contains a Democratic incumbent.

To predict the partisanship of each district using the two regression models, I generate predicted Republican and Democratic congressional vote share estimates for each district. For example, District 1 of the enacted plan supported Mitt Romney at a 31.47% rate, and 62.76% of the voting age population cast presidential ballots in November 2012. Additionally, District 1 contains a Democratic incumbent (G.K. Butterfield). Applying the two regression models to this information regarding District 1 generates the following predictions: Assuming an election race with a Democratic incumbent and no Republican incumbent, District 1 would support the Republican congressional candidate at a 27.90% rate, while 61.90% of the voting age population would cast congressional election ballots. Thus, the two models collectively predict District 1 to be a clearly Democratic-leaning district, and the models make a prediction not only about the level of partisan support for Republican and Democratic candidate, but also the total number of congressional election votes cast in each district.

I use this approach to generate predictions regarding the partisanship of all districts in the enacted plan and in the 1,000 plans in Simulation Set 2. This is the set of simulated plans produced under a districting algorithm that guarantees incumbents are never paired with one another within the same district while otherwise maximizing compliance with the five traditional districting criteria in the Adopted Criteria.

The predicted partisanship of these 1,000 simulated plans appears in the left diagram of Figure 13. The calculations in Figure 13 show that the vast majority of the 1,000 simulated plans contain 6, 7, or 8 districts that are predicted to favor Republican congressional candidates. Only 1.3% of plans ever create 9 predicted Republican districts, and no simulated plan ever contains more than 9 such districts.

By contrast, I find that the enacted SB 2 plan contains three districts predicted to favor Democratic candidates: Districts 1, 4, and 12. The remaining 10 districts are predicted to favor Republican candidates. This prediction of a 10-3 split in the partisan control of the enacted plan's seats confirms my earlier calculations regarding the enacted plan's partisanship using the Hofeller formula and using the 20 elections specified by the Adopted Criteria.

Finally, I calculate the efficiency gap of the enacted plan and the simulated plans using the predicted congressional election votes. The regression models I estimated predict not only the Republican vote share for congressional elections, but also the voter turnout level. Hence, the model effectively makes a prediction about the total number of Republican and Democratic votes cast in a congressional election in any given district. I thus use these total partisan vote predictions to calculate each plan's efficiency gap.

These efficiency gap calculations appear in the right diagram of Figure 13. In this diagram, the horizontal axis reports the efficiency gap of the plan, with lower efficiency gaps indicating more wasted Democratic votes than wasted Republican votes. The vertical axis measures the average Reock score for each plan. These calculations broadly confirm the earlier findings regarding the efficiency gap of the SB 2 plan. A districting process following the non-partisan criteria listed in the Adopted Criteria would have very easily achieved drawing a plan with zero efficiency gap, as measured by predicted congressional votes. In fact, 603 of the 1,000 simulated plans had an efficiency gap within 2% of zero. However, the enacted SB 2 plan's efficiency gap of -24.4%, as indicated in Figure 13 by a red star, is once again well outside of the entire range of efficiency gaps produced by the 1,000 simulations.

Together, these findings again confirm the main conclusion of this report described earlier: The enacted plan's creation of 10 Republican-leaning districts is an outcome that could not have emerged from a non-partisan map-drawing process adhering to the traditional districting criteria in the Adopted Criteria. Instead, the enacted plan could have been created only through a process in which the explicit pursuit of partisan advantage was the predominant factor, thus subordinating the traditional districting criteria from the Adopted Criteria.

Predicted Congressional Election Results with No Incumbents: Next, I apply the regression model to the simulated and enacted plans by asking a slightly different question: What would be the likely partisanship of each of the simulated and enacted districts if all districts were open seats with no incumbents? In other words, this analysis specifically focuses on predicting whether a Democratic or Republican would win each district in a hypothetical congressional election in which North Carolina has no incumbents, and all seats are therefore open races.

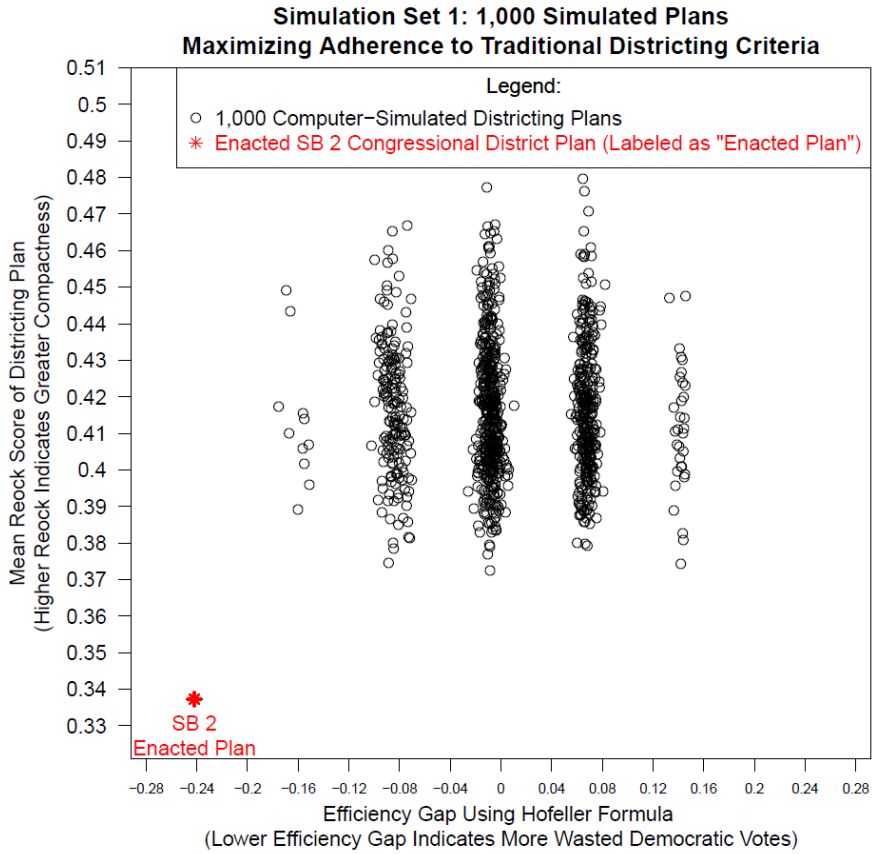
To predict the partisan voting patterns of each district in an open-seat election, I use the same regression model and predictive approach as before, but with one change: I assume that each of the 13 districts in each plan contains no incumbents. Thus, I intentionally compute no predicted incumbency advantage for either party when applying the regression models to data regarding each districting plan. Once again, I use this approach to analyze the 1,000 plans in Simulation Set 2, the set of simulated plans seeking to guarantee incumbents are never paired with one another within a district while otherwise maximizing compliance with the five traditional districting criteria in the Adopted Criteria.

The predicted partisanship of these 1,000 simulated plans appears in the left diagram of Figure 14. The calculations in Figure 14 show that over 90% of the 1,000 simulated plans contain 5 to 7 districts predicted to favor Republican congressional candidates. Fewer than 5% of the simulations produce 8 Republican districts, and only one simulation reaches 9 Republican districts. Once again, not a single plan contains ten or more Republican districts. As well, I evaluate the enacted SB 2 plan using the same hypothetical situation of 13 open seats with no incumbents. I found, once again, that 10 of the enacted districts out of 13 are predicted to favor Republicans, while only Districts 1, 4, and 12 favor Democratic candidates. Hence, under the assumption of elections with no incumbents, the enacted plan continues to exhibit a 10-3 split in

the partisan control of its districts, placing it completely outside the entire range of outcomes observed in the 1,000 simulations.

The right diagram in Figure 14 presents calculations of the efficiency gap of the 1,000 simulated plans and the enacted plan using predicted congressional votes under the assumption of no incumbents. Under this measure of partisanship, the enacted plan has an efficiency gap of -26.2%, which is very significantly outside of the entire range of the efficiency gaps for the simulated plans. Together, these findings provide further confirmation of this report's main conclusions. The enacted plan's creation of 10 Republican-leaning districts is not an outcome that could have plausibly emerged from a non-partisan map-drawing process respecting traditional districting criteria.

Figure 9:


Simulation Set 1: 1,000 Simulated Plans
Maximizing Adherence to Traditional Districting Criteria
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
SB 2
Enacted Plan
Efficiency Gap Using Hofeller Formula
(Lower Efficiency Gap Indicates More Wasted Democratic Votes)

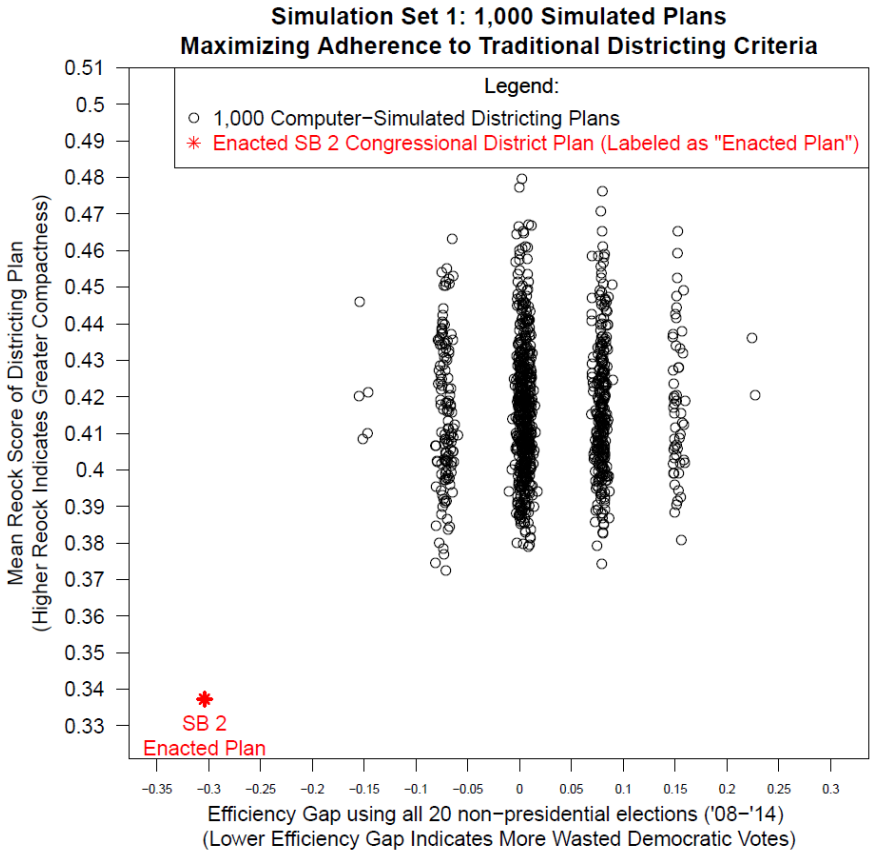
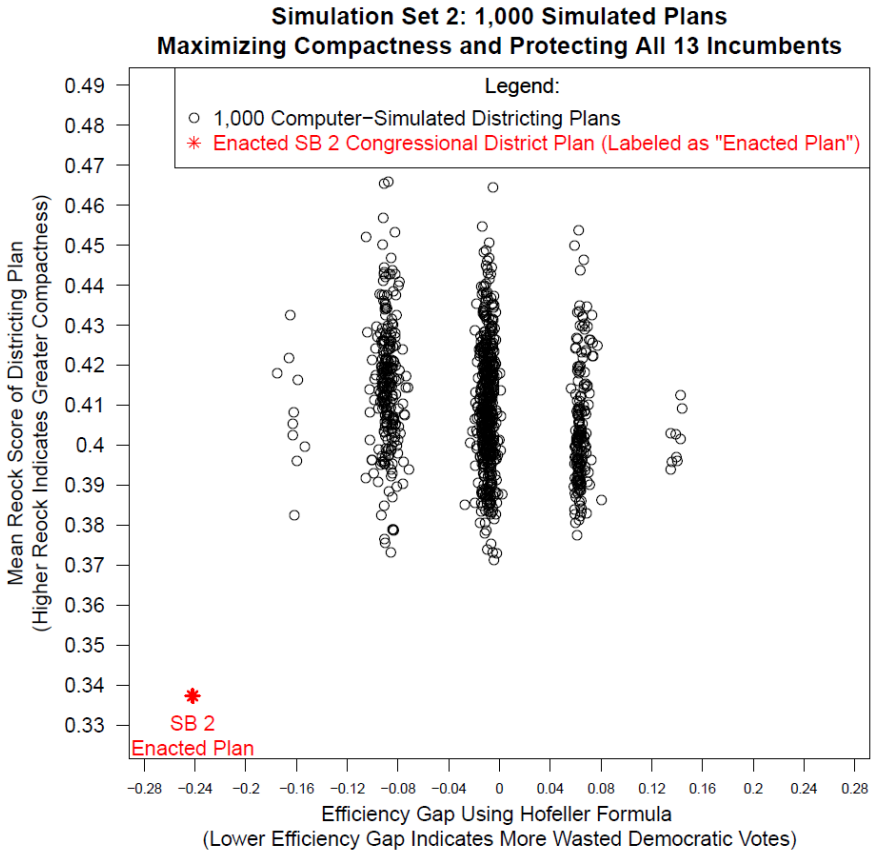

Simulation Set 1: 1,000 Simulated Plans
Maximizing Adherence to Traditional Districting Criteria
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
SB 2
Enacted Plan
Efficiency Gap using all 20 non−presidential elections ('08−'14)
(Lower Efficiency Gap Indicates More Wasted Democratic Votes)

Figure 10:


Simulation Set 2: 1,000 Simulated Plans
Maximizing Compactness and Protecting All 13 Incumbents
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
0.39
0.38
0.37
0.36
0.35
0.34
0.33
SB 2
Enacted Plan
−0.28 −0.24 −0.2 −0.16 −0.12 −0.08 −0.04 0 0.04 0.08 0.12 0.16 0.2 0.24 0.28
Efficiency Gap Using Hofeller Formula
(Lower Efficiency Gap Indicates More Wasted Democratic Votes)

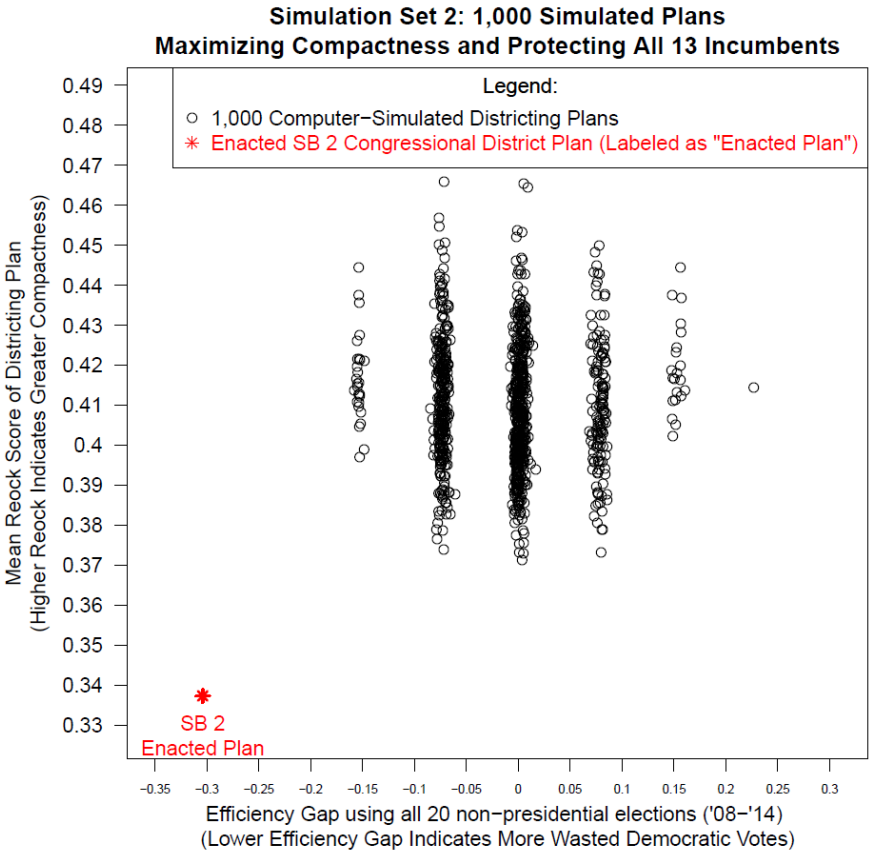

Simulation Set 2: 1,000 Simulated Plans
Maximizing Compactness and Protecting All 13 Incumbents
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
0.39
0.38
0.37
0.36
0.35
0.34
0.33
SB 2
Enacted Plan
−0.35 −0.3 −0.25 −0.2 −0.15 −0.1 −0.05 0 0.05 0.1 0.15 0.2 0.25 0.3
Efficiency Gap using all 20 non−presidential elections ('08−'14)
(Lower Efficiency Gap Indicates More Wasted Democratic Votes)

Figure 11:

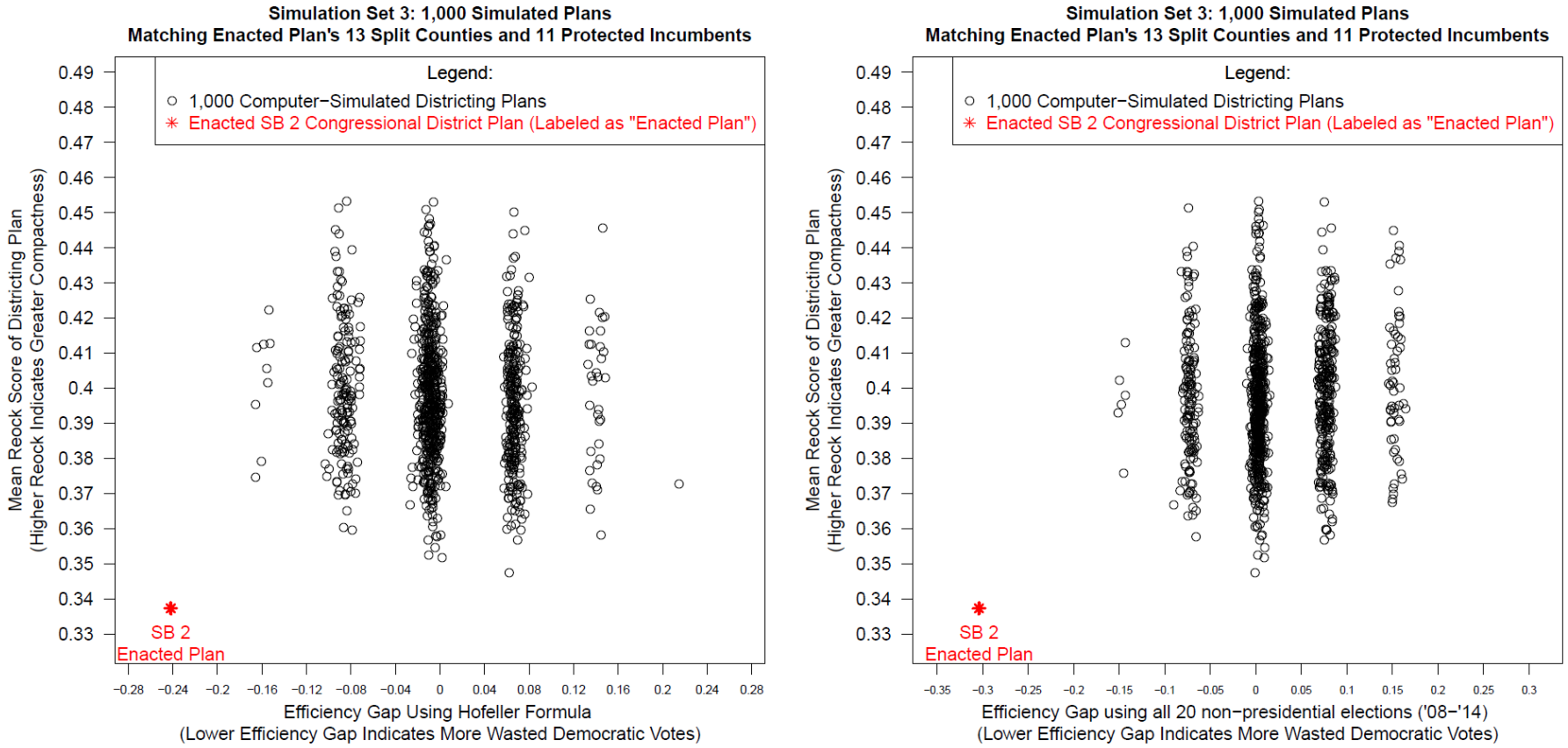
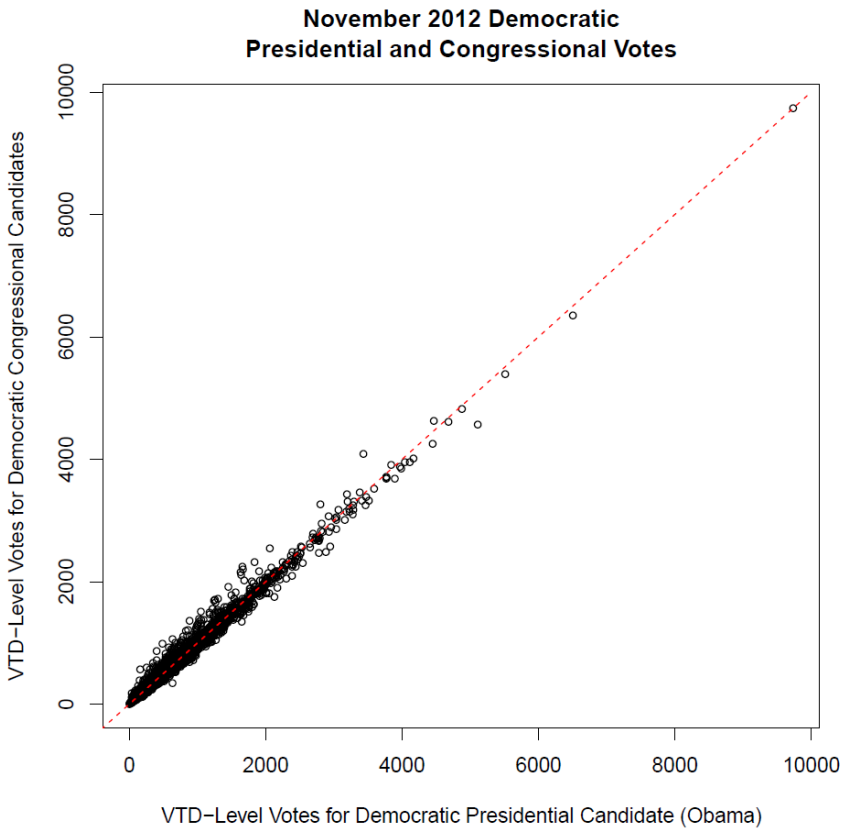

Simulation Set 3: 1,000 Simulated Plans
Matching Enacted Plan's 13 Split Counties and 11 Protected Incumbents
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
SB 2
Enacted Plan
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
Efficiency Gap Using Hofeller Formula
(Lower Efficiency Gap Indicates More Wasted Democratic Votes)
Simulation Set 3: 1,000 Simulated Plans
Matching Enacted Plan's 13 Split Counties and 11 Protected Incumbents
Legend:
1,000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
SB 2
Enacted Plan
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
Efficiency Gap using all 20 non−presidential elections ('08−'14)
(Lower Efficiency Gap Indicates More Wasted Democratic Votes)

Figure 12:


November 2012 Democratic
Presidential and Congressional Votes
VTD−Level Votes for Democratic Congressional Candidates
0
2000
4000
6000
8000
10000
VTD−Level Votes for Democratic Presidential Candidate (Obama)

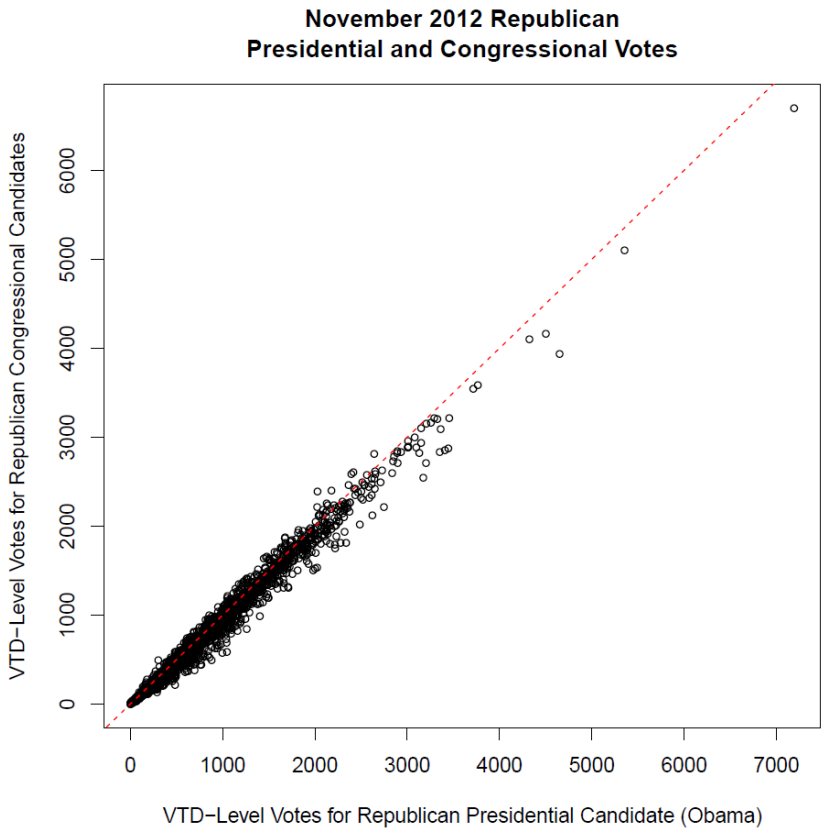
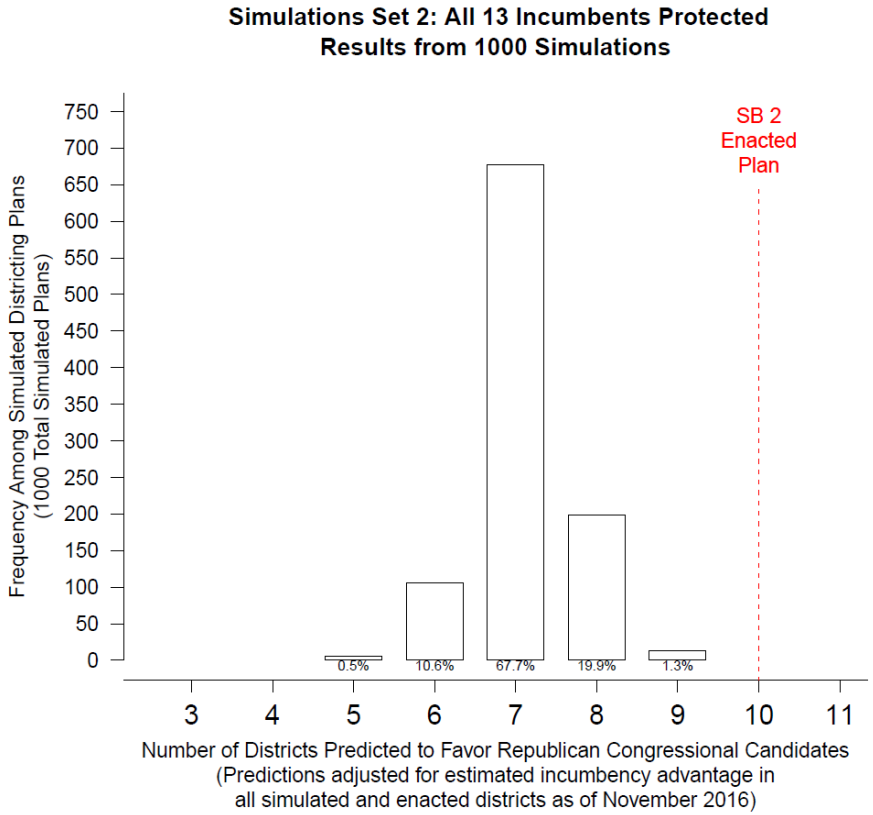

November 2012 Republican
Presidential and Congressional Votes
VTD−Level Votes for Republican Congressional Candidates
0
1000
2000
3000
4000
5000
6000
7000
VTD−Level Votes for Republican Presidential Candidate (Obama)

Figure 13:


Simulations Set 2: All 13 Incumbents Protected
Results from 1000 Simulations
Frequency Among Simulated Districting Plans
(1000 Total Simulated Plans)
SB 2
Enacted
Plan
0.5%
10.6%
67.7%
19.9%
1.3%
Number of Districts Predicted to Favor Republican Congressional Candidates
(Predictions adjusted for estimated incumbency advantage in
all simulated and enacted districts as of November 2016)

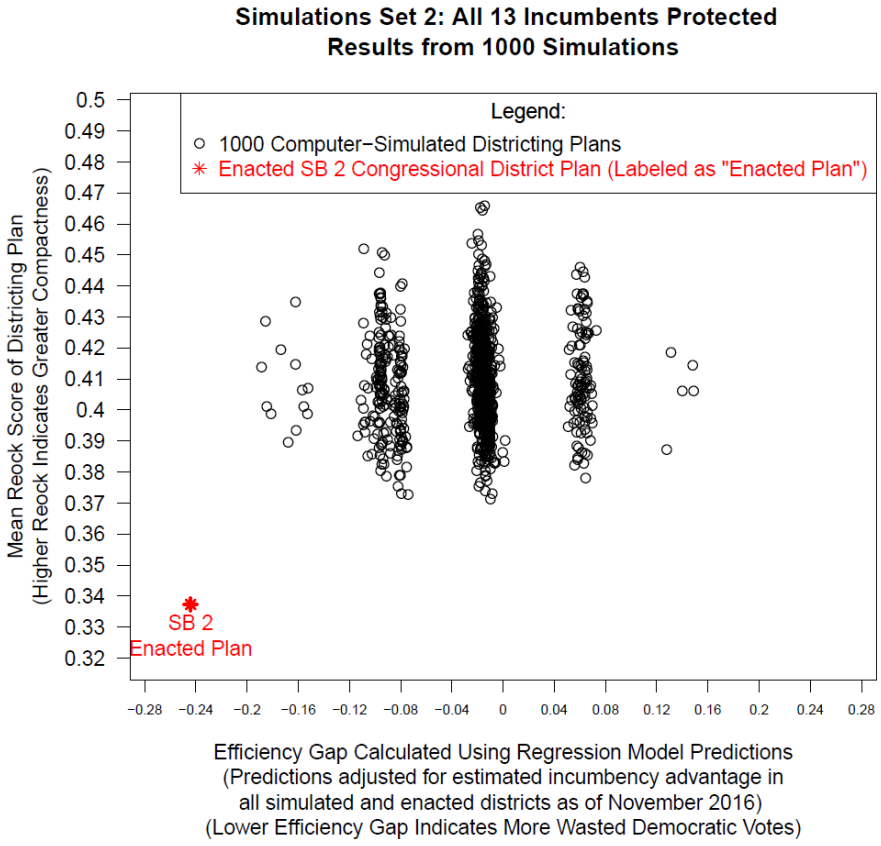
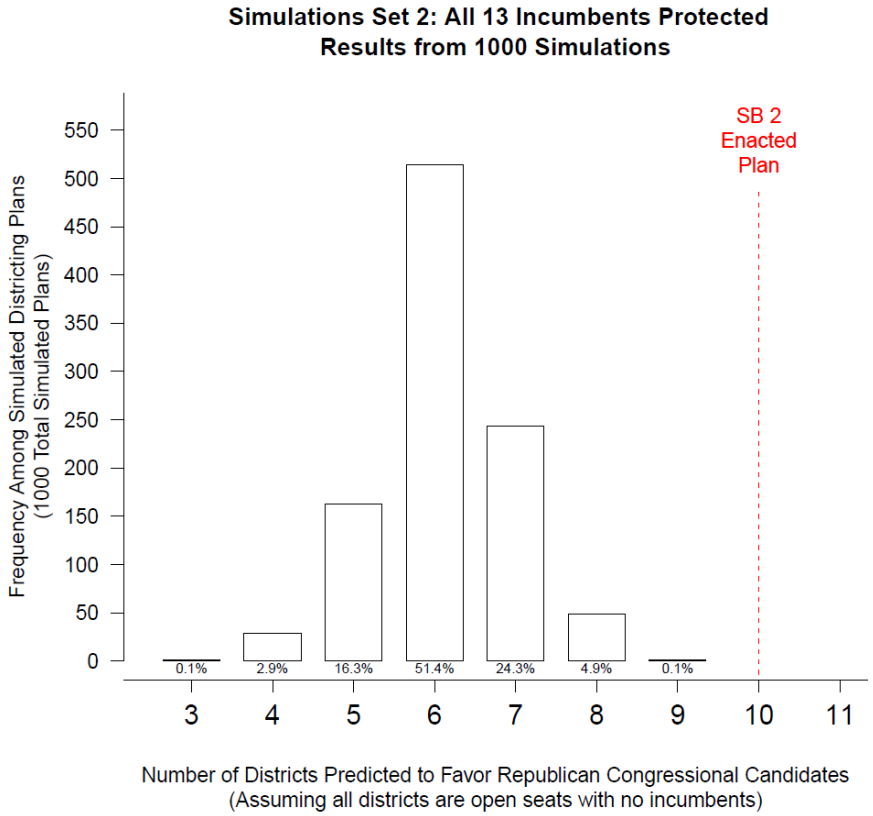

Simulations Set 2: All 13 Incumbents Protected
Results from 1000 Simulations
Legend:
1000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
SB 2
Enacted Plan
Efficiency Gap Calculated Using Regression Model Predictions
(Predictions adjusted for estimated incumbency advantage in
all simulated and enacted districts as of November 2016)
(Lower Efficiency Gap Indicates More Wasted Democratic Votes)

Figure 14:


Simulations Set 2: All 13 Incumbents Protected
Results from 1000 Simulations
Frequency Among Simulated Districting Plans
(1000 Total Simulated Plans)
SB 2
Enacted
Plan
0.1%
2.9%
16.3%
51.4%
24.3%
4.9%
0.1%
Number of Districts Predicted to Favor Republican Congressional Candidates
(Assuming all districts are open seats with no incumbents)

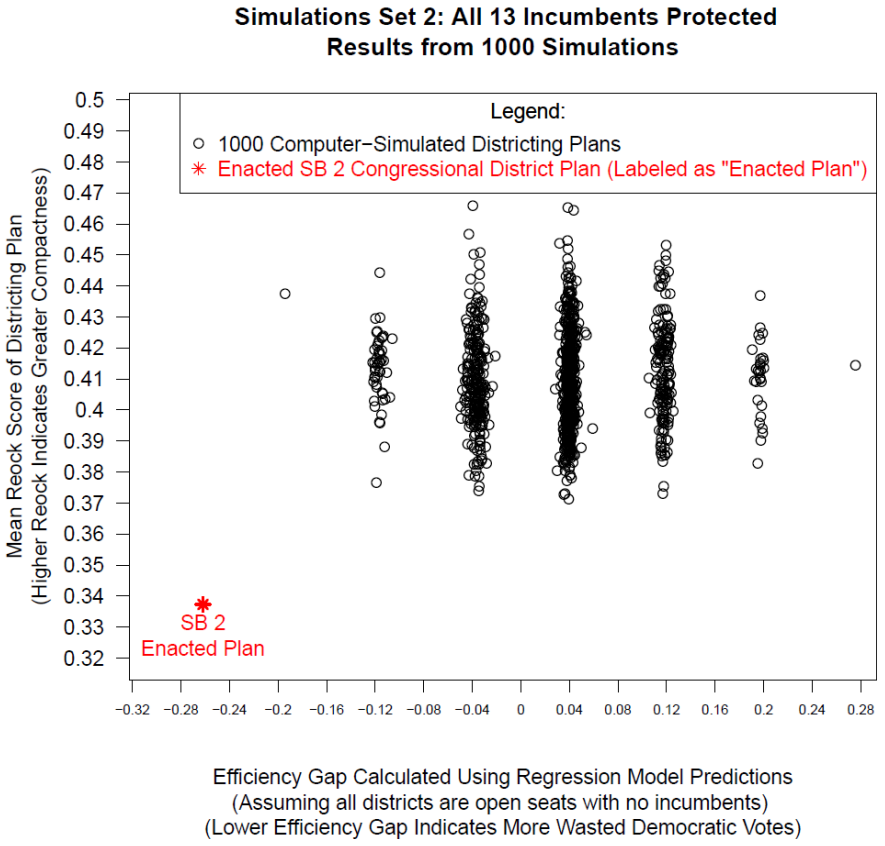

Simulations Set 2: All 13 Incumbents Protected
Results from 1000 Simulations
Legend:
1000 Computer−Simulated Districting Plans
Enacted SB 2 Congressional District Plan (Labeled as "Enacted Plan")
Mean Reock Score of Districting Plan
(Higher Reock Indicates Greater Compactness)
SB 2
Enacted Plan
Efficiency Gap Calculated Using Regression Model Predictions
(Assuming all districts are open seats with no incumbents)
(Lower Efficiency Gap Indicates More Wasted Democratic Votes)

Table 2:
VTD-Level Regression Models
Predicting 2012 Congressional Election Results and Turnout

	Model 1:	***Model 2:***
	Dependent Variable: Republican Vote Share in Congressional Elections (Nov 2012)	*Dependent Variable:* Turnout Rate for Nov 2012 Congressional Elections (Votes / Voting Age Pop.)
Independent Variables:		
Republican (Romney) Presidential Vote Share, November 2012	0.911***	0.007***
	(0.004)	(0.002)
Precinct's Congressional District has a Republican Incumbent	0.031***	0.006***
	(0.003)	(0.001)
Precinct's Congressional District has a Democratic Incumbent	-0.032***	0.008***
	(0.002)	(0.001)
Turnout Rate for Nov 2012 Presidential Elections (Votes / Voting Age Pop.)	0.009	0.978***
	(0.005)	(0.002
County Fixed Effects	Included	Included
Constant	0.026	-0.004
	(0.006)	(0.003)
N	2,692	2,692
Adjusted R-squared	0.985	0.992

*p<.05; **p<0.01, ***p<0.001

The foregoing is true and correct to the best of my knowledge.

Jowei Chen

March 1, 2017