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Can Gerrymanders Be Detected? An Examination of Wisconsin's State Assembly

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Abstract

In October 2017, the Supreme Court heard an appeal of a November 2016 ruling striking down Wisconsin's State Assembly districts as a Republican gerrymander that illegally dilutes the weight of Democratic votes. We take the opportunity to revisit this litigation to evaluate three proposed methods of detecting gerrymanders: the "efficiency gap," a count of Assembly districts carried by statewide candidates, and the difference between the district-level partisan median and mean. The first two measures figure either centrally or peripherally in the plaintiffs' case in Wisconsin, while the third is the approach we favor. We expand on the analysis offered at trial by evaluating how these measures fare across a variety of elections in Wisconsin and with the aid of 10,000 alternative Assembly maps drawn by computer. The alternative maps provide the appropriate baseline with which to gauge the level of vote dilution in Wisconsin and distinguish between the effect of residential geography and the Legislature's actions. The results show that Wisconsin's Assembly map is a substantial gerrymander according the median–mean comparison across all elections, while the two tests relied upon by the plaintiffs provide mixed results. We examine the measurement qualities of each test and show that the efficiency gap and

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districts-carried count both capture elements beyond partisan bias. We find no similar ambiguity with the median–mean comparison and conclude that the plaintiffs' claim that Wisconsin's Assembly map systematically dilutes the weight of Democratic votes is correct.

Keywords
gerrymandering, efficiency gap, *Gill v. Whitford*, neutral maps, partisan symmetry, median–mean comparison

Introduction

Partisan gerrymandering has been written off by many observers as an inherently subjective phenomenon (Schuck, 1987). When Democrats like one set of districts, Republicans are bound to object. When Republicans approve of another, it becomes Democrats' turn to complain. Yet, it is clear that district lines do affect who is elected, and obvious that parties often try to press their control of the line-drawing process to create systematic advantages for themselves in legislative elections. The questions are whether (a) these "systematic advantages" produce bias that is detectable using objective tests, and (b) whether that bias is linked to a constitutional violation. In short, can gerrymanders be measured and might they be unlawful? The Supreme Court, first in *Davis v. Bandemer* (1986) and later in Vieth v. Jubelirer (2004) and *League of United Latin American Citizens* [LULAC] *v. Perry*(2006), has held that partisan gerrymandering is a justiciable issue, effectively answering the second question. Some gerrymanders might indeed be illegal *provided that plaintiffs produce objective evidence demonstrating their effects.* The plaintiffs in *Gill v. Whitford*, a group of Democratic voters in Wisconsin, invoke the 14th Amendment by arguing that their state's Assembly map illegally dilutes the weight of Democrats' votes.[1] To support that claim, they present empirical results using one proposed method of detecting gerrymanders, the "efficiency gap" (EG), and by offering an affidavit about a second measure focusing on the count of Assembly districts carried (DC) by each party.[2]

In November 2016, a panel of federal judges ruled in favor of the plaintiffs by a 2-1 margin, and the Supreme Court agreed to hear the State's appeal with the oral argument taking place on October 3, 2017. During that argument, many of the Justices' questions were directed toward whether the EG could serve as a reliable and effective standard for detecting a gerrymander with several expressing skepticism bordering on derision. Chief Justice Roberts went so far as to suggest that any empirical assessment of gerrymandering might be nothing more than "sociological gobbedlygook."

Given the high stakes involved, we take the opportunity here to revisit the case to address a question of interest to political scientists, judges, and citizens: Can gerrymanders be reliably and objectively detected. Specifically, we examine these two measures used by the *Whitford* plaintiffs as well as a third we favor, a comparison of the partisan median and mean at the district level. We expand on the analysis offered at trial by examining a wider range of elections in Wisconsin and by comparing them to an appropriate, within-sample counterfactual that allows us to distinguish the effect of Legislature's actions from residential patterns. The results show that the plaintiffs' two measures do *not* reliably identify Wisconsin's Assembly districts to be a Republican gerrymander. The comparison of the partisan median and mean district, however, does detect a substantial Republican gerrymander achieved by diluting the weight of Democratic votes in every election and every test. If the plaintiffs' evidentiary standards are adopted, the ruling that Wisconsin's Assembly districts are a gerrymander is potentially in jeopardy. If the median–mean (MM) is to be believed, the plaintiffs' claims of vote dilution are correct. Sorting out who is right and why is essential for the current case as well as other lawsuits that may follow.

The circumstances of this lawsuit aside, Wisconsin is an ideal setting for this inquiry for several reasons. As we describe below, the State Legislature maintains and makes available an unusually comprehensive collection of election data. More important, the state is politically competitive. In the 13 statewide elections conducted between 2008 and 2014 (the two cycles before and after redistricting), Republicans won eight, Democrats won five, and all but two were fairly close. That makes the stakes of vote dilution particularly high for Wisconsin is the sort of state where either side could reasonably expect to win control of its Assembly in a given election. Gerrymandering in these sorts of circumstances could make it possible for a minority of voters to consistently win a majority of legislative seats. In an area of law where the debate rages over the proper translation of votes into seats, the notion of "majority rule" is perhaps the single clear and agreed-upon principle.[3]

The 2016 presidential election serves as a reminder that majority rule is not universally applied to all U.S. elections. Whatever the merits of the Electoral College, its example provides a useful contrast to partisan gerrymandering. Obviously, state boundaries would have unknown effects on elections taking place more than a century later. Legislative boundaries, by contrast, are redrawn every decade. They carry none of the historical weight of state lines, but they also give the party in control an opportunity to entrench its majority anew each decade. Indeed, the popular vote winner has almost always carried the Electoral College in U.S. history. An arrangement within a state or other jurisdiction that is biased so that it consistently awards a majority of seats to a minority of voters is far different.

We focus on three related issues in our examination of bias in the form of vote dilution in Wisconsin's Assembly districts: its magnitude, persistence, and source. The first two dimensions are straight forward. Magnitude refers to the size of the bias produced by a gerrymander, and persistence to its presence across elections. The latter is essential because we expect vote dilution would be detectable across a range of elections else it suggests that voters might do and undo the bias with their ballots.[4] Source is particularly important given the objections raised at trial and by the dissenting judge in *Whitford* that the apparent pro-Republican lean of the Assembly map could be the result of high concentrations of Democratic voters living in Madison and Milwaukee. This effect of residents essentially packing themselves is known as the "natural" or "accidental" gerrymander and has been recognized for decades (Chen & Rodden, 2013b; Erikson, 1972, p. 1237; Vieth, 2004, pp. 289-290). As a result, it is useful to distinguish between the effect of geography and the actions of the mapmakers. We do so here with the aid of 10,000 alternative Assembly maps of Wisconsin drawn by computer without reference to voting history. We argue these maps provide the appropriate baseline with which to establish the extent of the natural gerrymander and differentiate it from mapmakers' actions.

We proceed in this essay to evaluate these three methods of detecting gerrymanders as applied to Wisconsin's Assembly map. "Three Measures of Gerrymandering" section introduces and discusses the methods. "Data" section moves to the data, including a longer explanation of the computer mapping process used to produce the comparison set of neutral maps. "Results" section presents the empirical analysis, first showing the observed bias for all three measures across the 13 statewide races in Wisconsin from 2008 to 2014, then comparing these results to the results generated for each metric in the set of 10,000 alternative maps. Finally, we examine the measurement qualities of each of the three proposed gerrymandering metrics in "Is Wisconsin's Assembly Map a Republican Gerrymander?" section to resolve the disparity between their results, determine which reliably detects gerrymanders, and draw conclusions about the level of vote dilution produced by Wisconsin's Assembly districts.

Three Measures of Gerrymandering

The EG

The EG standard proposed by Eric McGhee (2014) and Stephanopoulos and McGhee 2015 proceeds from the insight that both the winner and loser of an election almost inevitably "waste" votes that play no role in determining the outcome. For instance, we know that Hillary Clinton and Donald Trump ran

up needlessly large margins in some states, and neither benefited from the votes they received in states they lost. Stephanopoulos and McGhee maintain that gerrymanders arrange district lines so that one side wastes many more votes than does the other, creating a system where one side enjoys greater efficiency in the process of aggregating votes within districts.

There is an intuitive appeal to this approach. Casting a party's advantage from gerrymandering as a function of wasted votes is consistent with the pair of maneuvers used by mapmakers: "packing" where the winning party uses many more votes than necessary to prevail in one or more districts, and "cracking" where the losing party falls just a few votes short of victory in multiple districts. In both situations, the disadvantaged party squanders votes by winning by a mile or losing by an eyelash. If that party were able to move some of these ballots into neighboring districts, it could change the outcomes in those districts by improving the efficiency of how their voters are distributed across the legislative map. Indeed, the EG is billed as simultaneously capturing both packing and cracking.

Stephanapoulos and McGhee define waste as votes received by the winner above 50% (of the two-party vote) and all votes by the loser.[5] For instance, in an election where 100 people cast ballots and the winner received 60 votes, the winner has wasted 10 votes in excess of the 50 votes needed to win (setting aside ties) and the loser has wasted all 40. The total waste by party is the sum of votes wasted by Democratic/Republican winners and losers across all the legislative districts in a jurisdiction, and the EG is disparity in wasted votes as a percentage of votes cast for the major parties. So, if Democrats wasted 100,000 more votes than Republicans and one million people cast ballots for those parties, EG = 100,000/1,000,000 = 10%. Stephanopoulos and McGhee (2015) examine a number of states over time and suggest that an EG greater than 8% generally indicates a gerrymander in legislative elections, though they are open to the possibility of different thresholds. The *Whitford* plaintiffs argue for a lower threshold of 7%. For the purposes of this article, we use the higher threshold of 8%.

The EG also has a noteworthy empirical property that reveals its underlying normative properties. If equal numbers of votes are cast in each district, its calculation reduces to a simple equation[6]:

$$\text{EG} = \text{Seat Margin} - \left(2 \text{ x Vote Margin}\right),$$

In this case, seat and vote margin are both measured by percentage-point deviations from 50%. So, the EG = 0 when the party that wins 55% of votes receives 60% of seats; any result above or below 60% could indicate a gerrymander in either direction.

As it is exceedingly rare to observe precisely equal turnout across a series of districts in a jurisdiction, this formula is no shortcut for calculating the EG.[7] Rather, Stephanopoulos and McGhee (2015, p. 852) herald it as offering "a normative guide" for the relationship of votes and seats in a fair system, a theoretically derived "swing ratio" (e.g., Butler, 1951; Tufte, 1973). They dismiss the concept of proportional representation as unrealistic in single-member districts where the winning party frequently receives a "winner's bonus" in seats beyond their share of the votes, and argue the EG's approach is normatively and legally superior. Several scholars object that this winner's bonus is arbitrary and questionable on any yet to be articulated ethical grounds (McGann, Smith, Latner, & Keena, 2015). It is also the empirical by-product of the specific way in which votes are designated as wasted (see Note 5).

Counting DC

The effect of a gerrymander—and the admitted purpose of mapmakers in Wisconsin and other states[8]—is to benefit one party by helping it receive more than its fair share of seats in legislative elections. Thus, a long-established way to detect a gerrymander is to examine its result, the seats won by each party in an election (e.g., Butler, 1951). Among other things, this line of research has produced a large empirical literature on how votes translate into seats in various electoral systems. As election outcomes affected by gerrymandering may involve both packing and cracking, detecting gerrymanders by focusing on the number of victories implicitly captures both maneuvers.

In isolation, the problem with counting wins and losses is that there is no agreement as to how votes *should* translate into seats. The Court has essentially dismissed proportional representation, notably in *Bandemer*.[9] Justice Thomas has gone so far as to assert that it is inappropriate bordering on foolish for the Court to insist on any standard for how undiluted votes are weighed or, as a consequence, how votes are translated into seats:

> A review of the current state of our cases shows that by construing the Act to cover potentially dilutive electoral mechanisms, we have immersed the federal courts in a hopeless project of weighing questions of political theory-questions judges must confront to establish a benchmark concept of an "undiluted" vote. (*Holder v. Hall*, 1994, p. 892)

Indeed, the dissenter in *Whitford*, Judge William Griesbach, dismisses the EG's version of a winner's bonus as a "phantom constitutional right. . .that voters for one party are entitled to some given level of representation proportional to how many votes that party's candidates win in every assembly

district throughout the state as a whole" (*Gill v. Whitford* 2016, p. 120).[10] It seems likely that any formulaic approach to translating votes to seats is certain to run into this sort of objection.

Gary King and Bernard Grofman (2007) offer a possible solution to this problem by arguing for "symmetry" whereby a fair system is one in which each party wins the same number of seats when it receives the same share of the vote. So, no matter if the Democrats win 55%, 65%, or 75% of seats with 52% of the two-party vote, disproportionate as some of those results may seem, the result is fair so long as the Republicans would do just as well were they to win 52% of the vote. This sidesteps the question of the appropriate swing ratio by reformulating it as a matter of equity. Unfortunately, we rarely get to observe elections whose outcomes mirror one another (e.g., 52% Democratic and 52% Republican) in the same jurisdiction over a short period of time, and we never observe the whole distribution of possible election outcomes. In response, King and Grofman simulate different election results to test the symmetry of a plan. While their insight about equivalent outcomes was praised by Justice Kennedy writing for the majority in LULAC (2006), he ultimately rejected this measurement approach as too hypothetical and unworkable for the Court (at 419-420).

Jowei Chen and Jonathan Rodden (2015) offer another way to use election outcomes without reference to any sort of formulaic translation of votes to seats by comparing the number of districts a party carries under the enacted map with the number it would have carried under a set of alternative maps. Their process features a computer algorithm that allows them to generate a large number of alternative maps by combining voting tabulation districts (VTDs or the generic term for precincts, wards, or election districts) in different ways without reference to their voting patterns. The districts they generate are geographically contiguous and equally populated, and as they are drawn from VTDs, it is simple to add election data to mix *after* they are drawn. For example, if two existing districts consisting of VTDs 1 to 10 and 11 to 20 swapped a pair of VTDs, it is straightforward to calculate a new set of district-level results for VTDs 1 to 9 and 11 and 12 to 20 and 10. The process essentially rearranges ballots already cast.

In their view, a gerrymander occurs when a party carries more or fewer districts in the enacted map than were the map drawn by some sort of neutral process. So, imagine a state where Donald Trump carried 55% of its Assembly districts in 2016. If 1,000 computer-generated districting plans had Trump carrying 45% to 50% of districts, Chen and Rodden would conclude enacted map is a Republican gerrymander because Trump did better than he would have done had the districts been drawn through a politically neutral process, and vice versa if he did worse.[11] This comparison is simple and bypasses

questions about normative fairness, speaking more to mapmakers' intent and potentially to voters' expectations. Like the Grofman and King symmetry standard, Chen and Rodden's test relies on a computationally intensive methodology, but theirs merely re-aggregates ballots cast within different sets of boundaries as opposed to simulating election results that have not occurred. There is reason to hope, at least, that judges might find that more acceptable because it tests a hypothesis—what would have happened had the district boundaries been different—that is observable with the evidence at hand.

Implicit in their approach to generating this counterfactual is that the ballots rearranged must offer the same choices to all the voters in a jurisdiction. This rules out using legislative elections as only the voters in the existing districts choose between exactly the same pair of legislative candidates; moving precincts in and out of the core of a district inevitably leaves some voters who never saw Candidates A and B when they cast their votes. Elections conducted throughout the jurisdiction—in this case, statewide elections like contests for president, U.S. Senate, and state constitutional offices—solve this problem because every voter, no matter the district in which they are placed, has faced the same choice. Importantly, there is no reason to believe that a voter's choice for president or governor is affected by the legislative district in which they live. As we describe below, there is consensus among political scientists that statewide elections are better indicators of the underlying partisan complexion of a precinct—and therefore its likely performance in other elections—than are the often idiosyncratic results of Assembly elections. Because Chen and Rodden's approach counts the number of districts carried by (in this case) statewide candidates rather than seats won, we refer to it as the "districts carried" (DC) test.

The MM Comparison

The MM comparison was introduced by Michael D. McDonald and several coauthors (McDonald, 2009; McDonald & Best, 2016; McDonald, Krasno, & Best, 2011), although its intellectual pedigree is much longer.[12] Unlike the EG and DC measures, by itself the MM detects packing only or what McDonald and Best (2016) refer to as "differential packing."[13] Everyone understands that gerrymanders most frequently function by skewing the distribution of partisans in legislative districts.[14] The MM asserts that fundamental way this skew can be observed is by comparing the partisan median district in a jurisdiction to the partisan mean across all districts, with the distance between the two revealing the degree to which the votes of the disadvantaged party are diluted by the legislative map. Indeed, the MM purports to observe vote dilution directly, unlike the EG and DC.

Inevitably expressed in the language of introductory statistics, the MM is best explained by illustration. There are 99 Assembly seats in Wisconsin, meaning the median district is the 50th most Democratic or Republican one in a given election and the mean is the average Democratic or Republican share of the two-party vote among 99 districts. The MM simply subtracts a party's mean vote across all 99 districts from its percentage in the 50th best district. A gerrymander is indicated when there is a large and persistent difference between the partisan median and mean at the district level.

Comparing median and mean is a standard way to observe skew in a distribution. This particular type of skew is relevant to gerrymandering because McDonald and his coauthors argue that the median represents the pivot point where majority control of the legislature (or legislative delegation) is at stake.[15] To win a majority of seats, a party must carry the district in the center of the partisan distribution. Doing so is a tall order for Republicans if the median district is 60% Democratic, an even shot if it is 50% Democratic. A median district that strongly favors one party is neither surprising nor objectionable if the underlying partisan division in the state strongly also favors that party, so McDonald et al. use the partisan mean to gauge a state's partisan leaning. While the district-level mean is generally close to the statewide vote no matter where district lines are drawn, the median is another story. Districting plans which differentially pack a large number of the disadvantaged party's voters into a small number of districts make it possible to adjust the partisan composition of the median district (McDonald & Best, 2016). In short, a "packing gerrymander" essentially arranges voters so that the median district is more favorable to a party than their performance statewide would indicate. In states like Wisconsin where both parties have often won a majority of votes statewide, differential packing gives one party a better chance of winning control of the legislature than the other party—even when the party fails to win a majority of votes. This is a clear violation of the principle of majority rule, an issue orthogonal to the debate about the proper translation of votes into seats.

From the standpoint of the *Whitford* plaintiffs, the MM is particularly useful because McDonald et al. argue that it directly measures the degree to which some the value of some votes are diluted relative to others. For example, if the median district in an election is 52% Democratic while the mean is just 47% Democratic, Republican voters essentially face a 5-point handicap. That is, to win the pivotal district and control of the legislature, they must win approximately 55% of the statewide vote, while the Democrats can achieve the same result with approximately 45% of the statewide vote. This is precisely the claim that the Democratic plaintiffs make in *Whitford*, that the Assembly districts created by the Legislature make their and other Democrats'

votes less valuable than are Republican votes as applied toward winning control the legislature.

Data

Apart from the litigation, Wisconsin offers several analytic advantages for evaluating these three measures. There were 13 statewide elections in the two election cycles immediately preceding and succeeding the districting plan enacted by the Legislature in 2011: presidential races in 2008 and 2012, U.S. Senate races in 2010 and 2012, and regular elections for four constitutional offices (Governor, Attorney General, Secretary of State, and State Treasurer) in 2010 and 2014, plus a gubernatorial recall in June 2012.[16] As we note above, statewide elections are necessary to estimate the DC test and they also provide the best available data about an area's partisan leanings. Partisanship is the sine qua non of gerrymandering because it provides the basis for predicting other behavior. Political practitioners and political scientists know that Democrats and Republicans are extremely likely to vote for their party's candidate—if most other things are equal. Things are decidedly not equal in legislative elections where many districts go uncontested and many others draw just token opposition. This is true in Wisconsin where one third of Assembly elections between 2008 and 2014 were uncontested, and most of the remainder were lightly contested at best. Races where a hopeless (and potentially disinterested) candidate essentially fills a ballot line offer a particularly misleading view of the underlying partisanship of an area for they are likely to lose by a much wider margin than would a more active candidate. Statewide elections may be one-sided, but the relative position of the VTDs remain fairly steady even when one of the candidates is stronger or weaker than expected in a particular area. That is why political scientists have long used statewide contests to make inferences about partisanship in geographic units within states (e.g., Ansolabehere, Snyder, & Stewart, 2001; Canes-Wrone, Cogan, & Brady, 2002; Erikson & Wright, 1980; Key, 1949). Stephanopoulos and McGhee and the two main plaintiffs' experts use either statewide elections or a combination of statewide and legislative results in their analyses.

Beyond these advantages in measuring partisanship, there is also useful variation in election returns. As we note, Democrats and Republicans both won multiple statewide elections between 2008 and 2014 and usually by relatively narrow margins, making Wisconsin the sort of closely divided state where either party might be expected to have a good chance to win control of the state Assembly in the absence of systematic vote dilution. The variation in outcomes also informs analysts about the persistence of the any bias caused

by gerrymandering across different races with different outcomes. Appendix A provides information about these contests, including summary data about these 13 races in Table A1, and the ward-level correlation of the Democratic vote showing the high stability in partisan voting patterns in Table A2.

Finally, Wisconsin features election data of unusual quality and availability. Few states collect and archive VTD-level election returns from counties and municipalities who administer elections. Fewer still collect maps of VTDs let alone make them available as shape files through a central repository.[17] Wisconsin's Legislative Technology Services Bureau (n.d.) provides all this information. Its GIS analysts also disaggregate ward returns to census blocks according to the proportion of the population of a ward who reside on those blocks, so if 80% of residents of a ward live on a block, it gets 80% of the vote cast for each candidate in that ward. This procedure is used in several other states including California.[18] The block-level data make it possible to bridge census decades to see how elections conducted prior to 2011 would play out in the current boundaries. They also have the advantages of being official in the sense that they are created by public law, and were the data relied upon by mapmakers in the most recent redistricting cycle.

We acquired population and election data for 252,596 census blocks from the State covering elections from 2002 to 2014.[19] We used the population data to produce an expansive array of 10,000 neutral maps drawn by computer using a new process introduced by Magleby and Mosesson (2018).[20] This process is vastly more efficient than are earlier approaches and allows us to produce large numbers of unique maps from census blocks (as opposed to VTDs).[21] While there is currently no known method for estimating the number of possible legislative maps that might be drawn in a jurisdiction like Wisconsin, Magleby and Mosesson have shown that their process has no discernable biases under existing tests.[22] Following their lead, we refer to these maps as "partisan blind" or "neutral" in that they are generated with no conditions other than contiguity and equal population. Election data are added only *after* the maps were produced. Each of the 10,000 maps is unique, contains 99 contiguous districts with a maximum population variation of 1.5%.[23]

These computer-generated maps are a necessary element in the districts-carried (DC) test of gerrymandering and they also play a vital role in our evaluation of the EG and MM comparison. First of all, they provide the appropriate in-sample comparison with which to assess the magnitude of the potential gerrymander in a jurisdiction. For instance, Stephanopoulos and McGhee's (2015) "suggestion" (p. 40) that a gerrymander is detected when the EG is greater than 8% comes from an empirical examination of state legislative elections going back to the 1970s. The *Whitford* plaintiffs use a similar examination of elections for state assemblies to argue for a 7% threshold

(Jackman 2016). Any dividing line is inevitably arbitrary, but the real difficulty here comes from what analyses of different places at different times tell us about a specific place at a specific time. As Stephanopoulos and McGhee (2015) observe, "(a)n eight-point gap in California simply is not commensurate, legally or politically, to an eight-point gap in Connecticut" (p. 42). Social scientists are used to making out-of-sample comparisons, often with controls to make situations as equal as possible. No matter the control variables, there is inherent risk due to unobserved factors that might make California different from Connecticut or Wisconsin circa 2014 different from Wisconsin circa 2004. An advantage of the neutral maps is that they make such comparisons unnecessary because they introduce the precise counterfactual in question: what would have occurred had the district lines been drawn differently. Thus, these maps offer a baseline relevant to all the measures examined here.

This baseline, moreover, has substantive significance for the EG and MM which measure bias without reference to a counterfactual. A process that combines blocks or VTDs on the basis of population and contiguity will produce maps that reflect the characteristics of residential geography plus chance.[24] As a result, bias detected by the EG and MM in the neutral maps would stem from the residential geography.[25] The plaintiffs' claim for relief in *Whitford* implies that mapmakers' actions have their own impact on vote dilution independent of Wisconsinites' residential choices. The impact of the map itself, what we refer to as the "unnatural gerrymander" in contrast to the natural gerrymander, can be observed by comparing the total bias observed in the enacted map with the natural gerrymander observed in the neutral maps. This matter of distinguishing between the effect of residential geography and the mapmakers' actions is emphasized in Judge Griesbach's dissent and has come up in gerrymandering cases elsewhere.[26] The neutral maps are an ideal tool with which to address this issue.

Results

We proceed to examine the current Assembly districts in Wisconsin for evidence of gerrymandering in these 13 statewide elections, first without the benefit of the neutral maps and then with them. We begin with the enacted map, calculating the three measures over all13 elections, focusing initially on the EG and MM, the two standalone measures of bias. The addition of the neutral maps to the analysis brings the DC back in, and provides the baseline from which to gauge the magnitude and source of the purported gerrymander in Wisconsin. These alternative maps also offer insight into the measurement qualities of all three metrics, so we pay attention to the distribution of results

obtained from them. For simplicity, we use the 2008 and 2012 presidential races to illustrate our full analysis, then proceed to examine all 13 statewide elections with a series of annotated histograms. We produce a simple scorecard showing whether a measure detects a Republican gerrymander in Wisconsin distinct from the neutral maps, and conclude by distinguishing the impact of the residential geography versus the district lines drawn by the Legislature for the EG and MM measures.

We start by computing the EG and MM under the current Assembly map using returns from the statewide elections conducted between 2008 and 2014. The MM shows a clear pro-Republican bias in Wisconsin's Assembly map in all elections ranging from +3.84 (2008 presidential) to +6.33 points (2012 gubernatorial recall). The interpretation is straightforward: Democrats need to win approximately 53.84% (i.e., 50% + 3.84%) to 56.33% of the two-party vote statewide to carry the median district and win control of the Legislature, while Republicans always carry the median district with a minority of votes. This is exactly the sort of vote dilution alleged by the *Whitford* plaintiffs. The readings from the EG are somewhat less clear cut. Twelve of the 13 elections show a clear pro-Republican bias from +10.53% (2014 Attorney General) to +15.63% (2010 Attorney General). While these results are not directly interpretable, they are larger than the suggested 8% threshold for a Republican gerrymander. The EG observed in the 13th election, the 2008 presidential, is –6.83%, close to suggesting the current Assembly districts are a *pro-Democratic* gerrymander. Thus, while the series of relatively close elections and the sizable Republican victory produce efficiency imbalances favoring Republicans, the largest Democratic win suggests the opposite. Nonetheless, the EG detects a Republican gerrymander in 12 of the 13 statewide elections conducted in Wisconsin between 2008 and 2014, while the MM detects one in all 13 contests.

Incorporating the neutral maps into this inquiry helps to bring these results into sharper focus, and allows examination of the DC test. As 10,000 different combinations of census blocks into 99 Assembly districts yield a range of values for each measure, we use histograms to display the distribution of their results. The six panels of Figure 1 provide an example of this setup using the 2008 and 2012 presidential elections. The *x* axis in each panel represents the value of a measure and the height of the bars indicate the number of times each value is observed in the neutral maps. The count of DC by the Democratic candidate is always a whole number, but the EG and MM produce fractions (e.g., 3.84 or −6.83) so we group them in bins to graph them. Each panel also contains a vertical, solid line representing the observed value in the enacted map. In addition, the panels showing the EG have the 8% gerrymandering threshold drawn in as vertical, dashed line.

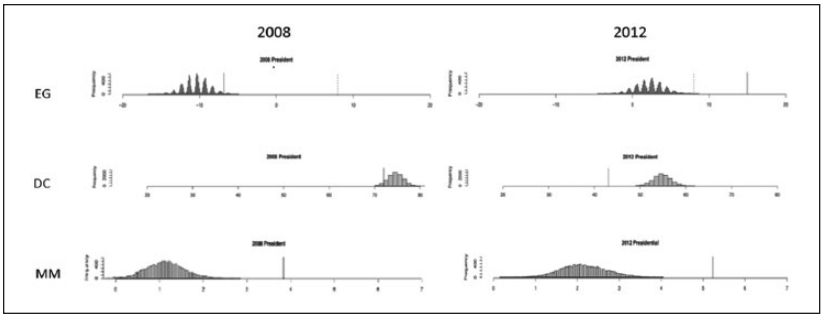

Figure 1. Three gerrymandering metrics in the 2008 and 2013 presidential elections using 10,000 neutral maps.
Note. *x* axis = observed value; *y* axis = number of observations; vertical line = observed value in enacted map.

Several aspects of these histograms are notable. First, the results obtained from the neutral maps for each measure appear normally distributed. This offers some reassurance that variations among the alternative maps are due to chance. The dispersion of results for all three measures suggests, too, that the 10,000 maps are more than incremental variations on a single theme. The EG displays a sort of jaggedness. We experimented with different sized bins and formats, but this pattern of peaks and valleys persists for reasons that are related to the measurement qualities of the EG discussed below. The EG and DC in the neutral maps shift (along the *x* axis) considerably in each election. For example, the mean EG in the 10,000 maps is −10.41 in the 2008 election and 2.29 in the 2012 election, and the mean DC (by Democrats) is 75.09 in 2008 and 55.24 in 2012. The MM from the neutral maps is more stable across these disparate results in this pair of presidential elections with a mean of 1.13 in 2008 to 2.15 in 2012.

Figure 1 also provides a mixed answer to the question, depending on the election used, of whether Wisconsin's Assembly map is a Republican gerrymander distinct from the neutral maps. All three measures detect a Republican gerrymander using 2012 presidential returns in that the observed value in the enacted map is noticeably distinct from the range of values in the neutral maps. Thus, the solid vertical line representing the status quo is to the right of the histograms representing the neutral maps for the EG and MM and to the left for the DC, indicating that all three measures show the enacted map is appreciably more favorable to the GOP than are any of the 10,000 neutral maps. Complications ensue when we examine the enacted map using returns from the 2008 presidential election. The neutral maps yield negatively signed

EGs in that election, 95% of which exceed the –8% threshold to qualify as *Democratic gerrymanders*. The DC measure strongly suggests the enacted map is a Republican gerrymander; Obama carried 73 of the current Assembly districts in 2008, while 95.5% of the neutral maps show him winning 74 or more. The MM offers even clearer evidence of a Republican gerrymander in 2008 as none of the neutral maps produce bias that equals the bias in the enacted map.

Given the variety of results found using presidential returns from 2008, it is fair to question whether that election is an outlier best set aside (see Note 4). On one hand, the 2008 presidential election was by far Democrats' largest victory during this period. On the other, 2008 was the year where the presidential election conducted prior to redistricting and testimony at trial confirms that the analysts hired by Republican legislators used its results to analyze their maps.[27] Fortunately, there are results from 11 other statewide races to evaluate, including 10 relatively close contests and one Republican victory larger than Obama's in 2008 (2010 Attorney General). Presumably the close races, at least, should produce results similar to the relatively narrow Democratic victory in the 2012 presidential election.

Figures 2 (EG), 3 (DC), and 4 (MM) provide the full set of histograms for all 13 elections using the same setup as Figure 1. The scale of the axes is constant within each metric and the histograms are stacked vertically to make it easier to discern differences between elections. While the histograms may be too small to discern fine details, some patterns are easy to see. We start with the stability of each measure in the neutral maps. Contrary to expectations, the EG shifts considerably even when election results are close. For instance, the bottom two panels in each figure show the results using the 2014 contests for Secretary of State and State Treasurer, down-ballot races whose outcomes nearly mirror another with the Democrat winning the first and the Republican winning the second with about 52% of the two-party vote. Figure 2 shows that the neutral mean EG in the former is 4.31 and the latter is 9.51—suggesting that a partisan-blind process essentially produces what looks like a Republican gerrymander in one race but not in the other. The 2014 Treasurer's race is not the only one where the EG in a large majority of neutral maps exceeds the suggested 8% gerrymandering threshold; the same patterns appear in the 2010 U.S. Senate election, 2010 and 2014 gubernatorial elections, the 2012 gubernatorial recall, the 2010 and 2014 elections for Attorney General, and the 2010 and 2014 elections for State Treasurer. These are all of the races won by the GOP candidate.

Figure 3 shows that the DC in the neutral maps moves considerably, too, though this is less surprising as these counts by themselves do not indicate

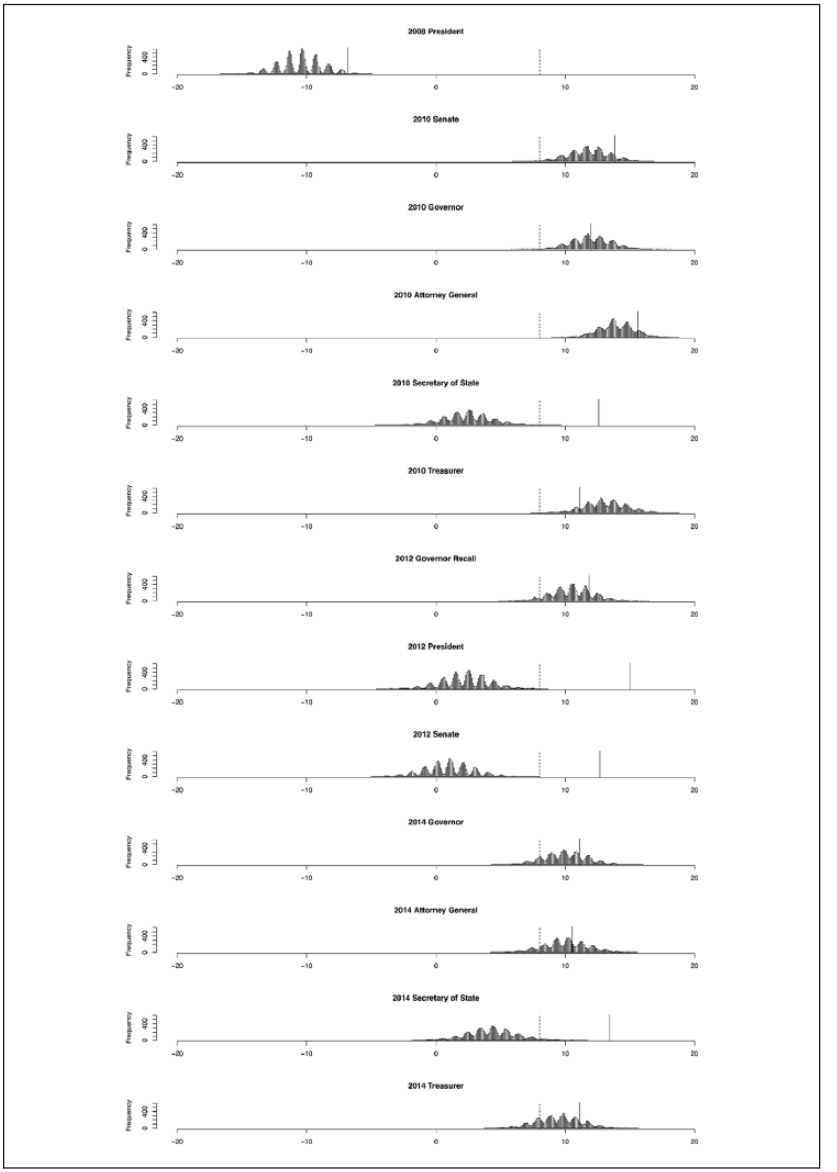

Figure 2. EG in 10,000 neutral maps across 13 statewide elections in Wisconsin.
Note. x axis = observed efficiency gap in a map; *y* axis = number of observations; vertical solid line = efficiency gap in enacted map; vertical dashed line = 8% gerrymandering threshold.

bias. Nonetheless, the movement here is noteworthy because of what it says about Wisconsin's political geography. To use the same two down-ballot 2014 races as an example, the Democratic candidate for Secretary of State carried a mean of 51.13 districts in the neutral maps, while the Democrat running for Treasurer carried just 37.31—a 14-point shift in districts from a 4-point shift in votes. This suggests that the political geography is such that a neutral process will produce a relatively large number of districts competitive enough to flip when the statewide vote moves from one to the other side of 50%. Interestingly, the Democratic statewide winners carry a majority of districts in most of the neutral maps, but Republican statewide winners always carry a majority. This asymmetry hints at a natural gerrymander favoring the GOP.

By contrast, the MM delivers reasonably stable results in the neutral maps no matter the election with a mean ranging from 1.13 in the 2008 presidential election to 3.86 in the 2012 gubernatorial recall. These fluctuations appear to make some sense. For instance, Obama's 2008 victory was marked by larger improvements in relatively Republican areas than in Democratic strongholds where gains were limited by ceiling effects, shifting the median district closer to the mean. Furthermore, these numbers are consistent with what is known about the natural gerrymander by essentially adding a few percentage points to Republicans' vote share in the contest to control the State Assembly. We argue below that stability should be evident in any measure of vote dilution as the disparate treatment of one group of voters would be observable no matter which party wins an election, at least within some plausible range of outcomes (see Note 4).

The main question of interest is whether the enacted map in Wisconsin is a Republican gerrymander when evaluated against this neutral baseline. That baseline is a required element in the DC test, and it provides perspective with which to judge the magnitude and source of bias for the EG and MM. The histograms in Figure 4 shows that the MM test meets these expectations. The solid vertical line of the enacted map is always to the right of the solid bars of the neutral maps, meaning that the enacted Assembly map favors Republicans more than do the neutral maps. In fact, the MM in the enacted map exceeds the MM found in *any* of the 10,000 maps across *all* 13 elections—130,000 comparisons in all. This is powerful evidence that Wisconsin's Assembly map is a Republican gerrymander. The MM says that this occurs because the enacted map packs Democratic voters into a relatively small number of districts beyond anything attributable to residential patterns, thereby diluting the weight of their votes relative to Republicans' in pursuit of the goal of winning a majority of Assembly seats.

The verdict from the EG and DC tests is more equivocal for it depends on the election examined. The panels in Figures 2 and 3 reveal multiple races

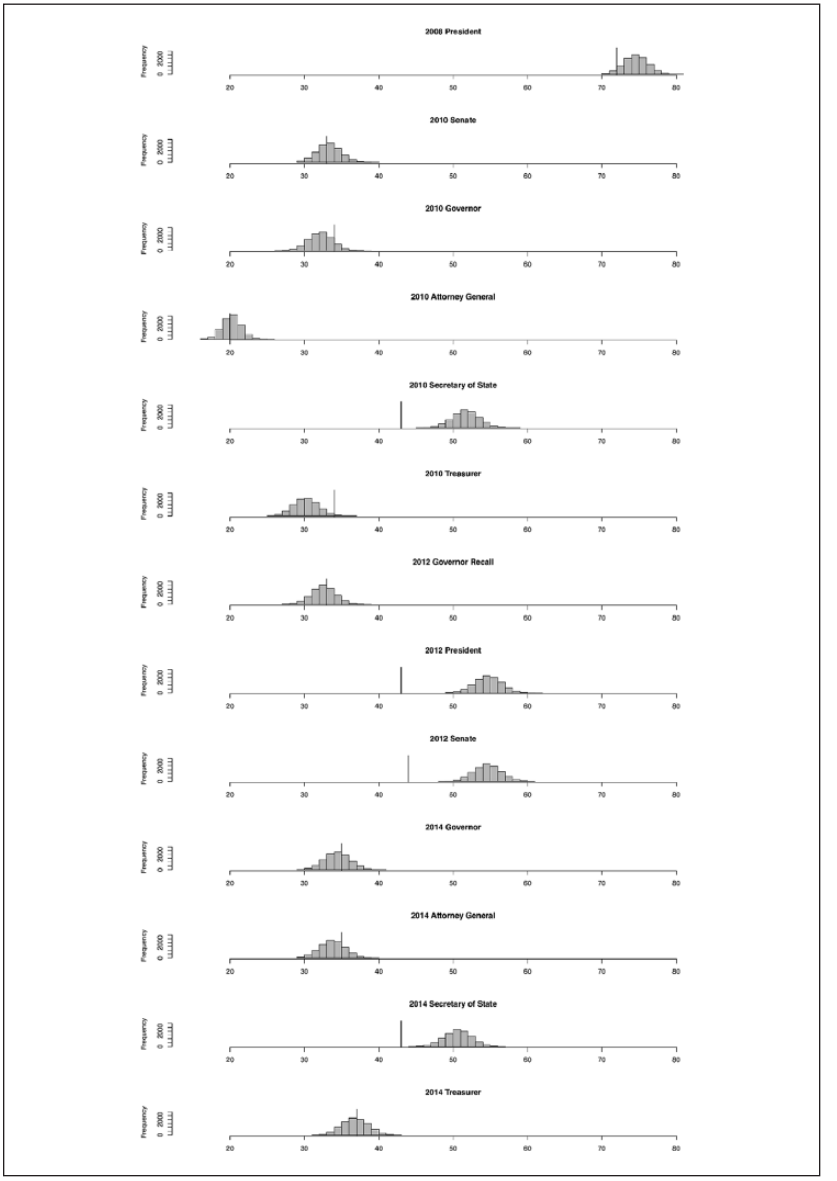

Figure 3. DC in 10,000 neutral maps across 13 statewide elections in Wisconsin.
Note. *x* axis = number of Assembly districts carried by the Republican candidate; *y* axis = number of observations; vertical solid line = actual number of Assembly districts carried by Republican candidate in enacted map.

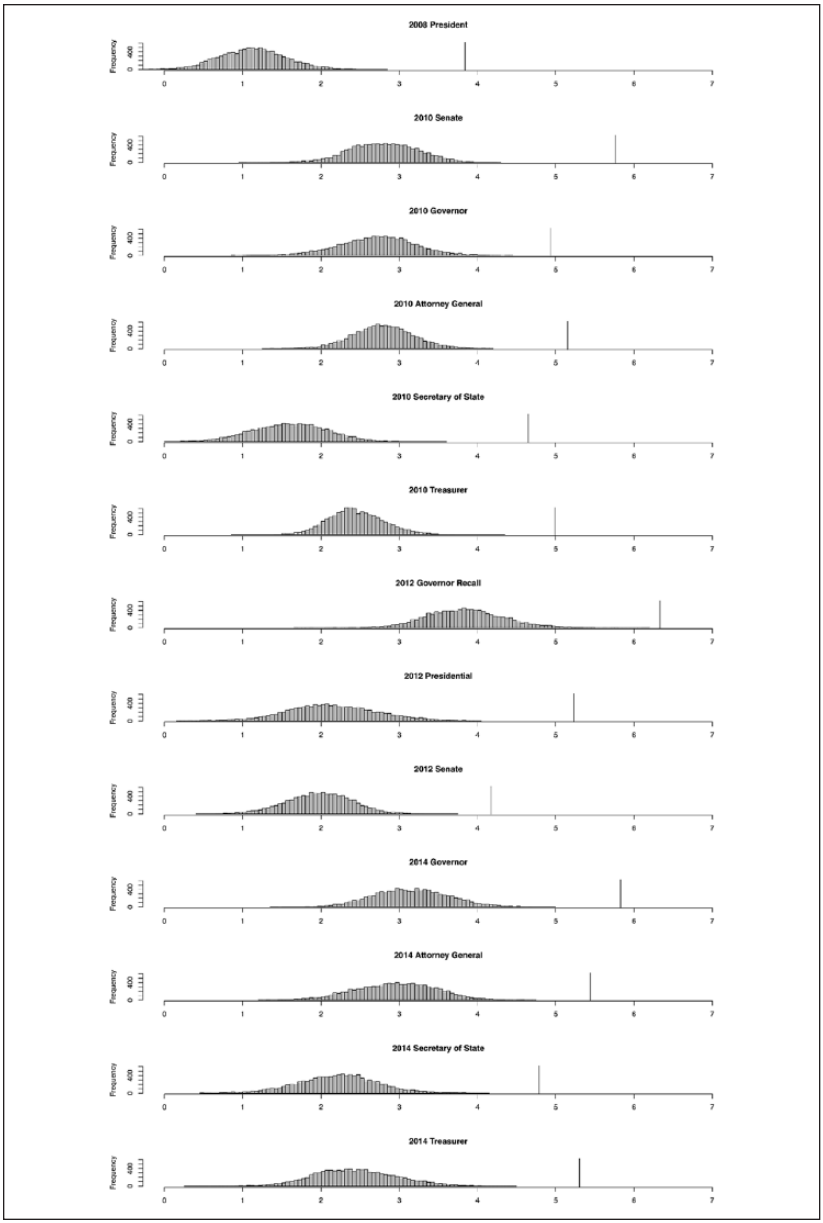

Figure 4. MM in 10,000 neutral maps across 13 statewide elections in Wisconsin.
Note. x axis = observed median–mean in a map; *y* axis = number of observations; vertical solid line = median–mean in the enacted map.

where the solid vertical line of the enacted map is distinct from the results obtained from the neutral maps and others where it intersects them. For instance, in the 2014 race for Secretary of State, the solid line of the enacted map is right of the bars of the histogram for the EG and left of them for the DC, indicating a gerrymander favoring Republicans. But with the 2014 election for Treasurer, the line representing the enacted map is located within the bars representing the neutral maps for both measures, meaning that the effects of the Legislature's map cannot be clearly distinguished from the maps drawn by a computer. Scanning upward in both figures reveals other panels similar patterns. By its own decision rule the DC indicates that the Wisconsin Assembly map is a gerrymander in some races but not in others, and we maintain that the EG's results should be read the same way. Both measures suggest that the Republican gerrymander in Wisconsin appears and disappears depending on the election.

Table 1 presents a series of summary statistics about the values returned from the neutral maps from each measure, including the percentage of neutral maps that diverge from the enacted map. We scored divergence so that larger numbers represent results consistent with the hypothesis that the enacted map is a Republican gerrymander. For the EG and MM, that is the percentage of neutral maps with scores less than the enacted map to assess whether the Legislature's map is more biased in favor of Republicans than are the computer's. For the DC, that is the percentage of neutral maps that show the Democrat carrying more districts than he or she carried in the enacted map. While the degree of divergence is always 100% in the anticipated direction for the MM, the results from the EG and DC vary considerably from as little as 1.2% (DC in 2010 race for State Treasurer) to 100% in multiple elections. Table 2 distills this information as a scorecard reporting whether each test indicates a Republican gerrymander distinct from the neutral maps. Chen and Rodden are not explicit about how much overlap between the enacted map and neutral maps is permissible to determine whether a gerrymander has occurred, so we adopt a sliding three-category standard: 100% divergence, 95% divergence, and 75% divergence. Obviously, the MM is the only metric to detect a Republican gerrymander in every race and at every confidence level. The EG shows a Republican gerrymander distinct from the neutral maps in between 31% (100% divergence) and 69% (75% divergence) of elections and DC shows one between 31% and 38% of elections. The most noteworthy aspect of these results is that the EC and DC tend to find gerrymanders or not in the same elections. When the Democratic candidate wins by a relatively narrow margin (i.e., not Obama in 2008), both show Republican gerrymanders. When the Republican candidate wins, neither finds one except (occasionally) at the most forgiving confidence level. We return to this matter of conditionality

Table 1. Summarizing the Results of the Neutral Maps for the Efficiency Gap, Victory Count, and Median–Mean Comparison Across 13 Statewide Elections in Wisconsin.

Efficiency gap					Victory count—no. districts carried by Dem			Median mean		
Election	Dem % statewide	Observed enacted map	Neutral map mean (minimum, maximum)	Overlap: % neutral > enacted	Observed enacted map	Neutral map mean (minimum, maximum)	Overlap: % neutral < enacted	Observed enacted map	Neutral map mean (minimum, maximum)	Overlap: % neutral > enacted
Presidential 2008	57.06	–6.83	−10.41 (–16.70, –4.93)	[a]	72	75.09 (70, 81)	9.60%	3.84	1.13 (–0.43, 2.83)	0.00%
Senate 2010	47.55	13.84	11.84 (5.91, 16.86)	8.84%	33	33.77 (29, 40)	20.40%	5.76	2.80 (0.99, 4.28)	0.00%
Governor 2010	47.08	11.97	12.03 (5.87, 18.16)	49.83%	34	32.64 (26, 39)	70.04%	4.94	2.72 (0.87, 4.45)	0.00%
Attorney General 2010	42.17	15.63	13.97 (8.96, 18.79)	10.88%	20	20.75 (16, 26)	15.16%	5.15	2.80 (1.27, 4.18)	0.00%
Secretary of State 2010	51.66	12.57	2.43 (–4.61, 9.64)	0.00%	43	52.18 (45, 59)	0.00%	4.65	1.60 (0.04, 3.57)	0.00%
Treasurer 2010	46.53	11.12	13.10 (7.34, 18.76)	88.28%	34	30.68 (25, 37)	95.79%	4.99	2.45 (0.89, 4.34)	0.00%
Governor recall 2010	46.58	11.86	10.55 (4.80, 16.46)	18.34%	33	33.06 (27, 39)	35.93%	6.33	3.86 (1.74, 6.19)	0.00%

(continued)

Table 1. (continued)

Efficiency gap					Victory count—no. districts carried by Dem			Median mean		
Election	Dem % state-wide	Observed enacted map	Neutral map mean (minimum, maximum)	Overlap: % neutral > enacted	Observed enacted map	Neutral map mean (minimum, maximum)	Overlap: % neutral < enacted	Observed enacted map	Neutral map mean (minimum, maximum)	Overlap: % neutral > enacted
Presidential 2012	53.46	15.01	2.29 (–4.56, 8.65)	0.00%	43	55.24 (49, 62)	0.00%	5.24	2.15 (0.19, 4.03)	0.00%
Senate 2012	52.85	12.68	1.03 (–4.97, 7.94)	0.00%	44	55.08 (48, 61)	0.00%	4.17	1.97 (0.42, 3.72)	0.00%
Governor 2014	47.17	11.1	9.98 (4.38, 15.92)	23.60%	35	34.92 (29, 41)	40.61%	5.84	3.15 (1.37, 4.98)	0.00%
Attorney General 2014	46.87	10.53	10.03 (4.28, 15.53)	35.75%	35	34.24 (29, 40)	56.04%	5.45	2.96 (1.22, 4.73)	0.00%
Secretary of State 2014	51.97	13.39	4.31 (–1.82, 11.65)	0.00%	43	51.13 (44, 57)	0.00%	4.79	2.22 (0.46, 4.15)	0.00%
Treasurer 2014	47.86	11.09	9.51 (3.71, 15.62)	17.18%	37	37.31 (31, 43)	32.49%	5.3	2.44 (0.30, 4.46)	0.00%

Note. Overlap column can be understood as the % age of neutral maps in which Democratic candidate fared better than he or she did in enacted map.

[a]Potential Democratic gerrymander.

Table 2. A Scorecard: Is Wisconsin's Assembly Map a Republican Gerrymander?.

	Efficiency gap			Victory count			Median–mean		
Election	100%	95%	50%	100%	95%	50%	100%	95%	50%
Presidential 2008	No[a]	No[a]	No[a]	No	No	Yes	Yes	Yes	Yes
U.S. Senate 2010	No	No	Yes	No	No	Yes	Yes	Yes	Yes
Governor 2010	No	No	No	No	No	No	Yes	Yes	Yes
Attorney General 2010	No	No	Yes	No	No	Yes	Yes	Yes	Yes
Secretary of State 2010	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Treasurer 10	No	No	No	No	No	No	Yes	Yes	Yes
Governor recall 12	No	No	Yes	No	No	No	Yes	Yes	Yes
Presidential 2012	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
U.S. Senate 2012	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Governor 14	No	No	Yes	No	No	No	Yes	Yes	Yes
Attorney General 14	No	No	No	No	No	No	Yes	Yes	Yes
Secretary of State 14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Treasurer 14	No	No	Yes	No	No	No	Yes	Yes	Yes
Percent of races indicating gerrymander	31%	31%	69%	31%	31%	54%	100%	100%	100%

Note. Italics indicates race won by Democrat.
[a]Potential Democratic gerrymander.

in the next section when we discuss the measurement qualities of all three metrics examined here.

Finally, what of the natural and unnatural gerrymander? As we have noted, many defendants and judges would distinguish between vote dilution caused by the residential geography as opposed to mapmakers, and the plaintiffs often introduce evidence on mapmakers' intent to produce advantage at the expense of some voters.[28] If the EG and MM observed in the enacted map is the total bias of the status quo and the EG and MM in the neutral maps represent the bias from residential geography, then the effect of the map itself is the difference between the two. Figure 5 depicts this calculation via a line graph with hash marks for each election. The solid line in each panel represents the EG and MM observed in the enacted map, and the dashed line is the *mean* EG and MM obtained from the neutral maps (a more forgiving standard than any in Table 2). The shaded area between zero and the dashed line thus reflects the natural gerrymander, while the striped area between the dashed and solid line represents the unnatural gerrymander. The EG again shows

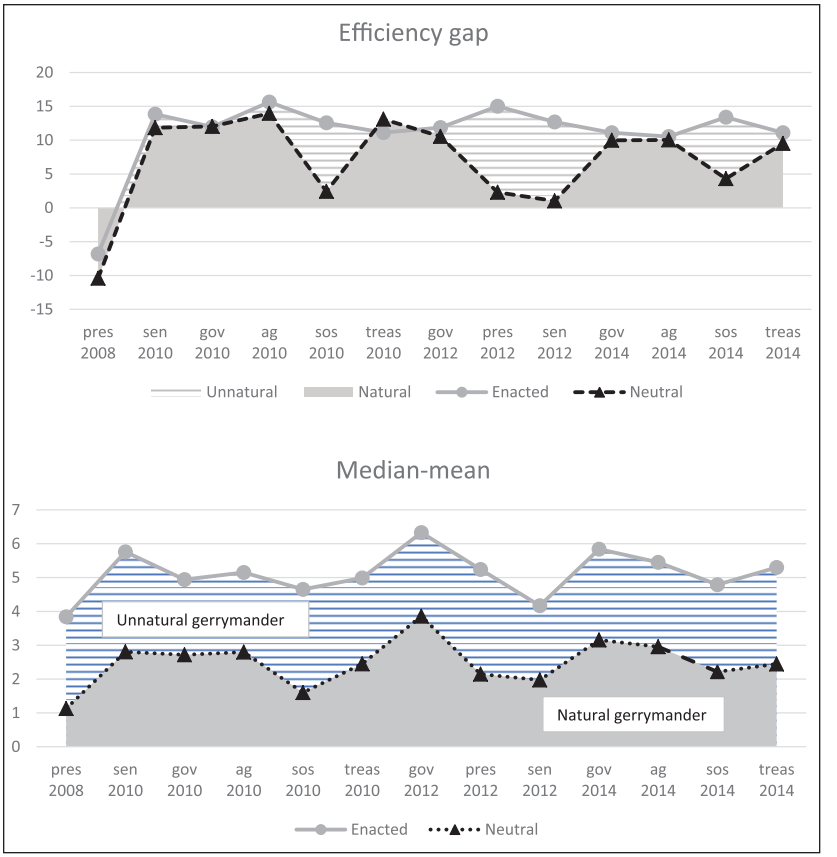

Figure 5. The "unnatural gerrymander" layered on top of the natural gerrymander.

uneven support for the notion that the Legislature's actions further dilute the weight of Democrats' votes beyond residential geography. In most elections, the total bias of the enacted map is barely distinguishable from the neutral mean. Only in the four Democratic victories smaller than Obama's margin in 2008 is there sign of a substantial pro-Republican bias clearly produced by the map itself.

By contrast, the MM reveals that the enacted map by itself does substantially dilute the voting strength of Democrats in every race. The MM in the enacted map ranges from 3.84 to 6.33 points and the mean in the neutral maps ranges 1.13 to 3.86 points. The difference between the two, the unnatural

gerrymander in the striped area in the second panel of Figure 5, varies from 2.20 (the 2012 Senate election) to 3.09 points (the 2012 presidential election). Thus, the Legislature's map has the effect of giving Republicans an additional 2.5% of the vote, approximately, in the battle to win control of the Wisconsin State Assembly. This is a significant hurdle for Democratic voters in Wisconsin for, coupled with the natural gerrymander, it means that they must produce a landslide there to win control of the State Assembly. In contrast, Republican routinely prevail in a majority of seats with a minority of votes.

Is Wisconsin's Assembly Map a Republican Gerrymander?

As we can see from Table 2, the answer to this question depends on which measure of gerrymandering is used. The EG and DC suggest a Republican gerrymander in Wisconsin may be evident in elections won by the Democrat, but not in elections won by the Republican. On a certain level, this makes sense for it suggests that the Legislature's map protects Republicans in the event of a Democratic victory while providing little help to the party when its candidate wins. That is certainly a more nuanced argument than the one normally made that gerrymanders systematically benefit one party or its voters. It also suggests that any dilution of Democratic votes is situational depending on how the voters behave. Only the MM finds that Wisconsin's Assembly districts are a Republican gerrymander in every election and in every test. Given judges' reluctance to intervene in political gerrymandering, we are skeptical that plaintiffs will succeed if they are only able to say that electoral arrangements are *sometimes* unfair to them.

This divergence in empirical results seems noteworthy given that all three measures implicitly capture some version of "vote dilution." The EG categorizes votes by the binary decision rule of whether they are wasted or not. An efficiency imbalance occurs when one side squanders far more votes than does the other, suggesting greater dilution of their ballots.[29] The DC and the MM treat vote dilution as the value of partisans' votes relative to some outcome. For the DC, the outcome is the number of seats won versus expected victories from a neutral process. Votes are aggregated by district, effectively making the district the unit of analysis. The outcome of interest for the MM is control of the legislature, making the median district vitally important. By comparing the partisan median and mean, the MM's unit of analysis remains voters. We would argue that focusing on voters is superior both for legal (the 14th Amendment claim being made) and empirical reasons (the direction of coding does not flip at 50%).

The ultimate question, however, is which of these measures ought to be believed. Before answering that, we address two issues about the neutral maps which play such a large role in our conclusions. First, we return to the matter of whether our maps should be regarded as a valid counterfactual. The State and Chen (2017) emphasized attributes about their map or maps which we ignored in creating our comparison set, including race, jurisdictional wholeness, and compactness. Race is a less of a concern in Wisconsin with its overwhelmingly White population (89%) than it is elsewhere. Nonetheless, the algorithm we use should produce a significant number of majority–minority districts due the high concentration of minority voters in neighborhoods north (Black) and south (Latino) of I-94 in Milwaukee (Magleby & Mosesson, 2018).[30] The State and Chen both pointed to the number of municipalities and counties kept whole in their map or maps. However desirable keeping municipalities and counties within the same Assembly district may be, wholeness is not a legal requirement in Wisconsin.[31] Nor is it evident what difference this would make to these analyses, even if we knew which jurisdictions to keep whole.[32] Compactness is not a legal requirement in Wisconsin either, nor do statutes or case law provide a single metric for measuring it.[33] Magleby and Mosesson (2018) note that compact districts are a likely by-product of their algorithm, although irregular shapes and juts cannot be ruled out in the effort to balance population. Finally, to the extent we can compare them, our maps and Chen's appear similar. He finds that Mitt Romney would have carried between 38 and 47 Assembly districts in his 200 maps compared with between 37 and 50 in our 10,000; his maps yield EGs ranging from approximately −3 to 6 (reading from figures) while ours range from −4.56 to 8.65. In short, we have no reason to suspect the 10,000 neutral maps we evaluate are either deficient or much different than Chen's.

Second is the matter of incorporating neutral maps into the analysis of Wisconsin's Assembly districts. A comparison set is a necessary component to the DC's method of detecting bias, but not for the EG and MM. As the neutral maps create such difficulties for the EG, why incorporate them at all? In a generic sense, we believe it is appropriate to evaluate a measure in as many settings as possible. Moreover, the neutral maps provide added value by approximating the effect of residential geography, allowing assessment of the State's claim that the enacted map merely reflects where Wisconsinites choose to live. While we do not endorse the principle that vote dilution from residential geography is acceptable where fairer arrangements are accessible, the courts have made the distinction between what we have called the natural and unnatural gerrymanders. Indeed, Judge Griesbach objects that the plaintiffs do "not adequately account for Wisconsin's political geography, which

naturally 'packs' large numbers of Democrats into urban areas like Madison and Milwaukee, resulting in hundreds of thousands of 'wasted' votes in inevitable landslide Democratic victories for assembly candidates" (p. 121). The neutral maps allow us to account for that political geography. Furthermore, the plaintiffs themselves refer to Chen's alternative maps in arguing for the EG, but Chen only examines the 2012 presidential elections with its cooperative results. As we have shown, other elections yield different results for both the EG and DC measures.

If the data and empirical tests here are appropriate, the question whether Wisconsin's Assembly map is a gerrymander boils down to which measure is most reliable. The goal of any tool designed to detect gerrymandering is to capture the partisan bias created by the way the votes are aggregated *without* picking up other electoral characteristics. The notion that a measure measures only what it is meant to measure is axiomatic. Otherwise, it risks being confounded by other factors, like a thermometer that also detects barometric pressure. It is potentially significant that the EG and DC exhibit the same pattern of results, tending to find that modest Democratic wins look like Republican gerrymanders while Republicans victories do not. This pattern raises the question whether both measures are capturing more than partisan bias.

There is ample reason to believe so for the components that build both measures are conditional on which party carries a district. This is obvious for the DC with its binary coding of wins and losses, but it also applies to the EG. For example, in a contest where the Democrat wins 51 votes and Republican wins 49, the disparity in wasted votes is enormously favorable to the Democrats (one wasted Democratic vote vs. 49 wasted Republican ones). If two Democratic voters change their minds and support the Republican, the disparity is now equally favorable to the Republican. Indeed, the EG goes substantially farther than the DC by using the difference in each party's wasted votes. In the pair of 51 to 49 examples above, the DC would have the Democrats winning 1 or 0 districts while the EG has a disparity in wasted votes as either +48 or −48. These sign flips account for the jaggedness in the histograms of the EG in Figures 1 and 2; the EG grows and shrinks as districts change hands. It also explains why the enacted map looks like a Democratic gerrymander when analyzed with the 2008 presidential returns. Obama's victory was broad enough to carry what in all other elections look like marginally Republican districts, turning the difference in wasted votes in Democrats' favor. We expect the EG to indicate the Assembly map is a Democratic gerrymander in any election the Democrat wins approximately 55% or more of the statewide vote—or when the Republican wins approximately 60% or more.[34]

Thus, both measures are susceptible to big changes from small movements in the vote near 50% in a district, suggesting that any map with a number of competitive districts will produce unstable results. That is exactly what appears to be happening here with the EG and DC. As we note, the 4-point difference in vote share in the 2014 contests for Secretary of State and State Treasurer triggers large shifts in the EG and DC obtained from the neutral maps. This occurs because Wisconsin is so politically competitive that the computer produces enough districts close enough to the 50-50 tipping point that a small shift in the vote moves a relatively large number of districts to the other party's column. When that happens, the EG in individual districts flips signs and the DC goes from 0 to 1, leading to big movements in both measures. Beyond capturing vote dilution, it is clear that both measures also pick up electoral performance, rendering them unreliable at detecting gerrymanders.[35] Presumably both would do better in uncompetitive states like Texas or California, but majority rule is rarely threatened in those places. Given these measurement properties, we would not use either metric to argue for or against a gerrymander. Other scholars have raised similar doubts about the EG in particular (Cho, 2017; Cover, 2018).

Does the MM fare better? Should we be suspicious that it is prone to discover gerrymanders, given it finds substantial dilution of Democratic votes in the enacted map across all 13 elections? This concern cannot be addressed from a single case. We expect similar results from analyzing the same maps, but consistency does not indicate whether those results are consistently right or wrong. Elsewhere we have analyzed legislative districts in other states and are reassured the MM in not prone to detect gerrymanders (Best, Donahue, Krasno, Magleby, & McDonald, 2017).[36] The fact it detects one in Wisconsin seems unsurprising given the array of evidence that Wisconsin's Assembly map actually is a gerrymander: the peculiar and secretive process by which the map was created,[37] the admission of several leading Republicans of partisan intentions while drawing the map,[38] Democratic candidates' failure to carry a majority of Assembly seats in circumstances short of a landslide, and so on. Still, it is circular reasoning to proclaim the MM finds the Wisconsin Assembly map is a Republican gerrymander because the map is a Republican gerrymander, no matter how much we may suspect that is true.

The best internal evidence of the MM's reliability in this single case comes from what the neutral maps say about the natural gerrymander in Wisconsin. We know that a natural gerrymander exists where there are high concentrations of Democratic voters in large cities. The same conditions exist in Wisconsin according to both sides in the litigation, and the MM finds a natural gerrymander whose mean across 10,000 maps is between 1.13 and 3.86

percentage points in all 13 races there. Thus, the MM confirms what everyone argues is present in Wisconsin, a modest yet important Republican advantage in legislative elections from the natural packing of Democratic voters. It also lends credence to our estimates that Legislature's map adds another 2.20 to 3.09 points of pro-Republican bias beyond the effect of residential geography. The MM exhibits the qualities expected in a measure by providing stable and sensible estimates of both components of a gerrymander across a relatively wide range of elections.

Ultimately, the MM stands or falls on its logic that gerrymandering skews the way votes are aggregated toward the goal of winning control of a legislature. That is not to say that mapmakers conceive of gerrymandering in statistical terminology like skew, distribution, median, or mean. These terms become relevant for the precision they bring in evaluating the degree of vote dilution in a map. This is evident in Wisconsin when we look separately at the district-level partisan mean and median in the enacted and neutral maps. The mean in all these maps tracks the statewide result closely; when a Democrat wins 47% or 52% of the vote statewide, her mean vote across 99 Assembly districts is around 47% and 52% in all maps. There is little that would-be gerrymanders could do to manipulate that result so long as the districts are relatively equal in population. The median, however, is a different story. Packing Democratic voters makes the remaining districts more Republican on average, thus shifting the probable location of the median. The partisan median in the enacted map is substantially more Republican than the median in any of the 10,000 alternative maps we produced in every election we examine. The end result is a nearly insurmountable advantage for Republicans in the battle to control the State Assembly; the Democrats must win about 55% or more of the vote statewide to carry a majority of districts while Republicans need only win 45% or more. This is an arrangement that routinely gives a minority of voters control over an important branch in state government, a form of entrenchment that insulates the GOP from the normal processes of democratic change.

We conclude that the *Whitford* plaintiffs are correct that Wisconsin's Assembly districts systematically dilute the weight of ballots cast by Democratic voters versus Republican voters. The vote dilution we observe is substantial, persistent, and created mainly from the Legislature's map. The fact that the best evidence for their case comes from material not presented at trial is unfortunate. The fact that their evidence at trial could be used both to undermine and support their case is ironic. No matter what was presented at trial, their claim remains demonstrably true. From our perspective, it is clear both that gerrymanders can be detected and that Wisconsin's Assembly map is a fairly substantial Republican gerrymander that directly harms Democratic voters in that state.

Appendix

Voting Behavior in Wisconsin's Statewide Elections

Table A1 shows the results of the 13 statewide elections conducted in Wisconsin in the two election cycles before and after the 2011 redistricting, including the number of current Assembly districts carried by the Democrat in each race.

Table A2 shows the ward-level correlation in the Democratic vote in these statewide elections. Despite the range of results and the 6-year time period, the correlations are high throughout every pair of races: the average correlation is .939 and only dips below .9 in three pairs of elections. The results demonstrate that partisan voting patterns in Wisconsin are remarkably stable—a fact that mapmakers who analyzed their work using returns from previous elections counted on in drawing Wisconsin's Assembly districts.

Table A1. Summary Information About 13 Statewide Elections in Wisconsin From 2008 to 2014.

Election	Democratic vote	Republican vote	Democratic % age	Number of districts carried by the Democrat (of 99)
Presidential 2008	1,677,112	1,262,318	57.06	72
Senate 2010	1,020,895	1,125,944	47.55	33
Governor 2010	1,004,242	1,128,885	47.08	34
Attorney General 2010	890,021	1,220,729	42.17	20
Secretary of State 2010	1,074,054	1,005,165	51.66	43
Treasurer 2010	958,410	1,101,264	46.53	34
Governor recall 2010	1,335,585	1,164,480	46.58	33
Presidential 2012	1,620,985	1,410,966	53.46	43
Senate 2012	1,547,104	1,380,126	52.85	44
Governor 2014	1,120,559	1,255,053	47.17	35
Attorney General 2014	1,064,633	1,206,968	46.87	35
Secretary of State 2014	1,158,498	1,070,809	51.97	43
Treasurer 2014	1,024,238	1,116,012	47.86	37

Table A2. Ward-Level Correlation in the Democratic Two-Party Vote in Wisconsin's Statewide Elections From 2008 to 2014.

	Presidential 2008	Senate 2010	Governor 2010	Attorney general 2010	Secretary of state 2010	Treasurer 2010	Governor recall 2012	Presidential 2012	Senate 2012	Governor 2014	Attorney general 2014	Secretary of state 2014	Treasurer 2014
Presidential 2008		.945	.94	.926	.942	.94	.885	.935	.929	.894	.903	.915	.915
Senate 2010	.945		.987	.969	.97	.976	.921	.937	.929	.927	.932	.931	.932
Governor 2010	.94	.987		.969	.966	.975	.927	.937	.93	.93	.935	.93	.933
Attorney General 2010	.926	.969	.969		.945	.978	.915	.925	.921	.916	.924	.912	.92
Secretary of State 2010	.942	.97	.966	.945		.969	.895	.925	.921	.903	.909	.925	.918
Treasurer 2010	.94	.976	.975	.978	.969		.913	.935	.933	.919	.926	.928	.928
Governor recall 2010	.885	.921	.927	.915	.895	.913		.939	.933	.962	.954	.931	.942
Presidential 2012	.935	.937	.937	.925	.925	.935	.939		.98	.952	.952	.952	.954
Senate 2012	.929	.929	.93	.921	.921	.933	.933	.98		.945	.952	.956	.957
Governor 2014	.894	.927	.93	.916	.903	.919	.962	.952	.945		.986	.968	.979
Attorney General 2014	.903	.932	.935	.924	.909	.926	.954	.952	.952	.986		.976	.985
Secretary of State 2014	.915	.931	.93	.912	.925	.928	.931	.952	.956	.968	.976		.984
Treasurer 2014	.915	.932	.933	.92	.918	.928	.942	.954	.957	.979	.985	.984	

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Notes

1. Vote dilution is the central element in gerrymandering. For instance, Justice Scalia cites the definition from the 1999 edition of *Black's Law Dictionary* in Vieth (2004): "[t]he practice of dividing a geographical area into electoral districts, often of highly irregular shape, to give a political party an unfair advantage by diluting the opposition's voting strength" (p. 271, n. 1). The *Whitford* plaintiffs invoke the 14th amendment by arguing the harm is experienced by individual voters as opposed to focusing on political parties themselves, a savvy move given that individuals have traditionally received more constitutional protection. We return to the question of what a diluted vote is in the conclusion.
2. The plaintiffs also offer a brief examination of the partisan symmetry standard (King & Grofman, 2007) in their trial brief to confirm the findings of the efficiency gap (EG). We discuss partisan symmetry as well as several other measures which played no role in the case elsewhere (Best et al., 2017).
3. For instance, in *Davis v. Bandemer*, 478 U.S. 109 at 132-133, Justice White in a plurality opinion wrote, "An equal protection violation may be found only where the electoral system substantially disadvantages certain voters in their opportunity to influence the political process effectively. In this context, such a finding of unconstitutionality must be supported by evidence of continued frustration of the will of a majority of the voters or effective denial to a minority of voters of a fair chance to influence the political process."
4. Gerrymanders may not be detectable in landslides where the normal patterns of voting are substantially disrupted.

5. This treatment of the winner's wasted votes is a peculiarity noted Judge Griesbach who observes that it is the equivalent of suggesting that the Indians need one more run than half the total they and the Cubs scored together as opposed to simply one more run than the Cubs scored (Griesbach, p. 150). This would seem to make more sense for exactly the reason Judge Griesbach observes: in elections, as in baseball, the winner needs only to surpass the loser. More important, this formulation appears to underestimate the winner's wasted votes. Later work by McGhee (2016) acknowledges that adjustments in how the EG is calculated might be necessary. There is no consensus among the few other academics who have used the concept of waste. Hacker (1964) defines votes wasted by winning candidates as those exceeding the loser's total, while Campbell (1996) says only the losers' votes are wasted.
6. McGhee (2014) is explicit about the assumption of equal numbers of votes cast when he derives this function in an appendix: "When there are only two parties and each district has exactly the same number of voters, proportions can be substituted for raw votes in all of the formulas" (p. 79). Stephanopoulos and McGhee (2015) only mention the requirement that "all districts are equal in population" (p. 853) and note that equality is constitutionally required. Their Figure 1 which shows how the EG is calculated has 10 districts with exactly 100 votes in each.
7. One of the plaintiff's experts, Prof. Simon Jackman, used this "simplified method" to calculate the EG in Wisconsin and elsewhere while another expert, Prof. Ken Mayer, used the "full method." Their results for the 2012 presidential election in Wisconsin differed by 3 percentage points (Whitford decision, p. 82).
8. Republicans have somewhat openly conceded partisan motivations in the *Whitford* and also in litigation in Virginia (*Page v. Virginia State Bd. of Elections*, 2015 WL 3604029, *19 (ED Va., June 5, 2015), appeal dismissed sub nom. *Wittman v. Personhuballah*, 136 S. Ct. 1732, 2016), Alabama (*Alabama Legislative Black Caucus v. Alabama*, 575 U. S. ___, 2015), and North Carolina (*Harris v. McCrory*, No. 1:13-cv-949, 2016 U.S. Dist. LEXIS 14581 (M.D.N.C. Feb. 5, 2016), *probable jurisdiction noted*, 136 S. Ct. 2512, 2016).
9. Justice White wrote, "Our cases, however, clearly foreclose any claim that the Constitution requires proportional representation, or that legislatures in reapportioning must draw district lines to come as near as possible to allocating seats to the contending parties in proportion to what their anticipated statewide vote will be." He referred back to *White v. Regester*, 412 U.S. 765, 765-766 (1973) and *Whitcomb v. Chavis*, 403 U.S. 156, 160 (1971).
10. The two judges who held for the plaintiffs, Judges Kenneth F. Ripple and Barbara B. Crabb have a different take. "To say that the Constitution does not require proportional representation is not to say that highly disproportional representation may not be evidence of a discriminatory effect. Indeed, acknowledging that the Constitution does not require proportionality, Justice Kennedy observed in *LULAC* that 'a congressional plan that more closely reflects the distribution of state party power seems a less likely vehicle for partisan discrimination than one

that entrenches an electoral minority.' 548 U.S. at 419 (opinion of Kennedy, J.). We do not believe, therefore, that the Constitution precludes us from looking at the ratio of votes to seats in assessing a plan's partisan effect."

11. The number of districts carried will end up being a range because each computer-generated map is a separate observation.
12. The lineage of this simple calculation as an aspect of fair districting can be traced as far back as a late-19th century analysis by Edgeworth (1898). Its connection to gerrymandering can be traced at least to David Butler's analysis of electoral bias in mid-20th century British general elections (Butler, 1951). The same comparison has been used in later work to provide the same check (e.g., Butler, 1952; Erikson, 1972).
13. McDonald and Best note that there are separate tests to detect cracking and turnout bias, which together with their measure of differential packing offer a comprehensive method for evaluating potential gerrymanders.
14. The exception would be a gerrymander that exclusively cracks a population by, for instance, dividing a 52% Democratic state into ten 52% Democratic districts. In that case, there would be no skew in the distribution of partisans and there would also be no evidence of dilution of the weight of Republican votes. Republicans' complaint about such an arrangement would be based on their inability to achieve "effective" representation ala *Reynolds v. Sims*, 377 U.S. 533 (1964).
15. The Court's concern about control of the legislature is expressed in many places, including *Bandemer* (at 133): "such finding of unconstitutionality must be supported by evidence of continued frustration of the will of a majority of voters."
16. June 2012 also featured a separate recall election for the Lt. Governor. Normally, Governor and Lt. Governor run as a team, but both were individually subject to recall. Given these unusual circumstances and nearly identical results, we only examine the gubernatorial recall.
17. The most heavily used repository of election data with shape files is Election Data Archive Dataverse at Harvard University which contains information for a number of states painstakingly gathered over a several-year period. See https://dataverse.harvard.edu/dataverse/eda.
18. We tested these estimates by deriving our own using a similar procedure as the described by Wisconsin's analysts. The comparisons showed little difference between our numbers and the State's.
19. The Census Bureau has information for approximately 500 more blocks than are in the Wisconsin files, but they appear to be areas covering water with no population.
20. The possibility of using computer-generated maps to evaluate districts was first suggested by Nobel Laureate economist William Vickrey in 1961. A number of scholars have attempted to follow up on his recommendation, including Cirincione, Darling, and O'Rouke (2000), Altman and McDonald (2009), Chen and Cottrell (2016), Chen and Rodden (2013b, 2015), Cho and Liu (2016), and Cho (2017). All appear to show the same analytic approach to the problem. Altman and McDonald

have provided an open-source statistical package, BARD, to allow others to produce districts (2009).

21. Chen (2017), by comparison, discusses an alternative set of 200 maps of Wisconsin Assembly districts. He and Rodden offered testimony about 1,000 maps in Florida, while Darling produced 5,000 maps in the trial phase in the same litigation (*League of Women Voters v. Detzner*, 188 So.3d 68 (Fla. 2016)). Chen, Rodden, and Darling all used voting tabulation districts (VTDs). Census blocks add substantial complexity to the process of producing districts, but they are the building blocks from which districts are created.
22. These two tests are proposed by Altman et al. (2015) and Fifield et al. (2017). As the underlying universe of possible maps is unknown, both sets of authors offer stylized examples of small jurisdictions with which to appraise the bias of mapping algorithms.
23. Maps are generated as lists of component census blocks, so testing for uniqueness is straightforward. Like the courts, we adopt the principle of "point contiguity" where two areas may be connected by a single point. The element insuring contiguity is an adjacency matrix of census blocks and their neighboring blocks. We regenerated this matrix multiple times to look for variations and rendered a random sample of maps to inspect by eye. Examples of these maps are available upon request.
24. A set of 10,000 unique maps will return a range of results on any given measure, including some maps that might appear to be gerrymanders. Theoretically, the larger the number of these maps, the more likely it is that resulting distribution should appear normal with a visually discernable median and mode and a decreasing number of observations farther from the mode.
25. Chen and Rodden (2013b) present a method of measuring the natural gerrymandering using neutral maps. As their method of detecting gerrymanders (the districts carried [DC]) produces such mixed results below, we do not attempt to replicate their calculations of the natural gerrymander.
26. For instance, in *League of Women Voters v. Detzner* (Fla. 2016), the State of Florida argued that its districts merely reflected the residential geography of the state using Chen and Rodden's (2013a) earlier analysis of the state as its proof.
27. Adam Foltz and Tad Ottman, who were legislative aides, admitted at various points that they used the 2008 election to assess the partisanship of proposed Assembly districts. This race was also considered in the analysis of the General Assembly's consultant, Professor Ronald Keith Gaddie of the University of Oklahoma.
28. For example, the *Whitford* plaintiffs introduced evidence on the intent of Republican legislators in drawing these lines, including the fact that those drawing the districts were using names for the plans such as "Adam Assertive" and "Joe Aggressive" to describe their partisan lean. The map team carefully assessed the anticipated bias using a variety of methods, eventually producing a color-coded chart to reflect each district's lean under various conditions. This chart was reproduced in the circuit panel's opinion in *Gill v. Whitford* (p. 117).

29. It is noteworthy that Stephanopoulos and McGhee's coding leaves 75% to 25% as the only perfectly balanced outcome within a single district as each side wastes 25% of the votes cast. The farther the vote departs from 75% to 25%, the greater the imbalance. We explore the ramifications of this formula, especially the sign flip that occurs at 50-50 (see below), in another paper.
30. In *Baldus v. Members of Wisconsin Government Accountability Board*, 849 F. Supp. 840 (E.D. Wisc. 2012), a three judge panel found two districts (AD-08 and AD-09) in the southern part of Milwaukee County to have violated the Voting Rights Act by diluting Hispanic votes. These districts were redrawn, but did not affect any others in the state.
31. Article IV, Section 4 of the Wisconsin Constitution (1982) states, "such districts to be bounded by county, precinct, town or ward lines, to consist of contiguous territory and be in as compact form as practicable." However, Atty. Gen. Opinion 58-88 has rendered previous state interpretation to prohibit splitting of counties negatory.
32. Chen (2017) speculates that a key difference between the enacted map and his alternatives is the number of counties kept whole (14 and 18, respectively). But the counties involved are relatively unpopulated, constituting just 4% (the state's 14 counties) and 5% (Chen's 18) of Wisconsinites.
33. Niemi et al. (1990) considered several different measures for compactness, among them dispersion, perimeter, and population. In *Wisconsin State AFL-CIO v. Election Board*, 543 F.Supp. 630 (E.D. Wisc. 1982), the court found that compactness was subservient to the overall objective of population equality.
34. There are two ways to think about this. In a GOP landslide, the party's increasing margin in Republican and marginal districts increases the number of votes it wastes in these districts. Or, the packing of Democrats into a handful of overwhelmingly partisan districts makes it impossible for the winning Republican to carry as many districts as her popular vote count suggests she should.
35. To express the statistical relationship between Democratic performance and the EG and DC measures in more rigorous and familiar terms, we regressed those measures on the Democratic statewide vote and a dummy variable for the Obama landslide in 2008 using the neutral maps. The expectation, of course, is that the Democratic vote should have little or bearing on a variety of dependent variables such as the size of the EG, an array of binary variables indicated whether a Republican gerrymander is detected or not (e.g., EG > 8, EG > observed EG in enacted map, and DC > observed DC in enacted map). No matter the specification, the coefficient associated with statewide Democratic performance is always sizable and statistically significant. We explore this topic in greater detail, especially for the EG, in another paper underway.
36. For example, we find that Iowa's State Senate districts are not a gerrymander using the median–mean (MM), a noteworthy departure from the EG which exceeds 8% in more than 60% of statewide races conducted in the current redistricting cycle.
37. Republicans in the Wisconsin Legislature had tried to assert attorney-client and legislative privilege in order shield communications and documents from the

public. They were repeatedly denied on this point by the three judge panel in *Baldus v. Members of the Wisconsin Government Accountability Board* (2012), which was comprised of two Republican judges and one Democratic judge. They found that privilege did not exist as this involved those hired at taxpayer expense. At one point, the Court became so displeased with the attorneys for the Wisconsin Legislature not complying with their orders that they issued sanctions against them.

38. Judge Griesbach writes: "I begin with a point upon which I agree with my colleagues. It is almost beyond question that the Republican staff members who drew the Act 43 maps intended to benefit Republican candidates. They accumulated substantial historical knowledge about the political tendencies of every part of the state and consulted with Dr. Ronald Gaddie to confirm their predictions about voting patterns. Though they denied the suggestion that such information was used to project future voting tendencies, my colleagues rightly conclude that when political staffers compile historical voting information about potential districts, their claim that they did not intend to use that information to predict future voting patterns is hardly worthy of belief. After all, these individuals are not operating under even the pretense that they are nonpartisan: they are employed by Republicans in leadership and draft district maps at their direction. That they would resort to partisan considerations in drawing the maps is therefore anything but surprising" (p. 121).

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