Reverse Gerrymandering Index:
An Analysis of US House Elections from 1872 to 2022

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Abstract:

This paper presents a new measure of gerrymandering, called the Reverse Gerrymandering Index (RGIx), and uses it to analyze the evolution of packed districts in the US House of Representatives from 1872 to 2022. Unlike the efficiency gap and partisan symmetry measures, which are influenced by vote variation across the entire state, the mainstay of RGIx is that it estimates the gerrymandering level of each district by comparing its partisan vote distribution with the partisan vote distribution of the districts adjacent to it. From there, RGIx can be used to identify highly gerrymandered districts, measure regional or historical variation in gerrymandering, or as a variable in statistical models, to name just a few applications. It can also calculate gerrymandering scores for an unlimited number of parties per district, making it applicable to comparative electoral systems research. In this paper, I use RGIx to show that there were few packed congressional districts for nearly a century after the American Civil War, that gerrymandering began rising rapidly in federal elections in the 1960s, and that it began to shift dramatically in a pro-Republican direction starting in the 1980s.

In 1812, in response to legislative districts drawn by Massachusetts Jeffersonian Republicans, led by then Governor Elbridge Gerry, a newspaper cartoon was published depicting one of these districts as a salamander and calling it a "Gerry-Mander." Funny and memorable, the name stuck. To this day, in the US and internationally, and both within public discourse and in political science literature, drawing district lines for political gain is called gerrymandering. Specifically, a partisan gerrymander is when district lines are drawn so that supporters of one major party are packed into a small number of districts or diluted across many districts so that the other major party wins a higher percent of legislative seats.

As effective as the cartoon was, it also emphasized a characteristic that might have hindered our analysis of this phenomenon. Gerrymandering in this context is assumed to be when a district is drawn oddly for political gain. While a "normal" district is supposed to be compact, looking more like a square or oval, a gerrymandered district is supposed to look like a salamander, duck, clam head, or squished insect. This idea also tacitly leads to another assumption common within the study of gerrymandering, that there are "fair" and "unfair" legislative districts. Unfair districts not only look abnormal; they are also drawn abnormally to distribute the vote in ways that hurts representation. Fair districts, in contrast, are compact. Moreover, these assumptions can lead to the tacit assumption that any form of electoral bias in the US is caused by gerrymandering—an assumption that Rodden (2019) clearly dispelled.

I would argue that these underlying assumptions about gerrymandering are a primary cause of problems within some prominent measures of gerrymandering. (1) Geographic measures like Polsby-Popper (Polsby and Popper 1991) treat lack of compactness as evidence of gerrymandering (except when there is an obvious reason that this is incorrect, in which the researcher is supposed to correct the data). I would argue that legislative districts can be geometrically compact and still be gerrymandered, such as by purposely drawing district lines around a small urban area that overwhelmingly supports one major party, even though neighboring areas have high support for another major party. (2) Measures that measure vote variations across districts, like the efficiency gap (Stephanopoulos and McGhee 2015), assume that all representation issues across an entire state are caused by gerrymandering, when gerrymandering is realistically possible only when there is partisan variation across legislative districts near each other. Differences in partisanship between districts in Manhattan and districts in upstate New York are never evidence of gerrymandering, for example.

But what if we reversed this salamander logic? Instead, of assuming that voters live in set locations and districts lines are drawn around them, *what if we conceptualize each district as a set of voters and gerrymandering as the switching of voters across adjacent districts for political gain*? For example, if there is a state with four congressional districts and roughly equal support between the Democratic and Republican parties, a gerrymandering strategy might be to put a large percent of those Democrats in one district while putting most Republicans in the other three districts, thereby leading to the Republican Party winning 75% instead of 50% of those four seats. However, this movement of voters is only possible when the districts are geographically close to each other. If four districts next to each other heavily support the same party, it becomes much harder to shift enough votes across districts to alter how many seats each party wins.

In this paper, I propose a new measure of gerrymandering called the Reverse Gerrymandering Index (RGIx) that is built on this logic. This measure simulates the reversing of gerrymandering by randomly shifting votes across adjacent districts. This shifting of votes effectively flattens the vote differences of districts next to each other but has no impact on districts that are in geographically different areas. This "flattened" value for each district then becomes an estimate of what the vote would have been had there been no gerrymandering. The difference between the actual vote and this "flattened" value is the RGIx score, an estimate of the level of packing in each district that can then be used for various forms of analysis. In this paper, I demonstrate this approach in more detail, including showing how it relates to graph theory, and then apply it to congressional elections from 1872 to 2022. As I will show below, RGIx demonstrates that there was little gerrymandering from the American Civil War through the first half of the twentieth century, that it began to rise rapidly in the 1960s, and that gerrymandering gained a distinctively pro-Republican bias starting in the 1980s. RGIx can also show detail in how these shifts occurred that go far beyond what most current measures are capable of.

Current Measures:

I would argue that current and existing measures of gerrymandering generally face two main problems. Many of them contain significant biases that weaken their ability to accurately measure gerrymandering. Some also require significant precinct or block level data that are often unavailable to researchers.

Political scientists generally conceptualize gerrymandering in terms of packing and cracking. District lines are often drawn in ways that pack a large percent of supporters of one party into a district, thereby leading to that party winning that one district by a high percent of votes but losing multiple neighboring districts by a small percent of votes. Cracking, on the other hand, is when district lines are drawn to dilute the supporters of a party across all districts, making it very difficult for that party to win any seats.

Many current methods of measuring gerrymandering capitalize on this logic. The Polsby-Popper method (Polsby and Popper 1991), for example, assumes that gerrymandered districts will be drawn oddly, and that geographically compact districts are the least gerrymandered. This method is surprisingly weak in several ways: (1) Districts are often non-compact for a wide range of reasons unrelated to gerrymandering, including if they are adjacent to bodies of water or state borders. (Researchers using this approach often spend considerable time "smoothing" district lines that follow state or natural borders, to compensate for this problem); (2) newer gerrymandering techniques, such as those used in Texas, are able to create districts that are both packed and geographically compact; and (3) the measure cannot handle single-district states, where gerrymandering is impossible, and therefore treats them as missing values. (4) Finally, Polsby-Popper and related gerrymandering measures based on the geographic shape of districts generally require scholars to acquire shape files of the districts and then use a programming language like R or Python to read those files and calculate the gerrymandering scores based on the data they contain.

Other measures focus on the votes themselves. An example is the efficiency gap measure (Stephanopoulos and McGhee 2015), which uses the notion of packing and cracking to estimate how many votes are "wasted" in districts across a state and uses that to estimate how gerrymandered these districts are. This measure has gained so much traction that it has been presented across major news outlets and even used in Supreme Court cases to argue against redistricting plans. However, I find this measure to be fundamentally flawed because it assumes that the only cause of "wasted votes" would be gerrymandering, even though the measure is influenced by both variations in turnout levels across districts and variations in the percent vote caused by nothing more than human geography. (For example, this measure treats partisan differences between districts in Atlanta and southern Georgia as gerrymandering, when an obvious cause might be demographic differences between urban and rural areas.)

Indeed, most measures that focus on variation of the vote across districts run into this issue: they do not distinguish between vote differences that could be caused by the manipulation of district lines and those that could be caused by geographic variation across districts. Chen and Rodden (2015), for example, present this as a critical reason why US Supreme Court justices rejected partisan symmetry (Gelman and King 1994; Grofman and King 2007) as a measure of gerrymandering. Partisan symmetry is based on the vote-seat curve, developed by Edward Tufte (1973). If the two-party vote across districts was shifted to exactly equal vote for both parties but one party still won more seats than the other, then the elections are biased in that winning party's favor. Certainly, gerrymandering could be one cause of electoral bias, but it is hardly the only possible cause. A very high percent of Democratic Party supporters living in urban areas like Manhattan could also create the same impact (Rodden, 2019), for example.

Another set of measures use the partisan composition of geographic subunits, like precincts, to run Monte Carlo simulations that randomly draw large numbers of possible combinations of district lines (Altman and McDonald 2011; Chen and Rodden 2015; Cirincione, Darling, and O'Rourke 2000; Fifield et al. 2020). This approach can estimate the probability that a particular level of gerrymandering would occur by chance, thereby potentially providing evidence against redistricting plans that are drawn explicitly to bias the results in one party's favor, and it can draw district lines without human interference. However, this approach also has limitations: (1) The method requires substantial subunit data that is not always available, especially for historical congressional and state legislative elections as well as for legislative elections in many countries. (2) Since the method is based on statistical simulation, the district lines drawn are often considered ad hoc and lacking theoretical grounding (Fifield et al. 2020). While this approach provides a useful test of existing redistricting plans when the necessary data is available, its ad hoc nature has made it less useful for actual redistricting than what its early proponents had envisioned (Vickrey 1961).

Additionally, I find that most current measures of gerrymandering are limited in their usefulness for either historical or comparative research. The Monte Carlo approach is often hampered for both comparative and historical research due to lack of subdistrict election data, for example. The geographic shape approach can indicate long-term, historical shifts in the compactness of legislative districts, for example, but cannot directly speak to questions of how much these shifts impact the relationship between voting behavior and electoral results, or how much these changes might be due to factors unrelated to partisan seat gains. Similarly, because they are based on the relationship between votes and seats of the top-two parties only, neither the efficiency gap nor partisan symmetry can be applied to multiparty electoral systems, nor can either identify which are the most packed legislative districts.

Reverse Gerrymandering Index:

RGIx approaches gerrymandering from a different angle. It begins with the argument that gerrymandering can impact only districts that are geographically near each other and that therefore any gerrymandering measure that focuses on the vote (as compared to how district lines are drawn, for example) has to compare only those votes across adjacent districts. In other words, both the efficiency gap and partisan symmetry (as well as any other measure based on the overall relationship between seats and votes) are influenced by variations in the vote across entire states, even though vote differences between two districts on the opposite side of a large state like California or Texas cannot be explained by gerrymandering.

The mainstay of my new measure for gerrymandering is that at a mathematical level, gerrymandering can be conceptualized as swapping voters across adjoining districts. In other words, when governments gerrymander districts, those districts are redrawn in ways that keeps the population numbers the same, but certain voters are switched over to other districts. In terms of outcome, this is equivalent to large numbers of people moving from one neighboring district to another, if for each person moving out of a district there was another person who moves into the district, thereby keeping the populations of each district constant. One could even compare it to individuals changing their party allegiances, as long as in a neighboring district the exact same number of individuals change their party allegiance in exactly the opposite direction. In terms of election outcomes, all of these conceptualizations would produce the same results.

My measure of gerrymandering is based on reversing this vote swapping and can be most easily understood as an iterative process. For example, if a state has only two districts, and the Democratic Party got 54% of the vote in one district and 60% in the other, then the reversing process would create an expected value of the vote in both districts as 57%.[1]

The math becomes more complicated in actual cases of gerrymandering, especially in states and localities with many districts. In a case like North Carolina, for example, where African American voters were packed into a small number of congressional districts, the Democratic vote for one of those districts might be 80% but only 40% in surrounding districts. Those surrounding districts, however, are also next to other districts, and so the reversing process

[1] In truth, this example is also a simplification, since the technique also treats a state line as a border and assumes that policymakers are less able to switch voters when a district is adjacent to that state line. RGIx would estimate the expected value for each of these districts as 56% and 58% and estimate the absolute gerrymandering bias for each district as only 2% (i.e., |54 – 56| and |60 - 58|).

can be seen as a chain of events across a geographic space that is not properly reflected by simply calculating geographically shifting means.

Instead, RGIx simulates this process of reversing gerrymandering by dividing the percent vote in each district into tiny groups, and then doing a step-by-step process in which each grouping is randomly allocated to its current district or any of the districts it is physically next to. So, if in a district in which 60% of the vote is Democratic and 40% is Republican, RGIx might treat this as 6000 Democratic and 4000 Republican votes. It would then iterate through this district 10,000 times, and each time it would randomly pick one of these 10,000 voters and then then randomly move that voter to either the same district or one of its neighbors.[2] When adjacent districts have similar partisan makeups, then this process has little impact. But when one of the districts has been heavily packed, this process would smooth the vote differences among adjacent districts: that is, the expected value would be much different for packed districts than the actual vote.

A critical characteristic of RGIx is that it would be much less likely to mistake geographic variation of voter preference as gerrymandering. An example would be Illinois, in which the Democratic vote is very high in the Chicago area, but Republican support is much higher in southern parts of the state. In this case, since these are demographically distinct areas, the vote differences among adjacent districts would be less, causing little difference between the expected value and actual vote.

Some measures, like the efficiency gap, also cannot be applied to less populated states and many local elections, since the presence of a small number of districts causes the results to shift wildly. Even measures based on geographic shape simply treat a state with only one district

[2] 10,000 iterations was chosen to balance speed with accuracy. The same process could easily be run, for example, with one million iterations.

as a missing value, since any oddity in the state's borders would appear to be gerrymandering. RGIx faces no such issues. For states with only one congressional district, for example, RGIx always finds the difference between the actual vote and expected vote to be zero, since there are no adjacent districts in the state and therefore there cannot be vote switching. The same would be true of at-large districts in multidistrict states before the 1967 Single-Member District Mandate. Since the borders of these at-large districts were the state lines, they effectively had no adjacent districts, leading to an RGIx score of 0.

Moreover, by conceptualizing legislative districts this way, the gerrymandering of districts could be understood through the lens of graph theory. Graph theory examines items as if they were **nodes** (represented as circles) connected by **vertexes** (represented as lines connecting nodes and sometimes pointing a node to itself), and where moving from one node to another across a vertex is called **traversing**. Graph theory was invented by Leonhard Euler in 1736 to solve the seven bridges problem of Königsberg, which asked whether an individual could walk across all seven bridges without repeating a bridge. Euler solved this problem by treating each area of town as a node and each bridge as a vertex, which led to an analysis that concluded that it is impossible. Graph theory subsequently became applied to a wide range of applications, especially in math and computer science. For example, each city in a region could be conceptualized as a node and the highways connecting these cites could be treated as vertexes; this framework could be used to find the fastest route from one city to another. The internet is also generally conceptualized as a giant graph with websites being nodes and links being vertexes.

RGIx is based on the assumption that legislative districts can be treated as nodes on a graph. For the US House of Representatives, each state would be treated as a separate graph, while for many national assemblies the graph would cover all the electoral districts in the country. The vertexes would then connect districts that are physically next to each other. To distinguish districts next to the state border and those completely surrounded by other congressional districts, the districts next to a state border could also have a vertex pointing to itself. The level of gerrymandering of each district can then be determined by how much different the vote in one node is to the nodes it is connected to via a vertex.

An example of this structure is shown in Figure 1. It shows a congressional district map of Louisiana after the 2020 reapportionment. Under that map, there is a small graph that contains all the relevant information about Louisiana in the 2022 election. Each circle is a node that represents a district. For example, the top left node represents the 4th district. The arrays show what districts are next to each other. For example, the 4th district is adjacent to the 3rd and 5th districts. The small ovals indicate that a district is next to the state border, which is important because RGIx assumes that a district against the state border is harder to gerrymander. In this case, the only district that isn't on a state border is the 2nd. Finally, the box in the circle shows the percent Democratic vote. In the 4th district, the Democratic vote was 25%, which means that the Republican vote was 75%. (The nodes are also colored red or blue, but this is simply a convenience for making it easier to match the map districts to the nodes.)

The first step in measuring RGIx is to calculate an expected value of districts, or what the vote would be in each district in the state had there been no packing of voters. This is shown in Figure 2. Since the Democratic vote in District 4 was 25%, RGIx would treat this district as if it had 10,000 voters: 2500 Democrats and 7500 Republicans. Every other district would also be assumed to have 10,000 voters distributed between Democrats and Republicans based on the

Figure 1: Louisiana 2022 Congressional Election as Graph

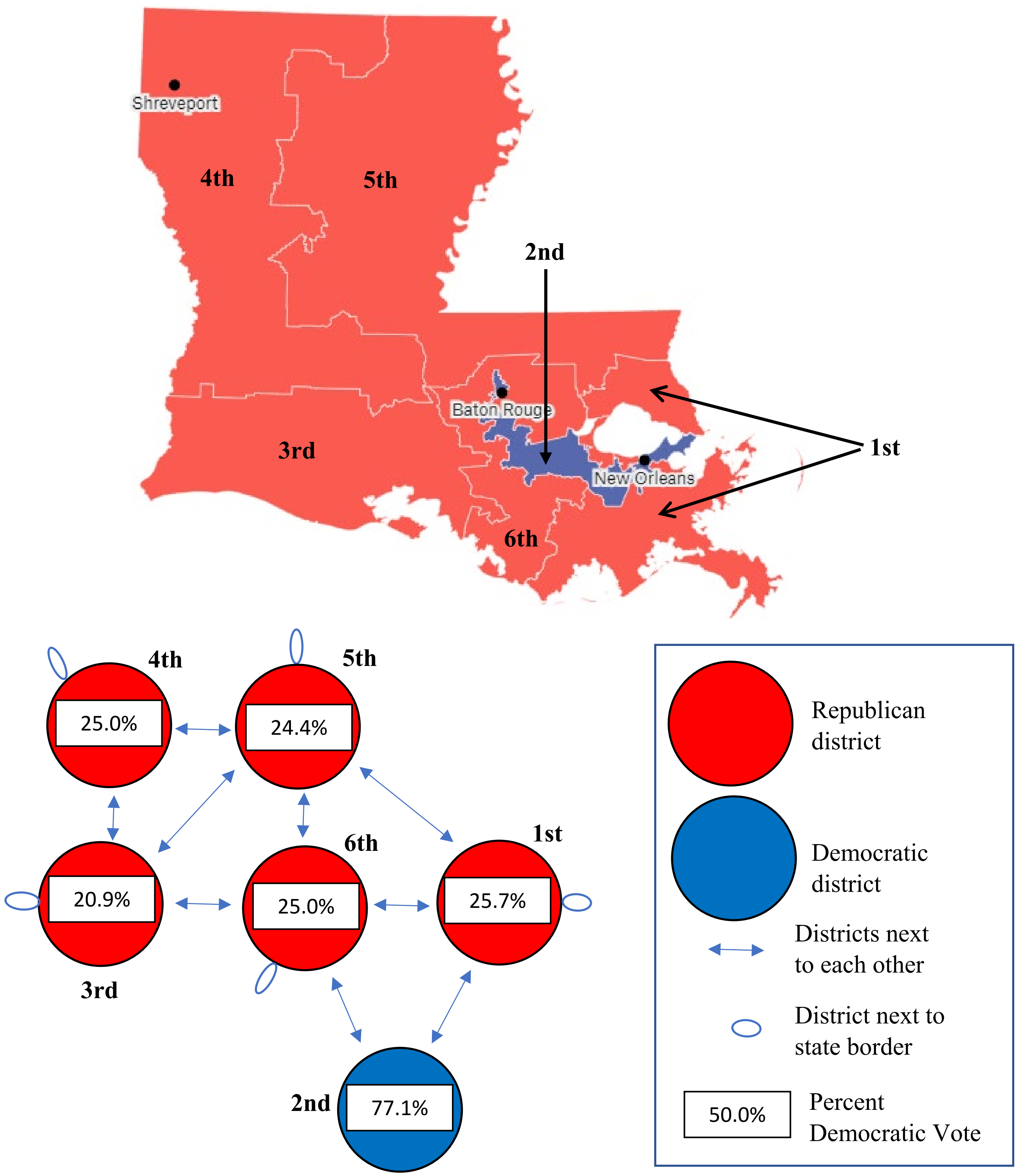
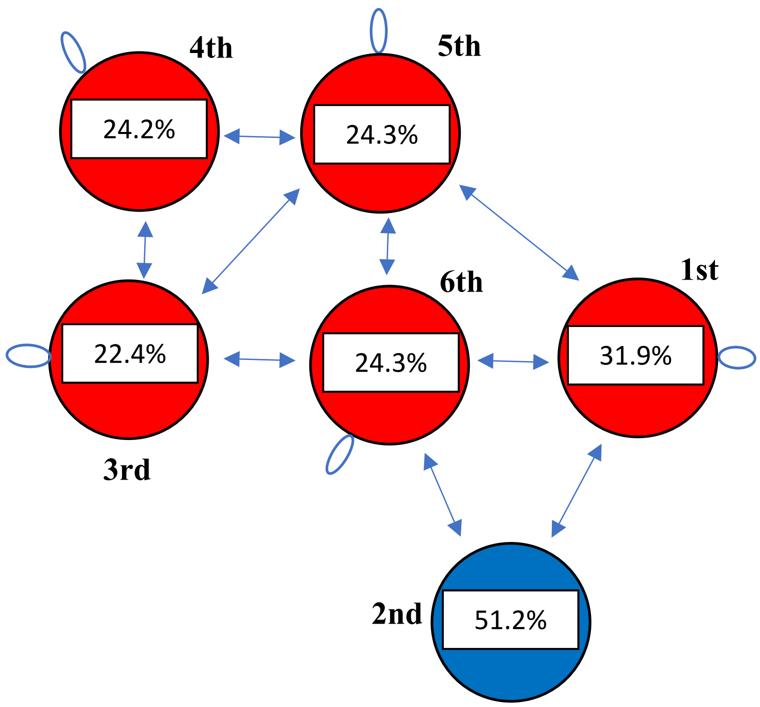
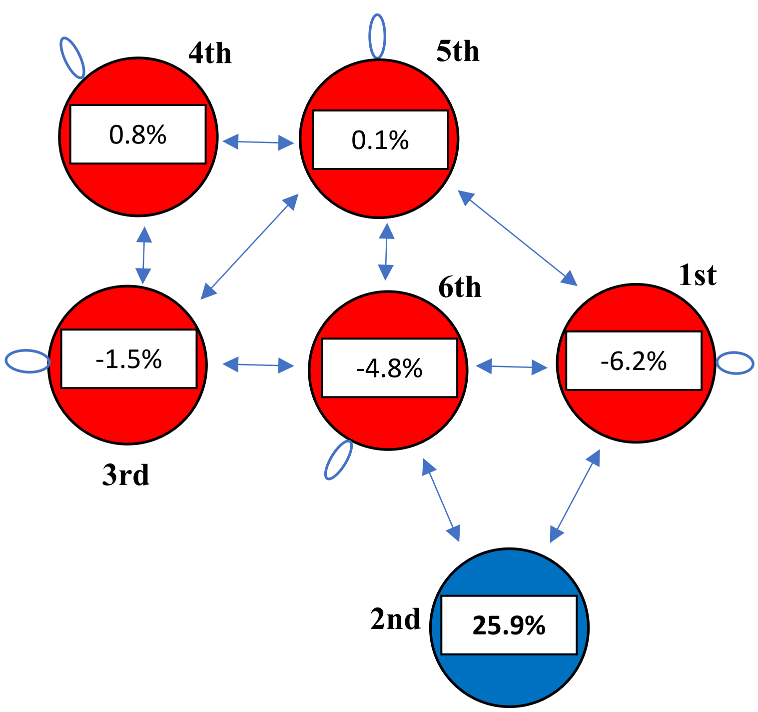


Figure 2: RGIx Scores for Louisiana 2022 Congressional Elections

The RGIx expected value for each district:



The RGIx score for each district. It is calculated by subtracting the expected value (above) from the actual vote (Figure 1) for each district.



percent vote. The RGIx application would then go through each district 10,000 times, and in each case a voter would be either kept in the same district or moved to a neighboring district. (In graph theory terms, each voter in each district would either stay in the same node or traverse one node over.) If a voter is in the 4th district, that voter has equal chance of landing in the 3rd, 4th, or 5th district. Similarly, each voter in the 5th district would have equal chance of landing in the 1st, 3rd, 4th, 5th, or 6th district, since each of these districts is either the 5th district or one of its neighbors. (In truth, the procedure is slightly more complicated. Since the 4th district is also on the state border, RGIx treats this node as if it is pointing to itself and thereby gives greater weight to not moving. In this case, there is a 50% chance that the voter would stay in the 4th district and a 25% chance of it landing in the 3rd and 25% chance of landing in the 5th district.)

The reason this works is because this process is heavily influenced by the partisan composition of each neighboring district. Since the 4th, 5th and 3rd districts have roughly the same partisan distribution, this random movement of voters would have very little impact on the partisan composition. The actual vote and the excepted value of the vote would be roughly the same. However, the 2nd district of Louisiana is highly gerrymandered. The percent vote for Democratic candidates is clearly much higher than its neighbors. In this case, this random movement of voters would cause the percent vote of District 2 to move much closer to that of Districts 6 and 7 – or what could be referred to it as the district votes being "flattened". This would produce an expected value for each district had there been no gerrymandering. These results of this flattening are shown in Figure 2. The expected value for District 4 is almost identical to its actual vote. But for the 2nd district, the percent Democratic vote flattens considerably from 77% to 51%.

From there, the level of packing can be determined simply by subtracting the actual vote from the expected value. This value can be referred to as the *RGIx score*. When the district is not very gerrymandered, then this score will be small. But if it is a packed district, then the score should be much larger. This can be shown in the lower graph of Figure 2. For the 4th district, the score is less than 1%. But for the packed 2nd district, the score is 26%.

There are a number of other gerrymandering measures that are also based on examining the relationship between the vote in each district and its adjacent districts. The partisan dislocation indicator (DeFord, Eubank, and Rodden, 2022), for example, examines the differences between the vote of individual districts and its neighbors with a focus on neighborhoods that have been dislocated due to packing or cracking. The GEO metric (Campisi, et al. 2022) also examines the differences in party support across neighboring districts. It is based on an algorithm that swaps votes across neighboring districts in a way that makes these districts more competitive, to see how the total number of seats won by the Democratic and Republican parties would change by redrawing district maps in this way. The most important difference between RGIx and these measures is that RGIx produces a gerrymandering score for each district. That score creates a wide range of ways that scholars can study gerrymandering at the same time that it provides a new way for practitioners and the courts to identify the most egregiously gerrymandered districts.

For the rest of this paper, I will show a simple application of RGIx for evaluating the evolution of gerrymandering in the US House of Representatives since 1872.

Analysis:

The analysis in this paper is based on election results to the US House of Representatives from 1872 to 2022. These results are based on data collected for a research grant funded by the MIT Election Data and Science Lab and the American Association of Political Science Centennial Fund, Ostrom Fund (Tamas, 2022). To simplify the results, only the two-party vote between the Democratic and Republican candidates were used. Uncontested races were treated as missing values, and a multiple imputation approach was used to impute values for these districts.[3]

In order to translate these election results into graphs that could be interpreted via RGIx, two pieces of information were needed for each congressional district from 1872 to 2022: (1) a list of all other congressional districts within the state that were adjacent to this district, and (2) an indicator of whether the district lines included the state border. For all districts from 1872 to 2012, I gathered this information via Python code that read shapefiles provided by Lewis, et. al (2013). Specifically, the code compared the location points of each legislative district line to see if it was identical to points in other districts in the state. Similarly, to determine if a district line

[3] Specifically, elections during each apportionment period (i.e., 1972 through 1980, 1982 through 1990, etc.) were combined into a single data set with each row being a single district. There were five data columns, each containing the two-party percent Democratic vote for each election (e.g., a column for 1972, 1974, 1976, 1978, and 1980). If the election was uncontested (i.e., either no Democratic or Republican candidate), then the cell for that election was made a missing value. The multiple imputation approach developed by King et al. (2001) was then used to impute these missing values for each election in which there was at least one contested race within the district. However, for some districts there were no contested races for the entire apportionment period. Similarly, for the 2022 election, there are no other elections during the 2022 through 2030 apportionment period to compare the uncontested elections to. In these cases, the Democratic vote was imputed as 75 percent if a Democratic candidate won and 25 percent if a Republican candidate won. This solution is based on the approach used to impute missing values for uncontested races in King and Gelman (1991). See endnote 4 in Kastellec, Gelman, and Chandler (2008) for explanation of the logic behind this approach.

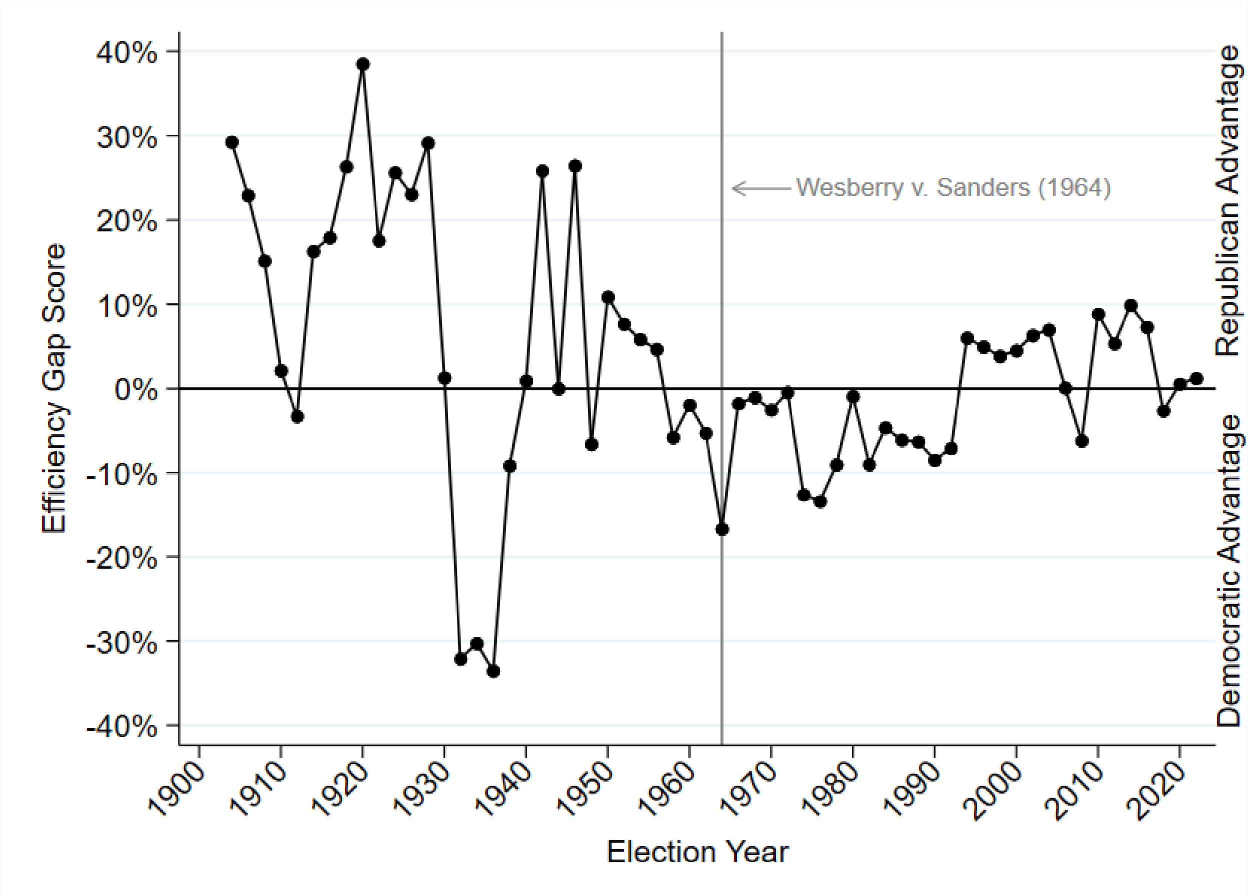
included a state border, the code also examined to see if the district line's locations matched the district line locations of congressional districts in neighboring states. For states that also bordered Canada, Mexico, the Gulf of Mexico, or the Atlantic/Pacific Ocean, physical maps (Martis, et. al 1982; Martis, et. al 1989) were used to determine if a district's lines included the US border. For elections after 2012, physical maps provided by the Census Bureau (for example, https://www.census.gov/geographies/reference-maps/2017/geo/cong-dist-115-wall.html) were used.

As my initial paper on RGIx, I have decided to keep the analysis simple in two ways. First, I am focusing entirely on packed districts, and I am defining a packed district as one that in any given election had an RGIx score of greater than 10% (which would be a Democratic packed district, which benefits the Republican Party) or less than -10% (which would be a Republican packed district, which benefits the Democratic Party). While this approach makes the results easy to interpret, the 10% cutoff is also rather arbitrary. It also ignores the variations of RGIx scores across each state, which help us understand how gerrymandered the state is. For example, for a midsized state like Louisiana or South Carolina, a standard gerrymandering structure would be all but one district having very low RGIx scores and one district with a very high RGIx score. For larger states that are heavily gerrymandered, there might be multiple districts with high RGIx scores, but they would all be positive or all be negative. However, it is also possible for states to have districts with large scores in both directions, which would indicate that these districts were packed by accident (or for reasons other than gaining partisan advantage) instead of intentional partisan gerrymandering. The approach in this paper is therefore good for evaluating the measure and showing historical trends but not conducting more advanced analyses.

Second, in order to simplify the presentation of results as well as reduce the impact of vote fluctuations between elections, the mean RGIx score for each district was calculated for each apportionment period, and then the results for each period was reported. The one exception was the 2022 election, since it is the first in the apportionment period. For 2022, therefore, there is a higher possibility that the RGIx scores are affected by the specific results of this election cycle.

I begin by showing a graph of the efficiency gap in Figure 3 for the period from 1902 to 2022. I do this simply to produce a point of comparison against the RGIx results. The graph suggests a number of issues with the efficiency gap as a measure of gerrymandering. (1) The efficiency gap shows a wild level of fluctuation, especially during the first half of the century. (Indeed, I reported the efficiency gap for each election instead of by apportionment period, since reporting it by decade would hide the wild fluctuation of the results by some years.) For example, even though there was limited redistricting from 1928 to 1932, the efficiency gap dropped from a positive 29% in 1928 (showing a strong Republican gerrymandering advantage) to a -32% in 1932 (showing a strong Democratic gerrymandering advantage). (2) The general argument about the evolution of gerrymandering in the twentieth century was that it started rising in the 1960s after *Wesberry v. Sanders*, 377 U.S. 533 (1964), when the Supreme Court began requiring states to draw congressional districts lines so that each district in that state for a legislative body would have equal population (Engstrom, 2013). The efficiency gap shows the exact opposite. According to the efficiency gap, the level of gerrymandering was, on average, three times larger (16%) before the Supreme Court required that districts have equal population than after (5%). In other words, even though it is one of the most widely known measures of gerrymandering, its

Figure 3: Efficiency Gap Scores for US House Elections, 1872 - 2022



This graph shows efficiency gap scores for all elections to the US House of Representatives from 1872 to 2022, including before and after *Wesberry v. Sanders*, 377 U.S. 533 (1964), which required states to redraw congressional district lines each decade and make their populations equal. The graph indicates that efficiency gap scores move wildly from election to election, even during periods without redistricting, and that these scores are substantially higher before *Wesberry v. Sanders* than after, even though most histories of gerrymandering in the US (Engstrom, 2013) would predict the exact opposite results.

results do not fit a pattern consistent with current understandings of the history of gerrymandering in the US, and the wild movement of results seems inconsistent with a measure of district composition, which changes more slowly.

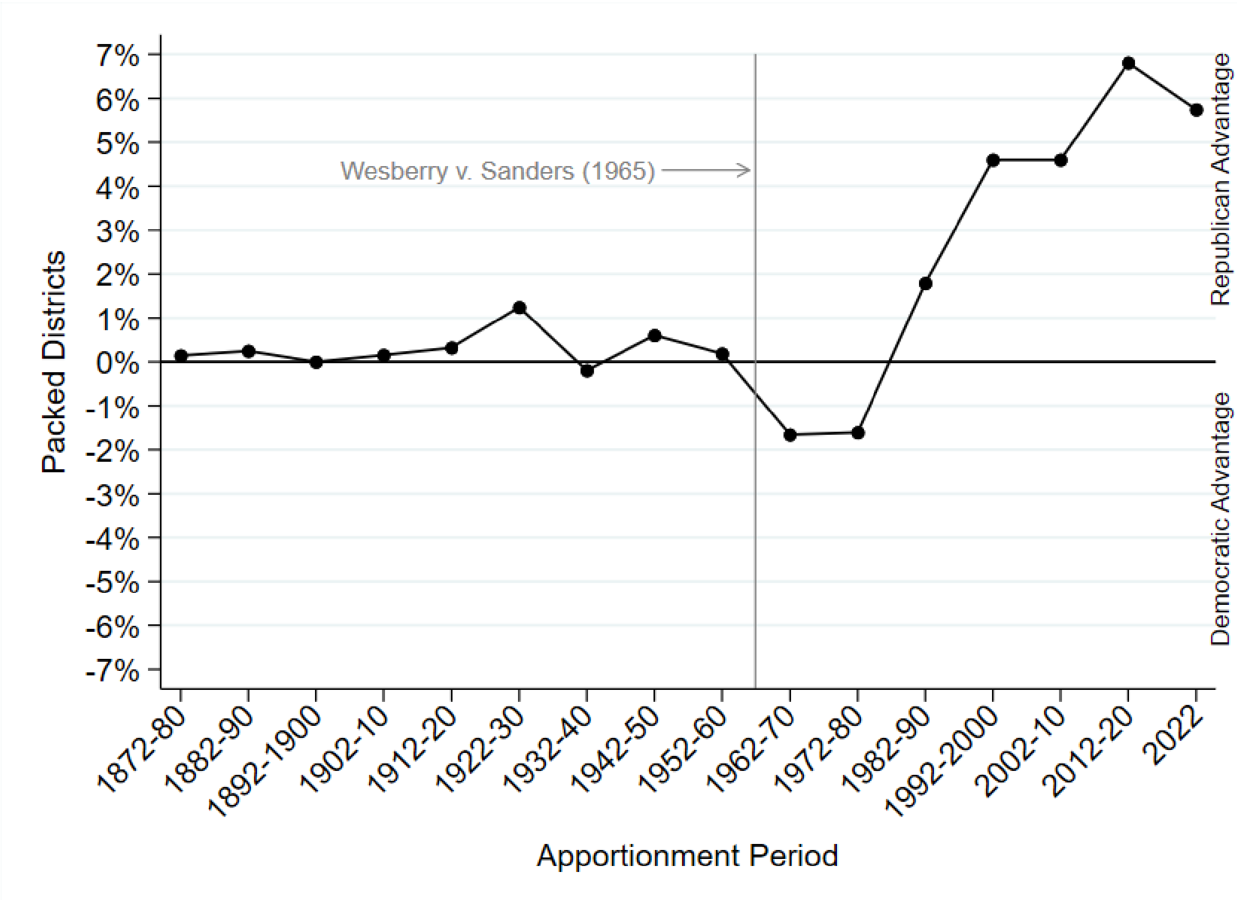
In sharp contrast, RGIx shows evidence that is consistent with the general history of gerrymandering in the US. As the figures below will show, RGIx indicates that there were few packed districts in the first half of the twentieth century. Instead, the number of packed congressional districts began to rise rapidly around the 1960s, when the Supreme Court forced state governments to reapportion district lines every decade. RGIx also shows that there was a sharp shift of gerrymandering in the Republican Party's favor over the past few decades. However, in both cases, RGIx indicates that these changes may have begun earlier than expected, and it suggests some surprising caveats to these changes. Indeed, I would argue that one strength of RGIx is that while it shows evidence consistent with our general understanding of the history of gerrymandering, it also provides details that go beyond that current understanding.

Figure 4 shows the partisan imbalance of gerrymandering by apportionment period from 1872 to 2022. Specifically, it shows the percent of districts packed with Democratic voters (which produce a Republican advantage) minus Republican packed districts (which produce a Democratic advantage). For Graphs 4 to 6, as discussed above, a packed district is measured as one that has an RGIx of an absolute value greater or equal to 10%. A positive RGIx of 10% or greater means that it a Democratic packed district while a negative RGIx of -10% or less means that it is a district packed with Republican voters.

Using RGIx, Figure 4 indicates that over the past few decades, the Republican Party has been significantly out-gerrymandering the Democratic Party. For most of the twentieth century there was little overall bias in either party's favor in US Houser elections due to gerrymandering. In the apportionment period from 1922 to 1930, there were slightly more Democratic packed districts than Republican packed districts, producing a small Republican advantage, and in the period from 1962 to 1980 there was also somewhat more Republican than Democratic packed districts, producing a modest Democratic advantage. But after the 1980 apportionment, created immediately after the large Republican win across the board with Reagan as the presidential candidate, including in state legislative races, the advantage began steadily shifting in favor of the Republican Party. By the apportionment period beginning in 2012, the difference between Democratic packed and Republican packed districts made up 7% of US House legislative districts. In other words, the gerrymandering shift towards the Republican Party did not begin with the 2010 reapportionment but instead grew steadily since the Reagan administration.

While this graph might give off the impression that this is a story of Republican-controlled states wildly gerrymandering while Democratic-controlled states sat idol, further analysis using RGIx suggests that Figure 4 actually hides critical information about this change in gerrymandering. Figure 5 shows the rise of packed districts separating between those packing Democratic voters and those packing Republican voters. It gives a very different story about how US congressional districts were drawn to benefit the Republican Party overall. Firstly, the rise of packed districts did not begin with Reagan, but instead in the 1950s or 1960s. The percent of Democratic and Republican packed districts *both* rose steadily until the 1970s, during which 7% of districts were Democratic packs, and 8% were Republican packs.

Figure 4: Partisan Imbalance of Packed US House Districts, 1872 - 2022

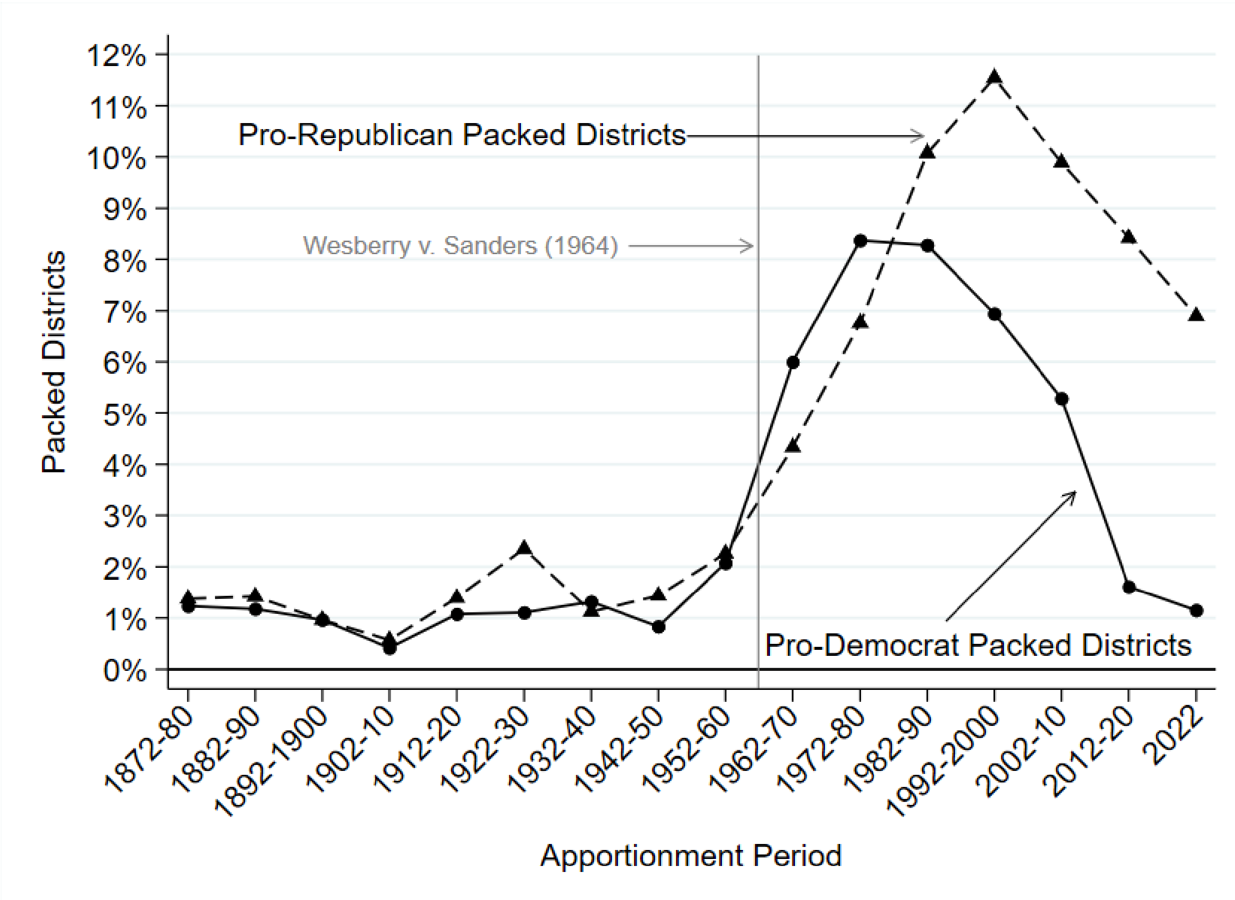


This graph shows the percent Democratic packed districts minus the Republican packed districts in US House elections by apportionment period from 1872 to 2022. A packed Democratic district is one in which Democratic House candidates receive substantially higher percent vote than their neighboring districts, and in this graph is defined as an RGIx of 10% or higher. (Since the Democratic voters make a substantially higher percent than is needed to win the seat, this leads to a Republican electoral advantage.) Conversely, a packed Republican district is one in which the RGIx is -10% or lower. The graph shows that packed districts had little impact on congressional elections until around 1980 and then started shifting substantially in the Republican Party's favor. The Democratic Party's attempt to reverse this bias had little impact on the 2022 election.

But then, starting with the 1980 apportionment, the percent of packed districts went in two directions: there was a steady rise of Democrat packed districts (favoring the Republican Party) while the percent of Republican packed districts (favoring the Democratic Party) dropped significantly. Part of the reason might be that the Republican Party gained control over more state governments starting in this period, but the dramatic drop in packed Republican districts might suggest a policy shift in most Democratic controlled states away from gerrymandering at the exact point that many Republican-controlled states were steadily increasing their gerrymandering.

As Figure 5 also suggests, the packing of congressional districts by Republican-led states did not continue to rise. Quite the opposite, the percent of packed congressional districts began to decline for both parties after the 2000 apportionment, including those that benefitted the Republican Party. The percent of Democrat packed districts peaked in the 1992-2000 apportionment at 11%, reduced to 10% of congressional districts in the 2002-2010 apportionment period, 8% of congressional districts in the 2012-2020 apportionment period, and 7% in the 2022 election. The percent of Republican packed districts also steadily declined during this period. *In other words, what this evidence suggests is not that the Republican Party had been increasing the amount of gerrymandering in congressional districts while Democrats did nothing. Instead, Figure 5 suggests that the number of packed districts at the federal level have been declining since the 1980s. The continued Republican gerrymandering advantage at the federal level is caused by the decline of Republican packed districts beginning earlier than the decline of Democratic packed districts.*

Figure 5: Percent of Democratic and Republican Packed US House Districts, 1872 - 2022

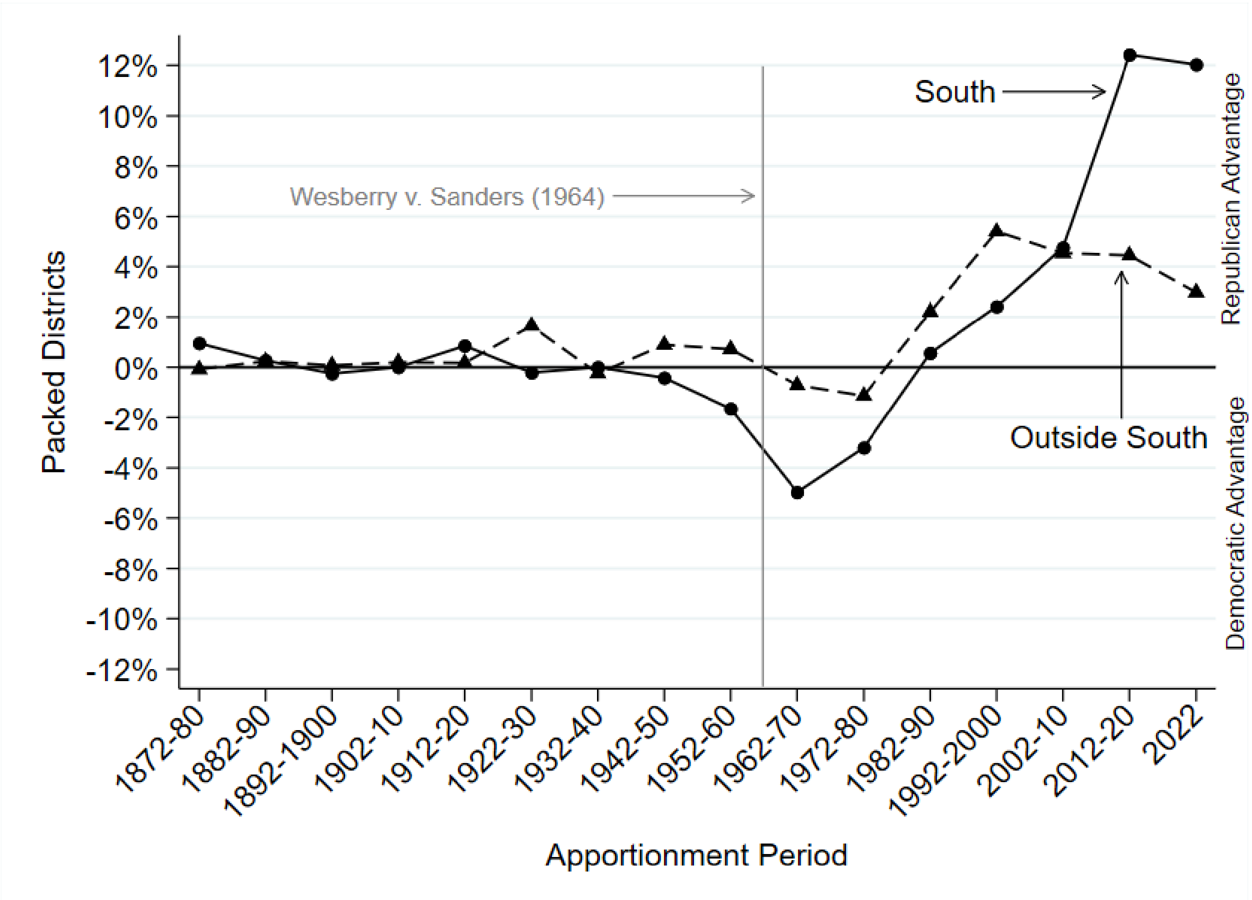


This graph shows the percent of Democratic and Republican packed US House districts by apportionment period from 1872 to 2022. A packed Democratic is one with an RGIx score of at least 10% while a packed Republican district is one with an RGIx score of -10% or less. The graph shows that percent of packed districts began to rise rapidly in the 1960s, but that Republican packed districts (which benefit the Democratic Party) began to decline in during the 1982-90 apportionment period while Democratic packed districts (which benefit the Republican Party) continued to rise until the 2002-10 apportionment period. Starting in 2002, the percent of Democratic and Republican packed districts both declined steadily, which maintained the pro-Republican advantage in gerrymandered districts.

Figure 5 also indicates the state of gerrymandering after the 2020 reapportionment. In reaction to the Supreme Court decision in Rucho v. Common Cause 588 U.S. ___ (2019), which ruled that claims of unconstitutional partisan gerrymandering present non-justiciable political question and are therefore not subject to federal court review, there were claims that the Democratic Party moved to counteract Republican-led gerrymandering by also gerrymandering in states that it controlled. Figure 5 suggests instead that at the federal level the number of both Democratic packed and Republican packed districts declined after the 2020 reapportionment. However, there was less of a decline in Republican packed districts (which advantaged the Democratic Party) than Democrat packed districts. In other words, the Republicans have retained the gerrymandering advantage after the 2020 apportionment, but to a lesser degree.

Finally, Figure 6 suggests that much of the Republican gerrymandering advantage over the past few decades has been driven by the South. That Republican advantage in the South began to rise after the 2000 reapportionment and became much more extreme after the 2010 reapportionment. During the 2022 election, there were zero Republican packed districts (which would advantage the Democratic Party) in the South while 12% of southern districts were packed with Democratic voters, a percent far higher than outside the South. What this suggests is that much (but not all) of the current Republican advantage because of gerrymandering at the federal level is because of aggressive packing of Democratic voters in the South. Outside the South, there are only 3% more Democratic packed than Republican packed districts, producing a far lower but still real advantage for the Republican Party there.

Figure 6: Partisan Imbalance of Packed US House Districts in and Outside South, 1872 - 2022



Conclusion:

My goal in this paper is to introduce RGIx and test the measure on the historical change to gerrymandering in United States House of Representative elections over the past 150 years. These tests focused entirely on the rise of packed Democratic and Republican legislative districts, with a packed district being defined as a district in which had an RGIx score of at least 10%. The results were largely consistent with the history of the gerrymandering over the twentieth century, as defined mostly by historical analysis (Engstrom, 2013), including the rapid rise of gerrymandering in the 1960s. (1) That the packing of districts actually began before a string of Supreme Court cases began requiring states to redraw legislative district lines each decade to make their populations equal within the state, suggesting that it might have begun as a reaction to the rise of the Civil Rights Movement. (2) That starting in the 1980s, gerrymandering at the federal level began shifting significantly in the Republican Party's favor and continued to shift farther in that direction through the 2012-20 apportionment period. (3) This shift in gerrymandering in the Republican Party's favor was not simply caused by Republican led states being more aggressive than Democratic led states in creating packed districts. Instead, there had been a steady increase in both packed Republican and packed Democratic districts, but then in the 1980s the pattern shifted. The number of packed Republican districts (i.e., those producing an advantage to the Democratic Party) began dropping rapidly at the same time that the number of packed Democratic districts (i.e., those producing an advantage to the Republican Party) continued to increase.

Combined, this evidence suggests that RGIx can provide significant information about gerrymandering when subdistrict data (like precinct or block level partisan information) is not available, which is often the case for historical or comparative analyses. Moreover, because of *the way RGIx is structured, the analysis shown above might be just the beginning of the ways this tool can be used for historical and statistical analysis.*

While this paper shows one approach to using RGIx, that approach also has its limitations. A packed district was one defined as a district that had an RGIx score of greater than 10% or less than -10%. I chose this approach because it was an easy way to demonstrate the movement of gerrymandering as indicated by RGIx scores. For example, for most readers, it is very easy to recognize what it means to have the percent of packed districts increase from the 1950s to the 1970s, or for there to be twice as many packed Democratic than packed Republican districts in the apportionment period. However, while simple, this approach is rather sweeping and lacks a way to conduct significance tests. For example, in the 2022 election, the 6th district in South Carolina was clearly packed in the Republican Party's favor. The only Democratic victory for the US House of Representatives in 2022 in South Carolina was in the 6th district, and while all the other districts had small, negative RGIx scores, the 6th district had a substantially larger, positive RGIx score, indicating that it is packed Democratic district. However, since that score was 9.5%, it did not register as a packed district in this analysis.

RGIx is meant to be a versatile tool that can be used in a variety of ways. RGIx scores are effectively point estimates for legislative district that can be used as variables in statistical equations, for example. Similarly, RGIx skew scores could be calculated based on the difference between the mean and median across a range of districts. This rather simple measure could be used to estimate the level of gerrymandering in each US state, for example. In other words, a state that is not highly gerrymandered would either have RGIx scores that are consistently close to zero, or a balance between districts with large, positive RGIx scores and districts with large, negative RGIx scores. In both of theses cases, the RGIx skew would be low. In comparison, a state with gerrymandering that benefits the Republican Party would have districts with RGIx scores close to zero as well as a few districts with RGIx scores that are large and positive. Conversely, a state that is gerrymandered in favor of the Democratic Party would have a combination of districts with RGIx scores close to zero and RGIx scores that are large and negative. In other words, RGIx scores can be used in a range of approaches depending on the research or political question being asked. One of those approaches is to use the RGIx skew to determine how gerrymandered a state is.

Finally, one of my goals is to create publicly available software that can calculate RGIx scores and all other associated statistics for users. While the logic behind RGIx is simple, it does require an iterative process that would necessitates coding that not all users would be comfortable with. Even for experienced coders, there would be no reason for individuals to rewrite script that had already been developed. Thus far, I have constructed the working model in Python, though at this stage it is prepared for only two parties and therefore not yet applicable to multiparty democracies. My plan is to build a website version via Python that virtually anyone can easily upload their data onto (in the correct format, including district identifiers, percent votes by party, and adjacent districts) and then download all RGIx statistics. The one limitation of this approach is that it will likely be able to handle only one election at a time. For this reason, I also plan to build an R package and possibly a Stata ado file to calculate the same results.

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