

An Evaluation of the Partisan Bias in Pennsylvania's
Congressional District Plan and its Effects on
Representation in Congress

Christopher Warshaw

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1 Introduction

My name is Christopher Warshaw. I am a Pennsylvania native. I grew up in Mechanicsburg and I attended Mechanicsburg Area Senior High School. I have been an Assistant Professor of Political Science at George Washington University since August 2017. Prior to that, I was an Associate Professor at the Massachusetts Institute of Technology from July 2016 - July 2017, and an Assistant Professor at MIT from July 2012 - July 2016.

I have been asked by counsel representing the plaintiffs in *League of Women Voters of Pennsylvania v. the Commonwealth of Pennsylvania* to analyze relevant data and provide my expert opinions.

More specifically, I have been asked:

- To evaluate the degree of partisan bias in the redistricting plan in Pennsylvania and place the degree of partisan bias in Pennsylvania into historical perspective.
- To evaluate the growing polarization of members of the Congress, and whether that polarization magnifies the effects of gerrymandering.
- To examine the consequences of the 2011 redistricting plan on the representation that Pennsylvania residents receive in Congress in the context of growing polarization in Congress.
- To examine the consequences of the 2011 redistricting plan in Pennsylvania on citizens' trust in government.

My opinions are based on the knowledge I have amassed over my education, training and experience, including a detailed review of the relevant academic literature. They also follow from statistical analysis of the following data:

- Data on the roll call voting behavior of members of Congress from the Voteview website maintained by the University of California, Los Angeles (Lewis et al. 2016).
- Well established estimates of the ideology of members of Congress based on their roll call votes using models originally developed by Professors Keith Poole and Howard Rosenthal (Poole and Rosenthal 1997),¹ and estimates of the percentage of conservative roll call votes cast by each member of Congress developed by Professors Andrew Hall and Anthony Fowler (Fowler and Hall 2017).

1. These DW-Nominate (“ideology”) scores were downloaded from the Voteview website maintained by the University of California, Los Angeles (Lewis et al. 2016).

- A large data set on candidacies and results in Congressional elections: I obtained results from 1972-2014 collected by the Constituency-Level Elections Archive (CLEA) (Kollman et al. 2017). The results from 1972-1990 are based on data collected and maintained by the Inter-university Consortium for Political and Social Research (ICPSR) and adjusted by CLEA. The data from 1992-2014 are based on data collected by CLEA from the Office of the Clerk at the House of the Representatives. I supplemented this dataset with 2016 election results collected by the MIT Election and Data Science Lab (MIT Election and Data Science Lab 2017).
- Data on presidential election returns and incumbency status. I used data on elections in congressional districts from 1972-2014 collected by Professor Gary Jacobson (University of California, San Diego). This dataset has been used in many Political Science studies and has canonical status in the political science profession (Jacobson 2015). For the 2016 election, I used two data sources to supplement Jacobson's dataset. First, I obtained information on candidates' incumbency status from Hodges (2016). I obtained data on presidential election returns for the 2016 election aggregated by congressional district from the DailyKos website.
- Information on who controlled each redistricting plan (e.g., Democrats, Republicans, or a Commission) from 1972-2012 assembled by the Brennan Center (Brennan Center 2017).
- Information on the congruence of the views of the mass public and the roll call votes of their representatives from the 2016 Cooperative Congressional Election Study (Ansolabehere and Schaffner 2017). This is a large-scale study of how Americans view Congress and hold their representatives accountable during elections, how they voted and their electoral experiences, and how their behavior and experiences vary with political geography and social context (for more information see Vavreck and Rivers 2008; Ansolabehere and Rivers 2013).
- Information on the mass public's trust in their Representatives from the 2014 Cooperative Congressional Election Study.

2 Qualifications, Publications and Compensation

My Ph.D. is in Political Science, from Stanford University, where my graduate training included courses in political science and statistics. I also have a J.D. from Stanford Law School. My academic research focuses on public opinion, representation, elections, and

polarization in American Politics. My curriculum vitae is attached to this report. All publications that I have authored and published appear in my curriculum vitae. My work is published or forthcoming in peer-reviewed journals such as: the *American Political Science Review*, the *American Journal of Political Science*, the *Journal of Politics*, *Political Analysis*, *Political Science Research and Methods*, the *British Journal of Political Science*, *Political Behavior*, the *Election Law Journal*, *Nature Energy*, and edited volumes from Cambridge University Press and Oxford University Press. I am also on the Editorial Board of the *Journal of Politics*. My non-academic writing has also been published in the New York Times Upshot. I am being compensated at a rate of \$220 per hour.

3 Summary

A key attribute of democracy, if not its very definition, is “responsiveness of the government to the preferences of its citizens, considered as political equals” (Dahl 1971, 1; May 1978). The relationship between the distribution of partisan support in the electorate and the partisan composition of the government—what Powell (2004) calls “vote-seat representation”—is a critical link in the longer representational chain between citizens’ preferences and governments’ policies. If the relationship between votes and seats systematically advantages one party over another, then some citizens will enjoy more influence—more “voice”—over political outcomes than others.

This report examines three distinct questions related to how the Pennsylvania 2011 redistricting plan affects citizens’ representation in the political process. First, it measures the partisan bias in the Pennsylvania plan and places it into historical perspective. Second, it examines polarization in Congress and how that magnifies the effect of partisan bias in the redistricting plan on the representation that citizens receive from their elected officials. Finally, it examines how partisan bias in the redistricting process weakens citizens’ trust in their elected officials. Based on this analysis, I reach the following conclusions.

- *I find that Pennsylvania’s 2011 redistricting plan does indeed disadvantage one party compared to the other, and does so in ways that are historically extreme. There are substantially more wasted Democratic votes in Pennsylvania congressional elections than Republican votes. This has led to a substantial and durable pro-Republican bias in the translation of votes to seats in congressional elections in Pennsylvania. One simple metric to capture the ratio of wasted votes by each party is called the “Efficiency Gap.” In recent elections, Pennsylvania has had a pro-Republican Efficiency Gap that is extreme relative to both its own historical Efficiency Gaps,*

and the Efficiency Gap in other states. The Efficiency Gaps in Pennsylvania in the past three elections were among the most Republican-leaning Efficiency Gaps the nation has ever seen. Moreover, recent Efficiency Gaps are quite durable. This suggests that partisan gerrymandering is unlikely to be remedied through the normal electoral process.

- *The pro-Republican advantage in congressional elections in Pennsylvania has important representational consequences for voters.* Due to the growing polarization in Congress, there is a massive difference between the roll call voting behavior of Democrats and Republicans. Thus, Democratic voters whose votes are wasted in Pennsylvania are unlikely to see their preferences represented in our nation’s capital. They effectively have no political voice.
- *The pro-Republican bias in Pennsylvania elections contributes to a lack of trust in Congress.* I find that in states with a pro-Republican Efficiency Gap, meaning states that are likely gerrymandered in favor of Republicans, Democrats are much less likely than Republicans to trust their representatives in Congress. Conversely, Republicans are less likely than Democrats to trust their representatives in Congress in states with a large pro-Democratic Efficiency Gap. Thus, voters in gerrymandered states trust their representatives less than voters in non-gerrymandered states. This suggests that gerrymandering is eroding Americans’ faith in our democracy.

4 Partisan Gerrymandering

The goal of partisan gerrymandering is to create legislative districts that are as “efficient” as possible in translating a party’s vote share into seat share (McGhee 2014, 2017; Caughey, Tausanovitch, and Warshaw 2017). In practice, this entails drawing districts in which the supporters of the advantaged party constitute either a slim majority (e.g., 55% of the two-party vote) or a small minority (e.g., 20%). The former is achieved by “cracking” local opposing-party majorities across multiple districts and the latter by “packing” them into a few overwhelming strongholds. Both types of districts “waste” more votes of the disadvantaged party than of the advantaged one. This suggests that gerrymandering can be measured based on the number of wasted votes for each party.

In a “cracked” district, the disadvantaged party narrowly loses, wasting a large number of votes without winning a seat. In a “packed” district, the disadvantaged party wins overwhelmingly, wasting a large number of votes above the 50%+1 needed to win. The

resulting asymmetry in the efficiency of the vote–seat relationships of the two parties lies at the core of normative and constitutional critiques of partisan gerrymandering.

There are a number of approaches that have been proposed to measure asymmetries in the efficiency of the vote–seat relationships of the two parties. In recent years, at least 10 different approaches have been proposed (McGhee 2017).² While no measure is perfect, much of the recent literature has used a simple yet powerful way to operationalize this concept of partisan gerrymandering called the *Efficiency Gap* (EG) (McGhee 2014; Stephanopoulos and McGhee 2015; Caughey, Tausanovitch, and Warshaw 2017; Brennan Center 2017; Chen 2017; Stephanopoulos 2018). This measure was recently applied by a three-judge panel as one of the justifications for striking down Wisconsin’s state house districts as a partisan gerrymander (“Whitford v. Gill” 2016).³

4.1 Measuring Gerrymandering using the Efficiency Gap

The Efficiency Gap (EG) focuses squarely on the number of each party’s wasted votes in each election. It is defined as “the difference between the parties’ respective wasted votes, divided by the total number of votes cast in the election” (Stephanopoulos and McGhee 2015, 831; see also McGhee 2014, 2017).⁴ All of the losing party’s votes are wasted if they lose the election. When a party wins an election, the wasted votes are those above the 50%+1 needed to win.

If Democrats are the focal party so that positive values of the Efficiency Gap imply a Democratic advantage in the districting process and negative ones imply a Republican advantage, the Efficiency Gap can be written mathematically as:

2. Two other complementary approaches for measuring asymmetries in the efficiency of the vote–seat relationships of the two parties are symmetry and responsiveness. A system is asymmetrical if one party receives a larger share of seats than the other party for the same share of vote. A system is responsive if a large number of seats change hands in response to large changes in the aggregate vote. While both of these concepts are valuable, they both have several weaknesses. See McGhee (2014) for more information.

3. This case is currently being reviewed by the United States Supreme Court.

4. The Efficiency Gap calculations here focus on wasted votes in *congressional elections* since these results directly capture voters’ preferences in these elections. However, we might also calculate the Efficiency Gap using district-level results from presidential elections or other statewide races. These have the “advantage of being (mostly) unaffected by district-level candidate characteristics” (Stephanopoulos and McGhee 2015, 868). This feature is particularly useful for simulating Efficiency Gaps from randomly generated districting plans since candidate characteristics are clearly influenced by the final districting plan. A downside of using presidential elections or other statewide races to calculate the Efficiency Gap, however, is that they are less closely tied to voters’ preferences in congressional races given the district lines that actually exist. In practice, though, both congressional races and other statewide races produce similar Efficiency Gap results for modern elections where voters are well sorted by party and ideology. Indeed, I find that the correlation between Efficiency Gap estimates based on congressional elections and presidential elections is approximately 0.8 for elections held after 2000 and 0.9 for elections held after the 2011 redistricting cycle.

$$EG = \frac{W_R}{n} - \frac{W_D}{n} \quad (1)$$

where W_R are wasted votes for Republicans, W_D are wasted votes for Democrats, and n is the total number of votes in each state. In order to account for unequal turnout across districts, this formula can be rewritten as:

$$EG = S_D^{margin} - 2 * V_D^{margin} \quad (2)$$

where S_D^{margin} is the Democratic Party’s seat margin (the seat share minus 0.5) and V_D^{margin} is the Democratic Party’s vote margin. V_D^{margin} is calculated by aggregating the raw votes for Democratic candidates across all districts, dividing by the total raw vote cast across all districts, and subtracting 0.5 (McGhee 2017, 11-12).

The Efficiency Gap mathematically captures the packing and cracking that are at the heart of partisan gerrymanders. A key advantage of the Efficiency Gap over other measures of partisan bias is that it can be calculated directly from observed election returns even when the parties’ vote shares are not equal. In either case, the Efficiency Gap measures the extra seats one party wins over and above what would be expected if neither party were advantaged in the translation of votes to seats (i.e., if they had the same number of wasted votes).

In the analysis that follows, I examine the historical trajectory of the Efficiency Gap in Pennsylvania and the nation as a whole. For all congressional elections that were contested between two major party candidates, I use the raw vote totals for the Efficiency Gap calculation. For congressional elections that are uncontested (i.e., those that lacked either a Democratic or Republican candidate), we do not directly observe the number of people that support each party’s candidate. In these cases, it is necessary to estimate the two-party vote share because “determining the degree of packing and cracking requires knowing how many people in each district support each party” (Stephanopoulos and McGhee 2015, 865). Using publicly available data and statistical models, I estimate the two-party vote share in each district based on previous and future elections in that district as well as the results in similar districts elsewhere. This is similar to the approach used in a variety of other studies of the Efficiency Gap (Stephanopoulos and McGhee 2015; Brennan Center 2017; Jackman 2017). The details of this calculation for uncontested races are described in further detail in the Appendix.

Now that we know voters’ two-party preferences in contested districts and we have estimates of their preferences in uncontested districts, we are finally in position to estimate the partisan advantage in the congressional districting process during each state-year. I

estimate the Efficiency Gap in all states for each election between 1972 to 2016.⁵ In the analysis that follows, I focus on states with more than 6 congressional seats. I omit smaller states for two reasons. First, these states contribute less to the overall distribution of seats in Congress (Stephanopoulos and McGhee 2015, 868). Second, the Efficiency Gap in smaller states tends to be more volatile and thus less informative about partisan bias. For example, in a state with only three seats, a change in the winner of one seat could cause a huge shift in their Efficiency Gap.

4.2 Efficiency Gap Distribution

Figure 1 shows the distribution of Efficiency Gaps between 1972 and 2016 in states with more than 6 congressional seats. It shows the relative proportion of states with different values of the Efficiency Gap. The Efficiency Gap in each election year is represented in the distribution.

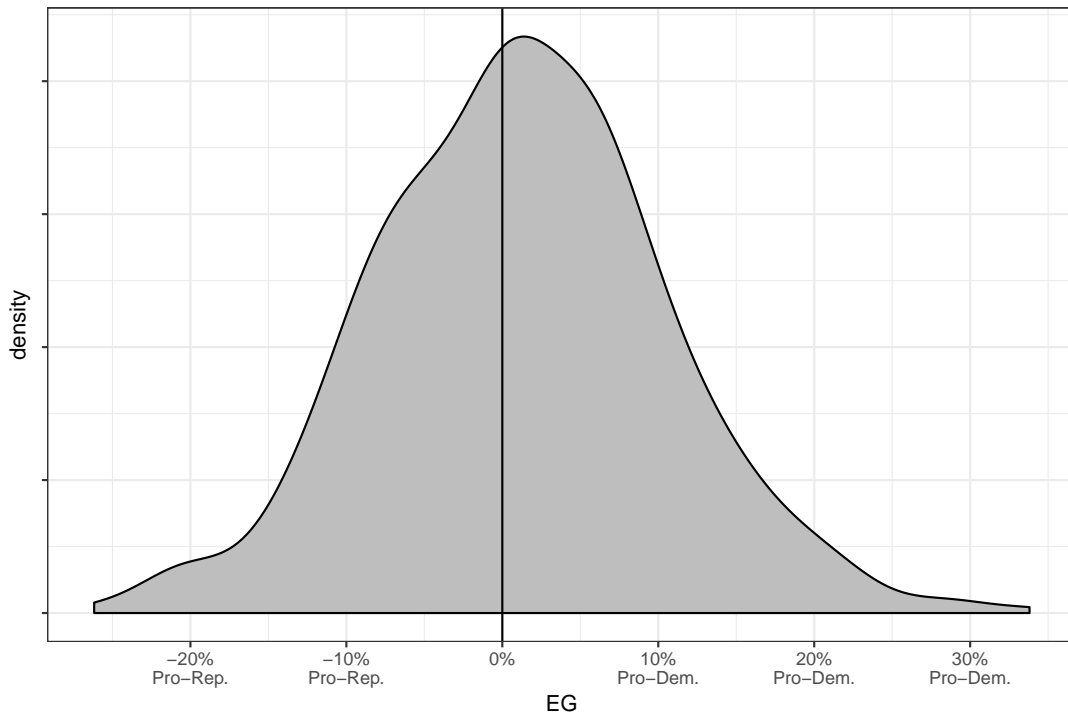


Figure 1: Distribution of Efficiency Gaps in States with More than 6 Seats: 1972-2016

5. I start the analysis in 1972 since those are the first districting plans drawn after the Supreme Court cases stemming from *Baker v. Carr* ended malapportionment and established the principle of one-person, one-vote. Also, I validate my measures of the Efficiency Gap to make sure that they align closely with Efficiency Gaps calculated using alternative modeling approaches for uncontested races. In the Appendix, I show that my estimates of the Efficiency Gap are extremely highly correlated with a variety of other measures of the Efficiency Gap developed using different assumptions for the imputation of uncontested districts.

This figure illustrates several important facts. First, it indicates that over this entire period the average state had a slightly Democratic leaning Efficiency Gap.⁶ Second, it indicates that the vast majority of Efficiency Gaps lie close to zero. In fact, roughly 75% of Efficiency Gaps lie between -10% and 10%. Only about 4% of state-level Efficiency Gaps have more than a 20% advantage for either party. This indicates that large Efficiency Gaps are extremely rare historically.

4.3 Historical Trajectory of the Efficiency Gap

Next, I examine the historical trajectory of the Efficiency Gap. Figure 2 shows the average Efficiency Gap in states with more than 6 congressional seats between 1972 and 2016. The vertical bars delineate changes in the decennial districting plans.

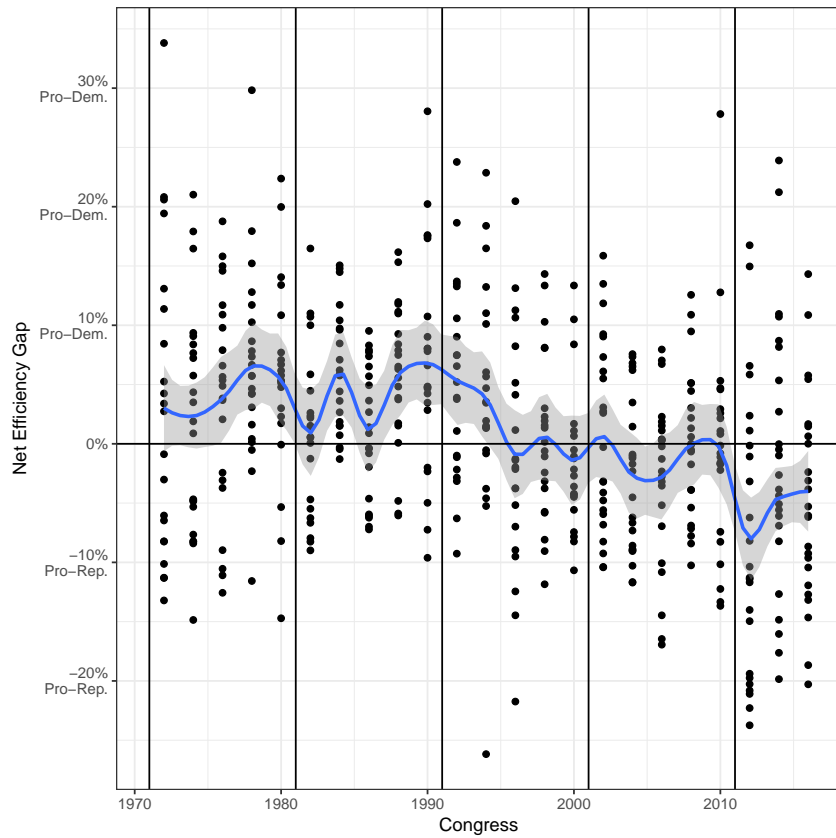


Figure 2: Historical Trajectory of the Efficiency Gap. Each vertical line shows the demarcation between decennial redistricting plans. The line shows the moving average and the grey bar is a confidence interval. The dots represent the Efficiency Gaps in individual states.

The plot indicates that the average Efficiency Gap was slightly Democratic leaning in

6. Stephanopoulos and McGhee (2015, 870) reach similar findings.

the 1970s and 1980s. This is consistent with a wide array of evidence from other Political Science studies showing that Democrats had a modest advantage from the districting process during this period (e.g., King and Gelman 1991; Cox and Katz 2002; Stephanopoulos and McGhee 2015). Indeed, Cox and Katz (2002) show that Democratic control of the redistricting process in many states during the reapportionment revolution in the 1960s led to a lasting net partisan advantage for Democrats in House elections. This advantage dissipated though by the end of the 1980s. In the 1990s, neither party had a significant net-advantage in the Efficiency Gap. In the first half of the 2000s, Republicans developed a very small advantage because they wasted fewer votes than Democrats (see also Kastellec, Gelman, and Chandler 2008; Stephanopoulos and McGhee 2015).

After the most recent redistricting in 2012, Republicans advantage grew significantly. Put simply, they abruptly developed a very substantial net advantage in the translation of congressional votes to seats (see also Brennan Center 2017; Stephanopoulos and McGhee 2015, 127). Indeed, my calculations indicate that the average Efficiency Gap went from approximately 0 in 2010 to an average Republican advantage of 8 percentage points in 2012 when the new districts came into effect. According to one recent report, the change in Efficiency Gaps during this period corresponds to a net Republican advantage of approximately 16-17 seats in the House of Representatives (Brennan Center 2017). Moreover, the sharpness of the change in the Efficiency Gap between 2010 and 2012 makes it unlikely to have been caused by geographic changes or non-political factors.

4.4 Partisan Control of the Redistricting Process and the Efficiency Gap

Of course, the Efficiency Gap can be non-zero and differ across states for reasons unrelated to the drawing of district lines, such as variation in how different demographic groups are distributed across geographic space (Chen and Rodden 2013). The Efficiency Gap can also be affected by the intentional drawing of district lines to accomplish goals other than maximizing partisan seat share, such as ensuring the representation of racial minorities (e.g., Brace, Grofman, and Handley 1987).

There is a wide body of evidence, however, from previous political science studies that control of the redistricting process influences the partisan balance in subsequent elections. Cox and Katz (2002) show that Democratic control of the redistricting process in many states during the 1960s led to a lasting partisan advantage for Democrats in House elections. More generally, Gelman and King (1994b) find that the party in control of redistricting shifts outcomes in its favor, and that “the effect is substantial and fades only very

gradually over the following 10 years” (543). This result has been confirmed in numerous recent articles. McGhee (2014) finds that “parties seek to use redistricting to shift bias in their favor and that they are successful in these efforts” (74). Finally, in a comprehensive analysis of congressional elections over the past forty years, Stephanopoulos (2018) shows that partisan control of the districting process has a large effect on the Efficiency Gap. He shows that states with unified Republican control have about 5 percentage points more pro-Republican Efficiency Gaps than states with split control, and states with unified Democratic control have about 3 percentage points more pro-Democratic Efficiency Gaps than states with split control.

Overall, these studies strongly suggest that political control of redistricting continues to have large and durable effects. But none of these studies focus on the most recent redistricting period. Thus, I extended their analysis to examine the effect of partisan control of redistricting on changes in the Efficiency Gap between 2010 and 2012. I focus on changes in the Efficiency Gap since a variety of factors could affect the absolute level of the Efficiency Gap. For example, one party could have a persistent geographic advantage which leads to an advantage in the Efficiency gap. However, geographic differences across states are unlikely to be correlated with the changes we observe in the Efficiency Gap between 2010 and 2012 when the new districting plans went into effect.

I find that states with unified Republican control of government almost all had large pro-Republican shifts in the Efficiency Gap. On average, these states shifted about 11 percentage points in a pro-Republican direction. The handful of states with unified Democratic control tended to have more modest pro-Democratic shifts in the Efficiency Gap. States with courts or non-partisan commissions running the redistricting process tended to have a mix of different outcomes, and little net advantage for either side. These differences are confirmed in a regression of the association between partisan control of the redistricting process and changes in the Efficiency Gap. This analysis shows that plans controlled by Republicans have an Efficiency Gap that is about nine percentage points more Republican than plans controlled by a Court or Commission. Moreover, this difference is clearly statistically significant.

Overall, this analysis shows that partisan control of government is highly correlated with changes in, and the magnitude of, the Efficiency Gap, providing strong support for the proposition that the Efficiency Gap is an effective measure of partisan gerrymandering.

4.5 Durability of the Efficiency Gap

In this section, I examine the durability of the Efficiency Gap. Put differently, how well does the Efficiency Gap immediately after the decennial redistricting predict subsequent Efficiency Gaps?

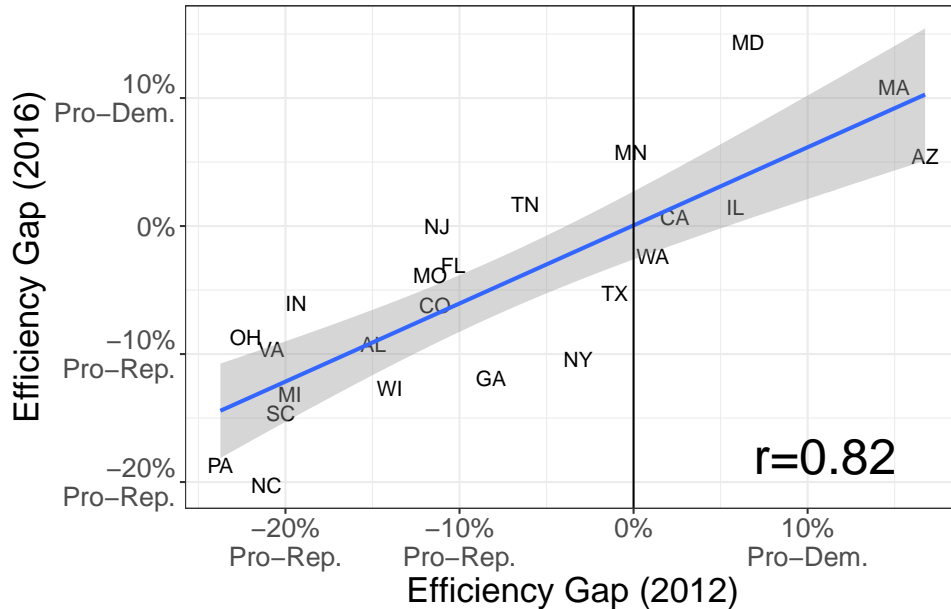


Figure 3: Durability of Efficiency Gap. This graph compares Efficiency Gaps in 2012 and 2016. It shows that recent Efficiency Gaps are quite durable.

Figure 3 shows that the Efficiency Gaps stemming from the 2011 redistricting have been extremely durable. For example, it shows that in North Carolina, the efficiency gap was -21% in 2012 and -20% in 2016, in Wisconsin, it was -13% in 2012 and -14% in 2016, and in Pennsylvania, it was -24% in 2012 and -19% in 2016. Overall, there is a 0.82 correlation between the Efficiency Gaps in states with more than 6 seats in 2012 and the Efficiency Gaps four years later in 2016. This means that the 2012 Efficiency Gaps predict 67% of the variation in the Efficiency Gaps four years later. Moreover, Pennsylvania's Efficiency Gap in 2016 was almost exactly the same as its Efficiency Gap in 2012. This analysis shows that recent Efficiency Gaps are quite durable, and thus partisan gerrymandering is unlikely to be remedied through the normal electoral process.

4.6 Efficiency Gap in Pennsylvania

The previous section showed trends in the nationwide trajectory of the Efficiency Gap. In this section, I focus on the Efficiency Gap in Pennsylvania. I find that in recent elections, Pennsylvania has had a pro-Republican Efficiency Gap that is extreme relative to both

its own historical Efficiency Gaps, and the Efficiency Gap in other states. The Efficiency Gaps in Pennsylvania in the past three elections were among the most Republican-leaning Efficiency Gaps the nation has ever seen. Moreover, the historical data I examine indicates there is nothing intrinsic about Pennsylvania that makes it likely to have a pro-Republican Efficiency Gap.

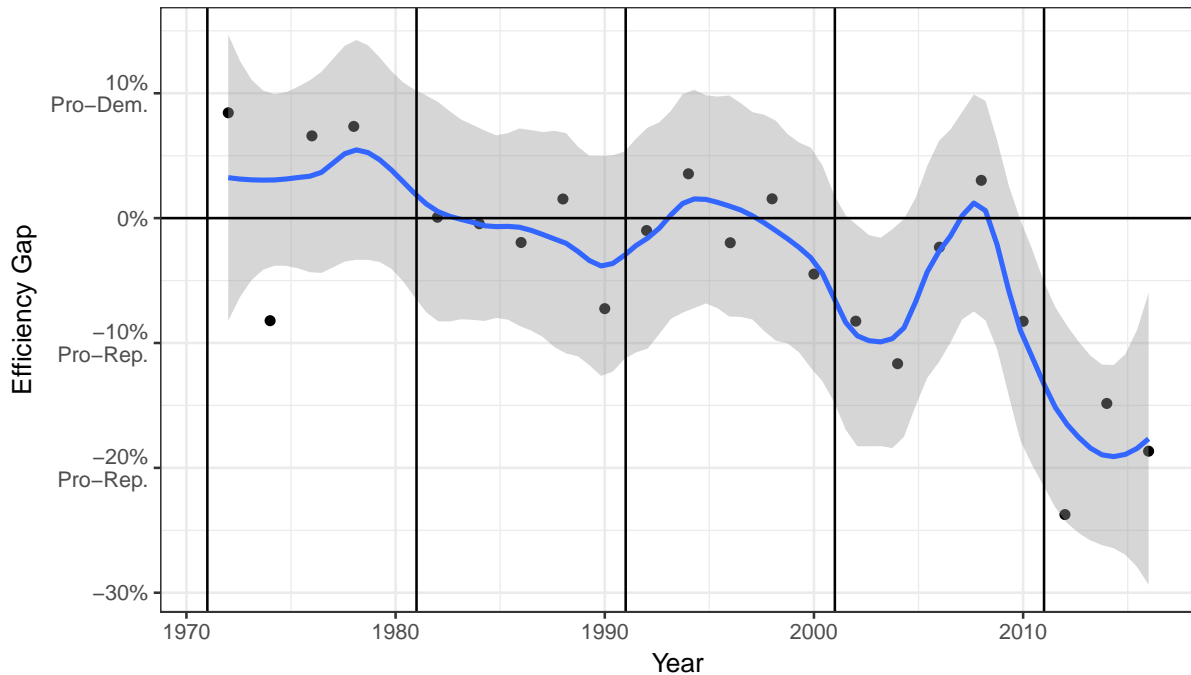


Figure 4: Historical Trajectory of the Efficiency Gap in Pennsylvania. Each vertical line shows the demarcation between decennial redistricting plans. The blue line shows the moving average and the grey bar is a confidence interval. The dots represent the Efficiency Gaps in each year in Pennsylvania.

Figure 4 shows trends in the Efficiency Gap in Pennsylvania between 1972 and 2016. Like other states, Pennsylvania had a modestly pro-Democratic Efficiency Gap in the 1970s. This gap evaporated by the 1980s. From about 1980 through 2010 neither party had a persistent advantage in the Efficiency Gap in Pennsylvania. However, the 2011 redistricting plan led to a large Republican advantage in Pennsylvania congressional elections unlike what the state experienced after previous redistricting periods.

After being relatively neutral for the past three decades, Pennsylvania’s congressional map developed a large and persistent pro-Republican Efficiency Gap after the 2011 redistricting. In 2012, Democrats wasted over 2 million votes, while Republicans only wasted 720,000 votes. As a result of their greater efficiency at translating votes into seats, Republican candidates won only 49% of the statewide congressional vote, but they won 13 of 18 – or 72% – of Pennsylvania’s congressional seats. This led to a pro-Republican Efficiency

Gap of approximately -24%.

Table 1 shows the district-level election results in the 2012 Pennsylvania congressional elections. It shows that many Democratic voters were packed into just five districts where the Democratic candidates won by overwhelming margins. The remaining Democratic voters were cracked across the other 13 districts. The Republican candidate received less than 60% of the vote in eight of these thirteen districts. This table also shows the disproportionate percentage of the statewide vote that Democrats would have needed to win a majority of Pennsylvania’s congressional seats in 2012. Democrats would have needed to win the 3rd District to win a majority of seats, and Democrats would have needed to win an additional 7.2% of the vote there to win—even though Democrats already won 50.8% of the vote statewide.

District	Democratic Vote Share
10	34.4%
18	36%
04	36.6%
05	37.1%
09	38.3%
07	40.6%
11	41.5%
16	41.6%
03	42.8%
06	42.9%
15	43.2%
08	43.4%
12	48.3%
17	60.3%
13	69.1%
14	76.9%
01	84.9%
02	90.5%

Table 1: Results in 2012 Pennsylvania Congressional Elections

The results in the next two elections were similar to those in 2012. In 2014 and 2016, Republican candidates retained the same 72% share of Pennsylvania’s seats, even while winning just narrow majorities of the statewide vote. This corresponded to an Efficiency Gap of approximately -15% in 2014 and -19% in 2016. According to several recent studies, these Efficiency Gaps imply that Republicans in Pennsylvania have won three or four more seats in these elections that they would have won if Pennsylvania had no partisan bias in

its Efficiency Gap (see Stephanopoulos and McGhee 2015; Brennan Center 2017).

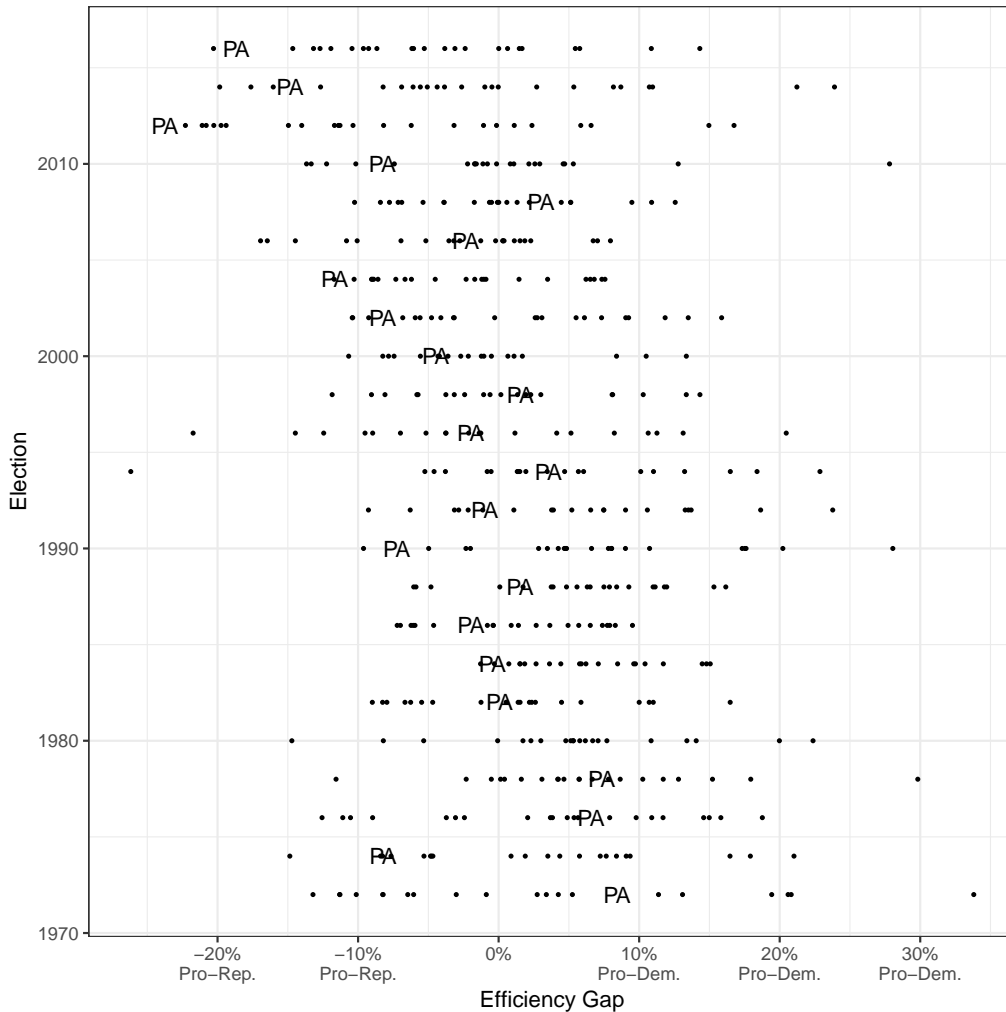


Figure 5: Efficiency Gap in Pennsylvania Relative to Other States. The dots represent the Efficiency Gaps in individual states. The Efficiency Gaps in Pennsylvania are labelled to distinguish them from other states.

Figure 5 compares the Efficiency Gap in Pennsylvania to other states. Each dot in the chart represent a particular state’s efficiency gap for congressional elections in that state that year. The chart shows that the Efficiency Gap in Pennsylvania was generally similar to that of other states until the most recent redistricting. However, recent Efficiency Gaps in Pennsylvania are extreme relative to both its own historical Efficiency Gaps, and the Efficiency Gap in other states. After the most recent redistricting, Pennsylvania had far more extreme pro-Republican Efficiency Gaps than it has ever had before. This further suggests that geographic factors are unlikely to be the root cause of the large Efficiency Gap in Pennsylvania in recent elections. Finally, I re-examined my

analysis using estimates of the Efficiency Gap from three other sources that account for uncontested districts in slightly different ways. I obtain very similar results using each of these alternative Efficiency Gap measures.⁷

In sum, the Efficiency Gaps in Pennsylvania in the past three elections were among the most Republican-leaning Efficiency Gaps the nation has ever seen. In fact, the 2012 Efficiency Gap in Pennsylvania was the *most Republican-leaning Efficiency Gap in the 2012 cycle among states with more than six seats and the second largest one in history*.⁸ If we average across the past three elections (2012-2016), Pennsylvania had the second most-Republican leaning Efficiency Gap in the country (-19%).⁹

5 Partisan Gerrymandering & Representation in Congress

In the previous section, I have shown that Pennsylvania's current districting plans has led to a substantial partisan advantage for Republicans. Moreover, this partisan bias is large both relative to other states and relative to previous districting plans in Pennsylvania. Now, I turn to the effects of this partisan advantage for the representation that Pennsylvanians receive in Congress. The growing pro-Republican Efficiency Gap creates conditions where many Democratic voters in Pennsylvania are unable to elect representatives of their choice. The growing polarization in Congress means that representatives in Congress nearly always vote the party line. So Democrats that are artificially deprived of the opportunity to elect someone that shares their values do not have their views represented in Congress. This means that they have little, if any, voice on important issues. Thus, the combination of partisan gerrymandering and polarization in Congress has a profound, pernicious effect on democratic representation.

7. First, the Efficiency Gap measure using the simpler assumption that the winner in uncontested races receives 75% of the vote and the loser receives 25% of the vote also indicates that Pennsylvania had the largest Efficiency Gap in the country in 2012 and the second worst across the 2012-16 elections. Second, the Efficiency Gap estimates produced by the Public Policy Institute of California also indicate that Pennsylvania had the largest Efficiency Gap in the country in 2012 and the second worst across the 2012-16 elections. Third, the Brennan Center's Efficiency Gap estimates indicate that Pennsylvania had the second largest Efficiency Gap in the country both in 2012 and across the 2012-16 elections. Finally, an estimate of the Efficiency Gap using presidential election results indicates that Pennsylvania had the third most pro-Republican Efficiency Gap in 2012.

8. Pennsylvania continues to stand out even if we lower the threshold of seats in a state. Pennsylvania also had the most pro-Republican Efficiency Gap in 2012 among states with more than four seats, and the second most after Arkansas among states with more than 2 seats.

9. It was only narrowly less Republican leaning than North Carolina's 2012-16 plan, which had a pro-Republican Efficiency Gap of approximately -20%, or only 1% more pro-Republican than Pennsylvania's plan. North Carolina's plan is the subject of a variety of federal litigation.

5.1 Growth of Polarization in Congress

It has been widely documented that partisan polarization in Congress has grown significantly in recent decades. This work has shown that congressional voting is increasingly polarized by party. Indeed, the gap between the roll call behavior of the two parties has grown substantially since the 1970s (Poole and Rosenthal 1997; McCarty, Poole, and Rosenthal 2006, 2009; Bartels, Clinton, and Geer 2016).¹⁰ The responsiveness of legislators to district preferences has also waned during this period. In recent years, there has been “muted responsiveness to localities” (Ansolabehere, Snyder, and Stewart 2001).

In this section, I first use a variety of methods to document the growing polarization in Congress. I also show that the gap between the parties has grown in Pennsylvania just as it has in the nation as a whole. One simple approach to showing the growth in polarization is to examine changes in the proportion of the time that members of each party vote in a conservative direction on individual roll calls. Recent work by Professors Anthony Fowler and Andrew Hall has classified whether each roll call vote is liberal or conservative, and the percentage of the time that each member of congress votes in a conservative direction relative to the median legislator (Fowler and Hall 2017).

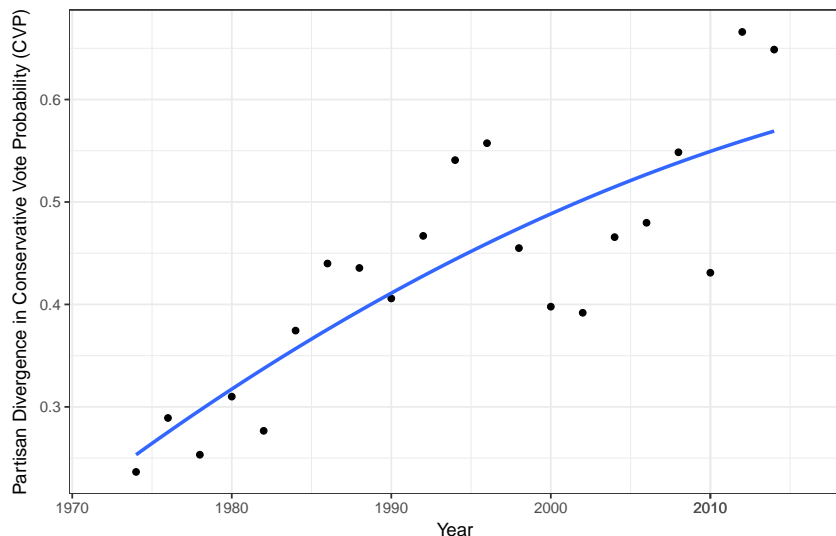


Figure 6: Difference in the Proportion of the Time that Members of Each Party Vote Conservatively. The dots represents the averages in each year, and the line shows a moving average.

10. It is important to note that the consensus among Political Scientists using pre-2011 redistricting period data is that gerrymandering did not cause this polarization (McCarty, Poole, and Rosenthal 2009). There is not yet a consensus about the effect of redistricting on polarization in recent years. Regardless of whether gerrymandering causes polarization, however, polarization exacerbates the effects of gerrymandering on the political process.

Figure 6 above shows the difference in the proportion of votes that members of each party vote in a conservative direction. It shows that the gap between the parties grew substantially in the late 1980s and early 1990s, and then again in 2012. In the most recent Congress where data is available (113th), there was a 65% difference between Democrats and Republicans.

A limitation of this analysis, however, is that it implicitly treats all “conservative” roll calls as equally conservative. Imagine that conservative roll calls today would enact more conservative policies than conservative roll calls in the 1980s. In this case, it might be reasonable for a moderate congressperson, who is equally conservative in both periods, to vote for the conservative position in the 1980s and against it today. Thus, the estimates of conservative vote probabilities are not comparable inter-temporally either for individual members or for Congress as a whole.

To address this issue, Political Scientists have developed a number of different ways to estimate the latent ideology of members of Congress based on their roll call votes (for a review, see McCarty 2011). In this section, I’ll focus on the most prevalent model – the DW-Nominate scores developed by Professors Howard Rosenthal and Keith Poole (Poole and Rosenthal 1997). These scores are considered the classic, established estimates of the ideology of members of Congress. They have been used by hundreds of political science studies.

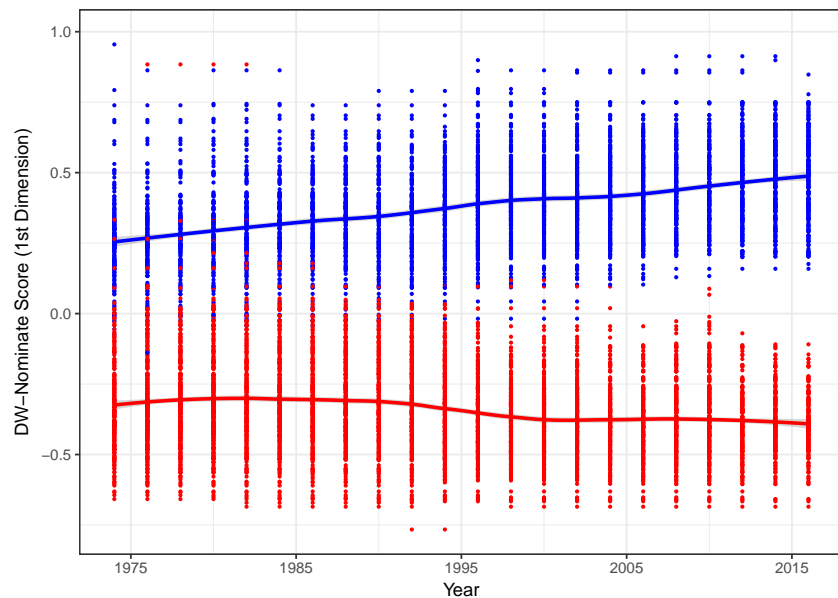


Figure 7: The average ideology of members of each party

These scores (shown in Figure 7 above) characterize legislators’ latent ideology using a

statistical model based on all of their roll call votes.¹¹ The score for each member ranges from -1 (most liberal) to +1 (most conservative). These ideology scores are made intertemporally comparable based on the assumption that individual members of Congress keep the same ideological position throughout their career in Congress.¹²

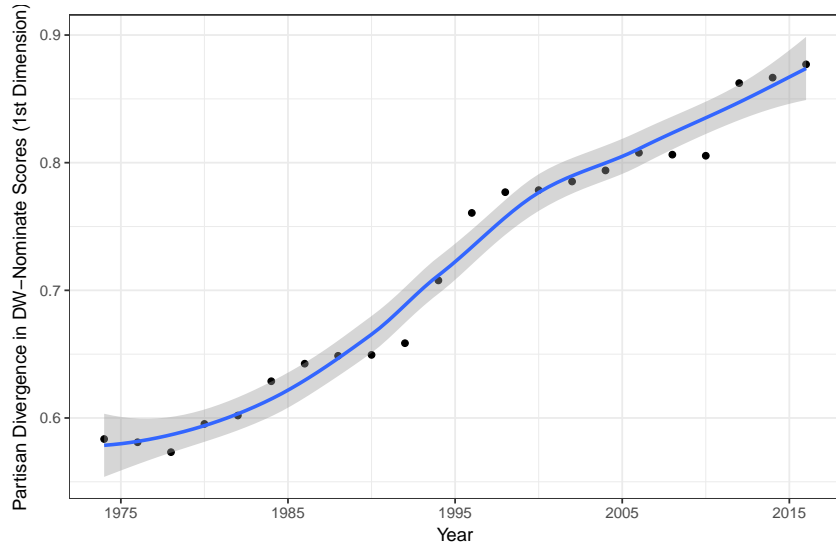


Figure 8: The growth in polarization between members of the two parties

Figure 7 (above) shows the trends in the average ideology of Democrats and Republicans in the United States House over the past forty years. It shows the DW-Nominate scores of each member of Congress, as well as the average for each party. It illustrates that there is no overlap at all in today’s Congress between the ideologies of Democrats and Republicans. In other words, Republicans are *always* substantially more conservative than Democrats in Congress. Figure 8 shows the gap between the parties. It indicates that the gap between Democrats and Republicans has been steadily growing for the past few decades. However, polarization has increased substantially in recent years.

11. Poole and Rosenthal (1997) show that a single dimension is sufficient to summarize congressional voting behavior quite accurately for most of the history of the United States.

12. Poole and Rosenthal also estimated DW-Nominate scores that assume that each legislator’s ideology can only change over time in a parametrically specified manner which generally rules out dramatic shifts in the ideology of individual legislators from one Congress to the next (see Bartels, Clinton, and Geer 2016). These scores show even larger increases in polarization than the scores that assume individual members of Congress keep the same ideological position. However, due to their more transparent assumptions and the fact that they yield more conservative estimates (in the nonpolitical sense of conservative) of the growth in polarization, I use the DW-Nominate scores that assume individual members of Congress keep the same ideological position throughout the analyses that follow.

5.2 Growth of Polarization among Pennsylvania's Members

Polarization has also grown significantly among Pennsylvania's representatives in the U.S. House. Figure 9 shows the growth in polarization between Democratic and Republican members of the House from Pennsylvania over the past forty years. The top panel of Figure 9 shows the ideology scores of each member of Congress, as well as the average for each party.

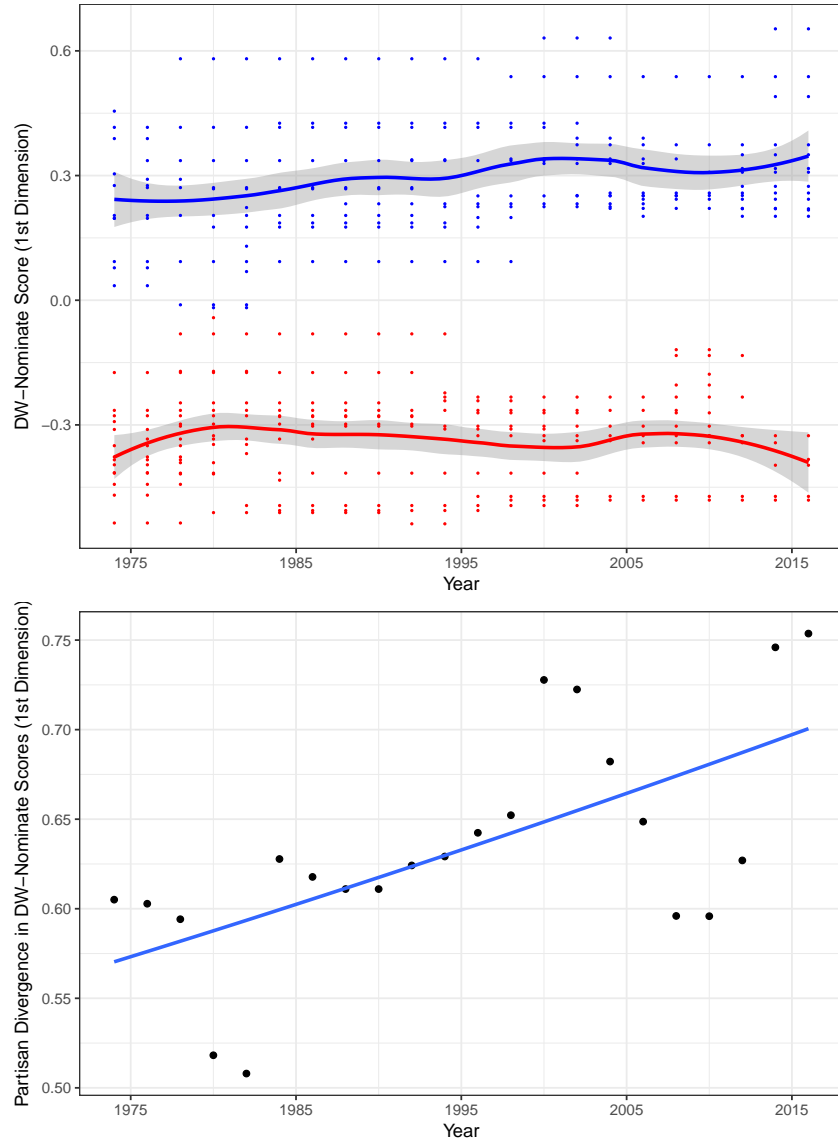


Figure 9: Polarization among Pennsylvania representatives: The top panel shows the average ideology of members of each party in Pennsylvania. The bottom panel shows the growth in polarization between members of the two parties in Pennsylvania

The figure illustrates that there has never been any substantial overlap in Congress

between the ideology scores of Democrats and Republicans from Pennsylvania. Republicans are *always* substantially more conservative than Democrats from Pennsylvania. The bottom panel of Figure 9 (above) shows the gap between the parties. Just like in the Congress as a whole, it indicates that the gap between Democrats and Republicans has been steadily growing in recent decades.

Figure 10 shows another way to visualize the growth in polarization among Pennsylvania’s legislators. It shows the proportion of non-unanimous votes where at least 90% of the representatives from Pennsylvania vote together. While it’s true that there was never a period when Pennsylvania legislators voted together a majority of the time, consensus among PA legislators has reached historic lows. In the 1980s, well over a third of the non-unanimous roll calls demonstrated a consensus among PA representatives.

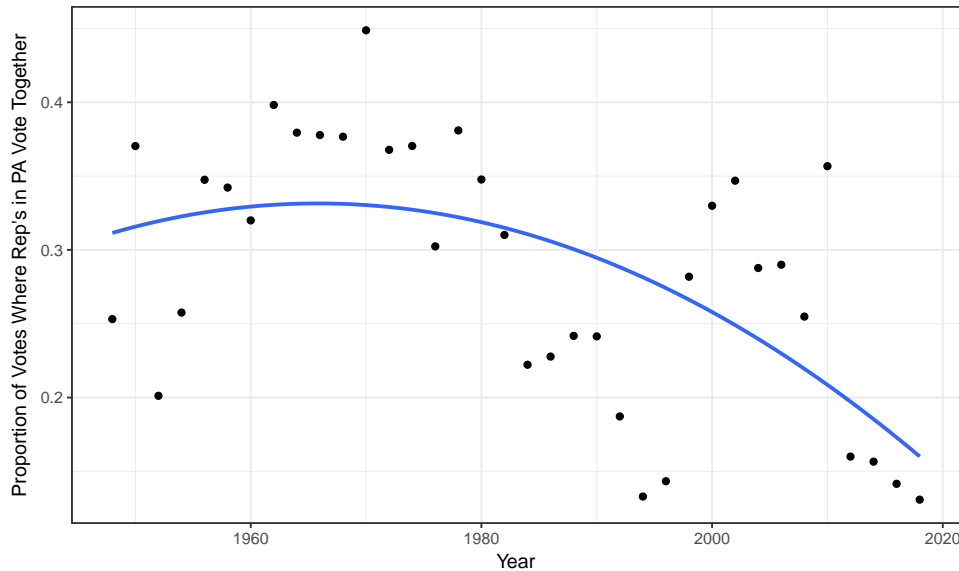


Figure 10: Proportion of Non-Unanimous Votes Where Representatives from Pennsylvania Vote Together

Today, less than 10% of non-unanimous congressional roll calls build a consensus among Pennsylvania representatives. This further indicates that Democratic and Republican legislators typically vote much differently, and there is rarely a consensus among legislators from Pennsylvania from both parties. These trends in Pennsylvania are consistent with findings at the national level on the increasing polarization of voting in Congress (Poole and Rosenthal 1997) and the nationalization of voting patterns in elections (Hopkins 2018).

Finally, Table 2 further demonstrates the polarization in Pennsylvania’s congressional delegation in recent years. Using data on votes from the 113th Congress in 2013-14, it shows that in recent years members of Congress from Pennsylvania have voted almost

Congress	Member	District	Party	Ideology Score	Perc. of Votes w/ Maj. of Same Party (All Votes)	Perc. of Votes w/ Maj. of Same Party (Non-Unan. Votes)
113	Bob Brady	1	D	-0.48	94%	92%
113	Chaka Fattah	2	D	-0.47	96%	94%
113	Mike Kelly	3	R	0.32	95%	93%
113	Scott Perry	4	R	0.65	94%	90%
113	Glenn Thompson	5	R	0.31	92%	87%
113	Jim Gerlach	6	R	0.22	91%	85%
113	Patrick Meehan	7	R	0.22	91%	87%
113	Mike Fitzpatrick	8	R	0.20	85%	76%
113	Bill Shuster	9	R	0.37	95%	92%
113	Tom Marino	10	R	0.35	95%	92%
113	Lou Barletta	11	R	0.27	94%	90%
113	Keith J. Rothfus	12	R	0.49	96%	93%
113	Allyson Schwartz	13	D	-0.34	96%	94%
113	Mike Doyle	14	D	-0.33	95%	93%
113	Charles W. Dent	15	R	0.24	90%	84%
113	Joe Pitts	16	R	0.54	95%	92%
113	Matt Cartwright	17	D	-0.40	96%	94%
113	Tim Murphy	18	R	0.26	95%	91%

Table 2: Polarization in Pennsylvania’s Delegation: The Percentage of time PA Representatives Vote with a Majority of their Party on All Votes and Non-Unanimous Votes

exclusively with representatives of the same party and rarely join with representatives from the opposing party to vote on a bipartisan basis. On average, Pennsylvania representatives took the same position as the majority of their own party 93% of the time when we average across all votes and 90% of the time on non-unanimous votes.¹³

5.3 The Efficiency Gap and Roll Call Voting in Congress

In this section, I examine the effect of the Efficiency Gap on roll call voting patterns in Congress. I show that a more pro-Republican Efficiency Gap leads to more conservative roll call voting. To be clear, I do not argue that gerrymandering causes more polarization in Congress. Rather, building upon previous work on both state legislatures (Caughey, Tausanovitch, and Warshaw 2017) and Congress (Stephanopoulos 2018), I show that pro-Republican changes in the Efficiency Gap leads to more conservative roll call voting in Congress because (1) more pro-Republican Efficiency Gaps lead to more Republicans taking office (see Section 4) and (2) more Republican seats leads to more conservative roll

13. Data are from the Voteview database of roll call votes in Congress maintained by the University of California, Los Angeles (Lewis et al. 2016).

call voting patterns (and increasingly so in recent years, as Republicans have gotten more conservative over time, as shown in Section 5.1).

Table 3: Effect of Efficiency Gap on Average Legislator Ideology in Each State

<i>Dependent variable: Ave. Ideology of Legislators in Each State</i>		
	(1)	(2)
Efficiency Gap	-0.732*** (0.038)	
EG (1970s)		-0.678*** (0.067)
EG (1980s)		-0.470*** (0.094)
EG (1990s)		-0.750*** (0.077)
EG (2000s)		-0.733*** (0.085)
EG (2010s)		-0.929*** (0.078)
State Fixed Effects	X	X
Year Fixed Effects	X	X
Observations	508	508
R ²	0.880	0.884

Note:

*p<0.1; **p<0.05; ***p<0.01

The details of my results are found in Table 3 (above).¹⁴ The key finding is that changes in the Efficiency Gap have a strong and robust relationship with roll call voting behavior. Across the entire time period, a 10% pro-Republican shift in the Efficiency Gap is associated with a .07 shift to the right in legislators' ideology (i.e., DW-Nominate scores). Moreover, due to the growing polarization in Congress, the effect of the Efficiency Gap on legislators' average ideology has grown substantially in recent years. The right column shows that in the most recent Congresses, a 10% pro-Republican shift in the Efficiency Gap is associated with a .09 shift to the right in DW-Nominate scores. This

14. I use a model with fixed effects for state and year. This model is the workhorse model for causal inference in economics and political science (Angrist and Pischke 2009). The state fixed effects account for time-invariant confounders in each state and the year fixed effects account for shocks that affect all states equally.

is roughly equivalent to the difference between the ideologies of Republican Senators John Cornyn and Lindsey Graham. Cornyn was rated as the second most conservative senator by the nonpartisan National Journal in 2011-12 (FactCheck.org 2013) and is one of the Senators most likely to support President Trump (FiveThirtyEight.com 2017). In contrast, Graham often takes moderate positions. For instance, he nearly co-sponsored legislation to address climate change (Lizza 2010) and he is one of the Republicans least likely to support Trump’s positions in the most recent congress (FiveThirtyEight.com 2017).

5.4 The Efficiency Gap & Representation in Affordable Care Act Repeal

In this section, I show how gerrymandering can impact representation. Specifically, I show that citizens are much more likely to agree with the roll call votes of same-party legislators than opposite party legislators on important policy issues. Moreover, people whose votes are artificially wasted due to gerrymandering are deprived of having legislators that agree with their views. As a result, gerrymandering can be responsible for voters effectively having no political voice in Congress.

For this analysis, I use data from the 2016 Cooperative Congressional Election Study (CCES) (Ansolabehere and Schaffner 2017). This is a large-scale study about how Americans view Congress and hold their representatives accountable during elections, how they voted and their electoral experiences, and how their behavior and experiences vary with political geography and social context.¹⁵ The large sample is capable of capturing variation across a wide variety of legislative constituencies. In fact, the state-level samples are large enough to measure with a reasonable degree of precision the distribution of voters’ preferences within most states.

First, I examine how much it matters whether citizens and legislators share the same political party. I focus on the vote to repeal the Affordable Care Act (“ACA”) in February 2015 since the ACA is probably the seminal political issue of the past decade.¹⁶ On this issue, about 29% of Democrats in Pennsylvania favored the repeal, while more than 88% of Republicans favored it. Congress split even more starkly – all of the Republicans in the House from Pennsylvania voted for the repeal and all of the Democrats voted against it. The division between Democrats and Republicans in Congress on the Affordable Care Act

15. The survey was conducted through the Internet by YouGov of Redwood City, CA.

16. The roll call is on H.R. 596, a bill “to repeal the Patient Protection and Affordable Care Act and health care-related provisions in the Health Care and Education Reconciliation Act of 2010, and for other purposes.”

is a microcosm of the polarization in Congress that I discussed in the previous section.

The CCES data indicate that voters are much more likely to agree on the ACA repeal with the position of members of their party than legislators from the opposite party. Democrats in Pennsylvania agreed with Democratic legislators' roll call votes about 71 percent of the time on the repeal vote. In contrast, they only agreed with Republican legislators' roll call votes about 30 percent of the time. This implies that Democrats were 41 percentage points more likely to agree with Democratic than Republican legislators on this issue. I find even stronger results for Republican citizens. They were about 74 percentage points more likely to agree with Republican than Democratic legislators. Averaging across both parties, Pennsylvanians were about 57 percentage points more likely to agree with a legislator of the same party on the repeal vote than one of the opposite party. I find similar patterns in the nation as a whole. Across the entire nation, Americans were about 56 percentage points more likely to agree with a legislator of the same party than one of the opposite party on the vote to repeal the Affordable Care Act. This shows that voters are extremely unlikely to see their preferences on major bills translated into action in Congress when their legislator is from the opposite party.

Next, I examine whether the congruence between the views of citizens and the actions of legislators on the repeal of the Affordable Care Act is lower in states where people's votes are more likely to be wasted. I estimate the weighted proportion of Democrats, Independents, and Republicans within each state whose views are congruent with the views of their legislator on the repeal of the Affordable Care Act."¹⁷

Figure 11 (below) shows that there is a strong association between the Efficiency Gap and the percentage of Democrats and Republicans in each state whose views on the repeal of the Affordable Care Act are congruent with the positions of their legislators. Democratic citizens and their legislators were about a third less likely to agree with each other in states with a large pro-Republican Efficiency Gap as in states with no Efficiency Gap. Likewise, Republicans were much less likely to agree with their legislators in states with a large pro-Democratic Efficiency Gap than in states with no Efficiency Gap. Finally, the graph shows that Democrats and Republicans are roughly equally likely to agree with their member of Congress on the Affordable Care Act in states with no Efficiency Gap.

Figure 11 also shows that Democrats in Pennsylvania were much less likely to agree with their legislators on the Affordable Care Act repeal vote than Republicans were. About 75% of Pennsylvania Republicans agree with their representative on the Affordable Care Act repeal, while only about 45% of Democrats agree with their representative. This is not surprising since Pennsylvania Democrats were much more likely than Republicans

17. I treated Independents that leaned toward a party as partisans for this analysis.

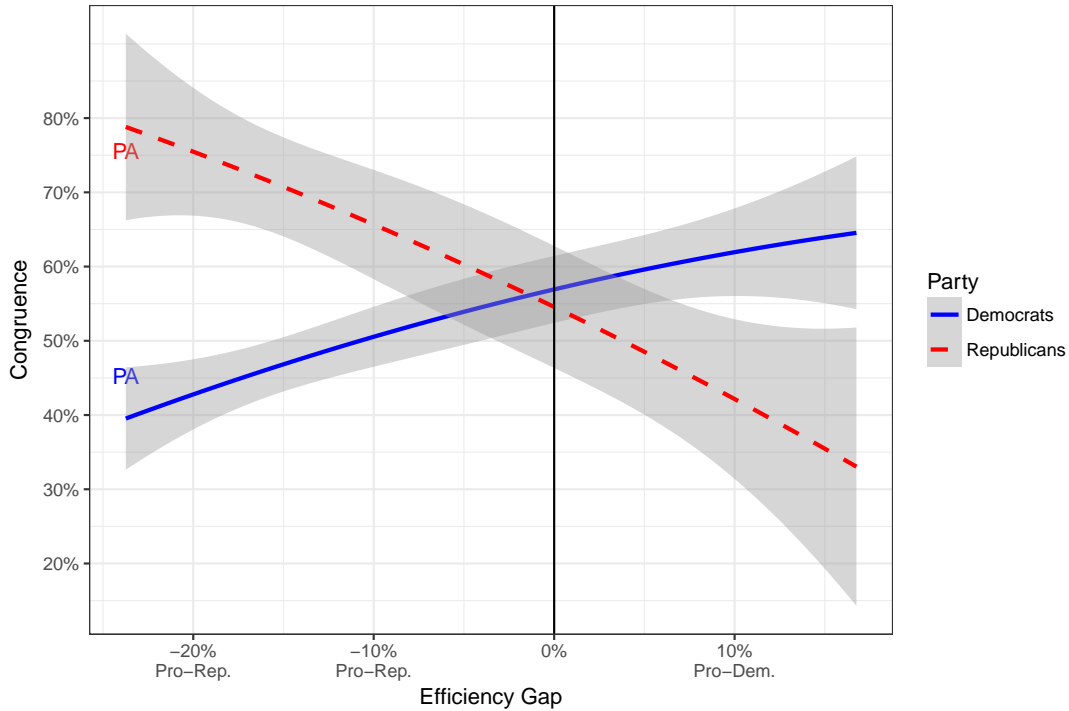


Figure 11: Association Between Efficiency Gap and the Congruence Between Public Opinion and Legislators' ACA Repeal Vote

to have their votes wasted.

Overall, the analysis in this section suggests that partisan gerrymandering has a large effect on representation. That is, it has a substantial effect on the congruence between citizens' views and legislators' roll call votes on important policy issues. Citizens whose votes are wasted have little, if any, voice in Congress on the Affordable Care Act, and other important issues.

6 Partisan Gerrymandering and Citizens' Trust in their Representatives

In the previous sections, I showed that the Efficiency Gap has an important effect on roll call voting patterns in Congress. It also affects citizens' representation in Congress. Citizens whose votes are wasted in states with large Efficiency Gaps are less likely to see their preferences translated into policy.

In this section, I show that citizens whose votes are wasted due to partisan gerrymandering also have less faith in their elected officials. Specifically, I show that Democrats in states with large pro-Republican Efficiency Gaps have less trust in their representatives

in Congress than Democrats in states with neutral or pro-Democratic Efficiency Gaps (and likewise for Republicans in states with pro-Democratic Efficiency Gaps). This suggests that partisan gerrymandering not only distorts the link between elections and the legislature, it undermines Americans’ faith in democracy itself.

For this analysis, I use data from the 2014 Cooperative Congressional Election Study (Ansolabehere and Schaffner 2015).¹⁸ I estimate the weighted proportion of Democrats, Independents, and Republicans within each state that “trust your district’s Representative in Congress to do what is right.”¹⁹ Nationwide, there is little difference between Democrats and Republicans on this question. In general, many people lacked trust in their Representative. Only about 30% of the people in each party indicate that they trusted their Representative to do what’s right.

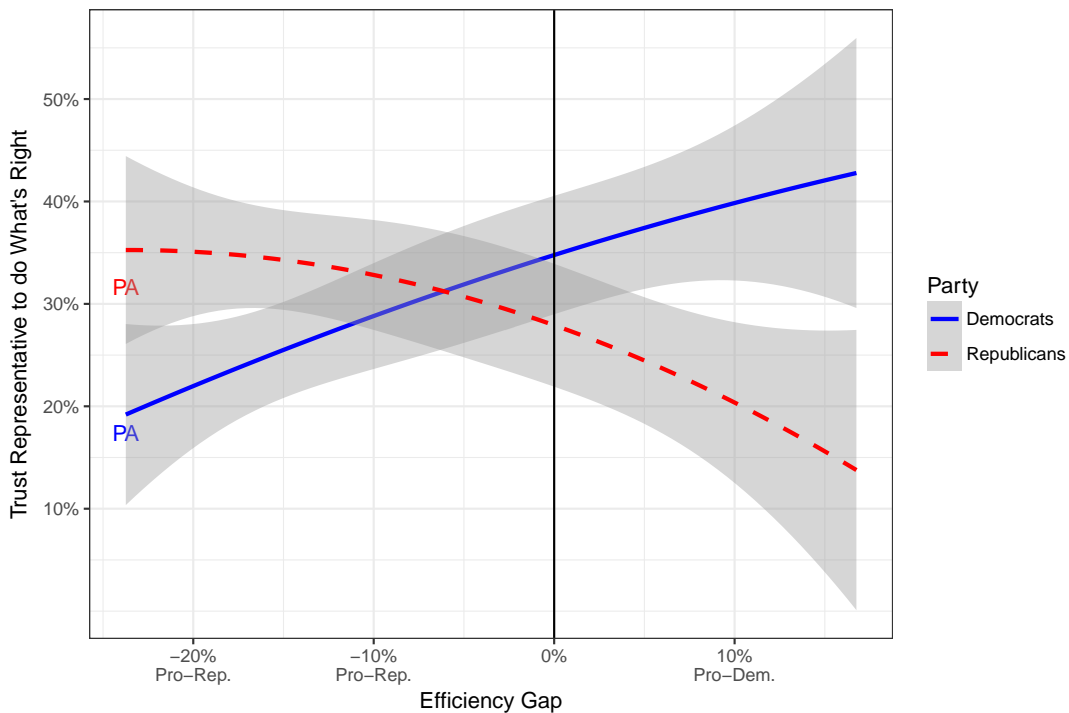


Figure 12: Association Between Efficiency Gap and Citizens’ Trust in their Representative in Congress

Figure 12 examines whether citizens’ trust for their representatives is lower in states where their vote is more likely to be wasted. The graph shows that the answer is clearly yes. Democrats are only half as likely to believe that their Representative will do what is right in states with a large pro-Republican Efficiency Gap than in states with no Efficiency

18. The survey was conducted through the Internet by YouGov of Redwood City, CA.

19. I treated Independents that leaned toward a party as partisans for this analysis.

Gap. Likewise, Republicans are much less likely to trust their Representative in states with a large pro-Democratic Efficiency Gap than in states with no Efficiency Gap.

The graph also shows the average levels of Democrats' and Republicans' trust for their representatives in Pennsylvania. Approximately 1.3 million more Democratic votes were wasted in Pennsylvania's 2012 congressional elections than were wasted by Republicans. As a result, we would expect that Democrats are less likely to trust their representatives than Republicans. Indeed, this is exactly what we observe. Democratic citizens of Pennsylvania were roughly 15 percentage points less likely to trust their Representatives than Republicans.

Overall, this analysis indicates that bias in the districting process has large and profound effects on citizens' trust in their representatives in Washington DC. When voters lose the ability to elect representatives of their party as a result of gerrymandering, this undermines their faith in their representatives. This suggests that gerrymandering impacts not just the representatives we select and their roll call votes in Congress, but citizens' faith in democracy itself.

7 Conclusion

Based on my review of the literature and relevant data, I have reached several conclusions about Pennsylvania's redistricting plan:

- There are substantially more wasted Democratic votes in Pennsylvania congressional elections than Republican votes. This has led to a substantial and durable Republican bias in the translation of votes to seats in congressional elections in Pennsylvania.
- Pennsylvania has one of the largest Efficiency Gaps in history. The pro-Republican Efficiency Gap in Pennsylvania is extremely large relative to other states. Moreover, Pennsylvania's current Efficiency Gap is much larger than its own Efficiency Gaps prior to the 2011 redistricting. Thus, the current Efficiency Gap in Pennsylvania cannot solely be a product of geography.
- The pro-Republican advantage in congressional elections in Pennsylvania causes Democratic voters whose votes are wasted to be effectively shut out of the political process in Congress. Due to the growing polarization in Congress, there is a massive difference between the roll call voting behavior of Democrats and Republicans. In today's Congress, a representative from one party increasingly does not represent the views of a constituent of the opposite party. Thus, Democratic voters whose

votes are wasted are unlikely to see their preferences represented in our nation's capital.

- Voters appear to be aware of this representational failure. In states with a pro-Republican Efficiency Gap, such as Pennsylvania, Democrats are much less likely than Republicans to trust their representatives in Congress to do what is right. Conversely, Republicans are less likely than Democrats to trust their representatives in Congress in states with a large pro-Democratic Efficiency Gap. This suggests that gerrymandering is eroding Americans' faith in our democracy.

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Supplementary Appendix

A Measurement Model for Uncontested Races

A factor that complicates the computation of the Efficiency Gap (as well as any other measure of partisan bias) is that many seats are uncontested. As Stephanopoulos and McGhee (2015, 865) put it, “Since gerrymanders redistribute voters in order to pack and crack the opposition, determining the degree of packing and cracking requires knowing how many people in each district support each party.”²⁰ In uncontested races, however, it is not possible to calculate a two-party vote share. Thus, we have no way of knowing based on the election returns alone how many people supported each party.

If there were only a handful of uncontested races, this might not be an important problem. However, approximately 14% of congressional races between 1972-2016 were uncontested. Moreover, in many states there are much higher rates of uncontested elections. For instance, 34% of the congressional elections in Alabama during this period were uncontested and 41% of the elections in Massachusetts were uncontested. In Pennsylvania, approximately 12% of the congressional elections were uncontested between 1972-2016. In each of the past two election cycles, 3 seats in Pennsylvania (17% of the total) were uncontested.

As a result, we need some strategy to impute the two-party vote shares in these districts in order to estimate the Efficiency Gap. There are a variety of potential approaches to address this problem. The simplest strategy is to simply assume that the winning candidate receives 75% of the vote and the losing candidate receives 25% of the vote. Many political science studies have adopted this approach (e.g., Gelman and King 1994a; Kastellec, Gelman, and Chandler 2008).²¹ However, Kastellec, Gelman, and Chandler (2008) point out that “there is no way to know whether the losing candidate would have actually received 25% of the vote. For example, in a heavily Democratic district in Philadelphia, this probably over-estimates the vote share a Republican candidate would have gotten. In contrast, it might under-estimate the Republican vote share in a more

20. A variety of other scholars have noted this problem. For instance, Campagna and Grofman (1990, 1247) note that “One key issue [for studies of redistricting] is how to handle uncontested seats. [One needs] to avoid using 100% as the vote share for a party in an uncontested seat (which, for Congress, tends to bloat ... vote share).”

21. Kastellec, Gelman, and Chandler (2008) justify this strategy by noting that King and Gelman (1991) and Gelman and King (1994a) examined the “vote shares received in the last election before a district became uncontested and the first election after a district became uncontested. The average of these values was about 0.75 for the incumbent party and represents the average ‘effective support’ for the party in uncontested races.”

suburban, swing district.”

A more sophisticated strategy to address uncontested races is to estimate the two-party vote share in district_{*i*} based on previous and future elections in that district as well as the results in similar districts elsewhere. A variety of recent analyses have used this approach. The Brennan Center’s recent report uses a variant of this approach for its estimates of Efficiency Gaps between 1992-2016 (Brennan Center 2017, 16).²² This strategy is also used by the Public Policy Institute of California for its estimates of the Efficiency Gap over the last decade, and by Professor Simon Jackman in his expert reports for litigation in Wisconsin and North Carolina (Jackman 2015, 2017). One downside of this approach, however, is that it relies on less transparent assumptions than the simpler strategy described above.

Unfortunately, there are no publicly available estimates of the Efficiency Gap that span the past four decades. As a result, I build my own estimates using both approaches described above. That is, I build one set of Efficiency Gap estimates based on the assumption that the winning party receives 75% of the vote in uncontested districts and another version using a model that imputes the vote shares in uncontested districts based on previous and future elections in that district as well as the results in similar districts elsewhere. I use the latter estimates in the main body of the report. But it is important to note that the substantive results in the report are robust to the precise details of how we calculate the Efficiency Gap.

1. First, I estimate the Efficiency Gap assuming that the winner in uncontested races receives 75% of the vote and the loser receives 25% of the vote. I estimate the statewide Democratic vote share by assuming that turnout in each district was equal and simply taking the average of the two-party vote shares in each district.
2. Second, I estimate the Efficiency Gap using a Bayesian model to impute both the vote share and turnout in uncontested districts. This model is closely related to the imputation strategy for uncontested districts adopted by previous studies of the Efficiency Gap (Stephanopoulos and McGhee 2015; Jackman 2017; Brennan Center 2017).
 - In order to estimate the vote shares in uncontested districts, I model the proportion of the two-party vote received by the Democrat ($p_{d,t}$) in each district

22. Brennan Center (2017, 16) states that ‘For districts without both a Democrat and Republican running in the general election, we estimated the vote share both parties would have received in a contested two-party election based on the prior election’s House results, the most recent district-level Presidential results using totals calculated and compiled by Daily Kos Elections for both 2012 and 2016, a district’s Cook Partisan Voter Index, and the winning candidate’s incumbency status.’

(d) using a binomial model.

$$s_{d,t}^v \sim \text{Binomial}(n_{d,t}^v, p_{d,t}^v), \quad (3)$$

where d indexes districts and t indexes elections. $n_{d,t}^v$ is set to 2000²³ and $s_{d,t}^v$ is the two-party vote share multiplied by 2000. For uncontested races, we set $n_{d,t}^v$ and $s_{d,t}^v$ to zero. We then model p as a function of: previous and future results in that district, each district’s presidential vote share, whether there is an incumbent running, and if so, their party, and the region that the district is in. More formally, we model

$$p_{d,t}^v = \Phi(\gamma_t + p_{d,t-1}^v + \beta_1 * pvote_{d,t} + \beta_2 * incumbency_{d,t} + \alpha_{s[d]}^{region}) \quad (4)$$

where $pvote$ is the percentage of the two-party presidential vote received by the Democratic candidate in each district; $incumbency$ is a factor equal to 1 if there is a Democratic incumbent, 0 if there is no incumbent, and -1 if there is a Republican incumbent; regions are based on economic regions defined by the Bureau of Economic Advisors; and the normal CDF Φ maps p to the (0, 1) interval. I estimate the model separately each decennial redistricting period (i.e., years ending in 02 - 12) using the `dgmpr` function in the `dgo` package in **R** (Dunham, Caughey, and Warshaw 2016).²⁴ The mean estimate of Democratic vote share in uncontested races won by Democrats is 71% and the average estimate of Democratic vote share in uncontested races won by Republicans is 31%.²⁵

- In order to estimate the turnout in uncontested districts, I model the proportion of the population ($p_{d,t}$) that votes in each district (d) using a similar binomial model.

$$s_{d,t}^t \sim \text{Binomial}(n_{d,t}^t, p_{d,t}^t), \quad (5)$$

where $n_{d,t}^t$ is set to 2000 and $s_{d,t}^t$ is the proportion of the population that voted for either the Democratic or Republican candidate multiplied by 2000. For

23. This number is set for computational efficiency. However, it could be arbitrarily set to some other number, and this would not affect the model results.

24. Due to data limitations, for both the models of turnout and vote share, I do not split apart states’ plans due to mid-decade redistrictings. In recent decades, however, only a handful of states have conducted mid-decade redistrictings.

25. These estimates are very similar to those of Stephanopoulos and McGhee (2015, 866). Based on a similar approach, they estimate a “mean Democratic vote share [in uncontested races] of 70 percent,” and for uncontested Republicans, they estimate “a mean Democratic vote share of 32 percent.”

districts with uncontested races, we set $n_{d,t}^t$ and $s_{d,t}^t$ to zero. We then model p as a function of: previous and future results in that district, whether there is an incumbent running, and if so, their party, and the region that the district is in. More formally, we model

$$p_{d,t}^t = \Phi(\gamma_t + p_{d,t-1}^t + \beta_1 * incumbency_{d,t} + \alpha_{s[d]}^{region}) \quad (6)$$

where *incumbency* is a factor equal to 1 if there is a Democratic incumbent, 0 if there is no incumbent, and -1 if there is a Republican incumbent; regions are based on economic regions defined by the Bureau of Economic Advisors; and the normal CDF Φ maps p to the (0, 1) interval. I estimate the model separately each decennial redistricting period (i.e., years ending in 02 - 12) using the `dgmnp` function in the `dgo` package in **R** (Dunham, Caughey, and Warshaw 2016).

- For uncontested districts, I estimate the number of Democratic votes in each district by multiplying the estimated, imputed Democratic vote share ($p_{d,t}^v$) by the estimate of the proportion of the population that voted ($p_{d,t}^t$) by the population. I estimate the total votes by multiplying $p_{d,t}^t$ by the population. For contested districts, I use the actual number of Democratic votes and total votes in each district. Combining these approaches, I estimate the statewide Democratic vote share by simply summing the Democratic votes in each district and dividing by the total number of votes.

Now that we know voters' two-party preferences in contested districts and we have estimates of their preferences in uncontested districts, we are finally in position to estimate the partisan advantage in the congressional districting process during each state-year. I estimate the efficiency gap in all states for each election between 1972 to 2012.²⁶ In the main body of the report, I focus on states with more than 6 congressional seats. I omit smaller states for two reasons. First, these states contribute less to the overall distribution of seats in Congress (Stephanopoulos and McGhee 2015, 868). Second, the Efficiency Gap in smaller states tends to be more volatile and thus less informative about partisan bias. For example, in a state with only three seats, a change in the winner of one seat could cause a huge shift in their Efficiency Gap.

Prior to examining our results, it is useful to validate my measures of the Efficiency Gap

26. I start the analysis in 1972 since those are the first districting plans drawn after the Supreme Court cases stemming from *Baker v. Carr* ended malapportionment and established the principle of one-person, one-vote.

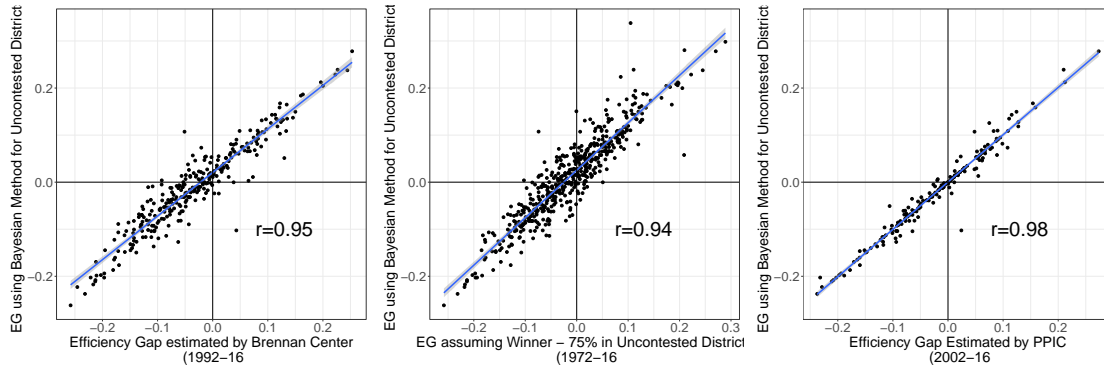


Figure A1: Validation of the Efficiency Gap Measure

to make sure that it aligns closely with alternative modeling approaches for uncontested races. In fact, Figure A1 shows that the precise method used to impute uncontested races makes relatively difference for estimates of the Efficiency Gap.

- The correlation between estimates of the Efficiency Gap I calculated using the Bayesian method described above and a simpler approach that assumes the winner in uncontested races received 75% of the two-party vote is 0.93.
- The correlation between my estimates of the Efficiency Gap and estimates for 1992-2016 developed by the Brennan Center is 0.94.
- The correlation between my estimates of the Efficiency Gap and estimates for 2002-2016 developed by the Public Policy Institute of California is 0.98.

Christopher S. Warshaw

Department of Political Science
2115 G Street, N.W.
Monroe Hall 440
Washington, D.C. 20052

Office: 202-994-6290
Fax: 202-994-1974
Email: warshaw@gwu.edu
Homepage: www.chriswarshaw.com

Academic Employment

George Washington University, Washington, DC

Assistant Professor, 2017 - present

Massachusetts Institute of Technology, Cambridge, MA

Associate Professor of Political Science (without tenure), 2016 - 2017

Assistant Professor of Political Science, 2012 - 2016

Education

Stanford University, Ph.D., Political Science, 2012

Advisors: Jonathan Rodden, Simon Jackman, Barry Weingast, and David Brady

Fields: American Politics, Comparative Politics, and Political Methodology (Statistics)

Stanford Law School, Juris Doctorate, 2011

Williams College, B.A., *magna cum laude*, 2002

Majors: Economics (highest honors) and Political Science

Research Interests

American Politics, Representation, Public Opinion, State & Local Politics, Environmental Politics and Policy, Statistical Methodology

Research

Published Articles

Peer Reviewed Articles

14. "Policy Preferences and Policy Change: Dynamic Responsiveness in the American States, 1936-2014." Forthcoming. *American Political Science Review*. (with Devin Caughey)

13. "Does the Ideological Proximity Between Candidates and Voters Affect Voting in U.S. House Elections?" Forthcoming. *Political Behavior*. (with Chris Tausanovitch)
12. "On the Representativeness of Primary Electorates." Forthcoming. *British Journal of Political Science* (with John Sides, Chris Tausanovitch, and Lynn Vavreck)
11. "Partisan Gerrymandering and the Political Process: Effects on Roll-Call Voting and State Policies." Forthcoming. *Election Law Journal*. Symposium on Partisan Gerrymandering and the Efficiency Gap. (with Devin Caughey and Chris Tausanovitch)
10. "Geography, Uncertainty, and Polarization." Forthcoming. *Political Science Research and Methods*. (with Nolan McCarty, Jonathan Rodden, Boris Shor, and Chris Tausanovitch)
9. "Incremental Democracy: The Policy Effects of Partisan Control of State Government." 2017. *Journal of Politics*. 79:4. (with Devin Caughey and Yiqing Xu)
8. "Renewable energy policy design and framing influences public support in the United States." 2017. *Nature Energy*. 2(17107). (with Leah Stokes)
7. "Estimating Candidates' Political Orientation in a Polarized Congress." 2017. *Political Analysis*. 25(2). (with Chris Tausanovitch)
6. "The Dynamics of State Policy Liberalism, 1936-2014." 2016. *American Journal of Political Science*. 60(4). (with Devin Caughey)
5. "Mayoral Partisanship and Municipal Fiscal Policy." 2016. *Journal of Politics*. 78(4). (with Justin de Benedictis-Kessner).
4. "Dynamic Estimation of Latent Opinion Using a Hierarchical Group-Level IRT Model." 2015. *Political Analysis*. 23(2). (with Devin Caughey)
3. "Representation in Municipal Government." 2014. *American Political Science Review*. 108(3). (with Chris Tausanovitch)
2. "Measuring Constituent Policy Preferences in Congress, State Legislatures and Cities." 2013. *Journal of Politics*. 75(2). (with Chris Tausanovitch)
1. "How Should We Measure District-Level Public Opinion on Individual Issues?" 2012. *Journal of Politics*. 74(1). (with Jonathan Rodden)

Book Chapters and Law Review Articles

5. "Latent Constructs in Public Opinion." Forthcoming. *Oxford Handbook on Polling and Polling Methods*. R. Michael Alvarez and Lonna Atkeson, ed. Oxford: Oxford University Press.
4. "The Application of Big Data in Surveys to the Study of Elections, Public Opinion, and Representation." 2016. *Data Analytics in Social Science, Government, and Industry*. R. Michael Alvarez, ed. Cambridge: Cambridge University Press.
3. "The Political Economy of Expropriation and Privatization in the Oil Sector." 2012. *Oil and Governance: State-Owned Enterprises and the World Energy Supply*. David G. Victor, David Hults, and Mark Thurber, eds. Cambridge: Cambridge University Press.
2. "Democratization and Counter-majoritarian Institutions: The Role of Power and Constitutional Design In Self-Enforcing Democracy." 2012. *Comparative Constitutional Design*. Cambridge: Cambridge University Press. (with Susan Alberts and Barry R. Weingast).
1. "Business as Usual? Analyzing the Doctrinal Development of Environmental Standing Doctrine since 1976." 2011. *Harvard Law and Policy Review*. Volume 5.2. (with Gregory Wannier).

Unpublished Articles

Under Review

"Ideology in the European Mass Public: A Dynamic Perspective" (with Devin Caughey and Tom O'Grady) (Invitation to revise and resubmit)

"Politics in Forgotten Governments: The Partisan Composition of County Legislatures and County Fiscal Policies" (with Justin de Benedictis-Kessner) (Invitation to revise and resubmit)

"Beyond politics: Climate concern responds to changing temperatures in the American states" (with Parrish Bergquist)

Works in Progress

Book Project: "Dynamic Democracy: Citizens, Politicians, and Policymaking in the American States, 1936-2015" (with Devin Caughey)

"Responsiveness and Election Proximity in the United States Senate"

"Polarization and Partisan Divergence in the American Public, 1946-2012" (with Devin Caughey and James Dunham)

"Economic Voting in Gubernatorial Elections"

"Urban Elections and Representation" (Invited submission for the 2019 Annual Review of Political Science)

Teaching Experience

Instructor:

Multi-level and Panel Models (Graduate-level) (GW), 2017

Public Opinion (GW), 2017

American Political Institutions (Graduate-level) (MIT), 2014, 2016

Public Opinion and Elections (MIT), 2016

Energy Policy (MIT), 2013

Democracy in America (MIT), 2013, 2014

Constitutional Law & Judicial Politics (MIT), 2013, 2015

Making Public Policy (MIT), 2012, 2014

Teaching Assistant:

Introduction to American Law (Stanford University), 2010

Judicial Politics and Constitutional Law (Stanford University), 2009

Political Economy of Energy Policy (Stanford University), 2008

Introduction to International Relations (Stanford University), 2008

Introduction to Public Policy (Stanford University), 2007

Introduction to Econometrics (Williams College), 2002

Invited Talks

2017-2018: BYU

2016-2017: University of Virginia; UCLA

2015-2016: Washington University in St. Louis; Texas A&M; Arizona State University Conference on Campaigns, Elections and Representation

2014-2015: Yale; Columbia; Duke

2013-2014: Princeton; Boston University; Rochester University

2012-2013: MIT American Politics Conference; Columbia Representation Conference; Princeton Media & Politics Conference; Annual Meeting of the Society for Political Methodology

Grants

Jeptha H. and Emily V. Wade Award (\$59,686)

MIT Energy Institute (MITEI) Seed Grant (\$137,147)

MIT SHASS Research Fund (\$8,734)

Awards and Honors

APSA award for best journal article on State Politics & Policy in 2016.

Award for best paper on State Politics & Policy at the 2014 American Political Science Conference.

Graduate Fellowship, Dept. of Political Science, Stanford University, 2006-2012

David A. Wells Prize in Political Economy for Best Undergraduate Economics Thesis, Williams College, 2002

Phi Beta Kappa, Williams College, 2002

University Service

Massachusetts Institute of Technology:

Member, Energy Education Task Force, 2012-2017

Parking and Transit Committee, 2013-2017

Member, Graduate Political Science Admissions Committee, 2013-2015

Faculty Fellow, Burchard Scholars, 2013-2015

Stanford University:

- President, Stanford Environmental Law Society, 2009-2010
- Executive Board Member, Stanford Environmental Law Society 2008-2010
- Member, University Committee on Graduate Studies, 2007-2009
- Member, University Library Committee, 2007-2008
- President, Political Science Graduate Students Association, 2007-2008

Professional Service

Reviewer: American Political Science Review, American Journal of Political Science, Journal of Politics, Political Analysis, Political Behavior, Econometrica, Quarterly Journal of Political Science, Legislative Studies Quarterly, Political Research Quarterly, American Politics Research, British Journal of Political Science, Journal of Law and Courts, Public Opinion Quarterly, Political Science Research and Methods, State Politics and Policy Quarterly, Journal of Experimental Political Science, Nature Climate, Urban Affairs Review

Editorial Board, Journal of Politics, 2017-

Executive Committee, Urban Politics Section of the American Political Science Association, 2015-2017

Member, Best Paper Committee, Urban Politics Section of the American Political Science Assoc., 2015

Member, Best Paper Committee, State Politics Section of the American Political Science Assoc., 2018

Consulting

Expert, *League of Women Voters of Pennsylvania v. the Commonwealth of Pennsylvania*, Partisan Gerrymandering Case

Community Service

Sierra Club: National Board of Directors (2009-2015)

I hereby certify that the foregoing statements are true and correct to the best of my knowledge, information, and belief. This verification is made subject to the penalties of 18 Pa.C.S. § 4904 relating to unsworn falsification to authorities.

Chris Warshaw 11-27-17
Christopher Warshaw