Party Lines: Competition, Partisanship, and Congressional Redistricting

Chapter 3

Pushbutton Gerrymanders? How Computing Has Changed Redistricting

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Introduction

Following the most recent round of redistricting, observers across the political spectrum warned that computing technology had fundamentally changed redistricting, for the worse. They are concerned that computers enable the creation of finely crafted redistricting plans that promote partisan and career goals, to the detriment of electoral competition, and that ultimately thwart voters' ability to express their will through the ballot box.

For decades, the Supreme Court has considered the issue of computers in redistricting. In 1969, Justice Harlan wrote that, "A computer may grind out district lines which can totally frustrate the popular will on an overwhelming number of critical issues" (*Wells* v. *Rockefeller*). In the Court's recent redistricting decision, *Vieth* v. *Jubelirer*, Justice Breyer amplifies this claim, "The availability of enhanced computer technology allows the parties to redraw boundaries in ways that target individual neighborhoods and homes, carving out safe but slim victory margins in the maximum number of districts, with little risk of cutting their margins too thin." Some observers of redistricting have concluded that, "Gerrymandering is not self-regulating anymore… the software has become too good." (Toobin, 2003, quoting Nathaniel Persily).

Although the claims about the corrupting power computers have in redistricting are often repeated, no one had rigorously examined the evidence. Have computers really changed redistricting? Are we now in a world of pushbutton gerrymanders? Are gerrymanders more effective, more aesthetically appealing, and more durable because of computer technology?

In prior work (Altman, Mac Donald and McDonald 2005), we describe the results of a survey we conducted to establish the facts of computer use in redistricting. We researched state redistricting authorities in 1991 and 2001, and described the key patterns in computer use and the fundamental capabilities of computer redistricting systems. Our investigation shows that computers were adopted practically universally in the 1991 round of redistricting. By the 2001 round of redistricting, mapping software had become substantially faster and cheaper, but its fundamental capabilities had not changed dramatically. The timing of almost universal adoption and the relative continuity of computer capabilities suggest that much of the blame assigned to computers for modern redistricting excesses has been misplaced.

The possibility remains that computer use, along with maps drawn using election data, has significant and complex effects on redistricting outcomes. While the technological innovations and benefits allowed redistricters to create maps at greatly diminished time and expense, from a quantitative standpoint it is difficult to directly assess the impact of these innovations on redistricting because of the near universal adoption of geographical information systems (GIS) during the 1991 redistricting cycle. Instead, we use the variation in the availability of electoral data and in the capabilities of the computer systems used to tease out the effects of computing on district compactness and competitiveness.

In this chapter, we provide a brief historical overview of computer use in redistricting and the fundamental capabilities of computer systems. We then use our previous survey data, along with data on the compactness and competitiveness of Congressional redistricting plans, to determine the effects that computer usage has had on 'traditional redistricting criteria.'

A Brief History of Computers in Redistricting

Between 1980 and 2000, computer systems have gone from being rare and expensive 'toys,' useful only for demonstration purposes, to cheap, powerful, ubiquitous, standardized, off-the-shelf software available to nearly everyone. Here we present a brief summary of our previous findings (Altman, Mac Donald and McDonald 2005).

The use of computers in redistricting is by no means a recent phenomenon. Computers were first used in redistricting in the 1960s, although their use did not become widespread until the 1991 round of redistricting. Political scientists in the early 1960s advocated the use of computers, at first, as an *antidote* to gerrymandering (Vickrey 1961). Software capable of performing automated redistricting was deployed, in a limited fashion, in at least three state legislatures in 1971. However, automation proved an illusive goal, and these systems were generally used simply for data tabulation. By 1981, only a handful of states used redistricting computer systems.

Computer use expanded in 1991 when all but four states – Idaho, New Hampshire, New Jersey, and Vermont – used computers for their congressional or state legislative redistricting. System customizations and capabilities varied tremendously – some software packages did little more than display maps on the screen, while others provided detailed interactive demography and geography reports. Some states used their state planning departments' software, but these systems were not specialized for redistricting and required modification to calculate newly imposed redistricting criteria, such as compactness. Other states hired consulting firms to develop specialized redistricting applications.

Despite the widespread use of computers in 1991, access to them was quite limited. Redistricting computing was expensive; it required high-end computers and needed ongoing programming assistance and technical support. Few states provided public terminals for the public to participate in the process, and few outside groups could afford to purchase their own systems.

By 2001, a GIS software revolution allowed more companies to compete in the niche market of redistricting software. Prices dropped sharply and redistricting mapping applications became over-the-counter merchandise that could run on any semi-current home computer. Personal computers had dramatically dropped in price and had become tremendously more powerful. The same computing power that had to be delivered by a mainframe computer in the 1991 could be delivered by a midrange laptop by 2001 for a fraction of the price. Computer hardware and redistricting software were now affordable to practically any interested organization.

Lower costs enabled a greater dissemination of the technology. All states except Michigan reported using redistricting software in 2000. Michigan's response to our survey indicated that the state did not purchase any redistricting packages because their affordability allowed private organizations and political parties to buy their own. By 2001, mapping software had also become easier to use through on-screen click and point applications. Within a few hours, a computer novice could learn enough skills to draw a redistricting plan. Websites were maintained by nearly all states and emerged as an additional tool to open the process to the public by providing meeting schedules, disseminating data, and presenting maps. The increased ease of use of redistricting systems with a broad set of standard software features combined with the drop in price of hardware and software, along with the availability of websites as a medium for disseminating information opened up the redistricting process to the participation of a wider array of political actors.

Software Capabilities

While faster and easier to use, the computerized systems used in the most recent round of redistricting did not provide radically new functionality compared to the previous generations of software. Redistricting software developed through 1981 was used primarily for tabulation of data by district, such as race or population data. Advances in GIS in the mid-1980s enabled thematic mapping, on-screen color-coding of geography by data in 1991 that would previously have been simply tabulated. Almost every 2001 redistricting package offered a relatively standard set of core capabilities in five broad functional categories: tabulation of district population and registration;

thematic mapping; geographic reporting and error checking (e.g. describing compactness and contiguity); and automated plan generation.

Tabulation and thematic mapping are basic capabilities now found in all redistricting software, as are geographic reports that calculate measures of compactness or detect errors, such as noncontiguous or unassigned geography. Table 1 reports that the in the 2000 round of redistrictings, approximately 90% of states used software with these capabilities.

Level	SOFTWARE PROVIDED THEMATIC MAPPING	SOFTWARE PROVIDED GEOGRAPHIC REPORTS AND DATA TABULATION	SOFTWARE PROVIDED AUTOMATED REDISTRICTING
Congressional	100% (42)	88.1% (37)	47.62 % (20)
Legislative	100% (50)	90% (45)	50% (25)

Table 1: Capabilities of Computer Systems Used In the 2000 Congressional and Legislative Redistrictings. (Source: authors' survey, on file. See note 1.)

Almost half of the states used software with automated redistricting capability, which has been the subject of commentary by pundits. A typical warning:

> Mappers were able to specify a desired outcome or outcomes — the number of people in a district, say, or the percentage of Democrats in it — and have the program design a potential new district instantly. These systems allow redistricters to create hundreds of

> rough drafts easily and quickly, and to choose from among them maps that are both politically and aesthetically appealing. (Peck and Caitlin, 2003).

Our assessment (Altman, Mac Donald, McDonald 2005) shows that the capabilities of automated redistricting are greatly exaggerated. A fundamental technical difficulty is the lack of efficient and effective automated redistricting algorithms. The most straightforward technique generates some or all of the possible districts using a partition-generating function. Those that do not meet legal acceptance criteria, such as those containing non-contiguous districts, are eliminated. Unfortunately, the underlying mathematical problem is extremely complex (see Altman 1997). As such, any automated redistricting algorithm is guaranteed to find the best solution only for extremely limited problems.

A method to sidestep mathematical complexity is to simplify the redistricting problem. However, simplification is not implemented easily in the United States where the legal demands for population equality are quite stringent and redistricting plans must often simultaneously satisfy several conflicting Federal criteria, such as equal population and the Voting Rights Act, and state constitutional criteria, such as compactness, respect for city and county boundaries, and respect for communities of interest. No commercially available automated redistricting software in 2001 was capable of optimizing on more than one criterion – our testing experience indicated that they did so poorly – making this software irrelevant for practical consideration. Only one custom program developed by the Texas Legislative Council was capable of multi-criteria redistricting, and the program functioned poorly in generating a map for the entire state. Even if fully functioning automated software were developed, we suspect that none of those currently in charge of redistricting would relinquish their authority to a computer, given the high political stakes.

Redistricting Data

Redistricting is a data intensive task. To create a viable redistricting plan, volumes of data are analyzed to determine if a plan meets the variety of legal criteria, such as equal population, the Voting Rights Act, and other state requirements. Computers were first used to tabulate census population data, and tabulation of data remains a core feature of redistricting software.

Computers and redistricting were brought together at a fortuitous point in American political development. Just as the U.S. Supreme Court articulated an equal population standard for districts in a series of court cases in the 1960s, computing technology crawled out of its infancy to aid tabulating these data. The basis for equal population is, of course, the decennial census of the U.S. population, and the conduct and release of new census data at the beginning of a decade now triggers redistricting activity at all levels of government. Racial and ethnicity data are used also to satisfy Sections 2 and 5 of the 1965 Voting Rights Act (VRA), and its subsequent extensions. The PL94-171 file, named after the public law that mandates its release, provides total population and population by voting age, race, and ethnicity at the census block level, which is roughly equivalent to a city block in urban areas and is larger in rural areas. Along with the population data, the Bureau of the Census provides maps of census geography, which since 1990, are released in an electronic form known as the TIGER (Topographically Integrated Geographic Encoding and Referencing) file.

The PL94-171 population data does not contain political data or any other data that might describe the population in more detail, such as educational attainment or socio-economic status. These later data are released after redistricting is complete in most states. Most redistricting entities, be they a political party, a state legislature or a redistricting commission often ‘enhance’ population data by merging in political data such as election or voter registration information, which is reported by precincts. However, these data are not easily merged since census blocks do not correspond directly to electoral or registration precincts. Some, but not all, states participate in a census program to define voting precincts in terms of census geography, known as Voting Tabulation Districts or VTDs. The correspondence between election precincts and VTDs (and consequently blocks) is usually reliable only for the most recent elections. Furthermore, voting and registration precincts may not have identical boundaries. In these cases, heuristics and statistical algorithms are usually used to match the census and election data. Creating these custom datasets is expensive, time consuming and computer intensive, but may be necessary to forecast the political consequences of a redistricting plan and to assess compliance with the Voting Rights Act.

Other official redistricting criteria, which vary among state constitutions or statutes, are compactness, contiguity, respect for communities of interest, the preservation of city and county boundaries, and the following of other geographic features. Once districts have been defined in terms of census geography, the geo-spatial data contained in the TIGER files can be manipulated to confirm districts are contiguous and create measures of compactness. City, county and most geographic features are defined in the TIGER files. The communities-of-interest criterion is neither well defined nor easy to implement. Among practitioners and scholars, there is no common definition of this redistricting principle, and implementation is severely constrained by lack of data.

Measuring the Effect of Computing on Congressional Redistricting

Our investigation of the effect of computers on redistricting, is constrained by practical considerations. First, our analysis is limited to the coverage of our survey: 1991 and 2001. Secondly, we possess only congressional district data. Unfortunately, the limited scope of our analysis prevents us from directly testing the effect of computers on congressional redistricting. All states with the exception of Idaho, New Hampshire, and New Jersey, that conducted congressional redistricting in 1991, used a computer system and all used computers in 2001. Without variation we cannot test for an effect, since in essence there is nothing to be explained.

Although computer use itself was ubiquitous by 2001, there are variations in that use: whether or not a state developed an in-house computer system, the capabilities of the computer system used (which is known for 2001, but not for 1991), and whether the state used an election database in conjunction with their redistricting effort. In Table 2, we show the overall patterns of variation of data use by summarizing responses to our survey regarding redistricters' data use. From 1991 to 2001, all indicators of redistricting sophistication increased. In the remainder of this section, we use this variation in computer use to tease out the effects of computers on redistricting plans themselves. In particular, we model the effects of computer use on the compactness and competitiveness of redistricting plans.

Year	LEVEL	MANUAL REDISTRICTIN G	USED Voting Data	USED Registration Data	USED Other Data	USED Consultants To Perform Redistricting	USED Block Data
1992	*Congressional*	5.3% (2)	71.4 (30)	64.3% (27)	21% (8)	31.6% (12)	66.7% (23)
	Legislative	.9.3% (4)	64.6% (31)	58.3% (28)	20.9% (9)	31.1% (14)	46.2% (24)
2002	*Congressional*	0% (0)	72.7% (32)	75% (33)	26.2% (11)	13.2% (5)	71 % (27)
	Legislative	0% (0)	66% (33)	68% (34)	24% (12)	15.2% (22)	53.9% (28)

Table 2: Summary of survey results regarding congressional redistricters' use of data and consultants. Numbers in parentheses are absolute counts. (Source: authors' survey, on file. See note 1.)

Competitiveness

A recent concern is that computing technology enables such fine slicing and dicing of a state's political geography that election outcomes are essentially predetermined. The editorial pages of *The New York Times* articulate a typical warning:

> Using powerful computers, line-drawers can now determine, with nearly scientific precision, how many loyal party voters need to be stuffed into any given district to make it impregnable. (*The New York Times* 2004: A14)

Several measures have been used to evaluate competitive electoral systems and districts: the number or competitive elections, the bias and responsiveness of the estimated seats-votes curve, and the number of competitive districts.

The argument that computers resulted in fewer competitive elections vis-à-vis redistricting does not jibe well with the timing of the influx of computing technology by several measures. Responsiveness and bias were clearly displaying a worsening trend by the 1980s – prior to any substantial computer use.[2] Sophisticated computer operations were used in nearly every state in 1991, yet the number of competitive House contests increased. In the 2000 round of redistricting, computer use was qualitatively very similar to the 1990's round, but the number of competitive House contests dropped substantially. (Cohen 2002). However, the widespread adoption of computers in the 1990's does correspond to a disturbing decrease in the number of competitive *districts*, which is one determinative component of the competitiveness of elections and a component that redistricters have considerable control over.

Given the timing of its adoption, computing technology seems unlikely to be the primary culprit for changing levels of competitiveness. Still, technology could be a contributing factor. Here, we evaluate this conventional wisdom by measuring district competitiveness and comparing it with aspects of computer usage. The political leaning of districts is relatively straightforward to measure from election data, and such measures are often constructed during redistricting to forecast the political effects of a map. We use a standard measure, the percentage of the 2002 congressional districts in a state within a 45-55% range of the 'normalized presidential vote,' which is the Democratic share of the Democratic plus Republican vote adjusted to the national mean for the 2000 presidential election. (For further discussion of this measure, see Cain, Mac Donald and McDonald in this same volume.)

If redistricting enables fine-tuning of district lines to reduce competitiveness, conventional wisdom implies that certain aspects of computer usage are associated with fewer competitive districts. Conventional wisdom also suggests that in-house organizations, particularly in 1991, pointed to high sophistication and a possible intent to gerrymander. Election data would be a valuable tool to affect a political outcome, so one might expect the creation of such a database to be associated with fewer competitive districts. Tabulation capabilities would provide the necessary statistics to assess political effects. To fine-tune a map, one might expect that district lines would be precisely drawn down to the census block level to realize every last ounce of electoral gain. As per our previous discussion, we would expect little use of automated redistricting algorithms and thus would expect no correlation with competition.

Compactness

A common complaint about redistricting is that it produces bizarrely shaped districts. The crab-shaped Illinois 2002 17th congressional district is emblematic of the issue. The district stretches hundreds of miles across farmland of western Illinois, and at one point cuts a block-wide swath through Springfield's shopping malls and golf courses without picking up population, to capture areas of Decatur to the east. Such districts that carefully divide voters expose the role of politics in redistricting. The U.S. Supreme Court, in addressing racial gerrymandering in *Miller* v. *Johnson* 63 U.S.L.W. 4726 (1995), places special virtue on 'traditional redistricting principles' such as "compactness, contiguity, respect for political subdivisions or communities defined by actual shared interests," and considers violation of compactness an indicator of possibly unconstitutional racial gerrymandering. However, violations of 'traditional redistricting principles' are neither prohibited by the U.S. Constitution nor by Federal law, though these principals may often be found in state constitutions and statutes.

Compactness is often claimed to be a preventative to and lack thereof an indicator of political or racial gerrymandering. Since many gerrymanders are easily identified by their 'unique' shapes that are anything but 'boxlike' it was assumed that holding redistricters to compact shapes would minimize 'voter-picking' along political or racial lines. As a consequence, statisticians and political scientists embarked upon a process of defining compactness.

A difficulty in implementing a compactness standard is that there are multiple ways of measuring it (Niemi, Grofman, Carlucci, and Hofeller 1990; Young 1988). We analyze two compactness measures, computed based on the TIGER files describing the 103rd and 108th congressional districts.[3] One calculates the ratio of the normalized area to the perimeter of the district, which we refer to as AP (Flaherty and Crumplin 1992). The other, is the ratio of the district area to the area of the minimum circumscribing circle which we refer after its inventor, Reock (1961). The unit of our analysis is the state, and we average the compactness measures across all districts within a state. Both measures lie on a [0,1] interval, with a higher value associated with higher degree of compactness. These measures capture different aspects of a district's shape, but are strongly and significantly correlated. The unit of our analysis is the state, and we average the compactness measures across all districts within a state. Both measures are strongly correlated, and both are weakly but significantly correlated with competitiveness.[4]

Although we are interested in the role that computers play in compactness, little research exists that explains state compactness variation. Niemi et al. (1990) investigated the measurement of compactness across states, and Altman (1998) demonstrated how compactness scores varied over the course of United States history. A compactness standard has been used as an independent variable in other analyses of redistricting output (Barbaras and Jerit 2004; Carsons and Crespin 2004). Thus, our analysis more broadly probes the factors that influence the creation of compact districts.

For our measures of computer use, conventional wisdom might generally expect that more sophisticated operations would fine-tune their lines politically, producing less compact districts. Similarly, we expect that states using political data, and states that used population data on the block-level (rather than the tract or VTD level, etc.) will more likely be tuned to a political purpose and be capable of finely slicing and dicing a state, thus differing in competitiveness and compactness.

We evaluate these expectations with an important caveat. As we pointed out in our previous research (Altman, Mac Donald and McDonald 2005), much of the dramatic change in district appearance over the last thirty years preceded the use of computers altogether. The trend in decreasing compactness started in the mid-1960s with the introduction of equal population and majority-minority district requirements (Altman 1998). The adoption of computing technology, however, is coterminous with the increase in districts with questionable contiguity – those connected by water or a single point.

Analysis

For the sake of exposition in this essay, we have simplified our analysis to examine only two-way relationships between competitiveness or compactness measures and aspects of computer usage. A more complete approach would utilize statistical tools to control for other potentially confounding effects, such as the type of gerrymander, the presence of Voting Rights Act concerns, the competitiveness or shape of the state, and many other factors. In more sophisticated analysis (not reported here), we find the similar relationships as reported in this essay.

We use a difference of means test to determine if competitiveness or compactness is greater or less in the presence and absence of an aspect of computer usage (full results are presented in the Appendix to this chapter). We generally found no difference in district competitiveness and compactness across computer usage in the states. Contrary to conventional wisdom, competitiveness and compactness were better by small but statistically significant ($p < .05$) amounts where redistricters used census block data rather than larger geographic units. The distribution of compactness scores also suggests that plans were slightly more compact (and perhaps more competitive) where the computer system supported automated redistricting. (See the appendix, below, for summary statistics, and for plots showing the corresponding distributions of compactness and competitiveness scores.) However, this finding was statistically significant only for one of our two compactness measures, PA ($p = .10$, one-tailed).

What can account for our findings? We speculate that when larger units of analysis are used redistricters are more constrained in their ability to produce 'box-like' districts. Units that are larger than blocks, such as precincts, are less 'pretty' in their geography and will consequently end up building less 'pretty' districts. This is especially true when entire counties are used to build districts. The irregular geographies of counties will not only produce irregular shapes in districts, but their use also prevents redistricters from slicing off smaller pockets of desirable communities. Consequently, line-drawers are also less likely to achieve a 'perfect' political make-up in a district because larger units of analysis inevitably mean more people with often larger variations in their political affiliations. Given a choice between drawing a district too competitive or not competitive enough, redistricters err on the side of caution and draw districts that are less competitive. Similarly for compactness, a more compact district might be achievable by slicing a county in two whereas adding an entire county may unnecessarily increase the perimeter of a district. Redistricters may now also anticipate complaints about the compactness of the districts they draw, and use the tools available to them to draw compact districts that still achieve their political goals.

Conclusion

We are reminded of the old National Rifle Association slogan, “computers don’t gerrymander, people do.” A systematic analysis of the extent and effect of computer use in redistricting reveals that the courts' fears, and pundits’ claims are somewhat overblown. The use of computers has not changed dramatically in the last round of redistricting – nor have the capabilities of redistricting systems. While there has been a dramatic decrease in cost and gain in speed in redistricting computing, there have been marginal changes only (with the exception of limited automated redistricting) in the range of features supported by the tool and in the power of the analyses provided. The automated redistricting capabilities that some have feared would produce instant, attractive, gerrymanders have not yet materialized – current packages cannot produce even adequate redistricting plans satisfactorily, and cannot compete with human-based line-drawing. However, the sophistication of the Texas automated system may foreshadow a change in how optimal gerrymandering can be achieved.

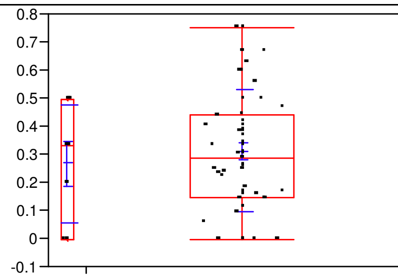
Moreover, the timing of the adoption of computers with redistricting does not jibe with the timing of the major changes in district competitiveness and compactness that have occurred in recent decades. Indeed, if anything, we find that computers may be beneficial to redistricting. Block level databases appear to provide more options to configure geography to map drawers, which in turn enabled the drawing of more competitive and more compact districts in 1991 and 2001. Other aspects of computer usage are generally unrelated to the drawing of competitive or compact districts.

In this context, computers are only a tool, not a means or motivation unto themselves. Improved tools can provide a greater set of possible redistricting plans, but that does not mean that those in charge of redistricting will necessarily choose the plans that suffer perceived defects. The true choices still reside in those drawing the districts. Computers do, however, provide valuable timesaving tools to redistricters, who we imagine may be heard to utter in response to this essay, “You can pry my computer from my cold and dying hands.”

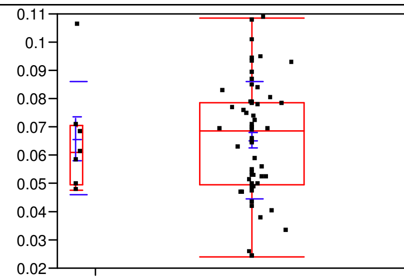
Appendix: Statistical Details

Competitiveness | **Compactness (PA)**

Voting Data Use

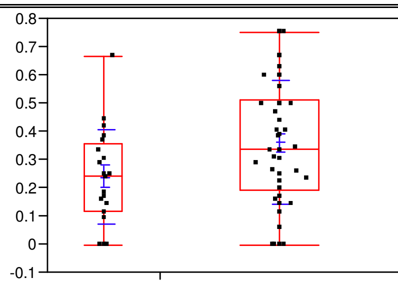


No Voting Data		Used Voting Data	
Mean	0.27	Mean	0.31
Std. Err	0.079	Std. Err	0.028
N	7	N	57

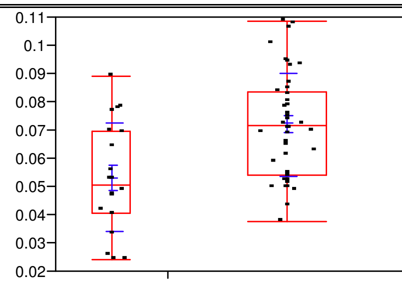


No Voting Data		Used Voting Data	
Mean	0.066	Mean	0.065
Std. Err	0.0075	Std. Err	0.0027
N	7	N	57

Block Data Use

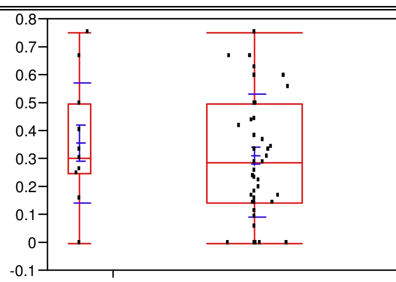


No Block Data		Used Block Data	
Mean	0.24	Mean	0.36
Std. Err	0.038	Std. Err	0.034
N	20	N	42

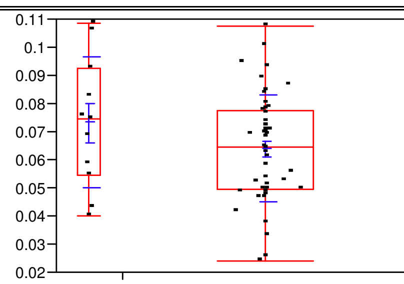


No Block Data		Used Block Data	
Mean	0.053	Mean	0.072
Std. Err	0.0043	Std. Err	0.0028
N	20	N	42

Redistricting Performed In-House



Not In-House (used consultant)		Redistricting in House	
Mean	0.36	Mean	0.31
Std. Err	0.065	Std. Err	0.032
N	11	N	47



Not In-House (used consultant)		Redistricting in-House	
Mean	0.073	Mean	0.064
Std. Err	0.0070	Std. Err	0.0028
N	11	N	47

Figure 1: Comparisons of the Compactness and Competitiveness of 1991 and 2001 Congressional Districts by Data and Consultant Use

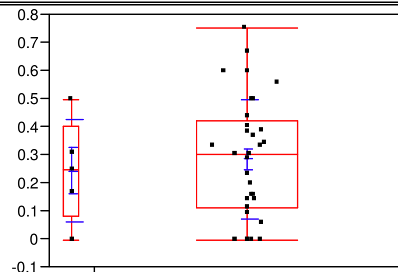
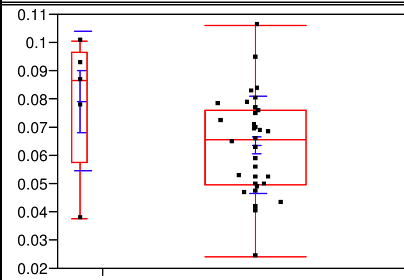
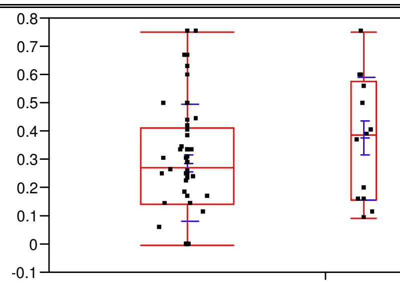
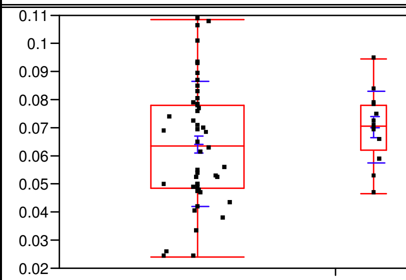
	Competitiveness		Compactness (PA)	
Tabulations and GIS Reports				
	No Reports	Provided Reports	No Reports	Provided Reports
	Mean 0.24 Std. Err 0.082 N 5	Mean 0.29 Std. Err 0.037 N 33	Mean 0.079 Std. Err 0.011 N 5	Mean 0.064 Std. Err 0.003 N 33
Automated Redistricting				
	No Automated Redistricting	Provided Automated Redistricting	No Automated Redistricting	Provided Automated Redistricting
	Mean 0.29 Std. Err 0.030 N 48	Mean 0.37 Std. Err 0.06 N 13	Mean 0.064 Std. Err 0.0032 N 48	Mean 0.070 Std. Err 0.0035 N 13

Figure 2 Comparisons of the Compactness and Competitiveness of 1991 and 2001 Congressional Districts by Data and Consultant Use

Figure 1 compares the mean (with accompanying standard errors) levels of competitive and compactness for states (not) using consultants, block data, and voting data. Figure 2 shows compares states (not) using automated redistricting and GIS reports. In each figure, Column 1 compares levels of competitiveness while Column 2 compares levels of compactness. (We show the PA measure of compactness in these figures. Similar findings for the REOCK measure are not displayed, but the data is available in our replication data set – see Author's note.) As a general rule of thumb in interpreting the results, a relationship between competitiveness or compactness with an aspect of computer use is statistically significant (i.e., likely not to have happened by chance) if the difference between the two means is large compared to the standard errors of each mean.

These figures also include 10 graphs that summarize the distribution of compactness and competitive scores for states using different levels of technology and data. We summarize these distributions using Tukey (1974) box-plots. Each graph comprises two side-by-side box plots, which compare the distribution of scores in states using a selected technology to those not using a selected technology. The middle line in each box plot shows the median score for states (not) using each technology. The 'box' portion of the graph contains the central 50% of the distribution, and the width of the box is proportional to the number of states (not) using that technology. (Each plot also shows the individual data points, with a small amount of random horizontal 'jitter' added for display purposes. The smaller lines show the mean and standard deviation.)

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[2] See, e.g., Gelman and King (1994: 540-41) who show worsening trends (in the non-south) beginning in the 1960's. The patterns of bias and responsiveness are cyclical, and substantially improve after redistrictings, but show an overall worsening trend over the decades.

[3] U.S. Census Cartographic boundary files were obtained from: http://www.census.gov/geo/www/cob/ . The compactness scores generated from those boundary files are included in our replication data.

[4] The correlation between PA and REOCK is 0.73 ($p<.01$). The strong degree of correlation is expected for two measures of the same concept, compactness. The correlation between PA and percent competitive districts is 0.23 ($p = .07$) and between REOCK and percent competitive districts is 0.31 ($p=.01$).