CALTECH/MIT
VOTING TECHNOLOGY PROJECT

A multi-disciplinary, collaborative project of
the California Institute of Technology – Pasadena, California 91125 and
the Massachusetts Institute of Technology – Cambridge, Massachusetts 02139

THE RELIABILITY OF ELECTRONIC VOTING MACHINES IN GEORGIA

Charles Stewart III
MIT

Key words: ***electronic voting, Diebold, Georgia 2002, residual vote***

VTP WORKING PAPER #20
October 2004

The Reliability of Electronic Voting Machines in Georgia

Charles Stewart III

Massachusetts Institute of Technology

October 8, 2004

Following the 2000 presidential election, the state of Georgia instituted the most comprehensive overhaul of voting technology in the country. Georgia's actions, led by Secretary of State Cathy Cox, were precipitated by the past poor performance of Georgia's voting machines. Although the Nation's eyes were on Florida, a case could be made that it was Georgia that deserved the scrutiny. Georgia's "residual vote rate," a measure of "lost votes" that has come to be used widely to measure voting technology reliability, was 3.5% — the second worst in the country, behind only Illinois. Florida's rate was "only" 2.9%. The best news for Georgia in 2000 was that George Bush won there handily, thus sending the national spotlight elsewhere.

Following study and action by the state legislature, Cox decided to purchase the Diebold AccuVote-TS touch screen system.[1] After a series of trials, the Diebold machines were first used statewide in the 2002 general election.

Georgia's use of the AccuVote-TS machines has enfolded the state, and Cox particularly, in a controversy over the security and accuracy of electronic voting. In the midst of implementing the new machines, computer scientists came upon versions of the Diebold computer code, analyzed it, and concluded that it was riddled with programming lapses, especially security vulnerabilities. The implementation in Georgia was further clouded by

[1]Georgia settled on Diebold's optical scanners to handle absentee votes.

difficulties encountered with the machines that were delivered, and the necessity to apply an uncertified software patch to the equipment as the election was imminent. If this was not enough, the actual results of the election excited the more conspiracy minded to wonder whether the machines had been tampered with to produce the "surprise" defeat of Governor Roy Barnes and Senator Max Cleland.

In the midst of this controversy, one important question has been left unaddressed by the scientific community: Did the Diebold machines perform better than the collection of older voting technologies that Georgia had used before? The purpose of this research is to answer this question. The answer is yes.

Unfortunately, the computer security controversy surrounding the 2002 election clouds any assessment of the Accuvote-TS's reliability, since any reliability assessment must rest on an assumption of a "clean" election. Still, policymakers and Democratic party officials in Georgia, along with most of its citizens, believe the election was clean; no concrete allegations of vote tampering have survived the legal system. Therefore, recognizing the controversy surrounding the implementation of the Diebold machine and the skepticism that many people will cast toward any analysis that assumes the machines were not systematically tampered with, I address the question of technology reliability using the standard tools that have emerged to judge voting technology efficacy.

This paper shows that the implementation of the Diebold system produced a significant reduction in the residual vote rate throughout the state of Georgia. Just as important, the implementation of the new machines removed gaping disparities in voting machine reliability that could have raised serious questions about the fairness of Georgia's electoral system. The

DREs are more reliable, their performance varies less across the state, and the least advantaged areas of the state have experienced the greatest gain in reliability. This is far from a categorical endorsement of the technology itself, however, since others facts associated with the implementation process may have produced this improvement. Chief among the other factors was the intense training effort that accompanied the roll-out of the new machines. Further research is warranted. Nevertheless, Georgia's first efforts at implementing DREs appear to have been a success.

Elections before 2002: How Bad Was It?

The statewide residual vote rate in the 2000 presidential election in Georgia was 3.5%, compared to a nationwide rate of 1.9%.[2] Four years before, it had been 3.3% in Georgia, compared to 2.1% nationwide.[3] To put this in perspective, if Georgia had simply had the same residual vote

---

[2]Because the residual vote rate is calculated by dividing the number of "lost" votes by the total turnout in an election, it cannot be calculated for states that do not require local jurisdictions to report total turnout. In 2000, this amounted to about a dozen states, the largest of which were Texas and Pennsylvania.

[3]The data in this report were derived from two primary sources. For before 2000, the Caltech/MIT Voting Technology Project (VTP) purchased basic election and voting technology data from Election Data Services. For 2000 and 2002, the VTP contacted Georgia directly for voting technology data and election returns. Election returns for 2002 are available on the Georgia Secretary of State's website: http://www.sos.state.ga.us/elections/. The statistics calculated for this report reflect the most recent versions of the various data sets, which are continually being corrected for errors and new additions.

rate as the national average, more than 16,000 additional Georgians would have had their vote counted for President in 2000.

Before the 2002 rollout of DREs, Georgia used a hodgepodge of voting equipment. In 2000, 44% of votes were cast on punch cards, 18% on mechanical lever machines, 0.1% on traditional paper ballots, and 38% on optical scanners. DREs were the only major voting technology category not used somewhere in Georgia. Over the decade of the 1990s, some counties had migrated their voting technologies in favor of optical scanners. In 1990, for instance, 58% of votes were cast on punch cards, 31% on mechanical lever machines, 7% on paper, 3% on optical scanners, plus another 1% on a mix of machines that cannot be determined. Therefore, voting technology evolution in Georgia had proceeded slowly, gradually replacing mechanical lever machines and punch cards with optical scanning.

One important background factor about Georgia that will affect our analysis is that the state has only recently required its counties to report overall election turnout. For the data we have acquired, turnout information only starts in 1998, which means we can calculate residual vote only from that date forward. The most statistically powerful assessments of voting machine reliability require us to gather comparable data across time. The fact that Georgia only recently started reporting turnout data at the county level limits the power of our assessment.

Before 2002, Georgia's different voting machines had different reliability rates, measured by residual votes.[4] This is illustrated in Table 1, which reports the residual vote rates of all

---

[4]The measure "residual vote rate" was introduced in the Caltech/MIT Voting Technology Project report *Voting: What Is/What Could Be* (July 2001). The report can be accessed at http://vote.caltech.edu/Reports/2001report.html. Residual vote is defined as (Turnout - Votes counted)/Turnout, or the percentage of voters who did not have their vote counted in a particular

voting machines types, in the 2000 presidential election and in the 1998 gubernatorial election. The table also reports the nationwide statistics for these classes of machines.

[Table 1 about here]

On the presidential front, the performance of voting machines in Georgia was consistent with prior research on machines nationwide: punch cards and mechanical lever machines performed the poorest, with traditional paper and optical scanning performing the best.[5] The 1998 gubernatorial results are not entirely consistent with previous national research, however. Nationwide, paper has performed well in gubernatorial races, which was not true in Georgia in

---

race. Residual votes can occur for many reasons, most of which have nothing to do with voting technology, per se. The most common of these reasons is intentional abstention. However, it is the only measure we have, aside from the more precise over- and under-vote statistics that very few jurisdictions report. The residual vote rate is an especially powerful measure of how reliability of voting systems change over time, since if we calculate the difference in residual vote rate in a community that has changed voting equipment, presumably we are subtracting out factors that are unattributable to voting technology.

[5]Ansolabehere and Stewart are responsible for the VTP research that has established the nationwide performance of different voting technologies. See their "Residual Votes Attributable to Technology," *Journal of Politics,* forthcoming. A draft is available at http://web.mit.edu/cstewart/www/papers/residual_vote.pdf until publication. Bullock and Hood have written about the performance of Georgia's voting technologies in 2000. See Charles S Bullock III and M.V. Hood III, "One person — no vote; one vote; two votes: Voting methods, ballot types, and undervote frequency in the 2000 presidential election," *Social Science Quarterly* 83(4): 981–993. Bullock and Hood distinguish between the different types of scanning technologies used in Georgia at the time, which is beyond the scope of this report.

1998. However, it is also important to note that only two Georgia counties used traditional paper ballots in 1998, and therefore this difference in performance might simply be idiosyncratic.

Unfortunately, the lack of the data necessary to calculate the residual vote rate in Georgia before 1998 makes it impossible to see whether these machine differences are due to the technologies themselves, or due to other factors that might be correlated with the use of the technologies. It is also impossible to account for the large part of the residual vote that is unrelated to machine performance, particularly intentional abstention.

As a second-best strategy, we can apply statistical controls, using multiple regression, to account for confounding factors that may be correlated with the type of voting machine used in a county. Based on past work, I chose four variables to control for these confounding effects: percentage of the population that had graduated from high school, percentage of the population that was African American, average household income, and total population itself.[6] Table 2 summarizes the results of that analysis. (The full analysis is contained in Appendix 1.) The nature of regression analysis is such that we have to choose one of the voting technologies as a comparison category; here, we have chosen punch cards. For the 2000 race, the effect of controlling for population and wealth pushes the measured performance of punch cards apart from the rest: they were even worse than the remaining technologies once the controls were applied. For the 1998 election, the results are inconclusive. Paper was the worst performer;

---

[6]Bullock and Hood used a slightly different set of controls: percent Africa-American registered, percent college graduates, and percent new registrants. Although Bullock and Hood use a different multivariate technique and different controls, their findings concerning relative voting technology performance in 2000 is broadly consistent with this analysis.

however, the small number of voters using paper makes the difference between traditional paper and punch cards statistically insignificant.

[Table 2 about here]

Before proceeding with an analysis of the 2002 election, the performance of the three statistical significant controls in predicting residual vote rates in 2000 (see Appendix 1) deserve some attention. These are the controls for high school graduation rate, African-American population, and turnout. The clearest way to illustrate their effects on residual votes is in Figures 1 through 3, which are scatterplots of the presidential residual vote rate against these three variables. (The circles are proportional to the population of the county in the first two figures.) In general, residual vote rates were lower in larger and wealthier counties, and in counties with fewer African-Americans. (The three factors are intercorrelated, but not perfectly.) This, too, is consistent with research we have conducted nationwide.

[Figures 1–3 about here]

Neither we nor anyone else has conducted research on why residual vote rates should be lower in areas that are larger, wealthier, and more urbanized, but there are obvious speculations.

Candidate hypotheses to explain these patterns come in two types, neither of which excludes the other. The first explanation is about voters. Voters in larger, wealthier, and more urbanized counties are likely to have greater literacy skills and greater experience in navigating bureaucracies. Factors such as these would help minimize mistakes that might lead to lost ballots, by either over- or under-voting. They may also have firmer opinions about politics, which would tend to produce fewer intentional abstentions, which are included in the residual vote.

The second explanation is about election administration. Election administrators in larger, wealthier, and more urbanized counties can draw on a greater pool of administrative talent in staffing the election bureaucracy, all the way from the courthouse to the precinct. A greater array of administrative skills will reduce the residual vote rate in a host of ways, including knowing how to help voters who are confused by the voting equipment and being better adept at moving through the long list of administrative details that must be attended to so that a vote can actually be counted. Probably most important, election administrators in larger, wealthier areas are more likely to work full time running elections.

To conclude, Georgia before 2002 could be characterized as follows: It tended to have a higher residual vote rate than the nation as a whole. However, the *relative* performance of its voting machines was substantially the same as the nation, especially in the presidential election, suggesting that the big difference between Georgia and the nation was not due to its machines, per se, but to the characteristics of its voters and election administrators. This observation is not intended to "blame the victim," but simply to note that Georgia labors under a set of circumstances that make election administration more difficult than in most states, with household income that is below the national average and counties that are smaller than average. Its wealthier, larger counties, such as those around Atlanta, had residual vote rates that rivaled the lowest in the nation. In the next section, we will pay particular attention to how the Diebold implementation affected the residual vote rate in the smallest, poorest counties.

2002 and Beyond: What Difference Did Diebold Make?

The Diebold DREs have now been used in three statewide elections and a handful of special elections. The most significant use of the Diebold machines came in the 2002 general election, which gained national attention when the two Democratic incumbents at the top of the ticket, Governor Roy Barnes and Senator Max Cleland, lost. Less prominently noted was the dramatic decline in the residual vote rate across the state.

Before examining this decline, it is first important to note what kind of comparison is needed to judge whether the Diebold machines are more reliable than past voting technologies in Georgia. It is common to pick any two elections to compare residual vote rates and to use that comparison as a direct gauge of voting machine reliability. For instance, one might note that the statewide residual vote rate for Georgia governor in 2002 was 1.1%, compared to the presidential residual vote rate in 2000 of 3.5%, and conclude that "lost votes" had been cut by 2/3 by the institution of the DREs. Such a comparison is generally unsatisfactory, because the factors leading to under- and overvotes in gubernatorial elections, compared to presidential elections, are likely to be different. In general, the number of residual votes in any given election are a consequence of many factors, including the prominence of the office being sought, the intensity of the campaign, and the presence of other offices on the ballot that might attract normally peripheral voters. As in all statistical studies, it is best to compare elections that are as similar along as many dimensions as possible.

Therefore, the best comparison to make with the 2002 election is the 1998 election, which had the same collection of statewide offices on the ballot. Table 3 reports the residual vote rates for all statewide races in these two years. The results are strong evidence that the

implementation of the Diebold machines brought a reduction in residual votes. Residual vote rates fell substantially in every race.

[Table 3 about here]

Reduction in residual vote occurred across all statewide offices. Did it decline uniformly across counties? The answer is "no." Here, we examine the influence of technology and county demographics.

Before doing that, however, it is instructive to examine the residual vote patterns across offices — both because this is intrinsically instructive, and because it will help us to simplify the analysis later on.

First, consider residual vote across time. In Figure 4, we examine two offices, governor and a "down ballot" office, school superintendent. Here is how to read these figures. The *x*-axis of Figure 4a represents the residual vote rate of each county in the 1998 gubernatorial election; the *y*-axis is the residual vote rate in 2002. The two axes are on the same scale. The diagonal divides the graph in half. If a county has a 2002 residual vote rate that is less than the 1998 rate, it will be represented by a circle below the diagonal. A county with a residual vote rate that grew will be above the diagonal. The further from the diagonal, the greater the change in residual vote rate. Finally, the sizes of the circles are in proportion to the population of each county.

[Figure 4 about here]

In both races, almost every county experienced a smaller residual vote rate in 2002 than in 1998. The biggest reductions, however, were made in the counties that had experienced the highest residual vote rates in the past. The biggest gubernatorial improvement occurred in

Jackson County, which went from a residual vote rate of 20% in 1998 to 0.8% in 2002, a reduction of 96%.

Because these figures were drafted to allow us to focus on the cross-time decline in residual vote rate, they mask the degree to which county residual vote rates were correlated across the two elections. If one looks carefully at the two figures, one sees that the two scatters of points drift generally upward, from left to right. Weighting by county population, the Pearson correlation coefficient for the residual vote rates across the two gubernatorial elections is .53; for the school superintendent race, the correlation is .71. This correlation across two elections is strong evidence that even as the implementation of the Diebold machines reduced the residual vote rate in Georgia, similar county-specific factors exerted influence on residual vote rates across the two elections. Buying new machines did not eliminate all sources of "lost votes."

Second, consider the residual vote rate across offices. Table 4 reports the correlation in residual vote rates across all statewide offices in 1998; Table 5 reports the same for 2002. In 1998, there was a very strong structuring of the data. Among the down-ballot offices, the intercorrelations range from .90 and above. Interestingly, the correlation between the gubernatorial residual vote rate and the residual vote rates for other offices is considerably less. The intercorrelations remain for 2002, but they are now considerably lower than before. While there is no way of knowing for sure, it is likely that the high intercorrelations in 1998 are partly a consequence of counties with similar voting technologies having similar residual vote rates. In 2002, with voting machines constant, the overall intercorrelations are lower, but the fact they are not zero is evidence that demographic, political, and administrative factors have similar effects across counties in the absence of voting machine differences.

[Tables 4 & 5 about here]

Even with the intercorrelations dropping in 2002, the high degree of correlation in residual votes across offices, and across elections, illustrates the fact that residual vote rate patterns persist even across changes in voting technologies.

These patterns also have implications for the analysis in the rest of this paper. In previous research, we found that residual vote rates tended to follow different patterns, depending on whether the office was "top of the ticket" or "down-ballot." These findings about Georgia confirm that general pattern, which we discovered in our national research using a more limited set of offices. Therefore, for the remainder of this paper, I will examine residual vote rates using three sets of measures. The two will be the residual vote rates of the two top-of-the-ticket races, governor and U.S. senator. The third will be the average of all the residual vote rates across all the remaining offices.[7]

With these three measures, we can now address the question of where residual votes tended to decline the most between 1988 and 1992. Table 6 reports the Pearson correlation coefficients between our three measures of residual vote rate change and a series of standard demographic and political variables: race (percent African-American population), total

---

[7]It is of course possible to use a more sophisticated method of combining the down-ballot residual vote rates into a single measure. The standard method of combining independent measures that are highly correlated, using a principal components analysis, confirms that doing simple averages is a good first approximation to the more refined technique. The advantage of taking simple averages is that the units of the combined measure are the same as in the original election. Using a technique like principal components to create a "residual vote scale" produces a measure that is unit-less, and therefore more difficult to interpret.

population (logged), wealth (average household income), education (percent completed high school), and partisanship (percentage vote for Al Gore in 2000). In this table, a reduction in residual vote rate is "good," and so a negative sign on the coefficient is associated with lower residual vote rates, and thus "better" results.

[Table 6 about here]

These results challenge assumptions that the widespread introduction of DREs must fall prey to problems of the "digital divide." In general, the greatest reductions in residual vote rates were in counties that had larger "disadvantaged" populations — counties with larger African American populations, rural counties, low-income counties, and counties who residents were less likely to have completed high school. The relationship between the vote for Gore in 2000 and the reduction in residual vote rates was essentially zero in all measures.

These results need to be interpreted with caution, lest we run afoul of the "aggregation fallacy." Simply noting that the residual vote rate improved the most in counties with more African Americans does not mean that more ballots of individual African Americans were counted. To establish that pattern, we would have to have data (both electoral and demographic) at a more finely tuned level of disaggregation, like the precinct level.[8] For the moment, all we

[8]The state of Georgia has performed a precinct-level analysis of residual vote rate change in precincts with greater than 80% African American population. That analysis showed that residual vote rates improved significantly between 2000 and 2002. However, there were no comparisons with precincts with high White populations, which would be necessary to confidently make the sorts of inferences were are interested in. I thank the Georgia Secretary of State's office for sharing this analysis with me. My own comparison of these statistics with overall residual vote rate improvements in the various counties suggests that the improvements in predominantly White precincts were probably similar to those in predominantly African

can confidently say is that the introduction of the Diebold machines shifted the weight of the effective electorate somewhat away from Atlanta and its suburbs.

The primary purpose of this study is to understand the effect that introducing DREs in Georgia has had on the reliability of voting technologies (measured by residual vote rate). Thus far, I have focused on the shift to DREs. However, it is important to remember that all voters were shifting *from* another technology. While the results thus far suggest that all voters experienced an increase in reliability, regardless of the equipment they were abandoning, we still need to examine whether all machine types were equally bad compared to the DREs.

Table 7 reports the average change in residual vote, broken down by the voting technology that counties were using in 1998. The biggest gains occurred in the counties that had previously used lever machines and traditional paper ballots. Because only a couple of small counties used paper in 1998, it's more accurate to state that the biggest gains, from a "recovered votes" perspective, were in the counties that used mechanical lever machines, which accounted for 17% of the electorate in 1998. The strongest predictor of whether a county used lever machines in 1998 is county wealth — poorer counties were more likely to use them. Aging lever machines require a significant amount of maintenance. Therefore, it is not too much of a leap to speculate that a major part of the increase in machine reliability in Georgia was due specifically to the retirement of these machines that were probably beginning to fail in subtle ways.

[Table 7 about here]

American precincts. Complicating matters is the fact that many precincts changed boundaries between 1998 and 2002, making the best comparisons nearly impossible to make.

To establish any individual-level effect with high confidence, we would need to study individual ballots and individual voters. The secret ballot makes such research impossible.

It is also important to note that voters in counties with punch cards and optical scanning devices saw an improvement in reliability, but not nearly as much as lever machine counties.[9] Thus in Georgia, unlike the nation as a whole, the biggest voting technology gains were to be had in retiring lever machines, not punch cards.

A Quasi-Experimental Look at Technology Performance

I end the analysis by combining our data and measuring as precisely as we can the gain in reliability due to the introduction of the Diebold DREs in Georgia. This estimation is based on a multivariate statistical technique that has previously been applied to assessing voting technology accuracy nationwide. What makes the analysis here different is that we are exploring a significant state-level push to adopt DREs, which we have not explored before. The cautionary note is this: The technique we use relies on repeated observations of election data in counties over a moderate length of time, roughly a decade. Because Georgia only started reporting total turnout recently, the estimation here relies on only two observations, the elections of 1998 and 2002. As a consequence, it is possible that any influence the introduction of the DREs had on residual vote rates could actually have been due to the more intense political campaign associated with 2002.

---

[9]The use of punch cards was concentrated in Atlanta (Fulton and De Kalb counties) and Augusta (Richmond County). Optical scanning was more evenly distributed throughout the state.

Here I perform a regression on a panel of data. The observations are at the county level for the elections of 1998 and 2002. The dependent variable is the residual vote rate in county *c* in election year *t* = 1998, 2002. The independent variables are the following:

1. A series of dummy variables ($punch_{c,t}$, $lever_{c,t}$, $paper_{c,t}$, $scan_{c,t}$, $dre_{c,t}$), each equal to 1 if county *c* had that technology in election year *t*, 0 otherwise. The omitted, comparison category is lever machines, since it was the most commonly used "legacy machine" in 1998.
2. The logarithm of election turnout in county *c* in year *t*. Because we also include a separate dummy variable for each Georgia county (see the next discussion), the turnout variable measures the effect that a surge in turnout, above the average for a given county, has on the residual vote rate. In previous research, we have discovered that once we control for the relative size of counties cross-sectionally, above-average turnout results in more residual votes.
3. A series of dummy variables, one for each Georgia county, to account for all non-machine-specific effects that give rise to different levels of residual votes across counties. Some of these factors will be the demographics of the electorate, and some will be the administrative practices of election officials. We treat these coefficients, 158 in all, as nuisance parameters.

Table 8 reports the coefficients of three regressions, with the residual vote rates associated with the gubernatorial, senatorial, and average down-ballot races as the dependent variables.[10]

[Table 8 about here]

Overall, the regression procedure describes variation in the dependent variables very well. Before turning our attention to the voting technologies, we see that, as in most other states, a surge in turnout in a given county causes the residual vote rate to go up, once we have controlled for the overall size of the county. This is due to three major factors. First, turnout surges usually happen because one race on a ballot is particularly hot. The voters who turn out especially to vote in that race are less likely to vote in other races. Second, a county that experiences an unusual surge across the board may be faced with an added increment of voters who are unfamiliar with voting procedures and who are therefore more likely to make mistakes. Third, a turnout surge also adds confusion in the polling places which puts strains on casting and counting votes.

Turning to the voting technologies, the results here are broadly consistent with what we have discovered previously in this report, without applying statistical controls. In general, all technologies in Georgia were more reliable than lever machines. The DREs are the most reliable of all, with punch cards and optical scanners not too far behind. There is an important difference

---

[10]In Appendix 2 I deal directly with the fact that the distribution of the three dependent variables in Table 8 is heavily skewed. If we use the logarithm of the residual vote rates as the dependent variable, the DREs are still far and away the best-performing technology. The difference in estimates affect the relative performance of the legacy machines compared to lever machines in the gubernatorial race, which is beyond the scope of this report.

between the gubernatorial race and the Senate and down ballot races. For governor, there is a significant difference between the DREs and all the rest. For the remaining statewide ballots, the superiority of the DREs over optical scanning and punch cards is not as great.

Discussion and Conclusion

The evidence presented here strongly suggests that Georgia recovered a significant number of "lost votes" in the 2002 election by implementing DREs. The statistical estimation in Table 8 suggests that over 40,000 additional votes were counted (among those who turned out) in the 2002 gubernatorial election than would have been counted had the implementation not occurred. According to the official election returns reported by the Secretary of State, the number of ballots cast for governor in 2002 was 233,053 greater than the number of ballots cast in 1998. Therefore, about 17% of the increase in turnout for the governor's race can be attributed to the implementation of the new technology. For down-ballot positions, the influence is even greater. For instance, between 1998 and 2002, 255,363 more votes were cast in the race for Insurance Commissioner. The results from Table 8 suggest that over 74,000 (29%) of those votes were a consequence of the new voting machines.

In assessing the change in Georgia's voting machines, it is very important that we be cautious in estimating the size of the effects and attributing those effects to the equipment per se. The main reason is that it is impossible to separate out two independent processes that occurred in 2002, each of which could account for the major gains in Georgia's residual vote rate we observe.

The first is equipment; the second is training.

It may simply be the case that the Diebold DREs were better voting machines than what a significant number of Georgians had previously used. They were certainly brand new. And the interface, which encourages voters to go systematically through the entire ballot, may have encouraged more voters to complete their ballots.

At the same time, the implementation of the machines was accompanied by an unprecedented amount of vendor support and precinct worker training. Georgia's training program involved a partnership between the Secretary of State's Office, Kennesaw State University's Center for Election Systems, and Diebold. Basic training was provided to each county's election supervisor and other top personnel, in addition to the training provided to county precinct workers. (The state targeted training at least two workers per precinct.) Video tapes were made and distributed to reinforce the training and to help educate voters. The State spent hundreds of thousands of dollars in voter education efforts. Diebold itself allocated "more than 360 professionals, including 190 field technicians, 160 county support technicians and a dozen regional support managers" throughout the state.[11]

What remains to be seen, then, is what happens in Georgia once the 360 professionals are redeployed to other elections and the use of the new equipment becomes routine. Will the residual vote rate creep up? Will the great variability that characterized voting machine reliability in Georgia before 2002 re-emerge, as counties with different administrative capacities

---

[11]URL: http://www.diebold.com/news/newsdisp.asp?id=2909, accessed 17 Sept. 2004. General information about the Georgia training efforts was provided through personal communications with officials in the Secretary of State's Office and Kennesaw University.

serving different electoral demographics rely on their own devices to maintain and use the equipment?

It is certainly too early to tell. The 2004 election will provide another data point. Even then, we will not be able to speak with great confidence about the effects of the Georgia DRE implementation until the end of the decade.

* * *

As the Nation turns its attention to the serious issue of the security of electronic voting machines, it is easy to forget the problems that faced the Nation's electoral process in 2000. The problem was not hackers, but bad machines and bad administrative practices. The Georgia case provides preliminary evidence that at least once state has made serious progress in addressing the problems that were demonstrated to vex Florida and other states. The implementation of DREs in Georgia has led to more voters having their votes counted and to voters in Jackson County (1998 residual vote rate: 20%) having their votes counted as well as those in Worth County (1998 residual vote rate: 0.3%).[12] It has led to improved vote counting in rural counties, heavily African American counties, and in less affluent counties. These are important equal protection gains that should not be overlooked.

---

[12]In fact, Jackson County's 2002 gubernatorial residual vote rate was lower than Worth County's (0.8% *vs.* 1.2%).

Appendix 1

Regression analysis underlying Table 2.

	Governor 1998		President 2000	
	Before controls	With controls	Before controls	With controls
Voting technology (punch cards, omitted category)	—	—	—	—
Lever	0.021 (0.005)	0.006 (0.008)	-0.007 (0.005)	-0.023 (0.005)
Paper	0.050 (0.045)	0.028 (0.043)	-0.014 (0.047)	-0.041 (0.035)
Scanning	0.003 (0.004)	-0.005 (0.005)	-0.019 (0.004)	-0.018 (0.004)
High school completion %	—	-0.068 (0.073)	—	-0.18 (0.06)
African American %	—	0.028 (0.013)	—	0.043 (0.011)
Avg. household income	—	-0.0002 (0.0003)	—	0.0002 (0.0002)
Log(turnout)	—	-0.002 (0.003)	—	-0.0038 (0.0020)
Intercept	0.024 (0.003)	0.088 (0.029)	0.047 (0.003)	0.16 (0.19)
R2	.12	.24	.17	.47
RMSE	.022	0.020	0.020	0.016
N	153*	153*	159	159

(Numbers in parentheses are standard errors)

*The following counties were excluded from the 1998 analysis because they had negative residual vote rates (i.e., more votes cast for governor than reported in total county turnout): Candler, Irwin, Jefferson, Pierce, Thomas, and Wilcox.

Appendix 2

Re-estimation of Table 8 results, taking into account skewness of dependent variables.

	Dependent Variable		
	Log of gubernatorial residual vote rate	Log of senatorial residual vote rate	Log of average down-ballot residual vote rate
Voting technology (lever machines, omitted category	—	—	—
Punch cards	0.12 (0.12)	-0.33 (0.11)	-0.60 (0.07)
Paper ballots	0.35 (1.06)	-0.29 (1.05)	-0.11 (0.61)
Optical scanning	-0.23 (0.12)	-0.86 (0.12)	-0.65 (0.07)
DREs	-0.87 (0.11)	-2.02 (0.10)	-1.09 (0.06)
log(turnout)	0.31 (0.38)	0.30 (0.37)	0.39 (0.21)
Intercept	-7.01 (3.86)	-5.96 (3.81)	-6.39 (2.20)
County dummies	F(158,147)=3.00	F(158,152)=3.52	F(158,152)=2.30
N	311	316	316
R^2	.88	.95	.93
Root MSE	.35	.35	.20

(Numbers in parentheses are standard errors)

Table 1. Residual vote rate of Georgia voting machines, 1998 and 2000.

	Governor, 1998		President, 2000	
	Georgia	Nationwide	Georgia	Nationwide
Punch cards	2.4%	3.6%	4.7%	2.6%
Mech. lever machines	4.5%	4.4%	4.0%	1.7%
Paper	7.4%	2.8%	3.3%	1.7%
Scanning	2.6%	2.0%	2.7%	1.2%
Total	2.8%	3.3%	3.5%	1.9%

Table 2. Residual vote rate of different voting machines in Georgia, compared to punch cards, after controlling for population and average wealth of county.

	Governor, 1998		President, 2000	
	Before controls	After controls	Before controls	After controls
Punch cards	Comparison	Comparison	Comparison	Comparison
Lever machines	+2.1%	+0.6%	-0.7%	-1.2%
Paper	+5.0%	+2.8%	-1.4%	-4.1%
Scanning	+0.3%	-0.5%	-1.9%	-0.5%

Table 3. Residual vote rates in Georgia statewide races, 1998 and 2002.

Office	1998	2002	Diff.
Gov	2.8% (153)	1.1% (159)	-1.7%
Atty. gen.	5.8% (156)	3.9% (159)	-1.9%
Agri. comm.	10.7% (155)	3.2% (159)	-7.5%
Insur. comm.	6.2% (157)	3.2% (159)	-3.0%
Labor comm.	8.0% (157)	3.9% (159)	-4.1%
Lt. gov.	4.7% (155)	2.1% (159)	-2.6%
Pub. Svc. comm.	9.2% (157)	6.3% (159)	-2.9%
PSC, spec. elect.	—	5.6%	—
School supt.	6.2% (157)	2.3% (159)	-3.9%
Secy. of state	5.6% (157)	2.1% (159)	-4.5%
U.S. Senate	4.9% (157)	0.9% (159)	-4.0%

Note: Numbers in parentheses are the number of counties used to calculate the residual vote rate. Counties with a negative residual vote rate for an office were excluded.

Table 4. Correlations among residual vote rates of statewide offices, Georgia, 1998.

	Atty. gen.	Agri. comm.	Gov	Insur. comm.	Labor comm.	Lt. gov.	PSC	School supt.	Secy. of state	U.S. Senate
Atty. gen.	1.00									
Agri. comm.	.90	1.00								
Gov.	.75	.76	1.00							
Insur. comm	.98	.93	.74	1.00						
Labor comm.	.95	.90	.68	.97	1.00					
Lt. gov.	.95	.91	.81	.95	.92	1.00				
PSC	.96	.93	.69	.99	.96	.94	1.00			
School supt.	.97	.92	.72	.99	.96	.94	.99	1.00		
Secy. of state	.95	.91	.72	.97	.95	.95	.96	.96	1.00	
U.S. Senate	.97	.92	.76	.98	.95	.95	.97	.97	.95	1.00

Table 5. Correlations among residual vote rates of statewide offices, Georgia, 2002.

	Atty. gen.	Agri. comm.	Gov	Insur. comm.	Labor comm.	Lt. gov.	PSC1	PSC2	School supt.	Secy. of state	U.S. Senate
Atty. gen.	1.00										
Agri. comm.	.58	1.00									
Gov.	.75	.79	1.00								
Insur. comm	.75	.88	.84	1.00							
Labor comm.	.74	.78	.71	.92	1.00						
Lt. gov.	.74	.86	.89	.93	.86	1.00					
PSC1	.62	.89	.73	.90	.86	.87	1.00				
PSC2	.67	.91	.78	.93	.90	.87	.95	1.00			
School supt.	.72	.87	.81	.93	.88	.88	.86	.89	1.00		
Secy. of state	.81	.82	.85	.93	.90	.94	.81	.84	.91	1.00	
U.S. Senate	.57	.51	.66	.60	.56	.63	.46	.50	.58	.66	1.00

Table 6. Correlations between demographic characteristics and changes in residual vote rates from 1998 to 2004.[a]

	Demographic/political factor				
Measure of resid. vote rate change	Black %	ln(Turnout)	H.H. income	H.S. completion	Gore %
Governor	-.14	.20	.24	.24	-.08
U.S. senator	-.14	.48	.49	.45	-.07
Down-ballot avg.	-.04	.51	.47	.46	.02

[a]Counties weighted by population. Counties with negative residual vote rates in 1998 excluded.

Table 7. Average change in residual vote rate from 1998 to 2002, by voting technology used in 1998.[a]

Measure of resid. vote rate change	Punch card	Lever machine	Paper	Optical scan	Total
Governor	-1.4%	-2.6%	-5.1%	-1.5%	-1.6%
U.S. senator	-2.5%	-10.8%	-11.6%	-2.2%	-3.8%
Down-ballot avg.	-1.9%	-10.3%	-10.4%	-2.0%	-3.3%

[a]Counties weighted by population. Counties with negative residual vote rates in 1998 excluded.

Table 8. Residual vote in Georgia as a function of voting technology and turnout, fixed effects regression, 1998 and 2002.

	Dependent Variable		
	Gubernatorial residual vote rate	U.S. Senate residual vote rate	Average down-ballot residual vote rate
Voting technology (lever machines, omitted category	—	—	—
Punch cards	-0.011 (0.004)	-0.084 (0.006)	-0.084 (0.006)
Paper ballots	-0.019 (0.040)	-0.005 (0.055)	-0.010 (0.053)
Optical scanning	-0.010 (0.004)	-0.086 (0.006)	-0.083 (0.006)
DREs	-0.031 (0.004)	-0.12 (0.01)	-0.11 (0.005)
log(turnout)	0.054 (0.010)	0.098 (0.019)	0.086 (0.019)
Intercept	-0.52 (0.15)	-0.89 (0.20)	-0.74 (0.19)
County dummies	F(158,148)=1.61	F(158,152)=1.64	F(158,152)=2.30
N	312	316	316
R^2	.75	.89	.90
Root MSE	0.013	.018	0.018

(Numbers in parentheses are standard errors.)

Figure 1. Residual vote rate against high school completion rate, 2000 presidential election.

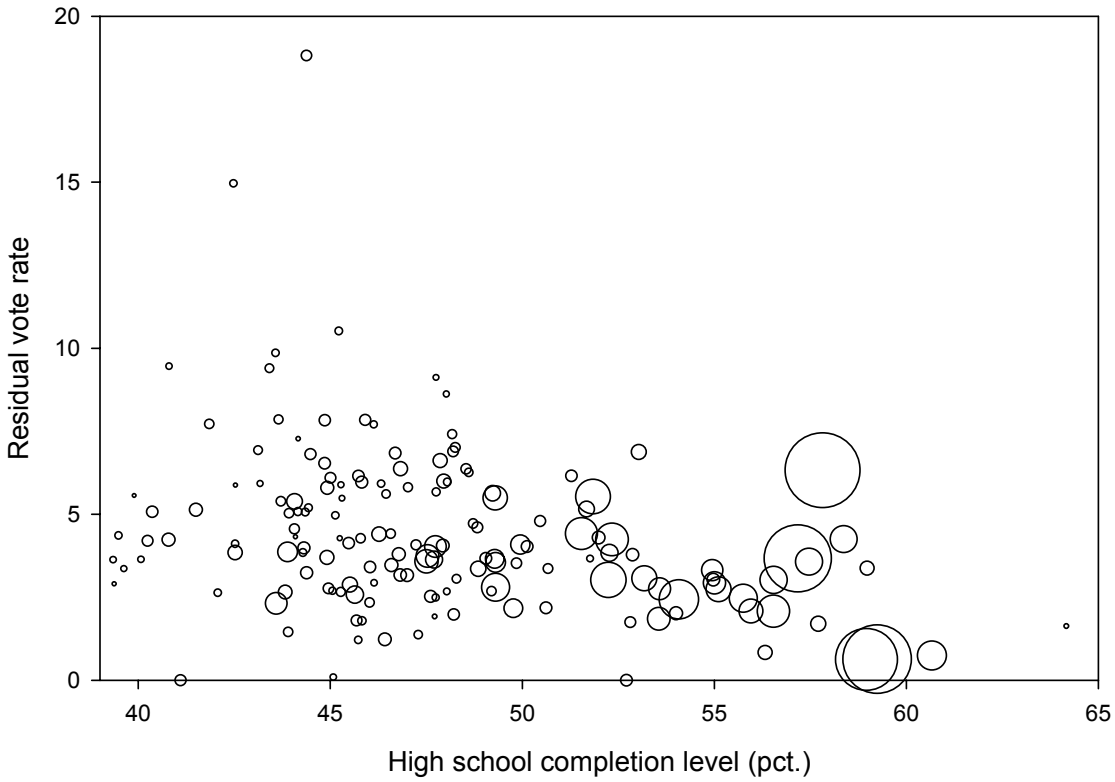


Figure 2. Residual vote rate against African American population, 2000 presidential election.

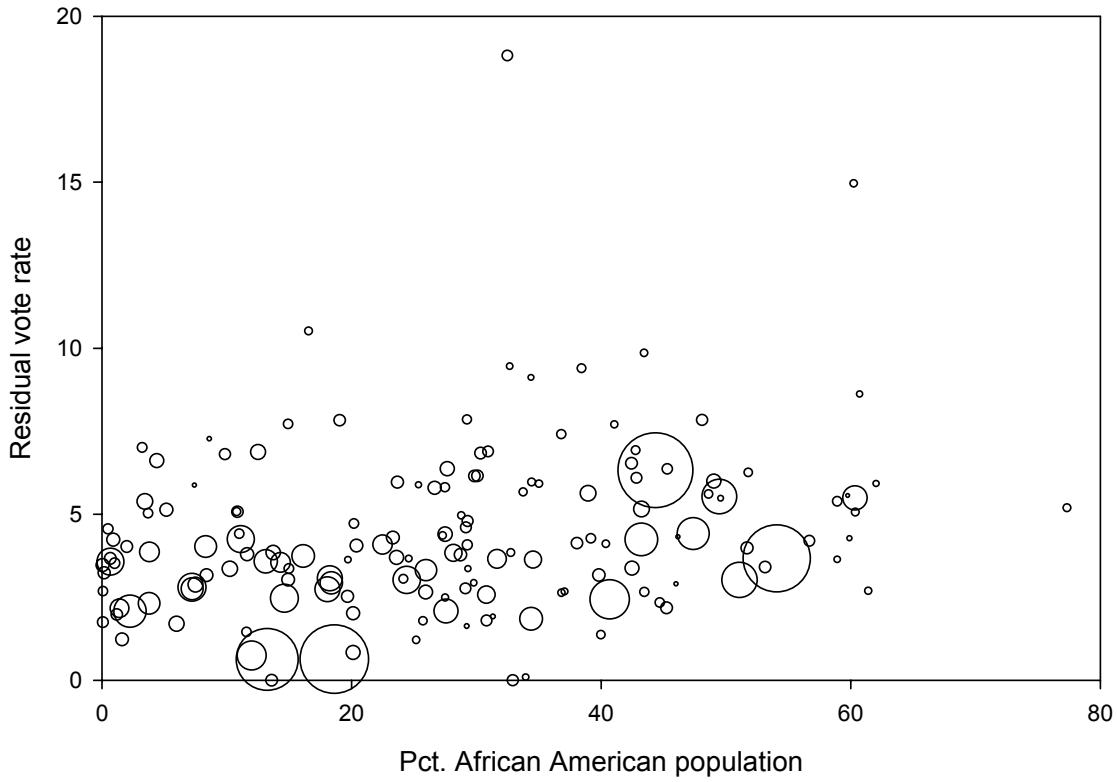


Figure 3. Residual vote rate against logged turnout, 2000 presidential election.

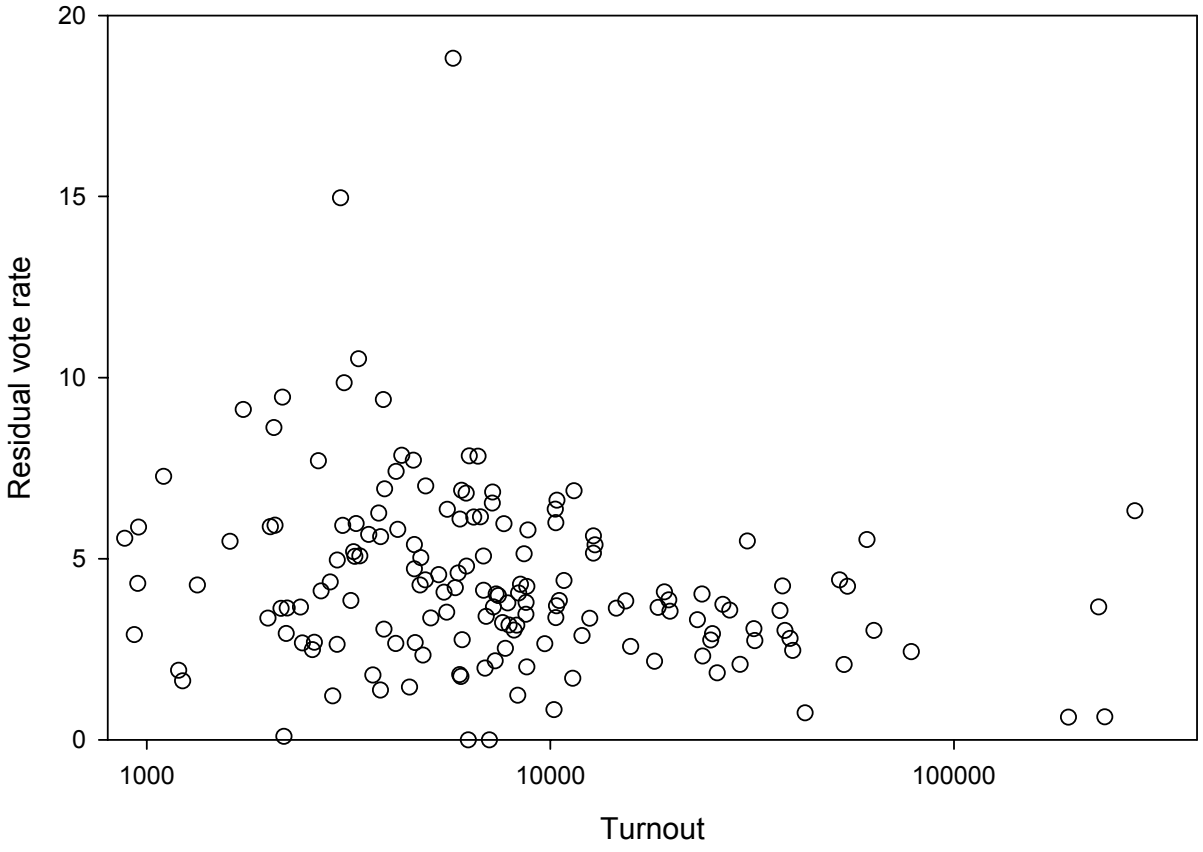
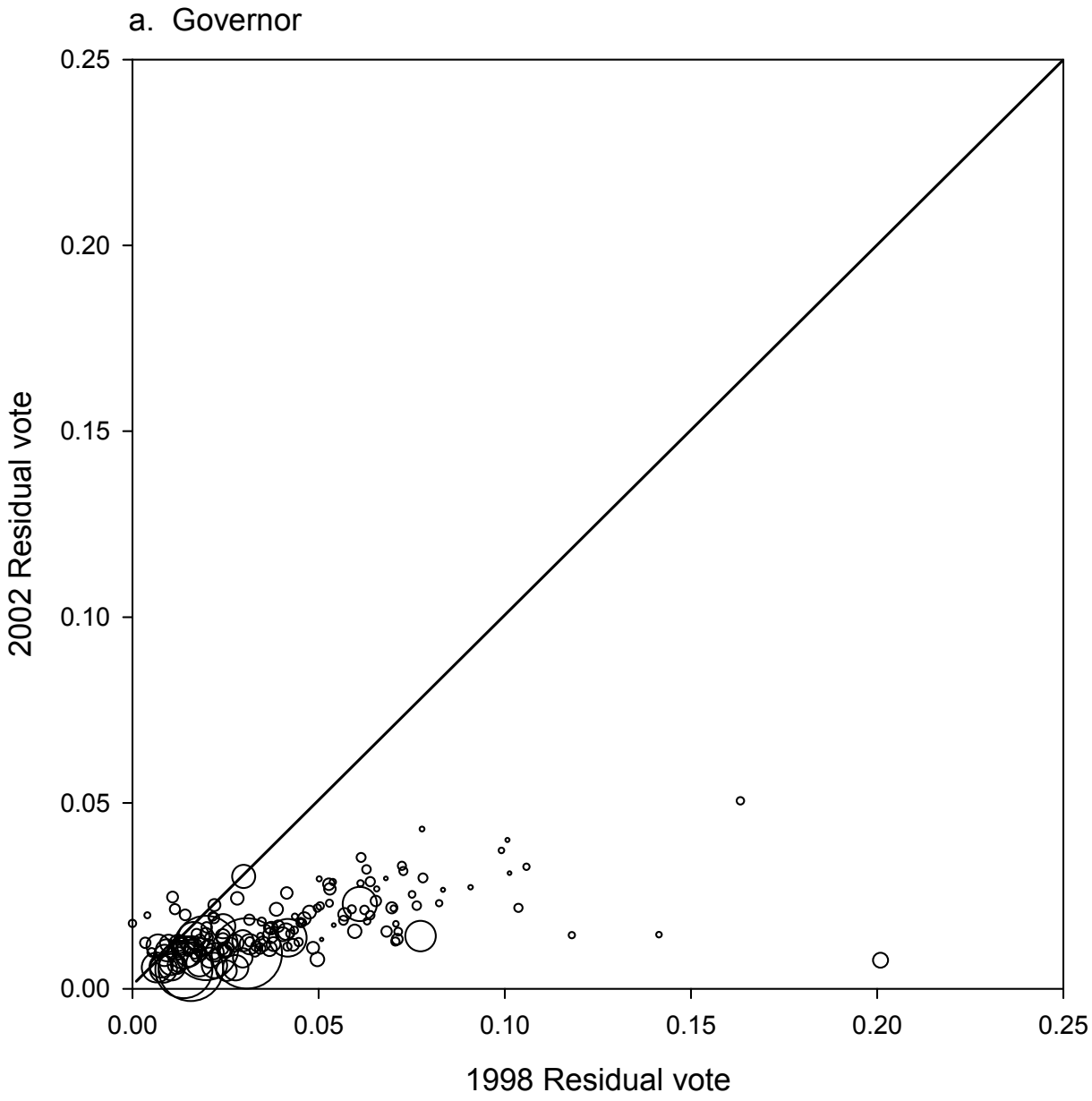


Figure 4. Residual vote rate in the Georgia gubernatorial and school superintendent races, 1998 and 2002.



b. School superintendent