Voting Technologies

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Abstract

A renewed, energetic interest in voting technologies erupted in political science following the 2000 presidential election. Spawned initially by the recount controversy in Florida, the literature has grown to consider the effects of voting technologies on the vote choice more generally. This literature has explained why localities have the voting technologies (lever machines, punch cards, etc.) they use. Although there are racial differences in the distribution of voting technologies used across localities, the strongest explanations for why local jurisdictions use particular technologies rest on legacies of past decisions. The bulk of the voting technology literature has focused on explaining how voting technologies influence residual votes, that is, blank, undervoted, and overvoted ballots. With the relative homogenization of voting technology since 2000, prospects for research that examines the effects of different machines on residual votes seem limited. However, opportunities exist to study the effect of voting machines historically, the effect of voting technologies on down-ballot rates, and the role of interest groups in affecting which voting technologies are made available to voters.

INTRODUCTION

Voters cast ballots on a variety of devices. For years, neither voters nor political scientists paid much attention to these devices or to whether their use affected election outcomes. The U.S. presidential election of 2000 changed this, leading to a vigorous literature on the role of voting technologies in America, and to a renewed interest in election administration more broadly (Herrnson 2002, Alvarez & Hall 2006, Montjoy 2008, Stein et al. 2008).

The current literature on voting technology began as an effort among political scientists to bring rigor to the speculations about who really won the 2000 presidential election in Florida (Wand et al. 2001, Mebane 2004; also see Keating 2002) and to provide a more considered assessment of how administrative practices in Florida exacerbated the recount crisis (Alvarez et al. 2004). As the Florida controversy receded into the past, questions about how technologies intervene between voter preferences and election outcomes took on a broader cast. Are some technologies more prone to malfunction than others? Do some technologies encourage greater voter fatigue than others? Do features of ballot design simplify or complicate voting? Do demographic groups vary in how they react to different technologies?

The term voting technology can refer to a wide variety of machines, devices, and systems for voting and election administration. First introduced by Shocket et al. (1992), political scientists typically use the term in a narrower sense, to refer to devices used to cast and count ballots, whether the device be as low-tech as a pencil and paper or as high-tech as the Internet.

Interest in voting technologies has entered the political science literature episodically since the turn of the twentieth century. Political scientists first addressed voting technologies when states and localities considered adopting mechanical lever machines during the Gilded Age. As computerization became more common in election administration, interest in voting technologies was rekindled in the 1970s and 1980s. The topic was largely dormant for the decade of the 1990s, finally erupting in response to the 2000 presidential election.

Answers to questions about the role of voting technologies in elections add to political science knowledge about factors that influence the vote choice, but they also touch on legal proceedings in the matter of recounts (*Jennings v. Election Canvassing Commission of the State of Florida* 2006) and race-based equal protection claims against voting machines that may promote disproportionate errors among minority voters (*Stewart v. Blackwell* 2005).

Policy makers reacted to the 2000 election controversy by enacting changes in election administration. These policy changes, in turn, prompted interest in whether they were salutary, as intended by lawmakers, or riddled with negative unintended consequences. The greatest impetus for change in voting technologies nationwide was the Help America Vote Act (HAVA), which passed in 2002 [Pub. L. No. 107–252, 116 Stat. 1666 (2002)]. Most relevant for political scientists, HAVA effectively mandated the phaseout of mechanical lever machines and punch card–voting devices, mandated the availability of an accessible voting machine in each precinct for the use of the physically disabled, and appropriated $3b for the improvement of voting systems, most of which went to purchase new voting machines.[1]

The machine mandates and appropriated funds under HAVA led to two policy changes that formed the background of much of the voting technology literature of the past decade. First, the mandated change in voting equipment, which can be considered an exogenous intervention, provided a clean test of how policy reform influences political behavior. Second, the accessibility mandate led many

[1]The effective mandate to replace machines was achieved in two ways, through a program in Section 102 that funded the replacement of punch card and lever machines, and through restrictions in Section 301, which set standards for voting machines used in federal elections. Although Section 301(c) allowed states to retrofit existing equipment to meet the new standards, all states with punch cards and lever machines accepted Section 102 funding.

localities that had long used paper ballots to adopt direct recording electronic (DRE) voting machines, which stoked controversy over the legitimacy and reliability of this specific technology.

Skepticism about DREs prompted efforts to develop techniques to identify fraudulent election returns, in the literature of election forensics (Mebane 2006, Alvarez et al. 2008, Myakov et al. 2009). Simultaneously, computer scientists began to develop a parallel literature on postelection audits (Aslam et al. 2008, Hall et al. 2009). The election forensics and postelection auditing literatures also have been developed in a series of articles and unpublished working papers arising in response to charges of fraud in elections held in other countries, such as the Ukraine in 2004, Russia in 2006, and Iran in 2009 (Myagkov & Ordeshook 2005; Myagkov et al. 2005; Mebane 2009, 2010).

More so than most topics in the study of American politics, voting technology scholarship has been highly applied and interdisciplinary. Important work has been done in fields as diverse as computer science (Hoffman 1988, Mote 2001, Mercuri 2002, Chaum 2004, Kohno et al. 2004, Chaum et al. 2005, Rubin 2006), geography (Leib & Dittmer 2002, Warf 2006), economics (Card & Moretti 2007, Dee 2007, Shue & Luttmer 2009), law (Tokaji 2004; Post 2005; Norden et al. 2006, 2007), and design (Roth 1998; Sinclair et al. 2000; Selker 2004, 2005; Everett et al. 2006; Everett 2007; Byrne et al. 2007; Lausen 2007; Redish et al. 2010). The topic of voting technology is a professional orphan in these fields, as it is in political science.

To review the research in the area of voting technology from the perspective of political science, the rest of this article proceeds as follows. First, I provide historical and legal background into the use of voting technologies in the United States. Next, I discuss the empirical research that has been conducted to assess the political consequences that arise from the use of different voting technologies to cast and count ballots. Most of this literature has focused on the issue of accounting for lost votes, but some has been devoted to assessing whether electronic voting technologies have been corrupted to favor certain, mostly Republican, candidates. I conclude with some remarks about obvious holes in the literature and opportunities for political science to influence public policy through further research into this area.

BACKGROUND ON USE OF VOTING TECHNOLOGIES IN THE UNITED STATES

The political science literature on voting technologies is focused on the United States. A small literature in English that treats developments in the rest of the world has grown up, as pockets of electronic voting have erupted in places as diverse as Brazil, Estonia, France, Germany, the Netherlands, Switzerland, and the United Kingdom (Stiefbold 1965, Kersting & Baldersheim 2004, Trechsel & Mendez 2005, Krimmer 2006, Carman et al. 2008, Alvarez et al. 2009).

Election administration in the United States is highly automated. By this, I mean that electronic and mechanical devices replace human labor in virtually every aspect of election administration. The American electoral system has three features that place great strains on election administration, driving election officials toward automation. The first is the practice of placing numerous offices and policy questions on the ballot. The second is federalism, which gives each state the right to tailor the regulation of voting technologies to its own tastes. The third is the frequency of overlapping, multiple local jurisdictions, which results in local election authorities needing to keep track of dozens of unique ballot styles. These factors not only lead to extraordinary complexity in the administration of elections at the local level (Montjoy 2008) but also to ballots that are complex and difficult to navigate (Niemi & Herrnson 2003).

Prior to the widespread use of automation to cast and count ballots, an important way of coping with the complexity of the electoral environment was the distribution of election days across the calendar—federal elections would be on one date, state elections on another, and local elections on a third. At the end of the nineteenth century, automation began to enter the world of election administration and, with it, came the consolidation of election days (Engstrom & Kernell 2005). This consolidation increased the correlation of electoral fates among copartisan candidates up and down the ticket. It is clear that this election-day consolidation would have been inconceivable without the introduction of new technologies to manage the complicated task of running elections for numerous offices on the same day. The precise linkage of election automation and election-day consolidation in the late nineteenth century is one of many topics about the role of technology in American electoral history that remains largely unexplored.

Similarly, a host of election reforms currently debated nationwide would be impractical without the assistance of electronic technologies developed over the past two decades to implement them. These reforms include election-day registration, which is aided by the use of networked electronic poll books; early voting centers, which are aided by flexible DREs and on-demand printing; the MOVE (Military and Overseas Voter Empowerment) Act, which was aided by the availability of electronic mail; and instant-runoff voting, which is aided by the programming capacities of ballot-counting computer systems.

Political scientists have largely taken for granted the role of technological innovations in changing how Americans vote. As the controversy over the adoption of DREs demonstrates, the use of technology in the conduct of elections can become a political issue, an issue political scientists have been surprisingly reluctant to pursue.

A related question that has gone virtually unexplored in political science concerns the technological sophistication of election administration in the United States—or more precisely, the uneven distribution of modern technologies and the experience to use them at the point where elections are administered. More than 10,000 jurisdictions run elections in the United States. These jurisdictions vary considerably in size, resourcing, and administrative sophistication. In New England states, for instance, cities and towns have direct responsibility for running all elections, which means that the town of Gosnold, Massachusetts (population 86) confronts many of the same complexities in running elections as Boston (population 590,000). In most states, counties run elections, but counties range in population from 67 (Loving County, Texas) to 9.5 million (Los Angeles County, California). Some large jurisdictions are well staffed with numerous professionals. A single part-time clerk staffs others. Recent surveys of the local election officials who are charged with the general management of all elections, the training of poll workers, and the implementation of complex federal and state election laws revealed that the median local election official is a low-paid, part-time employee without a college degree (Fischer 2008, Fischer & Coleman 2008, Kimball et al. 2009).

The overall quality of election administration varies across localities, due to factors such as resources, administrative organization, and influence of partisanship in running elections. Unfortunately, basic questions about election administration remain unexplored in the political science literature, despite the exposure of this variability in the 2000 Florida election controversy. Because voting technology is the most visible element of day-to-day election administration that regularly intrudes into the consciousness of political scientists, it often serves as a proxy for unmeasured administrative factors that are bundled with election systems (Stewart 2004). Consequently, any aggregate-level study that uses a measure of voting technology to predict election outcomes can be assumed to overestimate the role of the voting technology, per se, owing to the effects of omitted-variables bias.

Historical Development of Voting Technologies in the United States

Chronologically, the earliest voting technologies were hand-counted paper-and-pencil ballots.[2] Paper ballots for popular elections were used sporadically into the nineteenth century, with viva voce voting the norm in many places. Paper ballots printed by election officials, rather than by political parties, became ubiquitous at the end of the nineteenth century, as all states adopted some form of the Australian ballot. Although hand-counted paper ballots were for a brief period universal in the United States, by 1980 only 10% of American voters used this method, a fraction that dropped to less than 1% by 2008.[3]

Opportunities for fraud using paper ballots are well known within political science (Harris 1934). In addition, recent work has reacquainted scholars with another feature of hand-counted paper ballots: They are hard to count. This results in significant counting errors. Ansolabehere & Reeves (2004) provide an interesting window into this issue in research on recounts in New Hampshire. Among other things, they uncovered evidence that precinct officials sometimes simply stopped counting ballots if they believed the election was not close. Connecticut's new postelection audit requirement has inadvertently demonstrated the fragility of hand-counting ballots, insofar as the manual-counted audits appear to be more error prone than the original counts, which are done using optical scanners (Shvartsman 2009).

The introduction of automation for the casting of ballots in the United States occurred in 1892, when a mechanical voting machine was first used in Lockport, New York (Saltman 2006, p. 112). Not coincidentally, mechanical lever machines started appearing just as the Australian ballot was taking hold nationwide. The mechanical lever machines had features that many Progressive reformers found attractive, starting with the physical heft of the machines (which discouraged their theft), secrecy, minimization of spoiled ballots, speed and accuracy of tallying results, and economy (Zukerman 1925, pp. 45–55; Harris 1934). Counters on the outside of machines allowed election observers to guard against ballot stuffing. Bells attached to the machines, interlocked with the main lever, drew the attention of official observers to the machines when they were being used to vote. Because ballots no longer had to be counted by hand, precincts could be consolidated, which decreased the number of places that observers had to surveil on election day.

The introduction of mechanical lever machines was nonetheless controversial, and the trend of adoption was not monotonic. For instance, although Massachusetts was one of the first adopters of mechanical machines in 1899, the state's Supreme Judicial Court ruled them unconstitutional in 1907 (Ludington 1911, p. 36). As late as 1928, annual summaries of state legislative activity carried in the *American Political Science Review* featured discussions of mechanical lever machine controversies and the struggles to accommodate their use.

By 1964, almost two-thirds of all ballots cast for president were cast on mechanical lever machines (Saltman 2006, p. 157). As recently as 1980, more than 40% of all voters relied on mechanical lever machines, a proportion that dropped to 6% in 2008. New York remained the last holdout, but it too moved to using optical scanning in 2010.

Mechanical lever machines malfunction in predictable ways (Saltman 1988). For instance, the digits wheel on a mechanical lever machine was subject to much more use than virtually any other part of the machine. The stripping of the connection between the digits and the tens wheel could keep the tens wheel from incrementing, resulting in a systematic undercount of particular candidates and an abundance of vote counts ending with 9 at the machine level. How frequently those malfunctions occurred and, more important to political science, how often these malfunctions affected the outcomes

[2]An excellent online tutorial on the history of voting technologies has been developed by Douglas W. Jones of the University of Iowa Computer Science Department. The history may be found at **http://www.cs.uiowa.edu/~jones/voting/pictures/**.

[3]Statistics about the prevalence of different voting technologies were provided by Election Data Services, unless otherwise noted.

of elections in the past, remains unexplored in a systematic fashion.

Voting devices that relied on computer punch cards were developed in the 1960s, even though the underlying technology, the Hollerith card, was developed at roughly the same time as the technology underlying mechanical lever machines. There is a direct tie between the development of punch card–voting machines and political science—the inventor of the most common punch card device, the Votomatic, was Joseph P. Harris, a political scientist at the University of California, Berkeley, whose writings on election administration remained the definitive works on the subject into the mid-twentieth century (Harris 1929, 1934, Nathan 1983).

As eventually developed, punch card technologies were of two types, one that relied on prescored cards that went by the brand name Votomatic,[4] and another that required voters to punch through an unperforated ballot (much like the punch on a train ticket), known by the brand name DataVote®. Other companies marketed their own versions of these two designs, but the Votomatic and DataVote brands were so dominant that most references to punch card–voting systems simply adopted these brand names as generic labels.

In 1980, nearly one-third of all votes in the United States were cast on punch card technologies, a percentage that had not changed much by the time of the controversial 2000 presidential election. Punch cards had virtually disappeared by 2010 as a technology used in federal elections.

Also in the 1960s, vendors began developing paper-voting systems that allowed ink and pencil marks to be scanned optically by an electronic device (Jones 2010). These systems were similar to the technology used in standardized tests, which relies on mark-sense scanning.[5] Similar to punch cards, optical scanning also comes in two major varieties. In one, the voter fills in an oval or circle next to his or her choice on the ballot. In the other, the voter completes a discontinuous arrow that points to the choice she or he wishes to select; a vote is cast when the voter draws a line between an arrow's fletching and point, completing the arrow. In 1980, only 2% of ballots cast in the United States used some form of optical scanning. By 2000 this percentage had risen to almost 30%; by 2008 it had risen again to around 60%.

The final major voting technology is the direct recording electronic device (DRE). The first DREs were developed in the 1970s, emulating mechanical lever machines with push buttons replacing levers, lights replacing X marks, and 35mm film replacing the mechanical wheels that counted the votes. However, as touch screen technologies and personal computers became more common and cheaper, interfaces ceased looking like full-ballot mechanical lever machines and began resembling bank ATM machines; votes ceased to be recorded physically and began to be recorded electronically. Less than 1% of votes were cast on DREs in 1980, rising to around 10% in 2000. The use of DREs peaked in 2006, with 38% coverage of the electorate. Because of the backlash against DREs, stemming from the original lack of a voter-verifiable paper audit trail, the percentage of voters using DREs dropped to 33% in 2010.

As local officials considered abandoning paper ballots in communities with no history of using machines to cast ballots, a vocal movement grew up to resist the deployment of DREs. Opposition to DREs centered on three issues: First, a claim that the architecture of DREs made it impossible to tell whether they had been tampered with; second, a belief that DREs were simply more prone to error than other voting systems; and third, a suspicion

[4]The trademark registration expired in 2000.

[5]Saltman (2006, p. 13) notes that some scanners rely on detecting visible light while others rely on infrared sensing. Therefore, the use of the generic term optical scanning is a misnomer for this entire class of technology. The term mark-sense, covering both optical and infrared scanning, is in fact a more generic term. However, the press and political scientists tend to use optical scanning when generically discussing scanned paper ballots, which is the term I adopt here.

that DREs had been rigged to favor Republican candidates.

Almost all the scholarly literature on the vulnerability of DREs is outside the field of political science. Numerous political activists and organizations took up the anti-DRE cause, sometimes going so far as to advocate the removal of computers from all aspects of election administration. The most influential of the popular expressions of this concern was Harris's (2004) book *Black Box Voting*.

Academically serious critiques of computer-based voting technologies were produced by prominent computer scientists, who contributed their technical expertise to efforts to decertify existing DRE systems and resist their spread to new communities. This literature was facilitated when Harris posted on the Internet the source code of a common DRE, the AccuVote®-TS, manufactured by Diebold. The analysis of the code by a team of computer scientists revealed an astonishing set of defects, including those that would allow voters to vote multiple times with forged smart cards and others that could give precinct workers virtually unfettered access to machines, allowing them to alter ballot definitions and vote tallies (Kohno et al. 2004, table 1).

Of course, Diebold Election Systems (2003) released a report disputing criticisms of its election systems, as did election administrators who had adopted them (Zetter 2003). Rubin (2006, pp. 162–74) provides an accessible account of this episode, as well as an account of the critical report about the Secure Electronic Registration and Voting Experiment (SERVE) project discussed below.

The most comprehensive set of reports that addressed the security vulnerabilities of DREs was produced as part of the top-to-bottom review of California's voting technologies, ordered by Secretary of State Debra Bowen. A comprehensive accounting of the process is found in California Secretary of State (2007), including reports on the software reviews of the Diebold AccuVote®-TS (Calandrino et al. 2007), the Hart InterCivic voting suite (Inguva et al. 2007), and the Sequois Voting Systems AVC-Edge® (Blaze et al. 2007).

One stillborn voting technology that warrants mention is online voting using computer networks such as the Internet. By the early 2000s, as momentum was building for the diffusion of DREs as voting devices, advances were made toward Internet voting.

Advocates of Internet voting saw the greatest potential in increasing the participation of voters in chronically low-turnout elections, such as primaries. Another related advantage was cost and the ability to better manage the voting process centrally. The two major arguments against online voting focused on, first, the digital divide, or the social inequality in early Internet adoption, and second, network security (Gibson 2001, pp. 562–64; Alvarez & Hall 2004).

Prior to 2000, the trajectory toward more common network-based elections was positive. Online proxy voting had become common in shareholder elections; small experiments in e-voting had been held in Europe and the United States. The 2000 election saw the use of the Internet to conduct a straw poll of Alaska Republicans during the primaries, the Arizona Democratic primary, and the Voting over Internet (VOI) project of the Federal Voting Assistance Program (Alvarez & Nagler 2000; Solop 2001; Alvarez & Hall 2004, pp. 124–37). Unfortunately, the number of voters who participated in these trials was minimal and the analysis of the experiences cursory. Following 2000, online voting trials continued but less so in the United States than in Europe. European countries were particularly active in pilot projects aimed at allowing expatriates to vote in national elections (Alvarez & Hall 2008, pp. 72–82). The most active use of Internet voting occurred in Estonia, which held the first legally binding election that allowed Internet voting, a municipal election in 2005, followed by general elections in 2007, and municipal elections again in 2009 (Alvarez et al. 2009).

Expanded options for Internet voting in the United States have focused on attempts to facilitate voting by military and overseas residents. These efforts were embodied in the 2000 VOI project and the proposed SERVE project in 2004. The former involved a very small number of voters (84), whose participation came at the cost of $6.2 million, or $74,000 per vote (Alvarez & Hall 2004, p. 137). Because the number of participants was too small to produce robust research results and the participants were self-selected, the VOI project yielded few useful findings (Alvarez & Hall 2004, pp. 137–41; Alvarez et al. 2007, pp. 985–88). The SERVE program was a pilot project that arose in response to a congressional mandate to address the need of military voters by developing an Internet application to serve them. However, after a negative memo from an advisory group that had been created to advise SERVE on security matters (Jefferson et al. 2004), Deputy Secretary of Defense Paul Wolfowitz blocked the use of the SERVE system for the November 2004 general election (Alvarez & Hall 2008, p. 86).

Despite the controversies surrounding online voting early in the decade, Internet voting is poised to make a comeback, in light of the MOVE Act, which was passed in 2009 as part of the National Defense Authorization Act of 2010 (P.L. 111–84). The MOVE Act mandates that states provide methods for overseas voters to request absentee ballots and receive them electronically. From the perspective of Internet voting, it is significant that some states have developed methods by which oversees absentee ballots may be returned electronically as well. It is too early to tell whether the MOVE Act will become a back door through which Internet voting eventually becomes mainstream, but it is a trend that bears monitoring by political scientists.

Coevolution of Technology, Law, and Politics: Why Different Systems?

As this background discussion suggests, the devices that have been used to record voter choices have not followed deterministically from the underlying technological developments. Indeed, the fundamental science and engineering underlying mechanical lever machines, optical scanning, punch cards, and DREs underwent rapid development in the late nineteenth century, and so it is conceivable that any of these modern technologies could have been applied to voting over a century ago. Yet only mechanical lever machines took off as a voting method at that time, leaving the other technologies nearly a century to play catch-up. What explains this asynchronous development of different voting technologies?

To help frame an answer to this question, Ansolabehere & Stewart (2008) argue that voting technologies can be understood in terms of how they perform two functions. The first is presenting the voter a ballot and allowing the voter to respond. The most common interfaces are paper based, which the voter marks with a pencil or similar device, and machine based, such as a computer touch screen or the combination of printed ballot and levers offered by mechanical lever machines. The second function is managing the information contained in the choices that voters make, including counting the ballots. In the managing of ballots, voting technologies differ in whether they retain ballots for later counting or destroy them at the point of counting. All existing paper-based voting technologies retain the physical ballots for later counting. Mechanical lever machines and electronic voting machines essentially count each ballot the instant it is cast and then destroy it as a physical representation once the voter opens the privacy curtain or presses the "vote" button.

The framework can be conceived of as a two-by-two table. Along the rows are methods of vote recording, paper or machine. Along the columns are methods of ballot management, individual ballots or tabulations. The major types of election systems are found along the major diagonal of this table. TYPE ONE systems combine paper vote recording with individual ballots, which includes traditional hand-counted paper ballots, punch card ballots, and optically scanned paper ballots. TYPE TWO systems combine machine recording with tabulations, which includes mechanical lever machines and DREs.

There is no logical reason why the systems that reside in the antidiagonal elements of this table could not have been developed. It is possible to conceive of a paper ballot system only managing tabulations (TYPE THREE) if the ballot is scanned by a machine after being fed the ballot by the voter, votes are accumulated, and then the physical ballot is shredded. It is also possible to imagine either a mechanical or electronic voting machine producing a paper ballot based on the voter's choices (TYPE FOUR) with the paper ballot then counted by some other device. Indeed, ES&S, the largest manufacturer of voting systems in America, has begun marketing such a product, named the AutoMARK®.

Ansolabehere & Stewart (2008) argue that the reason all four cells of this two-by-two table have not been populated in the United States is because the machines evolved in equilibrium with laws that defined what ballots were and dealt with arcane issues of vote counting, particularly recounts. The laws were also protected by popular preferences for local election laws that grew up around these equilibria. For historical reasons, paper-machine hybrids were not contemplated by American electoral laws, and therefore the development of voting technologies over the years has followed either a strict paper or a mechanical path. By giving a strong push to localities that had used paper-based voting systems for generations to adopt DREs instead, HAVA unintentionally stoked controversy in these communities because their adoption often required the contentious task of overhauling election laws.

The technology upgrade path of local jurisdictions that changed voting technologies between 1980 and 2000 branched out into two directions based on the existing legacy technologies. Jurisdictions that relied on hand-counted paper gravitated toward other paper-based systems, either punch cards or optical scanning. Jurisdictions that had used mechanical lever machines migrated toward DREs.

Functional and Social Factors in the Use of Voting Technologies

Ansolabehere & Stewart (2008) focus on the constraints imposed by legal conventions and local culture to explain why we observe the particular variation in voting technologies that existed into the early years of the twenty-first century. Others highlighted functional constraints. For instance, Saltman (2006, p. 161) argues that mechanical lever machines were impractical in California because there were not enough rows and columns on the face of the machines to display all the candidates and ballot questions. The ballot laws required something more flexible.

It is also possible to answer the questions: "Why are there so many different systems?" and "Why does this community have punch cards and that one DREs?," statistically. Answering these questions well is relevant to the implementation of voting rights laws, especially if it can be shown that racial minorities are more likely to be burdened with outmoded technologies.

Answering the question of whether minorities were more likely to use antiquated equipment than whites is more complicated than it first seemed and illustrates some of the difficulties that arise in statistical studies of voting technologies that rely on county-level measures of election outcomes and voting technology use. Knack & Kropf (2002) produced the first published analysis that examined which types of counties used which types of voting technologies. They contradicted the widespread speculation that "African Americans, the poor, and Democratic voters were more likely to reside in counties using punch-card technology, and that a county's wealth determines its quality of voting equipment" (p. 546). Knack & Kropf based this analysis on a comparison of the percentage of African Americans, Latinos, and whites who lived in counties that used different technology types—punch card, lever machines, etc.

Building off this analysis, Ansolabehere (2002) showed how simple bivariate relationships were likely to obscure important patterns in the use of voting technologies by race. He demonstrated that the answer one gets about whether racial minorities were more likely to use punch cards and lever machines depended on whether one used the county or the voter as the unit of analysis. In addition, he showed that the clustering of technologies within particular states obscures county-by-county comparisons. Even when state authorities may wish to saddle minority communities with antiquated voting machines, state regulations severely constrain which machines may be used within a given state. Thus, if minority voters are using inferior technologies, it may be because of decisions made at the state level that apply to all voters, white and nonwhite alike. The correlation of voting technologies with population characteristics turns out to be an artifact of regional variations in population demographics and technology legacies.

Although they helped to document racial differences in the use of voting machines, the research represented by Knack & Kropf (2002) and Ansolabehere (2002) did not explore deeply why racial disparities may (or may not) exist. Garner & Spolaore (2005) pursue this question, comparing the influence of contemporary and historical factors that influenced the adoption of particular voting technologies. They find that historical factors best explain why counties had particular voting technologies in 2000 instead of contemporary ones. For instance, Garner & Spolaore (2005, pp. 382–89) find that the probability that a county used punch cards in 2000 was positively related to county income in 1969; when punch card technologies were all the rage, wealthier counties were more likely to adopt them. They also find that, conditioning on earlier per capita income in 1969, the use of punch cards in 2000 was negatively correlated with 1989 county income. This finding is consistent with the impression that punch cards were more likely to be used by declining counties—counties that bought them when they were flush with cash and then held onto them as their financial fortunes waned.

Garner & Spolaore's research does not weight observations by population; therefore, it cannot be used to explain the use of voting technologies at the level of the individual voter. However, to the degree that we observe counties as administrative units making decisions about the purchase of voting machines, this research illustrates how current voters may be held hostage to the choices made by earlier generations of election administrators. Whether a community uses a specific voting technology today may require no more complicated explanation than local election officials relying on the aphorism, "If it ain't broke, don't fix it."

ESTIMATING THE EFFECTS OF USING DIFFERENT VOTING TECHNOLOGIES

Understanding why communities have different voting machines is interesting only if it makes a difference that some voters vote on optically scanned paper ballots, whereas others use DREs. The early indications from the analysis in Florida after the 2000 recount seemed to suggest that it did matter. The greatest ballot confusion was confined to counties with punch card ballots; among counties that used optical scanners, those using scanners to count ballots in the precincts had fewer spoiled ballots than those that took the ballots back to the county election headquarters for counting.

Limitations of the Pre-2000 Roll-Off Literature for Studying Voting Technology Effects

To political scientists and policy makers trying to cast the earliest evidence from Florida at the end of 2000 in a more general light, the pre-2000 literature was of little assistance. The scant pre-2000 literature on voting technologies is often unpublished or published by state research bureaus. The typical dependent variable in these studies was not the number of lost votes at the top of the ballot, as had appeared in Florida, but the roll-off rate, which is a measure of lost votes down the ballot. Specifically, we can define roll-off as the difference in votes cast between the office at the top of the ballot and races down below.[6] Among the earlier studies that relied on the roll-off rate as a dependent variable were White (1960), Mather (1964), Walker (1966), Thomas (1968), Asher et al. (1982), Asher & Snyder (1990), Nichols & Strizek (1995), and Nichols (1998).

To scholars who studied the effects of voting technologies on roll-off prior to 2000, the primary framing device was voter fatigue, an informal idea that the long ballot simply exhausted voters, who eventually just gave up voting down the ballot (Bowler et al. 1992). Because the presidential race was always at the top of the ballot, and thus was the typical baseline against which other races were judged when roll-off was calculated, the direct influence of voting technologies on lost votes was, by definition, set to zero.

Attention Turns to Lost Votes due to Technology

Rather than fuss with the roll-off literature, initial studies of lost votes in Florida examined directly the number of over- and undervotes cast for president in the state, in addition to votes cast for Reform Party candidate Patrick Buchanan, who was seen as gaining votes because of poor ballot design in Palm Beach County. The most influential of the academic Florida studies was Wand et al. (2001), which concluded that the butterfly ballot in Palm Beach County induced more than 2,000 voters who intended to vote for the Democratic presidential nominee Albert Gore to vote for Buchanan instead. Herron & Sekhon (2003) likewise concluded that overvotes (i.e., ballots with more votes than allowed) in Florida tended to be cast by Democratic voters, which robbed Gore of a substantial number of votes.

Mebane (2004) used the actual ballots made available by the National Opinion Research Center Florida ballot project (Wolter et al. 2003) to explore the implications of the poor overvote handling in Florida for the outcome of the election in that state. Mebane finds that counties that had effective safeguards against voters overvoting had significantly smaller proportions of overvotes than counties that did not have these safeguards. He also concludes that a sizable portion of the overvoted ballots betrayed an intention to vote for one of the majority party candidates. Mebane develops a model of the true vote of these voters, estimating how they would have voted, had their overvoted ballots been brought to their attention, and concludes that Bush and Gore would have received roughly 11,000 and 46,000 more votes in Florida, respectively, if better safeguards had been employed. The implication of Mebane's analysis is that instead of losing by 537 votes, Gore would have won Florida by a margin of nearly 35,000 votes, had overvoting been impossible in Florida.

Studies such as Wand et al. (2001) and Mebane (2004) are fundamentally about the human-machine interface in voting technologies. They are similar in spirit to the earlier literature on the ballot-order effect, which is the relationship between the name order on the ballot and votes received by candidates for a particular office (Miller & Krosnick 1998, Brockington 2003). Researchers outside of political science had conducted a small number of studies about the nature of the human-machine interface of voting machines prior to 2000, such as Roth's (1998) study of mechanical lever machines, which concluded that inherent design features effectively hid certain races, particularly ballot measures, from voters, especially short ones.

Because the problem in Florida was manifest at the top of the ballot, roll-off could not be used as a dependent variable in studies based on large-*n* nationwide data sets. In its place came a new variable, the residual vote rate, which is defined as

$$\frac{\mathit{Turnout}_{\text{election year}} - \mathit{Total\ votes\ cast}_{\text{election year, office}}}{\mathit{Turnout}_{\text{election year}}}$$

where office could refer to any race on the ballot. In practice, researchers tended to calculate

[6]See Brace (1993, pp. xiii–xvii) for a discussion of the subtleties in measuring the total number of voters who come to the polls on election day.

the residual vote rate using votes cast for president. In a few cases, noted below, the offices studied were further down the ballot.

The study that coined the term residual vote was published by the Caltech/MIT Voting Technology Project (2001). Scholars from that project followed up with two studies that analyzed the relationship between voting technologies and residual votes for the decade prior to (and including) 2000 (Ansolabehere & Stewart 2005) and for the elections of 2000 and 2004 (Stewart 2006).

The initial goal of these three studies was to quantify the average residual vote rates for each type of voting technology used in the United States. They confirmed that punch card systems tended to have much higher residual vote rates in top-of-the-ballot races, compared with all other systems, with the possible exception of DREs. In particular, Ansolabehere & Stewart (2005, p. 380) found that punch card ballots produced 0.8 percentage points more residual votes for president, compared with the baseline category of mechanical lever machines. Hand-counted paper produced residual vote rates that were 1.4 percentage points less than lever machines and 0.5 percentage points less than optical scanning. DREs produced residual vote rates that were no different than mechanical lever machines.

Results analyzing senatorial and gubernatorial elections were different. Here, all technologies produced lower residual vote rates than mechanical lever machines, with the average deviations being paper (1.4 percentage points less), optical scanning (1.4 percentage points less), DREs (1.2 percentage points less), and punch cards (0.3 percentage points less).

Stewart (2006) later found that DREs actually had a role in reducing residual vote rates after 2000, in sharp contrast with the earlier findings concerning DREs and residual vote rates before 2000. For instance, voters in counties that shifted from punch cards to DREs in that interval were 1.1 percentage points less likely to cast a residual vote, compared with counties that kept the same equipment in 2004 as they had in 2000 (Stewart 2006, p. 165). The shift from optical scanners to DREs brought a reduction in casting residual votes by 0.7 percentage points. In contrast, voters in counties that shifted from punch cards or lever machines to optical scanning cast residual votes at the same rate as voters in counties that had kept their voting technologies unchanged. This change in the performance of DREs after 2000 is likely a result of design changes made to newer models of DREs that addressed earlier usability issues (Brady et al. 2001, Hanmer et al. 2010).

The residual vote literature that emerged immediately on the heels of the 2000 presidential election was influential to the drafters of the 2002 Help America Vote Act (HAVA), who mandated the retirement of punch card and mechanical lever machines in favor of optical scanners and DREs. This requirement appears to have been effective in reducing the number of unintentional over- and undervotes cast in presidential elections. For instance, Stewart (2006, p. 166) estimates that the net effect of upgrading to newer voting technologies from 2000 to 2004 was the addition of roughly one million additional presidential votes in 2004, accounting for roughly 6% of the increase in total votes counted in 2004, compared with 2000.

Specification Issues in the Estimation of Technology Effects on Residual Votes

Previously, in reviewing the literature that addressed the question of who uses inferior voting equipment, it was remarked that the answer could depend on model specification as it pertains to two issues: (*a*) jurisdiction-specific effects, which are often unmeasured and (*b*) variation in the size of jurisdictions. Failure to account for either can lead to invalid estimation of the effects of technology on voter behavior.

The studies reviewed above show that voting technology use is correlated with the demographic characteristics of the voters who use them, either by choice or by fate. Therefore, to produce an unbiased estimate of the effect of voting technology on the residual vote rate, observed at the county or precinct level, it is necessary to control for the full range of demographic characteristics that may be correlated both with the voting technology that is used and with the tendency of voters to cast residual votes. Garner & Spolaore's (2005) research particularly suggests that counties that are struggling because of declining wealth and population are more likely to use antiquated voting technologies. Jurisdictions with declining wealth and populations are also more likely to have problems marshalling the resources necessary to run a smooth election, thus creating an environment in which voters may see their votes fail to be counted, regardless of the technology used. Therefore, it is necessary to control for the administrative capacity of counties to produce an unbiased estimate of the effect of voting technology on voter behavior.

Even though the research reviewed in this essay reveals that progress has been made in uncovering potential demographic and administrative controls for these factors, this research is still in its infancy. Therefore, even if we include control factors such as demographic composition of a county, median income, or population, it is likely that the regression still will be misspecified.

To deal with this problem of unmeasured county-specific effects, the three studies cited that are associated with the Caltech/MIT Voting Technology Project—Caltech/MIT (2001), Ansolabehere & Stewart (2005), and Stewart (2006)—all employ a fixed-effects setup, using the county year as the unit of analysis. Other fixed effects are entered in the studies, depending on how many degrees of freedom are available to be exploited. For instance, because Ansolabehere & Stewart (2005) have between 8,900 and 11,600 observations at their disposal, they are able to employ a series of State × Year dummy variables, to account for the relative attractiveness of presidential candidates within each state, each election year.

Taking into account unobserved sources of between-unit variation requires the construction of a panel data set, so that leverage to estimate the effect of voting technologies on residual votes can be obtained from the counties that change voting technologies during the time period studied, compared with those that keep their voting technologies unchanged.

Although the Voting Technology Project studies find that voting technologies have statistically significant effects on the residual vote rate, the voting technology effects found in these studies pale in comparison to unobserved county characteristics in accounting for overall variation in residual vote rates across counties. For instance, the fixed-effects model that predicts the residual vote rate in presidential elections from 1988 to 2000 has an R^2 of 0.79 (Ansolabehere & Stewart 2005, p. 380). In contrast, parallel analysis using explicit controls instead of county fixed effects only has an R^2 of 0.14.

More important, though, is how the voting technology-related coefficients differ in the two types of analyses. In general, the coefficients that measure the performance of voting technologies, compared with mechanical lever machines, change by an order of magnitude when we move from explicit controls to fixed-effects analysis.[7] Such a large change in the size of coefficients when a more effective set of statistical controls is introduced is a classic sign of omitted-variables bias in the absence of controls. Therefore, any cross-sectional analysis that seeks to predict residual vote rates as a function of voting technology using only a series of explicit controls to handle confounding factors must be treated, at most, as suggestive (Darcy & Schneider 1989; Nichols & Strizek 1995; Nichols 1998; Brady et al. 2001; U.S. Civil Rights Commission 2001; Bullock & Hood 2002; Knack & Kropf 2003a,b; Kimball & Kropf 2005, 2008; Miller 2005).

Given the availability of election data at the county level, it is surprising that few studies have exploited the rich opportunities afforded

[7] For instance, in Ansolabehere & Stewart (2005, p. 380), the difference in the average residual vote rate between paper ballots and lever machines (the comparison category) in presidential elections is 1.4 percentage points in the fixed-effects estimation, compared with 0.12 percentage points using explicit controls.

by the underlying panel structure of that data. Recent articles by Lott (2009) and Hanmer et al. (2010) suggest that panel designs may become more common moving forward.

With the evidence so strong that cross-sectional analysis of the effect of voting technology on residual votes is prone to specification bias, and the ready availability of longitudinal election and voting technology data at the county level, it is natural to ask why fixed-effects analyses have not been more common until recently. One answer, to be explored more below, is that some of the most important contextual factors that affect the influence of voting technologies on voters are effectively constant on a county-by-county basis. Such factors include the obvious demographic variables such as race, income, and education. If one is interested in the role of these factors, and the only data are available at the county level, then cross-sectional analysis may be called for, if interpreted with caution.

Another specification issue concerns the issue of weighting observations in regression estimation. We know that jurisdiction size is strongly correlated with the choice of voting technology. In their study of voting technologies in 1998, Knack & Kropf (2002, p. 545) found that the average population of a county with hand-counted paper ballots was 9,123, compared with 59,609 for optical scanning, 101,748 for lever machines, 150,640 for Votomatic punch cards, and 183,984 for DataVote punch cards. Calculated another way, whereas 13.2% of all counties used hand-counted paper ballots, these counties only accounted for 1.4% of the population; conversely, whereas only 18.3% of counties used Votomatics, they accounted for 32.3% of the nation's population.

In the Knack & Kropf (2002) data, the technology with the most voters had the highest residual vote rates in 1996 (3.1% for Votomatics); the technology with the most counties had a significantly lower average residual vote rate (optical scanning, at 2.7%). In a data set of voters, in which we assume that each voter residing in a county has an identical chance of casting a residual vote as every other resident, voters in optical scanning counties will be shown to have a lower probability of casting a residual vote. In a data set of counties that weights each county's residual vote rate equal to all other counties, punch cards will appear to have the lower average residual vote rate.

To illustrate this paradox, consider the following table, which accounts for residual votes among nine hypothetical counties. [The example is constructed to reflect the statistics in Knack & Kropf's (2002) **Table 1**, but using only nine counties.] In this example voters who

Table 1 Example of how the average unweighted residual vote rate of counties can mislead in estimating the relative propensity to cast a residual vote on different machines

County	Technology	Turnout	Residual votes	Residual vote rate	Unweighted mean
A	Punch	1,200,000	30,000	2.5%	3.1% (A–C)
B	Punch	600,000	34,200	5.7%	
C	Punch	240,000	2,640	1.1%	
Subtotal	Punch	2,040,000	66,840	3.3%	
D	Optical scan	500,000	5,500	1.1%	3.6% (D–I)
E	Optical scan	250,000	7,000	2.8%	
F	Optical scan	100,000	6,800	6.8%	
G	Optical scan	500,000	5,500	1.1%	
H	Optical scan	250,000	7,000	2.8%	
I	Optical scan	100,000	6,800	6.8%	
Subtotal		1,700,000	38,600	2.3%	
Total		3,740,000	105,440	2.8%	

use punch cards are more likely to cast a residual vote than those who use optical scanners. However, the average residual vote rate of a county with punch cards is lower than the average residual vote rate of a county with optical scanners. This result occurs because very small counties with optical scanning have the highest residual vote rates in the example. These counties contribute few residual votes to the technology category subtotal, but they contribute a rate equal to that contributed by counties five times their size when the unweighted mean is calculated.

There are compelling reasons to favor analysis of residual votes cast in terms of voters, rather than in terms of county units. Theoretically, the voting model that lies beneath the behavior studied typically concerns individual voters who are casting ballots, not central decision makers in county seats determining who spoils a ballot and who does not. Legally, ever since the series of "one person, one vote" Supreme Court decisions of the 1960s, the normative unit of analysis in voting rights-related cases is the individual, not the county. Because the distribution of voting technologies in the United States is strongly correlated with county population, failure to weight by voter turnout when estimating the effect of voting technologies on residual votes, or other measures of voter behavior such as the vote choice, risks getting the sign of the resulting coefficients wrong.

The Effect of Voting Technologies on Down-Ballot Races

Finally, a word about the type of elections studied in this literature bears mentioning. With few exceptions, the analysis of voting technology and residual votes focuses on the presidential election. One exception is Stewart's (2004) assessment of the introduction of DREs in Georgia, which concluded that DREs had clear residual vote advantages in down-ballot statewide races compared with lever machines, but only slight advantages compared with optically scanned ballots and punch cards (pp. 18–19).

For instance, DREs produced reductions in average residual vote rates in down-ballot races, compared with lever machines (11 percentage points) and scanners and punch cards (3 percentage points). This was in sharp contrast with the top-of-the-ballot gubernatorial pattern, in which DREs clearly produced fewer residual votes than all other technologies, in a statistical sense, although the variability in residual vote rates across technologies was much lower to begin with.[8]

Research by Traugott et al. (2005) employed a differences-in-differences approach to changes in residual votes in Florida across the 2000 and 2004 elections. In addition to their general findings that voting machine changes accomplished the goal of decreasing overvotes while not increasing undervotes, they also find that residual vote rates among all statewide races, including ballot questions, seemed to be a function of voting technology type in both 2000 and 2004. In 2000, with the exception of the presidential race, the residual vote rate pattern was, optical scanning $<$ paper $=$ punch cards $<$ lever machines, with the gap between optical scanning and lever machines down ballot being particularly pronounced (Traugott et al. 2005, p. 25). In 2004, residual vote rates for DREs were higher than for optical scanners across all races, but only by a small amount (p. 26).[9]

Herron & Lewis (2006) also employ an interesting methodology to study the influence of DREs on candidate choice and down-ballot

[8]For instance, the average residual vote rate reduction in gubernatorial elections due to a change from lever machines to DREs was 3 percentage points, compared with 1 percentage point for punch cards and optical scanning and 2 percentage points for paper ballots.

[9]The differences summarized here are based on figures, rather than tables, and therefore the magnitudes of the differences are open to some interpretation. However, in the 2000 comparison (Traugott et al. 2005, figure 2, p. 25), the cross-technology differences in residual vote rates range up to 15 percentage points for one judicial race, and tend to be in the 10 percentage point range for most races. In the 2004 comparison (figure 3, p. 26), the biggest difference in technology performance, measured by residual vote rate, was in the range of two percentage points.

residual vote rates. They were able to obtain the ballot images in Pasco County, Florida for 2000, when voters used the Votomatic punch card device, and for 2004, when the county switched to the iVotronics DRE. Therefore, unlike all other studies reviewed here, they are able to analyze the behavior of individual voters as they used one type of technology and then the other. (Of course, the identity of the voters was unknown to Herron and Lewis.) By analyzing the individual ballot images, they are able to show that voters who used the DREs in 2004 exhibited (*a*) more coherent partisan patterns of voting and (*b*) less tendency to abstain in the low-information judicial retention races. By aggregating ballot information to the precinct level, they also show that patterns of residual voting changed with the introduction of the DREs. In particular, with the older punch card equipment, poorer, more Democratic precincts produced more residual votes in 2000; there was no correlation between income or partisanship with the propensity to cast down-ballot residual votes in 2004.

Knack & Kropf (2008) contrast residual votes cast on ballot measures nationwide in 2004 with residual votes in the presidential election. They find sharp performance differences among punch cards, lever machines, and DREs across these two types of races. For instance, whereas lever machines produced no more residual votes in presidential voting compared with central-count optical scanning (the comparison category), they produced over 19 percentage points more residual votes in voting on ballot measures. Because these findings are based on a cross-sectional research design, the caveats mentioned above apply.

Lott (2009) also studies down-ballot races, this time in Ohio during the 1990s. The races studied, in addition to president, include U.S. Senate, U.S. House, State Senate, and State House. He disaggregates election results at the ward level, constructing a panel data set, and using ward-level fixed effects in at least some of his estimation. Lott concludes that the poor performance of punch cards in Ohio at the top of the ticket was more than made up for by their superior performance down ballot.

Demographic Variability in Voting Technology Effects

The finding that the variation in the residual vote rate is primarily caused by county-specific factors, such as demographics, administrative practices, and the rest, is a particular problem in trying to research whether voting technologies produce differential effects across demographic groups. From a human factors perspective, it would be good to know, for instance, whether people with limited education are more or less likely to be confused by different types of voting technologies. This question can be addressed in an experimental setting (Herrnson et al. 2008b), but to establish the external validity of such experiments, it is necessary to see whether there is an association between measures of voter confusion (such as the residual vote rate) and the fraction of voters in a county with limited education. However, we generally have to choose between adopting something such as a fixed-effects or differences-in-differences approach to studying variation in residual vote rates or including explicit controls on the right-hand side of regressions. Thus, making any progress on understanding how specific demographics interact with different voting technologies has run head-on into the problem of specification.

One demographic category that is especially important to know about, because of its status in American law, is race. Because practices that dilute the votes of minority voters are prohibited by the Voting Rights Act, it is natural to ask whether particular voting technologies vary in causing residual votes among African Americans and Hispanics.

Prior to the renewed interest in voting technologies, a previous generation of research established that African Americans tend to cast more residual votes than whites (Walker 1966, Clubb & Traugott 1972, Vanderleeuw & Engstrom 1987). This pattern was generally explained in social psychological terms, such as attitudes and information, or by the availability of African American candidates (Vanderleeuw & Utter 1993, Harris & Zipp 1999, Wattenberg et al. 2000, cf. Herron & Sekhon 2005), not the voting machines used. The pattern of disproportionate residual votes by African Americans continues, even though studies of the problem do not address voting technologies directly (Bullock & Hood 2002, Sinclair & Alvarez 2004, Herron & Sekhon 2005).

Experiments provide a fruitful framework for exploring racial differences in the usability of voting machines. The most systematic experimental study of human factors issues pertaining to voting technologies was conducted by Herrnson et al. (2008a, 2008b), who tested subjects against a suite of existing DREs and a prototype system developed by a member of the research team. On the particular question of race, they find persistent patterns of ballot-marking mistakes among African Americans, even after controlling for income, education, and partisan strength (Herrnson et al. 2008a, pp. 91–110, 173–85).

Most research into the issue of racial disparities in the use of voting technologies has proceeded at a macro level, extending the county-level analysis that explored voting machine effects on residual vote rates to interactions between machines and race. Tomz & VanHouweling (2003) assessed the racial gap in residual votes that is attributable to voting technologies by constructing creative data sets involving precinct returns and demographics from South Carolina and Louisiana. Using ecological inference techniques, they concluded that paper-based technologies caused racial disparities in residual vote rates that did not occur when voters used DREs and mechanical lever machines. The estimated racial gap in residual vote rates was in the range of 4 to 6 percentage points in areas that used punch cards or optical scanning in 2000—technologies that did not restrict voters from overvoting. In areas that used DREs and mechanical lever machines, which did prohibit overvotes, the racial discrepancy was reduced by an order of magnitude.

Based on close examination of precinct-level returns in selected California and Illinois localities, Buchler et al. (2004) provide suggestive evidence that Votomatic voting systems in particular were responsible for significant discrepancies in residual vote rates between white and nonwhite voters in these states. The logic of their research is to compare how the correlation between precinct-level racial composition and residual vote rate changed when counties switched from Votomatic to optical scanning between 1996 and 2000. Without fail, when the localities in their study used Votomatic equipment, the residual vote rates among predominantly minority precincts were significantly higher than in white precincts; when the counties switched equipment, this correlation declined significantly, though it was not eliminated entirely.

For instance, in counties that switched away from punch cards between 1996 and 2000, the difference in the residual vote rate among the precincts with the fewest minority voters, compared with precincts with the most, was 4 percentage points in 1996, but less than 1 percentage point in 2000 (Buchler et al. 2004, figure 3*b*). By holding county constant, comparing racial patterns of residual vote rates during and after in localities that used Votomatics, Buchler et al. (2004) minimize the interferential problems associated with purely cross-sectional studies. At the same time, without the inclusion of a comparison set of counties for a control group—for instance, counties that retained their Votomatic equipment in 2000—the size of the reduction in the racial disparity of the residual vote rate among those that abandoned Votomatics is difficult to calibrate.

Both the Tomz & VanHouweling (2003) and Buchler et al. (2004) studies open a door into a research strategy that holds promise for estimating more precisely the size of racial disparities in residual vote rates and learning the role voting technologies play in producing them. Each study can be critiqued on the basis of specification issues—Tomz & Van Houweling for failing to include a longitudinal element, to help control for county-specific effects, and

Buchler et al. for failing to include a cross-sectional element, to help control for factors particular to the two election years studied.

At the same time, the sheer difficulty of assembling relevant data sets should not be underestimated. Few states require local jurisdiction to report residual vote data at the precinct level; when they do, local jurisdictions have been known to ignore the state mandate (Gronke et al. 2010). Demographic data tied to precincts are even more fugitive, depending on whether a state participates in the Census Bureau's Voting Tabulation District program and whether one can trust intercensus data interpolations when research is conducted on mid-decade elections. Finally, precinct boundaries regularly change across elections—although ward boundaries are generally stable—which only adds to the difficulty of constructing panel data sets at the precinct level.

Therefore, Tomz & VanHouweling (2003) and Buchler et al. (2004) point the field in the right direction for estimating the technology-related contribution to residual vote rate disparities between races. Pinning down the estimates even more precisely will require considerable effort to construct the appropriate precinct-level data sets. Because of varying state laws and other local factors, we should not expect this literature to produce a single nationwide study but rather to proceed through a series of studies that focus on particular states, or even counties, across time.

Voting Technology, Vote Choice, and Election Manipulation

No doubt because of the nature of the problems encountered in Florida, the political science literature has been focused on the degree to which voting technologies induce voters to make mistakes. Even though the net effect of the mistakes made in Florida overwhelmingly favored the Republican candidate (Wand et al. 2001, Mebane 2004), political scientists have shied away from asking whether voting technologies in general induce errors that advantage one party or the other or one type of candidate over another.

The issue of whether voting technologies have particular political biases gained currency in the run-up to the 2004 election.[10] Skepticism about the security and reliability of DRE voting machines mushroomed when computer scientists who gained access to the software running in commonly used DREs published studies that questioned the overall quality of the code, and whether DREs were immune to surreptitious manipulation of the vote count (Kohno et al. 2004). These questions echoed issues that had been raised at least a quarter of a century before in a classic set of technical studies by Saltman (1975, 1988).

Academic criticisms of the reliability and security of computer-based voting systems were reinforced in the popular mind by a highly publicized quote from the CEO of one of the largest manufacturers of voting machines stating that he was "committed to helping Ohio deliver its electoral votes to the president" (Warner 2003, p. BU1). Thrown into the mix was a significant controversy over exit polls conducted in 2004. Although early information leaked from the polls suggested that John Kerry (D) was outpacing George Bush (R), later exit poll information, along with the official election results, showed a clear Bush win (Traugott, Highton et al. 2005). However, for those who were already skeptical about the introduction of DREs into the polling place, the exit poll discrepancies were evidence of fraud and that DREs were a major contributor to this fraud.

The most widely circulated academic working paper that pointed directly at DREs as a factor in Bush's victory was authored by a team of researchers at Berkeley (Hout et al. 2004). This paper was the subject of considerable criticism among other scholars, a guide to which may be

[10]This is not to say that concerns about fraud had not been raised elsewhere. This is at least part of the context in which the two classic National Institute of Standards and Technology (NIST) technical reports by Saltman (1975, 1988) were written.

found in archived versions of McDonald (n.d.). The one prominent published academic article to address the question of whether DREs could have contributed to Bush's vote total was by Card & Moretti (2007), which used a panel data set to ask whether changes in votes for George W. Bush, from 2000 to 2004, were associated with the adoption of new DREs, controlling for county fixed effects.

Although the data set is organized as a panel, the analysis muddies the issue of time-invariant covariates. In their analysis, Card & Moretti (2007) include dummy variables for states, but rely on explicit controls for county effects. Their results appear to depend on the control strategy used. Without any controls, the direct effect of adopting DREs between 2000 and 2004 is actually associated with a decrease in the vote share for Bush in 2004. With controls applied at the county level, they can get the coefficient associated with DRE adoption to move into the positive range, although not always significantly so. Finally, although they test for the adoption of DREs between 2000 and 2004, Card & Moretti do not test for other shifts in voting technologies, which would serve as a control by which the claims about DREs could be assessed. Hence, it is unclear whether Card & Moretti satisfactorily deal with the specification issues that were discussed above, and thus skeptics on both sides of the issue are likely to remain unmoved in their convictions.

Following up on Card & Moretti, three other articles of note have investigated whether voting technologies influence election outcomes. Herron & Wand (2007) followed up on allegations that the AccuVote optical scan system misallocated votes away from Democratic candidate John Kerry in the 2004 New Hampshire presidential primary. They demonstrate that the poor showing of Kerry among towns with the AccuVote system was caused by the nonrandom selection of voting systems by towns—factors related to the prior choice of voting systems were also correlated with the same political and demographic factors that explained voting for Kerry.

Dee (2007) examines the effect of voting technology in the October 2003 gubernatorial recall election in California. The ballot in this election was constructed so that after the voter indicated whether he or she wished for the incumbent governor, Gray Davis (D), to be recalled, he or she could vote for a new governor, in case the recall was successful. Because of the low barriers to file as a candidate, 135 California residents appeared on the second part of the ballot. Because California utilized a random alphabet to determine the order in which the candidates appeared on the ballot, voters had to hunt for their preferred candidate on the ballot without the benefit of the candidates in traditional alphabetical order. Thus, a confluence of factors produced a confusing ballot, which in turn, caused numerous voters to make mistakes in voting on the recall.

To estimate the number of errors and the role of voting technologies in making those errors, Dee analyzed the vote for bookend candidates on the ballot, that is, minor candidates who always appeared next to the two major candidates, Arnold Schwarzenegger (R) and Cruz Bustamante (D). Do obscure candidates who, by chance, appear next to more prominent candidates on the ballot gain votes, because some people who intend to vote for the prominent candidate slip up and put a mark next to the obscure candidate instead?

Dee's findings confirm that users of Votomatic punch cards were especially likely to vote for bookend candidates, compared with users of other machines, even when controls were introduced. Although the net effect was trivial in the context of the number of votes received by Schwarzenegger and Bustamante, these erroneous votes represented a significant fraction of votes credited to these minor candidates. For instance, Dee estimates that three-quarters of the votes received by Steven Strauss and 16 percentage points of the votes received by George Schwartzman, the bookend candidates surrounding Schwarzenegger, were the result of vote-casting errors (Dee 2007, p. 680).

Finally, in a recent article, Allers & Kooreman (2009) study the effects of introducing new voting technologies in the Netherlands on outcomes in municipal and national elections using panel data sets. Although they found effects of introducing DREs on increasing turning in local elections and a decrease in the residual vote rate in national elections, they found no effect of introducing DREs on the vote shares of left-leaning parties.

DISCUSSION AND CONCLUSION

Voting technology has been an orphan in political science since the creation of the profession, as it has also been for its sister profession, public administration. Lack of sustained research on voting technologies has paralleled lack of attention more generally to issues of election administration and its effects on election outcomes.

In fairness to political science, a decade of research into the effects of voting technologies on elections has demonstrated them to generally be small. The failures in Florida in 2000 were near the extreme in election maladministration in the United States. Once research was opened up to include the nation as a whole, problems related to voting technologies were revealed to be more modest. The effect of voting technologies on residual vote rates, for instance, tends to be in the range of 1.5 to 2.5 percentage points. Only in rare circumstances, such as the razor-thin margin of the 2000 presidential election in Florida, will such small effects be politically significant.

Nonetheless, attention to election technologies by political scientists is still only in its infancy. Studying the effects of election technologies on election outcomes has tended to focus almost exclusively on results at the top of the ballot. Much less is known about down-ballot effects, which are of course more important for the conduct of state and local politics. And, because the rest of the world has proven to be more risk taking when it comes to adopting new voting technologies than Americans, there is a lot of work to be done to examine whether election technologies affect politics in democracies where the demands placed on the ballot are different.

Looking beyond the well-trod path of residual vote studies, where are the gaps in our knowledge about voting technology that political scientists may consider filling? One obvious gap is the historical dimension of voting technology and its role in elections past. Research into voting technologies has been almost exclusively contemporary. The findings that can be gleaned from the contemporary literature—that voting technologies can potentially affect the residual vote rate, turnout, and vote totals—resonate with an earlier literature on the political consequences of election reform during the Gilded Age and Progressive Era (Burnham 1965; Rusk 1970, 1974; Kousser 1974; Kleppner & Baker 1980; Kleppner 1982; Heckelman 1995). The role played by the introduction of new voting technologies during this period in "the changing shape of the American political universe" (Burnham 1965) has gone entirely unexplored, and may in fact have been another effective tool at suppressing turnout and helping native-born political interests retain their hold over American cities during this tumultuous period in American history (Zukerman 1925). Roberts (2009) is an early entrant into the historical dimension of voting technology research.

Whether the time focus is the present or the past, controversies over the deployment of new voting technologies have sparked new political movements. The politics of these movements has flown under the political science radar screen. It could be argued that the quiet activism of the disabilities rights community was responsible for the accessibility requirements that were built into HAVA, but this story has not been widely told, nor has the story of the backlash against DREs that resulted been sufficiently analyzed. The backlash is particularly interesting because it received much of its energy and substance from prominent academic computer professionals, a class of people who are generally considered politically weak.

If a significant source of political energy behind the passage of HAVA was the disabilities rights community, then the silence by political scientists about the role of voting technologies in facilitating voting by the disabled is also especially puzzling. The scholarly literature that does exist comes primarily from scholars who study human factors engineering (Ward et al. 2009).

Given the source of the accessibility requirement and the strength of the anti-DRE backlash, it would seem natural to want to study whether disabled voters have become more likely to vote and more likely to complete their ballots now that new voting machines have been introduced. The data problems associated with this type of research are inherently more challenging than studies of race and voting technologies, but the policy importance of the issue remains high.

Finally, the issue of voting technology has opened up to a new generation of political scientists to the broader question of how changes in election law and election administration affect election outcomes. Numerous questions have arisen in the realm of public policy about the relationship between election administration practices on the one hand and the size and composition of voter turnout on the other. Among other things, these questions arise in the context of precinct consolidation, the proliferation of convenience voting practices such as vote centers and vote by mail, heightened voter identification requirements, election-day registration, reforms such as instant-runoff voting, and preregistration of 16- and 17-year olds. Amid concerns about the policy relevance of the profession of political science, the range of issues that the study of voting technologies opens up provides the profession the opportunity to be influential in a rare area of public policy in which political science has a comparative advantage.

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