Who Uses Inferior Voting Technology?*

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Following the 2000 presidential election and the disputed vote in Florida, controversy arose over the previously obscure issue of differences in voting equipment across jurisdictions. The American public became acquainted with the potential for punch-card voting mechanisms to produce large numbers of invalidated ballots. The U.S. Supreme Court ruling that the manual recounts in Florida violated the Equal Protection clause of the Constitution raised the prospect that states may require uniform voting technologies among their counties, with Florida and other states subsequently banning punch-card systems entirely.

A *Washington Post*-ABC News survey found 64% of respondents in favor of (with only 29% opposed to) the federal government "outlawing so-called punch-card ballots." An overwhelming 87% favored (with 12% opposed to) a law "requiring all states and counties to use one kind of voting machine."[1] Both houses of Congress have passed election-reform legislation, with conferees attempting to reconcile differences in the two bills as of early July 2002. The House version provides $400 million to subsidize replacement of punch-card machines, while grant programs under the Senate version focus on providing mechanisms for voters to check their ballots for errors.

After the election, a widespread perception emerged among politicians and in the news media that the use of punch cards, and of antiquated voting machinery more generally, was more common in counties with a greater percentage of minorities and poor people. Al Gore repeatedly claimed that "the old and cheap, outdated machinery is usually found in areas with populations that are of lower income people, minorities, and seniors on fixed incomes."[2] Joe Lieberman suggested that antiquated voting equipment "may be undermining the electoral rights of many poor and minority citizens."[3] A series of editorials and op-ed articles in the *Washington Post* stated as fact that "it is mainly affluent counties that have switched" from punch cards to more modern equipment while "poor and minority voters tend to be stuck with less accurate machines," that African Americans "were far more likely to be stuck with the lousy machines than were affluent whites," that "voters in predominantly minority communities had to vote using antiquated machines," and that "the most error-prone machines tend to be in the poorest counties."[4]

Only very limited and selective analyses underlie these assertions, however. A *New York Times* study reported that in the 2000 election in Florida, 64% of African-American voters but only 56% of whites lived in punch-card counties. Similarly, Democratic voters were somewhat more likely than Republican voters in Florida to reside in counties using punch cards.[5] A *Washington Post* article concluded from an examination of the Atlanta and Chicago metropolitan areas that the problem of racial differences in invalidated ballots caused by gaps in voting technology "extended well beyond Florida."[6]

This conventional wisdom that emerged so rapidly in late 2000 on poor, minority areas being stuck with the worst voting equipment was superficially plausible for two reasons. First, the proportion of ballots for which no valid presidential choice was registered was much higher in areas heavily populated by minorities and the poor than elsewhere. Second, income and ethnicity are often strongly related to the quality of other public services, such as education. It seems reasonable to assume that where incomes and local tax revenues are low, election administration would be less well funded, and inferior voting technology—namely, punch-card equipment—would still be in use.

In this article, we report on the incidence of punch-card and other voting equipment by ethnicity, incomes, and other variables, combining county-level demographic data from the Census Bureau with county-level data on voting equipment collected by Election Data Services, Inc. Our findings, reported in the national print and electronic media in early 2001, provide remarkably little support for the view that resource constraints cause poorer counties with large minority populations to retain antiquated or inferior voting equipment.

Voting Equipment in Use

The choice of voting equipment is determined at the county level in most states. Voting equipment can be classified in six broad categories: (1) paper ballots, (2) lever machines, (3) punch card systems, (4) Datavote, a variant of punch card voting, (5) optical scanning, and (6) electronic systems.

Paper ballots constitute the oldest voting system still in use. Candidates' names are printed next to boxes, which voters mark. Because they are hand counted, paper ballots remain in use mostly in small counties with few contested offices.

On mechanical-lever machines, each candidate's name is assigned to a lever on a rectangular array of levers on the face of the machines. The voter pulls down selected levers to indicate choices. Levers are connected to a counting wheel, which at the close of the polls indicates the number of votes cast on the lever that drives it. Interlocks are arranged to prevent "overvoting," e.g., voting for two candidates in the presidential contest. Lever machines were

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https://doi.org/10.1017/S1049096502000811 Published online by Cambridge University Press

introduced in New York State in 1892. They have not been manufactured since 1982, as the availability of lower-cost alternatives dried up the market for new lever machines.

Punch-card systems employ one or more cards and a clipboard-sized device for recording votes. Information about the ballot choices is provided in a booklet attached to a mechanical holder and centered over the punch card, which is inserted by the voter. Voters use a provided stylus or other punching device to punch holes at the appropriate locations on the card, forcing out the inside of a prescored area in the shape of a rectangle (the source of chad). In 1964, Fulton and De Kalb (Atlanta, GA) became the first counties to use punch-card systems for voting.

Datavote also uses punch technology, but is different enough to warrant a separate category. A stapler-like tool creates holes on the card with sufficient force that prescoring of ballot cards is unnecessary. The name and party of the candidates are printed directly on the Datavote card, so it is easier for voters to ascertain after completing their ballot whether they voted as intended.

Optical scanning, or opti-scan systems are widely used in standardized testing and other functions besides voting. Optical scanning began to be used in voting at about the same time as punch-card systems, although its use spread more slowly until the 1980s. These systems use large ballots similar to those of paper ballot systems, so that information about candidates can be printed directly on the ballot. The ballots are counted by a machine that uses light or infra-red as a sensor to discern which oval or rectangle the voter marked from a set of choices. "Precinct count" optical scan equipment allows voters themselves to feed the ballot into a reader, which can be programmed to return the uncounted ballot to the voter if it contains any overvotes, giving the voter a chance to correct the ballot. With "central count" equipment, voters drop the ballot in a box and the ballots are all collected and fed into the machines later by election workers.

Direct recording electronic (DRE) systems are similar to lever machines, and different from other systems, in the absence of any physical ballot, and no possibility of overvotes if the equipment is programmed correctly. Voter choices directly enter electronic storage, using touch screens, push buttons, or keyboards. Use of DRE for voting began in the mid-1970s.

In Maine, Massachusetts, New Hampshire, Vermont, and Wisconsin, voting equipment is chosen at the municipal level, and so is not uniform throughout some counties in those states. These mixed systems were in effect in about 4.5% of counties in 1998, representing about 8% of the population (see Table 1).

Table 1
Voting Equipment in Use, November 1998

	Florida		U.S.		
Voting Equipment	% of counties	% of population	% of counties	% of population	Invalidated votes, 1996
Punch card	22.4	60.4	18.3	32.3	3.1%
Datavote	28.4	11.9	2.0	4.3	3.4%
Lever machine	6.0	0.4	15.3	18.3	2.2%
Paper ballots	1.5	0.1	13.2	1.4	2.6%
Optical scan	35.8	25.1	38.7	27.0	2.7%
Electronic	0.0	0.0	8.1	8.8	3.1%
Mixed	6.0	2.2	4.5	8.0	1.9%

Before the advent of punch-card systems in the mid-1960s, most voters in large cities, and many in medium-sized cities, together accounting for a majority of the nation's voters, used lever machines, with the remainder using paper ballots. By 1998, the most recent year for which complete data are available, use of paper ballots had dropped to about 13% of counties, representing about 1.4% of the population.

Lever-machine use also declined steadily since the mid-1960s, although less rapidly than for paper ballots. By 1998, about 15% of counties throughout the nation (including all of New York) representing about 18% of the population still used lever machines.

Beginning in 1964 and continuing throughout the 1970s, punch-card systems rapidly became more prevalent, particularly in large counties previously using lever machines. For the price of two lever machines, a country could buy about 15 punch-card devices and a card reader. Punch-card machines were thus viewed as an effective way to combat long lines at the polls in large and growing counties. At their peak in the late 1970s and early 1980s, punch-card systems were likely the form of voting used by a majority of the nation's population (FEC 1982). Very few counties have converted recently from other systems to punch cards, and many have abandoned punch cards in favor of opti-scan or DRE. In the 1998 elections, about 18% of counties, covering about 32% of the U.S. population, employed punch-card systems. Los Angeles County alone represents nearly one-tenth of all voters using punch-card technology.

The use of Datavote technology has remained constant in recent years. In 1998, 2% of counties nationally, representing about 4% of the population, used this system.

Opti-scan use increased dramatically in the 1990s. Only about 6% of counties, and less than 8% of voters, used opti-scan systems in 1988. These figures rose to about 39% of counties, representing about 27% of the population, in 1998. Most smaller counties that no longer use paper ballots converted to opti-scan.

Electronic voting has also gained in market share, replacing many lever machines but also punch-card systems in some areas. In 1988, about 2% of counties and 3% of voters used DRE systems. These figures rose to about 8% of counties, accounting for about 9% of the population, in 1998.

The gradual shift away from punch-card systems toward opti-scan and more expensive DRE systems is attributable in part to recognition among election officials of serious deficiencies in punch-card technology, problems that only recently became well known to the public. Many voters do not insert cards into the holder correctly, and punch the holes in the wrong places. Voters may apply insufficient force, or prescoring of the cards may have been done poorly. Incompletely removed chad may lead to intended votes being recorded as undervotes. Because no candidate information is printed directly on the cards, it is difficult for voters to discern mistakes by examining the card after removing it from the holder.

Al Gore was not the first to sue for a recount based on flaws associated with the use of punch card ballots. For example, a defeated candidate for property appraiser of Palm Beach County, Florida in 1984 sued for a hand recount, arguing that incomplete punches led machine counts to be unreliable, concluding

https://doi.org/10.1017/S1049096502000811 Published online by Cambridge University Press

that "because of the type of equipment and method used . . . it is impossible to accurately count any election" (Saltman 1988, 78). A study by the National Bureau of Standards (Saltman 1988, 110–11) more than a decade ago called for eliminating the use of prescored punch card ballots, noting that "it is generally not possible to exactly duplicate a count obtained on pre-scored cards, given the inherent physical characteristics of punch card ballots and the variability in the ballot punching performance of real voters."

In light of these now well-known problems, one might assume that any county that could afford to replace punch cards would have done so. Lost in all of the publicity regarding Florida, however, are the potential drawbacks of alternative systems. Errors are not unique to punch-card systems. As Saltman (1988, 8) notes, "Each type of system has its own particular vulnerabilities." Counter mechanisms on lever machines may fail to turn, due to a disconnect in the mechanical system or to excessive friction. Unlike the case with punch-card systems, there are no independent ballots available for recounting if a lever machine suffers from a rare failure such as this. If the printed strips inserted in a lever machine which identify candidates are incorrect, voters may cast votes for the wrong candidate. If not all of the counters have been set to zero before the polls open, incorrect totals can be produced.[7] Even where lever machines work perfectly, their higher cost may result in an insufficient number of machines (ECRI 1988, 7).

With opti-scan systems, there are recorded instances of ballot readers failing to read inordinately large numbers of ballots (Saltman 1988). An optical scanning malfunction in Volusia County, Florida caused hundreds of votes to be missed in the 2000 election.[8] *The Orlando Sentinel* conducted a manual review of more than 6,000 ballots read by optical scanners as invalid in Lake County, Florida in the 2000 presidential election, and found hundreds of overvotes in which voter intent was clear from attempted erasures or from notes written on the ballots, and several undervotes in which voters had circled a candidate's name instead of filling in an oval.[9] The precinct-count variant of opti-scan can alert voters to many but not all of these errors, and elections officials concerned about long lines at the polls sometimes do not even program the equipment to detect such mistakes.

Most DRE systems do not provide recountable individual records of voter choices, meaning that certain software or other problems in vote tallying may not be correctable. Any system relying on computerized vote tallying, including electronic voting, opti-scan, and punch cards, is subject to both security concerns and the possibility of programming errors. Numerous instances of voting system failures and near failures for electronic and other voting systems are documented in a FEC report (1982).

Although the media now revile any technology that appears to produce voter error, before the 2000 election the media's interest was mostly in producing quick vote totals on election night.

Despite the deficiencies of punch cards and potential advantages of DRE systems in reducing voter errors, these equipment types produced very similar rates of invalid presidential ballots until the 2000 elections (Caltech/MIT 2001). No valid presidential vote was recorded in 1996 for 3.1% of voters on average in both punch-card and DRE counties (see Table 1). Datavote counties had the highest rate at 3.4%, and lever machines the lowest at 2.2%.[10]

Punch cards do not always perform as poorly as in Florida in 2000. Some punch-card counties in other states provide voters with access to card readers to check their ballots for overvotes or other problems. (Some opti-scan counties in Florida provided this option in 2000.) In many punch-card counties, but apparently not in Florida's in 2000, election workers fan the ballot cards to remove loose chad, or pull off hanging chad from individual ballots, before machine counting them on election night.[11] Confusion in Palm Beach and Duval Counties was the result of poor ballot design and faulty instructions provided by Democratic Party workers, respectively; neither one of these problems is unique to punch-card systems.

Nor is minimizing voter mistakes the only criterion by which election administrators have typically assessed the performance of voting technology. Although the media now revile any technology that appears to produce voter error, before the 2000 election the media's interest was mostly in producing quick vote totals on election night. By that criterion, punch-card systems perform far better than opti-scan systems, particularly for large jurisdictions such as Los Angeles County. Maximizing accuracy may also conflict with the goal of enhancing turnout, particularly if there are mechanisms to alert voters to all undervotes as well as overvotes (as required in the Senate bill), which could confuse and frustrate voters and deter some from voting by producing longer lines at the polls.

The retention of punch-card technology in many counties, therefore, was not always dictated by sheer inability to afford newer and better systems. To the extent that cost matters, income per capita may not predict quality as well as does county size. Volume discounts from vendors, and economies of scale in setting up new systems, favor larger counties. As noted in FEC (1982, 11):

> New voting systems are, typically, first adopted by large metropolitan jurisdictions where the complexity of the ballots and the volume of voters create pressures for improved vote recording and tabulating techniques. Such jurisdictions are also blessed with the fiscal, technical, and managerial resources equal to the challenge. Only when new devices are tested and debugged in this way are they normally then adopted by intermediate-sized jurisdictions.

Because minorities and Democratic voters tend to be concentrated in larger urban counties, we should not necessarily expect to find a bias against them in the distribution of antiquated or inferior voting equipment. Tennessee is an illustrative case. In 1998, fewer than one-fifth of all the state's counties had electronic voting systems. However, these included the three largest counties of Shelby (Memphis), Davidson (Nashville), and Knox (Knoxville), which account for a disproportionate share of the state's poor, minority, and Democratic voters. Shelby County alone is home to nearly one-half of the state's African Americans, but just over one-tenth of its whites.

Data

Testing the emerging conventional wisdom in late 2000 regarding who

https://doi.org/10.1017/S1049096502000811 Published online by Cambridge University Press

uses inferior voting technology proved to be very straight forward. Following the general election in November of each even-numbered year, Election Data Services, Inc. surveys states and counties to obtain data on voter registration, vote totals, and voting equipment in use. Each county is classified in the Voting Equipment Data File as either using paper ballots, lever machines, Votomatic-style punch cards, Datavote, optical scanning, electronic, or mixed. The following results use the voting equipment data for 1998, which was the most recent year available when we began our study. Subsequently, a GAO (2001) report corroborated our findings using data for the 2000 election.

We merged the Voting Equipment File with demographic data from USA Counties 1998, a data file available from the U.S. Census Bureau.[12] This file provides estimates of the number of whites, African Americans, and Latinos[13] (who may be of any race) residing in each county in 1996, and of the number of poor[14] and nonpoor persons as of 1993.[15] Personal income per capita and property tax revenues per capita are available for 1994 and 1992 respectively. Finally, data are available in *USA Counties* (provided to the Census Bureau by the Election Research Center) on the number of votes cast for the Democratic and Republican candidates (Clinton and Dole) in the 1996 presidential election, which can be used to approximate the partisan distribution within counties.

Ethnicity

Table 2 shows the percentage of whites, African Americans, and Latinos who lived in counties using each type of voting equipment in 1998, for Florida and for the U.S. overall. Differences between African Americans and whites in Florida are small, with African Americans slightly more likely to live in punch-card counties, but also slightly more likely to live in opti-scan counties. The notable difference is for Latinos, 84% of whom lived in punch-card counties, compared to just over 60% for whites and African Americans. This difference is entirely attributable to the use of punch-card voting in Miami-Dade County, home of more than half of Florida's Latinos, but fewer than one in seven whites and fewer than one in five African Americans.

For the U.S. overall, black–white differences in punch-card use were negligible: 31.9% of whites and 31.4% of African Americans lived in counties using this voting technology.[16] Latinos were again much more likely than whites or blacks to live in punch-card counties. However, this difference is entirely attributable to Los Angeles County, where nearly one in seven Latinos in the country reside.

Whites (27.7%) were more likely than Latinos (24.4%) or blacks (21.8%) to live in opti-scan counties. To the extent we are able to identify precinct-count models of opti-scan technology in the voting equipment data, there was little difference across ethnic categories in the likelihood that voters were able to check their ballots for errors.[17]

Blacks were much more likely than whites or Latinos to live in counties using DRE or lever machines, both of which are typically programmed to prevent overvoting. In New York City's five counties, however, sensor latches intended to prevent accidental undervoting have been disabled, producing far higher rates of voided ballots than in other lever-machine counties.[18] Excluding these disproportionately minority counties, 18.2% of blacks, 15.6% of whites, and only 7.4% of Latinos lived in lever-machine counties.

Table 2
Voting Equipment and Ethnicity

	Florida			U.S.		
Voting Equipment	White	Black	Latino	White	Black	Latino
Punch card	60.4	63.1	83.8	31.9	31.4	44.3
Datavote	12.3	8.7	3.7	4.3	2.9	7.6
Lever machine	0.39	0.37	0.05	17.6	25.2	14.5
Paper ballots	0.07	0.16	0.03	1.6	0.4	0.7
Optical scan	24.6	26.2	11.8	27.7	21.8	24.4
Electronic	0.0	0.0	0.0	8.4	12.6	6.2
Mixed	2.3	1.5	0.55	8.5	5.8	2.5

Table entries indicate percentage of persons of a given ethnicity who reside in counties with voting equipment of a particular type. Note that Latinos may be of any race.

Poverty Status

Table 3 provides comparisons in voting equipment used for persons above and below the poverty line. Differences are very minor, in Florida and in the nation overall. The poor were slightly more likely than the nonpoor to live in punch-card counties, but also slightly more likely to live in DRE counties.

Party Voting

Based on presidential voting patterns in 1996, Democratic voters were more likely than Republicans to live in punch-card counties in Florida, as shown in Table 4. Nationally, however, the difference was negligible. Democrats were more likely to live in lever-machine counties, although half of this gap disappears when New York City is excluded.

Table 3
Voting Equipment and Poverty Status

	Florida		U.S.	
Voting Equipment	Above poverty level	Below poverty level	Above poverty level	Below poverty level
Punch card	61.5	63.1	31.8	33.4
Datavote	11.7	10.3	4.1	3.7
Lever machine	0.33	0.5	19.3	18.7
Paper ballots	0.06	0.08	1.5	1.5
Optical scan	24.3	24.0	26.3	26.1
Electronic	0.0	0.0	8.6	9.8
Mixed	2.1	2.0	8.5	6.7

Table entries indicate percentage of poor or nonpoor persons who reside in counties with voting equipment of a particular type. The poverty line was $14,763 for a family of four.

https://doi.org/10.1017/S1049096502000811 Published online by Cambridge University Press

Table 4
Voting Equipment and Party Vote, 1996

	Florida		U.S.	
Voting Equipment	Dole voters	Clinton voters	Dole voters	Clinton voters
Punch card	55.6	63.8	31.2	31.0
Datavote	14.3	11.3	4.4	3.8
Lever machine	0.4	0.3	15.9	20.3
Paper ballots	0.1	0.1	1.7	1.5
Optical scan	26.7	22.6	29.5	24.7
Electronic	—	—	9.5	8.6
Mixed	3.0	1.8	7.8	10.2

Table entries indicate percentage of Dole and Clinton voters who reside in counties with voting equipment of a particular type.

Republicans were somewhat more likely to live in opti-scan counties.

State-Level Comparisons

In practical terms, the nationwide comparisons in Tables 2–4 are relevant only for the popular vote in the presidential election. Equity in voting technology is better addressed by examining differences across counties within states. The electoral college system grants each state a fixed number of electoral votes, regardless of the number of valid votes cast in the state. Therefore, differences in voting technology that are purely cross-state cannot disadvantage a state's voters relative to other states. For example, suppose that most whites who live in punch-card counties reside in states where punch card use is universal, so they are not electorally disadvantaged in any way (except by contributing fewer valid votes to the nonbinding popular vote). Further suppose that most African Americans who live in punch-card counties reside in states with nonuniform systems, where whites tend to live in counties using less error-prone technology. Despite being disadvantaged across counties within states, the inclusion of cross-state differences in the data could obscure these differences and produce findings at the national level like those in Tables 2–4.

We therefore examined differences across counties within states, to exclude purely cross-state differences that can have no electoral impact. In 29 states in 1998, some but not all counties used punch-card technology. The conventional wisdom regarding racial disparities in voting equipment is contradicted by these state-level comparisons: in 18 of the 29 states, whites were more likely than African Americans to live in punch-card counties. The 11 states in which blacks were more likely to live in punch-card counties tend to be larger, however, accounting for 191 electoral votes, compared to 162 for the 18 states in which whites were more likely to live in punch-card counties.

Whites were more likely than Latinos to live in punch-card counties in 21 of the 29 states. These states accounted for 235 electoral votes, while the eight states in which Latinos were more likely to live in punch-card counties represent 118 electoral votes.

The conventional view that the poor live disproportionately in punch-card counties also turned out to be incorrect for the majority of states. In 21 states, representing 203 electoral votes, it was the nonpoor who were more likely to reside in counties using this type of voting equipment. In only eight states, representing 150 electoral votes, were the poor more likely to live in punch-card counties.

Party differences, as measured by voting in the 1996 presidential election, also contradict popular belief. A greater share of Dole voters than Clinton voters lived in punch-card counties in 16 of 28 states. However, the states in which Democratic voters were more likely to live in punch-card counties account for slightly more electoral votes (183 to 167). Percentages were virtually equal in the twenty-ninth state, South Dakota.[19]

Economic Factors

The belief that minorities, the poor, and Democrats tend to reside in areas using more error-prone voting equipment rests in large part on the reasonable presumption that cost matters. Electronic voting systems are more expensive than punch-card systems,[20] and counties with a lower poverty rate (and thereby a smaller share of minorities and Democratic voters in general) may be better able to afford the newer, more expensive technology. On the other hand, larger counties—where minorities and Democratic voters[21] disproportionately reside—may benefit from economies of scale in purchasing and implementing newer systems such as electronic voting. Here, we consider several county-level economic factors: county size, per capita income, and per capita property tax revenues (the major source of revenue for most county governments).

Results shown in Tables 5–7 provide little evidence that the retention of punch-card systems, or the adoption of less error-prone opti-scan or electronic alternatives, is heavily influenced by considerations of affordability. Punch-card counties in Florida were much larger (see Table 5), wealthier (Table 6), and richer in revenue (Table 7) than any other group of counties. It is exactly those counties that should be able to afford modern equipment which were the most likely to retain punch cards.

Nationally, punch-card and Datavote counties were larger (Table 5) and wealthier (Table 6) on average than counties using other voting systems. Surprisingly, DRE counties had the lowest incomes on average, and (by a wide margin) the lowest per capita property tax revenues (Table 7). Among opti-scan counties, those with

Table 5
Voting Equipment and County size (mean population)

Voting Equipment	Florida	U.S.
Punch card	589,824	150,640
Datavote	91,841*	183,984
Lever machine	14,410*	101,748*
Paper ballots	12,359*	9,123*
Optical scan	153,026*	59,609*
Electronic	—	92,565*
Mixed	79,736	150, 257

A * indicates the mean is significantly (.05, two-tailed test) less than the corresponding punch-card mean.

https://doi.org/10.1017/S1049096502000811 Published online by Cambridge University Press

Table 6
Voting Equipment and Personal Income Per Capita (mean)

Voting Equipment	Florida	U.S.
Punch card	22,540	18,299
Datavote	16,609*	18,585
Lever machine	13,497*	17,322*
Paper ballots	10,783	17,590*
Optical scan	17,239*	17,530*
Electronic	—	16,930*
Mixed	20,040	19,160

A * indicates the mean is significantly (.05, two-tailed test) less than the corresponding punch-card mean.

Table 7
Voting Equipment and Property Taxes Per Capita (mean)

Voting Equipment	Florida	U.S.
Punch card	710.3	499.6
Datavote	470.6*	605.7
Lever machine	196.0*	478.1
Paper ballots	135.0*	876.7
Optical scan	546.0	541.7
Electronic	—	312.2*
Mixed	674.5	751.1

A * indicates the mean is significantly (.05, two-tailed test) less than the corresponding punch-card mean.

precinct-count systems were somewhat larger on average (80,000 vs. 55,000, $\rho = .02$), but differences in per capita income and property tax revenues were insignificant.

Comparisons across counties for each state separately produce similar findings. The 28 states considered are those in which some counties used punch cards while others used modern (opti-scan or electronic voting) equipment.[22] In 17 of the 28 states, punch-card counties were larger than counties with modern equipment. This difference was significant in 11 states: punch-card counties were larger in eight states and smaller in only three states. Also in 17 (but not the same 17) of the 28 states, punch-card counties had higher average incomes. This difference was significant in 13 states: per capita incomes were higher in punch-card counties in eight of these, and lower in only five states. Similarly, in 17 of the 28 states, punch-card counties on average had higher per capita property tax revenues. Taxes were significantly higher in punch-card counties in seven states, and in counties with modern systems in only three states.

Florida fits these general patterns. Population, income, and tax revenues were all significantly higher in its 15 counties using punch cards in 1998 than in its 24 opti-scan counties (there were no DRE counties, because its use had not been approved in Florida). Among the opti-scan counties, however, those with precinct-count systems had higher property tax revenues per capita ($770 vs. $471, significant at .01).

Probit Regressions

We also conducted several county-level probit regression analyses examining the factors associated with use of each type of voting technology. These tests can tell us how ethnicity relates to equipment type, controlling for county size and other economic variables.[23] The most noteworthy finding is that counties with a higher share of African Americans were significantly *less* likely than others to use punch-card machines. They were also less likely to use paper ballots, and more likely to use lever machines.

Counties with more Latinos were significantly less likely to use lever machines, and more likely to use Datavote or opti-scan technology. Higher incomes were associated with a lower likelihood of using paper ballots; we found no other significant relationship with income. Higher property taxes were associated with a greater use of paper ballots (likely reflecting low population density) and a lower likelihood of using DRE. Low population levels strongly predicted the use of paper ballots as expected, while large counties were more likely to use punch-card or DRE systems.

Conclusion

Results from this study contradict the widespread belief 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. Media reports of ethnic and party disparities in Florida, and in selected metropolitan areas such as Atlanta and Chicago, prove to be inconsistent with evidence from most other states and the country as a whole. In fact, in the majority of states with some counties using punch cards and others using alternative systems, whites, the nonpoor, and Republican voters are more likely than African Americans, the poor, and Democratic voters to reside in punch-card counties.

What about variation in age or condition of equipment within counties—perhaps the poorer precincts get stuck with the faulty machines, or with more poorly trained poll workers who assemble the devices less carefully? In fact, the punch-card devices are assembled at a central location before distribution to precincts, not by election-day poll workers, and machines do not "belong" to particular precincts.

Moreover, there is little evidence that the choice between punch cards and more modern, less error-prone systems is influenced by economic factors. In Florida and elsewhere, larger, wealthier, and more tax-rich counties were more likely to use punch-card technology, and less likely to use DRE.

We note several caveats in closing. First, Latinos are more likely than whites (or blacks) to live in punch-card counties. However, this disparity would be eliminated entirely if Los Angeles County abandoned its use of punch cards—and the white–Hispanic gap in most of the individual states is in the opposite direction from the disparity for the nation as a whole.

Second, although lever machines perform well in terms of producing low rates of invalidated ballots, there is anecdotal evidence that they are associated with much longer waits at the polls to vote. If lines deter some people from voting, the greater likelihood that

https://doi.org/10.1017/S1049096502000811 Published online by Cambridge University Press

African Americans live in lever machine counties is a mixed blessing.

Third, we cannot rule out the possibility that among punch-card counties, the poorer ones are less likely to provide voters access to card readers allowing them to check that their ballots accurately reflect their voting intentions. However, the availability of this equipment could just as easily be a function of county size rather than income levels.[24] We also do not have data on the number and characteristics of absentee and early voters in each county and on which system is used for tallying their ballots.[25]

Fourth, this analysis addresses only the question of who uses punch-card and other voting systems. Other studies (Herron and Sikhon 2001; Knack and Kropf N.d.; Tomz and Van Houwelling N.d.) have found that the effects of punch-card technology on the rate of invalidated ballots vary positively and significantly with the African-American share of the population. Those findings suggest that eliminating punch-card voting would reduce ethnic disparities in the rate of invalidated ballots.

A final matter concerns the impact of our findings: is this a case in which political science research overturned conventional wisdom among pundits and policymakers regarding who uses inferior voting technology? The answer is yes, but with major qualifications. Our results were reported initially in the *Washington Post* and subsequently in the *Wall Street Journal*, on CNN, and in numerous other media outlets. We provided testimony at hearings by the Senate Rules Committee in March 2001 and the Senate Governmental Affairs Committee in May of 2001. No one at these hearings or in any other forum has disputed the data or the conclusions based on them.

However, editorials in the *New York* Times and *Washington Post* continued to assert that less affluent areas were stuck with inferior voting equipment.[26] The Economist (2001) wrote even later that "everybody knows that the worst voting machinery is concentrated in poor areas." Hillary Shelton, director of the Washington bureau of the NAACP, who also testified at the Senate Rules Committee hearing, subsequently asserted that "most election machines that were utilized in black communities throughout the country were quite old and quite antiquated and need to be replaced."[27] A letter printed in the *Washington Post* in August of 2001 alleged that "the most antiquated machines that routinely discard votes . . . continue to be reserved for poor and minority precincts . . ."[28] The letter was coauthored by Senator Dodd (D-Conn)—an intent listener at the Rules Committee hearing.

Notes

*We purchased voting-equipment data from Election Data Services, Inc. Kim Brace and Dale Tibbits of Election Data Services provided valuable information on voting equipment. We are responsible for all interpretations of the data and any errors.

1. Richard Morin and Claudia Deane, "Public Backs Uniform U.S. Voting Rules," *Washington Post*, 18 December 2000, sec. A.

2. Josh Barbanel and Ford Fessenden, "Racial Pattern in Demographics of Error-Prone Ballots,'' *New York Times*, 29 November 2000, sec. A.

3. David S. Broder and Helen Dewar, "A Changed Lieberman Rejoins Senate," *Washington Post*, 15 December 2000, sec. A.

4. "Fixing the Vote," 11 December 2000, sec. A; E. J. Dionne, "Back to Florida," 5 December 2000, sec. A; Jesse Jackson and John Sweeney, "Let the Count Continue," 12 December 2000, sec. A; William Raspberry, "Post-Traumatic Suggestions," 1 January 2001, sec. A.

5. Josh Barbanel and Ford Fessenden, "Racial Pattern in Demographics of Error-Prone Ballots," *New York Times*, 29 November 2000, sec. A.

6. John Mintz and Dan Keating, "A Racial Gap in Voided Votes: A Precinct Analysis Finds Stark Inequity in Polling Problems," *Washington Post*, 27 December 2000, sec. A.

7. According to a long-time Chicago political consultant, "When we voted by machine, there were machines where you opened up the back at 5 in the morning before the balloting began and you found a hundred votes for a certain candidate." Robin Toner, "Behind the Scenes, It's Old News that Elections are not an Exact Science," *New York Times*, 17 November 2000, sec. A.

8. Dana Milbank, "2 Systems, 1 Punch Problem," *Washington Post*, 17 November 2000, sec. A.

9. David Damron, Ramsey Campbell, and Roger Roy, "Gore Would Have Gained Votes," *Orlando Sentinel*, 19 December 2000.

10. These rates are calculated using voting equipment data for 1996, and presidential voting and turnout data from Election Data Services and state election offices. Invalid votes do not include mistaken votes accidentally cast for the wrong candidate—likely less frequent with DRE than with punch-card equipment. Moreover, they do not exclude intentional undervotes, which should vary little by equipment type.

11. John Mintz, "It's Not as Easy as 1-2-3: Problems Exist With Both Hand, Machine Counts," *Washington Post*, 19 November 2000, sec. A.

12. See <www.census.gov/statab/www/county.html>. Voting equipment for Alaska is listed by election district rather than by county, so a simple merge with census data was not possible. However, because every election district used optical scanning (except for some remote communities that use hand-counted paper ballots), we coded each Alaskan county as optical scan and retained those observations.

13. The Census Bureau uses "Hispanic," but Latino is APSA's preferred terminology.

14. The Census Bureau defines poverty on the basis of income and family size. In 1993, a person (under 65) was considered poor if living alone with a pre-tax income (excluding capital gains and non-cash benefits) of no more than $7,518. For a household of four, the threshold was $14,763.

15. We would prefer data on persons of voting age, rather than all persons, in each of these demographic categories, but data on voting-age population are not broken down in this way at the county level. Ideally, we would also have data on ethnicity, poverty, etc., available for 1998. The impact of these time discrepancies is likely trivial; e.g., there is no reason to expect a different rate of population growth for minorities in punch-card counties and in other counties.

16. If these data are treated as a sample for purposes of conducting significance tests, even minuscule differences such as this one turn out to be statistically significant, because of the enormous sample sizes. Causation should not be inferred from significance, however, as a switch in voting equipment in a single large county could reverse a small black–white gap.

17. In the equipment data file, the model of opti-scan system used is not always identified. Nor do we know which counties with precinct-count systems programmed them to detect errors of different sorts.

18. See Stephanie Saul, "Many Ballots Not Counted in Runoff," *Newsday*, 18 November 2001.

19. Detailed tables of the state-level comparisons are available in the January 2001 version of this paper, accessible at <www.umkc/edu/pol-sc>.

20. The price of touch-screen systems varies from $1500–$6000 per unit, compared to about $5000 per precinct for an optical scanning machine or a card reader for punch-card ballots. See John Hendren, "Armed to Send Chads into Voting Oblivion," *New York Times*, 17 December 2000, sec. 3, and Ford Fessenden, "New Focus on Punch Card System," *New York Times*, 19 November 2000, sec. 1.

21. Bush won a plurality over Gore in 78% of all counties, but had fewer votes nationwide, as Gore won most large, urban counties.

22. Combining these two categories to form a larger "modern" category lets us include many more counties and states—facilitating tests of significance—than could be included in a table comparing only electronic, or only optical scanning, to punch-card counties.

23. Regression tables are available in the January 2001 version of this paper at <www.umkc/edu/pol-sc>.

24. Cook County, Illinois (Chicago), has card readers available at the precincts, but their use by voters has been prohibited because it is unavailable in other punch-card counties in the state. See *Washington Post*,

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"A Racial Gap in Voided Votes," 27 December 2000, sec. A.

25. Obviously absentee voters cannot use lever machines or DRE; lever and DRE counties send to absentee voters ballots or punch cards that are counted by hand or by machine. Punch cards sent to absentee voters are particularly difficult to use, without the vote-recorder devices and attached booklets and card holders available at the polls. Los Angeles and some other punch-card counties allow early voting using DRE.

26. See *New York Times*, "Toward Chad-free Elections," 6 March 2001, sec. A, and *Washington Post*, "Fixing the Vote," 25 February 2001, sec A.

27. Ellen Nakashima and Dan Keating, "Technology Slashes Detroit Voting Error," *Washington Post*, 5 April 2001, sec. A.

28. John Conyers and Christopher Dodd, "A Response to Florida" (letter to the editor), *Washington Post*, 4 August 2001, sec. A.

References

Caltech/MIT Voting Technology Project. 2001. "Residual Votes Attributable to Technology: An Assessment of the Reliability of Existing Voting Equipment" (March 30 revision). <www.vote.caltech.edu> (June 11, 2002).

The *Economist*. 2001. "The Florida Recount: Unfair, Again," 9 June.

ECRI. 1988. *An Election Administrator's Guide to Computerized Voting Systems.* Plymouth Meeting, PA: ECRI.

FEC. 1982. *Voting System Standards: A Report to the Congress on the Development of Voluntary Engineering and Procedural Performance Standards for Voting Systems.* Washington, DC: The National Clearinghouse on Election Administration of the Federal Election Commission.

GAO. 2001. "Statistical Analysis of Factors that Affected Uncounted Votes in the 2000 Presidential Election." Report to ranking Minority Member, Committee on Government Reform, U.S. House of Representatives, October. Washington, DC: U.S. General Accounting Office.

Herron, Michael C., and Jasjeet S. Sekhon. 2001. "Overvoting and Representation: An Examination of Overvoted Presidential Ballots in Broward and Miami-Dade Counties." <http://elections.fas.harvard.edu/election2000/HerronSekhon.pdf> (June 11, 2002).

Knack, Stephen, and Martha Kropf. N.d. "Voided Ballots in the 1996 Presidential Election: A County-Level Analysis." *Journal of Politics.* Forthcoming.

Saltman, Roy G. 1988. *Accuracy, Integrity and Security in Computerized Vote-Tallying.* National Bureau of Standards Special Publication 500–158.

Tomz, Micahel, and Robert Van Houwelling. N.d. "How Does Voting Equipment Affect the Racial Gap in Voted Ballots?" *American Journal of Political Science.* Forthcoming.

https://doi.org/10.1017/S1049096502000811 Published online by Cambridge University Press