Residual Voting, Voting Equipment, and Inequality in the 2016 U.S. General Election

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Abstract

In the hyperfederalized American electoral system, in which voting equipment can vary by county, a key question is whether this variation is related to inequalities in residual voting across demographic groups. A persistent concern regarding voting equipment is that some types are more reliable than others in correctly recording the choices voters make via ballots. A related concern is that county election jurisdictions with fewer financial resources may have lower quality voting equipment, and these areas tend to be more populated by poor individuals and racial minorities. Two questions are assessed in this paper: (1) Are more racially diverse and lower income counties less likely to have quality voting equipment, and (2) does lower quality voting equipment in such counties lead to a higher rate of residual voting among these groups relative to non-Hispanic whites and the middle class and affluent. To evaluate these questions, this study merges American nationwide county-level data on polling place equipment from Verified Voting from 2016 with county-level vote count and turnout data from the Election Assistance Commission and the Leip's *Atlas of U.S. Elections.* The polling place equipment examined includes paper ballots, optical scan ballots, and digital recording electronic (DRE) voting. Multivariate regression analyses, with residual voting as the dependent variable, and polling place equipment and county demographic variables as key independent variables, is used to assess the outcomes of interest. Ultimately, this study shows that the U.S. is a mixture of equality and inequality when it comes to election machines and residual voting across difference demographic groups.

Introduction

In June of 2020, Georgia primary voters encountered an obstacle to casting ballots: improperly operating election machines. The new devices – "new generation ballot-marking devices" – were designed to optimize the voting process for Georgians by offering ballots in different languages and providing audio ballots for those visually impaired (Corasaniti and Sail 2020). However, a "cascade of problems" associated with the machines "caused block-long lines across Georgia" (Corasaniti and Sail 2020). Problems associated with the machines included the machines requiring too much power for polling locations, blown fuses, and never powering on. Inadequate poll worker training with the equipment and late arrivals of election machines to polling locations also complicated matters. But this story of election machines creating an obstacle to ballot casting is not new.

Among the key functions of election machines are to present voters with ballots on which to register their choices, and then managing the "information contained in the choices that voters make, including the counting of ballots" (Stewart 2011, 360). Ideally, election machines would be a convenient means by which voters can make their choices, and their vote intentions would be translated in every case into actual vote choices. But, as the Georgia example indicates, sometimes election machines do not function perfectly with reference to these benchmarks. In the 2000 presidential election in Florida, millions of individuals were not able to have their ballots counted because of "hanging chad" issues associated with punch card voting machines and other election administration issues. Because the Florida contest decided the 2000 election, and because faulty election machines and uncounted ballots possibly contributed to the narrow Bush victory, Congress and scholars were motivated to conduct to research to improve the quality of election machines and other elements of election administration.

Within this context Caltech/MIT (2001) scholars found that election machines of varying levels of quality are related to varying levels of residual voting rates. The residual voting rate measures the percentage of ballots that remain uncounted out of total ballots cast. What Caltech/MIT (2001) and the U.S. federal government (U.S. Commission on Civil Rights 2001) found is that election machines such as punch card machines were particularly likely to lead to high residual voting rates. This prompted the federal government to pass the Help America Vote Act (2002) to provide funds to state and municipal governments to replace problematic punch card machines with other electronic voting machines such as optical scan ballots and direct-recording electronic (DRE) machines. Since the 2000 election, punch card machines have virtually disappeared and largely been replaced by these machines, with a wide consensus of scholars agreeing that this election machine development has resulted in a reduction of residual voting rates in election jurisdictions across the United States (Alvarez, Atkeson, and Hall 2013; Alvarez and Hall 2008; Stewart 2011).

Despite these developments, a continuing issue in the United States regards inequalities in state and local voting systems that place extra burdens on racial minorities and the poor. From poll taxes and literacy tests of the Jim Crow era, to felon disenfranchisement laws, to voter ID requirements, a long list of election administration provisions have been adopted that make it harder to voter for individuals from these historically marginalized demographic groups to engage in elections (Alexander 2012; Anderson 2018; Keyssar 2008; Springer 2014). This is also true of election machine quality, with research following the 2000 election indicating the poor and racial minorities were more likely to reside in areas with problematic election equipment that made it more likely that their ballots would be rejected rather than ballots from more affluent or non-Hispanic white individuals (United State Congress. Committee on Government Reform.

2001). A long train of research has noted that racial minorities in particular have been more likely to experience higher residual voting rates because of faulty election equipment, but have also found that racial group disparities in residual voting can be narrowed by the adoption of better election machines such as DREs or optical scan ballots (Knack and Kropf 2003; Stewart 2004; Stewart 2006; Tomz and van Hauweling 2003).

This study seeks to further this area of study by determining whether disparities in election machine quality continue in the 2016 presidential election to be a source of disparities in residual voting between historically more and less advantaged voting groups. Using a unique county-level dataset on residual voting produced by combining vote county data from the Election Assistance Commission (2016), voter turnout data from Leip's (2019) *Atlas of U.S. Elections*, and voting machine data from Verified Voting (2019), this study is able to assess whether racial minorities and lower income relative to higher income and non-Hispanic white Americans are less likely to have access to quality voting machines and have higher election machine linked residual voting rates. Theoretically and empirically, this study contributes to the broad literature on inequality and election administration by showing that election machines continue to impact the equality of voting in this country.

Literature Review

Historical Background

With the template set by Time, Place, and Manners Clause of the U.S. Constitution (Article 1, Section 4), most matters regarding the administration of elections takes place at the state and municipal levels. Among the policy implications of this provision are that the fifty states possess different combinations of voting and registration laws, have varying numbers of polling locations per precinct, and have different types of voting machines. While often not thought of by the average citizen as being a central feature of the voting process, such machines and their quality are necessary to allow citizens to register their preferences for political candidates in elections. Election machines are a vital connective tissue in the American democratic system that bind citizens to leaders.

For election machines to serve this purpose, they must be easy for citizens to use, protect the independence and privacy of the ballot casting process, and accurately record vote choices. Naturally, as technology has evolved, the types of machines employed for these purposes have evolved as well. According to Alvarez and Hall (2008, 15), there are three general periods of election machine dominance in U.S. history. From the beginning the American republic to the late nineteenth century, partisan paper ballots were dominant. Although these years coincided with the highest voter turnout elections in the country's history, mainly because partisan ballots gave parties a critical mobilization tool, voter privacy was limited, and the closer partisan connections to election administration incentivized voter fraud (Gumbel 2005; Keyssar 2009). With the introduction and adoption of the Australian ballot in the late nineteenth century, the country entered a period of nonpartisan elections. Election machines commonly used during this period included paper ballots and, later, lever machines. The lever machines were designed "to alleviate problems associated with the use of paper ballots, the most significant problems being fraud and corruption" (Alvarez and Hall 2008, 16). However, Alvarez and Hall (2008, 16) noted that these machines were not impervious to fraud or corruption, could break down, and could be difficult for citizens to use. Nonetheless, paper and level voting machines were dominant until the middle of the twentieth century.

The third period, beginning in the 1960s, is represented by the rise in electronic voting machines. One example of these is punch card voting machines, which became particularly dominant in “large election jurisdictions to provide a cheaper and easy-to-administer voting system” (Alvarez and Hall 2008, 17). These preprinted cards permitted citizens to register their choices by marking their vote choices, which were then tabulated by “large punch card readers” (Alvarez and Hall 2008, 18). Punch cards were a commonly used machine across election jurisdictions until the 2000 presidential election in Florida brought to national attention the difficulty some citizens had with indicating their voter intention on punch card ballots, and also issues related to the accessibility of the machines to voters with disabilities and mechanical maintenance.

Today, optical scanning and direct-recording electronic (DRE) machines are the two dominant ballot casting mechanisms, with a small number of election jurisdictions making use of paper hand-counted ballots (Desilver 2016; Stewart 2014, 232). Optical scanning machines were first developed in the 1960s, permitting individuals to make “ink and pencil marks to be scanned by an electronic device” (Stewart 2014, 230). According to Stewart (2014, 232), more than 60% of voters in 2012 reporting casting a ballot using an optical scan machine. DREs came into existence during the 1970s, allowing individuals to engage in elections by recording their votes on a touch screen. As of 2012, Stewart (2014, 230) reports that approximately 25% of individuals submitted their ballot choices on DREs. By the late-2000s and 2010s, two other types of voting machines – punch cards and level machines – had “virtually disappeared in federal elections” (Stewart 2014, 233). As of 2016, 47% of “registered voters live in jurisdiction that use only optical-scan as their standard voting system, and about 23% live in DRE-only jurisdictions” (Desilver 2016). These numbers are from the Pew Research Center, which also show that individuals in the remainder of election jurisdictions – not including all-mail voting states – use combinations of optical scan ballots, DREs, and hand-counted paper ballots (Desilver 2016).

Assessing the Impact of Voting Machines

In an ideal democratic society, election machines should not be cumbersome to operate for either election workers or ballot casters, and they should perfectly translate voter intent to voter choice. A large reason for the technological evolution of voting machines is connected to these objectives. But, as in earlier election machine periods of U.S. history, today their prevails debates over the suitability and possible need to update the dominant optical scanner and DRE election machines used in most election jurisdictions. Herrnson et al. (2008) executed a multifaced evaluation of these voting machines in a study involving expert reviews, controlled laboratory experiments, and field studies. While optical scan machines may partially avoid the voter intent discernment problem associated with punch card ballots, these researchers find that optical scan ballot users were more likely to report that ballot pages contained too much information, that it was difficult to correct vote problems, that there was a lack of verification that one's ballot was correctly filled out and accepted, and that undervotes and overvotes were occasional problems because some optical scan systems lacked a confirmation mechanism that would tell individuals that they had incorrectly filled out the ballot. DREs, ideally, correct for these issues by providing voters with a convenience "similar to [using] ATMs at banks," by not overloading voters with all the ballot information on a single screen, and by including more safeguards against undervoting and overvoting (Alvarez and Hall 2008; Herrnson et al. 2008, 50-52). However, Herrnson et al. (2008, 53) find that DREs have problems, too; they note the machines can be problematic for those with a lack of computer experience, because they may lack a voter verification mechanism, and because of security issues. In the wake of the 2016 election, security concerns about Russian infiltration into county and state electronic management systems that provide the software necessary to operate DREs has motivated a large number of jurisdictions to turn more to optically scan ballot (National Academies of Sciences, Engineering, and Medicine 2018; Schwartz 2018). Even with these problems linked to optical scanner and DRE machines, Herrnson et al. (2008, 48) found that individual users of these machines either agreed or strongly agreed that these machines inspired confidence, were easy to understand, were comfortable to use, and had overall satisfaction regarding their performance.

Even though there may be broad satisfaction with these types of election machines (Herrnson et al. 2008), subtle differences in election machine quality can shape not only the confidence that voters have that their ballots are accurately counted, but also that their votes are counted at all. A measure that taps into concern is known as the residual vote rate, which represents what percentage of all ballots cast were not actually counted (Caltect/MIT 2001). High residual vote rates indicate that many individuals did not have their ballots counted, while low rates indicate the opposite. While high residual vote rates can be produced by factors such as purposeful abstention from voting in certain election contest, an uncompetitive election environment, or a lack of descriptive representation (Herron and Sekhon 2005; Kimball and Kropf 2008; Stewart 2020**)**, many scholars (see Stewart 2011 for summary of research) use the residual voting rate as a measure of the quality of election machines**.** Better designed and maintained election machines will be easier for individuals to use and thus clearly indicate their voting intent when they cast a ballot; they will also make it less likely that a voter will inadvertently undervote or overvote, and thus have their ballot rendered invalid for counting. Regarding the impact of the evolution of voting technologies on residual voting rates across county election jurisdictions, Stewart et al. (2020) estimate that the if optical scan and DREs had not entirely replaced punch card voting machines the average residual voting rate in the country would be 0.25 percentage points higher in 2016 than in 2000; the implication is that advances in election machine technology and better implementation of them through the Help American Vote Act (2002) considerably enhanced the likelihood that an individual's ballot was accurately counted. While different designs of optical scanner and DRE machines are related to variations in residual voting levels, many studies show that optical scanners and DREs are linked to lower residual voting rates than paper ballots, lever machines, and punch card ballots (Alvarez and Hall 2008; Ansolabehere and Stewart 2005; Herrnson et al. 2008; Stewart 2014; Stewart 2006; Stewart et al. 2020).

Election Administration Inequality and Election Machines

The U.S. has a long history of biases in election laws and procedures treating non-Hispanics whites and middle to higher socio-economic class citizens more favorably than racial minorities and the poor (Keyssar 2009; Ritter and Tolbert 2020; Springer 2014). With the exception of the Help American Vote Act, passed in 2002 in the wake of the 2000 Florida election debacle, funding for state and local election machine must come from either state or local taxes (Lichtenheld 2020; Stewart 2011). This means that more affluent areas are more likely to be able to afford higher-quality election machines that are less likely to lead to high residual vote rates. Since in the United States income inequalities track race based inequalities closely because of the long history of various structural inequalities in U.S. history (Schlozman, Verba, and Brady 2012**)**, this means also that non-Hispanic whites tend to earn more income than racial minorities such as African Americans and Hispanics. Since there is a large degree of de facto residential segregation in the United States even today (Rothstein 2018), this makes it likely that not only will poorer areas have less money to invest in quality voting machines, but also that racial minority areas will have less money to invest in such machines

Following the 2000 election, research found that high residual vote rates in Florida were uniquely likely to be features of racial minority and lower income areas. In these areas, faulty election equipment such as punch card voting machines were more likely to be present obstacles to voters (Caltech/MIT 2001; U.S. Civil Rights Report 2001). Research indicates that between 4 to 6 million votes nationwide, and 1.5 to 2 million in Florida, were unrecorded or uncounted. The House of Representatives Committee on Government Reform (2001) sponsored research that analyzed voting results from 40 congressional districts in 20 states; 20 of these districts had high poverty rates and small minority populations, while 20 had low poverty rates and small minority populations. The research found that voters in low-income, high-minority districts were significantly more likely to not have their votes counted, and that low quality election machines (e.g., punch cards and level machines) were a significant factor behind the outcome. The research also found that better election machine technology available in low income and high-racial minority density areas minimized the disparity in uncounted voters. One of the resulting recommendations from this research was that election jurisdictions replace punch card and level election machines with optical scan ballot and DRE election machines (MIT/Caltech 2001; U.S. Civil Rights Report 2001). Many election jurisdictions have abided by these recommendations and have replaced punch cards with optical scanners or DREs (Stewart 2014, 231-232).

Stewart (2014) examines various legal and demographic factors behind election machine usage across the American states. Before the federal-level Help American Vote Act (HAVA) of 2002, voting machines varied more across localities and states, and were selected for either functional reasons, such as local or state laws that required certain types of election machines, or demographic factors, such as larger and more prosperous jurisdictions being able to afford automated voting systems. Since HAVA and more federal involvement and financial disbursement to states for the improvement of election administration, including the utilization of higher-quality election machines, "differences across localities using difference machines has flattened out" (Stewart 2014, 233). Before HAVA, automated voting systems such as DREs were more common in counties that were on average of higher income and more racially diverse. After HAVA, "the racial compositions and median incomes of counties using DREs and optical scanners are now virtually equal" (Stewart 2014, 233-234). Consistently, various studies have shown that counties with new election equipment (DREs and optical scan machines) are more likely to have narrower residual vote differences between racial minorities and non-Hispanic whites (Knack and Kropf 2003; Stewart 2004; Stewart 2006; Tomz and van Hauweling 2003).

Evaluating Whether Election Machine Inequalities Persist

This study contributes to the voting and inequality literatures by assessing whether inequalities in access to quality election machines persist, and whether these disparities continue to result in higher residual voting rates for racial minorities (African Americans and Hispanics) relative to non-Hispanic Whites, and higher residual voting rates for lower relative to higher income Americans. While studies have examined the racial dimensions of residual voting, they have not given extensive attention to how election machines impact racial minorities relative to non-Hispanic whites. Additionally, little attention has been allocated to how low versus high income individuals are impacted by election machines. The expectations are that counties with higher percentages of non-Hispanic whites (relative to racial minorities) and high income individuals (relative to low income individuals) will be more likely to have access to higher-quality election machines, and also will have lower residual voting rates linked to election machine usage. Higher income areas, which are also more likely to more highly populated by non-Hispanic whites, are more likely to be able to afford higher quality election machines and more timely updates.

Data and Methods

This study employs county level residual voting and demographic data to evaluate the impact of election machines on voting equality by income and race. Most election machine decisions take place at the county level, and therefore this level analysis was selected. The geographical coverage includes all counties in the American states plus Washington, D.C. Alaska is treated a single unit because elections are administered by the Alaskan state government (Kimball and Kropf 2008). The residual voting rate is calculated using the following equations:

(1) Residual Vote = Total Votes Cast – Total Votes Counted

(2) Residual Vote Rate = (Residual Vote/Total Votes Counted) x 100

This is the "percentage of ballots that were cast without a vote" in the 2016 election (Alvarez, Atkeson, and Hall 2013, 24). Data on total votes cast per county or election jurisdiction comes from the 2016 Election Assistance Commission survey of election laws, procedures, and statistics from U.S. election jurisdictions. The vote count statistic reports "the total number of people in [. . .the local election official's] jurisdiction who participated in the November 2016 general election," and includes both under and overvotes. McDonald (2020) uses these figures in his United States Elections Projects data to calculate total votes cast for a number of states. Data on voter turnout per county comes from Leip's (2019) *Atlas of U.S. Elections.* Across 2,761 U.S. counties and election jurisdictions, the mean residual voting rate is 1.67%, which is similar to the average county-level residual voting rate from Alvarez et al. (2020) calculated from the U.S. Elections Project, Election Data Services, and various state election data sources. 279 election jurisdictions were removed from analyses because they had residual voting rates of less than 0; Alvarez, Ansolabehere, and Stewart III (2004, 9) note that negative residual rates are a sign of state election working inconsistencies in differentiating vote counts from turnout, and they recommend removing such cases from analyses since they would otherwise introduce measurement error into estimations. A key advantage of using the U.S. Election Assistance Commission's vote count measure is that it covers more county or election jurisdictions (2,761 vs. 2,597) than in Alvarez et al. (2020) and is hence more spatially representative of differences in election machine impacts across the country.

Data on election machines per election jurisdiction at the county level come from Verified Voting (2019). According to this data source, in 2016 94% of county-level jurisdictions reported having optical scan machines, 47% having DREs, and 7% relying on paper ballots. Of jurisdictions employing combinations of these machines, 43% use both DREs and optical scanners, while approximately 2% use either optical scanners and paper ballots or DREs and paper ballots, and 1% implement all three types of machines. Of jurisdictions that utilize only one machine, 49% use only optical scanners, 2% singly DREs, and 1% exclusively paper ballots.

The dependent variable is county-level residual voting rate. Key independent variables include three binary election machine variables: Paper ballots (reference category in multivariate models), optical scan machines, and DREs. Four other key demographic independent variables include the percentages of the population of a county consisting of non-Hispanic whites, African Americans, Hispanics, and what is a county's per capita income. Control variables include what percentage of the population of a county has a four year college degree or more, the median age of a county's population, and fixed state effects to control for state laws and other environmental factors that may impact the residual voting rates (Stewart 2011). Data for demographic variables comes from the 2012-2016 American Community Survey. All residual vote outcomes are weighted by county-level voter turnout (Stewart 2011).

Results

To first evaluate whether there are disparities in quality election machine access by racial or income groups, this study first estimates pairwise correlations between residual voting rates, election machines, the key demographic variables of interest, as well as the control variables. Since counties with higher densities of non-Hispanic Whites and higher income individuals are expected to be able to more easily acquire high-quality voting machines (optical scan ballots and DRES), the expectation is that there will be higher correlations between higher income and non-Hispanic white counties and these election machines relative to the correlations between racial minority and lower income counties and these election machines.

As displayed in Table 1, the correlation evidence indicates that residual voting rates tend to be higher in election jurisdictions that have higher populations of non-Hispanic whites and Hispanics, as well as rely on paper ballots. On the other hand, higher African American county populations are associated with lower residual voting rates. Regarding election machine correlations, paper ballots are linked to election jurisdictions that have more non-Hispanic whites, and have higher income, education, and age population averages. Conversely, paper ballots are less associated with areas with higher African American and Hispanic populations. Optical scan machines are more common in areas with more African Americans, Hispanics, higher income, and higher education levels but are less common in areas with more non-Hispanic whites and older individuals. DRE machines are more common in heavily African American areas but tend to be less present in areas with more non-Hispanic whites, and of higher income, education, and age levels.

Table 1: Pairwise Correlations between Features of Counties and Election Jurisdictions

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Residual Vote	1.00									
(2) Paper Ballot	0.06**	1.00								
(3) Optical Scan	0.03	-0.45**	1.00							
(4) DRE	-0.07**	-0.02	-0.16**	1.00						
(5) Pct. White	0.13**	0.12**	-0.01**	-0.15**	1.00					
(6) Pct. Black	-0.21**	-0.08**	0.06**	0.25**	-0.62**	1.00				
(7) Pct. Hispanic	0.04*	-0.07**	0.04*	0.03	-0.61**	-0.11**	1.00			
(8) Income	-0.01	0.06**	0.05*	-0.21**	0.20**	-0.26**	-0.04*	1.00		
(9) Education	-0.01	0.03	0.08**	-0.17**	-0.003	-0.10**	0.02	0.77**	1.00	
(10) Age	0.06**	0.16**	-0.16**	-0.12**	0.47**	-0.21**	-0.31**	0.12**	-0.17**	1.00

*** $p<0.05$, * $p<0.1$*

Regarding the question of whether lower versus higher income, and non-Hispanic whites versus racial minorities, are more or less likely to have access to high quality voting technologies – DRES and optical scan machines – the evidence is mixed. Areas with larger African American and Hispanic populations are more likely to have optical scan and DRE machines, while the inverse is true of areas with larger non-Hispanic white populations. DRE machines are associated with lower residual voting rates, so African Americans appear to have both access to and be advantaged by these machines. The only voting technology linked to higher residual vote rates is paper balloting, but only areas with higher non-Hispanic white populations are more likely to have these ballots. Areas with higher African American and Hispanic populations are less likely to use this technology. These findings suggest that racial minorities are more likely to be located in election jurisdictions with election machines less linked to residual voting, while non-Hispanic whites are more likely to be located in jurisdictions with a voting machine mechanism – paper ballots – more linked to residual voting.

The negative correlation between DRE and income suggests that individuals in lower income areas are more likely to have access to DRE machines, but the positive correlation between optical scan and income suggests this voting machine type is more common in higher income areas. This finding makes sense insofar higher income areas have more financial resources to devote to voting machine changes and maintenance, which also doubles as evidence that these areas have led recent American election jurisdiction movements away from DREs to optical scan machines (Stewart 2014).

In general, these correlational results suggest that racial minorities are not disadvantaged relative to non-Hispanic whites in terms of election machine quality. The income findings indicate that individuals in wealthier counties have access to latest voting machine technology, but the correlational evidence does not indicate whether this quicker responsiveness has resulted in a reduction of residual voting rates in higher income jurisdictions.

The next three sets of models employ multivariate regression to determine whether there are significant relationships between election machines and several demographic groups (African Americans, Hispanics, non-Hispanic whites, and by income levels) to residual voting rates. Possible confounding factors are controlled for by including education, age, and state fixed effects control variables. The first pair of models, displayed in Table 2, examines the impact of optical scan and DRE machines varying the percentage of African Americans and Hispanics at the county-level. The baseline model on the left indicates that neither election machine has a direct impact on residual voting rates, but higher percentages of African Americans are related to significantly lower residual voting rates. None of the control variables is significant.

Table 2: Impact of Voting Machines and Demographic Factors on County Residual Voting Rates (African American and Hispanic Models)

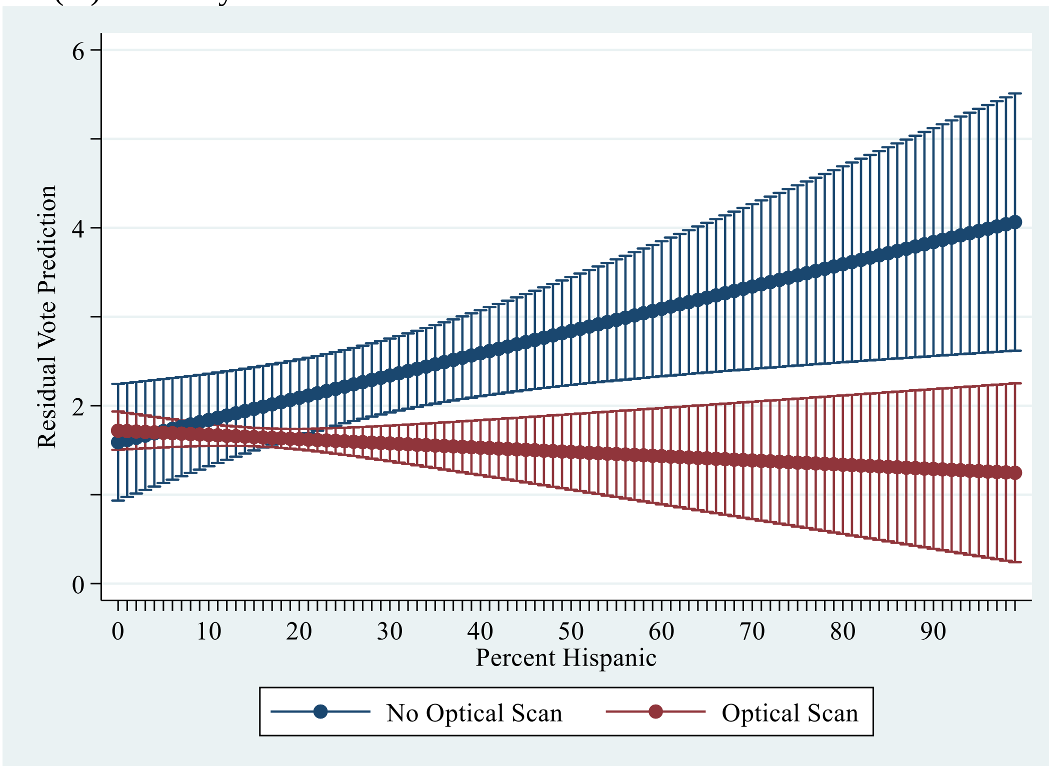
	Baseline Model	Racial Minority x Voting Machine Model
Optical Scan	-0.442	0.616*
	(0.270)	(0.322)
DRE	-0.080	0.099
	(0.188)	(0.277)
Percent Black	-0.016**	0.031*
	(0.006)	(0.018)
Percent Black x Optical Scan		-0.042**
		(0.017)
Percent Black x DRE		-0.011
		(0.008)
Percent Hispanic	-0.002	0.023**
	(0.007)	(0.009)
Percent Hispanic x Optical Scan		-0.030***
		(0.008)
Percent Hispanic x DRE		0.004
		(0.009)
Percent College Degree or More	-0.011	-0.015
	(0.010)	(0.010)
Per Capita Income	0.000	0.000
	(0.000)	(0.000)
Median Age	-0.021	-0.023
	(0.015)	(0.015)
Constant	2.529**	1.411*
	(0.770)	(0.754)
R^2	0.311	0.316
Observations	2761	2761

Robust standard errors in parentheses. State fixed effects also included in models.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

The model on the right includes interaction variables between each minority group with the election machines. There are two key results. First, the negative and significant interaction effect between optical scan machines and African American county population indicates that this election machine contributes to lower residual voting rates in counties with higher African American populations. Regarding the substantive impact of this relationship, varying African American population percentages from their lowest (0%) to highest (86%) values shows that in counties without optical scan machines residual voting rates there is no significant change in residual voting rates; however, in counties with optical scan machines, residual voting rates significantly decrease by 1.4% (1.83-0.43%).

The second key relationship is a negative and significant interactive relationship between optical scan machines and a county's Hispanic population. This means that more densely Hispanic counties can be expected to benefit more from these voting machines. The substantive impact of this relationship is depicted in Figure 1. Varying the Hispanic county population from minimum to maximum values, in counties with no optical scan machines residual voting rates are expected to increase from 1.6% to 4%. Conversely, in counties with optical scan machines, the residual vote rate is expected to decrease from 1.7% to 1.24%. This latter effect is discernible with 95% confidence intervals.

Figure 1: Effect of Optical Scan Voting Machines on Residual Voting Rate, varying Hispanic Population (%) at County-Level



For purposes of comparison, the models in Table 3 depict the impacts of election machines on residual voting rates among counties with a covariate representing the percentage of non-Hispanic whites. The baseline model indicates that optical scan machines have a negative and significant impact on this outcome, but that residual voting rates increase with increases in the percentage of county populations that consist of non-Hispanic population. The second model in this table shows what happens when this non-Hispanic white variable is interacted with each of the voting machine variables. While the second model continues to show the optical scan machine variable to have a negative impact on residual voting rates, there is a positive and significant interaction effect between the two variables. This suggests that residual voting rates linked to optical scan machines are worse in counties with higher non-Hispanic white populations.

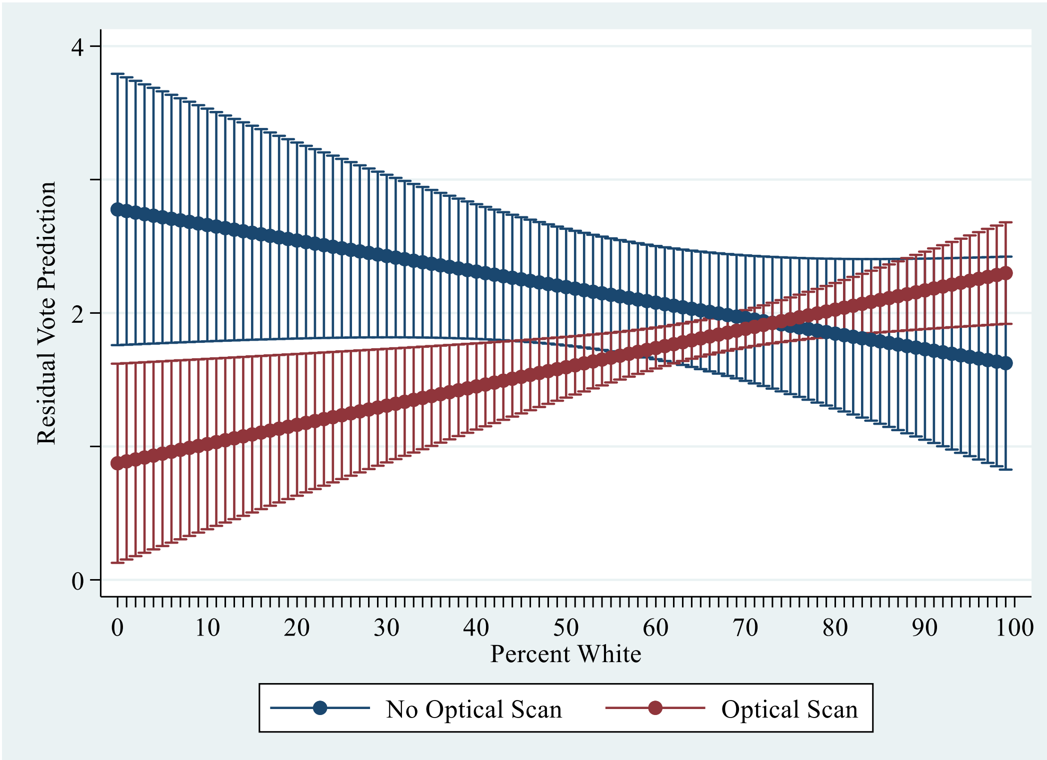
Table 3: Impact of Voting Machines and Demographic Factors on County Residual Voting Rates (Non-Hispanic White Models)

	Baseline Model	Non-Hispanic White x Voting Machine Model
Optical Scan	-0.502*	-1.734***
	(0.275)	(0.333)
DRE	-0.061	0.086
	(0.192)	(0.425)
Percent White	0.008*	-0.014*
	(0.005)	(0.007)
Percent White x Optical Scan		0.023***
		(0.005)
Percent White x DRE		0.000
		(0.006)
Percent College Degree or More	-0.014	-0.016
	(0.010)	(0.010)
Per Capita Income	0.000	0.000
	(0.000)	(0.000)
Median Age	-0.025	-0.027*
	(0.016)	(0.015)
Constant	1.754**	2.933***
	(0.589)	(0.619)
R^2	0.309	0.313
Observations	2761	2761

Robust standard errors in parentheses. State fixed effects also included in models.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

The substantive import of this interactive relationship is charted in Figure 2, varying the non-Hispanic white county population from minimum to maximum values. At the lowest levels, optical scanning machines are significantly related to lower predicted residual voting rates. However, at higher levels of non-Hispanic white populations, residual voting rates linked to optical scanning machines increase from 1.05% to 2%.

Figure 2: Effect of Optical Scan Voting Machines on Residual Voting Rate, varying Non-Hispanic White Population (%) at County-Level



The last two statistical models, displayed in Table 4, evaluate the impact of county per capita income has on residual voting rates. By itself, per capita income does not have a direct effect on this outcome. However, there is a negative and significant interactive relationship between per capita income and optical scan machines. This indicates that residual voting rates linked to this election machine are lower in counties of higher income. Of the control variables, counties with higher percentages of non-Hispanic whites are related to higher residual voting rates.

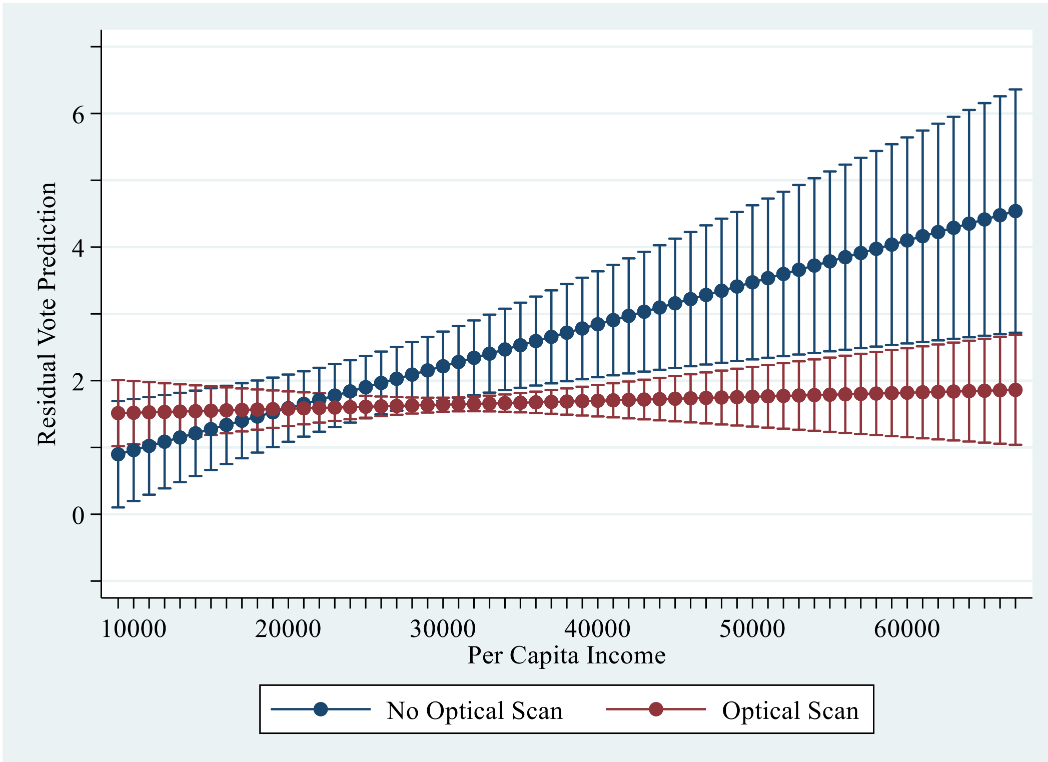
Table 4: Impact of Voting Machines and Demographic Factors on County Residual Voting Rates (Income Models)

	Baseline Model	Income x Voting Machine Model
Optical Scan	-0.502*	1.127**
	(0.275)	(0.429)
DRE	-0.061	0.078
	(0.192)	(0.401)
Per Capita Income	0.008 x 10^{-3}	0.004 x 10^{-3}
	(0.000)	(0.000)
Income x Optical Scan		-0. 006 x 10^{-2**}
		(0.000)
Income x DRE		-0.004 x 10^{-3}
		(0.000)
Percent White	0.008*	0.008*
	(0.005)	(0.005)
Median Age	-0.025	-0.024
	(0.016)	(0.015)
Constant	1.754**	0.081
	(0.589)	(0.633)
R^2	0.309	0.310
Observations	2761	2761

Robust standard errors in parentheses. State fixed effects also included in models.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

To aid in the interpretation of the interactive effect, Figure 3 shows how the relationship between income and optical scan machine varies between the minimum ($9,000) and maximum ($67,000) county per capita income values. At the lowest values of per capita income, residual rates associated with the non-presence or presence of optical scan machines are approximately the same at about 0.5%. However, at higher levels of per capita, counties with no optical scan machines are linked to higher residual voting rates – by nearly 2.5% -- than counties with optical scan machines. These results clearly show that optical scan machines have a more favorable relationship to residual voting rates in counties with higher per capita incomes.

Figure 3: Effect of Optical Scan Voting Machines on Residual Voting Rate, varying Per Capita Income at County-Level



In review, the results in Tables 1 to 4 provide a mixed assessment of the hypotheses evaluated in this study. There is evidence that more highly racial minority populated counties are not disadvantaged relative to more non-Hispanic white counties in their access to quality election machines, and further results show that optical scan machines actually have more favorable linkages to residual voting rates in counties with higher percentages of racial minorities rather than non-Hispanic whites. Conversely, evidence indicates that election machines such as optical scan machines are more likely to be available in higher income areas, and these machines are related to lower residual voting rates in these same areas. While the racial group-election machine relationships show that counties with higher percentages racial minorities derive more benefits from these machines, the per capita income-optical scan machine finding suggest that poorer relative to wealthier counties get less of a benefit.

Conclusion

In conclusion, this study shows that counties with higher numbers of racial minorities are not disadvantaged relative to counties with more non-Hispanic whites in terms of access to quality election machines, or residual voting rates linked to the use of these election machines. However, poorer counties are less likely to have access to quality election machines, and the results indicate that this is also linked to higher residual voting rates in poorer counties. Overall, the findings demonstrate that more American election administration equality has been achieved since 2000 in terms of access to and impact of election machines along racial dimensions, but not income. The story of election machine access continues.

One possible issue with this research relates to the ecological fallacy, that is, positing individual level inferences from county-level results. To gain greater certainty on the reliability of this study's findings, research on the individual-level effects of voting machines would permit greater precision in the estimation of residual voting rates linked to racial and income variables. Treatment-control group studies, for example, could be conducted comparing the impact of voting machines on individuals within these demographic groups in metropolitan areas that encompass multiple counties in multiple states and thus have varying election administration systems. Other future research could examine the impact of voting machines on other dimensions of voting equality, such as individuals with disabilities.

Nonetheless, this study demonstrates that election machine advances have been made in making American voting systems more accessible across counties along a racial dimension. Additionally, this study has shown that data from the Election Assistance Commission and

Leip's *Atlas of U.S. Elections* can be leveraged to conduct residual voting studies. Lastly, this study demonstrates that policymakers and reformers must continue to make efforts to make quality voting machines more prevalent and accessible in lower income counties. Doing so will enhance the equality and participatory elements of American democracy.

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