IN THE UNITED STATES DISTRICT COURT
FOR THE SOUTHERN DISTRICT OF TEXAS
LAREDO DIVISION

Sylvia Bruni, Texas Democratic Party, DSCC, DCCC, and Jessica Tiedt, Plaintiffs, v. RUTH HUGHS, in her official capacity as the Texas Secretary of State, Defendant.	Civil Action No. 5:20-cv-35

APPENDIX XIII TO PLAINTIFFS' MOTION FOR PRELIMINARY INJUNCTION

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Exhibit 10 - Caltech-MIT Voting Technology Project, Waiting in Line to Vote (2013)

Exhibit 10

CALTECH/MIT
VOTING TECHNOLOGY PROJECT

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

TITLE Waiting in Line to Vote

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This is one of a set of research papers prepared for The Presidential Commission on Election Administration. The research reported in this paper represents the research, inferences and opinions of the authors, and not the Caltech/MIT Voting Technology Project nor the individual research members of the VTP.

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VTP WORKING PAPER #114
July 28, 2013

EXECUTIVE SUMMARY
Waiting in Line to Vote

Charles Stewart III
Stephen Ansolabehere

July 28, 2013

- Waiting in long lines discourages some people from voting, undermines confidence in the electoral system, and imposes economic costs on voters.
  - Estimates of lost votes due to long lines in 2012 range from 500,000 to 700,000.
  - Voters who wait in long lines are less confident their votes are counted as intended, and that votes nationwide are counted as intended.
  - Long lines affect the confident of voters in states with long lines, even when individuals do not experience the long lines themselves.
  - The economic cost to voters of standing in line to vote is approximately $500 million.

- Waiting in long lines was not universal in 2012.
  - Average wait times ranged from 2 minutes in Vermont to 39 minutes in Florida.
  - Wait times in states and counties were consistent with patterns in 2008.
  - There was significant variation in wait times within states, and even within counties.
  - Minority voters, early voters, and urban dwellers experienced the longest lines.

- Most standard recommendations for shortening lines derive from simple, straightforward application of queuing theory.
  - These recommendations revolve around reducing the number of in-person voters, increasing service points, and decreasing transaction times.
  - There is little empirical evidence that the recommendations prescribed as solutions to long lines have actually been effective in reducing waiting times.
  - Budgetary and space constraints weigh heavily in implementing reforms to reduce lines.

- Unlike the response to the “lost votes” that beset the 2000 presidential election, there are no easily implemented reforms that have been demonstrated to be effective through systematic study.

Waiting in Line to Vote

Charles Stewart III[1]
Stephen Ansolabehere

July 28, 2013

Waiting in line to vote is the most visible sign of the administrative friction of managing elections.

The visibility of long lines makes them a convenient symbol for those who seek to improve election administration. However, absent comprehensive, reliable information about lines — where they appear, who endures them, and strategies to mitigate them — it is easy to flail at the problem without making much progress. The purpose of this white paper is to lay the groundwork with some evidence about where long lines occur and what is thought to cause them. The major points are these:

- *Long lines are costly*. Not only does waiting impose a monetary cost on voters, it discourages some from voting altogether, and ultimately undermines the confidence that citizens have in the electoral process.

- *Long lines are not universal.* They are concentrated in a handful of states. Racial minorities tend to wait to vote longer than white voters; city dweller wait longer than suburbanites and rural residents.

- *The scientific field of queuing theory can help frame thinking about polling place lines.* This theory helps to clarify the possible causes of inordinately long lines, and suggests strategies for improvements.

- *The research on the effectiveness of strategies to mitigate long lines at the polls is thin.* Unlike the problem with voting machines unearthed following the 2000 election, the literature provides no "magic bullets" that can be immediately applied to polling places in time to dramatically improve the voting experience by the 2016 presidential election.

The Costs of Lines

Long lines at the polling place are often taken to be a sign that something is wrong. This need not always be the case. Lines can also be viewed as a sign that the public is excited by an election or the candidates. This alternative interpretation of lines is often associated with elections in emerging democracies, as the following Associated Press report from the 2005 Iraq general election suggests:

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> BAGHDAD -- Iraqis embraced democracy in large numbers Sunday, standing in long lines to vote in defiance of mortar attacks, suicide bombers and boycott calls. Pushed in wheelchairs or carts if they couldn't walk, the elderly, the young and women in veils cast ballots in Iraq's first free election in a half-century. . . . "I am doing this because I love my country, and I love the sons of my nation," said Shamal Hekeib, 53, who walked with his wife 20 minutes to a polling station near his Baghdad home.[2]

The American electoral context is certainly less dire than that in countries such as Iraq. Still, considering the fact that long lines are sometimes used as an indicator of citizen confidence in democracy, we should provide evidence of the alternative view. Here, we provide evidence about three ways in which long lines may be regarded as a problem in American elections: they may discourage voting, lower voter confidence, and impose economic costs on voters.

Long lines may discourage voting.

Long lines may discourage some from voting, thus undermining the quality of elections as an expression of the people's will. Still, an important question needs to be addressed up front: when is a line to vote "too long"?

We could answer this question one of two ways. First, we could observe actual lines, noting the point at which newly arriving voters decide not to join the line ("balking" in the language of queuing theory) — or how long people waited in line until they left ("reneging"). Few studies have addressed this question directly, and none at the national level, so it is not possible to estimate the size of the deterrent effect of long lines in presidential elections.[3]

An indirect way to answer this question is via survey research. In November 2008, right before the presidential election, the Marist poll asked of 716 adults, "What is the longest amount of time, in minutes, that you would wait on line to vote?" Here, 41% responded "as long as it takes," with 27% answering "30 minutes or less," 17% "31 to 60 minutes," and 15% "more than an hour."

Because "as long as it takes" is a socially desirable response, it is likely that the willingness of voters to wait in line is less than what is reflected here. However, even if we take the responses to the Marist poll at face value, a significant fraction of voters are unwilling to wait as long as it takes to vote. This suggests that the prospect of long lines

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[2] Sally Buzbee, "In Iraq, long lines, much joy and violence and uncertainty," *Associated Press*, Jan. 31, 2005, accessed via *LexisNexis Academic.*

[3] The best published research in this regard was by Spencer and Markovits, who collected data during the 2008 presidential primary in California by observing 30 polling stations across three counties. They discovered a positive correlation between the number of people standing in line and the probability of someone in line reneging. See Douglas M Spencer and Zachary S Markovits, "Long Lines at Polling Stations? Observations from an Election Day Field Study," *Election Law Journal* 9, no. 1 (2010).

can serve as a deterrent to some voters turning out — precisely which voters these may be is still an open question.

Other survey research studies provide us with estimates of how many people did not vote because of long lines. Responses to the 2012 Voting and Registration Supplement (VRS) of the Current Population Survey suggest that over 500,000 eligible voters failed to vote because of a list of polling place problems that include long lines — inconvenient hours or polling place location, or lines too long. On the other hand, among non-voting respondents to the 2012 Cooperative Congressional Election Study (CCES), 0.8% stated that the main reason they did not vote was that "lines at the polls were too long." If we apply this percentage to the 91.6 million eligible voters who failed to vote in 2012,[4] we calculate that there were 730,000 non-voters due to long lines in the most recent federal election.[5]

Long lines can reduce voter confidence in elections.

While long lines can cause voters to be turned away at the polls, the greater effect is on those who turn out to vote. Responses to the SPAE suggest that waiting a long time to vote reduces the confidence voters have that their votes are counted. For instance, among Election Day voters, 68% of those who waited ten minutes or less to vote stated they were very confident their vote was counted as intended, compared to 47% of voters who waited over an hour.[6] For early voters, the difference in confidence was only slightly less: 69% of those waiting ten minutes or less were very confident, compared to 54% who waited an hour or more.

What is more, the experience of waiting in a long line influences the judgments that form in voters' minds about the quality of vote counting throughout the nation. The following table reports the percentage of voters who were very confident that votes were counted as intended in their county, state, and nationwide, as a function of how long they waited to vote. Among Election Day voters who waited 10 minutes or less, 68% were very confident *their own vote* was counted as intended, 56% were very confident that votes *throughout their county* were counted as intended, etc.[7]

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[4] Turnout and data about eligible voters was obtained at the web site of the United States Elections Project, http://elections.gmu.edu.

[5] There are no statistically significant differences along race, income, or education among those citing long lines as the reason for not voting in the 2012 CCES.

[6] Research by Sances and Stewart, among others, has shown that the most important influence on answers to the question about whether one's vote was counted as intended is the partisanship of the respondent — respondents who voted for the winning candidate are generally more confident their vote was counted properly than those who voted for the losing candidate. See Michael Sances and Charles Stewart, III, "Partisanship and Voter Confidence, 2000-2010," in *MIT Political Science Department Working Papers* (2012). In a multivariate statistical analysis that adds controls for partisanship and state of residence of the voter, the relationship reported here, between voter confidence and wait times, remains.

[7] With the exception of the last cell entry — attitudes among early voters about whether votes nationwide were counted as intended — the differences reported in Table 1 remain once we control statistically for the party identification of the respondent and the respondent's home state.

Table 1. Percentage of respondents very confident that votes were counted as intended in the 2012 election.

	Election Day voters		Early voters	
	Waited 10 minutes or less	Waited an hour or more	Waited 10 minutes or less	Waited an hour or more
Their own vote	68%	47%	69%	54%
Votes in their county	56%	32%	57%	48%
Votes in their state	46%	23%	43%	34%
Votes nationwide	24%	13%	23%	21%

Source: SPAE, 2012

Finally, the existence of long lines influences assessments made about the accuracy of vote counting *even among those who do not experience long lines.* Consider, for instance, individual voters who live in states with long average wait times, but who did not experience long lines themselves. Among voters who live in the five states with the longest average wait times in 2012[8] but who reported that they, themselves, did not have to wait at all to vote, 23% said they were very confident that votes in their state were counted as intended. This compares to similarly-situated voters in the five states with the shortest average wait times, 63% of whom were very confident that votes in their state were counted as intended.[9]

Long lines impose monetary costs on voters.

Finally, there are monetary costs to waiting in line to vote. Even if these costs are regarded by voters and by society as a reasonable price to pay for exercising the franchise, and even if voters receive paid time off to vote, time spent waiting to vote represents the lost opportunity of voters to engage in productive work or leisure time activities. If costly solutions are proposed to reduce waiting times, it would be useful to have an estimate of what waiting in line to vote costs Americans in economic terms.

We are aware of no published analysis that attempts to place an economic value on the time that Americans spend waiting to vote. A simple way to produce a ballpark estimate is to multiply the total number of hours waiting in line by average hourly earnings. Based on an average wait time in 2012 of 13.1 minutes as reported below and an estimate that 105.2 million people voted in-person in 2012 (either on Election Day or in early voting), we calculate that voters spent a total of 23.0 million hours waiting to vote in 2012.[10] According to the U.S. Bureau of Labor Statistics, average hourly earnings were

[8] These states were Florida, the District of Columbia, Maryland, South Carolina, and Virginia. Oregon and Washington are excluded from this analysis, because so few voters in those states vote in-person.

[9] These findings remain in a multivariate statistical model in which we control for the party identification of the respondent.

[10] The in-person turnout estimate starts with Professor Michael McDonald's 2012 turnout estimate of 129.1 million. http://elections.gmu.edu/Turnout_2012G.html. Using the 2012 Voter Registration Supplement of the CPS, we can estimate that 81.5% of voters voted in-person. Multiplying the turnout estimate by the estimate of the rate of in-person voting yields 105.2 million.

$23.67 in November 2012. Multiplying the number of hours waiting to vote by average hourly earnings yields an economic cost estimate of $544.4 million.

We have no opinion about whether this amount is "too high," "too low," or "just right." However, it is of a similar magnitude to previous estimates about the annual costs of administering elections in the U.S. For instance, in 2001 the Caltech/MIT Voting Technology Project estimated that local governments spent about $1 billion conducting and administering elections in 2000.[11] If we combine the estimated costs borne by local governments conducting elections with the economic cost of waiting in line, a significant fraction of the economic cost of conducting a presidential election is the time spent by voters waiting in line.

To summarize, long lines at the polls impose real costs, economic and otherwise, though it is important to keep those costs in perspective. Long lines reduce turnout by a small amount; the bigger practical effect is the inconvenience imposed on those who do turn out to vote, an inconvenience that is not uniformly borne by all voters. Not only are some voters inconvenienced by long lines, but the existence of long lines undermines confidence in the electoral system, even among those who do not encounter lines themselves.

Basic Facts about Lines

To help focus attention on the distribution of long lines in the United States, we turn our attention to the evidence we can adduce about who waits in line, and how long they wait, by using answers to two major academic surveys, the Cooperative Congressional Election Study (CCES) and the Survey of the Performance of American Elections (SPAE).[12]

Relying on responses to the 2008 and 2012 CCES, the following table reports the distribution of responses to the question, "Approximately, how long did you have to wait in line to vote?"

[11] Caltech/MIT Voting Technology Project, *Voting: What Is/What Could Be* (Pasadena, Calif. and Cambridge., Mass.: Caltech and MIT, 2001).

[12] Ansolabehere and Stewart are the principal investigators of the CCES and SPAE, respectively. Both are Internet surveys and both ask an identical question concerning the amount of time voters waited at the polls. In 2012, the CCES interviewed 54,535 adults, 39,675 of whom voted; the SPAE interviewed 10,200 registered voters, 9,336 of whom voted. The CCES asks fewer questions about election administration, but has a larger sample size that is distributed across the nation in proportion to population. The SPAE focuses its questions entirely on election administration, with a smaller sample size distributed *within states* in proportion to population. Depending on the nature of the analysis, one survey will be more appropriate to use than the other. In some cases, specifically estimating waiting times within states, we can combine the two surveys to create more precise estimates.

Table 2. Average waiting times to vote, 2008 and 2012

	2008	2012
Not at all	36.8%	37.3%
Less than 10 minutes	27.6%	31.8%
10-30 minutes	19.0%	18.4%
31-60 minutes	10.3%	8.6%
More than one hour	6.3%	3.9%
Average (min.)	16.7	13.3
95% margin of error (min.)	0.1	0.1
N	18,836	30,124

Source: CCES, 2008 and 2012.

Most voters in the past two general elections did not wait very long to vote. Roughly one-third report not waiting at all, and roughly two-thirds report waiting ten minutes or less.

It is important to note, though, that among those who wait more than one hour, the waits can be quite long. Among those waiting more than an hour in these two presidential elections, the average reported wait time was 109 minutes in 2008 and 110 minutes in 2012. Viewed another way, 31% of the total time waiting to vote in 2012 was endured by the 3.9% of voters who waited more than an hour to vote. (In 2008, voters waiting more than an hour accounted for 40% of all time consumed in line.)

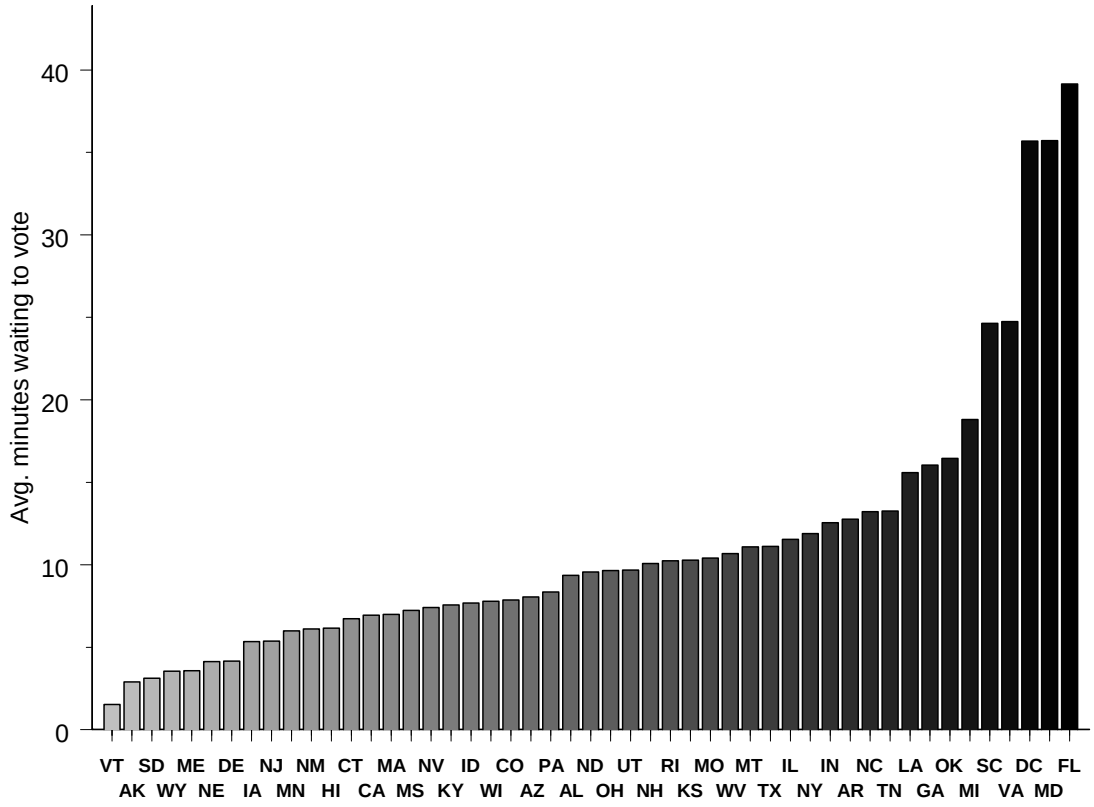
By far, the longest lines occur in presidential elections. The same waiting-in-line question has been asked in other studies sponsored either by the CCES or SPAE projects in recent years. The answers allow us to gauge average waiting times in lower-turnout elections. In the 2006 CCES, for instance, the average waiting time in that midterm federal election was 6.6 minutes. In the 2008 "Super Tuesday" presidential primaries, the average wait time was 3.9 minutes in the ten states that held a primary that day.

As these statistics suggest, there is significant variation in the amount of time people wait to vote. The variation is not distributed randomly among voters. We first review the geographic distribution of lines, followed by demographic characteristics of voters who wait.

The geography of waiting

The factor that is associated with the biggest differences in wait times is the residence of the voter, in particular, the state where the voter lives. According to estimates derived by combining responses to the CCES and SPAE, average wait times in 2012 ranged from 1.5 minutes in Vermont to 39.2 minutes in Florida — a difference of a factor of 26 between these two states. The table in Appendix 1 reports the state estimates, along with 95% margins of error. The figure below displays the 2012 waiting times graphically.

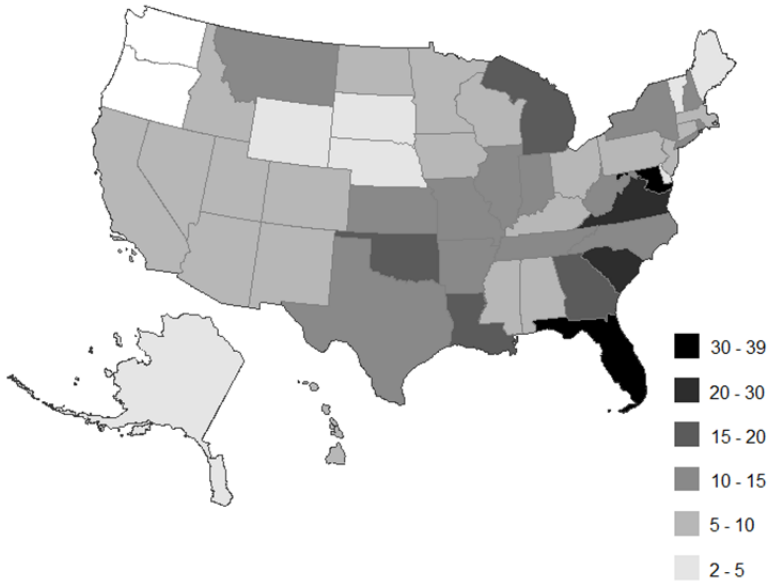
Figure 1. Average waiting times to vote, 2012



Source: CCES and SPAE, 2012.

The following map helps to highlight the regions of the country where line length tends to be longer or shorter. (Oregon and Washington, which primarily use vote-by-mail, are not shaded in this map.) The shortest waiting times tend to occur in the western half of the country and in the northeast, while the longest waits tend to occur in the lower eastern seaboard.

Figure 2. Average waiting times to vote, 2012



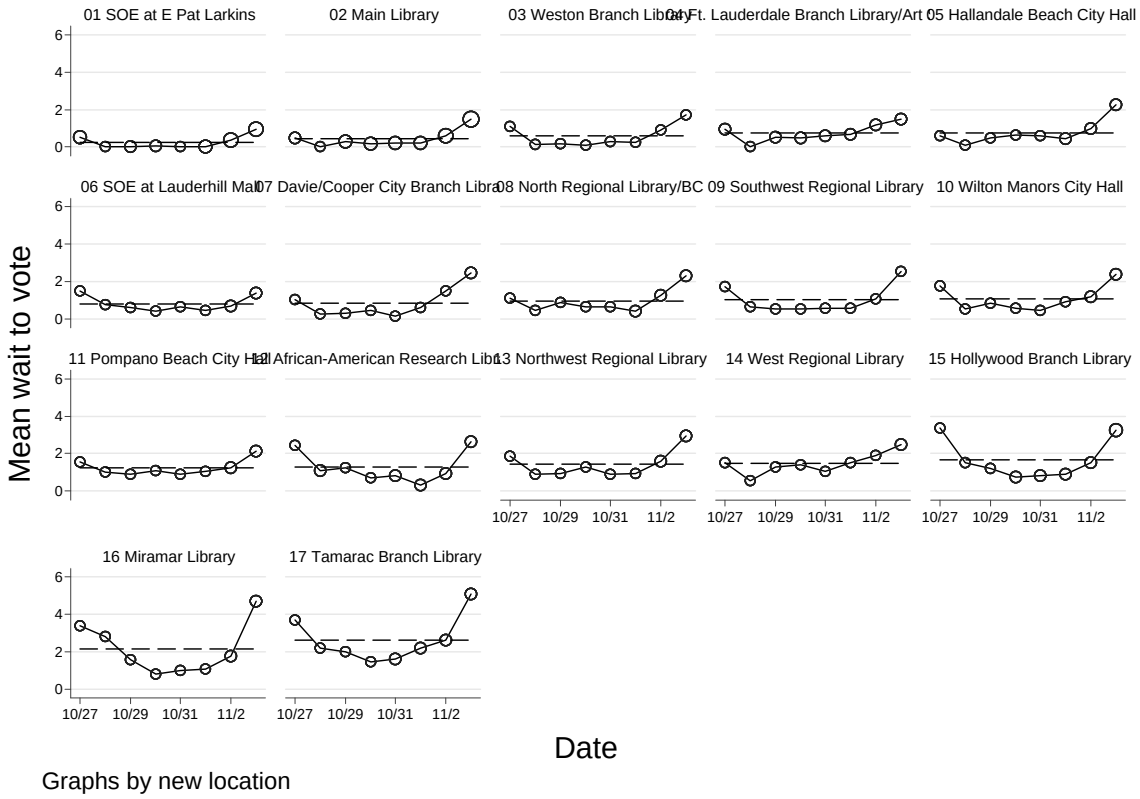
Source: CCES and SPAE, 2012.

Waiting times also vary within states. Consider two urbanized states that are toward the ends of the spectrum, New Jersey, with an average wait time of 5 minutes, and Florida, averaging 39 minutes. In New Jersey, average wait times ranged from 3.6 minutes in Gloucester County to 10 minutes in Union County.[13] In Florida, average estimated wait times range from 5.7 minutes in Marion County to 136.6 minutes in Lee County.[14]

There is also variation within counties. Unfortunately, it appears that very few local election officials systematically collect waiting times at the polls, and fewer still make those reports available to the public. One exception, which allows us to catch a glimpse into local variation, is Broward County, Florida, which in 2012 posted regular updates about estimated waiting times at the 17 early voting sites in the county. The following graph shows the average posted waiting times, for each day of the early voting period, for each early voting location. The graphs in the figure are ordered according to the overall average wait time for each early voting site, ranging from 14 minutes at the Supervisor of Elections branch office at the E. Pat Larkins Community Center, to 2.6 hours at the Tamarac Branch Library. The solid line in each graph plots the average posted wait time each day. The horizontal dashed line shows the average across the entire early voting period.

[13] These estimates take into account counties for which we have 25 or more observations per county. The 95% confidence intervals are 1.6 minutes for Gloucester and 4.5 for Union.
[14] The 95% confidence intervals are 1.6 minutes for Marion County and 11.4 minutes for Lee County.

Figure 3. Average waiting time, Broward County, Florida early voting sites, 2012.



Source: Broward County, Florida Supervisor of Elections Web site.

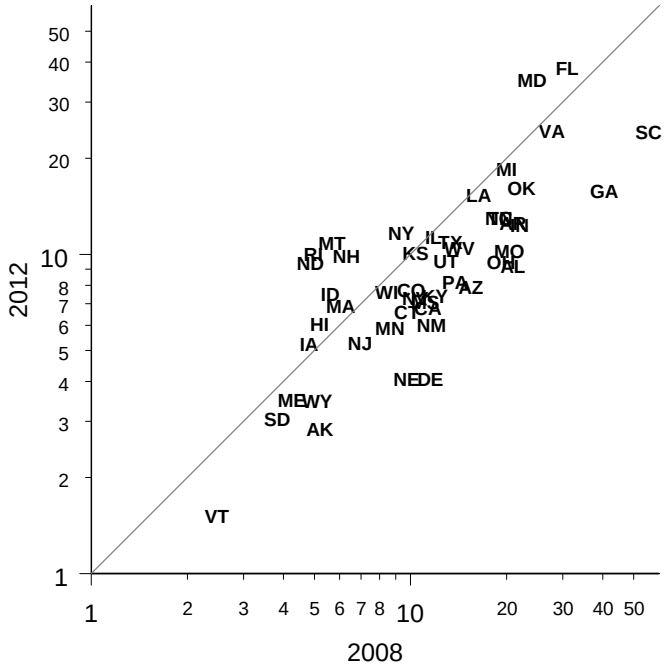
The great variation across states suggests there are state-specific factors, such as laws, regulations, and state norms, which influence how long voters wait to vote. The great variation within states suggests that there is further influence of demographics and local administrative practices in determining line lengths at the polls.

Waiting times vary across all levels of geography, ranging from the state level to the level of the particular polling place. *Why* we have such geographic variation remains largely a matter of speculation. As we show below, demographics explain some of these differences. However, demographics are insufficient to explain why the average Floridian waits 26 times longer to vote than the average Vermonter, or why the average early voter at the Tamarac Branch Library waits three times longer than the average early voter at the E. Pat Larkins Community Center.

There is one final topic to be visited under the heading of the geography of waiting: the persistence of waiting times from one election to the next. When we compare the estimated average wait times at the state level in 2012 with 2008, we see remarkable consistency, which is illustrated in the following graph. In Figure 4, we plot the average wait time by state in 2012 along the *y*-axis, and the 2008 average along the *x*-axis. (The axis scales are logarithmic, which aids in the legibility of the individual data points.) The diagonal line helps to orient us and

inform us which states showed increases in wait time in 2012, compared to 2008 (above the line), and which showed decreases (below the line).

Figure 4. Average wait time at the state level, 2012 and 2008.



Source: CCES and SPAE, 2012.

States with long wait times in 2012 generally had long wait times in 2008. There are certainly some exceptions. Still, if one wanted to predict which states would have long wait times in 2012, the best place to start would be to identify those states with long wait times in 2008.

This observation is important for thinking about how to tackle the problem of long lines. In the wake of the long lines in 2012, many commentators and election officials pointed out factors that were unique to the 2012 election as the causes. The best example is Florida, which saw significant changes in its election law which, in hindsight, seem ripe to have caused longer lines at the polls. (Some of these changes include cutting the early voting period significantly and lengthening the text on the ballot to describe referenda.) While such one-off events may have increased waiting times on the margin, they often were building off of waiting times that were long to begin with. To be effective in tackling the problem of long lines at the polls, it is important to understand both the long-term and short-term factors that lead to them, which may be distinct.

The demography of waiting

Not only are wait times unevenly distributed geographically, they are unevenly distributed demographically, as the following statistics, drawn from the CCES, illustrate:

1. *Mode of voting.* Early voters in 2012 waited an average of 18 minutes, compared to 12 minutes for Election Day voters.[15]

2. *Race of voters.* Minority voters waited longer to vote than white voters. The following table reports the average wait times for the different racial groups recorded in the CCES. White voters waited an average of 12 minutes to vote, compared to 24 minutes for African American voters and 19 minutes for Hispanic voters. These differences largely remain when we control for the state of residence and mode of voting (Election Day *vs.* early voting).[16]

Table 3. Average wait time by racial groups, 2012

Race	Avg.	95% margin of error
White	11.6	0.3
Black	23.3	1.6
Hispanic	18.7	2.2
Asian	15.4	3.0
Native American	13.3	3.2
Mixed	13.6	2.0
Other	13.3	2.0
Middle Eastern	11.7	6.0

Source: CCES, 2012

3. *Population density.* Voters in densely populated neighborhoods wait longer to vote than voters from sparsely populated areas. Respondents to the CCES who lived in the least densely populated ZIP Codes waited an average of 6 minutes to vote, compared to 18 minutes for residents of the most densely populated ZIP Codes.[17]

It is not the case that all socially relevant demographics are correlated with the waiting time of voters. For instance, there was little, if any, relationship between the household income and the length of time voters waited to vote. Voters from families with household incomes of less than $30,000 waited an average of 12 minutes to vote, compared to 14 minutes for voters from families with incomes greater than $100,000. This difference is statistically insignificant.

[15] This difference remains when we control for the state in which the respondent lives.

[16] Before controlling for state of residence and mode of voting, the average wait time for African Americans is 12 minutes greater than that of whites; the average wait time for Hispanics is 7 minutes greater. After controlling, the differences are 9 and 7 minutes, respectively.

[17] This analysis was performed, first, by merging population density data to the CCES, using ZIP Code, and then dividing the sample into equally populated quarters, or quartiles. Respondents from the least densely populated areas lived in ZIP Codes with a population density of 75 persons per square mile or less. Residents from the most densely populated areas lived in ZIP Codes with a population density of 2,739 persons per square mile or more.

Combining geography and demography

The geographic and demographic factors discussed here that predict longer wait times are interrelated. For instance, African Americans are more likely than whites to live in urban areas, and are more likely to vote early. Each of these factors considered in isolation — being African American, living in an urban area, and voting early — is associated with longer waiting times. How do we assess these competing factors when they are clearly confounding each other? The standard way to distinguish between factors that are confounded in this way is through multivariate statistical analysis, such as multiple regression.

In Appendix 2, we have reported the results of such an analysis, in which the waiting time of individual respondents to the CCES are analyzed in terms of voting mode, race, and ZIP Code population density. The analysis begins with a simple multiple regression, and then adds geography as a control through a technique known as "fixed effects regression."

Avoiding a technical discussion of the statistical results reported in Appendix 2, the following points emerge from the analysis:

- The simple multivariate analysis shows that the differences in wait times between Blacks and Hispanics, on the one hand, and whites, on the other, hold up even once we account for differences in how different racial groups tend to vote in-person (on Election Day or early) and differences in the types of communities members of racial groups tend to live in (cities *vs.* rural areas).

- The fixed effects analysis shows that as we control for the residence of the respondent at a finer and finer level (from state to county to ZIP Code), differences between whites and Blacks decline consistently, to the point that when we control for location of residence at the county level, the difference between whites and blacks is cut in half, compared to the difference that is observed before we start doing statistical analysis.

This analysis suggests that minority voters do not tend to wait longer than white voters because of discrimination at the polls against individuals. Rather, the neighborhoods that have high minority populations tend to experience long waiting times for all voters in that neighborhood, regardless of the race of individual voters. Whites who live in racially diverse ZIP Codes wait to vote longer than whites who live in all-white neighborhoods; African Americans who live in predominantly white neighborhoods stand in shorter lines than African Americans who live in more diverse neighborhoods.

Based on a thorough review of the literature, there does not appear to be any easy explanation for why neighborhoods with large African American populations tend to be subjected to longer lines. It seems unlikely to be because of widespread concerted efforts to lengthen waiting times in minority communities for partisan gains, since the local governments of most of these communities are controlled by Democrats. In all likelihood, longer waiting times in minority

communities are part of a larger pattern of government service maldistribution, of which election administration is just one piece.

Queuing Theory and Election Lines

The discussion of polling place lines up to this point has been cast at a very high degree of aggregation. However, the lines themselves occur on the ground, in particular polling places. It is quite possible for the wait at one precinct on Election Day to be more than an hour, while the wait at the neighboring precinct is less than ten minutes. Ultimately, the solution to long lines at the polls — in the places where they exist — will come through a better understanding of the particular factors that influence long lines at particular polling places.

The scientific discipline that analyzes waiting in line to receive a service is queuing theory, taught at business schools throughout the country.[18] In its simplest expression, queuing theory can be applied to the problem of long lines at the poll. Unfortunately, very few professional students of queues, from academia or the business world, have attacked the issue of queuing in the context of elections.[19] Therefore, the following comments are intended to help frame the problem of long polling place lines, and suggest the direction that such research could go if attended to by professionals in this area of specialization.

To start with the most basic building blocks, consider a simple case where people walk up to a counter to receive some type of service (this can be to check out of a supermarket, ride an amusement park ride, or register to vote). The setting can be summarized in the figure below, in which we have a population (of known or unknown size) that arrives to receive the service, stands in a queue, receives the service, and then departs.

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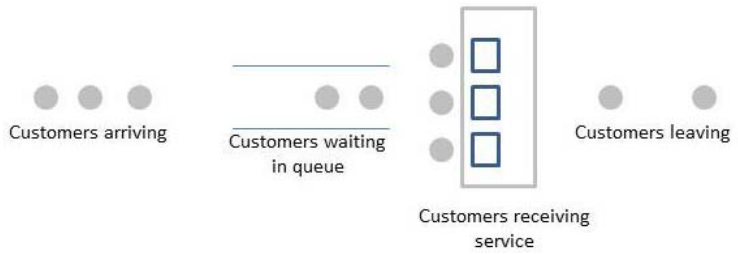
[18] A (relatively) accessible introduction to queuing theory may be found in Chapter 4 of the online version of Richard C. Larson and Amedeo R. Odoni, *Urban Operations Research*, Prentice-Hall, 1981, available at http://web.mit.edu/urban_or_book/www/book/chapter4/contents4.html.

[19] See Theodore Allen and Mikhail Bernshteyn, "Mitigating Voter Waiting Times," *Chance* 19, no. 4 (2006); Alexander S. Belenky and Richard C. Larson, "To Queue or Note to Queue?" http://www.orms-today.org/orms-6-06/queues.html; William A Edelstein and Arthur D Edelstein, "Queuing and Elections: Long Lines, Dres and Paper Ballots," *Proceedings of EVT/WOTE 2010* (2010); Ugbebor O Olabisi and Nwonye Chukwunoso, "Modeling and Analysis of the Queue Dynamics in the Nigerian Voting System," *Open Operational Research Journal* 6, no. (2012); Douglas A. Samuelson, Theodore T. Allen, and Mikhail Bernshteyn, "The Right Not to Wait" http://www.orms-today.org/orms-12-07/frvoting.html; M. Yang, M. J. Fry, and W. D. Kelton, "Are All Voting Queues Created Equal?," in *Simulation Conference (WSC), Proceedings of the 2009 Winter* (2009); Muer Yang and others, "The Call for Equity: Simulation-Optimization Models to Minimize the Range of Waiting Times," *IIE Transactions* (2012).

Figure 5. Simple queuing.

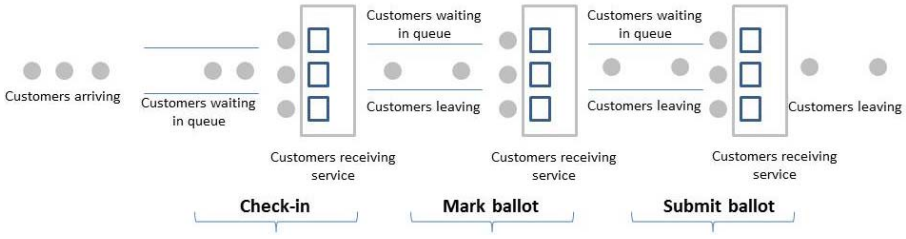


Using a simple set of mathematical tools, knowledge about the design of the system (e.g., how many service stations are in place) and assumptions or knowledge about inputs (e.g., how frequently new customers arrive), it is possible to predict ahead of time quantities such as the average wait in the queue, the average length of the queue, and the number of customers the system can handle in a given unit of time.

It is a simple set-up like this that has motivated the two most direct applications of queuing theory to the issue of polling places — studies by Allen and Bernshteyn and by Edelstein and Edelstein that were previously cited. These studies have provided an analysis of waiting times in Franklin County (Columbus), Ohio, in light of the allocation of equipment to precincts (Allen and Bernshteyn) and a method for allocating voting machines to precincts (Edelstein and Edelstein).

Research papers such as these are just the start of the application of queuing theory to the field of election administration. The reason it is just a start is that the actual complexity of even the simplest polling site is much greater than what was depicted in the figure above. Most importantly, three major services are provided at each polling place, not one: checking in (including verifying one's identity and receiving the proper ballot), marking the ballot, and submitting the ballot for counting. Thus, even at its simplest, the typical in-person voting station (either Election Day or early) should be described using a figure such as the one below, in which the issue is not managing one queue, but three related queues, in which departures from one feed the next.

Figure 6. Queuing in a polling place.



A fundamental observation that emerges from this figure is the potential cascading of problems "downstream." For instance, a delay in scanning ballots, which is part of submitting ballots at the end of the process, can produce a long line of people with marked ballots who wish to leave the polling place, but can't. This, in turn, can lead managers of the polling station to restrict

access to check-in, to preserve order at the voting booths and the check-out tables. Lines accumulate at the door, even though the bottleneck is at the end of the process. Indeed, press reports of polling places with notoriously long lines have noted these cascading effects — such as voters waiting to scan in a large number of ballot cards after they had marked their ballots in south Florida counties in 2012 or voters waiting to gain access to electronic voting machines after they had checked in at the registration table.

All things being equal, average wait times to check-in and average service times for the complete voting process will be reduced as more places are available for voters to check in, for them to mark their ballots, and for them to scan their ballots and leave. Of course, as the figure above suggests, simply adding capacity at one of the three major services may have little-to-no effect on service time at the polling place, if the capacity at the other services is not complementary. In other words, adding more voting machines to a polling place that has a registration check-in bottleneck will be unlikely to reduce waiting times much, if at all.

In addition, all things being equal, service times will be shortened as the number of voters arriving at a polling place is decreased. We will address the effectiveness of following this strategy in the next section. For now, suffice it to say that there are two ways to implement a decrease in voters arriving at a polling place in the short term. First, the number of voters assigned to a polling place can be reduced. Second, voters can be removed from in-person voting, by having them vote by mail, or voters can be shifted from Election Day voting to in-person early voting. Whether such a strategy is effective depends heavily on the "all things being equal" (*ceteris paribus*) proviso. For instance, encouraging more voters to use the mails at the same time as the number of precinct polling places are reduced may have no, or a negative, effect on waiting times, if the resources for handling the remaining in-person voters do not increase on a per-voter basis.

Mitigating Long Lines

All of the strategies to mitigate long lines can be thought of in terms of the simple queuing theory schematic sketched out above. Leaving aside for the moment the issues of ensuring that the capacities within the specific polling place service points are properly balanced, and applying the *ceteris paribus* proviso, lines will be lowered if (1) the number of voters coming to a polling place is reduced, (2) the number of service points is increased, or (3) average transaction times are reduced. The following categorize various policy proposals that have been put forward as means to improve the problem of line lengths under these topics, providing some comments about the empirical basis of many of the proposals.[20]

Reduce the number of voters coming to the polling place

- *Increase opportunities to vote by mail, thus reducing the total number of people using all forms of in-person voting.* Assuming that personnel and equipment are not shifted away from the in-person voting sites, the remaining in-person voters would presumably be

[20] These proposals draw heavily on Justin Levitt, "Means to Reduce Lines at the Polls," (Los Angeles, Calif.: Loyola Law School, 2012). See the Levitt paper for a longer list of proposals than the one presented here.

processed more quickly. At the macro level, the shift of voters away from in-person voting has not decreased wait times. Indeed, there is a statistically significant *negative* correlation between the change in people voting in-person in 2012 (compared to 2008) and the change in average waiting times, measured at the state level. (In other words, states that had relatively more people vote in-person in 2012 had a slight *decrease* in average wait times.)

- *Increase opportunities to vote early in-person, removing pressure from traditional precincts.* This is similar to the proposal discussed immediately above. The empirical evidence that this has been effective is also weak. For instance, a decline in the percentage of voters voting on Election Day between 2008 and 2012 at the state level is uncorrelated with a decline in average wait times on Election Day.

- *Make Election Day a holiday, allowing for arrival times to be smoothed out during the day at traditional polling places.* This proposal is aimed at the problem that Election Day experiences an early morning pre-work rush that is particularly inconvenient to voters. In 2012, according to responses to the SPAE, voters arriving on Election Day before 9:00 a.m., who accounted for 24% of all Election Day voters, waited an average of 16 minutes to vote. In comparison, those arriving after 9:00 a.m. waited an average of 10 minutes.[21] This is a popular reform. Among SPAE respondents, 58% supported this reform, ranging from 40% in Iowa to 75% in the District of Columbia.[22] Currently, no American state has an Election Day holiday, and the academic literature is mixed on whether Election Day holidays are associated with an increase in turnout in the countries that have them.[23]

Increase the number of service points

- *Increase the number of precincts.* This would reduce the number of voters who need to be processed through each Election Day polling place. Note that the trend in many states has been in the opposite direction, often in response to the decline in in-person voters. However, it may be that the decline in polling places is outpacing the decline in in-person voters. For instance, the total number of Election Day voters in Florida declined by 7% from 2008 to 2012.[24] Through the merger of precincts and the co-location of precincts in a single polling place, the number of precincts in Florida declined at a faster rate, by 11% (from 6,992 to 6,242), and the number of polling locations similarly declined by 12%

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[21] The survey results also suggest a much smaller surge between 5:00 p.m. and 6:00 p.m., but it is much less intense and shorter-lived than the early morning rush. (These comments, of course, reflect national patterns. Local conditions will vary.)

[22] It should be noted that support for this proposal is strongly divided by party identification, being favored by 70% of Democrats, 57% of independents, and 44% of Republicans.

[23] Compare Mark N. Franklin, Electoral Participation, in *Comparing Democracies: Elections and Voting in Global Perspective*, Lawrence LeDuc, Richard G. Niemi and Pippa Norris (eds.), Thousand Oaks, Calif., 1996 and Andre Blais, Louis Massicotte, and Agnieszka Dobrzynska, *Why Is Turnout Higher in Some Countries than Others?* Ottawa, Elections Canada, 1996.

[24] The data reported here were obtained from the Florida Division of Elections. Upon examination of the recently released draft 2012 EAVS data, it is clear that a significant amount of data cleaning is needed before we can draw conclusions about the ratio of voters to polling places nationwide.

(from 5,598 to 4,928). As a result, the average number of Election Day voters per precinct actually grew by 4% (from 552 to 576).[25] Florida's counties did increase the total number of early voting sites from 2008 to 2012, from 276 to 296, a 7% increase. Despite the fact that the number of early voters declined by 11% across the two elections, the total number of early voting days was reduced by six. Thus, on a per-day basis, Florida's early voting sites had to handle 46% more voters in 2012 than they did in 2008.[26]

- *Increase the number of poll workers.* An increase in the number of poll workers would presumably provide the opportunity to increase the number of service points, especially at the check-in table, and provide redundant coverage in the event of a problem at the polls. As an empirical matter, there is no correlation between the number of poll workers per voter, at the state level, and wait times, but that could be because the unit of analysis, the state, is too crude to pick up any relationship that does in fact exist. An important caution about this proposal is offered by the research of Spencer and Markovits, cited above, who found a *positive* relationship between the length of lines in their study of northern California precincts and the number of people staffing the check-in tables. While the causality of the situation described by Spencer and Markovits is ambiguous (e.g., perhaps more workers were assigned to precincts known to be prone to lines), they note that when there were more poll workers assigned to a precinct, they tended to be deployed inefficiently. Therefore, the issue may not be so much *how many* poll workers are assigned, but how they are organized.

- *Increase the number of machines.* The same intuition applies to this recommendation as to the one immediately above. The same cautions also apply. There is no correlation between the number of voting machines and waiting time at the state level, and the Spencer and Markovits research found no relationship between the number of privacy booths at the precincts they observed and waiting times. Again, the issue may be more a matter of efficient deployment than a matter of numbers.

- *Favor paper balloting over DREs.* Although technologies are evolving all the time, there is evidence that voters who use electronic voting machines (DREs, for *D*irect *R*ecording *E*lectronic) take longer to vote than users of paper system. Research by Stewart that examined reported waiting times in the 2008 presidential election showed that voters who used DREs waited an average of 4.4 minutes longer to vote, compared to a baseline 11.3 minutes for users of optical scanners.[27] The mechanism giving rise to these longer lines is unclear. Two major factors are thought to be responsible. First, voters who use DREs appear to be more likely to vote all races on a ballot, causing service time at the machine to lengthen. Second, because of the high unit cost of DREs, compared to the unit cost of

[25] The EAVS data does not record the number of scanners deployed to Election Day and early voting locations, so it is not possible to tell whether the consolidation of precincts was accompanied by a decrease in scanners available on Election Day at the polls.

[26] In 2008 early voting sites had to process an average of 689 voters per day. That grew to 1,005 in 2012.

[27] Charles Stewart III, The Performance of Election Machines and the Decline of Residual Votes in the U.S., *The Measure of American Elections*, Barry C. Burden and Charles Stewart III (eds.), forthcoming. Similar findings are reported by Paul S. Herrnson and others, "Exceeding Expectations? Determinants of Satisfaction with the Voting Process in the 2008 U.S. Presidential Election.," *Journal of Politics* 75, no. 2 (2013).

privacy booths to mark paper ballots, local election offices that use DREs may find it more expensive to expand capacity in response to an anticipated surge in turnout.

Reduce average transaction times

- *Increase information to voters.* Not knowing where to vote continues to be a problem for some voters; when voters show up at the wrong polling place, they slow down transactions at the registration table, as the error is caught and the voter (perhaps) redirected. Not knowing for whom to vote ahead of time — or how to vote on complicated initiatives and referendums — can cause voters to occupy more time in the voting booths. Local governments, often in partnership with information technology companies such as Google, have moved quickly to push more information about voter registration and ballot items onto the Internet, although no systematic studies have yet to be published that gauge their effectiveness. It is not unreasonable to surmise, however, that one of the reasons why California's average polling place wait times are so short, despite the state's notoriously long ballots, is due to the comprehensive information booklets sent to voters ahead of each election.

- *Increase the functionality of electronic poll books.* Electronic poll books hold the promise to speed up the check-in process and lower error rates at precincts. As of yet, however, there is no evidence that electronic poll books have cut down on waiting times. Further work to increase the functionality of electronic poll books, including more sophisticated search capabilities, holds the promise to cutting down waiting times.

- *Decrease the length of ballots.* The general trend in American elections over the past century has been the consolidation of elections onto a single day. Whereas a century ago it was common for states to hold local, state, and federal elections on different days, today it is common for states to schedule elections at all levels of government on the same first Tuesday after the first Monday of November in even-numbered years. This has the virtue of saving money — a topic that is increasingly prominent whenever a special election must be held to fill a vacancy — but it comes at the cost of lengthening the ballot, requiring voters who wish only to vote for president to wait for voters ahead of them to fill out ballots for state and local races. Furthermore, long, legalistic text associated with ballot questions can slow down voters who are unfamiliar with the issues being voted on or, as was demonstrated in Florida in 2012, require the use of multiple ballot cards, each of which must be separately scanned for the voter to check out. Finally, ballots that disregard best-practices in the field of graphic design — which may describe most ballots used by voters — slow down the process. Overall, better attention to factors that cause ballots to grow in size could reduce the time it takes voters to mark their ballots.[28]

[28] A recently published article by Herrnson et al. demonstrated a relationship between ballot length and expectations about how long it would take to vote. In a simple analysis using their data, we were able to estimate that in 2008, each additional item on the ballot increased the time waiting to vote by about 13 seconds. See Herrnson and others.

One final comment is important here: All of these policy proposals not only are offered under the proviso of "all things being equal," they need to be kept in mind in light of budgetary and space constraints. Most of these proposals would cost money, at a time when local governments are trying to find ways to economize. (And, of course, election administration has rarely been a top priority for local government spending.) Despite the strong desire to deal with the problem of long lines within the envelope of current government spending, it is hard to imagine how the most promising possibilities can be pursued without an infusion of at least some new money into election administration.

Space is another constraint that is rarely highlighted, but in the context of trying to streamline operations, it could be critical. Nearly all physical polling places are located in repurposed space. According to the 2012 SPAE, 32% of Election Day voters voted in school buildings, 22% in churches, and 16% in community centers, with the remaining 30% of voters using a hodgepodge of police/fire stations, libraries, stores, and private residences; for early voting, 44% voted in government buildings such as court houses and city halls, 16% in libraries, and 14% in community centers. The important thing to note is that these are not standardized spaces, and it may not be possible to configure many of them optimally to reduce service times.

Conclusions

The previous section reviews a list of the most common recommendations that have been proffered as solutions to the problem of long lines. Unlike post-2000, where research using existing data established a clear pattern that relate the use of antiquated voting machines to increased "lost votes," there is no single, high-impact solution to long lines that emerges from existing research — and certainly nothing that seems to apply everywhere.

It seems undoubtedly true that, *ceteris paribus*, if a state or locality were to reduce the number of voters coming to polling places, increase the number of service points, and decrease transaction times, lines would be shortened. However, the cost of these proposals is unknown, and more to the point, the effect of these proposals measured on a per-minute-reduced basis has yet to be quantified.

Therefore, while there may be some consensus solutions to local and state problems with long lines, much work still needs to be done to establish a basis for making changes that may seem less obvious, or for understanding trade-offs across competing values. We conclude this paper by making some observations about how the required fact base might be established, building off the evidence that already exists.

1. The "line problem" consists of two parts, *chronic* long lines and long lines due to *one-off events.*

2. Chronic long lines appear to beset only a handful of states and counties. Research that compares states that are similar demographically, but which have significantly different average wait times, would advance our understanding of how laws and practices facilitate expeditious service at polling places. Even in states with short average waiting periods,

urban areas can still have long lines. Understanding the chronic challenges of urban areas appears to be a distinct area where more research is needed.

3. All jurisdictions can be prone to emergencies that cause specific precincts to have long lines, and all jurisdictions could be helped by gaining access to better information about service times, to aid in a process of continued improvement. The EAC and professional associations are well positioned to facilitate the sharing of best practices among election officials, as they cope with the inevitable service crises on Election Day. The private and nonprofit sectors can be enlisted to develop tools that better capture customer service data, such as queue lengths, in real-time.

4. The EAC can provide a helpful role in supporting the research on voters' experiences and the extent and causes of line problems. It is within the EAC's mandate to report on the progress of state and local election officials in improving the customer service provided to voters in polling places, and to develop resources on the management of lines that can assist counties that have chronic line problems.

Appendix 1

Average wait times by state, 2008 and 2012

	2008		2012			2008		2012	
State	Wait	95% m.o.e.[a]	Wait	95% m.o.e.[a]		Wait	95% m.o.e.[a]	Wait	95% m.o.e.[a]
Alabama	21	5.5	10	2.4	Montana	6	2.1	12	5.2
Alaska	5	1.7	3	1.2	Nebraska	10	3.2	4	1.1
Arizona	15	4.5	8	2.9	Nevada	10	2.4	8	1.3
Arkansas	21	4.7	13	2.4	New Hampshire	6	1.7	11	2.2
California	11	2.6	7	0.8	New Jersey	7	1.5	5	0.7
Colorado	10	4.1	8	2.7	New Mexico	12	2.9	6	1.4
Connecticut	10	23.	7	1.6	New York	9	1.3	12	1.5
Delaware	12	3.2	4	1	North Carolina	19	2.9	13	1.4
D.C.	28	9.8	37	7.5	North Dakota	5	1.9	10	7.5
Florida	31	3.5	39	4	Ohio	19	2.7	10	1.3
Georgia	40	5.8	16	2	Oklahoma	22	4.9	17	2.7
Hawaii	5	1.6	7	2	Oregon	na	na	na	na
Idaho	6	1.8	8	1.9	Pennsylvania	14	1.7	8	1
Illinois	12	1.8	12	2.2	Rhode Island	5	2	11	2.2
Indiana	22	3.6	13	2.3	South Carolina	56	7.7	25	3.8
Iowa	5	1.5	6	1.8	South Dakota	4	1.7	3	1.2
Kansas	10	2.3	11	2	Tennessee	19	3.6	13	1.7
Kentucky	12	2.6	8	1.5	Texas	13	1.4	11	1.1
Louisiana	16	3.5	16	3	Utah	13	3.3	10	2
Maine	4	1.3	4	1.1	Vermont	2	1.2	2	0.7
Maryland	24	4.3	36	4	Virginia	28	4.6	25	2.5
Massachusetts	6	1.2	7	1.2	Washington	na	na	na	na
Michigan	20	3.5	19	2.3	West Virginia	14	3.4	11	2
Minnesota	9	2	6	1	Wisconsin	8	1.6	8	1.4
Mississippi	11	2.9	7	1.4	Wyoming	5	2	4	1.2
Missouri	20	3.7	11	1.8					

Oregon and Washington are excluded because they are vote-by-mail states.

Source: CCES and SPAE, 2008 and 2012.

[a] Margin of error.

Appendix 2

Multivariate Regression Predicting Wait Times in 2013
(Standard errors in parentheses)

Mode of voting				
(Election Day = comparison category)				
-Early voting	5.82***	3.75***	5.73***	5.92***
	(0.51)	(0.56)	(0.59)	(0.70)
Race of voters				
(White = comparison category)				
-Black	9.53***	7.06***	4.99***	0.82
	(0.64)	(0.63)	(0.67)	(0.87)
-Hispanic	5.09***	5.99***	0.28	0.21
	(0.86)	(0.85)	(0.87)	(1.13)
-Asian	0.76	2.28	2.19	4.20*
	(1.56)	(1.50)	(1.50)	(2.05)
-Native American	3.09	3.51	2.62	2.25
	(2.38)	(2.28)	(2.57)	(3.33)
-Mixed	0.42	0.28	0.66	2.06
	(1.60)	(1.53)	(1.51)	(1.81)
-Other	3.90*	2.14	1.42	3.21
	(1.90)	(1.18)	(1.90)	(2.28)
-Middle Eastern	-3.01	0.08	1.19	2.29
	(4.41)	(4.24)	(4.08)	(5.92)
log(ZIP Code density)	2.05***	2.24***	0.51*	—
	(0.11)	(0.12)	(0.22)	
Intercept	-2.91***	-3.48***	8.40***	12.30
	(0.79)	(0.84)	(1.51)	(0.25)
Fixed effects?	None	State	County	ZIP Code
N	18,580	18,580	18,580	18,580
R^2	.05	.14	.33	.76

*p < .05; **p<.01; ***p<.001

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