Racial Disparities in Voting Wait Times: Evidence from Smartphone Data

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Abstract

Equal access to voting is a core feature of democratic government. Using data from millions of smartphone users, we quantify a racial disparity in voting wait times across a nationwide sample of polling places during the 2016 US presidential election. Relative to entirely-white neighborhoods, residents of entirely-black neighborhoods waited 29% longer to vote and were 74% more likely to spend more than 30 minutes at their polling place. This disparity holds when comparing predominantly white and black polling places within the same states and counties, and survives numerous robustness and placebo tests. Our results document large racial differences in voting wait times and demonstrates that geospatial data can be an effective tool to both measure and monitor these disparities.

One Sentence Summary: Smartphone-location data measure significant racial disparities in voting wait times in the 2016 US election.

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Reports of long wait times are frequently discussed in the media each election cycle, and surveys of voters suggest US elections display worrying wait-time disparities. A significant fraction of voters (between 10-20%) report waiting in voting lines for more than 30 minutes (*1*). Surveys such as the Cooperative Congressional Election Study and the Survey of the Performance of American Elections suggest that wait times vary systematically across racial groups, with minority — especially black — voters experience waiting longer in lines than white voters (*1–3*).

Long wait times — and racial disparities in those waits — have important consequences. One study estimates the aggregate cost of voting wait times at over a half a billion dollars (*4*). This inconvenience may discourage voters from going to polls, or induce them to drop out upon facing a long line. A 2016 observational study suggests that about three percent of individuals leave the polling place before voting (*5*). Beyond the direct effect on voting, long times may undermine voters' confidence that their votes were counted as intended (*6–8*). Similar concerns have galvanized interest in voting wait times, and President Obama followed up mentioning the problem in his 2012 Election victory speech with the appointment of a presidential commission to investigate the issue. Despite this interest, comprehensive administrative data on voting wait times is lacking.

Much of the prior research has been based on surveys, which face limits due to recall and reporting biases. Studies based on field observations may provide more reliable estimates, but typically only cover small samples of polling places such as a single city or county (*9–11*). Stein et al. collect the largest sample to date, using observers with stopwatches across a convenience sample of 528 polling locations in 19 states (*5*). They find evidence of racial disparities in wait times, but do not report significant differences in time to cast a ballot.

Building on these findings, we examine differences in voters' total time to vote as a proxy for disparities in wait time. To do this we study a large anonymized smartphone-location data set which allows us to measure voters' total polling time at a much broader scale than has been previously possible. By measuring how long smartphones spend at voting locations on election day in 2016, we estimate wait times for over 150,000 voters at more than 40,000 polling locations across all 46 US continental states (and DC) with in-person voting.

Data and Methods

We use anonymized location data for more than 10 million U.S. smartphones provided by Safegraph, a firm which aggregates location data across a number of smartphone applications

(*12*). These data cover the days between November 1st and 15th, 2016, and consist of "pings" which record a phone's location at a series of points in time. The rate of ping measurements vary by application and intensity of use, but the modal time between pings is 5 minutes.

We also construct a dataset which contains the coordinates and rooftop outlines of 93,658 US polling places from 2016, comprising 80.1% of the full 116,900 polling locations in the 2016 election (*13*). These data were collected from files provided to us by state or county election officials. We translate polling place addresses to latitudes and longitudes using the Google Maps API and use Microsoft-OpenStreetmaps building footprint shapefiles for building geofences of each polling location (see Appendix A for a more detailed description of this process). As a proxy for the likely demographics of the voters at a polling place, we use the census-block demographics of each polling place's location.

In our main analysis, we identify all cellphones that record a ping within a 60-meter radius of a polling station (see Appendix B and Appendix D for an explanation and robustness tests of this 60-meter threshold choice). We create upper and lower bounds for the amount of time spent voting by measuring the time between the last ping before entering and the first ping after exiting a polling-place radius (for an upper bound), and the first and last pings within the radius (for a lower bound). For example, pings may indicate a smartphone user was not at a polling location at 8:20am, but then was at the polling location at 8:23, 8:28, 8:29, and 8:37, followed by a ping outside of the polling area at 8:40am; translating to a lower bound of 14 minutes and an upper bound value of 20 minutes. We use the midpoint of these bounds as our best guess of a voter's time at a polling place (e.g. 17 minutes in the aforementioned example). Summary statistics and robustness when using measures other than the midpoint are discussed and presented in Appendix C.

Another important step in measuring voting times from pings is to restrict our study to likely voters, not people simply passing by a polling place or people who live or work at a polling location. To avoid including people who are just passing by, we restrict the sample to individuals who spent at least one minute at a polling place and did so at only one polling place on Election Day. To avoid including people who live or work at the polling location, we exclude individuals who we observe spend time at that location in the week before or the week after Election Day. To further help identify actual voters and reduce both noise and false positives, we also restrict the sample to individuals who: had at least one ping within the convex hull of the polling place building on Election Day, logged a consistent set of pings on Election Day (posting at least 1 ping every hour for 12 hours), and spent no more than 2 hours at the polling location (to eliminate, for example, poll workers who spend all day at

a polling place). Figure 3, Appendix D, and Appendix J provide robustness to these various sample restrictions.

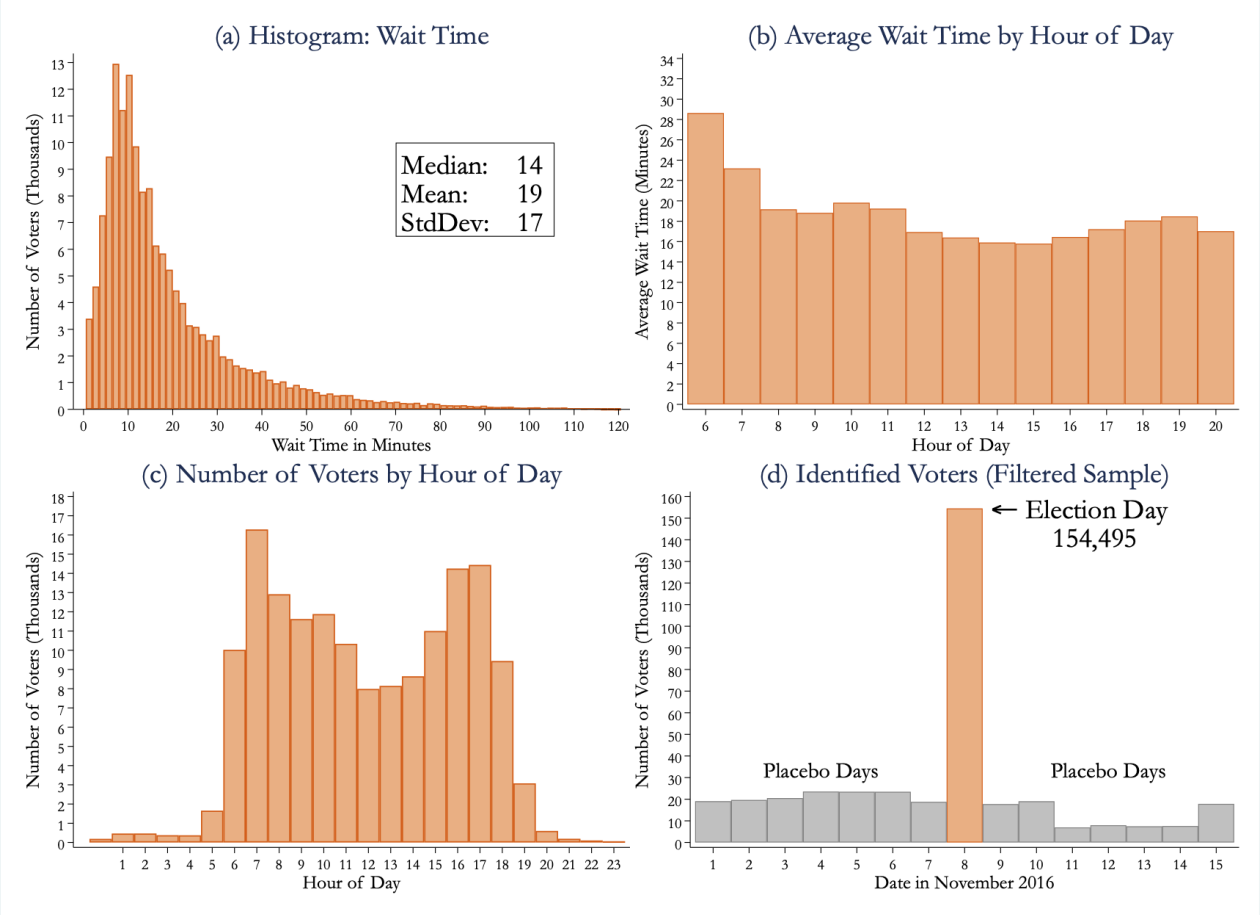
After these data restrictions, our final sample consists of 154,495 individuals whom we identify as likely voters across 43,414 polling locations. Panel D in Figure 1 shows how many people pass our likely-voter filter on both election day, and — as a placebo analysis — on non-election days one week in either direction. This analysis suggests that more than 87% of our sample are likely voters who would not have been picked up on days other than Election Day. To the degree that we can not completely eliminate false positives in our voter sample, we would expect the noise introduced by non-voters to bias us towards not finding systematic disparities in vote-times.

Overall Voter Wait Times

We plot the distribution of wait times in Panel A of Figure 1. The median and average times spent at polling locations are 14 and 19 minutes, respectively, and 18% of individuals spent more than 30 minutes voting. As the figure illustrates, there is a non-negligible number of individuals who spent 1-5 minutes in the polling location (less time than one might imagine is needed to cast a ballot). These observations might be voters who abandoned after discovering a long wait time. Alternatively, they may be individuals who pass our screening as likely voters, but were not actually voting (Appendix E shows what the wait times look like when we do a placebo analysis on non-election days and confirms that most of the very short wait times are likely to not be actual voters).

Panel C of Figure 1 shows the number of people who arrived to vote at the polling locations by time of day. As expected, people are most likely to vote early in the morning or later in the evening (e.g. before or after work). As a consistency check, Appendix F show that likely-voter arrivals match state-by-state poll opening and closing times in each state. Panel B displays the average wait time by hour of arrival. Wait times are fairly constant throughout the day with slightly longer wait times in the very early morning (6-8am). Finally, Panel A in Figure 2 shows average wait times by congressional district, while Panel B shows our coverage of polling locations. Average wait times vary from as low as $\sim$ 11 minutes in Massachusetts's sixth congressional district — primarily in Essex County — to as high as $\sim$ 41 minutes in Missouri's fifth congressional district, which contains Kansas City.

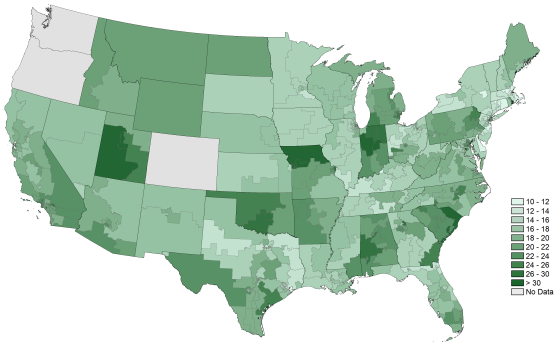
Figure 1: Wait Time Summary



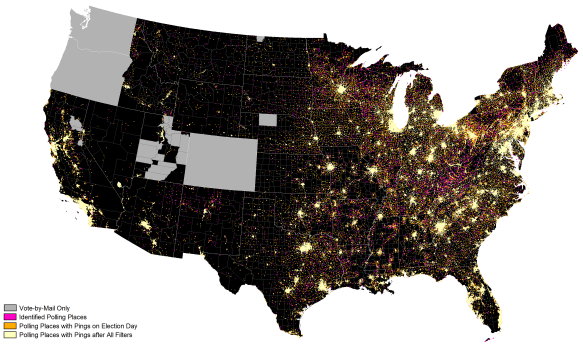
Notes: Panel A uses 1.5 minute bins. Panel B only shows hours of the day over which most polls are open (6am to 8pm).

Figure 2: Geographic Variation and Coverage

(a) Average Wait Time



(b) Data Coverage (Polling Places)

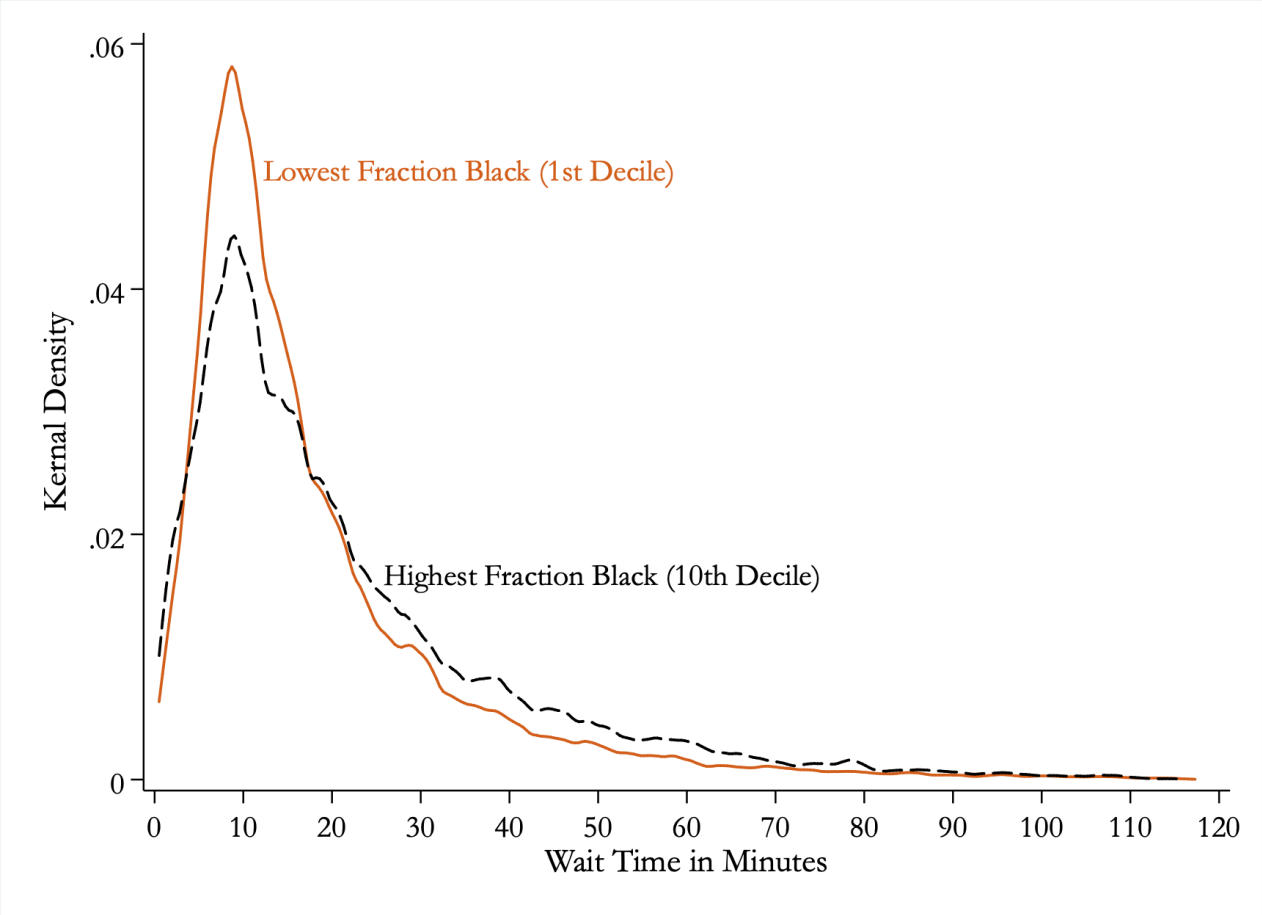


Notes: Panel A shows variation in average wait time by Congressional District. Panel B shows polling place locations overlaid on county shapes colored by whether smartphone pings were observed.

Racial Disparities in Wait Times

To visualize wait time differences by race, Figure 3 plots the smoothed distribution of wait times (analogous to Panel A of Figure 1) separately for polling places in the top and bottom deciles of the fraction-black distribution. These deciles average 58% and 0% black, respectively. Voters from areas in the top decile spent 19% more time at their polling locations than those in the bottom decile. Further, voters from the top decile were 49% more likely to spend over 30 minutes at the polling location. Appendix G shows wait-time comparisons for other demographic characteristics.

Figure 3: Wait Time: Fraction Black 1st vs. 10th Decile



Notes: Kernal density estimated using 1 minute half widths. The 1st decile corresponds to the 34,421 voters across 10,319 polling places with the lowest percent of black citizens (mean = 0%). The 10th decile corresponds to the 15,439 voters across the 5,262 polling places with the highest percent of black citizens (mean = 58%).

Panel A of Table 1 provides regression estimates of the wait-time impact of a polling place's racial composition. In column 1, we estimate the bivariate regression which shows that moving from a census block group with no black citizens to one that is entirely composed of black citizens is associated with a 5.23 minute longer wait time. In column 2, we broaden our focus by adding additional racial categories which reveals longer wait times for block groups with higher fractions of Hispanic and other non-white groups (Native American, other, multiracial). Column 3 examines whether these associations are robust to controlling for the population, population density, and percent below poverty line of the block group (see Appendix I for the full set of omitted coefficients). We see a remarkably stable coefficient on fraction black. Column 4 adds state fixed effects and again the coefficient stays very similar. Finally, in column 5 we add county fixed effects. This specification isolates within-county variation in the racial composition of polling places, thereby allowing us to control for observable and unobservable difference between counties that may influence wait times. For example, this specification would account for differences in ballot length between counties – longer ballots may lead to longer wait times in the voting booth, and queueing theory suggests that could in turn lead to backlogs at other points of service (*1, 14, 15*). County fixed effects further allows us to account for differences between counties in polling places resources (e.g. workers and machines) and procedures, and, as with column 4, will account for between-state variation (e.g. voter identification laws). As expected, the measured racial differences diminish in column 5, though only by thirty percent, and it remains significant. Our results in column 5 translate to all-black precincts facing wait times 3.27 minutes (or more than 15%) longer than all-white precincts in their same county. As shown in Appendix H, this estimate is uniquely positive on Election Day as opposed to placebo days, suggesting that we likely produce a lower bound estimate of the racial disparity. Appendix K plots state-by-state variation in this disparity.

Panel B of Table 1 is analogous to Panel A, but changes the outcome to a binary variable indicating a wait time longer than 30 minutes. We choose to report a threshold of 30 minutes as this was the standard used by the Presidential Commission on Election Administration in their 2014 report, which concluded that, "as a general rule, no voter should have to wait more than half an hour in order to have an opportunity to vote" (*16*). The bivariate regression shows that entirely black areas are 12 percentage points more likely to wait more than 30 minutes than entirely white areas, a 74% increase in that likelihood. This remains at 10 percentage points with polling-area controls and 7 percentage points once we add county fixed effects.

Table 1: Fraction Black and Voter Wait Time

	(1)	(2)	(3)	(4)	(5)
Panel A: Ordinary Least Squares (Y = Wait Time)					
Fraction Black	5.23***	5.22***	4.96***	4.84***	3.27***
	(0.39)	(0.39)	(0.42)	(0.42)	(0.45)
Fraction Asian		-0.79	-2.48***	1.30*	-1.14
		(0.72)	(0.74)	(0.76)	(0.81)
Fraction Hispanic		1.15***	0.43	3.90***	1.47***
		(0.37)	(0.40)	(0.46)	(0.50)
Fraction Other Non-White		12.01***	11.76***	1.67	2.02
		(1.94)	(1.95)	(1.89)	(1.94)
N	154,417	154,417	154,266	154,266	154,266
R^2	0.00	0.00	0.01	0.06	0.13
DepVarMean	19.13	19.13	19.12	19.12	19.12
Polling Area Controls?	No	No	Yes	Yes	Yes
State FE?	No	No	No	Yes	Yes
County FE?	No	No	No	No	Yes
Panel B: Linear Probability Model (Y = Wait Time > 30min)					
Fraction Black	0.12***	0.12***	0.11***	0.10***	0.07***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Fraction Asian		-0.00	-0.04**	0.04**	-0.02
		(0.02)	(0.02)	(0.02)	(0.02)
Fraction Hispanic		0.03***	0.01	0.08***	0.03***
		(0.01)	(0.01)	(0.01)	(0.01)
Fraction Other Non-White		0.21***	0.21***	0.03	0.05
		(0.04)	(0.04)	(0.04)	(0.04)
N	154,417	154,417	154,266	154,266	154,266
R^2	0.00	0.00	0.01	0.04	0.10
DepVarMean	0.18	0.18	0.18	0.18	0.18
Polling Area Controls?	No	No	Yes	Yes	Yes
State FE?	No	No	No	Yes	Yes
County FE?	No	No	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Robust standard errors, clustered at the polling place level, are in parentheses. Unit of observation is a cellphone identifier on Election Day. *DepVarMean* is the mean of the dependent variable. The dependent variable in Panel B is a binary variable equal to 1 if the wait time is greater than 30 minutes. *Polling Area Controls* includes the population, population per square mile, and fraction below poverty line for the block group of the polling station. "Asian" includes "Pacific Islander." "Other Non-White" includes the "Other," "Native American," and "Multiracial" Census race categories.

Conclusion

Exploiting the recent advent of large geospatial datasets, we provide new, nationwide estimates for the wait times of voters during the 2016 US presidential election. We find substantial and significant evidence of racial disparities in voter wait times, and detail that geospatial data can robustly estimate these disparities. This provides policymakers an easily available and repeatable tool to both diagnose and monitor progress towards reducing such disparities.

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Appendix A: Background on Data Sources

In this section we outline our three sources of data: (1) SafeGraph cell phone location records, (2) Polling locations, (3) Census demographics.

Anonymized smartphone location data were provided by Safegraph, a firm that aggregates pings from several smartphone applications. Pings record the time, a set of latitude and longitude coordinates, an estimate of the accuracy of this location estimate, and a device ID that links pings across applications.

Polling place addresses for the 2016 General Election were collected by contacting state and county election authorities. When not available, locations were sourced from local newspapers, public notices, and state voter registration look-up webpages. State election authorities provided statewide locations for 32 states, five of which required supplemental county-level information to complete. Four states were completely collected on a county-by-county basis. In twelve states, not all county election authorities responded to inquiries. The largest counties by population not covered by the resultant dataset are Nassau County, New York; Westchester County, New York; Niagara County, New York; Chautauqua County, New York; Rapides Parish, Louisiana; St. Landry Parish, Louisiana; Iberia Parish, Louisiana; Lonoke County, Arkansas; Acadia Parish, Louisiana; Lowndes County, Mississippi; and Blount County, Alabama.

When complete addresses were provided, the polling locations were geocoded to coordinates through the Google Maps API. When partial or informal addresses were provided, buildings were manually assigned coordinates by identifying buildings through Google Street View, imagery, or local tax assessor maps as available. Additionally, Google Maps API geocodes are less accurate or incomplete in rural locations or areas of very recent development, and approximately 8% of Google geocodes were manually updated. Another 1% of coordinates were provided by the state or county directly; in the case of Michigan, these coordinates proved insufficiently precise and were updated by the same process used for other states. Approximately 93% of all precincts with physical polling places were matched to coordinates either by algorithm or manually, about 3% of polling places had building names or addresses which could not be readily located on a map, and the other 4% did not receive a response from election authorities. These coordinates were compared to Microsoft-OpenStreetMap building footprint shapefiles, with a 72% match rate to a building's footprint and a 74% match to a building's convex hull. As these shapefiles are based on satellite imagery, they do not capture every building in the United States–especially in heavily forested areas or on islands–but they are the most complete set available nationally. Of the 116,990 national polling places reported by the U.S. Election Assistance Commission, 93,658 polling places were identified and geocoded, of which 69,452 resided in the convex hull of a Microsoft-OpenStreetMap building footprint.

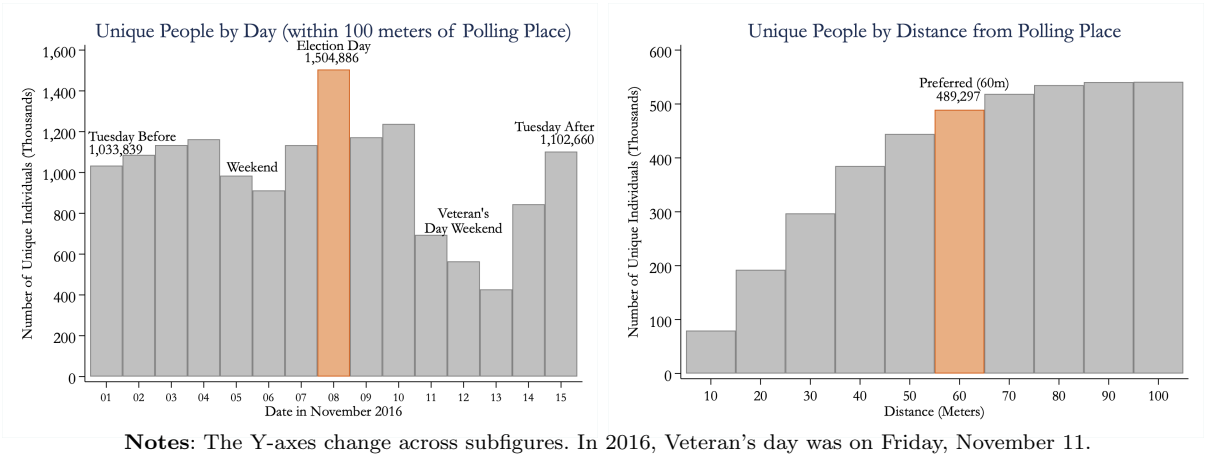
Each precinct was matched to one or more polling places to which their voters were assigned. 71% of polling places had exactly one precinct assigned to them and only to them, 27% were assigned multiple precincts, 2% were countywide vote centers wherein any precinct resident may vote, and less than 1% were one of several possible polling places a single precinct's residents could vote in. The mean number of precincts assigned to a multi-precinct polling place was 2.7. The most non-empty precincts assigned a single polling place which was not a countywide voting center was 32 at the Kansas State Fairgrounds Meadowlark Building in Reno, Kansas.

Polling place coordinates were also matched to census block groups and congressional districts. Census block groups were chosen as the number of block groups most closely matches the number of voting precincts of any common Census geography. Block group demographic data from the 2013-2017 American Community Survey was appended to each polling place.

Appendix B: Defining the Radius and Filters

In this section, we provide support for our choice of 60 meters as the bounding radius around a polling station. We start in Figure B.1 by examining whether there are more unique individuals who show up near a polling place on Election Day relative to the week before and after the election (using a 100 meter radius around a polling location). Panel A shows the number of unique people by day. As can be seen, there appear to be more than 400k additional people on election day compared to the days around it. In Panel B, we plot the difference in the number of people who show up within a particular radius of the polling place (10 meters to 100 meters) relative to the average across all other days. As we expand the radius, we are able to identify more and more voters (but also are picking up more and more false positives). We argue that the number of additional unique individuals starts to plateau around 60 meters, and thus use this choice in our analysis. In Appendix D, we examine sensitivity to this assumption.

Figure B.1: Defining the Radius



Notes: The Y-axes change across subfigures. In 2016, Veteran's day was on Friday, November 11.

Appendix C: Summary Statistics

Table C.1: Summary Statistics for Voter Wait Time Measures

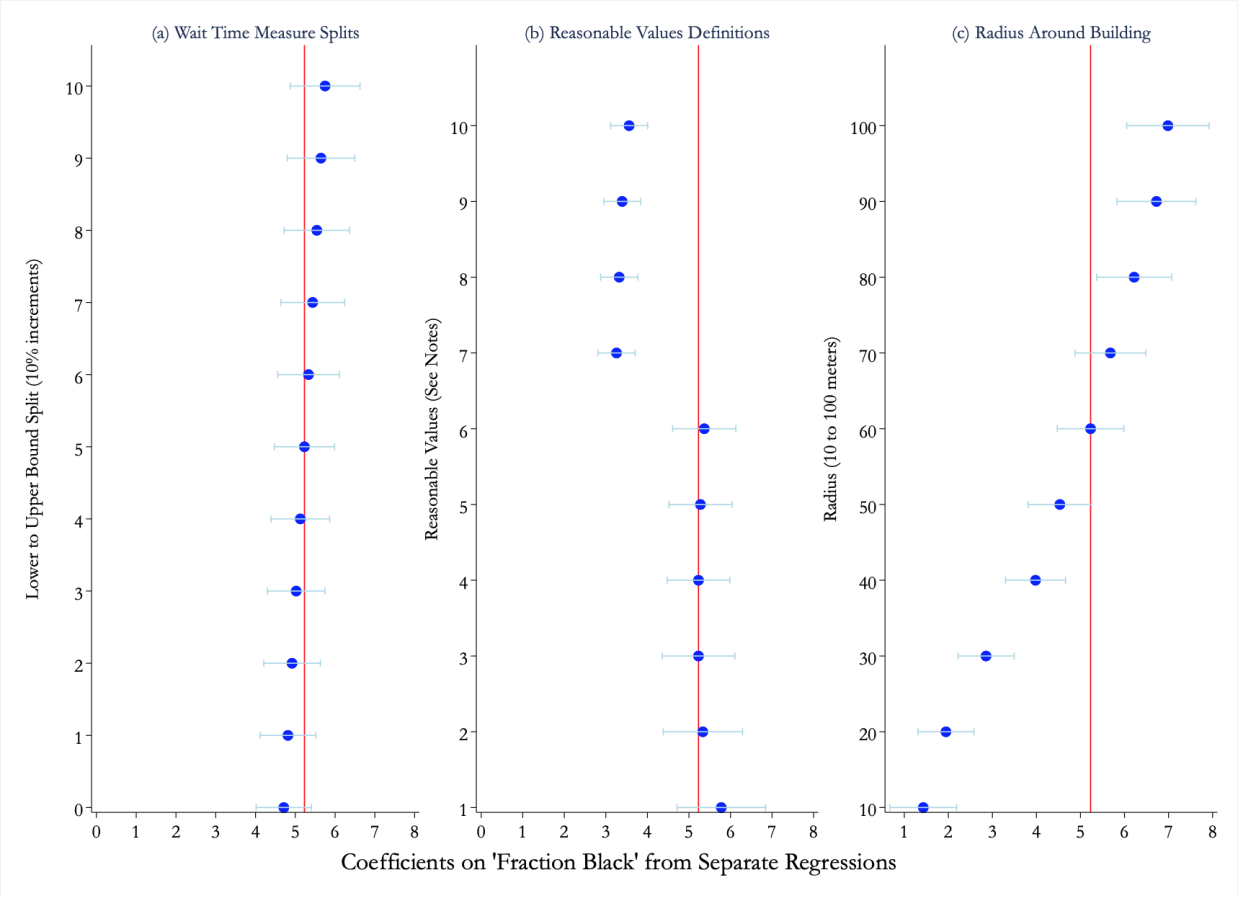
	(1) N	(2) Mean	(3) SD	(4) Min	(5) p10	(6) Median	(7) p90	(8) Max
Wait Time Measures								
Primary Wait Time Measure (Midpoint)	154,495	19.13	16.89	0.51	5.02	13.57	40.83	119.50
Lower Bound Wait Time Measure	154,495	27.00	20.33	1.02	9.28	20.30	54.52	119.98
Upper Bound Wait Time Measure	154,495	11.26	16.19	0.00	0.00	5.52	30.62	119.08
Wait Time Is Over 30min	154,495	0.18	0.38	0.00	0.00	0.00	1.00	1.00
Race Fractions in Polling Area								
Fraction White	154,417	0.70	0.26	0.00	0.27	0.79	0.96	1.00
Fraction Black	154,417	0.11	0.18	0.00	0.00	0.03	0.31	1.00
Fraction Asian	154,417	0.05	0.09	0.00	0.00	0.02	0.14	0.96
Fraction Hispanic	154,417	0.11	0.17	0.00	0.00	0.05	0.31	1.00
Fraction Other Non-White	154,417	0.03	0.04	0.00	0.00	0.02	0.07	0.99
Other Demographics								
Fraction Below Poverty Line	154,266	0.11	0.12	0.00	0.01	0.07	0.26	1.00
Population (1000s)	154,495	2.12	1.87	0.00	0.84	1.71	3.56	51.87
Population Per Sq Mile (1000s)	154,495	3.81	9.44	0.00	0.20	1.99	7.04	338.94

Notes: Race fractions and other demographics are defined at the Census-block-group of the associated polling place. These demographics correspond to the 2013-2017 American Community Survey.

Appendix D: Robustness

Figure D.1 examines the robustness of our results as we relax or change the various assumptions built into our variable and sample construction. In Panel A, we vary the wait time measure from the lower bound to the upper bound in 10 percent increments, finding that it has little impact on the significance or magnitude of our estimates. We further vary the wait time trimming thresholds in Panel B and the radius around a building centroid used to identify the polling location in Panel C. While these do move the average wait times around, and the corresponding differences, we find that the difference remains significant even across fairly implausible adjustments (e.g. a tight radius of 20 meters around a polling place centroid). We show the associated regression output in tables D.1, D.2, and D.3.

Figure D.1: Robustness to Different Data Construction Choices



Notes: Points correspond to coefficients on "Fraction Black" from separate regressions (+/- 1.96 robust standard errors, clustered at the polling place level). Unit of observation is a cellphone identifier on Election Day. All specifications are of the form used in Column 1 of Panel A, Table 1. Panel A varies the dependent variable across splits between the lower and upper bounds for our wait time measure (as described in Data and Methods); the first point (y = 0) corresponds to the lower bound, the last point (y = 10) corresponds to the upper bound measure, and all other points are intermediate deciles of the split (e.g. y = 5 corresponds to the midpoint of the two measures). Panel B varies the "reasonable values" (RV) filter, as follows: [RV1] Upper Bound under 5 hours (N = 159,052; Mean of Dependent Variable = 22.92) [RV2] Upper Bound under 4 hours (N = 158,172; Mean = 21.79) [RV3] Upper Bound under 3 hours (N = 156,943; Mean = 20.63) [RV4] Upper Bound under 2 hours (N = 154,417; Mean = 19.13) [RV5] Upper Bound under 2 hours and over 1.5 minutes (N = 154,020; Mean = 19.17) [RV6] Upper Bound under 2 hours and over 2 minutes (N = 153,439; Mean = 19.24) [RV7] Upper Bound under 1 hour and over 2 minutes (N = 141,176; Mean = 15.64) [RV8] Upper Bound under 1 hour and over 2.5 minutes (N = 140,476; Mean = 15.71) [RV9] Upper Bound under 1 hour and over 3 minutes (N = 139,794; Mean = 15.78) [RV10] Upper Bound under 1 hour and over 4 minutes (N = 138,458; Mean = 15.91). Panel C varies the bounding radius around the polling station centroid from 10 meters (N = 60,822; Mean = 12.09) up to 100 meters (N = 113,802; Mean = 21.81). The red line on each figure corresponds to the coefficient from the choice we use in our primary analysis, i.e. the midpoint wait time measure (Panel A), a filter of upper bounds under 2 hours (Panel B), and a radius of 60 meters (Panel C).

Table D.1: Robustness: Wait time Measure (Lower to Upper Bound Split)

	(1) Lower b/se	(2) S1 b/se	(3) S2 b/se	(4) S3 b/se	(5) S4 b/se	(6) Midpoint b/se	(7) S6 b/se	(8) S7 b/se	(9) S8 b/se	(10) S9 b/se	(11) Upper b/se
Fraction Black	4.71***	4.82***	4.92***	5.02***	5.13***	5.23***	5.33***	5.44***	5.54***	5.65***	5.75***
	(0.35)	(0.36)	(0.36)	(0.37)	(0.38)	(0.39)	(0.40)	(0.41)	(0.42)	(0.43)	(0.45)
N	154,417	154,417	154,417	154,417	154,417	154,417	154,417	154,417	154,417	154,417	154,417
r2	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
DepVarMean	11.256	12.830	14.404	15.979	17.553	19.127	20.701	22.275	23.849	25.424	26.998

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Robust standard errors, clustered at the polling place level, are in parentheses. Unit of observation is a cellphone identifier on Election Day. *DepVarMean* is the mean of the dependent variable. All specifications are of the form used in Column 1 of Panel A, Table 1.

Table D.2: Robustness: "Reasonable Values" Filter Definitions

	(1) RV1 b/se	(2) RV2 b/se	(3) RV3 b/se	(4) RV4 b/se	(5) RV5 b/se	(6) RV6 b/se	(7) RV7 b/se	(8) RV8 b/se	(9) RV9 b/se	(10) RV10 b/se
Fraction Black	5.78***	5.33***	5.23***	5.23***	5.28***	5.37***	3.26***	3.32***	3.39***	3.56***
	(0.54)	(0.49)	(0.45)	(0.39)	(0.39)	(0.39)	(0.23)	(0.23)	(0.23)	(0.23)
N	159,052	158,172	156,943	154,417	154,020	153,439	141,176	140,476	139,794	138,458
r2	0.001	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.004
DepVarMean	22.923	21.787	20.631	19.127	19.174	19.243	15.639	15.710	15.780	15.914

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Robust standard errors, clustered at the polling place level, are in parentheses. Unit of observation is a cellphone identifier on Election Day. *DepVarMean* is the mean of the dependent variable. All specifications are of the form used in Column 1 of Panel A, Table 1.

Table D.3: Robustness: Radius Length (10 to 60 meters around Building Centroid)

	(1) Rad10 b/se	(2) Rad20 b/se	(3) Rad30 b/se	(4) Rad40 b/se	(5) Rad50 b/se	(6) Rad60 b/se	(7) Rad70 b/se	(8) Rad80 b/se	(9) Rad90 b/se	(10) Rad100 b/se
Fraction Black	1.43***	1.95***	2.86***	3.98***	4.53***	5.23***	5.68***	6.22***	6.72***	6.99***
	(0.39)	(0.32)	(0.33)	(0.35)	(0.37)	(0.39)	(0.41)	(0.43)	(0.46)	(0.48)
N	60,822	120,927	151,000	161,733	161,144	154,417	144,885	134,139	123,420	113,802
r2	0.000	0.001	0.001	0.002	0.003	0.003	0.004	0.004	0.005	0.005
DepVarMean	12.093	13.996	15.633	16.996	18.164	19.127	19.999	20.711	21.322	21.813

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

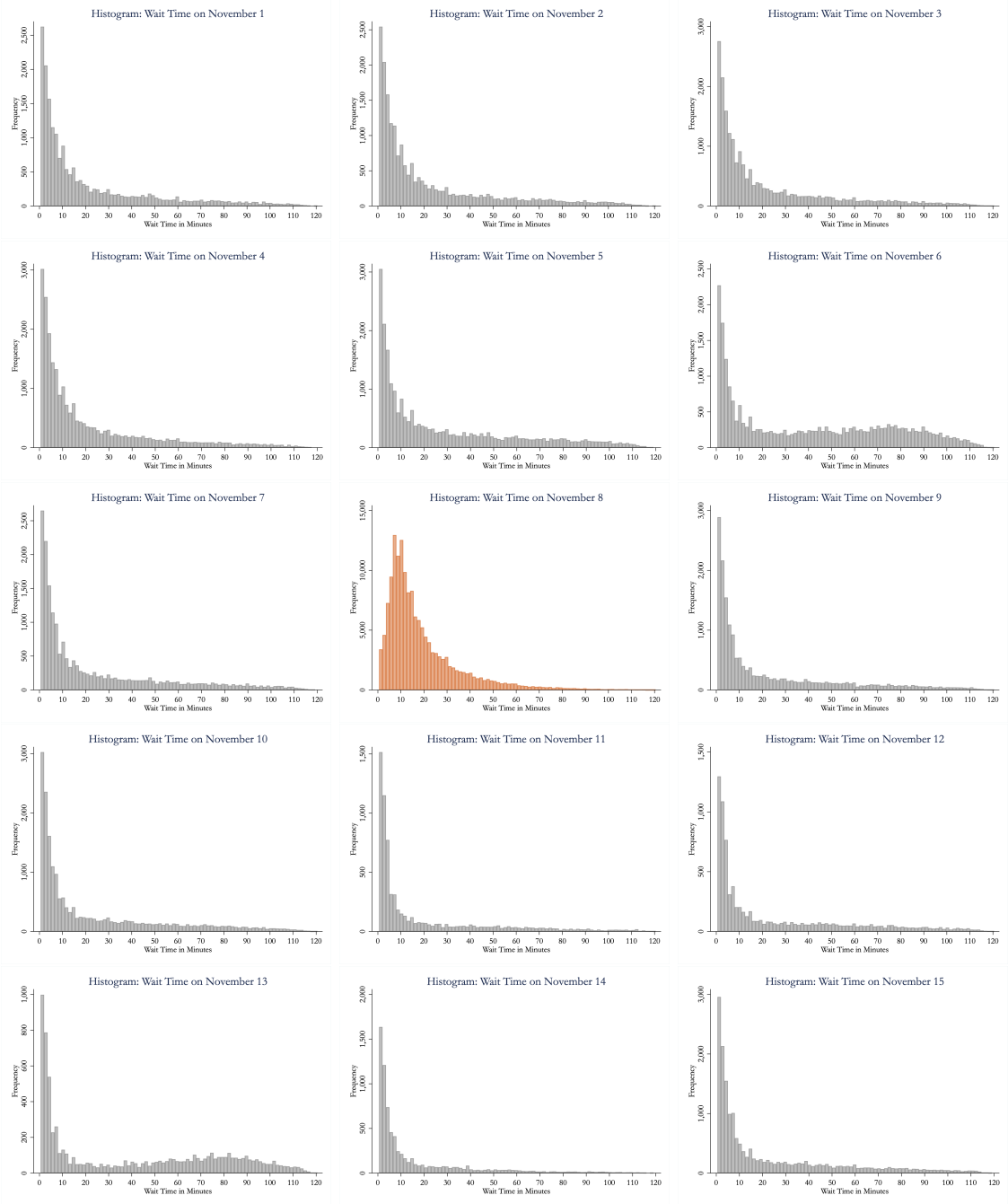
Notes: Robust standard errors, clustered at the polling place level, are in parentheses. Unit of observation is a cellphone identifier on Election Day. *DepVarMean* is the mean of the dependent variable. All specifications are of the form used in Column 1 of Panel A, Table 1.

Appendix E: Wait Time Distributions (Placebo Days)

In this section, we replicate our sample construction across 14 placebo days (i.e. we apply our filters to identifying a "likely voter" but replace the sample and the date used in each filter definition to the placebo date). The figure corresponding to Election Day (i.e. Figure 2 of the paper) is also shown, highlighted in orange. The figure illustrates that our filters

identify a plausible distribution of wait times on Election Day, but that applying the same set of filters (with dates shifted accordingly) produces a very different distribution shape on other dates.

Figure E.1: Placebo Day Wait Time Histograms

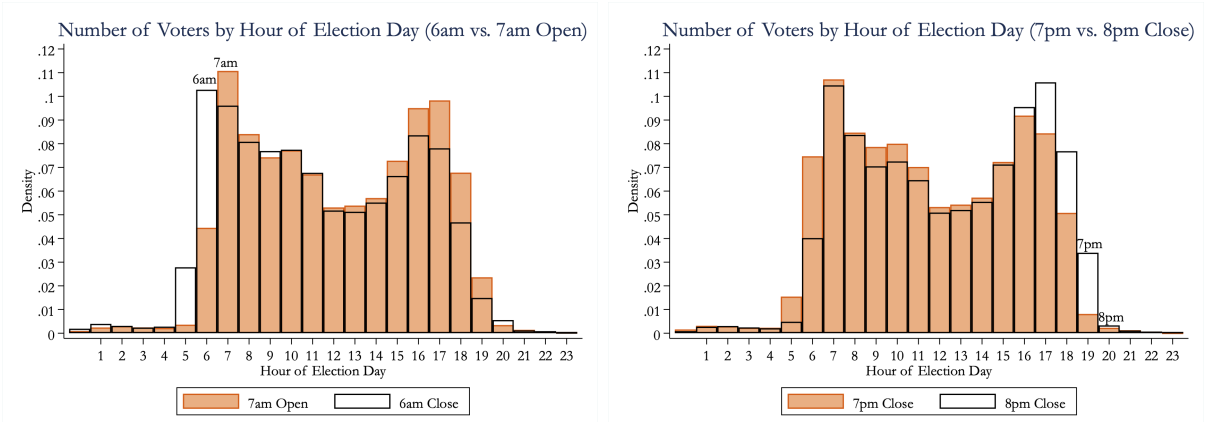


Notes: The Y-axes change across sub-figures.

Appendix F: Voter Volume by Hour of Day (Early vs. Late Poll Open and Close States)

In this section, we use state poll opening and close times to further validate our filters as identifying likely voters. Specifically, we show in Figure F.1 that volume patterns correspond to variation in poll opening & closing times at the state level. Both panels correspond to the sample of wait times after applying all filtering steps. The "hour of day" is defined using the "hour of arrival" for a given wait time (i.e. the earliest ping within the polling place radius for a given wait time spell). The panel on the left separately plots the histogram for the 9 states that open at 6am and the 23 that open at 7am; the panel on the right shows it for the 17 that close at 7pm versus the 16 that close at 8pm. We see relative spikes at 7am for the states that open at 7am (orange histogram), and that the number of voters falls substantially at 7pm for states that close at 7pm (transparent histogram).

Figure F.1: Voter Volume by Hour of Day (Early vs. Late Poll Open and Close States)



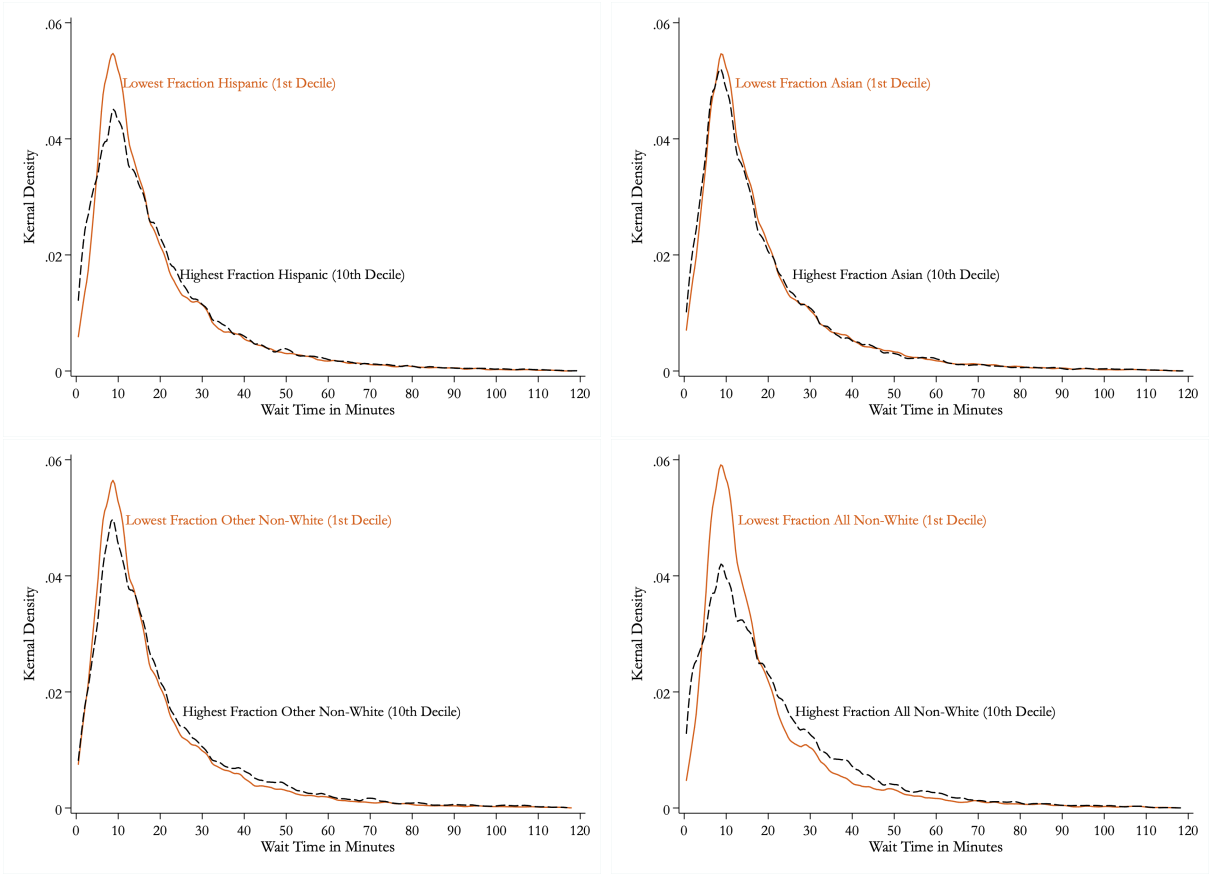
Notes: The panel on the left separately plots the histogram for the 9 states that open at 6am and the 23 that open at 7am; the panel on the right shows it for the 17 that close at 7pm versus the 16 that close at 8pm.

Appendix G: Wait Time Distributions by Race and Poverty Deciles

Figures G.1 and G.2 repeat Figure 3 of the paper for different Census block group level demographics. In Figure G.1, we show the decile splits by Hispanic (Panel A), Asian (Panel B), and "Other Non-White" (Panel C), and then finally grouping together those categories

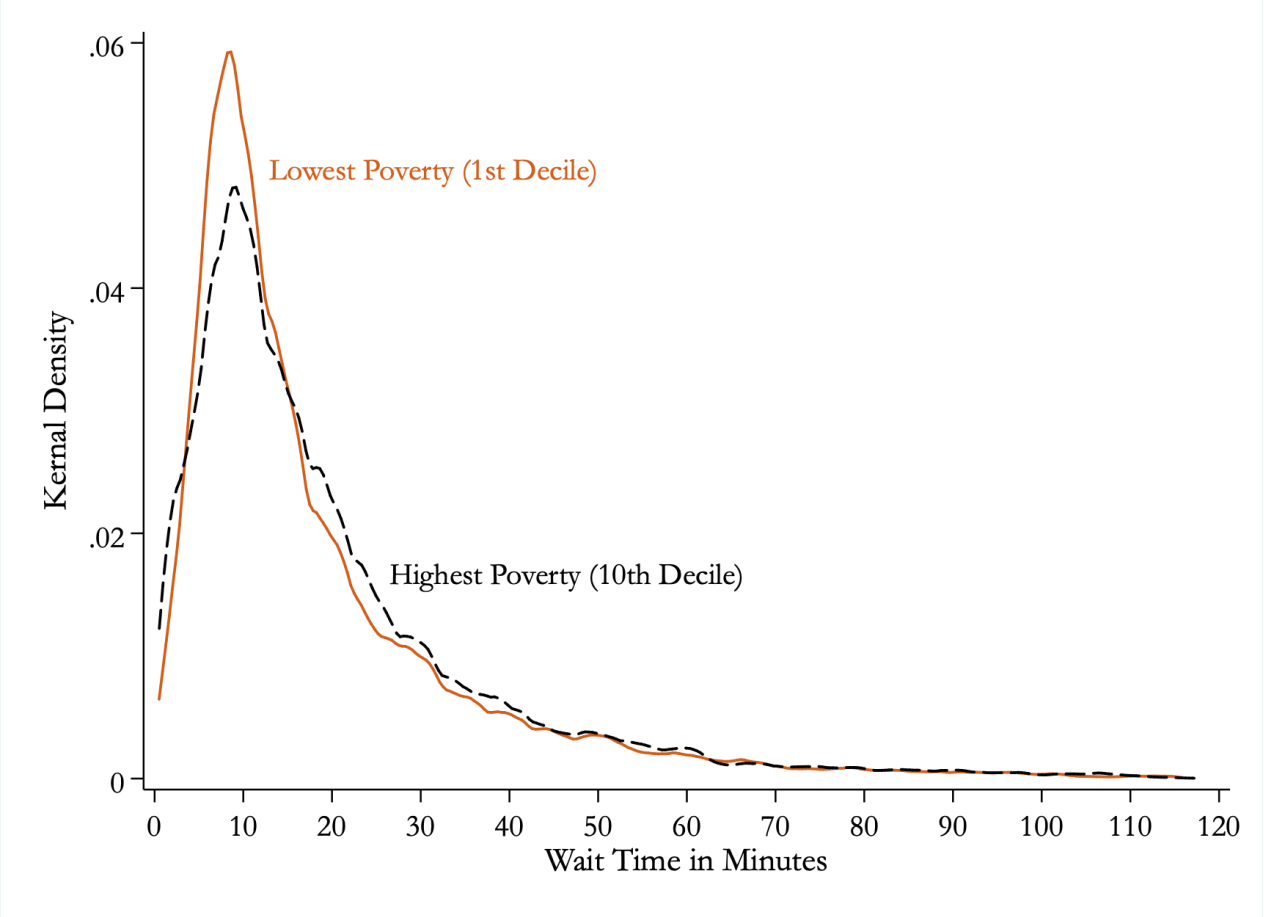
with Black in Panel D. In Figure G.2, we show the decile split by the fraction of the block group living below the poverty line.

Figure G.1: Wait Time Disparities by Racial Categories



Notes:"Asian" includes "Pacific Islander." "Other Non-White" includes the "Other," "Native American," and "Multiracial" Census race categories. "All Non-White" includes Black, Hispanic, Asian, and Other Non-White.

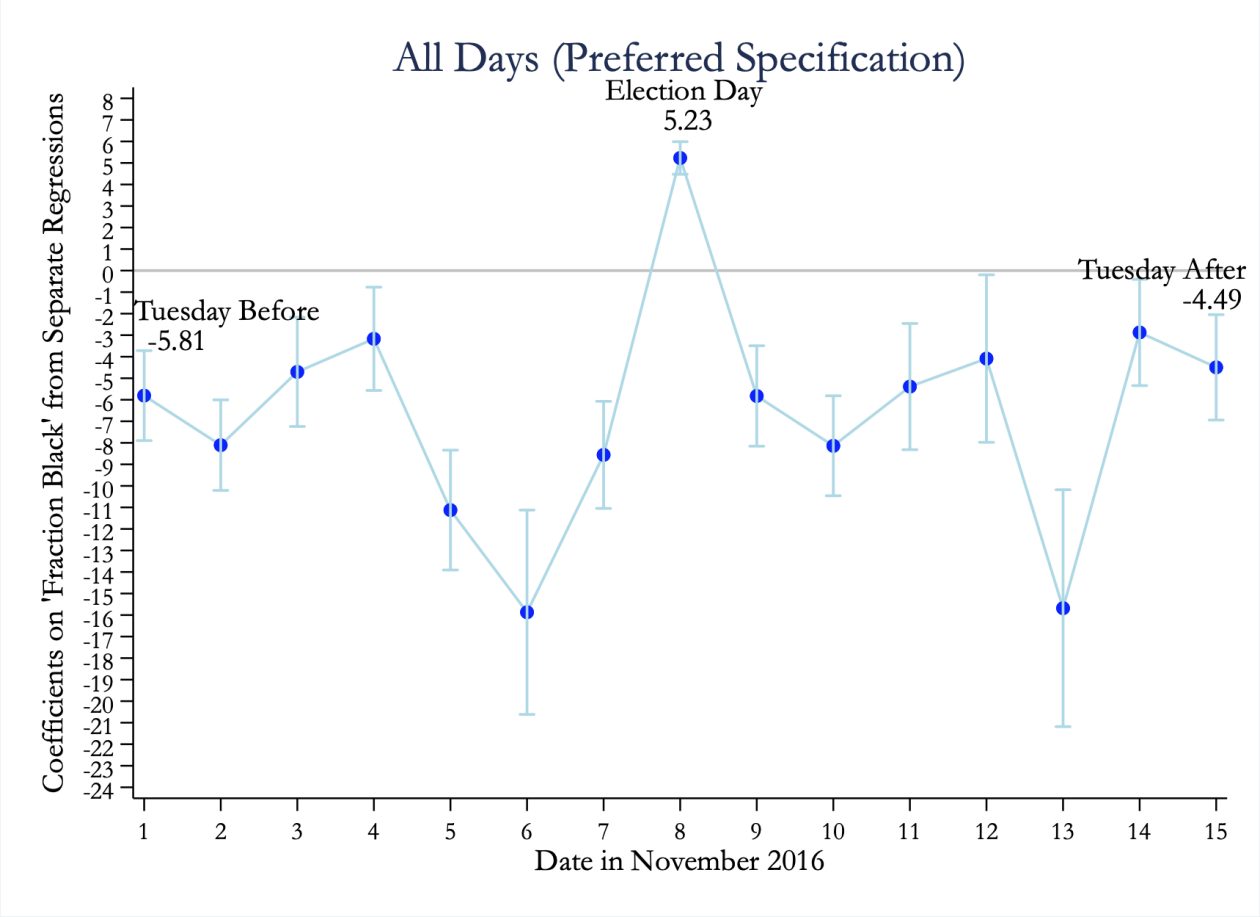
Figure G.2: Wait Time Disparities by Fraction Below Poverty Line



Appendix H: Coefficients Across Placebo Days

In this section, we replicate our sample construction for the 14 placebo days around Election Day, similar to Appendix E. We then repeat the regression used in Table 1, Panel A, Column 1 for each of these days. Figure H.1 shows the coefficients for each date. We find that none of these alternative dates produces a positive coefficient, suggesting that our approach likely identifies a lower bound on the racial gap in wait times.

Figure H.1: Main Specification Run on Placebo Days



Notes:Points correspond to coefficients on "Fraction Black" (+/- 1.96 standard errors) from separate regressions. All specifications are of the form used in Column 1 of Panel A, Table 1.

Table H.1: Primary Specification Across Placebo Days

	(1) Nov2 b/se	(2) Nov2 b/se	(3) Nov3 b/se	(4) Nov4 b/se	(5) Nov5 b/se	(6) Nov6 b/se	(7) Nov7 b/se	(8) Nov8 b/se	(9) Nov9 b/se	(10) Nov10 b/se	(11) Nov11 b/se	(12) Nov12 b/se	(13) Nov13 b/se	(14) Nov14 b/se	(15) Nov15 b/se
Fraction Black	-5.81***	-8.11***	-4.71***	-3.17***	-11.12***	-15.87***	-8.56***	5.23***	-5.82***	-8.14***	-5.39***	-4.09**	-15.68***	-2.87**	-4.49***
	(1.07)	(1.07)	(1.29)	(1.22)	(1.42)	(2.42)	(1.27)	(0.39)	(1.19)	(1.18)	(1.50)	(1.99)	(2.81)	(1.26)	(1.25)
N	19,053	19,608	20,504	23,519	23,430	23,415	18,766	154,417	17,702	19,011	6,942	7,942	7,440	7,583	17,831
R^2	0.002	0.003	0.001	0.001	0.004	0.007	0.003	0.003	0.002	0.003	0.002	0.001	0.007	0.001	0.001
DepVarMean	21.759	22.576	22.517	21.655	28.473	40.608	23.875	19.127	22.768	23.845	19.058	25.046	39.381	16.688	23.313

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Robust standard errors, clustered at the polling place level, are in parentheses. Unit of observation is a cellphone identifier on the corresponding day. *DepVarMean* is the mean of the dependent variable. All specifications are of the form used in Column 1 of Panel A, Table 1.

Appendix I: Expanded Table 1

We repeat Table 1, Panel A (Table I.1) and Panel B (Table I.2), but here we do not suppress the display of coefficients on control variables (Fraction Below Poverty Line, Population, Population Per Sq Mile). We additionally add column 6 which adds two additional sets of control variables: fixed effects for each hour of the day (hour of arrival for a wait time) and whether the cellphone is Android (vs. iPhone). We find that the inclusion of these additional controls has little impact on our coefficients of interest.

Table I.1: Fraction Black and Voter Wait Time: OLS

	(1)	(2)	(3)	(4)	(5)	(6)
Fraction Black	5.23***	5.22***	4.96***	4.84***	3.27***	3.10***
	(0.39)	(0.39)	(0.42)	(0.42)	(0.45)	(0.44)
Fraction Asian		-0.79	-2.48***	1.30*	-1.14	-0.69
		(0.72)	(0.74)	(0.76)	(0.81)	(0.81)
Fraction Hispanic		1.15***	0.43	3.90***	1.47***	1.69***
		(0.37)	(0.40)	(0.46)	(0.50)	(0.50)
Fraction Other Non-White		12.01***	11.76***	1.67	2.02	1.76
		(1.94)	(1.95)	(1.89)	(1.94)	(1.93)
Fraction Below Poverty Line			0.06	-2.03***	0.29	1.11*
			(0.74)	(0.71)	(0.67)	(0.67)
Population (1000s)			0.43***	0.32***	0.28***	0.27***
			(0.06)	(0.05)	(0.05)	(0.05)
Population Per Sq Mile (1000s)			0.04***	0.07***	0.06***	0.06***
			(0.01)	(0.01)	(0.01)	(0.01)
Android (0 = iPhone)						0.38***
						(0.10)
N	154,417	154,417	154,266	154,266	154,266	154,266
R^2	0.00	0.00	0.01	0.06	0.13	0.17
DepVarMean	19.13	19.13	19.12	19.12	19.12	19.12
Polling Area Controls?	No	No	Yes	Yes	Yes	Yes
State FE?	No	No	No	Yes	Yes	Yes
County FE?	No	No	No	No	Yes	Yes
Hour of Day FE?	No	No	No	No	No	Yes

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Robust standard errors, clustered at the polling place level, are in parentheses. Unit of observation is a cellphone identifier on Election Day. *DepVarMean* is the mean of the dependent variable. *Polling Area Controls* includes the population, population per square mile, and fraction below poverty line for the block group of the polling station. "Asian" includes "Pacific Islander." "Other Non-White" includes the "Other," "Native American," and "Multiracial" Census race categories. Column 6 adds an additional specification beyond Table 1; there we include fixed effects for the hour of arrival (i.e. the first ping of a waiting spell within the 60 meters of the polling place centroid) and a dummy variable for whether the observation corresponds to an Android phone.

Table I.2: Fraction Black and Voter Wait Time: LPM

	(1)	(2)	(3)	(4)	(5)	(6)
Fraction Black	0.12***	0.12***	0.11***	0.10***	0.07***	0.06***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Fraction Asian		-0.00	-0.04**	0.04**	-0.02	-0.01
		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Fraction Hispanic		0.03***	0.01	0.08***	0.03***	0.04***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Fraction Other Non-White		0.21***	0.21***	0.03	0.05	0.04
		(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Fraction Below Poverty Line			-0.02	-0.05***	0.01	0.03*
			(0.02)	(0.02)	(0.01)	(0.01)
Population (1000s)			0.01***	0.01***	0.01***	0.01***
			(0.00)	(0.00)	(0.00)	(0.00)
Population Per Sq Mile (1000s)			0.00***	0.00***	0.00***	0.00***
			(0.00)	(0.00)	(0.00)	(0.00)
Android (0 = iPhone)						0.01***
						(0.00)
N	154,417	154,417	154,266	154,266	154,266	154,266
R^2	0.00	0.00	0.01	0.04	0.10	0.14
DepVarMean	0.18	0.18	0.18	0.18	0.18	0.18
Polling Area Controls?	No	No	Yes	Yes	Yes	Yes
State FE?	No	No	No	Yes	Yes	Yes
County FE?	No	No	No	No	Yes	Yes
Hour of Day FE?	No	No	No	No	No	Yes

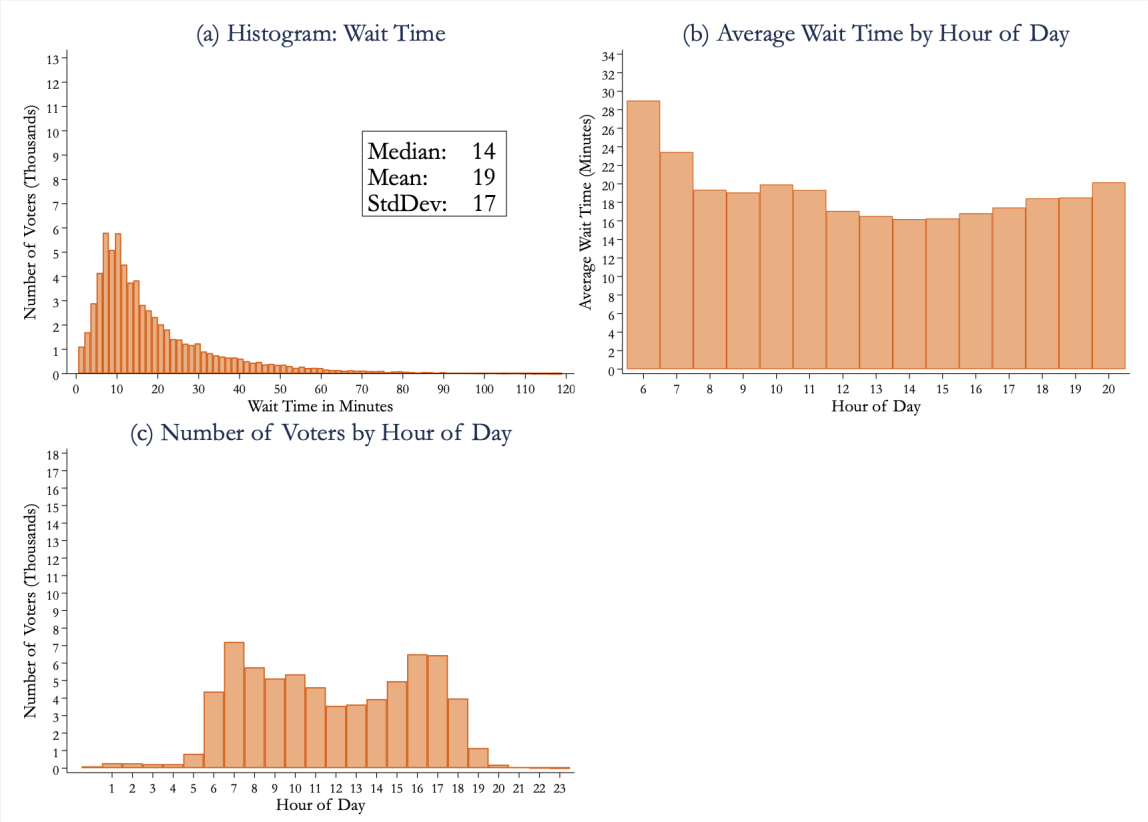
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Robust standard errors, clustered at the polling place level, are in parentheses. Unit of observation is a cellphone identifier on Election Day. *DepVarMean* is the mean of the dependent variable. The dependent variable is a binary variable equal to 1 if the wait time is greater than 30 minutes. *Polling Area Controls* includes the population, population per square mile, and fraction below poverty line for the block group of the polling station. "Asian" includes "Pacific Islander." "Other Non-White" includes the "Other," "Native American," and "Multiracial" Census race categories. Column 6 adds an additional specification beyond Table 1; there we include fixed effects for the hour of arrival (i.e. the first ping of a waiting spell within the 60 meters of the polling place centroid) and a dummy variable for whether the observation corresponds to an Android phone.

Appendix J: Repeating Table 1 and Figures 1 -3 with a Stricter "Likely Voter" Filter

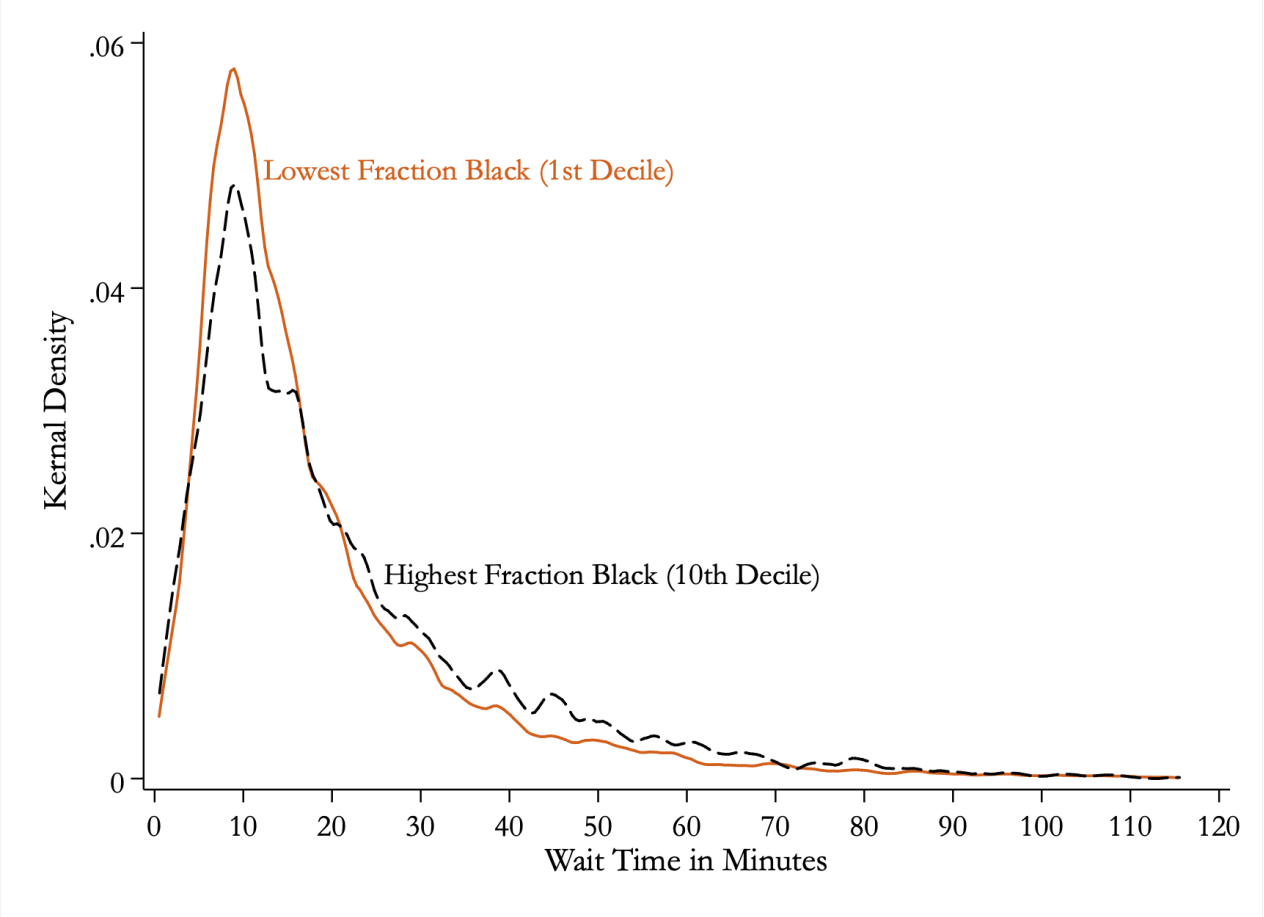
In this section, we repeat our primary analysis with a subsample of voters. Specifically, we use a more conservative first filter for identifying "likely voters." Our primary analysis limited the sample to individuals who (a) spent at least one minute at a polling place, (b) did so at only one polling place on Election Day, and (c) did not spend more than one minute at that polling location in the week before or the week after Election Day. Here we make (c) stricter by dropping anyone who visited *any other polling place* on any day in the week before or after Election Day, e.g. we would thus exclude a person who only visited a school polling place on Election Day, but who visited a church (that later serves a polling place) on the prior Sunday. This drops our primary analysis sample from 147,907 voters down to 66,690 voters.

Figure J.1: Summary Figures: Wait Time



Notes: Panel A uses 1.5 minute bins. Panel B only shows hours of the day over which most polls are open (6am to 8pm).

Figure J.2: Wait Time Disparities



Notes: Kernal density estimated using 1 minute half widths. The 1st decile corresponds to the 15,405 voters across 6,577 polling places with the lowest percent of black citizens (mean = 0%). The 10th decile corresponds to the 6,880 voters across the 3,228 polling places with the highest percent of black citizens (mean = 54%).

Table J.1: Fraction Black and Voter Wait Time

	(1)	(2)	(3)	(4)	(5)
Panel A: Ordinary Least Squares (Y = Wait Time)					
Fraction Black	4.97***	4.93***	4.38***	4.31***	2.68***
	(0.53)	(0.53)	(0.56)	(0.57)	(0.63)
Fraction Asian		-1.97*	-3.79***	0.78	-2.24*
		(1.05)	(1.11)	(1.11)	(1.19)
Fraction Hispanic		1.21**	0.22	4.26***	2.07***
		(0.52)	(0.56)	(0.67)	(0.74)
Fraction Other Non-White		12.55***	11.86***	0.85	2.07
		(2.26)	(2.27)	(2.22)	(2.46)
N	68,816	68,816	68,729	68,729	68,729
R^2	0.00	0.00	0.01	0.06	0.14
DepVarMean	19.38	19.38	19.36	19.36	19.36
Polling Area Controls?	No	No	Yes	Yes	Yes
State FE?	No	No	No	Yes	Yes
County FE?	No	No	No	No	Yes
Panel B: Linear Probability Model (Y = Wait Time > 30min)					
Fraction Black	0.11***	0.11***	0.11***	0.09***	0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Fraction Asian		-0.00	-0.04*	0.05*	-0.03
		(0.02)	(0.02)	(0.02)	(0.03)
Fraction Hispanic		0.03**	0.01	0.09***	0.04**
		(0.01)	(0.01)	(0.02)	(0.02)
Fraction Other Non-White		0.22***	0.21***	0.02	0.05
		(0.05)	(0.05)	(0.05)	(0.06)
N	68,816	68,816	68,729	68,729	68,729
R^2	0.00	0.00	0.01	0.05	0.12
DepVarMean	0.18	0.18	0.18	0.18	0.18
Polling Area Controls?	No	No	Yes	Yes	Yes
State FE?	No	No	No	Yes	Yes
County FE?	No	No	No	No	Yes

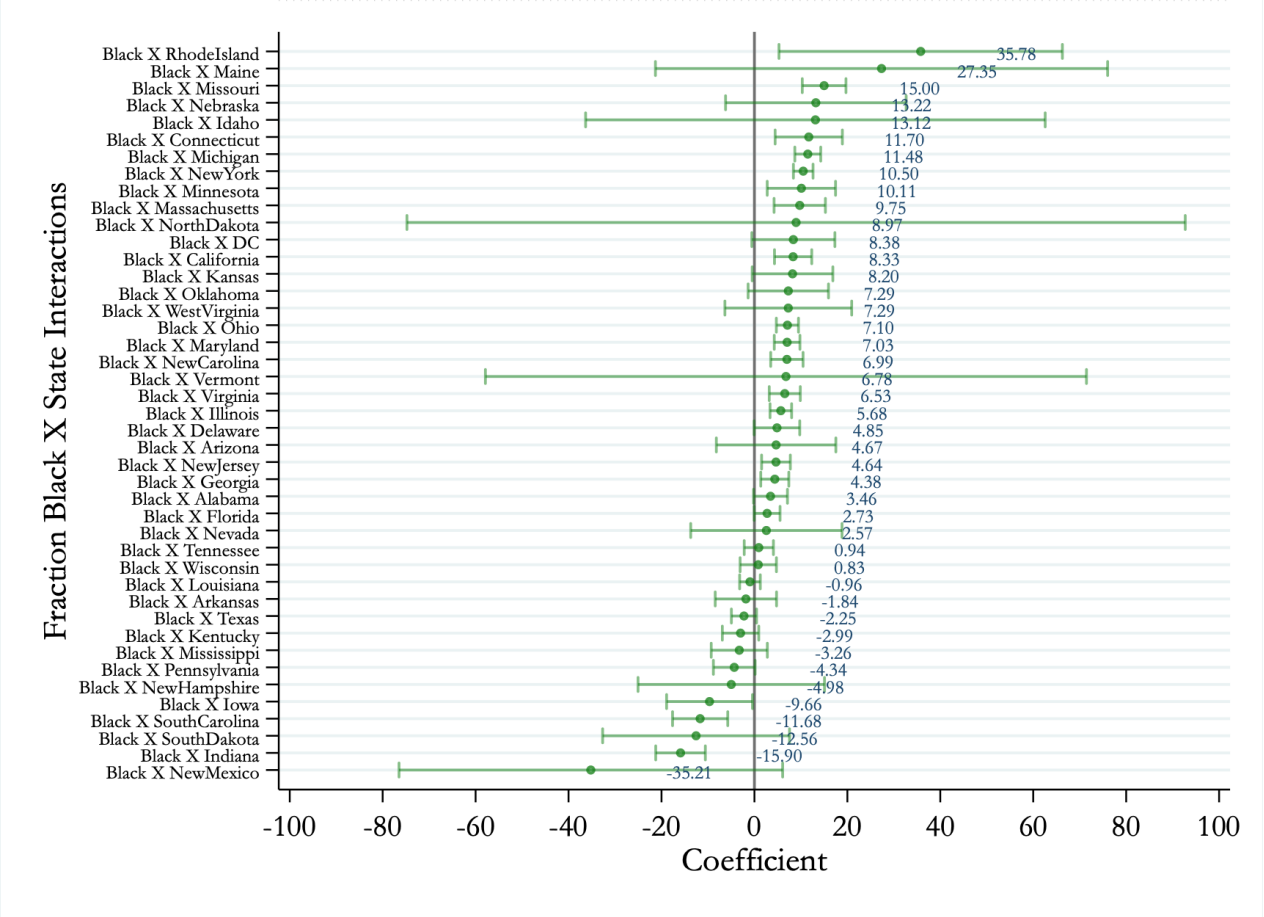
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Robust standard errors, clustered at the polling place level, are in parentheses. Unit of observation is a cellphone identifier on Election Day. *DepVarMean* is the mean of the dependent variable. The dependent variable in Panel B is a binary variable equal to 1 if the wait time is greater than 30 minutes. *Polling Area Controls* includes the population, population per square mile, and fraction below poverty line for the block group of the polling station. "Asian" includes "Pacific Islander." "Other Non-White" includes the "Other," "Native American," and "Multiracial" Census race categories.

Appendix K: Coefficient Heterogeneity by State

In this section, we examine heterogeneity by state in the measured racial disparities in voting wait time. Specifically, we modify the regression specification in Column 1, Panel A, Table 1 to include state dummy variables and their interactions with the "Fraction Black" variable. We omit the "Fraction Black" variable as well as the constant, so that each interaction can be interpreted as the linear projection of the difference in wait times from moving from a census block group with no black citizens to one that is entirely composed of black citizens in that state. Figure K.1 plots the interaction term coefficients from this regression. We omit the state dummy variables from the figure to maintain visual clarity, but as shown in Figure 2, Panel A, there is significant variation in average wait times between states. For example, voters in areas with no black citizens in South Carolina face an average wait time of 29 minutes, whereas those in Delaware face an average wait of 11 minutes. We also omit the coefficients on the three noisiest interaction terms (states with very little racial variation) for visual clarity as well. Finally, we order coefficients on the interaction terms from largest to smallest. To give one relatively precisely-estimated example, the coefficient on "Black X Missouri" shows that polling places in Missouri in block groups composed of entirely black citizens wait 15 minutes longer than those with no black citizens.

Figure K.1: Wait Time Disparities



Notes: Points on "Black X *State*" (+/- 1.96 robust standard errors, clustered at the polling place level) correspond to coefficients on interaction terms between "Fraction Black" and state dummy variables from a single regression. The levels (i.e. dummy variables for each state) are included in the regression, but omitted from the figure. We also omit the coefficients on the three noisiest coefficients to maintain visual clarity; these are "Black X Montana" (b = -117.11, se = 92.15), "Black X Utah" (b = -34.32, se = 51.98), and "Black X Wyoming" (b = 17.90, se = 44.06).