When Time Is of the Essence: A Natural Experiment on How Time Constraints Influence Elections

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Foundational theories of voter turnout suggest that time is a key input in the voting decision, but we possess little causal evidence about how this resource affects electoral behavior. In this article, we use over two decades of elections data and a novel geographic regression discontinuity design that leverages US time zone boundaries. Our results show that exogenous shifts in time allocations have significant political consequences. Namely, we find that citizens are less likely to vote if they live on the eastern side of a time zone border. Time zones also exacerbate participatory inequality and push election results toward Republicans. Exploring potential mechanisms, we find suggestive evidence that these effects are the consequence of insufficient sleep and moderated by the convenience of voting. Regardless of the exact mechanisms, our results indicate that local differences in daily schedules affect how difficult it is to vote and shape the composition of the electorate.

Although in recent years the administrative barriers to voting have declined in many democracies (Blais 2010), many eligible citizens still fail to vote. In the United States, about 40% of registered voters do not participate in presidential elections, with abstention rates soaring as high as 60% in midterms and 70% in local elections (Hajnal and Trounstine 2016). Moreover, rates of political participation have remained stubbornly low among vulnerable groups—particularly among young, minority, uneducated, and low-income citizens (Leighley and Nagler 2013). Why don't more people vote?

Foundational models of voter turnout suggest that time (or a lack thereof) might be a key reason. For example, the resource model of voting predicts that citizens who "have more free time [to] spare for politics" will be more likely to be civically engaged (Verba, Schlozman, and Brady 1995, 291; see also Schlozman, Brady, and Verba 2018). Despite this clear theoretical prediction, very little research has explicitly explored the role of time-based inputs for citizen participation (Smets and Van Ham 2013). Yet, previous empirical work provides some—albeit very limited—evidence that this gap is unfortunate. In surveys, when asked directly why they do not vote, many nonvoters report "not having enough time"—or a close derivative (e.g., "I'm too busy" or "[Voting] takes too long"; Pew Research Center 2006). Moreover, recent studies suggest that levels of turnout may be shaped by time costs such as how long it takes to register to vote (Leighley and Nagler 2013), to find and travel to a polling location (Brady and McNulty 2011; Dyck and Gimpel 2005), and to wait in line to vote (Pettigrew 2016).

While this work suggests that time-based inputs may play a large role in affecting who votes, it has important limitations. First, teasing apart the role of time-based inputs from other factors has proved difficult. Previous work has mostly relied on conditional on observables approaches rather than exogenous changes to the time cost of voting. As such, it has struggled to estimate the causal effect of time independent from other factors. Second, prior causal work has narrowly focused on variation in time costs related to the act of voting itself. As a result, we are left with little sense of the potential political consequences of differences in how individuals manage their time. We argue that for busy citizens with jobs, families, and other responsibilities, voting decisions might be shaped not only by the time it takes to cast a ballot but also

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by the broader time-related factors that regulate their everyday lives. Crucially, certain segments of the population may be more constrained by their daily schedules than others.

Do differences in time constraints causally affect turnout decisions? And do they attenuate or exacerbate participatory inequalities? To help address these glaring gaps in the literature, we explore the political consequences of plausibly exogenous variation in time-based inputs. Specifically, we use a novel geographic regression discontinuity design (GRDD) that leverages the precise location of US time zone borders. As we describe in great detail below, the first-order effect of time zone boundaries is to shift the labeled time in a given location, which fundamentally affects how individuals allocate their waking hours across the day. This change allows us to estimate the causal effect of the disruption in time allocations that occurs at these boundaries as individuals do not fully adapt their social schedules to patterns of ambient light (for reasons we discuss below). This discontinuity has been used previously in economics and medicine to study the effects of time use on health and productivity—with recent studies showing that individuals living on the eastern side of the time zone boundaries are generally worse off, given the disruptive nature of this boundary (e.g., Giuntella and Mazzonna 2015; Gu et al. 2017; Heissel and Norris 2018). Using county-level data from 1992 to 2014, we find—consistent with prior work looking at economic and health outcomes—that turnout is 1.5–3 percentage points lower in counties located on the marginally eastern side of US time zone cutoffs relative to counties on the marginally western side. This effect is magnified in low-turnout communities—thus, serving to exacerbate participatory inequality—and pushes election results toward Republicans.

These findings are vitally important, regardless of the exact mechanisms at play. They provide direct causal evidence that local differences in daily schedules make it more difficult to vote and significantly affect the composition of the electorate. But, what exactly might be driving these time allocation effects? Fully cognizant of the inherent difficulties of mechanism testing (Green, Ha, and Bullock 2010), we provide suggestive evidence of one potential explanation. Building on prior work in other fields and drawing from rich time-use data not often used in political science, we find that time zone discontinuities trigger behavioral effects that may have downstream effects on turnout. Namely, individuals living on the marginally eastern side of a time zone border are 5 percentage points ($p < .01$) less likely to achieve recommended levels of daily sleep (at least 7 hours). Citizens appear to replace this sleeping time with additional leisure. This suggests that, *even though* citizens on the eastern side of the boundary have more free time, they may be less likely to vote, perhaps because they are too tired to do so. This finding represents an important departure from the predictions of the resource model of voting, which imply that free time will uniformly increase levels of civic participation (Schlozman et al. 2018; Verba et al. 1995). Our results suggest that this core assumption might need to be updated to reflect a more nuanced relationship between time and levels of civic engagement. Moreover, just because time is equally distributed does not mean that additional allocations of time will narrow participatory inequality, as some have explicitly argued (Schlozman et al. 2018; Verba et al. 1995). Indeed, the time zone disruption, which provides citizens with additional waking time, appears to do quite the opposite: making it less likely that low-propensity citizens turn out to vote. Simply put, we provide a compelling real-world example that when free time comes at the expense of other time-based inputs (e.g., sleep)—which have been ignored in the literature—the result is a decrease in overall turnout and an increase in participatory inequality.

Our findings hold across numerous robustness checks. Our preferred specification leverages variation within states that are split between time zones and absorbs many potential confounds, but we also show that a host of covariates are balanced across the cutoffs. Although individuals may conceivably be aware of time zones when deciding where to live, we find no differences in population sizes, migrations, housing prices, and commute distances (to name a few) around the borders. We also conduct permutation tests to demonstrate that our effects are not the result of the idiosyncratic distribution of counties around time zone borders. Furthermore, we show that the negative effect on turnout is present across all four time zones in the contiguous United States and persists across different electoral contexts. In an additional test, we use archival data and focus on the few states that most recently changed time zone boundaries in significant ways. Finally, we explore the possibility that the time zone effects we document are moderated by the convenience of voting. Consistent with this explanation, we find that the demobilizing effects of time zones are magnified when it rains—that is, when voting is more difficult. Our results are remarkably robust across all checks—suggesting that exogenous disruptions to time allocations do, indeed, affect voting.

Our findings have significant theoretical implications for the study of low and unequal participation. Our approach focuses on how time allocations shape opportunity costs, that is, the relative preference for displacing voting with other behaviors. Overall, our results show that time-based inputs influence elections beyond the time it takes one to vote. While many factors influence turnout, the forces that shape individuals' everyday experiences appear to play an underappreciated role in political behavior (Egan and Mullin 2012).

Importantly, our results indicate that finding time to vote may be more difficult for marginalized segments of the electorate. This departs from previous work on the role of time in turnout, which describes time as a great equalizer (Schlozman et al. 2018; Verba et al. 1995). We contend that a democratic system in which the main cost of participation is time rather than money may still be significantly stratified, even if leisure time is more equally distributed than money.

We also consider the practical implications of our findings. Our design takes voting rules as given and instead highlights how local context constrains political behavior. This approach abstracts away from recent convenience voting laws such as early voting and nonexcuse absentee ballots but still lends insights to how to target interventions seeking to increase voter turnout. First, our findings show that the current administration of elections appears to be more conducive to the preferences of individuals living on the western side of the time zone border. This contributes to recent work showing that where individuals live influences their voting decisions (Enos 2017) and suggests that adjusting voting rules and programs to better fit local contexts may increase turnout. Second, the potential sleep mechanism speaks to a salient public health debate. Over recent decades, Americans have tended to sleep less (Huffington 2016; Jones 2013). Our findings provide evidence of the potential link between sleep deprivation and another individual well-being outcome: civic engagement. In all, our work highlights the need to place greater focus on time as a voting input and to explore the contextual factors that shape its political consequences.

THE POLITICAL CONSEQUENCES OF TIME CONSTRAINTS

Our conceptual framework builds on a large theoretical base that views time as a key component of the cost of participating in politics (e.g., Verba et al. 1995; Wolfinger and Rosenstone 1980). The relationship between time allocations and voting is consistent with various theories of turnout, including rational choice, resource, psychological, and sociological models. While these models differ in many ways, they agree that casting a ballot is costly and that time is a vitally important voting input.

In their seminal work, Verba et al. (1995, 333; see also Schlozman et al. 2018) argue that time is a core participatory resource (standing prominently alongside money and skills) and that a democratic system built on time reduces political inequalities: "In sharp contrast to money, spare time is not differentially available to those who are in other ways privileged by virtue of their occupation, race, or ethnicity. The implications for political activity are profound. If the necessary resource is money, politics will be more stratified than if the necessary resource is time." To support their claim, Verba et al. (1995) provide descriptive evidence that leisure time is more equally distributed than money.[1] Yet, their conclusions hinge on the assumption that individuals who have more free time will be uniformly more willing to participate in elections. In this article, we contend that this is not necessarily true. In our view, the opportunity cost of voting depends not only on how long it takes to vote and how much time individuals possess overall but also on whether they are able to balance their broader life constraints and find time to vote.

Focusing on the latter allows us to address several gaps in the literature. First, prior work suggests that citizens who are more constrained by family, work, or social obligations are less likely to vote (e.g., Stoker and Jennings 1995). However, few, if any, studies have explored the effects of exogenous changes in time allocations. As a result, it has proved difficult to tease apart the role of time-based inputs from other unobserved influences that shape the cost of voting. Second, recent work indicates that marginalized segments of society struggle to find time to overcome barriers such as the distance to a polling location and waiting in line to vote (Brady and McNulty 2011; Pettigrew 2016). However, these findings do not necessarily imply that time allocations increase participatory inequality. Instead, they may indicate that the administration of elections is more conducive toward the preferences of higher income individuals. For example, wealthier citizens may be more likely to own a car or to live in a desirable neighborhood with easy access to infrastructure needed to navigate elections.

We argue that differences in time allocations shape citizens' relative preference for displacing voting with other behaviors. By investigating the effects of exogenous changes in daily schedules, our work contributes to our understanding of low and unequal participation and its consequences for democratic representation. We return to a discussion of why time allocations may influence voting in our examination of potential mechanisms below.

TIME ZONE DISCONTINUITIES

Our empirical analysis aims to expand the scant literature on the time-based inputs of voting by exploring the political consequences of exogenous disruptions in daily schedules that are independent from the time it takes to vote. To do so, we leverage a unique naturally occurring quasi-experiment. Briefly, our approach leverages an exogenous shift in time

1. This view is broadly consistent with systematic studies of time use, although the literature documents growing inequality in leisure time that mirrors the growing inequality of wages and expenditures since the 1990s (Aguiar and Hurst 2007).

allocations at the boundaries of US time zones. Within each time zone, the time at which the sun rises and the sun sets varies continuously as a function of longitudinal (east-west) and latitudinal (north-south) location. By convention, however, counties located on the eastern side of time zone cutoffs have their clocks shifted one hour ahead compared to counties on the western side. Near the border, this results in a discontinuity in labeled times. Although the physical sunset time is about the same, it usually gets dark around 5:00–6:00 p.m. on Election Day in counties located on the marginally western side of the border and around 6:00–7:00 p.m. in counties located on the marginally eastern side. Thus, our treatment consists in a shift in sunrise and sunset times relative to social schedules at the time zone cutoffs. This treatment results in a bundle of changes that we argue are vitally relevant for political behavior.

For reasons that we elaborate in the Potential Mechanisms section below, individuals do not fully adapt their social schedules to patterns of ambient light, and the fit between the two appears to be worse on the eastern side of the time zone border. This "circadian disruption" affects human behaviors across a number of important domains. For example, Giuntella and Mazzonna (2015) show that time zone boundaries fundamentally change citizens' behavioral responses in the health domain—with those on the eastern side of the time zone boundary (where it gets darker later) having lower levels of health (see also Gu et al. 2017). Similarly, scholars have shown that time zones affect individuals' cognitive skills (Heissel and Norris 2018)—again, with those on the eastern side of the boundary performing at a lower level.[2]

This design constrains us to estimating an intent-to-treat effect, as exact patterns of individual compliance with shifts in daily schedules are inherently difficult to observe. However, if time allocation disruptions on average negatively affect behaviors on the eastern side of the time zone boundary, they may also negatively affect political behavior.

Quasi-experimental design

The key assumption underlying our design is that close to cutoff the assignment of counties to specific time zones is unrelated to other factors that may affect turnout today. We discuss and explore this assumption in greater detail below. Yet, on its face, it seems plausible when we look at how the four main US time zones (eastern, central, mountain, and pacific) were officially established in the Standard Time Act of 1918 (Shanks 1987). Borders had originally been drawn by the Interstate Commerce Commission based on a "convenience of commerce" principle, determined by an agreement the major railroads had reached in 1883 to coordinate their clocks in order to regulate traffic. The Uniform Time Act of 1966 placed the authority to make occasional changes to time zone boundaries with the US Department of Transportation—a fact we use to test the robustness of our identification strategy.

As time zones are arbitrarily defined administrative boundaries that split individuals into areas with different times, and thus daily schedules, they are well suited for a GRDD. As long as these barriers divide subjects in an as-good-as-random manner, the GRDD will estimate causal effects (Keele and Titiunik 2015). This seems most plausible when geographic boundaries do not overlap with major political boundaries. Time zones follow county borders but often cut through state borders.[3] Thus, in our preferred approach, we focus on states that are split between two time zones. At present, 13 states in the contiguous United States fit this description.[4] Moreover, 2 states (NM and MT) are located in one time zone but span large distances between borders and, thus, contain both treated and control observations. These split states allow us to estimate GRDD models augmented with state, year, and state-by-year fixed effects. Figure 1 illustrates the assignment of counties to treatment and control in our design.

As we show below, our results are robust when we use within-county variation in states where time zone boundaries were most recently changed. This provides an even more conservative approach, which leverages changes within the same county across our discontinuity. This check comes at the expense of restricting our analysis to Indiana and Kentucky, thus potentially constraining the external validity of our estimates. Before the 1960s, Indiana and Kentucky were, for the most part, located in the central time zone. However, between 1960 and 1961 both states were divided into roughly equal parts between the central and eastern zones. In 1967, after conducting numerous hearings, the US Department of Transportation placed most of Indiana in the eastern zone—leaving counties adjacent to Chicago in

2. These results are consistent with studies that show that other exogenous time disruptions—such those that come around the start and end of daylight savings time (DST)—affect crime (Doleac and Sanders 2015) and driving (Smith 2016).

3. A few (10) counties allow small towns to follow the neighboring time zone. We use centroids to code these counties, but our results are robust when we drop them from the analysis.

4. States with counties in two time zones are ID, OR, AZ (during DST), ND, SD, NE, KS, TX, MI, IN, KY, TN, and FL. Note that some counties in states such as AZ and IN do not observe DST, whereas others do (results are robust to excluding these states). Election Day is usually on Tuesday after the end of DST but fell during DST in 2010.

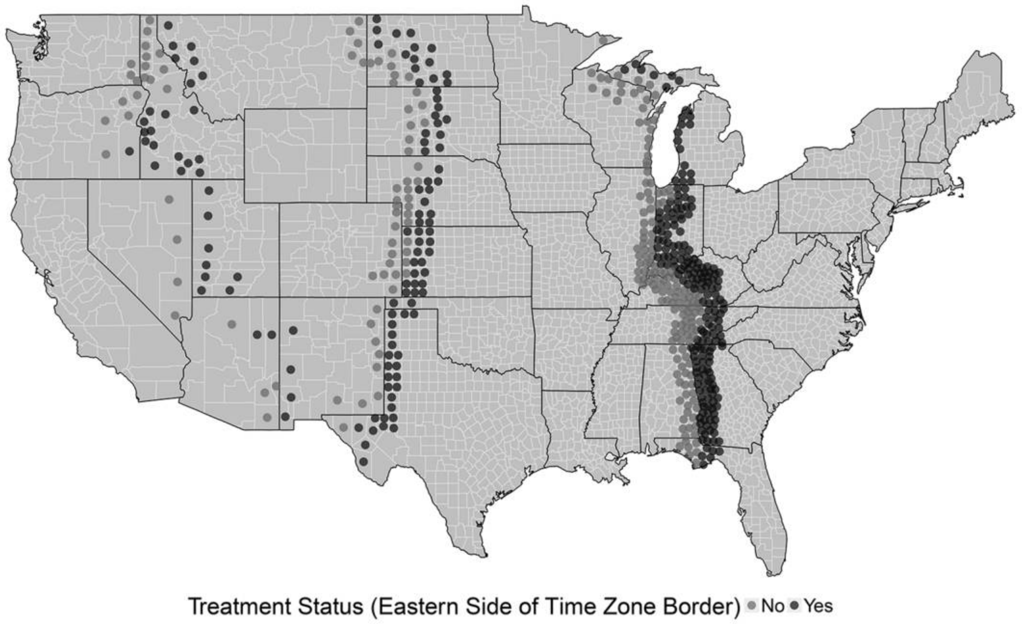

Figure 1. Visualizing the time zone GRDD. Counties (with their geographic centroids marked) within 1 degree (latitude and longitude) of the time zones in the contiguous United States as of Election Day in 2010.

the central zone. The distribution of counties was changed again in 2005–7, with seven counties switching across the time zone boundary during that period. The most recent change in Kentucky occurred in 2000, when Wayne County switched from the central to the eastern time zone (Shanks 1987). This allows us to estimate GRDD models augmented with county fixed effects. These checks provide a level of internal validity rarely achieved in GRDD studies given that many treatments with political consequences only vary at state boundaries (Clinton and Sances 2018; Keele and Titiunik 2015).

In their work discussing the conceptual and practical issues associated with the GRDD, Keele and Titiunik (2015) show that under modest assumptions, which we explore in our checks, this model behaves as any other standard RDD with two running variables. In our case, these are the latitudinal and longitudinal movement (in degrees) in the chordal distance from the center of a county to the nearest contiguous US time zone cutoff.[5] Decomposing the chordal distance into two dimensions accounts for the idiosyncratic assignment of counties located at similar geographic coordinates.[6] However, our results are robust to alternative direct distance specifications. Consistent with our identification strategy, we code the running variables as positive on the eastern side of the border and negative on the western side.

Data

Our data set combines information from election results, geographic maps, the Census, and the American Time Use Survey (ATUS). We outline these data sources here.

Elections data. For our primary outcomes of interest—voter turnout and election results—we use Dave Leip's atlas (https://uselectionatlas.org/) of county-level electoral returns for general elections between 1992 and 2014.[7] This repository provides the most comprehensive collection of election results over time at the county level. The unit of observation in this data set is the county-year. With about 3,000 counties in the contiguous United States spanning midterm and presidential elections over a 12 year period, our total sample size is just over 36,000. We calculate voter turnout as the number of votes divided by the total population. We do this because estimates of the county-level voting-age population vary in

5. One degree of latitude is approximately 69 miles. One degree of longitude is approximately 53 miles at the latitude of New York City and 62 miles at the latitude of Miami.

6. For example, the northern part of ID is on Pacific time, whereas the southern portion is on mountain time (see fig. 1). Note also that our setup excludes time zone boundaries at sea and with Canada/Mexico because they lack a counterfactual.

7. We have validated that our results hold at the individual level in nationwide voter file samples from Catalist (https://www.catalist.us/; results available on request). We also explored using the Cooperative Congressional Election Survey as another check, but, unfortunately, our results are underpowered because of the small number of observations near the time zone thresholds.

their availability over time, while the total population is available in all years. However, the results are equivalent when adjusting for available measures of the voting-age population (see fig. A9; figs. A1–A12 are available online).

Geographic data. To execute the analysis for this natural quasi-experiment, we use the geographic software ArcGis 10.3. We retrieved county shapefiles from the Census and matched these with historically accurate time zone shapefiles. In order to estimate chordal distances between the county centroid and the time zone cutoff, both shapefiles were projected into a two-dimensional plane.[8] We then computed distances to the nearest time zone cutoff using ArcGis.

Archival data of time zone boundary changes. In a robustness check, we leverage historical changes in the location of US time zones. Most of these changes occurred before the period of analysis used in the rest of the article (1992–2014). Thus, we extend the timeframe of our study to also include data from Indiana and Kentucky from 1948 to 1992.[9] In order to code historically accurate geodata, we use the archive of US time zone changes documented in Shanks (1987).

Census data. To explore potential mechanisms and the balance of observable characteristics across the time zone boundary, we use data from the US Census Bureau (American Community Survey and decennial Census) and the ATUS. The Census data are widely used and include a host of information about the types of people who live around the time zone boundary. The ATUS has been conducted by the US Bureau of Labor Statistics since 2003. We specifically employ data from the ATUS over the years 2003–15, with a sample size for these several waves that varies between 8,000 and 13,000. The ATUS sample is drawn from the existing sample of Current Population Survey participants. Respondents are asked to fill out a detailed time-use diary of their previous day. This rich data set has rarely (if ever) been used in political science applications—further illustrating the dearth of studies on time-based inputs.

With the Census and ATUS data, we are able to look for imbalances that might explain our results. Our intent is to be as thorough as possible. In total, we look for imbalances along 99 observable dimensions.

8. We accessed these maps using the web page http://efele.net/maps/tz/us/ and restrict the analysis to the 48 contiguous US states.

9. This data set comes from Fujiwara, Meng, and Vogl (2016). Because of incomplete midterm election data during this time period, we use only presidential election years.

Method

To estimate our GRDD models, we fit the following equation:

$$V_{ct} = \alpha + \beta_1 T_{ct} + \beta_2 Y_{ct} + \beta_3 X_{ct} + \beta_4 T \times Y_{ct} + \beta_5 T \times X_{ct} + u_{ct}, \tag{1}$$

where V_{ct} is the proportion of individuals who turn out to vote in a given county (c) and a given election year (t).[10] The variable T is an indicator taking the value 1 if a county is situated to the east of the closest neighboring time zone boundary and 0 if it is on the western side. The variables Y (distance latitude) and X (distance longitude) are positive on the eastern side of a time zone boundary and negative on the western side. As recommended in regression discontinuity applications (e.g., Lee and Lemieux 2010), we allow these to vary flexibly on either side of the cutoff. This estimation strategy controlling for geographic distance reflects the assumption that assignment to treatment and control is as-if random in the vicinity of the cutoff (Keele and Titiunik 2015). However, we also report results from a nonparametric model using the running variable and bandwidth criterion suggested by Calonico, Cattaneo, and Titiunik (2014).

As can be seen in figure 1, time zone borders often follow state lines. This raises the concern that other state-level factors may confound the estimates from equation (1). Yet, we address this issue by leveraging the states that are split between two time zones. This offers an opportunity to use an even stronger model specification that addresses potential state-level confounds. This approach estimates the effect of treatment with the inclusion of the full set of state-by-year fixed effects. It absorbs the confounding effect of all state (battleground status, electoral rules, the time the polls close in a given state, etc.) as well as time (electoral contexts, presidential vs. midterm, etc.) and state-time (differences in candidates or campaigns, competitiveness, etc.) factors that may be imbalanced at the cutoff. This more conservative specification represents our preferred model. However, the addition of fixed effects does not alter the substantive interpretation of our results.

The key identifying assumption underlying this design is the continuity of the conditional expectation function of the running variable. This requires that individuals cannot precisely sort or self-select to one side of the boundary on the

10. We conceptualize treatment at the county-year level (ct), given that all decisions to be on one side of the time zone or the other near the cutoff are determined for each county in a specific period. Hence, our elections data are collapsed to the level of the treatment, addressing potential correlations in our standard errors (Angrist and Pischke 2008). However, our preferred estimates with fixed effects remain discernible from 0 over a large bandwidth even if we cluster at the county level.

basis of factors that are also correlated with the outcomes of interest (Keele and Titiunik 2015). While sorting is inherently difficult to rule out in a GRDD and continuity is a difficult assumption to validate (as is the case in all RDD applications), we demonstrate below that observable time-varying factors overwhelmingly show balance at the cutoff and that our results are robust to modeling choices that rule out imbalances of various forms through the inclusion of fixed effects of several types.

In order to assess whether our results may be biased by preexisting differences, we leverage archival data on historical changes to time zone boundaries. With these data we estimate a similar model with county and year fixed effects, which allows for even stronger comparisons. Again, as we show below, our main results are robust to this augmentation—adding even further credence to the strength our design.

Our last series of robustness checks explores whether our results are driven by various potential confounds—observed or unobserved. These checks see whether our effects are driven by one of the specific time zone cutoffs (eastern-central, central-mountain, mountain-Pacific), electoral context (i.e., presidential or midterm), individual states, individual counties/localities, or unobserved idiosyncratic distribution of counties around time zone borders. Our results are remarkably consistent across all of our checks—providing more evidence supporting the robustness of the design.

Heterogeneities

We also investigate several theoretically compelling heterogeneities. First, we explore whether participation on the eastern side of time zone cutoffs is not only lower but also more (or less) unequal. This test is of theoretical interest given that citizens who have different vote propensities may vary in their ability to deal with disruptions to their daily schedules. If lower propensity citizens were to have a harder time dealing with broader time constraints, we would expect to see greater levels of participatory inequality. To examine whether our time disruption effects vary by baseline vote propensity, we use quantile regression. This approach is an empirically driven way of exploring treatment heterogeneity (Gamper-Rabindran, Khan, and Timmins 2010). Rather than focus on average treatment effects only, quantile regression examines the effect of treatment on the conditional quantiles of the dependent variable. The advantage of this approach over stratification-based (or similar interaction) approaches is that it avoids arbitrary decisions regarding how to define high- and low-propensity subgroups and provides a more comprehensive mapping of treatment effects over the distribution of the dependent variable (Angrist and Pischke 2008, chap. 7). By comparing various quantiles across treatment and control rather than the mean, it permits us to show how treatment affects the entire distribution of the outcome.[11]

Because time allocation disruptions may shift not only overall levels of turnout but also the composition of the electorate, we explore whether time zones potentially affect which party gains votes. Inasmuch as right-wing parties tend to benefit from lower, more unequal, turnout (Hansford and Gomez 2010), we would expect to see the time zone disruption bleeding into electoral outcomes and nudging electoral returns toward Republicans. To explore this possibility, we simply substitute Democratic two-party vote share in races for the House of Representatives (D_{ct}) as the dependent variable in our GRDD and GRDD and fixed effects models. If time zones move this outcome, we can conclude that exogenous changes to time allocations affect not only electoral participation but also election results. To further unpack the roots of these party effects, we explore the "two effects hypothesis," which posits that the relationship between turnout and vote share is conditioned by political context (Hansford and Gomez 2010).

Third, to examine whether our effects are moderated by voting costs (i.e., whether time-disrupted citizens have a harder time overcoming other obstacles that stand in their way), we explore whether our GRDD estimates vary along exogenous increases in voting obstacles. To do so, we use rainfall as a proxy. Several studies have shown that rainfall negatively affects voting by placing an additional hurdle in voters' way (Fujiwara et al. 2016; Gomez, Hansford, and Krause 2007; Henderson and Brooks 2016). This literature has also shown that rainfall is exogenous, hence, making this subgroup analysis plausibly causal.[12]

RESULTS

Figure 2 plots a nonparametric GRDD model showing that exogenous shifts in time allocations affect turnout. As can be seen, there appears to be a disruption on the eastern side of the time zone boundary. Specifically, we observe a clear decline in voter turnout of about 2.2 ($p < .001$) to 3.2 percentage points ($p < .001$), at the boundary between observations on the east (the right side of the graph) and those on the west side (the left of the graph) of the time zone cutoff.[13]

11. In our GRDD, quantile regression models, we omit the state-by-year fixed effects, given the difficulties associated with combining these two methods (Gamper-Rabindran et al. 2010).

12. Our results are robust if we instead split our sample by how hard it is to register and vote in a given state, which may be endogenous.

13. The first effect comes when we use longitudinal distance (CCT bandwidth = 1 degree), the second if we use Euclidean distance (CCT bandwidth = 1.3 degrees; Calonico, Cattaneo, and Titiunik 2014).

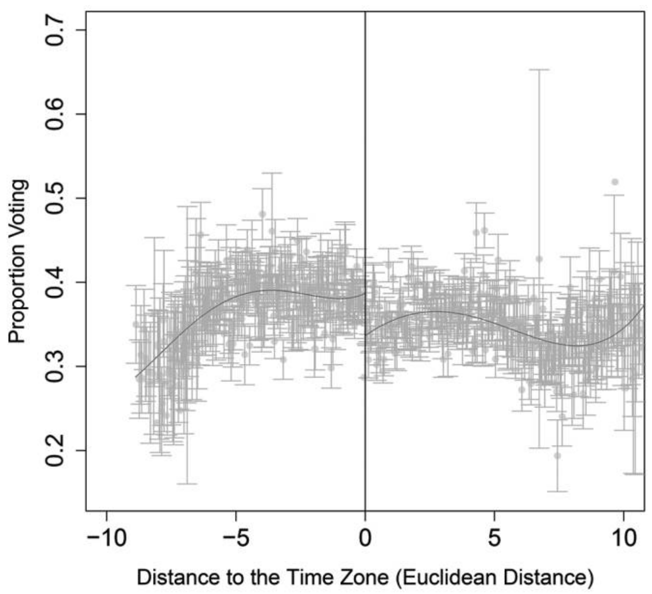

Figure 2. Effect of being on the eastern side of a time zone border on voter turnout. Local polynomial (order 4) fit of county-level turnout over 1992–2014 (as share of the total population), implemented with the rdplot command in R. Results come from a specification of the GRDD with CCT optimal bandwidth (1.3 degrees) and local polynomial regression (Calonico, Cattaneo, and Titiunik 2014). Points represent bin averages, with corresponding 95% confidence intervals shown with the corresponding bars. When the distance crosses the threshold from being located barely to the west to being located barely to east, the level of turnout drops noticeably: being lower by approximately 3.2 percentage points ($p < .001$). $N = 35,282$. Corresponding results focusing on split states in figure A6.

This effect is noticeable—representing approximately 20%–30% of a standard deviation in voter turnout.

Figure 2 also shows that the relationship between geographic location and turnout overall is relatively smooth and continuous across geographic location. The function modeling the relationship appears to be approximately constant on either side of the cutoff within about 3 degrees of the time zone border. This suggests that there is little evidence of competing treatments relevant to voting varying near the cutoff (Lee and Lemieux 2010). Moreover, figure A6 shows that our nonparametric estimates are robust and similar in magnitude when we restrict the data set to states that either are split between or span two time zones. This indicates that our first set of results is not driven by the partial overlap between state and time zone boundaries.

Figure 3 shows this effect with state-by-year fixed effects—our preferred modeling approach. It provides point estimates at different bandwidths. In the narrowest specification—the least exposed to confounding influences away from the cutoff—the estimate suggests that treatment assignment decreases turnout by 1.81 percentage points ($p < .001$). The lowest point estimate (−0.38 percentage points) includes observations within 5 degrees of the cutoff. There is evidence of a bias-variance trade-off: the estimates are stable and become more precise in the first 3 degrees but decrease in size afterward. Even in these models, however, there is evidence of an effect. In subsequent analyses and robustness checks, we focus on estimates using a 1 degree bandwidth (1.49 percentage points, $p < .001$), which appears to be both close to the cutoff and precisely estimated. In all, these results suggest that the time disruption that occurs at the time zone boundaries has a negative effect on voter turnout.

As shown in figure A7, the decline at the time zone border remains negative and significant in both presidential and midterm election years. The effect is also robust when examining the time zone cutoffs individually (eastern, central, and mountain) and to including a large number of political and demographic controls.

Next, to demonstrate that our effects are not biased by unobserved county-level differences—such as the local administration of elections or any other time-invariant local factor—we use historical data from changes in time zone boundaries in the states of Indiana and Kentucky. This approach is identified on the basis of Indiana and Kentucky counties that change time zones.

Figure 4 shows that being in the eastern rather than the central time zone causes about 2 percentage points lower turnout over the period of interest. These within-county effects are consistent with our within-state estimates, which further corroborates our quasi-experimental design.

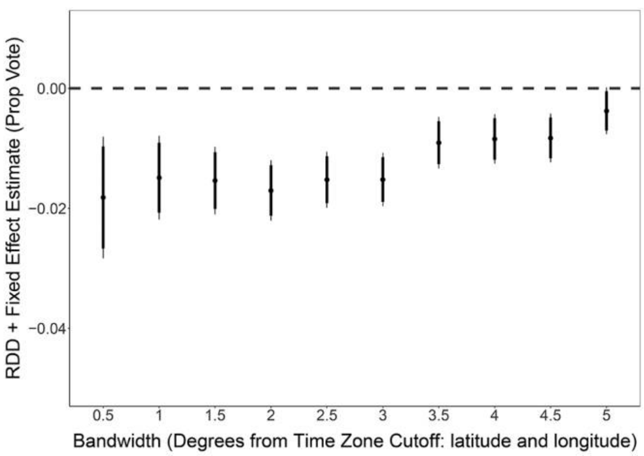

Figure 3. Coefficient estimates for the effect of being marginally on the eastern side of the time zone cutoff on county-level turnout (1992–2014), comparing only counties in the same state and in the same election year. Coefficient estimates are shown as points, with corresponding 90% (*wider*) and 95% (*narrow*) confidence intervals also shown. Results come from a GRDD specification outlined in equation (1), augmented with state-year fixed effects. Model N from left to right: 3,089, 6,293, 9,206, 12,002, 14,597, 17,290, 19,906, 22,262, 24,671, 27,032.

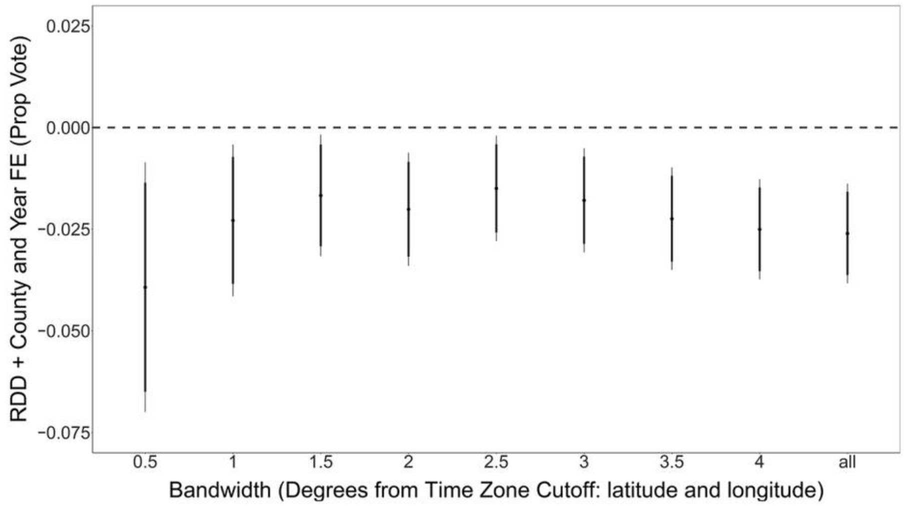

Figure 4. Coefficient estimates for the effect of being marginally on the eastern side of the time zone cutoff on county-level turnout in Indiana and Kentucky (presidential election years only as percentage of the voting-age population) for 1948–2014, comparing only same counties and while controlling for election year. Coefficient estimates are shown as points, with corresponding 90% (*wider*) and 95% (*narrow*) confidence intervals also shown. Results come from a GRDD specification outlined in equation (1), augmented with county and year fixed effects. Model *N* from left to right: 1,106, 2,042, 2,851, 3,274, 3,457, 3,496, 3,520, 3,539, 3,546.

Additional robustness checks

To formally explore whether our results are confounded by other factors that affect voting, we employ data of county-level characteristics from the US Census Bureau and report the results in figure A3. Across the 39 covariates observed in the Census files, only one—the proportion American Indian—shows signs of imbalance, and we do not find that the covariates are jointly different from 0. We find balance on demographics including age, race, gender, education, and income. Importantly, we find no evidence of imbalances in population, migrations, commute distances, and housing prices—suggesting that individuals are not precisely sorting around the time zone cutoffs.

Finally, to investigate whether our results might be driven by a chance distribution of counties around the time zone cutoff, we execute a series of permutation tests often used in GRDDs (e.g., Clinton and Sances 2018). This entails randomly shuffling counties and iteratively estimating the same specification as in equation (1). This series of placebo tests offers a strong check of natural experiments' validity. With these, we show that only 0.6% of our placebo estimates are as large as those we observe in our preferred specification (see fig. A4). Only very rarely do we obtain a placebo estimate that is greater than or equal to the observed estimates. This shows that our results are not driven by the idiosyncratic distribution of counties unrelated to our treatment.

Participatory inequality

Next we estimate the turnout effects with quantile regression models. If time zones were to demobilize low-propensity citizens more—as theory would predict—we would expect to see stronger effects at the bottom of the voter turnout distribution than at the top.

Our empirical findings comport with this prediction. Figure 5 shows this visually by plotting the estimated coefficients across turnout deciles. The effect of time zones on turnout is noticeably larger (in absolute value) in lower propensity areas than in higher propensity areas. These results indicate that time zones have their largest negative impact where turnout is already low—thus exacerbating participatory inequality. It appears, then, that time disruptions are particularly harmful in low-propensity areas, where the additional burden of a shift in time allocations appears to be more difficult to overcome.

Partisan effects

We have just shown that our exogenous shift in time allocations lowers turnout and does so in a way that significantly exacerbates participatory inequality. Given previous research, we would expect that such a change in the level and composition of the electorate points toward potential differences in electoral returns—with these effects possibly working against Democrats, who tend to do better in situations with higher turnout overall and higher turnout from low-propensity citizens in particular. We explore whether this is the case here. We do so by running regression discontinuity models with state-by-year fixed effects but this time with Democratic two-party vote share as the outcome variable.

Comporting with our expectations, our results suggest that the exogenous change in time allocations produces a distinct disadvantage to Democrats and, conversely, advantage to

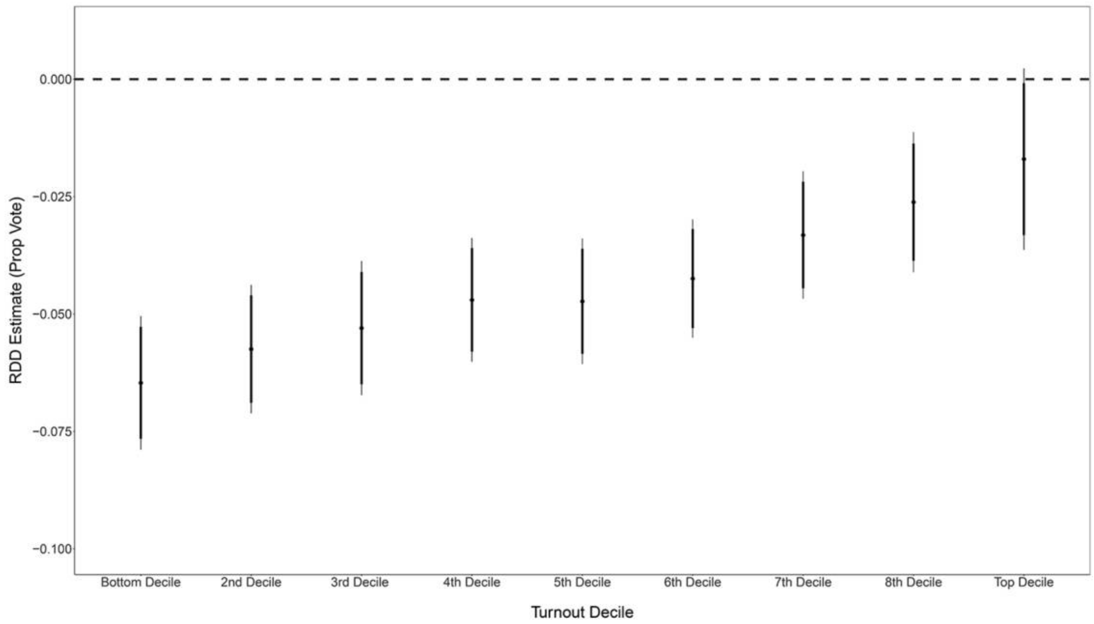

Figure 5. GRDD and quantile regression. Coefficient estimates for the effect of being marginally on the eastern side of the time zone cutoff on county-level turnout decile levels for 1992–2014. Coefficient estimates are shown as points, with corresponding 90% (*wider*) and 95% (*narrow*) confidence intervals also shown. Each coefficient shows the results from a separate RDD, quantile regression discontinuity model with a 1 degree bandwidth (latitude and longitude). Fixed effects are not included given the inherent difficulties of estimating quantile regression models with fixed effects (Gamper-Rabindran, Khan, and Timmins 2010). $N = 6,293$.

Republicans in elections for the House of Representatives. Figure 6 shows the effect of being on the eastern side of the time zone cutoff (i.e., the exogenous decrease in turnout) on Democratic vote share. We report results from both the simple GRDD and our preferred within-state specification. We find that the heterogeneity in turnout effects appears to translate into decreases in vote shares by 1.7–2.3 percentage points for Democratic Party candidates.[14] This effect is statistically significant and substantively meaningful.[15] It represents about 8%–10% of a standard deviation in Democratic two-party vote shares. When races for Congress are close, time zones have the potential to swing election outcomes toward Republicans.

These partisan effects are consistent with previous work showing that Democrats are particularly demobilized by voting obstacles (e.g., Brady and McNulty 2011; Hansford and Gomez 2010; Henderson and Brooks 2016). Scholars have argued that this heterogeneity occurs because "Democratic voters, in particular, are sensitive to such costs, since they lack many of the participation-relevant resources of their wealthier Republican counterparts" (Henderson and Brooks 2016, 656). In the appendix (available online), we provide additional evidence indicating that time zone effects tend to demobilize the Democratic voters in predominantly Republican constituencies but not to demobilize Republicans in Democratic constituencies (see fig. A11). This suggests that the partisan differences follow from heterogeneities in the effect of time zones on voter turnout.

In all, these effects line up with those shown in figure 5. It appears that in disrupting time allocations, time zones demobilize low-propensity voters the most, thus exacerbating participatory inequality and pushing elections toward Republicans.

POTENTIAL MECHANISMS

Our identification strategy allows us to demonstrate that the precise locations of US time zone boundaries have significant political consequences, and our robustness checks indicate that the decline in turnout on the eastern side of the time zone border is not a result of potential political confounds. But what exactly is behind these time allocation effects? Below we explore two alternate pathways indicating that voting is more difficult on the eastern side of US time zone borders. We emphasize the suggestive nature of these findings given the inherent difficultly of establishing causal mechanisms (Green et al. 2010).

14. Midterm ($\beta = -2.2$ percentage points, $p < .05$), presidential ($\beta = -1.2$ percentage points, $p = .26$). These effects are robust and more precise at larger bandwidths.

15. We measure partisan effects with two-party vote shares and turnout effects as a proportion of the total population. With average turnout around 40%, this implies that the number of Democratic votes is reduced about twice as much than the number of Republican votes.

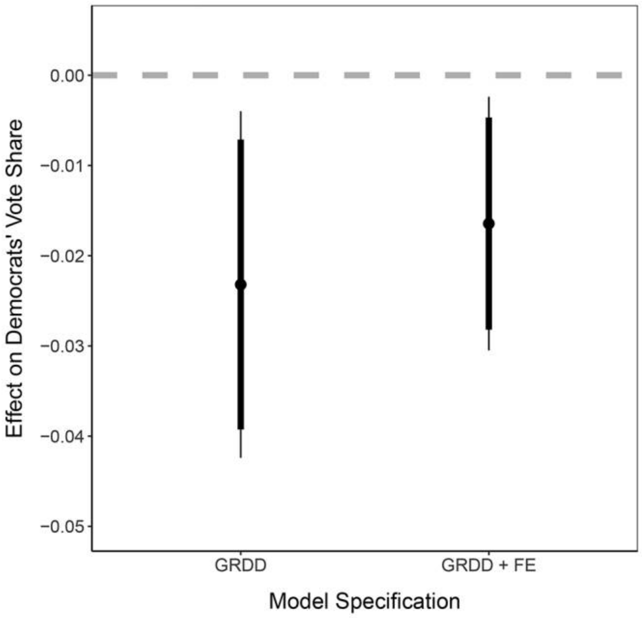

Figure 6. Coefficient estimates for the effect of being marginally on the eastern side of the time zone cutoff on county-level two-party vote share for Democrats for 1992–2014. *Left*, GRDD model; *right*, GRDD and fixed effects model comparing only counties in the same state and in the same election year. Coefficient estimates are shown as points, with corresponding 90% (*wider*) and 95% (*narrow*) confidence intervals also shown. Results come from a model specification of 1 degree on either side of the cutoff (both dimensions of the running variable). $N = 6,389$ in both models.

Sleep deprivation

Recent work in medicine and economics shows that individuals living on the eastern side of US time zone boundaries exhibit a bundle of health and economic behaviors that appear to follow from sleep deprivation (Giuntella and Mazzonna 2015; Gu et al. 2017; Heissel and Norris 2018).[16] The brief intuition is that individuals possess a biological sleep cycle, driven by the presence of "circadian rhythms" or "circadian clocks." These circadian rhythms are biologically influenced by levels of ambient light and may conflict with social schedules (Giuntella and Mazzonna 2015; Heissel and Norris 2018). As the sun sets at a later hour, individuals living on the eastern side of time zones borders tend to go to sleep later. Yet, the time at which they wake up is determined by social schedules, such as going to work or bringing children to school, which remain constant across the threshold. As a result, they will tend to get less sleep. We further explain this sleep effect and its potential sources in the appendix. For example, there we discuss how TV shows aired simultaneously across time zones may contribute to circadian disruptions (Giuntella and Mazzonna 2015).

This circadian disruption at the border of time zones may affect how difficult it is to vote. If individuals who live on the marginally eastern side of time zones tend to get less sleep, they may be simply too tired to vote. Tiredness may also influence turnout indirectly through its downstream effects on health and productivity (see below). The same may be true in politics: when people are tired, they may simply not follow through and vote.[17]

To our knowledge no prior work has systematically examined the link between sleep and voting. Verba et al. (1995, 284, emphasis added) perhaps come the closest, by arguing—but not testing—that "time devoted to an informal community effort is time away from work, family, recreation, or *sleep*." This viewpoint is consistent with their broader theory, which treats time as uniformly increasing participation. Yet, this premise may be misleading. For instance, recent studies in economics show that individuals who achieve an adequate level of sleep tend to be more productive, even though—strictly speaking—time spent sleeping is time away from work (Gibson and Shrader 2018; Giuntella and Mazzonna 2015). The same may hold true in the political realm: obtaining sufficient levels of sleep, although technically leaving less time for civic participation, may actually enhance one's capacity to engage.

To explore this possibility, figure 7 shows the within-state effect of being on the eastern side of the time zone border on levels of sleep reported in the ATUS. Consistent with the potential sleep mechanism, we find that, on average, individuals living on the eastern side of a time zone border report sleeping about 21 minutes less than individuals living on the western side of the border ($p < .02$).[18] While at first glance this may seem like a modest average effect, this change is meaningful in size. It represents 15.3% of a standard deviation, which is equivalent to a 5 percentage point drop in achieving the recommended level of seven hours of sleep a night ($p < .02$). Moreover, this effect is sufficient to trigger health and productivity changes in the real world (Gibson and Shrader 2018; Giuntella and Mazzonna 2015; Gu et al. 2017) and to affect behavior in the lab (Dickinson and McElroy 2017).

Although individuals who live on the eastern side of the boundary have more waking time overall as they sleep less, they appear to spend their available free time less productively. When grouped together in like categories, the ATUS

16. We use the terms "tiredness," "sleep deprivation," and "insufficient sleep" interchangeably.

17. Lab sleep studies have shown that temporary sleep deprivation reduces proxies of prosociality (e.g., Dickinson and McElroy 2017).

18. Data from sleep trackers and the Behavioral Risk Factor Surveillance System show a similarly sized discontinuity in sleep patterns. See fig. A1 and Giuntella and Mazzonna (2015).

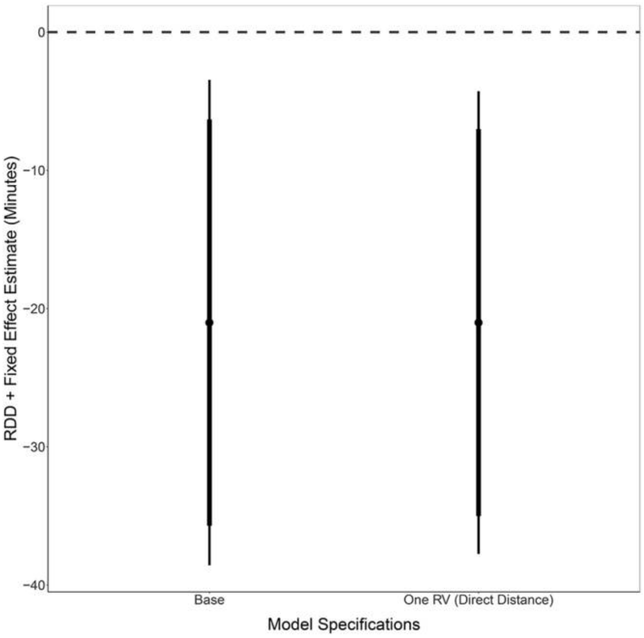

Figure 7. Coefficient estimates for the effect of being marginally on the eastern side of the time zone cutoff on time spent sleeping. Data come from the American Time Use Survey. Coefficient estimates are shown as points, with corresponding 90% (*wider*) and 95% (*narrow*) confidence intervals also shown. Standard errors clustered at the county-year level. Results come from a GRDD and fixed effects specification. $N = 20,042$.

data indicate that people may be more likely to engage in additional leisurely activities. This result is consistent with Giuntella and Mazzonna (2015), who find that people who live east of a time zone boundary exercise less, are generally less healthy and less productive, and tend to eat out more. They argue that insufficient sleep lowers the motivation to perform tasks that may be costly. This suggests that, even though citizens on the eastern side of the boundary have more free time—and, thus, supposedly have an additional resource to be active in politics (Schlozman et al. 2018; Verba et al. 1995)—they may be less likely to vote. This suggests that the core assumption of the resource model related to time (i.e., that more time produces more votes) might need to be updated to reflect a more nuanced relationship between time and levels of civic engagement. If to gain free time people sleep less, they may be too tired to engage.

We note that our results are compatible with other studies that have found important discontinuities in economic and health outcomes at the time zone boundary (e.g., Giuntella and Mazzonna 2015; Gu et al. 2017; Heissel and Norris 2018). In these studies, scholars have shown compelling evidence that people are worse off on the eastern side of the time zone boundary. Theoretically and empirically, these studies have pointed toward a lack of sleep as the most compelling mechanism. Given the strong connection between health, productivity, and voting (e.g., Burden et al. 2017), it seems theoretically plausible that lower turnout may be a downstream result of these secondary channels. Simply put, these imbalances do not threaten our design but rather serve to reinforce the disruptive nature of the time zone boundary and to point toward sleep as a potentially important intervening variable.

One additional result supports a lack of sleep as a potential mechanism. We find that the negative turnout effect is larger in places where the sun sets later in November (i.e., the south over the north; $\beta_{\text{south}} = -0.027$ $[-0.040, -0.014]$; $\beta_{\text{north}} = -0.010$ $[-0.018, -0.002]$, $p_{\text{difference}} < .001$). That is, the turnout effects are magnified in areas where the nudge to go to sleep does not happen until even later—thus potentially exacerbating sleep deprivation.

We show in the appendix that our results do not appear to reflect other changes in how individuals spend their time beyond sleeping less and having more leisure time. To do so, we use other individual-level time-use measures from the ATUS. These include measures of how much time individuals spend working and doing various types of activities. Across the 60 covariates observed in the ATUS relating to how people spend their day, 59 (98.3%) are balanced.[19] The one exception (time spent homeschooling children) is likely the result of chance. These checks, combined with the 39 tests from the Census data mentioned above, lend support to our conceptual framework outlined here. People living on the eastern side of the time zone boundary are not observationally different but appear to simply spend less time sleeping and thus have more waking free time.

Although our findings corroborate the notion that sleep deprivation reduces turnout, we emphasize that they do not unequivocally show that our results are driven by this mechanism alone. Even still, our results are meaningful in that they show that the relationship between quantity of time and levels of civic participation may be more complex than acknowledged in previous work. Not only does the quantity of time matter, so too does how one spends that time.

Convenience of voting

We explore a complementary mechanism suggesting that patterns of ambient light might directly affect the convenience of voting on Election Day. As discussed above, on the eastern side of the time zone boundary, it gets lighter later in the morning (by about an hour) and stays lighter for longer

19. For the full list of measures, see the appendix (Covariate Balance section).

into the evening (by about an hour). Yet, we find lower turnout on the eastern side of the boundary. This shows that this finding is not the result of excess darkness at night. However, our results could be driven by differences in morning darkness. If individuals simply prefer to vote when it is light, then our results could be explained by less convenient voting in the morning on the eastern side of the time zone boundary.

As discussed in greater detail in the appendix, we cannot fully rule out this possibility. To our knowledge, no existing comprehensive data sets show whether more people have voted in the early morning or in the evening on Election Day over the past three decades. However, the available evidence tends to be inconsistent with a convenience of polling hours explanation. During the first part of November, sunrises usually occur by about 6:30 a.m. (with some latitudinal variation). Following a review of polling hours over the period of study, it is clear that most polling locations do not open until after the sun has already risen. Even if we set aside the exceptions where the polls all open at 6:00 a.m. (AZ, IL, IN, and KY), our effect remains (within state: $\beta = -1.5$ percentage points, $p < .001$). The same holds true if we exclude all states with 6:30 a.m. openings (within state: $\beta = -1.5$ percentage points, $p < .001$). This suggests that additional light in the morning is unlikely to explain our effects.

Our fixed effects absorb many of the contextual and political barriers that influence the convenience of voting and could be explaining our findings. However, it is possible that our time zone effect is moderated by the convenience of voting (broadly defined). To explore this possibility, we examine whether the effect of time zones varies when other obstacles to voting are higher. To do so, we focus on levels of precipitation—a commonly used exogenous proxy for Election Day voting costs. Figure A12 shows this heterogeneity visually, by plotting the GRDD coefficient estimates stratified by rainfall levels.

The coefficients are noticeably larger (in absolute terms) when rainfall is higher, that is, when voting obstacles are exogenously higher. When obstacles are lower, the impact of our treatment is significantly reduced and not discernible from zero (although it is statistically significant at larger bandwidths). This interaction suggests that our time zone effect is especially strong when obstacles are high and implies that time zones combine with other channels to make it harder to vote on Election Day.

Overall, we cannot exactly pinpoint whether our results are driven by tiredness, the convenience of voting, a mix of the two, or something else. However, our results are consistent with the clear directional prediction of the sleep mechanism and unequivocally show that voting is more difficult when time allocations are disrupted. This corroborates the conceptual argument of our study: time constraints matter, and tremendously so, but not exactly in the way that has been outlined in previous work.

CONCLUSION

In this article, we have shown that local differences in time allocations have significant effects on levels of turnout and the composition of the electorate. Individuals who are exogenously nudged one hour forward in their daily schedules by time zone boundaries vote 1.5–3 percentage points less than all-else-equal individuals on the other side of the cutoff. Moreover, our results show that this treatment pushes election results toward Republicans. We provide suggestive evidence that these effects may follow from lower levels of sleep and may be moderated by lower convenience of voting on the eastern side of time zone cutoffs. Regardless of the exact mechanisms, our results show that time zones make voting more difficult, exacerbate participatory inequality, and push elections toward Republicans.

These findings have important theoretical implications for the study of the individual motives that drive people to participate in politics. They suggest that relative preferences for displacing voting with other behaviors are affected not only by how long it takes to vote but also by how citizens allocate their time from day to day. This indicates that the constraint exerted by the local context on individual political behavior may be stronger than suggested in previous work. Moreover, the potential tiredness mechanism indicates that individuals who have more waking time because they sleep less may be less likely to vote because they are less motivated to use their time to participate in politics. This indicates that the relationship between time and voting may depend not only on the quantity of time one possesses but also on one's ability to balance participation in elections with life allocations that are seemingly unrelated to politics. Crucially, our results indicate that vulnerable social groups struggle to find time to vote. This shows that, contrary to results reported previous work, participation may be stratified even if it is based on time rather than money.

Our design takes voting rules as given and pools observations over time. The strength of this approach is to leverage an novel instrument for the cost of voting with high external and ecological validity that allows us to isolate the effects of time allocations from other influences. However, this makes it difficult to assess whether the partisan implications of our findings are becoming more or less consequential as convenience voting rules such as early voting become more common. Future work may incorporate survey data on wait-lines and fine-grained precinct-level information (Pettigrew 2016). Another limitation pertains to the bundled nature of the potential sleep mechanism. While we have suggested several direct and indirect pathways, the relationship between sleep and voting remains to be unpacked in future work. Potential mechanisms may be explored in short-term sleep deprivation experiments.

In conclusion, we note that our results have significant implications for policy and practice. From a practical perspective, they suggest that interventions designed to increase voter participation may have to grapple with the fact that voters are constrained by their daily schedules. This may have implications for both how (e.g., getting prospective voters to get a good night's rest before Election Day) and where (e.g., on the eastern side of time zone boundaries) resources should be allocated to increase participation. For example, our findings suggest that polls ought to stay open an hour later just east of time zone boundaries to accommodate the preferences of local voters. From a public health perspective, our results indicate that recent trends toward lower levels of sleep may have detrimental effects on levels and inequalities of citizen participation.

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