Democracy Out of Sync: Circadian Misalignment and the Cost of Voting*

Xuan Li[†] Muzhi Liu[‡]

This version: January 2026

Abstract: We extend the calculus-of-voting framework by identifying circadian misalignment as a novel cost of electoral participation. Exploiting the fall transition of Daylight Saving Time (DST), which sets clocks back one hour, we leverage quasi-experimental variation from Arizona's nonobservance of DST and variation in the timing of the transition relative to Election Day. We estimate the effect on voter turnout using both a geographic regression discontinuity difference-in-differences design and a national analysis of individual-level voter records. Across both specifications, voter turnout is lower in general elections following the DST transition. This decline is partly driven by a time-compression channel: effects are more pronounced in areas with earlier sunsets, rural areas, and longer commutes, while access to convenient voting options attenuates these effects. Turnout declines are concentrated among Republican, leading to systematic shifts in electoral composition. These findings highlight "temporal governance" as a critical yet overlooked determinant of democratic participation.

Keywords: Circadian Misalignment, Voter Turnout, Temporal Policy

JEL: D72; D91; I18

*We thank James Feigenbaum, Raymond Fisman, Donald Green, Hans Hassell, Shigeo Hirano, John Holbein, Benjamin Marx, Daniele Paserman, Spencer Piston and seminar participants at Columbia University for their helpful comments. All errors are our own.

[†]Boston University (email: xuanli@bu.edu)

[‡]Columbia University (corresponding author, email: ml4967@columbia.edu)

1 Introduction

The ideal of democratic participation presupposes that citizens are capable of exercising their franchise under the institutional schedules set by the state. Yet, as classic rational-choice theory emphasized, turnout is subject to the costs of participation (Downs, 1957). These costs are often understood as informational or administrative (Blais, 2000; Cantoni, Pons and Schafer, 2025), but participation occurs at specific times and under concrete conditions, experienced by embodied individuals managing work schedules, family responsibilities, and physiological states. When institutional structures misalign with these realities, they introduce subtle but consequential frictions that can suppress political participation (Cools et al., 2022; Schafer and Holbein, 2020). This paper investigates one such friction: the mismatch between socially defined clock time and individuals' internal biological rhythms. We show that this mismatch not only depresses overall voter turnout in U.S. general elections but also imposes unequal participatory burdens across the electorate.

We conceptualize this friction as *circadian misalignment*—the gap between social time and biological time. Social time is shaped by temporal governance, including time zones, Daylight Saving Time (DST), and the institutional timing of elections, whereas biological time follows endogenous circadian rhythms calibrated to natural light cues, or solar time (Gaggero and Tommasi, 2022). The fall DST transition provides a policy-induced laboratory that generates circadian misalignment: the social clock shifts abruptly by one hour, while biological rhythms adjust only gradually. This resulting divergence between social and biological time combines a short-run physiological disruption with a more persistent alteration of the temporal environment. In the short run, individuals may experience acute fatigue as activities are conducted out of sync with internal physiological states (the fatigue channel). More importantly for our empirical analysis, the earlier sunset induced by the clock change compresses usable after-work time while institutional schedules remain unchanged (the time-compression channel). Together, these channels increase the cost of effortful activities, including voting, for a large share of the electorate.

We exploit within-individual variation in circadian misalignment on Election Day generated by cross-state differences in DST observance and by variation in the timing of the fall transition relative to Election Day. The fall transition of DST is nearly nationwide: every continental U.S. state except Arizona observes DST. While the transition always occurs on the first Sunday of November, its proximity to Election Day varies across election cycles. Figure 1

https://doi.org/10.33774/apsa-2026-74h67 ORCID: https://orcid.org/0009-0007-3491-3480 Content not peer-reviewed by APSA. License: All Rights Reserved

illustrates how DST transitions align with general election dates over time. In most years, DST ends exactly two days before Election Day, which falls on the first Tuesday after the first Monday of November. A notable exception is the 2010 midterm election, when DST remained in effect on Election Day, resulting in later sunsets and the absence of acute circadian disruption. We contrast this setting with the subsequent 2014 midterm election, which also took place during the Obama administration, when DST ended on the usual schedule in the preceding Sunday. Taken together, cross-state differences in DST observance and cross-year variation in the timing of the fall transition relative to Election Day generate plausibly exogenous, within-individual variation in circadian misalignment on Election Day.

Our empirical strategy employs two complementary identification approaches. First, we implement a Geographic Regression Discontinuity Difference-in-Differences (GRD-DiD) design that exploits Arizona's nonobservance of DST. By comparing voters in census tracts immediately bordering Arizona in neighboring states (California, Nevada, Utah, and New Mexico) to voters on the Arizona side, we hold geographic and demographic factors approximately constant while isolating the effect of DST-induced circadian misalignment. Second, to assess the national relevance of these effects, we estimate a national Difference-in-Differences specification using individual-level voter file data covering over 146 million voters in the continental United States. Across both approaches, our findings consistently demonstrate that circadian misalignment reduces voter turnout.

In the GRD-DiD analysis, we first validate that census tracts in Arizona and adjacent census tracts in neighboring states along the state border are comparable across a comprehensive set of socioeconomic and demographic characteristics. We then estimate that exposure to post-DST conditions leads to a reduction in turnout of 4.7 to 6.0 percentage points among border-region voters and matched voters. Placebo tests comparing election pairs in which DST ended before Election Day in both years, including the 2002 versus 2006 midterm elections and the 2004 versus 2008 presidential elections, further support the conclusion that our results are driven by DST-induced circadian misalignment rather than by fundamental changes in census tracts near the state border. The national Difference-in-Differences analysis yields smaller average effects, with circadian misalignment reducing turnout by approximately 0.6 percentage points overall. This specification draws on a broader comparison set with substantially richer geographic and institutional variation. Although this comes at the cost of weaker comparability with Arizona than in the border-based design, the national setting allows us to assess the broader policy relevance of the main effect and to investigate the mechanisms underlying it.

While acute fatigue is an inherent component of DST-induced circadian misalignment, it does not generate sharp, spatially varying predictions that can be separately identified in our setting. We therefore focus on heterogeneity patterns with clear, empirically testable implications of a time-compression mechanism, examining variation in sunset timing, nighttime lighting, and commuting duration. We find that the negative effect is concentrated in areas with earlier sunset times, a pattern consistent with the time-compression channel. Effects are also larger among voters with longer commuting times, who face greater time constraints in the evening. By contrast, the effect is attenuated in more urban areas, potentially reflecting the mitigating role of artificial lighting and urban infrastructure. Effects are further amplified in states with more restrictive voting laws that channel participation toward Election Day. Finally, we find larger turnout responses to circadian misalignment among Republican voters. This heterogeneity is consistent with correlated institutional and geographic factors—such as greater residence in rural areas and heavier reliance on in-person voting on Election Day—rather than partisan identity *per se*.

This paper contributes most directly to the literature on the costs of voting (Downs, 1957; Riker and Ordeshook, 1968). Prior research highlights two broad categories of costs that depress turnout: informational costs (Blais, 2000) and administrative costs, including registration and other administrative burdens (Burden et al., 2014; Holbein and Hillygus, 2016; Braconnier, Dormagen and Pons, 2017), strict voter identification laws (Hajnal, Lajevardi and Nielson, 2017; Cantoni and Pons, 2021), and the travel distance and wait times associated with reaching polling places (Brady and McNulty, 2011; Haspel and Knotts, 2005; Cantoni, 2020; Pettigrew, 2021; Chen et al., 2022; Alipour and Lindlacher, 2025). Reducing these barriers, such as through electronic voting and internet voting, has been shown to increase political participation (Fujiwara, 2015; Goodman and Stokes, 2020). A nascent literature highlights how temporal frictions can depress turnout when daily obligations conflict with the institutional timing of elections. For example, Cools et al. (2022) show that childcare responsibilities create scheduling conflicts that reduce political participation.

Closest to our research is the contribution by Schafer and Holbein (2020). They study differences in political behavior arising from the structure of U.S. time zones and show that residents on the eastern edge of time zones experience chronic sleep deprivation due to later sunsets, which in turn reduces their likelihood of voting. Conceptually, their analysis focuses on persistent, spatially fixed misalignment between social and biological time, capturing long-run effects after individuals have had time to adapt to this environment. By contrast, we study circadian misalignment as an abrupt, policy-induced shock generated by the timing of the DST transition relative to Election Day. The instantaneous nature of the clock change leaves little scope for short-run biological adjustment, enabling us to identify the immediate effects of circadian misalignment before adaptation occurs. Moreover, while their mechanism operates through chronic sleep deprivation under persistent exposure to late sunsets, our analysis highlights acute fatigue and compressed subjective usable time following the DST transition as key channels through which circadian misalignment affects electoral participation. Finally, time-zone boundaries reflect largely unavoidable spatial demarcations in a geographically vast country, and their effects are inherently localized in regions near the boundary. DST, by contrast, constitutes an adjustable policy margin that shifts clock time nationwide and generates a broad shock to electoral participation. Taken together, we introduce circadian misalignment as a previously unmeasured cost of political participation, highlighting how institutional time structures can systematically shape both the level and composition of democratic participation.

Understanding this relationship carries significant electoral relevance, especially in the United States. Although many countries around the world observe DST, the United States is unusual in that the end of DST occurs just two days before Election Day in most years. This timing creates a setting in which the sudden circadian disruption from the clock change, combined with an earlier sunset, can directly shape electoral participation. In addition, as Figure 1 shows, the 2032 presidential election is the only upcoming presidential election in which DST is expected to end after Election Day, making it a rare exception among recent and forthcoming cycles. This pattern implies that voters will experience earlier sunsets and immediate physiological disruption from the clock change in nearly all presidential elections for the foreseeable future, which feature greater partisan stakes than midterms.

Lastly, this paper contributes to the ongoing global debate over the Daylight Saving Time policy (Silver, Clancy and Hatfield, 2023). About half of all countries once observed DST but have since abandoned it. In the United States, President Donald Trump has publicly advocated for making DST permanent (Guggenheim, 2025), and approximately twenty states have already passed permanent-DST laws that will be implemented immediately once federal authorization is granted. Although DST was initially adopted to promote energy conservation, household-level evidence from Indiana suggests that it increases rather than reduces electricity demand (Kotchen and Grant, 2011). At the same time, other studies identify unintended benefits: later sunsets have been shown to reduce crime and traffic accidents by extending evening daylight (Doleac and Sanders, 2015; Bünnings and Schiele, 2021). However, the transitions themselves can generate circadian disruption; Smith (2016) find that the spring-forward shift temporarily increases traffic accidents due to acute sleep loss and circadian misalignment. Together, these findings indicate that DST entails a complex set of trade-offs. Our results add a new dimension to this policy debate by demonstrating that the timing of DST transitions can affect the functioning of democratic participation—reducing overall voter turnout and systematically reshaping the composition of the electorate. These effects are disproportionately concentrated among Republicans, rural voters, voters in early-sunset areas, individuals with long commutes, and those residing in states with less convenient voting institutions. More broadly, our findings underscore that temporal policy is not neutral and can interact with high-stakes social activities in economically and politically consequential ways.

2 Theory and Hypotheses

2.1 The Calculus of Voting

The decision to vote has long been understood through a rational choice framework. In the canonical model developed by Downs (1957) and formalized by Riker and Ordeshook (1968), a citizen votes if the expected benefits outweigh the costs:

$$p_i B_i + D_i \geq C_i \tag{1}$$

where p_i is the probability that individual i's vote is pivotal, B_i is the differential benefit from one's preferred candidate winning, D_i reflects the intrinsic satisfaction derived from fulfilling civic duty, and C_i captures the costs of voting.

Given the infinitesimally small probability of casting a decisive vote in large electorates, the $p_i B_i$ term approaches zero, and the decision to vote effectively reduces to whether the psychic benefits of participation (D_i) exceed the costs (C_i). This formulation has directed scholarly attention toward understanding what constitutes C_i—the costs that might deter an otherwise motivated citizen from casting a ballot.

Prior literatures identify two broad categories of costs: informational and administrative costs. We extend this framework by identifying a previously overlooked source of voting costs: *circadian misalignment*—the divergence between socially-defined clock time and individuals' internal biological rhythms. Unlike traditional cost components, circadian misalignment operates through physiological channels that affect cognitive function, fatigue, and motivation. Crucially, it can change abruptly due to policy interventions like Daylight Saving Time, generating quasi-experimental variation that allows us to isolate its causal effect on turnout. The following section develops this concept formally and derives testable predictions for how DST-induced circadian disruption should affect voter behavior.

2.2 Circadian Misalignment and Voting Costs

We define *circadian misalignment* as the divergence between biological and social (wall) time. Because biological time (B_t) tracks solar time (S_t) but cannot shift instantaneously, while wall time (W_t) can change abruptly, circadian misalignment comprises two distinct components.

Clock-based misalignment arises from discrete institutional shocks that shift wall time while biological time remains fixed:

$$M^{shift} = |B_t - W_t| \tag{2}$$

The experience of jet lag provides an intuitive illustration of clock-based circadian misalignment. A traveler flying from New York to London may arrive when local wall time reads 9:00 AM, while their biological clock signals that it is 3:00 AM. This six-hour gap between wall time and biological time generates pronounced fatigue, impaired cognition, and reduced motivation for effortful activity.

The DST transition operates through the same mechanism, albeit at a smaller magnitude (i.e., $M^{shift} = 1$). Wall time shifts instantaneously by one hour, while biological rhythms, entrained to solar cues, adjust only gradually over subsequent days or weeks (Harrison, 2013; Kantermann et al., 2007). During this adjustment period, individuals experience a "jet-lag–style" shock: the body signals that it is one hour earlier or later than the clock indicates, leading to fatigue and reduced motivation for effortful activity such as voting. This clock-based misalignment dissipates as the biological clock gradually resynchronizes with wall time.

Light-based misalignment reflects the mismatch between solar time and wall time:

$$M_i^{solar} = |S_t - W_t| \tag{3}$$

Sunset timing varies systematically across space and time. Cross-sectionally, it differs by longitude within a time zone, with residents on the western edge experiencing later sunsets by the clock than those on the eastern edge, and temporally, it varies with seasonal changes in day length. Under Standard Time following the end of DST in the fall, sunset occurs one hour earlier by the clock than in the previous week, even though the underlying solar day changes only marginally. This earlier onset of darkness signals the body's circadian system to begin transitioning into evening mode, thereby compressing subjective usable time for after-work activities even as social schedules, including polling hours, remain unchanged.

Earlier sunsets thus induce circadian misalignment by accelerating the body's transition to evening mode while wall time continues to demand activity. Holding poll-closing times constant, a voter in a location where sunset occurs at 4:30 PM experiences greater misalignment than a voter in a location where sunset occurs at 5:30 PM, as the former's body signals that the day is ending while social institutions remain active. Each year, the end of DST further amplifies this divergence by shifting sunset one hour earlier on the social clock. A canonical example arises at time-zone boundaries. Residents in these areas experience chronic circadian misalignment (Schafer and Holbein, 2020): two adjacent counties may share nearly identical sunrise and sunset times—and thus similar biological time—yet fall under different time zones, placing them one hour apart in wall time. Our setting differs in that it allows us to isolate short-run, within-individual effects of DST-induced shifts in sunset timing, net of persistent spatial differences and long-run adaptation.

The total circadian misalignment is therefore:

$$M_i = f\left(M^{\text{shift}},\, M_i^{\text{solar}}\right), \tag{4}$$

Intuitively, both an abrupt clock shift and earlier sunset timing contribute positively to circadian misalignment, potentially in an interacting manner.[1] In the context of DST, although the clock change provides exogenous within-individual variation in circadian misalignment, it is difficult to separately isolate the effect of the abrupt clock shift itself. This is because the policy simultaneously alters multiple dimensions of the temporal environment. In particular, the clock change mechanically coincides with shifts in sunset timing and light exposure, so these components are jointly determined by the same institutional intervention rather than varying independently. Nevertheless, we can provide suggestive evidence on the light-based compo-

[1]We provide a detailed discussion of solar time, biological time, and wall time in Appendix A, along with a formal extension of the voting cost function that incorporates circadian misalignment.

nent of circadian misalignment by exploiting heterogeneity in sunset timing, urban versus rural environments, and the availability of artificial lighting.

3 Daylight Saving Time and Data

3.1 Daylight Saving Time in the United States

Daylight Saving Time (DST) is observed in most U.S. states, with clocks advancing one hour on the second Sunday of March and returning to standard time on the first Sunday of November. The policy, originally adopted during World War I to conserve energy, now affects over 300 million Americans twice each year.[2] However, two states have opted out: Hawaii, due to its tropical latitude where seasonal variation in daylight is minimal, and Arizona, where the additional hour of evening sunlight during summer months was deemed undesirable given the state's extreme heat.[3]

Arizona's non-observance of DST creates a sharp spatial discontinuity at its borders. Residents of California, Nevada, Utah, and New Mexico experience the twice-yearly clock change, while Arizonans—mere miles away—do not. This discontinuity provides one source of identifying variation in our research design.

3.2 DST Timing and Election Day

The timing of the DST transition relative to Election Day varies across election cycles. Under current federal law, DST ends on the first Sunday of November, while Election Day falls on the first Tuesday following the first Monday of November. When November 1 falls on a Monday, the DST transition occurs after Election Day; in all other cases, DST ends two days before Election Day. This calendar-driven variation is central to our research design. As Figure 1 shows, 2010 is the only recent election year in which the DST "fall back" occurred after the general election. We therefore use 2010 as the baseline year and compare it to the imme-

[2] The most recent major change came with the Energy Policy Act of 2005, which extended DST by approximately four weeks—moving the spring transition from April to March and the fall transition from October to November. This extension was supported by an unusual coalition of interest groups, including the National Association of Convenience Stores, the Sporting Goods Manufacturers Association, and notably the National Confectioners Association, which had long lobbied for Halloween to fall during DST so that children would have an extra hour of evening daylight for trick-or-treating.

[3] The Navajo Nation, which spans portions of Arizona, New Mexico, and Utah, does observe DST to maintain temporal consistency across its territory. We exclude the Navajo Nation in our empirical analysis. In addition, DST observance in Indiana was non-uniform prior to 2006, with many counties not observing DST; since 2006, DST has been observed statewide.

diately subsequent midterm general election in 2014, when DST ended before Election Day. Importantly, both elections took place during the Obama administration, limiting confounding from changes in national political leadership.

- **2010 Midterm Election (November 2):** DST ended on November 7, 2010—five days *after* Election Day. Voters in DST-observing states cast ballots while still on Daylight Saving Time, with later sunsets and no acute circadian disruption from a recent clock change.
- **2014 Midterm Election (November 4):** DST ended on November 2, 2014—two days *before* Election Day. Voters in DST-observing states had just experienced the clock transition, with earlier sunsets and potential sleep disruption.

Figure 2 illustrates county-level sunset times on Election Day in the 2010 and 2014 U.S. midterm elections. In 2010, Daylight Saving Time (DST) was still in effect on Election Day, yielding later sunsets across most of the continental United States; by contrast, DST had ended prior to Election Day in 2014, resulting in uniformly earlier sunsets. While both years exhibit pronounced east–west gradients within time zones, the comparison highlights an approximately one-hour reduction in evening daylight in 2014 for otherwise comparable locations.

This temporal variation, combined with the spatial discontinuity at the Arizona border, underpins our identification strategy. In 2010, voters on either side of the border faced similar conditions—no recent clock change and sunset times differing only by the time-zone offset—whereas in 2014, voters in DST-observing states experienced the transition-induced circadian disruption and earlier darkness, while Arizona voters did not. A difference-in-differences comparison across these elections therefore identifies the causal effect of DST timing on turnout.

3.3 L2 Voter File and Supplemental Data Sources

Our analysis draws on the L2 voter file, a comprehensive database compiled from official state voter registration records and enhanced with commercial data. The L2 file provides individual-level information on voter registration status, turnout history, and demographic characteristics for virtually all registered voters in the United States.[4] For each registered voter, we observe: (1) a unique identifier enabling longitudinal tracking across elections; (2)

[4] Because the L2 voter file is updated multiple times each year, we rely on the earliest release that includes validated turnout records for the 2014 general election. Doing so minimizes potential bias from post-election residential mobility and sample attrition.

residential address at the census tract level; (3) validated turnout in each general election; (4) party registration, where recorded by the state; and (5) demographic attributes.

Our primary analysis sample consists of registered voters residing in census tracts directly adjacent to the Arizona border in Arizona, California, Nevada, Utah, and New Mexico. We identify border census tracts using geographic information system (GIS) methods, retaining tracts whose boundaries are contiguous with Arizona (for neighboring states) or with a neighboring state (for Arizona). This yields approximately 208,000 voter-election observations across the 2010 and 2014 midterms.

For the national analysis, we expand the sample to include all registered voters in the continental United States who were registered to vote in both the 2010 and 2014 midterm elections. The resulting dataset comprises approximately 146 million unique voters observed across both elections, yielding roughly 292 million voter–election observations. Table 1 reports summary statistics for both samples.

For robustness checks and heterogeneity analyses, we supplement the L2 voter file with additional data sources merged at the census-tract or county level using FIPS codes. For the covariate balance check of our GRD-DiD specification, we obtain census-tract-level demographic characteristics for the 63 border tracts along the Arizona boundary. These data come from the 2010 American Community Survey, accessed via the U.S. Census Bureau's public API. For the mechanism tests in our national DiD specification, we merge several county-level data sources. Commuting patterns come from the 2011–2015 American Community Survey county-to-county commuting flows.[5] Urbanicity measures come from the National Neighborhood Data Archive (NaNDA) for 2010.[6] We construct state-level voting law indicators using two sources. The primary source is the Cost of Voting Index (Schraufnagel, Pomante and Li, 2022), which compiles voting requirements for presidential elections from 1996 to 2024; we use their 2008 and 2012 waves. Because our analysis focuses on the 2010 and 2014 midterms, we cross-reference the COVI data with the Statutory Overview reports from the U.S. Election Assistance Commission, which document legislative changes between elections, and update the coding where statutes changed. Finally, we calculate the interval between sunset and poll

[5]Commuting Flows from the American Community Survey: https://www.census.gov/topics/employment/commuting/guidance/flows.html

[6]National Neighborhood Data Archive (NaNDA): Urbanicity by Census Tract, United States, 2010. https://www.icpsr.umich.edu/web/ICPSR/studies/38606

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480 Content not peer-reviewed by APSA. **License:** All Rights Reserved

closing for each county-election. Poll closing times come from The Green Papers.[7] County-level sunset times are computed using the `suncalc` package in R.

4 Empirical Strategy

We employ two complementary identification strategies. Our primary approach is a Geographic Regression Discontinuity Difference-in-Differences (GRD-DID) design that exploits the sharp policy discontinuity at the Arizona border. We complement this with a national Difference-in-Differences specification that leverages the full scope of the L2 voter file. The GRD-DiD design prioritizes internal validity by exploiting tight geographic comparisons, whereas the national DiD design prioritizes national electoral relevance and facilitates mechanism analysis.

4.1 Geographic Regression Discontinuity Difference-in-Differences

We focus on tracts directly adjacent to the Arizona border to ensure that treatment and control voters face similar local environments while differing sharply in DST exposure. Figure 3 displays the census tracts in our GRD-DiD sample. Based on this geographically contiguous sample, we estimate the following linear probability model:

$$Y_{ipt} = \beta \cdot \mathrm{DST}_{it} + \alpha_i + \gamma_{pt} + \varepsilon_{ipt} \tag{5}$$

where Y_{ipt} is an indicator for whether voter i in border pair p turned out in election year t. The treatment variable DST_{it} equals one for voters in DST-observing states during the 2014 election—when DST ended before Election Day—and zero otherwise.[8] The term α_i denotes individual fixed effects, absorbing all time-invariant voter characteristics including demographics, baseline propensity to vote, and residential location. The term γ_{pt} represents border pair-by-year fixed effects, which flexibly control for time-varying shocks affecting both sides of a given border segment—such as local weather, and socio-economic conditions.

The coefficient β identifies the effect of DST exposure on voter turnout. Under our theoretical framework, we expect $\beta < 0$: voters exposed to post-DST conditions, including circadian disruption and earlier sunsets, should be less likely to turn out than voters not experiencing these conditions. Standard errors are clustered at the census tract level.

[7] For 2010: https://www.thegreenpapers.com/G10/closing.phtml; for 2014: https://www.thegreenpapers.com/G14/closing.phtml.

[8] Formally, $\mathrm{DST}_{it} = \mathbf{1}[\mathrm{State}_i \neq \mathrm{Arizona}] \times \mathbf{1}[\mathrm{Year}_t = 2014]$.

In principle, whether DST ends before or after Election Day in a given year is orthogonal to other political or economic factors, as the timing of the fall transition is mechanically determined by whether November 1 falls on a Monday. However, within our sample period, 2010 is the only (midterm) election in which DST remained in effect on Election Day. We therefore use the immediately adjacent 2014 midterm election, which occurred under the same presidential administration, as the primary comparison.

To ensure that our estimates are not driven by differential time trends between Arizona and neighboring states, we conduct placebo tests using election pairs in which DST ended before Election Day in both years. Specifically, we examine the 2002 and 2006 midterm elections, as well as the 2004 and 2008 presidential elections. In these placebo settings, we find no discontinuous changes in turnout at the Arizona border, supporting the interpretation that our main results capture the effect of DST-induced circadian misalignment rather than spurious border-specific trends.

4.2 National Difference-in-Differences

To assess national electoral relevance and facilitate mechanism analysis, we complement the GRD-DID with a national Difference-in-Differences specification:

$$Y_{it} = \beta \cdot \mathrm{DST}_{it} + \alpha_i + \delta_t + \varepsilon_{it} \tag{6}$$

where the sample now includes all registered voters nationwide. The treatment variable DST_{it} equals one for voters residing in DST-observing states in the 2014 election, with the 2010 election as the baseline and Arizona serving as the non-DST control group. The specification includes individual fixed effects, α_i, which exploit within-individual variation in circadian misalignment, as well as year fixed effects, δ_t.

The national specification offers two advantages over the GRD-DiD design: substantially greater statistical power, with approximately 292 million observations compared to about 208,000, and broader relevance to the U.S. electorate as a whole. At the same time, the national sample differs in meaningful ways from the border-region sample. In particular, it exhibits substantially greater variation in sunset timing across locations, as well as heterogeneity in commuting times and urban–rural environments. Although this broader comparison set may weaken causal identification relative to the tightly matched border design, the resulting variation enables us to probe the mechanisms through which DST operates. Specifically, it allows us to assess whether the effects of circadian misalignment are amplified in settings where earlier sunsets compress usable evening time, as well as in contexts characterized by greater time constraints, providing evidence on the role of the time-compression channel.

We view these two designs as complementary. The GRD-DiD provides credible causal estimates with strong internal validity, while the national DiD yields estimates that speak to the broader electoral relevance of DST in U.S. politics and help elucidate the underlying mechanisms.

5 Results

We present our findings in three parts. First, we report estimates from the Geographic Regression Discontinuity Difference-in-Differences (GRD-DID) design exploiting Arizona's non-observance of DST. Second, we present results from the national Difference-in-Differences specification covering over 292 million voter-election observations. Third, we examine heterogeneous effects that speak to the mechanisms underlying our main results.

5.1 Geographic Regression Discontinuity Difference-in-Differences

As a first validation step, we assess whether census tracts on either side of the Arizona border are comparable along a wide range of baseline characteristics in 2010. Figure 4 presents covariate balance tests comparing tracts in DST-observing states to adjacent Arizona border tracts, which do not observe DST. Across demographic composition, socioeconomic and educational characteristics, housing shares, and broader structural and economic indicators, differences are uniformly small and statistically indistinguishable from zero. The estimated differences are precisely estimated, and nearly all confidence intervals include zero, indicating a high degree of balance across the border in the baseline year. These results suggest that census tracts near the Arizona border are largely comparable prior to treatment.

Table 2 presents our main GRD–DiD estimates. Panel A reports the effect of Daylight Saving Time (DST) on voter turnout in midterm elections, comparing 2010—when DST ended after Election Day—to 2014—when DST ended before Election Day. The coefficient of -0.060 in Column (1) indicates that ending DST before Election Day reduced voter turnout by 6.0 percentage points among voters residing in border census tracts. This effect is statistically significant at the 1% level.

To further enhance comparability between treatment and control units, we restrict the analysis to a matched sample constructed using propensity score matching based on basic demographic characteristics such as age, gender, and party affiliation (Column 3). Under this specification, the estimate attenuates modestly to -0.047 but remains statistically significant at the 5% level. Overall, these results indicate that the fall transition of DST occurring prior to Election Day has a non-trivial effect on voter turnout.

To better understand the magnitude of this effect, we benchmark it against Schafer and Holbein (2020), who find that residing just east of a time zone boundary is associated with a 2.2 to 3 percentage point reduction in voter turnout, providing a point of reference for our estimated 4.7 to 6.0 percentage point decline. Two factors may explain why our estimates are somewhat larger. First, we examine midterm rather than presidential elections. Midterm voters likely perceive lower benefits from voting and face weaker civic incentives, making turnout more sensitive to increases in participation costs, including those induced by circadian misalignment. Second, DST constitutes an acute temporal shock, whereas time-zone boundaries impose a chronic condition. In the latter case, voters' circadian rhythms have largely adapted to persistent misalignment, attenuating its effect on turnout. More broadly, our estimates are identified from short-run within-individual exposure to circadian misalignment, whereas time-zone boundary comparisons primarily reflect long-run between-location differences.[9]

Although we verify that the two border regions are broadly comparable in baseline socioeconomic characteristics in 2010, a natural concern is that a comparison limited to 2010 and 2014 may capture differential underlying time trends across these areas. This limitation arises because 2010 is the only midterm election in which the end of Daylight Saving Time occurred after Election Day, a feature mechanically determined by the institutional rules governing DST transitions. While, in principle, whether November 1 falls on a Tuesday should be orthogonal to local economic development, we nonetheless address this concern in two ways. First, we conduct two sets of placebo tests designed to detect spurious time-trend differences across the border regions. Second, in our national Difference-in-Differences analysis, we provide additional evidence and mechanism-based discussion that further supports a causal interpretation of the main results.

Panel B presents placebo tests that assess the validity of our identification strategy. If our

[9]For additional comparison, Gerber, Green and Larimer (2008) show that social pressure mailings, among the most effective get-out-the-vote interventions documented, increase turnout by approximately 4 percentage points. By contrast, Cantoni (2020) find that a one-standard-deviation increase in distance to polling places reduces turnout by 2 to 5 percent, and Gomez, Hansford and Krause (2007) estimate that one inch of rainfall lowers turnout by roughly one percentage point.

design is capturing the causal effect of DST timing rather than spurious trends or unobserved confounders, we should observe null effects in election pairs where the timing of the DST transition relative to Election Day is the same across years. We examine two such placebo pairs: the 2002 and 2006 midterm elections, and the 2004 and 2008 presidential elections. In both cases, the estimated effects are small and statistically insignificant, a pattern inconsistent with confounding but consistent with our identification assumptions. The contrast between the significant negative effects in Panel A and the null effects in Panel B and Panel C provides further support that our estimates reflect the causal impact of DST timing on voter turnout.

5.2 National Difference-in-Differences

While the GRD–DiD design offers strong internal validity by comparing voters in adjacent census tracts, it is geographically limited to the Arizona border region and therefore cannot fully answer our core interest: the relevance of these effects for the broader U.S. electorate. We therefore complement the GRD-DID analysis with a national Difference-in-Differences specification that leverages the full scope of our voter file data.

Table 3 reports the main national DiD estimates. Column 1 shows that across the full sample of approximately 146 million registered voters in the continental United States, DST reduces turnout by 0.60 percentage points. At the national level, the baseline estimate corresponds to approximately 876,000 fewer voters turning out in elections occurring after the DST fallback. The difference in magnitudes between the border design and the national DiD likely reflects a combination of factors. Relative to the border design, the national DiD compares voters who differ more in individual characteristics (such as partisan affiliation), local environments (including sunset times, commuting patterns, and urbanization), and institutional contexts (such as voting laws and access to early or mail voting). At the same time, precisely because the national setting encompasses this broader heterogeneity, it provides richer variation for probing the mechanisms underlying the average effect—variation that would be difficult to recover in a more locally homogeneous setting. We exploit this variation in the heterogeneity analyses that follow.

Daylight Saving Time has been shown to affect both crime rates and traffic accident rates (Doleac and Sanders, 2015; Smith, 2016; Bünnings and Schiele, 2021). To rule out the possibility that our estimates are driven by changes in safety-related costs induced by DST, Column 2 adds time-varying controls for county-level crime rates and county-level traffic accidents on election day. We further control for other election-day conditions that may affect voter turnout, such as rainfall (Fujiwara, 2015). Our main results remain robust after accounting for these election-day factors.

5.3 Heterogeneity and Mechanism Tests

Our theoretical framework yields testable implications for heterogeneous responses to circadian misalignment. We examine these implications using sample splits and interaction models to assess the relevance of a time-compression channel, identify which voters are most affected, and evaluate whether these differential responses translate into systematic shifts in electoral composition.

5.3.1 Light-based Misalignment Channel

We examine three conditions that theory predicts should amplify the light-based misalignment mechanism: sunset timing, commute time, and urbanicity.

Sunset timing. Our theoretical framework predicts that earlier sunsets increase light-based circadian misalignment by accelerating the body's transition to evening mode: when darkness falls, biological time signals that the day is ending even as wall time (polling hours) continues to demand activity. This divergence compresses subjective usable time, raising voting costs. We calculate the precise sunset time on Election Day for each county using standard astronomical algorithms. Panel A of Table 4 splits the sample by whether Election Day sunset time is above or below the median.

The results are consistent with this prediction. In areas with below-median sunset times, circadian misalignment reduces turnout by 2.02 percentage points—more than three times the full-sample estimate. In areas with above-median sunset times, we find a null result. This striking heterogeneity suggests that the light-based misalignment channel—where early darkness shrinks the perceived window for after-work voting—constitutes a primary mechanism. Figure 2 illustrates the geographic variation in sunset times across the two elections.

Panel D reinforces this conclusion using a continuous measure. We estimate a triple-difference specification:

$$Y_{it} = \beta_1 \cdot \text{DST}_{it} + \beta_2 \cdot \text{DST}_{it} \times \text{PollSunsetGap}_i + \alpha_i + \delta_t + \varepsilon_{it} \qquad (7)$$

where PollSunsetGap_i measures the hours between sunset and poll closing in voter i's location, centered at the sample mean. The coefficient β_2 tests whether the effect of DST is larger in areas with earlier sunsets, given the poll closing time. We find that greater disparity in the duration of darkness between sunset and poll closing amplifies the negative effect on voter turnout. This continuous specification confirms that circadian misalignment operates along the entire distribution of sunset times, not merely above and below an arbitrary threshold.

Commute time. In our theoretical framework, light-based misalignment compresses voters' subjective usable time. Those voters with longer commutes begin with less usable time, so the marginal effect of light-based misalignment should be larger on these voters—the compression imposed by early darkness leaves them with a vanishingly small window for voting. Panel B of Table 4 tests whether time pressure amplifies the effects of circadian misalignment. We interact the DST indicator with an indicator for whether voters reside in a county with high commuting exposure, defined as counties with an above-median share of residents who work in a different county based on county-to-county workflow data.

Consistent with this prediction, the effect of circadian misalignment is nearly six times larger among high-commute voters (-4.02 percentage points) than among low-commute voters (-0.68 percentage points). Both estimates are statistically significant, but the differential magnitude suggests that baseline time pressure substantially amplifies the costs circadian misalignment imposes.

Urbanicity. Panel C of Table 4 examines heterogeneity across urban, suburban, and rural contexts. We expect larger effects in rural and suburban areas, where longer travel distances, reduced street lighting, and fewer transportation alternatives amplify the inconvenience and safety costs of after-dark voting.

The results confirm this expectation. Suburban ("mixed") areas exhibit the largest effects (-3.24 percentage points), followed by rural areas (-2.10 percentage points), with urban areas showing the smallest effects (-0.47 percentage points). All three estimates are statistically significant. This pattern is consistent with our framework: urban voters benefit from well-lit streets, shorter distances to polling stations, and robust public transportation that reduce the costs of voting after biological time has signaled the day's end. Suburban and rural voters, facing longer travel distances on poorly lit roads, experience the full burden of the divergence between social demands and biological rhythms.

Across all three dimensions, the evidence consistently supports the light-based time-compression channel. The negative effect of light-based circadian misalignment on turnout is concentrated in early-sunset areas where the gap between wall time and biological time is largest, amplified by each additional hour of darkness before poll closing, more pronounced among time-pressured commuters for whom the compression of usable time is most binding, and strongest in suburban and rural settings where after-dark travel is most burdensome. Together, these patterns provide converging evidence that light-based circadian misalignment constitutes a meaningful and policy-relevant determinant of electoral participation, as it effectively compresses voters' subjective usable time for voting.

5.3.2 Convenience Voting Laws

Although many voters choose to cast their ballots in person on Election Day, many states offer a range of convenience voting options designed to increase turnout. States lacking these alternatives effectively channel voters toward Election Day in-person participation, where they face the full force of circadian misalignment following the DST transition. Figure 5 displays the geographic distribution of three key voting policies across U.S. states as of 2010. The top-left panel shows no-excuse mail voting, which allows any registered voter to request an absentee ballot without providing a reason; roughly two-thirds of states offered this option, concentrated in the West and scattered across the Midwest and Northeast. The top-right panel shows formal early voting periods, which permit voters to cast ballots in person at designated locations before Election Day; early voting was available in about half of states, with notable holdouts in the Northeast and parts of the Midwest. The bottom panel shows in-person absentee voting, which allows voters to complete an absentee ballot at an election office before Election Day; the availability of this option concentrated in the upper Midwest and Mountain West.

Table 5 tests whether these institutional features amplify the effects of circadian misalignment. We interact the DST indicator with state-level indicators for restrictive policies: requiring an excuse for absentee voting, lacking early voting, and lacking in-person absentee voting.[10] Our framework predicts that voters with access to early voting, mail ballots, or other alternatives will be less heavily impacted by circadian misalignment, because they can cast ballots before the DST transition or avoid the need to travel to polls after dark.

[10]The main purpose is to identify which states drive the DST-related results by leveraging heterogeneity in convenience voting laws across states. Because Arizona exhibits no within-state variation in convenience voting laws over the sample period, we exclude Arizona from this part of the analysis.

All three interactions are negative and highly significant, confirming that the turnout penalty from circadian misalignment is larger in states where voters have fewer alternatives to showing up at the polls on Election Day. The largest interaction is observed for states without in-person absentee voting (-2.73 percentage points), followed by states without early voting (-2.35 percentage points) and states requiring an excuse for absentee voting (-0.98 percentage points). These results support the theoretical expectation that institutional substitutes attenuate the costs circadian misalignment imposes by allowing voters to participate when social and biological time are better aligned.

5.3.3 Demographic Heterogeneity

Table 6 presents demographic heterogeneity in the national DiD estimates. The partisan asymmetry observed in the GRD-DID replicates at the national level: the effect among Republicans (-1.42 percentage points) is substantially larger than among Democrats (-0.08 percentage points, statistically insignificant). Panel B shows that this pattern persists when we restrict the sample to states where party affiliation is directly observed from voter registration records rather than inferred by L2 from voting history: the Republican effect remains significant at -0.52 percentage points while the Democratic coefficient remains small and insignificant.

Several mechanisms may explain this partisan gap. First, Republicans are more likely to vote in person on Election Day, while Democrats disproportionately utilize early and absentee voting options that allow them to cast ballots before the DST transition or avoid traveling to polls after dark (Gronke et al., 2008; Herron and Smith, 2014). Second, Republican voters tend to reside in more rural areas where longer commutes and fewer polling locations may amplify the costs of voting in darkness. While this compositional shift does not change underlying voter preferences, it alters the pool of citizens who actually cast ballots. In competitive elections where margins are thin, the selective demobilization of Republican voters could prove consequential—effectively creating an unintended partisan bias in election timing policy.

Effects are similar across gender, education, and income, suggesting that the circadian mechanism operates broadly across demographic groups while the partisan gap reflects differences in voting mode rather than socioeconomic factors.

6 Concluding Remarks

As policymakers and administrators navigate the complexities of election design, the connection between temporal policy and democratic engagement has been a crucial concern: participation occurs at specific times, by embodied individuals whose capacity for effortful action fluctuates with biological rhythms. This paper has examined what happens when the institutional timing of elections diverges from voters' internal clocks—when social time and biological time fall out of alignment.

Exploiting the natural experiment created by Arizona's non-observance of DST and the varying timing of the clock change relative to Election Day, we find consistent evidence that circadian misalignment depresses voter turnout. Heterogeneity analyses reveal that these effects are concentrated in areas with earlier sunset times, among voters with longer commutes, in states with restrictive voting laws, and in suburban and rural areas—a pattern that strongly supports the time-compression channel of our theoretical model. Although the bundled nature of the DST transition prevents us from isolating acute disruption as a distinct mechanism, all such effects operate through circadian misalignment. The heterogeneity patterns we document are therefore informative about which dimensions of circadian misalignment are most salient, and they are difficult to reconcile with explanations based on acute fatigue alone.

6.1 Policy Implications

Our findings carry potential implications for two policy domains: the regulation of time and the administration of elections.

Temporal policy. The debate over DST reform has intensified in recent years, with political figures across the ideological spectrum calling for an end to the twice-yearly clock change. Our results add a new consideration: the timing of DST transitions relative to elections has consequences for democratic participation. Under current law, most presidential elections occur just two days after the "fall back" transition, maximizing circadian misalignment precisely when electoral stakes are highest.

Our framework clarifies the relevant trade-offs. Eliminating clock changes entirely—whether through permanent standard time or permanent daylight saving time—would remove this source of clock-based circadian misalignment associated with abrupt clock shifts. However, these two regimes differ in the level of sunset timing they impose: relative to permanent daylight saving time, permanent standard time would entail sunsets that occur one hour earlier by the clock, potentially increasing chronic light-based misalignment even as it eliminates acute disruption. If policymakers retain the current system, an alternative approach is to schedule the fall DST transition to occur after Election Day, thereby ensuring that voters are not exposed to clock-based disruption and face later sunset times on Election Day.

More broadly, our findings suggest that the design of temporal policy should take into account its interaction with other high-stakes social activities. In practice, policymakers have recognized such concerns in educational settings, for example by postponing DST transitions when they coincided with nationwide college entrance examinations in Brazil. Our results indicate that analogous considerations may be relevant for democratic institutions, particularly when DST transitions occur in close proximity to elections.

Election administration. For election administrators, our results underscore the value of providing alternatives to Election Day in-person voting. Over recent decades, states have increasingly adopted early voting, no-excuse absentee balloting, and vote-by-mail—a trend accelerated by the COVID-19 pandemic, though some states have since moved to restrict these options. Our findings suggest that such flexibility has benefits beyond convenience: these alternatives allow voters to select alternative contexts for participation when circadian misalignment is weaker, by casting ballots before the clock change occurs or avoiding travel to polling places after dark. More broadly, our results illustrate how seemingly peripheral institutional features—such as the calendar placement of clock changes—can interact with administrative rules to shape electoral participation.

6.2 Limitations and Future Directions

Several limitations warrant acknowledgment. First, our identification relies on comparing two midterm election years, 2010 and 2014, that differ in the timing of the DST transition relative to Election Day. While placebo tests using other midterm and presidential elections support the validity of this comparison, future research could naturally extend our framework to presidential elections, where electoral stakes are even higher, as suitable election pairs become available.

Moreover, our framework points to additional sources of circadian misalignment beyond DST that future research could exploit to more fully understand how circadian disruption affects political participation. One promising setting involves workers with irregular or abruptly

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480 Content not peer-reviewed by APSA. **License:** All Rights Reserved

changing schedules, such as shift workers or individuals with rotating or nonstandard hours, who account for 20% of the U.S. workforce (Presser and Ward, 2011). These environments generate both acute and persistent forms of circadian misalignment through disruptions to daily routines that are independent of clock changes. Exploring such settings would not only help assess the generality of our findings across different sources, but also shed light on broader democratic implications, including whether circadian misalignment disproportionately suppresses participation among specific socioeconomic groups, thereby shaping the representativeness of democratic institutions.

6.3 Conclusion

Democratic participation depends not only on citizens' preferences and institutional rules, but on the alignment between social demands and biological rhythms. We have shown that when this alignment breaks down—when social time races ahead of biological time—voter turnout falls. The calculus of voting, it turns out, is sensitive to factors as fundamental as the relationship between clock and body.

As policymakers debate the future of Daylight Saving Time and election administrators seek to reduce barriers to participation, the connection between temporal policy and democratic engagement documented here deserves attention. Institutions that ignore the embodied nature of citizenship—that treat voters as disembodied actors equally capable at any hour—impose hidden costs on participation. In democracy, the alignment of social and biological time matters.

References

Alipour, Jean-Victor, and Valentin Lindlacher. 2025. "No Surprises, Please: Voting Costs and Electoral Turnout." *Journal of Political Economy Microeconomics*, 3(1): 59–97.

Blais, André. 2000. *To vote or not to vote?: The merits and limits of rational choice theory.* University of Pittsburgh Pre.

Braconnier, Céline, Jean-Yves Dormagen, and Vincent Pons. 2017. "Voter registration costs and disenfranchisement: experimental evidence from France." *American Political Science Review*, 111(3): 584–604.

Brady, Henry E, and John E McNulty. 2011. "Turning out to vote: The costs of finding and getting to the polling place." *American Political Science Review*, 105(1): 115–134.

Burden, Barry C., David T. Canon, Kenneth R. Mayer, and Donald P. Moynihan. 2014. "Election Laws, Mobilization, and Turnout: The Unanticipated Consequences of Election Reform." *American Journal of Political Science*, 58(1): 95–109.

Bünnings, Christian, and Valentin Schiele. 2021. "Spring Forward, Don't Fall Back: The Effect of Daylight Saving Time on Road Safety." *The Review of Economics and Statistics*, 103(1): 165–176.

Cantoni, Enrico. 2020. "A Precinct Too Far: Turnout and Voting Costs." *American Economic Journal: Applied Economics*, 12(1): 61–85.

Cantoni, Enrico, and Vincent Pons. 2021. "Strict Id Laws Don't Stop Voters: Evidence from a U.S. Nationwide Panel, 2008–2018*." *The Quarterly Journal of Economics*, 136(4): 2615–2660.

Cantoni, Enrico, Vincent Pons, and Jerome Schafer. 2025. "Voting Rules, Turnout, and Economic Policies." *Annual Review of Economics*, 17(Volume 17, 2025): 217–239.

Chen, M. Keith, Kareem Haggag, Devin G. Pope, and Ryne Rohla. 2022. "Racial Disparities in Voting Wait Times: Evidence from Smartphone Data." *The Review of Economics and Statistics*, 104(6): 1341–1350.

Cools, Angela, et al. 2022. "Parents, infants, and voter turnout: evidence from the United States." *Quarterly Journal of Political Science*, 17(1): 91–119.

Doleac, Jennifer L., and Nicholas J. Sanders. 2015. "Under the Cover of Darkness: How Ambient Light Influences Criminal Activity." *The Review of Economics and Statistics*, 97(5): 1093–1103.

Downs, Anthony. 1957. *An Economic Theory of Democracy.* New York:Harper & Row.

Fujiwara, Thomas. 2015. "Voting Technology, Political Responsiveness, and Infant Health: Evidence From Brazil." *Econometrica*, 83(2): 423–464.

Gaggero, Alessio, and Denni Tommasi. 2022. "Time of Day and High-Stake Cognitive Assessments." *The Economic Journal*, 133(652): 1407–1429.

Gerber, Alan S., Donald P. Green, and Christopher W. Larimer. 2008. "Social Pressure and Voter Turnout: Evidence from a Large-Scale Field Experiment." *American Political Science Review*, 102(1): 33–48.

Gomez, Brad T., Thomas G. Hansford, and George A. Krause. 2007. "The Republicans Should Pray for Rain: Weather, Turnout, and Voting in U.S. Presidential Elections." *The Journal of Politics*, 69(3): 649–663.

Goodman, Nicole, and Leah C. Stokes. 2020. "Reducing the Cost of Voting: An Evaluation of Internet Voting's Effect on Turnout." *British Journal of Political Science*, 50(3): 1155–1167.

Gronke, Paul, Eva Galanes-Rosenbaum, Peter A. Miller, and Daniel Toffey. 2008. "Convenience Voting." *Annual Review of Political Science*, 11: 437–455.

Guggenheim, Benjamin. 2025. "Cotton Blocks Trump-Backed Effort to Make Daylight Saving Time Permanent." *Politico*, Accessed: November 25, 2025.

Hajnal, Zoltan, Nazita Lajevardi, and Lindsay Nielson. 2017. "Voter Identification Laws and the Suppression of Minority Votes." *Journal of Politics*, 79(2): 363–379.

Harrison, Yvonne. 2013. "The Impact of Daylight Saving Time on Sleep and Related Behaviours." *Sleep Medicine Reviews*, 17(4): 285–292.

Haspel, Moshe, and H Gibbs Knotts. 2005. "Location, location, location: Precinct placement and the costs of voting." *The Journal of Politics*, 67(2): 560–573.

Herron, Michael C., and Daniel A. Smith. 2014. "Race, Party, and the Consequences of Restricting Early Voting in Florida in the 2012 General Election." *Political Research Quarterly*, 67(3): 646–665.

Holbein, John B, and D Sunshine Hillygus. 2016. "Making young voters: the impact of preregistration on youth turnout." *American Journal of Political Science*, 60(2): 364–382.

Kantermann, Thomas, Myriam Juda, Martha Merrow, and Till Roenneberg. 2007. "The Human Circadian Clock's Seasonal Adjustment Is Disrupted by Daylight Saving Time." *Current Biology*, 17(22): 1996–2000.

Kotchen, Matthew J., and Laura E. Grant. 2011. "Does Daylight Saving Time Save Energy? Evidence from a Natural Experiment in Indiana." *The Review of Economics and Statistics*, 93(4): 1172–1185.

Pettigrew, Stephen. 2021. "The Downstream Consequences of Long Waits: How Lines at the Precinct Depress Future Turnout." *Electoral Studies*, 71: 102188.

Presser, Harriet B, and Brian W Ward. 2011. "Nonstandard work schedules over the life course: A first look." *Monthly Lab. Rev.*, 134: 3.

Riker, William H., and Peter C. Ordeshook. 1968. "A Theory of the Calculus of Voting." *American Political Science Review*, 62(1): 25–42.

Roenneberg, Till, Tim Kuehnle, Myriam Juda, Thomas Kantermann, Karla Allebrandt, Marijke Gordijn, and Martha Merrow. 2007. "Epidemiology of the Human Circadian Clock." *Sleep Medicine Reviews*, 11(6): 429–438.

Schafer, Jerome, and John B. Holbein. 2020. "When Time Is of the Essence: A Natural Experiment on How Time Constraints Influence Elections." *The Journal of Politics*, 82(2): 418–432.

Schraufnagel, Scot, Michael J. Pomante, and Quan Li. 2022. "Cost of Voting in the American States: 2022." *Election Law Journal: Rules, Politics, and Policy*, 21(3).

Silver, Laura, Laura Clancy, and Jenn Hatfield. 2023. "Most countries don't observe daylight saving time." *Pew Research Center.*

Smith, Austin C. 2016. "Spring Forward at Your Own Risk: Daylight Saving Time and Fatal Vehicle Crashes." *American Economic Journal: Applied Economics*, 8(2): 65–91.

7 Tables and Figures

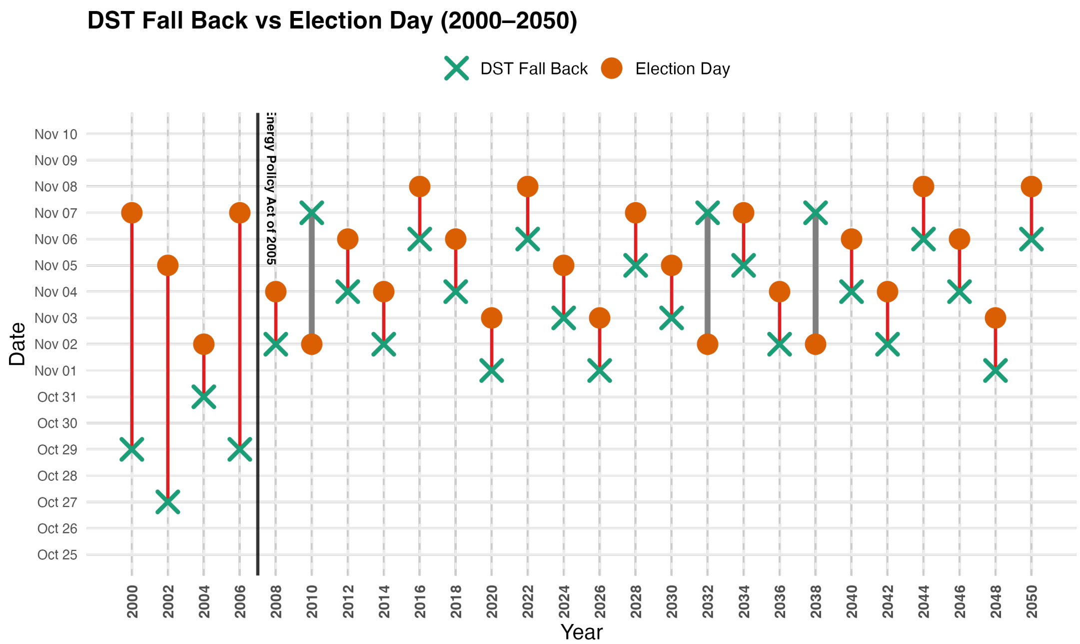
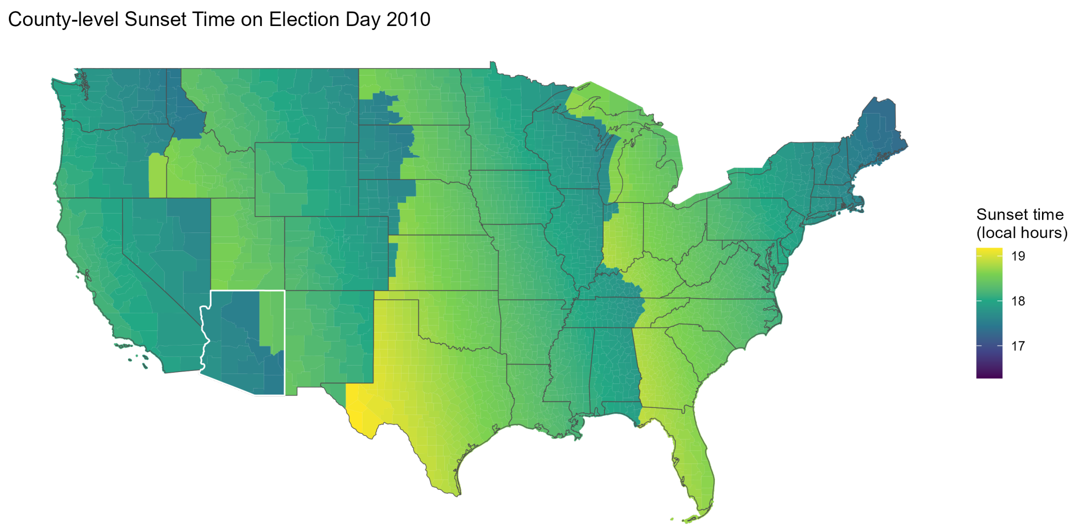


Figure 1: DST Fall Back vs. Election Day (2000–2050)

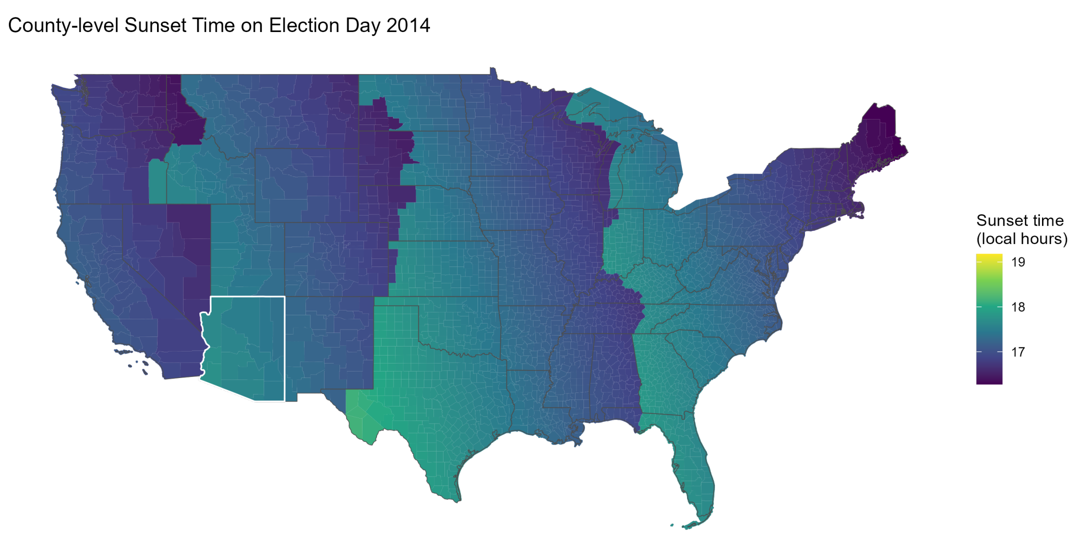
Notes: This figure displays the timing of the DST "fall back" transition (green X) relative to Election Day (orange circle) for U.S. general elections from 2000 to 2050. The vertical line marks the Energy Policy Act of 2005, which changed the end date to the first Sunday in November. Red connecting lines indicate the gap between DST end and Election Day. In most years after 2007, DST ends before Election Day; however, in 2010—and again in 2032 and 2038—DST ends *after* Election Day, meaning voters go to the polls while still on Daylight Saving Time and experience no acute circadian disruption.

[Back to Page 1]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480 Content not peer-reviewed by APSA. **License:** All Rights Reserved



(a) 2010 Midterm Election



(b) 2014 Midterm Election

Figure 2: Sunset Times on Election Day, 2010 vs. 2014

Notes: These maps display sunset times on Election Day for the 2010 and 2014 midterm elections. In 2010, DST was still in effect on Election Day (November 2), resulting in later sunset times. In 2014, DST ended before Election Day (November 4), resulting in earlier sunset times. The difference in evening daylight between these elections forms the basis of our identification strategy.

[Back to Page 9]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480

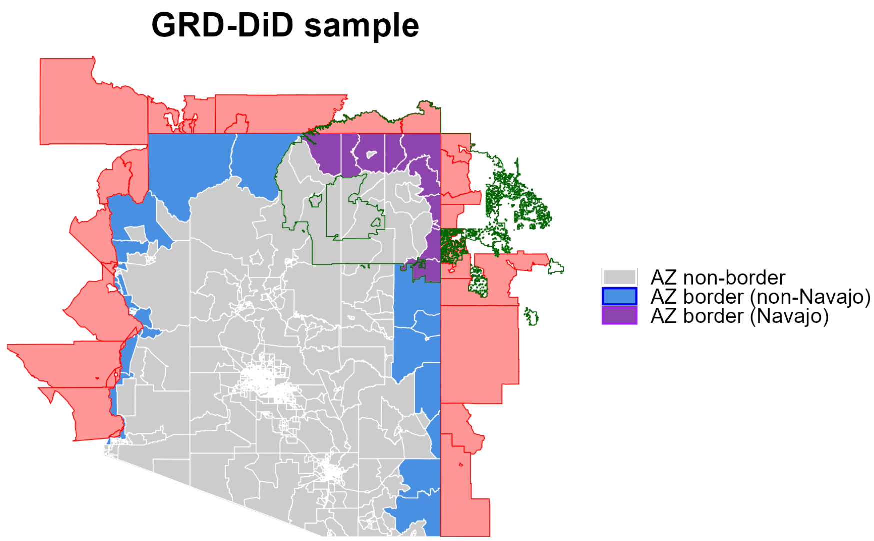


Figure 3: Sample Construction: Arizona Border Census Tracts

Notes: This figure displays the census tracts used in our GRD-DID analysis. Gray areas represent non-border census tracts in Arizona. Blue areas indicate Arizona census tracts adjacent to the state border (control group). Red/pink areas show census tracts in neighboring DST-observing states (California, Nevada, Utah, New Mexico) adjacent to the Arizona border (treatment group). Purple and green areas denote the Navajo Nation, which observes DST despite being partially located in Arizona; these tracts are excluded from the main analysis.

[Back to Page 11]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480 Content not peer-reviewed by APSA.

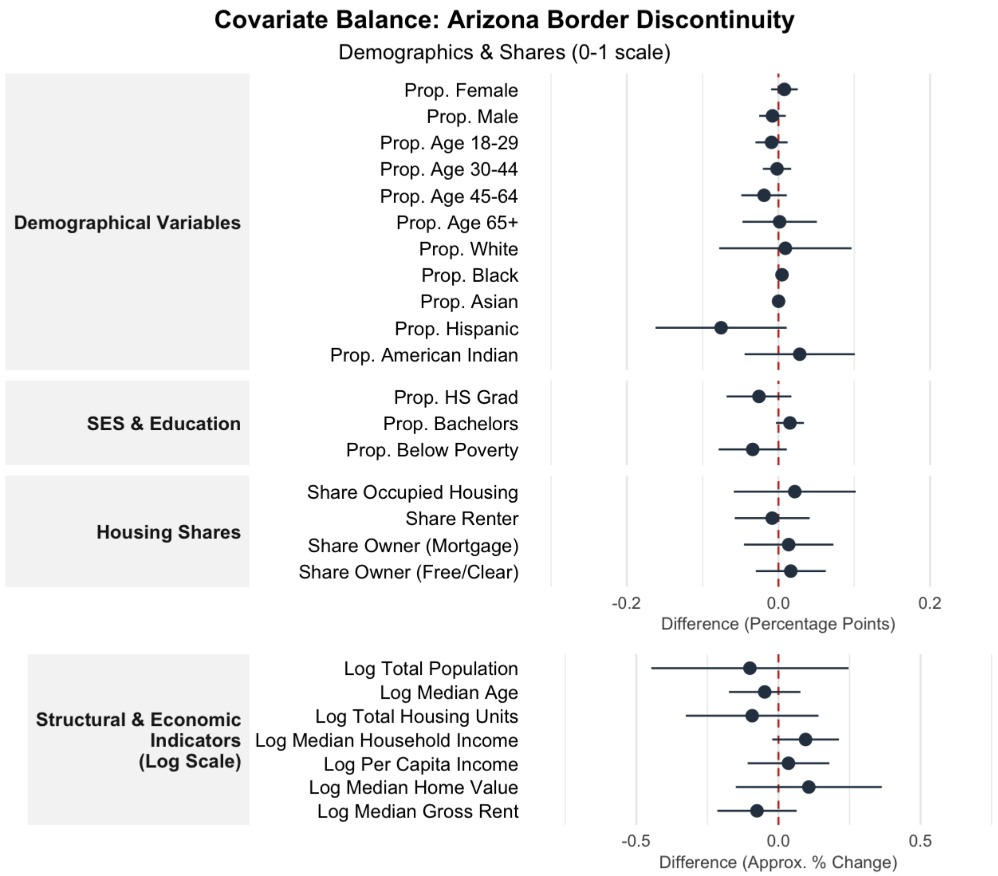


Figure 4: Covariate Balance: Arizona Border Discontinuity

Notes: This figure displays covariate balance tests comparing census tracts on either side of the Arizona border. Each point represents the difference in means between treatment (DST-observing states) and control (Arizona) border census tracts; horizontal lines show 95% confidence intervals. The top panel shows demographic and share variables on a 0–1 scale. The bottom panel shows log-transformed structural and economic indicators, where coefficients represent approximate percentage differences. Data are from the 2010 United States census and 2010 American Community Survey.

[Back to Page 13]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480

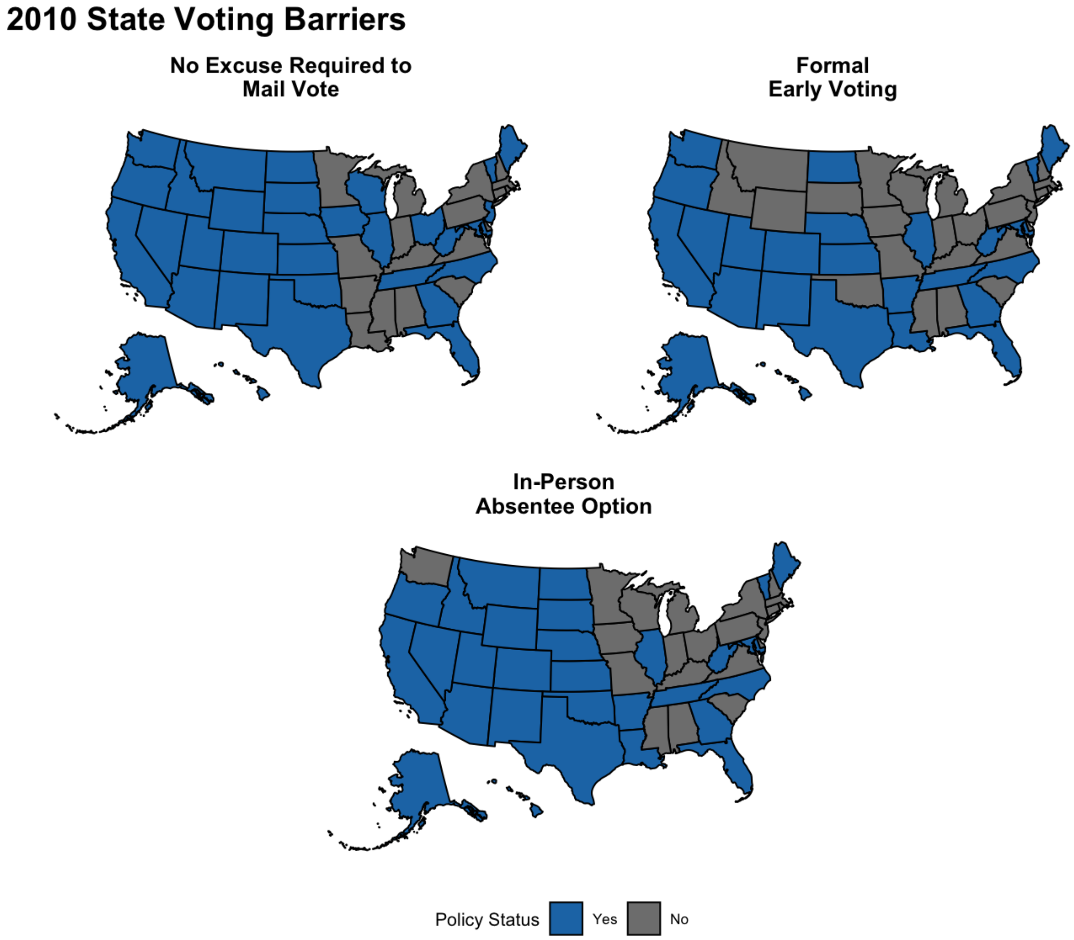


Figure 5: State Voting Barriers in 2010

Notes: This figure displays the geographic distribution of voting restrictions across U.S. states as of 2010. Blue states indicate policies that facilitate voting (allowed/no restriction); gray states indicate restrictive policies. Top left: states requiring an excuse to vote by mail. Top right: states without formal early voting periods. Bottom: states without in-person absentee voting options. These policy variations are used to examine heterogeneous effects of DST on turnout, testing whether voting convenience moderates the impact of the time change.

[Back to Page 18]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480 Content not peer-reviewed by APSA. **License:** All Rights Reserved

Table 1: Summary Statistics

	Border Sample		National Sample	
	Mean	SD	Mean	SD
Panel A: Turnout				
Voted in 2010	0.47	0.50	0.50	0.50
Voted in 2014	0.48	0.50	0.51	0.50
Panel B: Demographics				
Female	0.51	0.50	0.54	0.50
Age	52.8	17.1	47.3	17.1
Republican	0.46	0.50	0.32	0.47
Democrat	0.20	0.40	0.39	0.49
# of Voters	103,888		146,201,300	

Notes: This table presents summary statistics for the border and national samples. The border sample includes registered voters in census tracts adjacent to the Arizona border. The national sample includes all registered voters in the L2 voter file present in both 2010 and 2014.

[Back to Page 10]

Table 2: Effect of Daylight Saving Time on Voter Turnout: GRD-DID Estimates

	Full Bordering Sample	Matched Bordering Sample
	(1)	(2)
Panel A: Main Result (Midterm 2010 & 2014)		
DST	-0.060^{***}	-0.047^{**}
	(0.022)	(0.020)
Panel B: Placebo Test (Midterm 2002 & 2006)		
DST	0.009	-0.014
	(0.012)	(0.019)
Panel C: Placebo Test (Presidential 2004 & 2008)		
DST	0.022	0.022
	(0.041)	(0.030)
Observations	207,776	75,026
Individual FE	✓	✓
Pair × Year FE	✓	✓

Notes: This table reports GRD-DID estimates of the effect of Daylight Saving Time on voter turnout in general elections. The treatment group consists of voters living in census tracts bordering Arizona in states that observe DST (California, Nevada, Utah, New Mexico). The control group consists of Arizona voters in adjacent census tracts. In 2010, DST ended after Election Day; in 2014, DST ended before Election Day. Panel A shows the main results for midterm elections. Panels B and C present placebo tests using earlier midterm elections (2002, 2006) and presidential elections (2004, 2008) when DST timing relative to Election Day was similar across years. Standard errors clustered at the census tract level are reported in parentheses. Column (2) uses propensity score matching. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

[Back to Page 13]

Table 3: Effect of DST on Voter Turnout: National Difference-in-Differences

	(1)	(2)
DST	-0.0060^{***}	-0.0108^{***}
	(0.0014)	(0.0014)
Observations	292,402,600	291,944,866
Individual FE	✓	✓
Year FE	✓	✓
Controls		✓

Notes: This table reports national DiD estimates of the effect of DST on voter turnout in general elections. Column (1) includes individual and year fixed effects. Column (2) adds controls for precipitation, logged crime rate, and traffic accidents. Standard errors clustered at the census tract level in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

[Back to Page 15]

Table 4: Testing the Evening Darkness Channel: Geographic and Environmental Factors

Subgroup / Interaction	Coefficient	Std. Error	p-value	Observations
Panel A: By Sunset Time				
Early Sunset (< median)	-0.0202^{***}	(0.0014)	0.000	173,890,800
Late Sunset (≥ median)	0.0019	(0.0071)	0.789	118,511,800
Panel B: By Commute Time				
High Commute	-0.0402^{***}	(0.0062)	0.000	109,747,986
Low Commute	-0.0068^{***}	(0.0014)	0.000	182,642,374
Panel C: By Urbanicity				
Rural (≤25% urban)	-0.0210^{***}	(0.0055)	0.000	38,741,208
Mixed (25–75% urban)	-0.0324^{***}	(0.0075)	0.000	29,634,546
Urban (≥75% urban)	-0.0047^{***}	(0.0014)	0.001	222,174,036
Panel D: Continuous Interaction (Triple-Difference)				
DST × Treated × Poll-Sunset Gap	-0.3671^{***}	(0.0302)	0.000	292,402,600

Notes: Panels A–C report national DiD estimates for subgroups defined by factors that might influence daylight exposure. Panel D reports the triple-interaction coefficient from a fully interacted model. Poll-Sunset Gap measures hours between sunset and poll closing, centered at the sample mean; positive values indicate longer periods of darkness before polls close. All specifications include individual and year fixed effects. Standard errors clustered at the census tract level in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

[Back to Page 16]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480 Content not peer-reviewed by APSA. **License:** All Rights Reserved

Table 5: Testing the Evening Darkness Channel: Voting Law Interactions

	(1) Absentee Excuse Req.	(2) No Early Voting	(3) No In-Person Absentee
DST × Restrictive Policy	-0.0098^{***}	-0.0235^{***}	-0.0273^{***}
	(0.0007)	(0.0008)	(0.0008)
Observations	286,501,784	286,501,784	286,501,784

Notes: This table reports national DiD estimates interacted with state voting law indicators. We include the state voting law indicator as the control variable. The sample excludes Arizona, which does not observe DST, due to a lack of variation. Column (1): states requiring an excuse for absentee voting. Column (2): states without early voting. Column (3): states without in-person absentee voting. All specifications include individual and year fixed effects. Standard errors clustered at the census tract level in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

[Back to Page 18]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480

Table 6: Heterogeneous Effects by Voter Demographics: National DiD

Subgroup	Coefficient	Std. Error	p-value	Observations
Panel A: By Party Registration				
Republican	-0.0142^{***}	(0.0016)	0.000	93,827,218
Democrat	-0.0008	(0.0014)	0.586	114,728,092
Panel B: By Party Registration (Excluding L2-Inferred States)				
Republican	-0.0052^{***}	(0.0016)	0.002	56,078,278
Democrat	0.0014	(0.0015)	0.333	73,545,486
Panel C: By Gender				
Male	-0.0053^{***}	(0.0014)	0.000	134,924,918
Female	-0.0064^{***}	(0.0014)	0.000	157,477,682
Panel D: By Education				
High Education	-0.0060^{***}	(0.0015)	0.000	121,317,706
Low Education	-0.0050^{***}	(0.0017)	0.003	60,310,828
Panel E: By Income				
High Income	-0.0051^{***}	(0.0019)	0.008	63,963,010
Low Income	-0.0038^{***}	(0.0014)	0.009	198,944,670

Notes: This table reports national DiD estimates for voter subgroups. All specifications include individual and year fixed effects. Panel B excludes states where L2 infers party affiliation from voting history rather than official registration records (AL, GA, HI, IL, IN, MI, MN, MO, MT, ND, OH, SC, TX, VT, VA, WA). Standard errors clustered at the census tract level in parentheses. $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

[Back to Page 19]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480

8 Appendix

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480

A Further Discussion on Theory

Democratic participation occurs at institutionally specified times. Election Day falls on a particular date; polling places operate during fixed hours; the window for after-work voting is bounded by the end of the workday and the closing of the polls. These temporal structures constitute what we term *social time*: externally imposed clock time and institutional schedules that define when citizens are expected to perform civic acts.

Yet citizens are not disembodied rational actors who can perform equally well at any clock time. Human physiology follows endogenous circadian rhythms—approximately 24-hour cycles that regulate alertness, cognitive function, and motivation. These rhythms define *biological time*, which determines when individuals naturally feel awake, energetic, and capable of effortful activity, versus when they feel tired and ready to rest. Biological time is primarily entrained by light-dark cycles: the rising and setting of the sun calibrates the body's internal clock, signaling when to be alert and when to wind down (Roenneberg et al., 2007).

This calibration points to a third temporal system: *solar time*, the natural light-dark cycle determined by astronomical conditions—sunrise, sunset, and day length. Solar time varies smoothly with longitude (earlier in the east, later in the west within a timezone) and with season (shorter days in winter, longer in summer). Biological time synchronizes gradually toward solar time through daily light exposure, while social time is defined by legal and institutional convention and can change discontinuously through policy decisions such as Daylight Saving Time transitions.

To formalize how circadian misalignment affects voting costs, we decompose the cost term C_i into its constituent components:

$$C_i = c_0 + c_T T_i + c_F F_i + \varepsilon_i \tag{8}$$

where c_0 represents fixed costs (distance to polling place, registration burden), T_i denotes the voter's subjective *usable time*—the perceived window of time and energy available for activities like voting after completing work obligations—and F_i captures the voter's *fatigue level.* The parameter $c_T < 0$ indicates that more usable time reduces voting costs, while $c_F > 0$ indicates that greater fatigue increases them. The term ε_i captures idiosyncratic cost factors.

Both components of circadian misalignment affect voting costs through the same two channels. First, misalignment compresses subjective usable time:

$$T_i = T_0 - \beta(M^{shift} + M_i^{solar}), \quad \beta > 0 \tag{9}$$

When biological time runs ahead of social time—when the body signals that the day is ending even though clock time indicates hours remain—voters perceive less available time for discretionary activities. A voter whose body feels it is 6:30 PM when the clock reads 5:30 PM experiences a foreshortened evening: though polling places remain open, the subjective sense of "time left today" has diminished. This mechanism operates through both components: acute misalignment produces immediate temporal disorientation, while chronic misalignment—particularly

https://doi.org/10.33774/apsa-2026-74h67 ORCID: https://orcid.org/0009-0007-3491-3480

earlier sunset timing—signals the transition to evening rest, compressing the perceived window for after-work voting.

Second, misalignment directly increases fatigue:

$$F_i = F_0 + \alpha(M^{shift} + M_i^{solar}), \quad \alpha > 0 \tag{10}$$

When social time demands activity at moments biological time signals for rest, the resulting strain manifests as tiredness, reduced alertness, and diminished motivation for effortful tasks. Acute misalignment produces immediate fatigue in the days following a DST transition as voters perform daily activities while experiencing physiological strain. Chronic misalignment produces sustained fatigue when persistent divergence between solar and social time requires regular activity at biologically suboptimal hours.

Substituting the expressions for T_i and F_i into the cost function yields:

$$C_i = c_0 + c_T[T_0 - \beta(M^{shift} + M_i^{solar})] + c_F[F_0 + \alpha(M^{shift} + M_i^{solar})] + \varepsilon_i \tag{11}$$

Collecting terms and allowing the two components to have potentially different effect sizes:

$$C_i = C_0 + \gamma_1 M^{shift} + \gamma_2 M_i^{solar} + \varepsilon_i \tag{12}$$

where $C_0 = c_0 + c_T T_0 + c_F F_0$, and $\gamma_1, \gamma_2 > 0$. The parameters γ_1 and γ_2 may differ if the two forms of misalignment operate with different intensities through the time-compression and fatigue channels.

Substituting into the voting condition $p_i B_i + D_i \geq C_i$ yields two theoretical predictions:

Prediction 1 (Clock-based effect):

$$\frac{\partial P(\text{vote}_i = 1)}{\partial M^{shift}} < 0 \tag{13}$$

Elections occurring near DST transitions exhibit lower turnout due to jet-lag-style circadian shock.

Prediction 2 (Light-based effect):

$$\frac{\partial P(\text{vote}_i = 1)}{\partial M_i^{solar}} < 0 \tag{14}$$

Earlier sunset timing (greater solar-social mismatch) reduces turnout.

[Back to Page 7]

https://doi.org/10.33774/apsa-2026-74h67 **ORCID:** https://orcid.org/0009-0007-3491-3480 Content not peer-reviewed by APSA. **License:** All Rights Reserved