Addressing Seasonality in Veil of Darkness Tests for Discrimination

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Abstract

Race is more easily observed by police prior to traffic stops in daylight relative to darkness, and Veil of Darkness tests of discrimination compare stops made in daylight to those made in darkness at the same time of day exploiting seasonal variation in sunset. This paper addresses concerns that seasonal variation in traffic patterns could bias Veil of Darkness tests. First, we examine the approach of comparing stops made near Daylight Savings Time (DST) using a regression discontinuity approach to uncover the effect of more daylight immediately before or after the DST change. We find much larger racial differences in Texas highway patrol stops using the regression discontinuity approach as compare to the annual sample, even though traditional approaches to using the DST change yield smaller estimates. We also exploit a new source of daytime variation in the ability to observe race, surface visibility. Comparing stops made with different levels of surface visibility during the same season of the year and time of day yields smaller effects than traditional Veil of Darkness tests, but very precise estimates of the racial differences.

JEL Codes: K14, K42, J15, H11

Key Words: Police, Traffic Stops, Seasonality, Veil of Darkness, Racial Profiling, Racial Discrimination, Regression Discontinuity, Surface Visibility

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Identifying whether police discriminate in the decision to stop minority motorists is challenging because it is difficult to observe or measure the share of motorists at risk of being stopped who are minorities. A recent solution to this counterfactual problem in traffic stops, deemed the Veil of Darkness (VOD) test, was proposed by Grogger and Ridgeway (2006) and more recently applied by Ridgeway (2009), Horace and Rohlin (2016) and Ross et al. (2017). The authors argue that race is more easily observed by police during daylight relative to darkness. Thus, the racial composition of stops in darkness provides a counterfactual distribution for stops that are made in daylight at the same time of day and day of week. To control for differences between day and night traffic stops, the test is implemented by exploiting seasonal variation in the timing of sunset occurring within the “inter-twilight window” and controlling for time of day and day of week. Over the last decade, an increasing number of states have mandated the collection of motorist race in traffic stop records, and the VOD approach has quickly become the gold standard for evaluating such data for evidence of discrimination.[1]

The maintained assumption is that the composition of drivers on a given roadway at a given time of day and day of week is unaffected by changes in the timing of sunset, an assumption that appears especially reasonable within evening commuter traffic. This assumption, however, will be violated if the composition of motorists changes with the seasons. For example, summer traffic patterns may differ because schools are not in session, or winter traffic patterns may be affected

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[1] Applications of the Veil of Darkness include Grogger and Ridgeway (2006) in Oakland, CA; Ridgeway (2009) Cincinnati, OH; Ritter and Bael (2009) and Ritter (2017) in Minneapolis, MN; Worden et al. (2010; 2012) as well as Horace and Rohlin (2016) in Syracuse, NY; Renauer et al. (2009) in Portland, OR; Taniguchi et al. (2016a, 2016b, 2016c, 2016d) in Durham Greensboro, Raleigh, and Fayetteville, North Carolina; Masher (2016) in New Orleans, LA; Chanin et al. (2016) in San Diego, CA; Ross et al. (2015; 2016; 2017a; 2017b) in Connecticut and Rhode Island; Criminal Justice Policy Research Institute (2017) in Corvallis PD, OR; Milyo (2017) in Columbia, MO; Smith et al. (2017) in San Jose, CA; and Wallace et al. (2017) in Maricopa, AZ.

by winter weather. Grogger and Ridgeway (2006) and Ridgeway (2009) suggest addressing the concern about seasonality by exploiting the sunset variation around Daylight Savings Time (DST), and they estimate the same model restricting the sample to stops that are close to a DST time change. However, a few concerns remain with respect to this more restrictive model. First, the model actually still contains two significant sources of changes in sunset: the hour change in sunset arising from DST, and the rapid pace of change in the timing of sunset that occurs in the fall and spring. Seasonal changes in sunset account for just over half of the sunset timing change that occurs during a 42 day window on either side of DST. Second, there is a recent but rich literature that documents the health and labor market impact from DST. Related specifically to our concern, Smith (2016) documents that accident rates rise after spring DST possibly due to drivers being tired, raising concerns that driving patterns are affected by DST.

In order to address these concerns, we provide two innovations to this visibility strategy for detecting racial discrimination in traffic stops. First, in order to completely eliminate seasonality from the VOD estimates, we propose examining the effects of DST on the racial composition of stops using a regression discontinuity approach. Rather than controlling for daylight and simply restricting the time period of data considered, we control for whether the stop is before or after DST where stops after DST are treated by more or less daylight during the inter-twilight window, and then we include a running variable for days before and after the DST change. Second, we exploit a new measure of visibility, surface visibility, which is captured by the Automated Surface Observing System that records air clarity at weather stations in order to facilitate air traffic control activities. By exploiting hourly variation in surface visibility throughout each day, we can identify racial differences by comparing stops that were made during the same seasonal conditions, specifically stops made during the same month when the timing of sunset and the weather conditions are relatively similar.

We apply these techniques and new data in the context of stops by Texas Highway Patrol officers. Starting by applying traditional VOD techniques, we show that in Texas daylight leads to a 1.5 percent increase in the fraction of speeding stops by Texas Highway Patrol officers that involve African-American motorists. This effect is relative to an 14 percent fraction of African-American motorists among all speeding stops during the inter-twilight window. Following Grogger and Ridgeway (2006), we initially address seasonality by restricting the sample to 42 days before or after DST. This restriction reduces the effect of daylight by almost half to 0.8 percentage points, suggesting that seasonality is a serious concern. We then estimate IV style estimates of the effect of daylight using the regression discontinuity approach and find dramatically larger effects of approximately 7 percentage points. The estimate for the simple difference-in-difference approach (omitting the running variable) is also much smaller at 1.6 percentage points implying that these changes are not simply due to measurement error in daylight, but larger than the traditional DST estimate of 0.8 suggesting that the decline arising from restricting seasonality in the sample may be in part due to measure error.

Finally, we investigate the surface visibility data as a possible approach to assessing discrimination. Surface visibility measures are not directly driven by changes in daylight, but rather arise from fog, rain and other particulates in the air that reduce visibility. With daylight versus darkness comparisons, the ability to observe race arises from the presence of ambient light which illuminates the driver and passengers within the car, while surface visibility will affect the distance at which an officer can clearly identify race. Therefore, surface visibility estimates capture a more subtle effect where poor daytime visibility may reduce the time between when the officer observes race and when the car passes by making it more difficult for the officer to consider race in their traffic stop decisions. Exploiting within time of day, day of week and month of year variation in visibility, we again find significant effects of visibility on the racial composition of stops. While we cannot directly compare these estimates with the daylight effects, a one standard deviation increase in visibility increases the share of stops that are African-American by approximately 0.1 percentage points, where one standard deviation is approximately 1.3 miles and the average is 9.6 miles, which represents high visibility conditions. Even dropping by three standard deviations, which is at the edge of our sample, implies less than a 0.5 percentage point increase in the percent African-American for speeding stops. Therefore, the potential effects of typical changes in surface visibility are more modest in magnitude. However, we must acknowledge that surface visibility levels tend to be high in Texas and results might differ in places with greater variation in air quality.

The paper also presents all results for individual state highway patrol districts. The results for individual districts are somewhat noisy for the DST samples. However, after imposing a Bonferroni correction, racial differences are significant at or near the 10% level for the districts east and northeast of the Dallas district for both the VOD test using the annual inter-twilight window sample and for the surface visibility test using the annual daylight sample. For these districts, a very modest one standard deviation change in visibility of only 1.3 miles implies 0.5 percentage point change in the likelihood of a motorist being African-American, as compared to the 2.5 to 3.0 percentage point changes from the shift from darkness to daylight using the annual sample.

Texas Highway Patrol Traffic Stop Data

The paper uses data collected as part of the Stanford Open Policing Project which contains 13.5 million stops made by 3,606 Texas Highway Patrol officers from 2010 to 2015. These officers are assigned to one of nineteen highway patrol districts, and each district contains between 3 and 30 counties, on average approximately 13 counties per district. The data identifies the location of the stop, date and time of the stop, all violations associated with the stop, the resulting disposition for each violation (warning or citation), the race and ethnicity of the motorist stopped, and an identifier for the police officer making the stop.[2]

Following Grogger and Ridgeway (2006) and based on findings in Kalinowski, Ross and Ross (2018), we select a sample of all speeding stops because the composition of stops over citation type may change between daylight and darkness for the same time of day. We also restrict the sample to just stops of non-Hispanic whites and African-Americans. For VOD tests, we establish an inter-twilight window using data from the United States Naval Observatory such that the lower bound is the earliest time of day that sunset begins during the year in the easternmost county of the state and the upper bound is the latest time of the end to the evening, civil twilight in the westernmost county. We select only stops that fall within the inter-twilight window, but do not fall during actual twilight for the date of the stop, again using the earliest start and latest end of twilight in Texas. For the regression discontinuity analysis, we then further restrict the data to time periods within 42 or 21 days for the fall or spring DST time change. For the surface visibility analyses, we use a sample of all stops during daylight and exclude stops during periods that are

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[2] The raw data contains a patrol district indicator for each officer which is one of the few variables in the data with poor coverage. Rather than rely on this indicator, we assign officers to patrol districts based on the locations where they made the majority of their stops within a given month.

ever in darkness or twilight at any point during the year, i.e. that occur at night or during the morning or evening inter-twilight periods.

The descriptive statistics for each of these four samples are shown in Table 1. The first column shows descriptive statistics for the inter-twilight window sample, and columns 2 and 3 show the statistics after restricting the sample to be near the date of the DST time change. The DST samples include stops made during twilight since those stops are included in the regression discontinuity analysis, even though they are excluded from the traditional DST approach. The fourth column shows the statistics for the sample of all daylight stops excluding twilight, which is used for the surface visibility analysis. Approximately, 13-14 percent of speeding stops are of African-American motorists. About half of stops are in daylight, but this falls to 25% of stops (about one-third of stops excluding twilight) when looking near the DST time change, illustrating that driving or stop patterns may change significantly across the seasons. About 28% of stops are on interstate highways, half are on state highways and the rest are divided between rural, county and city roads. Almost 40% of speeding stops are issued as warnings, but less warnings are issued in daylight. We also observe a lot more stops on Friday and Saturday, than on other days of the week. Most variables are relatively stable across the samples with the exception of less stops in daylight near the DST time change, and less warnings and less Friday stops in the daylight sample as compared to the inter-twilight window samples.

As noted above, the stops can be divided by county into 19 Highway Patrol Districts. For the district level analyses, we restrict our attention to districts around or near the large population centers of Houston, Dallas, Austin, San Antonio and Corpus Christi.[3] Focusing on these districts results in 12 districts mostly in the eastern half of the state. In table 2, we show the fraction of

[3] The other relatively large city, El Paso, is excluded because it is located near a time zone boundary.

speeding stops in each district that are African-American for different samples, as well as the fraction of stop residents who are African-American based on the 2017 U.S. Census Bureau estimates. Some districts have a substantially higher fraction of African-American stops than their share of population, such as districts northeast and east of Dallas and around Houston and northwest of Houston, but other nearby districts have substantially less stops than expected based on population share, such as Fort Worth and southwest of Dallas.

Traditional Veil of Darkness (VOD) Tests

First, we estimate traditional VOD tests by regressing whether the motorist stopped is an African American (R_i) on whether the stop was made in daylight (D_i) and controls for time of day and day of week (X_i) using a linear probability model.

$$R_i = \beta_1 D_i + \gamma_1 X_i + \varepsilon_i$$

For the baseline model, X_i contains a fixed effect for each hour time period and a fixed effect for each day of the week. Additional models are presented that include year or year and county fixed effects. Standard errors are clustered at the county level.[4]

Table 3 presents these estimates. Regardless of controls, a speeding stop made in daylight at the same time of day and day of week is associated with the stop being approximately 1.5 percentage points more likely to involve an African-American motorist relative to a total African-American share of stops in the state of 14%. Table 4 presents similar estimates for each district. Most of the districts have statistically significant differences. Similar to the descriptive statistics, the largest differences are observed east and northeast of Dallas and around Houston and northwest of Houston. For these four locations, the racial differences between daylight and darkness range between just under half and just under 100% of the unconditional racial differences in Table 2.

[4] All results are robust to the inclusion of officer or officer by county fixed effects.

The t-statistics are near or above three for all districts except northwest of Houston, implying that the estimates for the three locations are statistically significant at the 5% level even after applying a Bonferroni correction with Houston having a t-stat of 2.5 and so being near significance at the 10% level. None of the estimates are negative, and so within the inter-twilight window the fraction of each district's stops that are of African-American motorists in daylight always equals or exceeds the fraction in darkness.

We next follow Ridgeway (2009) in restricting the sample to stops made near the Daylight Savings Time (DST) time change. The results within a 42 day window surrounding DST are shown in Tables 5 and 6. In columns 2 and 3 of Table 5, the year fixed effects are replaced by DST window (fall/spring) by year fixed effects. Table 5 shows that the statewide effects are again stable across model specifications, but much smaller with daylight raising the likelihood that a stop is of an African-American motorist by 0.8 percentage points. For the district results in Table 6, the daylight differences are only significant in one district, southwest of Dallas, a district that had only small differences in Table 4. Further, the t-statistic is about 2 and so this district result does not survive a Bonferroni correction. The results in Tables 3 and 4 suggest that seasonality can be important for assessing discrimination in police stops using VOD approaches.

Regression Discontinuity Tests

In order to develop the regression discontinuity tests, we modify the model specification to examine the effect of the DST time change (C_i) where the change treats the inter-twilight window with more daylight. Then, we add additional controls for the number of days before or after the DST change (V_i) where the running variable is reversed in fall, relatively to spring so that the running variable always represents an increase in daylight. Following the standard RD structure, the model specification also includes the interaction of V_i and C_i and can be extended to allow V_i to be vector of polynomial terms of the running variable.

$$R_i = \beta_2 C_i + \gamma_2 X_i + \delta_a V_i + \delta_b V_i C_i + \varepsilon_i$$

In order to assess the magnitude of these effects, we also estimate a first stage model where we regress whether the stop was made in daylight on the DST time change. For consistency with our RDD model, we include twilight stops with those occurring in darkness by setting the dependent variable daylight to zero. Specifically, we estimate

$$D_i = \beta_3 C_i + \gamma_3 X_i + \delta_a V_i + \delta_b V_i C_i + \varepsilon_i$$

and then the ratio β_2 to β_3 shows the effect of daylight, which can be compared to the estimates of β_1 above. Finally, by setting δ_a and δ_b to zero, we obtain a standard difference-in-differences analysis for before and after DST that should be directly comparable to the traditional VOD estimates in Tables 3 through 6.

Table 7 shows the difference-in-differences (column 1) and regression discontinuity estimates (all other columns).[5] All models control for DST window by year and county fixed effects. Using the 42 day window on either side of DST, the difference-in-difference analysis implies that a stop on the more daylight side of the DST change is associated with a 0.4 percentage point increase in the likelihood of a stopped motorist being African-American. This effect increases modestly when linear controls for the running variable are included to between 0.5 and 0.6 percentage points. However, when the model includes quadratic or cubic functions of the running variable, the effect of DST increases to about 1.0 percentage points. Figure 1 shows a graphical representation of the share of African-American stops within the intertwilight window

[5] As in previous models, the estimated magnitude is robust to variation in the list of fixed effects included.

over the running variable and the discontinuity, which shows a strong decline in share African-American stops as the DST boundary is approached.

The sensitivity to controls suggest that the bandwidth may be too large, and the last two columns present models with a bandwidth of only 21 days on either side of DST and linear controls for the running variable. The estimates are also about 1.0 percentage points. Figure 2 shows a graphical representation of share African-American over the running variable for a 21 day window on either side of the DST time change. In this case, the linear control for the running variable accurately captures the decline in share African-American as the DST boundary is approached, and supports the earlier estimates based on the quadratic and cubic controls for the running variable.

Table 8 shows the first stage estimates where column 1 does not include any running variable and is equivalent to a difference-in-differences tests, and Columns 2 and 3 include linear controls for the running variable. The estimates in columns 2 and 3 are based on the 21 day window and are both 0.148. Scaling the estimates in the last column of Table 7 implies that the effect of daylight is to increase the fraction of stops that involve African-American motorists by 7.0 percentage points. The resulting estimate implies a 50 percent increase over the average fraction of African-American motorists stopped for speeding.

Table 8 Column 1 presents difference-in-differences estimates for the 42 day window sample, and using those estimates to scale the estimate in column 1 of Table 7 results in an effect size of 1.6 percentage points. Surprisingly, this effect is similar to the annual sample estimate and twice as large as the estimate using the traditional DST approach. Perhaps the loss of seasonal variation when the sample is restricted increases the bias from measurement error in the daylight variable leading to the smaller estimates in Table 5. The timing of DST is observed without error and the two stage estimates correct for measurement error in daylight leading to the larger difference-in-differences estimates for the sample sample.

Table 9 presents the district specific estimates for the 21 day window with linear controls for the running variable. Significant differences are identified for east of Dallas and the area around San Antonio, but the t-statistics are close to two and the significance of these estimates would not survive a Bonferroni correction.

Surface Visibility Tests

Finally, we return to estimating a more traditional VOD test where we regress whether the motorist stopped is an African American (R_i) on a measure of visibility, but in this case the measure of visibility is surface visibility (S_i), and X_i in the model is expanded to include month fixed effects so that the effect of visibility is identified by comparing stops made during the same season of the year. The X_i vector also includes a continuous control for the intensity of rain during hour of the day and in the county for each specific stop.

$$R_i = \beta_4 S_i + \gamma_4 X_i + \varepsilon_i$$

The statewide results are shown in Table 10. Column 1 presents estimates including fixed effects for hour of day, day of week, month of year, year and county. Columns 2 and 3 present estimates after adding month by year or month by year by county fixed effects, respectively. The estimates are quite stable across the models at approximately 0.0009. The surface visibility is standardized such that a one unit change corresponds with a 1.26 mile change in visibility (the standard deviation) relative to the mean of 9.60 miles. High visibility, during very good clear conditions, is approximately 10 miles. The data is censored above 10 miles, and the distribution of surface visibility is skewed towards zero so that observations 2 standard deviations below the mean are not uncommon. Regardless, even a dramatic 3 standard deviation reduction in visibility, which is clearly near the edge of the sample, would imply an increase of only about 0.35 percentage points. Therefore, the statewide racial differences in the composition of stops identified using this approach are much smaller than those identified based on the loss of ambient lighting after sunset.

However, we do find sizable differences in the composition of stops in the districts that are east and northeast of Dallas. A two standard deviation reduction in visibility is associated with about a 1 percentage point increase in the share of stops that are of African-American motorists in these two districts. The t-statistic for the east of Dallas district is above 3, and the statistic for northeast of Dallas is near 2.5 suggesting that they are significant at the 5% level and close to significant at the 10 percent level, respectively, after a Bonferroni correction. These findings are consistent with earlier estimates. These two districts had some of the largest racial differences on average and for the annual sample VOD test, and the district east of Dallas has sizable racial differences for the regression discontinuity analyses. Further, unlike the DST estimates where we observe several noisy, but sizable estimates, of both positive and negative sign, the estimates for all other districts are near zero using surface visibility.

Discussion

This paper investigates the sensitivity of Veil of Darkess (VOD) tests for discrimination in traffic stops to seasonal variation in traffic patterns. The VOD test compares stops at the same time of day that are in darkness at one time of year and in daylight at another due to seasonal variation in the timing of sunset. The impact of daylight using an annual sample where a large amount of variation arises from comparing summer to winter is almost twice as large as comparable analyses conducted only using stops during the three months surrounding each Daylight Savings Time (DST) time change. However, when we use a regression discontinuity analysis to focus on the effects right at the DST time change, we find that the racial differences in stops between daylight and darkness increase to magnitudes substantially larger than in the annual sample. However, the

DST analyses do not have sufficient power to identify racial differences within individual highway patrol districts in Texas. The results suggest that traditional approaches for exploiting variation around the DST time change may be 1. biased downwards due to measurement error in daylight and 2. biased in an unknown direction by the seasonal variation that occurs near the time change.

We also investigate an alternative measure of surface visibility using daytime stops rather than the presence of ambient lighting near twilight. The estimates are consistent with discrimination in traffic stops, but the estimated magnitudes are quite small. We speculate that the small effects arise because surface visibility likely influences differences in treatment due to the differential time available between observing race and making the stop decision, but traditional VOD tests are able to exploit the inability to see the driver behind the windshield due to a lack of ambient light. Nonetheless, the results arising from the district level analyses are quite promising. For two districts, we identified sizable and precisely estimated racial differences in traffic stops, and relatively precisely estimated zeros in all other districts. In future work, we hope to use the same weather station reports in order to capture variation in ambient lighting due to cloud cover or other factors in order to obtain within season variation that is more directly comparable to the type of variation exploited in Veil of Darkness tests for discrimination.

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Table 1. Descriptive Statistics for Speeding Stops

		Intertwilight Window						Daytime	
		Annual Sample		42-Day DST Sample		21-Day DST Sample		Annual Sample	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
African-American		0.14	0.34	0.13	0.34	0.13	0.34	0.13	0.34
Visibility	Daylight	0.55	0.50	0.24	0.43	0.25	0.43	N/A	N/A
	Darkness	0.45	0.50	0.47	0.50	0.46	0.50	N/A	N/A
	Twilight	N/A	N/A	0.29	0.45	0.29	0.45	N/A	N/A
	DST (Lighter)	N/A	N/A	0.52	0.50	0.51	0.50	N/A	N/A
	Visibility (Miles)	N/A	N/A	N/A	N/A	N/A	N/A	9.595	1.259
	Precip. (Inches)	N/A	N/A	N/A	N/A	N/A	N/A	0.001	0.011
Type	Warning	0.37	0.48	0.39	0.49	0.39	0.49	0.33	0.47
	Com. Veh.	0.01	0.10	0.01	0.10	0.01	0.10	0.02	0.12
Location	Const. Zone	0.02	0.14	0.02	0.13	0.02	0.13	0.03	0.16
	Interstate	0.28	0.45	0.28	0.45	0.28	0.45	0.30	0.46
	US/State Hwy	0.51	0.50	0.51	0.50	0.51	0.50	0.50	0.50
	Rural/Farm Rd	0.13	0.33	0.13	0.33	0.13	0.33	0.12	0.33
	County/City Rd	0.08	0.28	0.08	0.28	0.08	0.28	0.08	0.26
Day of Week	Mon.	0.11	0.32	0.11	0.31	0.11	0.31	0.12	0.33
	Tues.	0.12	0.32	0.12	0.32	0.12	0.32	0.13	0.34
	Weds.	0.13	0.33	0.13	0.34	0.13	0.34	0.14	0.35
	Thurs.	0.14	0.35	0.14	0.35	0.14	0.35	0.14	0.35
	Fri.	0.21	0.41	0.21	0.41	0.21	0.40	0.15	0.36
	Sat.	0.18	0.38	0.17	0.38	0.17	0.38	0.16	0.37
	Sun.	0.12	0.32	0.12	0.32	0.13	0.33	0.14	0.35
Observations		510614		341947		165488		1508676	

Notes: Descriptive statistics for the regression samples. Columns 1 and 2 present means and standard deviations for the annual sample. Columns 3 and 4 present statistics for the DST regression discontinuity analysis with the 42 day window on either side. The 21 day window sample statistics are shown in Columns 5 and 6. The DST samples for the race on daylight regressions are smaller because stops made during hours in actual twilight are ommited. Columns 7 and 8 present statistics for the daytime sample used in the surface visibility analysis.

Table 2. Speeding Stops by Highway Patrol District

District	Traffic Stops (Speeding)			Census			Difference
	Total Stops	White	African-American	Population	White	African-American	Stops - Residence
Dallas	201,173	0.688	0.171	4,123,615	0.704	0.186	-0.015
E of Dallas	266,313	0.672	0.218	860,334	0.809	0.152	0.066
NE of Dalla	145,451	0.717	0.158	489,253	0.831	0.120	0.038
Ft. Worth	224,679	0.803	0.071	3,395,287	0.775	0.132	-0.061
Houston	279,393	0.521	0.225	5,391,914	0.710	0.189	0.036
NE of Hous	229,460	0.703	0.185	782,269	0.753	0.201	-0.017
W of Houst	306,075	0.607	0.160	1,672,798	0.719	0.147	0.013
NW of Hou	81,577	0.613	0.195	335,431	0.804	0.124	0.071
Corpus Chri	189,214	0.670	0.033	598,806	0.919	0.039	-0.006
San Antoni	339,427	0.700	0.055	2,794,113	0.866	0.073	-0.018
Austin	300,077	0.722	0.087	2,237,922	0.827	0.076	0.010
SW of Dalla	195,882	0.684	0.152	854,154	0.751	0.179	-0.026

Notes: Table presents distribution of speeding stops and residential population overall and by race across patrol districts using 2017 census estimates of county population for the later. The last column presents the difference between share of black speeding stops and the share of residents who are black.

Table 3. VOD Analysis Annual Sample				
LHS: African-American		Baseline	Year FE	County FE
Daylight		0.0154***	0.0151***	0.0149***
		(0.0016)	(0.0015)	(0.0015)
Fixed-Effects	County			X
	Year		X	X
	Day of Week	X	X	X
	Hour	X	X	X
Observations		510,614	510,614	510,614

Notes: Linear probability model of black dummy variable on daylight dummy variable plus controls for all speeding stops in the intertwilight window. Column 1 presents results including fixed effects for time of day using hour time segments and for day of week. Column 2 and 3 present results after controlling for year fixed effects and year and county fixed effects, respectively. *** 1% significance level, ** 5% significance level, * 10% significance level.

Table 4: VOD Analysis Annual Sample by District													
LHS: African-American		Dallas	E of Dallas	NE of Dallas	Ft. Worth	Houston	NE of Houston	W of Houston	NW of Houston	Corpus Christi	San Antonio	Austin	SW of Dallas
Daylight		0.010	0.030***	0.026***	0.014***	0.034***	0.001	0.014**	0.030**	0.002	0.005	0.009*	0.013*
		(0.007)	(0.007)	(0.009)	(0.005)	(0.008)	(0.007)	(0.006)	(0.012)	(0.004)	(0.004)	(0.005)	(0.007)
Fixed-Effects	County	X	X	X	X	X	X	X	X	X	X	X	X
	Year	X	X	X	X	X	X	X	X	X	X	X	X
	Day of Week	X	X	X	X	X	X	X	X	X	X	X	X
	Hour	X	X	X	X	X	X	X	X	X	X	X	X
Observations		28,732	40,464	20,428	32,283	34,456	32,684	38,781	11,945	22,924	42,181	39,039	28,843

Notes: Linear probability model of black dummy variable on daylight dummy variable plus controls. All models include fixed effects for time of day using hour time segments, day of week, year and county. Each column presents estimates from a seperate regression for all speeding stops during the intertwilight window for a single district. *** 1% significance level, ** 5% significance level, * 10% significance level.

Table 5. VOD Analysis Daylight Savings Time Sample				
LHS: African-American		Baseline	Year FE	County FE
Daylight		0.0082**	0.0082***	0.0082**
		(0.0033)	(0.0032)	(0.0033)
Fixed-Effects	County			X
	Year		X	X
	Day of Week	X	X	X
	Hour	X	X	X
Observations		243,772	243,772	243,772

Notes: Linear probability model of black dummy variable on daylight dummy variable plus controls for all speeding stops in the intertwilight window and within 42 days of a DST time change. Column 1 presents results including fixed effects for time of day using hour time segments and for day of week. Columns 2 and 3 present results after controlling for year fixed effects and year and county fixed effects, respectively. *** 1% significance level, ** 5% significance level, * 10% significance level.

Table 6. VOD Analysis Daylight Savings Time Sample by Highway Patrol District

LHS: African-American		Dallas	E of Dallas	NE of Dallas	Ft. Worth	Houston	NE of Houston	W of Houston	NW of Houston	Corpus Christi	San Antonio	Austin	SW of Dallas
Daylight		-0.028*	0.024	-0.029	0.013	0.019	-0.009	0.006	-0.022	0.018*	0.004	0.009	0.038***
		(0.015)	(0.016)	(0.019	(0.010)	(0.016)	(0.016)	(0.014)	(0.027)	(0.010)	(0.008)	(0.010)	(0.014)
Fixed-Effects	County	X	X	X	X	X	X	X	X	X	X	X	X
	DST Window x Year	X	X	X	X	X	X	X	X	X	X	X	X
	Day of Week	X	X	X	X	X	X	X	X	X	X	X	X
	Hour	X	X	X	X	X	X	X	X	X	X	X	X
Observations		14,110	19,836	10,033	15,718	16,568	15,435	18,453	5,951	10,386	19,456	18,259	14,017

Notes: Linear probability model of black dummy variable on daylight dummy variable plus controls for all speeding stops in the intertwilight window and within 42 days of a DST time change. All models include fixed effects for time of day using hour time segments, day of week, year and county. Each column presents estimates from a seperate regression for all speeding stops during the intertwilight window for a single district. *** 1% significance level, ** 5% significance level, * 10% significance level.

Table 7. Race as a Function of Daylight Savings Time (DST)

LHS: African-American	42 Day Window					21 Day Window	
	Diff-in-Diff	Linear	Interaction	Quadratic	Cubic	Linear	Interaction
DST	0.0035***	0.0056**	0.0053**	0.0095***	0.0101**	0.0099***	0.0103***
	(0.0012)	(0.0022)	(0.0022)	(0.0033)	(0.0045)	(0.0032)	(0.0032)
Running		-0.00006	0.00005	0.00065***	0.00071	-0.00030**	-0.00054***
		(0.00004)	(0.00006)	(0.00024)	(0.00058)	(0.00013)	(0.00019)
Running*DST			-0.00021**	0.00052	0.00022		0.00046*
			(0.00009)	(0.00034)	(0.00085)		(0.00026)
Running^2				-0.00001***	-0.00002		
				(0.00001)	(0.00003)		
Running^2*DST				0.00001	0.00002		
				(0.00001)	(0.00004)		
Running^3					0.00000		
					(0.00000)		
Running^3*DST					-0.00000		
					(0.00000)		
Observations	341,947	341,947	341,947	341,947	341,947	165,488	165,488

Notes: Linear probability model of race dummy variable on DST dummy variable plus controls for all speeding stops in the intertwilight window and within 42 or 21 days of a DST time change. All models include fixed effects for DST change by year and county. Column 1 presents the difference-in-differences estimates using the 42 day window. Columns 2 through 5 presents regression discontinuity estimates using the 42 day window after controlling for polynomials of the running variable. Columns 5 and 6 present results after controlling for a linear running variable plus in column 6 its interaction with DST using the 21 day window. *** 1% significance level, ** 5% significance level, * 10% significance level.

Table 8. Daylight as a Function of DST			
LHS: Daylight	Diff-in-Diff	Linear	Interaction
DST	0.2132***	0.1476***	0.1476***
	(0.0014)	(0.0039)	(0.0038)
Running		0.0017***	0.0018***
		(0.0002)	(0.0002)
Running*DST			-0.0000
			(0.0003)
Observations	318,499	165,488	165,488

Notes: Linear probability model of daylight dummy variable on DST dummy variable plus controls for all speeding stops in the intertwilight window. All models include fixed effects for DST change by year and county. Column 1 presents difference-in-differences estimates using the 42 day window on either side of a DST time change. Columns 2 and 3 present regression discontinuity results after controlling for the running variable and in column 3 its interaction with DST using the 21 day window. *** 1% significance level, ** 5% significance level, * 10% significance level.

Table 9. Race as a Function of Daylight Savings Time (DST) by District using 21 Day Window

LHS: African-American	Dallas	E of Dallas	NE of Dallas	Ft. Worth	Houston	NE of Houston	W of Houston	NW of Houston	Corpus Christi	San Antonio	Austin	SW of Dallas
DST	0.024	0.026*	0.011	0.006	0.008	0.007	0.003	-0.022	0.009	0.020**	-0.003	-0.001
	(0.016)	(0.015)	(0.019)	(0.009)	(0.017)	(0.017)	(0.015)	(0.027)	(0.010)	(0.009)	(0.011)	(0.016)
Running	-0.00155	-0.00199**	-0.00151	-0.00026	0.00020	-0.00163	0.00008	0.00195	0.00046	-0.00018	0.00083	-0.00099
	(0.00095)	(0.00089)	(0.00109)	(0.00055)	(0.00102)	(0.00099)	(0.00085)	(0.00161)	(0.00058)	(0.00053)	(0.00065)	(0.00095)
Post-DST Running	0.00114	0.00223*	0.00150	-0.00005	-0.00031	0.00245*	-0.00023	-0.00199	-0.00105	-0.00091	-0.00098	0.00166
	(0.00129)	(0.00122)	(0.00150)	(0.00076)	(0.00140)	(0.00136)	(0.00119)	(0.00220)	(0.00078)	(0.00073)	(0.00089)	(0.00127)
Observations	9,424	12,652	6,706	10,782	11,129	10,001	12,354	4,010	7,489	13,309	12,468	9,346

Notes: Linear probability model of black dummy variable on daylight dummy variable plus controls for all speeding stops in the intertwilight window and within 42 days of a DST time change. All models include fixed effects for DST change by year and county. Each column presents estimates from a seperate regression for all speeding stops during the intertwilight window for a single district. *** 1% significance level, ** 5% significance level, * 10% significance level.

Table 10. Race as a Function of Surface Visibility				
LHS: African-American		Month FE	by Year	by Year by County
Surface Visibility		0.00094***	0.00094***	0.00085**
		(0.00036)	(0.00036)	(0.00038)
Rain		-0.00023	-0.00023	-0.00017
		(0.00029)	(0.00029)	(0.00030)
Fixed-Effects	Month*Year*County			X
	Month*Year		X	
	Month	X		
	Year	X		
	County	X	X	
	Day of Week	X	X	X
	Hour	X	X	X
Observations		1,508,676	1,508,676	1,508,676

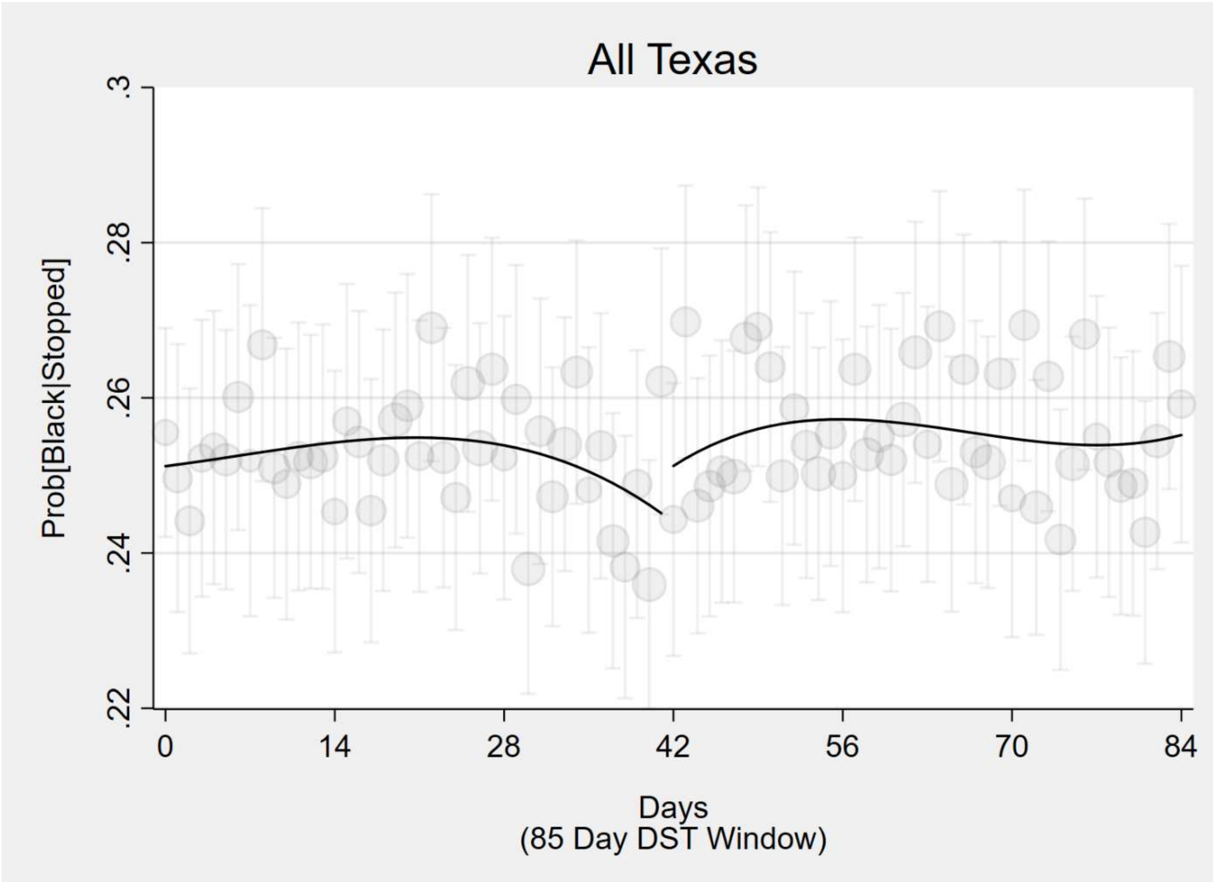
Notes: Linear probability model of black dummy variable on Surface visility plus a control for inches of rain during hour time segment using sample of all speeding stops during the day excluding morning and evening twilight. Column 1 presents results including fixed effects for time of day using hour time segments, day of week, county, year and month. Column s2 and 3 present results after controlling for month by year fixed effects and month by year by county fixed effects, respectively. *** 1% significance level, ** 5% significance level, * 10% significance level.

Table 11. Race as a Function of Surface Visibility by District

LHS: African-American	Dallas	E of Dallas	NE of Dallas	Ft. Worth	Houston	NE of Houston	W of Houston	NW of Houston	Corpus Christi	San Antonio	Austin	SW of Dallas
Visibility	0.0005	0.0049***	0.0047**	0.0005	0.0017	0.0015	-0.001	0.0038	-0.0008	-0.0002	0.0014	0.0005
	(0.0023)	(0.0014)	(0.0019)	(0.0012)	(0.0015)	(0.0016)	(0.0014)	(0.0027)	(0.0010)	(0.0009)	(0.0011)	(0.0018)
Rain	-0.001	-0.0014	-0.0013	0.0003	-0.0033***	0.0014*	-0.0007	0.0013	-0.0004	0.001	0.0022	0.0014
	(0.0017)	(0.0012)	(0.0013)	(0.0006)	(0.0013)	(0.0008)	(0.0013)	(0.0021)	(0.0006)	(0.0009)	(0.0014)	(0.0012)
Observations	80,641	117,828	59,983	965,63	99,299	107,440	113,062	32,231	62,301	133,923	129,181	79,312

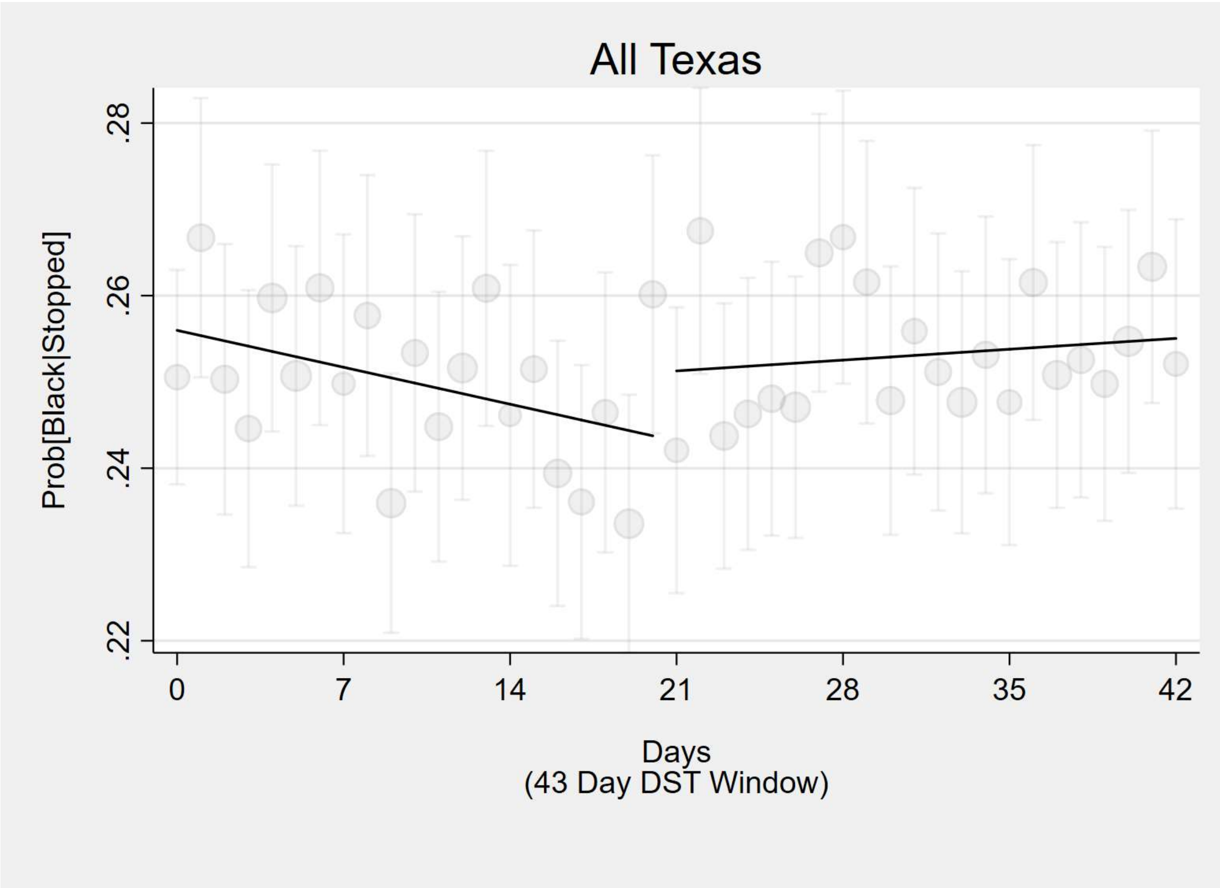
Notes: Linear probability model of black dummy variable on Surface visility plus a control for inches of rain during hour time segment. All models include fixed effects for time of day using hour time segments, day of week, and month by year by county. Each column presents estimates from a seperate regression for all speeding stops during the day excluding morning and evening twilight for a single district. *** 1% significance level, ** 5% significance level, * 10% significance level.

Figure 1. Regression Discontinuity Plot for 42 Day Window on Either Side of the DST Change



Notes. The running variable is shown on the horizontal axis running from less to more daylight with DST occurring at day 42. The vertical axis shows the fraction of stops that were of African-American motorists during the intertwilight window. Each circle represents a single day. The solid line represents a third-order polynomial fit to the day on either side of the DST boundary.

Figure 2. Regression Discontinuity Plot for 21 Day Window on Either Side of the DST Change



Notes. The running variable is shown on the horizontal axis running from less to more daylight with DST occurring at day 21. The vertical axis shows the fraction of stops that were of African-American motorists during the intertwilight window. Each circle represents a single day. The solid line represents a linear fit to the day on either side of the DST boundary.