Appendix

Criminal Deterrence when there are Offsetting Risks: Traffic Cameras, Vehicular Accidents, and Public Safety

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1 Data Appendix

1.1 Data Sources

1.1.1 Vehicle Accidents

The 2003-2014 accident data from the Texas Department of Transportations (TxDOT) Crash Records Information System (CRIS) includes all reported motor vehicle traffic accidents in Texas. We use information on all accidents in the cities of Houston and Dallas during this time period. The 2010-2014 CRIS data were downloaded via the TxDOT online database by month and year http://www.txdot.gov/government/enforcement/data-access.html

As of 2016, TxDOT did not retain CRIS information prior to 2010. All existing information prior to 2010 was transferred to the University of Texas at Austin Center for Transportation Research (CTR) (https://ctr.utexas.edu/). Researchers at CTR, who frequently use the data to investigate traffic-related questions and publish in peer-reviewed academic journals, initially refused to grant access to the 2003-2009 CRIS data.

We submitted a public information request to the University of Texas at Austin Center for Transportation Research to release the CRIS data. The public information request was appealed to the Texas attorney generals office by the University of Texas. In a letter dated January 23, 2017, the assistant attorney general of Texas ruled that the University of Texas must release the CRIS data. The University of Texas at Austin open records coordinator electronically transferred the complete record of accidents in CRIS from 2008-2009 on February 15, 2017. Michael R. Murphy, Research Engineer at the University of Texas at Austin Center for Transportation Research, subsequently sent data from 2003-2007 on a CD on April 28, 2017. Documents related to the Public Information Request and all of the original CRIS data are posted here: http://faculty.weatherhead.case.edu/jpg75/research.html. The original CRIS data files can also be downloaded from Dataverse (https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/GGLKEM.).

1.1.2 Red-light Cameras

We use information on red-light camera intersections from the annual TxDOT red-light camera reports (Texas Department of Transportation (2009-16)). The earliest available reports are from 2009. These reports are compiled and published by the state of Texas using information submitted by municipalities. The reports provide the location of each camera. In addition, municipalities with a camera program are required to submit annual information on each camera, including: the date of installation, intersection speed limits, total tickets issued, and estimates of average daily traffic.

1.1.3 Intersection Engineering Characteristics

We collect information on a number of structural intersection characteristics, including whether the intersection has a median separating traffic, the speed limit, the number of lanes, and whether the intersection includes a frontage road. A frontage road is defined as a road running parallel to a highway that is often used as an access point to the highway. The intersection characteristics were collected using Google Maps and Google MyMaps from June-July 2016. The dates of the images used to collect the data roughly match the end of our panel period.

1.1.4 Average Daily Traffic

We collect average daily traffic (ADT) from three sources. The first source is the red-light camera enforcement intersection reports (TxDOT (2009-16)). Average daily traffic data from the TxDOT reports are likely from around the year the reports were first filed in 2008 or the year of installation. ADT data retained in the annual reports do not change year-to-year at the same intersection. We infer, in turn, that the ADT information was not collected again for these reports after the initial reporting year.

We also use information from two other sources that provide traffic counts in Houston and Dallas at numerous street locations (North Central Texas Council of Governments (2016) and City of Houston (2017)). The rationale for

using street-based (rather than intersection-based) ADT information is so we will have a consistent ADT measure for camera and non-camera intersections in each city. The street-based ADT measures also allow for multiple ADT measurements for a subset of our camera intersections.

Intersections are assigned ADT values using GIS software by summing the ADT values for all roads at the intersection. We take the ADT points and join them to the closest road segment using GIS software. We then identify all intersections that have an ADT measurement for two or more approaches. We sum ADT from each approach if two approaches are covered. If more than two approaches are covered, then we calculate the average ADT across all approaches and multiply it by two (e.g., if all four approaches on two roads report ADT).

1.1.5 Red-light-running Tickets

We use two sources for the number of red-light-running tickets. First, red-light-running tickets issued at each camera controlled intersection in both Houston and Dallas are available from the camera reports (Texas Department of Transportation (2009-16)). The camera ticket data are reported by fiscal year (July 1 - June 30), beginning in 2008-09. There is no published 2010-11 annual report for Houston even though the Houston cameras were in operation for four months.

We also obtained red-light-running ticket data on tickets issued by Houston police. These data exclude tickets issued via the traffic cameras. We requested the data via an open records request (Municipal Court Record Number: 341JUNE17). We received the monthly intersection count of all red-light-running tickets from April 2006 to December 2016.

1.1.6 Additional Information for Welfare Calculation

Accident Costs

We use accident cost estimates from a recent National Highway Traffic Safety Administration (NHTSA) report (Blincoe et al. (2015)). The NHTSA report

compiles accident costs by accident severity using the KABCO scale. The scale is: K= killed, A = incapacitating injury, B = non-incapacitating injury, C = complaint of pain, and 0 = no injury. The scale matches the police coded accident data in CRIS, with the exception that CRIS uses "possible injury" instead of "complaint of pain." We also combine the "unknown" and "no injury" categories in the CRIS accident data into a single grouping to correspond to the KABCO no injury category. Note that the NHTSA report explicitly accounts for misreporting of injuries, by either those involved in the accident or the police officers filling out the reports. For example, the NHTSA report estimates that on average there are $7,789 (2010 $) in injury-related costs for the no-injury category (Blincoe et al. (2015), p251).

We use the total accident costs for the four non-fatal KABCO categories in Table D-1 (Blincoe et al. (2015), p251). These categories include estimates for direct injury related costs (medical, lost wages, and legal costs), traffic congestion costs due to the accident, property damage, and lost quality of life from accident sustained injuries.

We use the Department of Transportations recommended value of statistical life, $8,860,000 (2010 $), as the cost of a fatal accident (Blincoe et al. (2015)).

Houston Program Costs

We obtained Houston red-light camera program cost information via a public records request (ID number: 13541750291) from the Texas comptroller of public accounts. The information provided includes the annual costs of running the program in two categories: (1) operating enforcement system (including administrative costs), and (2) system maintenance and up-keep. Data for fiscal years (July 1-June 30) begins with the 2007-8 fiscal year. We use operating and maintenance estimates from fiscal year 2009-10, the last year of the program.

The comptroller data did not include information on the fixed costs of installing the cameras. We use estimates on the purchase and installation of a standard digital camera system from Maccubbin et al. (2001). These estimates are also used by the Centers for Disease Control and Prevention

(https://www.cdc.gov/motorvehiclesafety/calculator/factsheet/redlight.html). We divide the fixed costs equally by the expected number of years of the contract. The Houston camera contract was scheduled to continue through 2013. Twenty cameras were installed in 2006 and 46 in 2007. The average expected service time of a camera under the contract was 7.3 years. The industry-wide estimate for the installation costs is only a small fraction of the annual operating and maintenance costs of the Houston program.

Number of Residents

The number of Houston residents age 18-64 is from a 2013 report by the Houston Planning and Development Department (http://www.houstontx.gov/planning/Demographics/docspdfs/SN/AgeTotalPopulation.pdf). The source of the underlying data is the 2007-2011 American Community Survey.

Mean Wage

The Federal Reserve Bank of St. Louis calculates the average weekly wages for "employees in total covered establishments" in the Houston-Sugar Land-Baytown MSA using Bureau of Labor Statistics information (https://fred.stlouisfed.org/series/ENUC264240010SA). We calculate the average hourly wage in Houston by averaging across the four 2011 quarters and dividing by 40.

Number of Persons per Vehicle

The average number of persons per vehicle is from US Department of Transportation report that analyzes the 2001 National Household Travel Survey (USDOT (2003)). We use the mean across all personal vehicle trips. A link to the report can also be found here: https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/highlights_of_the_2001_national_household_travel_survey/html/table_a14.html

Length of Red Light Signal

We calculate the average length of a red light in Houston using two sources. The duration of yellow lights and red-light lag times (i.e., when both directions are red) are provided for each camera controlled intersection in the annual red-light camera enforced intersection reports (Texas Department of Transportation (2009-16)). We estimate green-light durations using the *Traffic Signal Operations Handbook*, which is published by the Texas Transportation Institute and provides guidelines for minimum green-light times based on speed limit (Bonneson et al. (2009), p2-5).

We assume that when one street has a green light that the intersecting street has a red light. In other words, red-light times are assumed equal to the green-light time of the perpendicular street plus the red-light lag time. The drawback to this method is that it ignores the possibility that the intersection has a separate signal phase for a turning lane. We have no information on turn-only signal phases. We view our calculation of the red-light time as a conservative lower bound on the actual wait time for a complete signal cycle at the intersection. Under these assumptions using the above data we estimate that the average red-light-waiting time per signal cycle is 0.91 minutes.

Number Additional Vehicles Stopping at Camera Intersections

We use an estimate of the number of additional vehicles stopping at camera intersections (rather than continuing through the intersection) to estimate the travel time delay in Houston under the camera program. We use two sources of information to estimate the reduction in vehicles passing through an intersection when the light turns red.

First, a conservative estimate from the literature is that the number of red-light running vehicles decreases by 42% in the first year of a camera program, relative to the year before the program (McCartt and Hu (2014)). Next, we use red-light ticket data from two camera intersections in Dallas to benchmark how the number of red-light tickets change in the second and third years of a camera program (Texas Department of Transportation (2009-16)). These are

the only two camera intersections with cameras installed (in either Houston or Dallas) after the mandated annual camera reports began documenting the number of tickets in 2009, and which had an installation month in June or July. The installation month is important since the ticket data are reported by fiscal year (July 1-June 30). While we are only using two camera intersections for our benchmark, it is well documented that the number of tickets decreases over (at least) the first few years of a red-light camera program as drivers learn about the cameras.

Our estimate is conservative, for we do not account for vehicles under the camera program that stop when the light is yellow and might have passed through the intersection before the light turned red. This group of vehicles is likely to be large, potentially of a similar magnitude as the number of vehicles that stop running red lights.

In summary, we use the observed change in camera tickets in Dallas combined with the estimated change in red-light running during the first year of a camera program to estimate the number of vehicles running red lights the year before the camera program begins. We estimate that there were 242,724 vehicles that ran a red light at one of the 66 camera intersections in the year before cameras were installed. This translates to 220,866 minutes of additional waiting at a traffic intersection (calculated by multiplying by a 0.91 minute delay), 0.17 minutes of additional waiting per person (dividing by the population), and 0.0025 minutes of waiting per person per camera (dividing by 66).

1.2 GIS Data Processing

We start with the police-recorded (accident-level) CRIS data for each accident in the cities of Houston, Dallas, and San Antonio. Next, we limit the sample to accidents that occur within 200 feet of an intersection. We use GIS software (ESRI ArcMap) to buffer the intersections by 200 feet and intersect them with the accident (latitude/longitude) point shapefile to create an accident-level output file containing all accidents within 200 feet of an intersection.

We use the US Census TIGER/Line USA Major Roads shapefile as the street map in GIS to determine the list of intersections in each city. All camera intersections in Houston and Dallas are included on the street map. We exclude non-camera intersections in Houston within one-half mile of a camera intersection, for camera intersections may impact driving behavior at nearby intersections (e.g., Shin and Washington (2007); Høye (2013)). We also exclude Houston non-camera intersections if the intersection does not have associated ADT information, or if there are no recorded accidents from 2003-2014. Finally, as a reliability check, we visually check all remaining intersections in GIS to confirm that there are no duplicate intersections and that we are not double-counting an intersection.

1.3 San Antonio Intersection Risk Index

We determine the most dangerous intersections in San Antonio using a simple weighting method. We adapt the weighting formula that Stein et al. (2006) utilized to rank order Houston intersections by accident risk. Our intersection risk index is a weighted sum of San Antonio accidents for 2003 using the following weights: 4 = fatal, 3 = incapacitating, 2 = non-incapacitating or possible, 1 = unknown injury or no injury. Under the weighting scheme of Stein et al. (2006), fatal accidents receive a weight of 3. Still, the two weighting schemes produce similar intersection risk rankings. We select the 66 most dangerous intersections to use as our placebo treatment intersections, since this is the same number of 2006 and 2007 Houston camera intersections.

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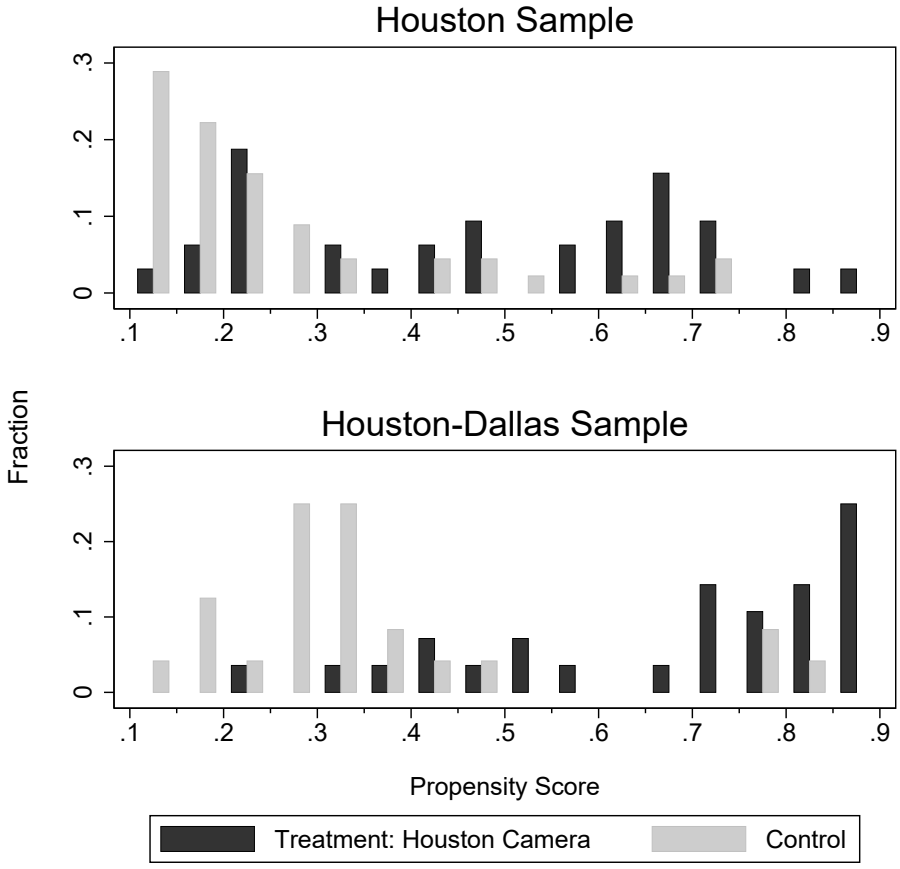
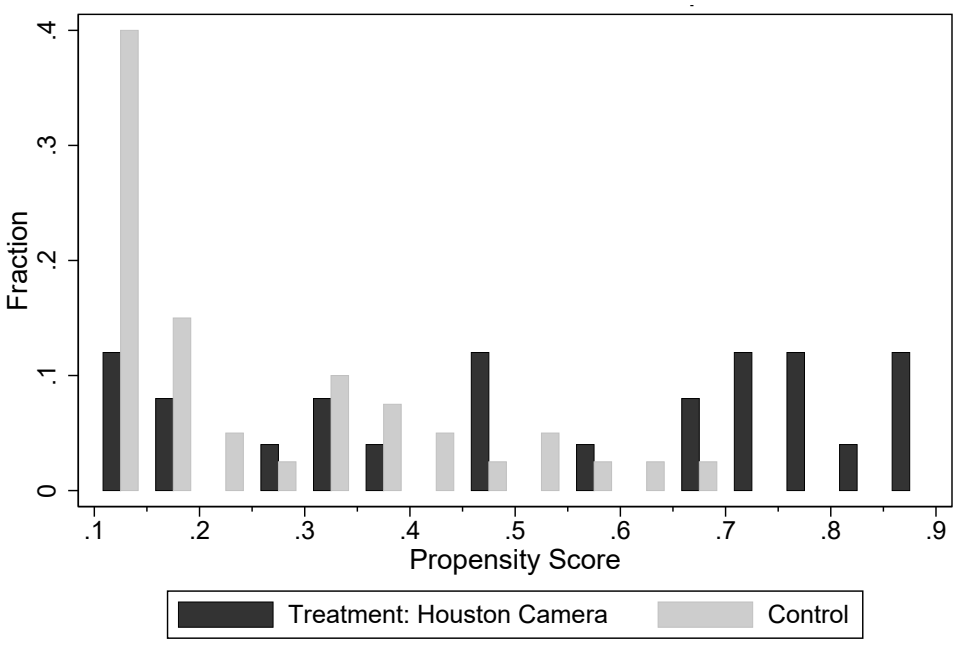
3 Figures and Tables

Figure 1: **Distribution of Propensity Scores: Houston and Houston-Dallas Samples**



The figure shows the distribution of propensity scores in the Houston and Houston-Dallas samples. The leftmost bin is for observations with propensity scores ranging from 0.10 to 0.15, while the rightmost bin is for observations with scores from 0.85 to 0.90. Data sources: City of Houston, Texas Department of Transportation.

Figure 2: **Distribution of Propensity Scores: Houston 2003-2005 Sample**

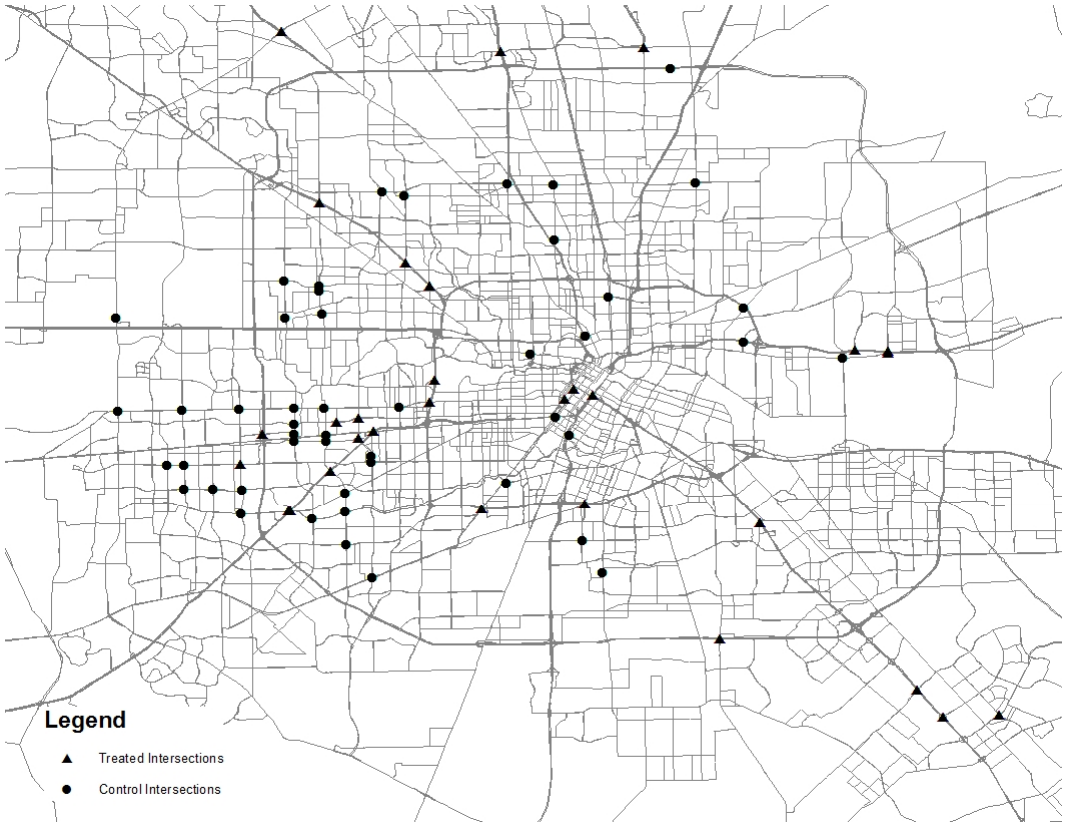


The figure shows the distribution of propensity scores in the Houston sample that uses accident characteristics from 2003-2005 to estimate the propensity of treatment in a logistic regression. The control group of intersections are Houston non-camera intersections. The figure plots the fraction of observations that fall within five percentage point propensity score bins inside the interval [0.10, 0.90]. The leftmost bin is for observations with propensity scores ranging from 0.10 to 0.15, while the rightmost bin is for observations with scores from 0.85 to 0.90. Data sources: City of Houston, Texas Department of Transportation.

Figure 3: **Houston Camera and Non-camera Locations 2008-2014 Sample**

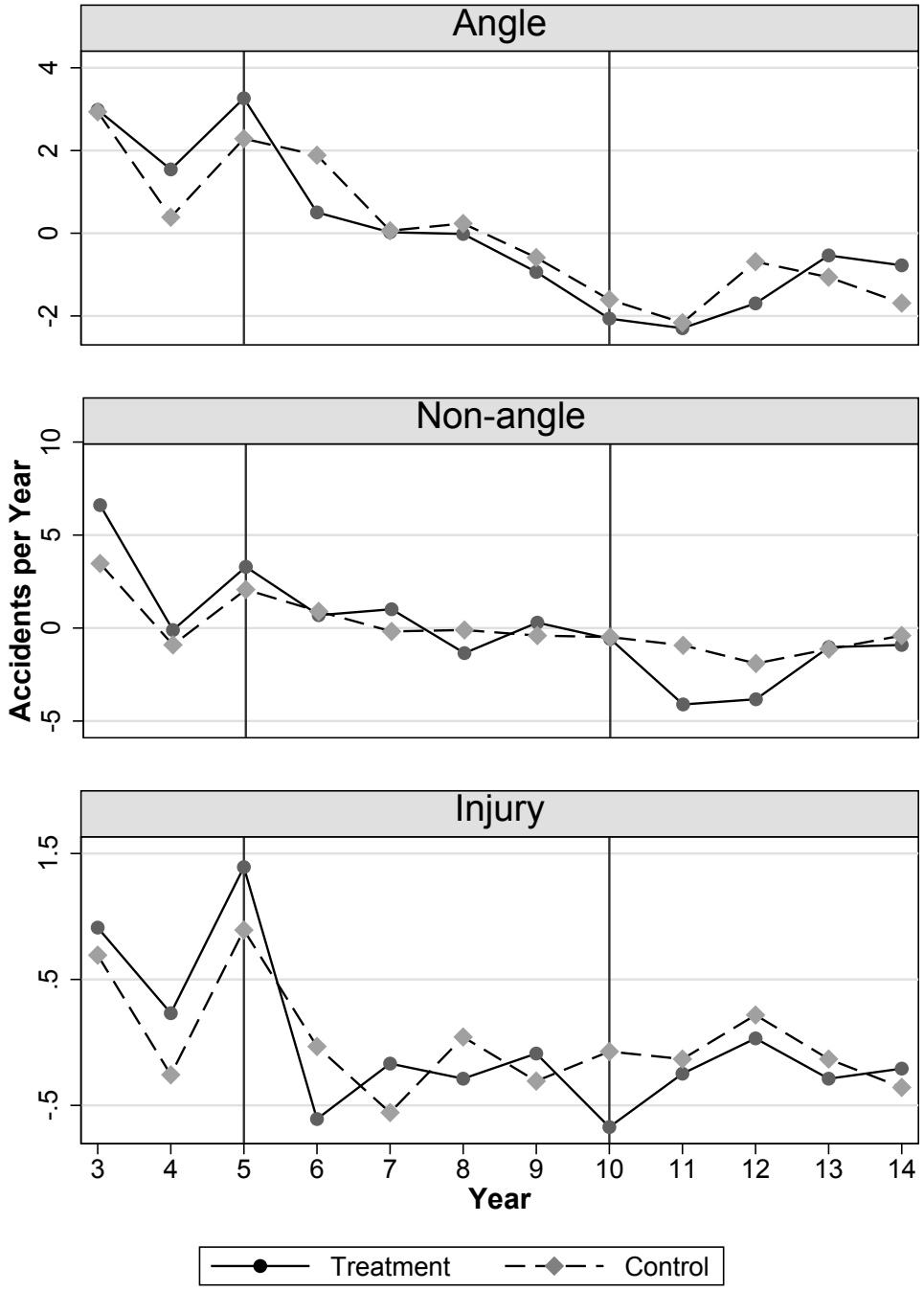
The figure plots the 32 camera intersections (triangles) and 45 non-camera intersections (squares) in our Houston 2008-2014 sample. Map source: US Census TIGER/Line USA Major Roads.

Figure 4: **Houston Camera and Non-camera Locations 2003-2005 Sample**



The figure plots the 24 camera intersections (triangles) and 40 non-camera intersections (squares) in our Houston 2003-2005 sample. Map source: US Census TIGER/Line USA Major Roads.

Figure 5: **Treatment and Control Intersection Accident Trends 2003-2005 Houston Sample**



The figure plots yearly accident residuals from an OLS regression of yearly angle (row 1), non-angle (row 2), and injury (row 3) accidents on a vector of intersection fixed effects. The residuals are plotted separately for the control and treatment intersections. Treatment and control intersections are Houston camera and propensity score matched non-camera intersections (2003-2005). The accident data from 2010 are multiplied by 6/5 before running the regression, in order to account for 10 months of available data. Data source: Texas Department of Transportation.

Table 1: **Frequencies of Accident Subtypes for Angle and Non-angle Accidents**

Accident Group	*Accident Type*	*Percent of Group*	*Percent of Total*
Angle	Both Going Straight	0.779	0.163
	Straight - Backing	0.038	0.008
	Straight - Stopped	0.003	0.001
	Straight - Right Turn	0.062	0.013
	Straight - Left Turn	0.103	0.022
	Both Right Turn	0.000	0.000
	Right Turn - Left Turn	0.002	0.000
	Right Turn - Stopped	0.006	0.001
	Both Left Turn	0.002	0.001
	Left Turn - Stopped	0.004	0.001
	Total		**0.209**
Non-angle	Single Vehicle - Going Straight	0.216	0.171
	Single Vehicle - Right Turn	0.008	0.006
	Single Vehicle - Left Turn	0.010	0.008
	Sincle Vehicle - Backing	0.050	0.039
	Single Direction - Rear End	0.214	0.169
	Single Direction - Sideswipe	0.147	0.116
	Single Direction - Straight - Stopped	0.125	0.099
	Single Direction - Straight - Right Turn	0.021	0.016
	Single Direction - Straight - Left Turn	0.030	0.023
	Single Direction - Both Right Turn	0.003	0.002
	Single Direction - Right Turn - Left Turn	0.000	0.000
	Single Direction - Right Turn - Stopped	0.000	0.000
	Single Direction - Both Left Turn	0.005	0.004
	Single Direction - Left Turn - Stopped	0.000	0.000
	Opposite Direction - Both Going Straight	0.014	0.011
	Opposite Direction - Straight - Backing	0.011	0.009
	Opposite Direction - Straight - Stopped	0.001	0.000
	Opposite Direction - Straight - Right Turn	0.000	0.000
	Opposite Direction - Straight - Left Turn	0.067	0.053
	Opposite Direction - Backing - Stopped	0.005	0.004
	Opposite Direction - Right Turn - Left Turn	0.001	0.001
	Opposite Direction - Right Turn - Stopped	0.000	0.000
	Opposite Direction - Both Left Turn	0.001	0.000
	Opposite Direction - Left Turn - Stopped	0.000	0.000
	Parking - Straight	0.015	0.012
	Parking - Right Turn	0.000	0.000
	Parking - Left Turn	0.000	0.000
	Parking - Stopped	0.001	0.001
	Other - Both Parking	0.001	0.000
	Other - Both Backing	0.004	0.003
	Other	0.052	0.041
	Total		**0.791**

The table provides a list of accident causes (types) in Houston from 2003-2005 by frequency of the type of the accident. There are 45 different accident types, 10 of which include the word "angle" and other details (e.g., "Angle: Both Going Straight"). Five non-angle accident types ("OMV other," "other," "not reported," "undetermined," and "reported invalid") are combined into the category "other" listed in the table. Source: Texas Department of Transportation.

Table 2: **Sample Accident Intersection Characteristics**

	All Intersections			All Intersections, Trimmed		
	(1)	(2)	(3)	(4)	(5)	(6)
	Treatment	Control	Difference/SD	Treatment	Control	Difference/SD
Accident Characteristics						
Total	33.12	3.97	2.84	24.59	18.43	0.68
Angle	14.93	1.63	2.59	8.93	7.58	0.27
Non-angle	18.19	2.33	2.64	15.65	10.85	0.60
Injury	3.25	0.41	2.24	2.57	2.08	0.31
Red-light Running	11.39	1.05	2.58	6.63	5.69	0.23
Engineering Characteristics						
Average Daily Traffic	58,540	29,811	1.49	51,812	44,214	0.31
Frontage Road	0.82	0.01	3.33	0.63	0.03	1.38
Lanes	7.36	4.21	1.83	7.04	6.30	0.45
Speed Limit	39.93	33.38	1.35	39.11	35.25	0.78
Divided	0.92	0.70	0.49	0.88	0.95	-0.28
Number of Intersections	66	938		24	40	

The table shows the means for accident and intersection characteristics before and after propensity score trimming. Houston camera intersections are the treatment group, while Houston non-camera intersections are the control group. The means are taken over the three years before the first camera was installed (2003-2005). Data sources: City of Houston, Google Maps, North Central Texas Council of Governments, Texas Department of Transportation.

Table 3: **The Effect on Average Daily Traffic from Ending the Camera Program**

	(1) Houston Sample	(2) Houston-Dallas Sample
Panel A: OLS		
*After Removal * Treated*	-87	7,271
	(6,781)	(8,205)
Percent Change	0	18
Panel B: OLS, IPS Weighted		
*After Removal * Treated*	1,430	2,970
	(7,528)	(8,553)
Percent Change	4	7
Treatment	26	22
Control	10	19

This table shows the coefficient of interest from estimating our difference-in-differences model using OLS on the (2008-2014) Houston and Houston-Dallas samples. The dependent variable is the average daily traffic (ADT) at each intersection. Intersection ADT values are not available for each year, nor for every intersection. The intersections included in the models have one observation before the program (measured between 2008 and 2010), and one observation after the program (measured between 2011 and 2014). The intersections included in the analysis are a subset of those intersections in our complete Houston and Houston-Dallas samples. Panel B uses inverse propensity score weighting. Standard errors are robust to heteroskedasticity and clustered by intersection, * < 0.10, ** < 0.05, *** < 0.01.