The Effect of ShotSpotter Technology on Police Response Times

Michael Topper and Toshio Ferrazares*

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Abstract

ShotSpotter is an acoustic gunfire detection technology utilized by police departments in over 150 cities with the intention of rapidly dispatching police officers to violent crime scenes to catch perpetrators and reduce gun violence. Despite its world-wide prevalence, little is known about its effectiveness in reducing gun violence (intended consequence) nor its effect on 911 emergency response times (unintended consequence) given its resource-intensive operating procedure. In this paper, we utilize variation in timing from ShotSpotter rollouts across Chicago police districts from 2016-2022 to estimate the causal effects of ShotSpotter on 911 emergency response times that are designated as priority 1 (immediate dispatch). Using comprehensive 911 dispatch data from the Chicago Police Department, we find that ShotSpotter leads police officers to be dispatched one-minute slower (23%) and arrive on-scene two-minutes later (14%) while controlling for the police officer availability and overall 911 call quantities. Moreover, these effects are driven by resource-constrained periods, and consequently, reduce police officers' success rate in arresting perpetrators (5%) when responding to emergency calls. However, we also find that ShotSpotter reduces the number of gun-victimizations, thereby indicating success in achieving its primary goal, albeit at a significant cost.

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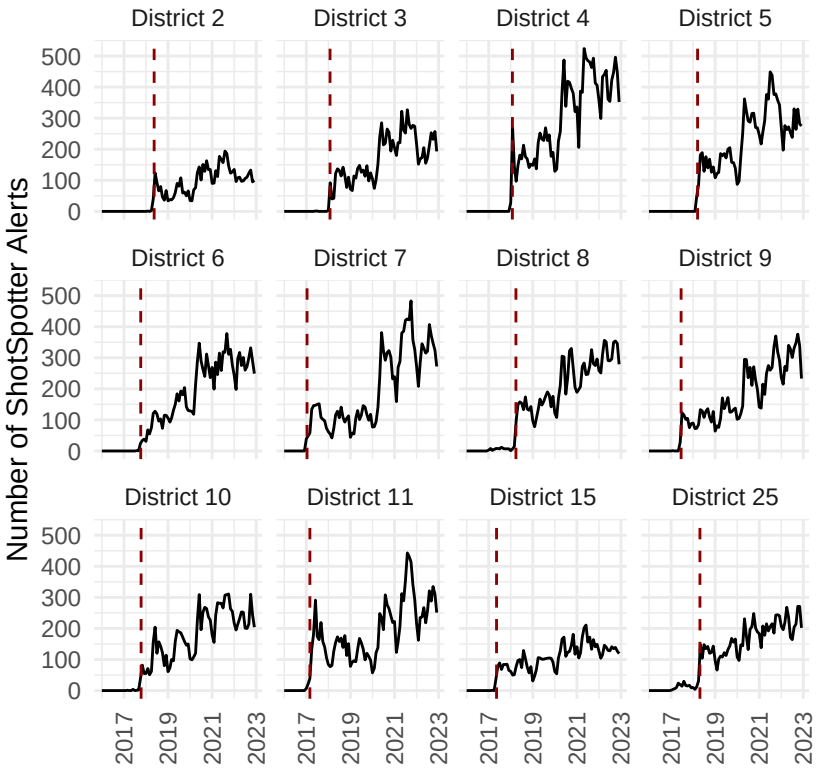
1 References

2 Figures



District	Enactment
2	2018−05−16
3	2018−01−29
4	2018−01−29
5	2018−03−16
6	2017−10−06
7	2017−01−13
8	2018−03−28
9	2017−06−16
10	2017−10−12
11	2017−03−01
15	2017−05−11
25	2018−04−24

Figure 1: ShotSpotter Alert Trends and Enactment Dates

Note: This figure depicts only districts that have ShotSpotter technology. The x-axis is months, while the y-axis is the number of ShotSpotter alerts aggregated to the monthly level. The table on the right shows the average number of shots per-day in a ShotSpotter district. In Chicago, 12 of 22 police districts have ShotSpotter technology. The dashed red line shows the treatment date used in the main results, in some cases this differs from the date given from public records (in blue). Analysis using public records date is shown in Appendix Figure BLANK.

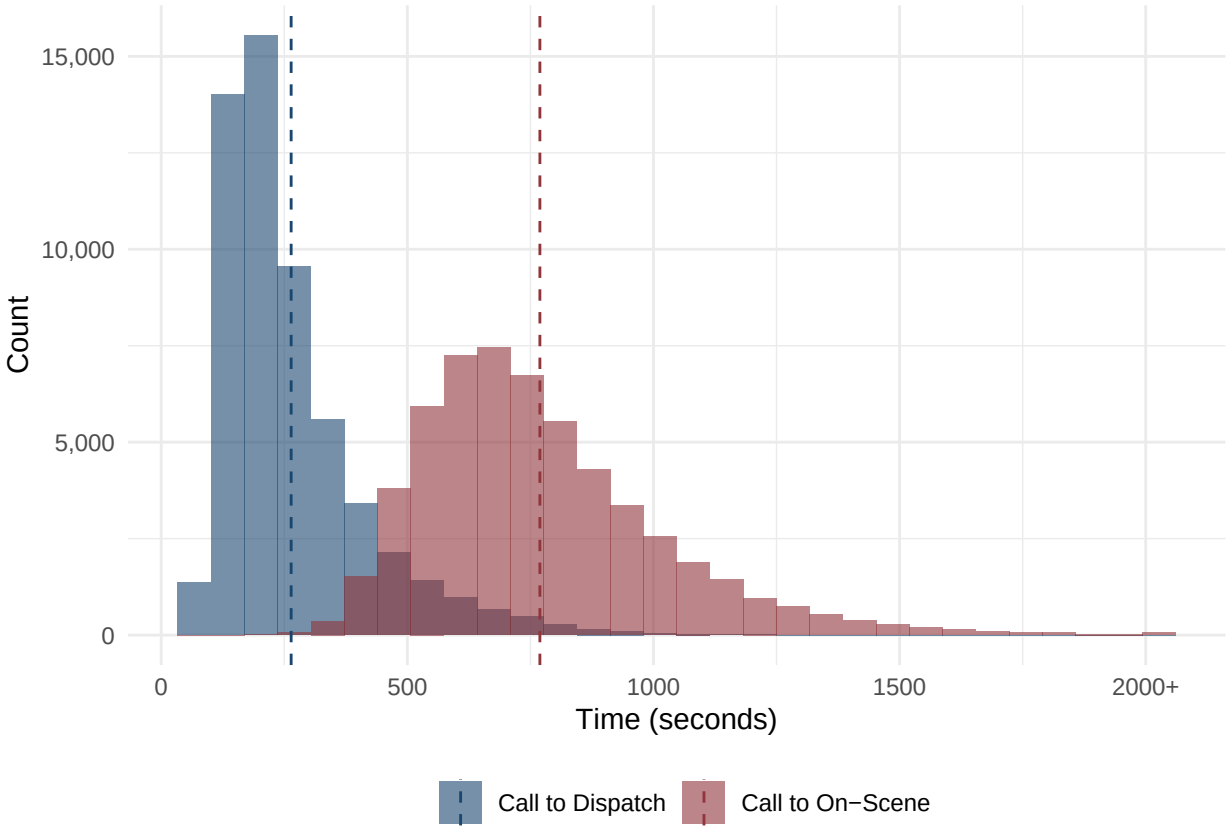


Figure 2: Distribution of Outcome Variables

Note: The two plotted variables are Call-to-Dispatch and Call-to-On-Scene. Call-to-Dispatch is time it takes for a police officer to be dispatched to the scene of the reported crime from the time of the 911 call. Call-to-On-Scene is the time from a 911 call to the time a police officer arrives at the scene of the reported crime. This sample excludes outliers that are greater than three standard deviations from the mean for each outcome, however, the main results remain consistent when including these outliers (see Appendix Figure BLANK).

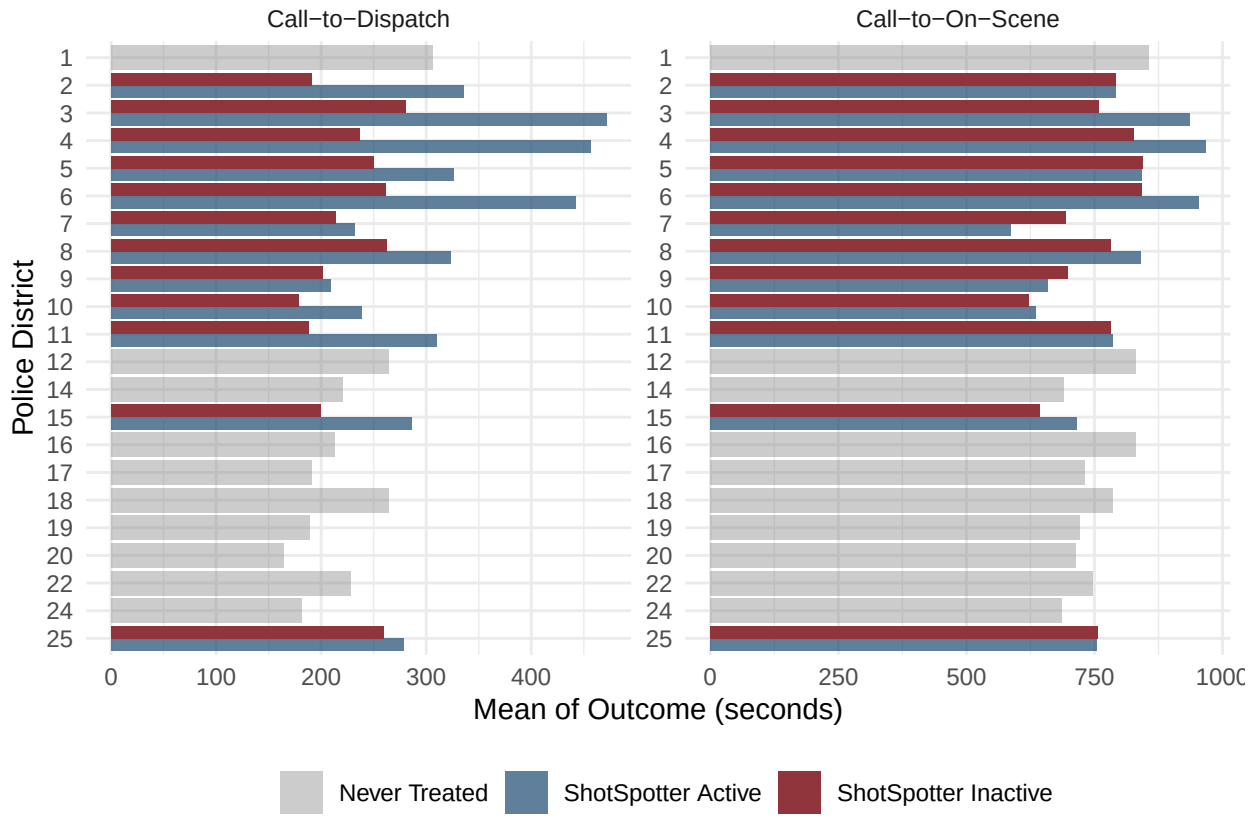


Figure 3: Outcome Averages for Never Treated/ShotSpotter Activated/ShotSpotter Inactive Districts

Note: Each police district is on the y-axis and the average of each outcome (seconds) is on the x-axis. There are three groupings: Never Treated, ShotSpotter Active, and ShotSpotter Inactive. Never Treated refers to police districts that never received ShotSpotter technology. All other districts have two possibilities: ShotSpotter Active and ShotSpotter Inactive. There are 12 of 22 police districts in Chicago that receive ShotSpotter technology.

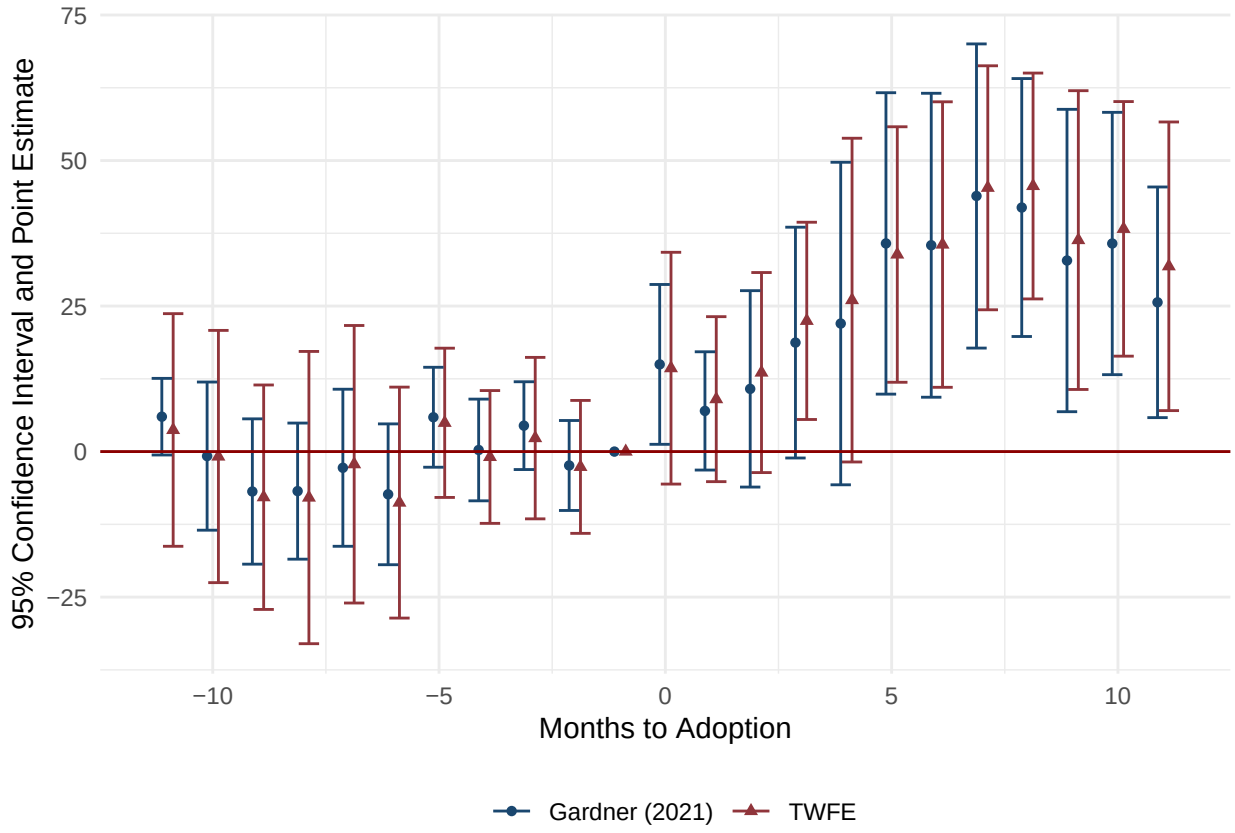


Figure 4: Event Study (Call-to-Dispatch)

Note: The x-axis denotes the number of months pre/post adoption of ShotSpotter technology. The y-axis denotes the 95% confidence intervals and point estimates (in seconds). The red errorbars/points represent confidence intervals/point estimates from OLS estimation while the blue are from Gardner (2021) two-stage difference-in-difference estimators which are robust to heterogeneous treatment effects in staggered adoptions. All pre/post periods are normalized by the month before ShotSpotter adoption. Controls are synonymous with the preferred specification. Standard errors are clustered at the district level.

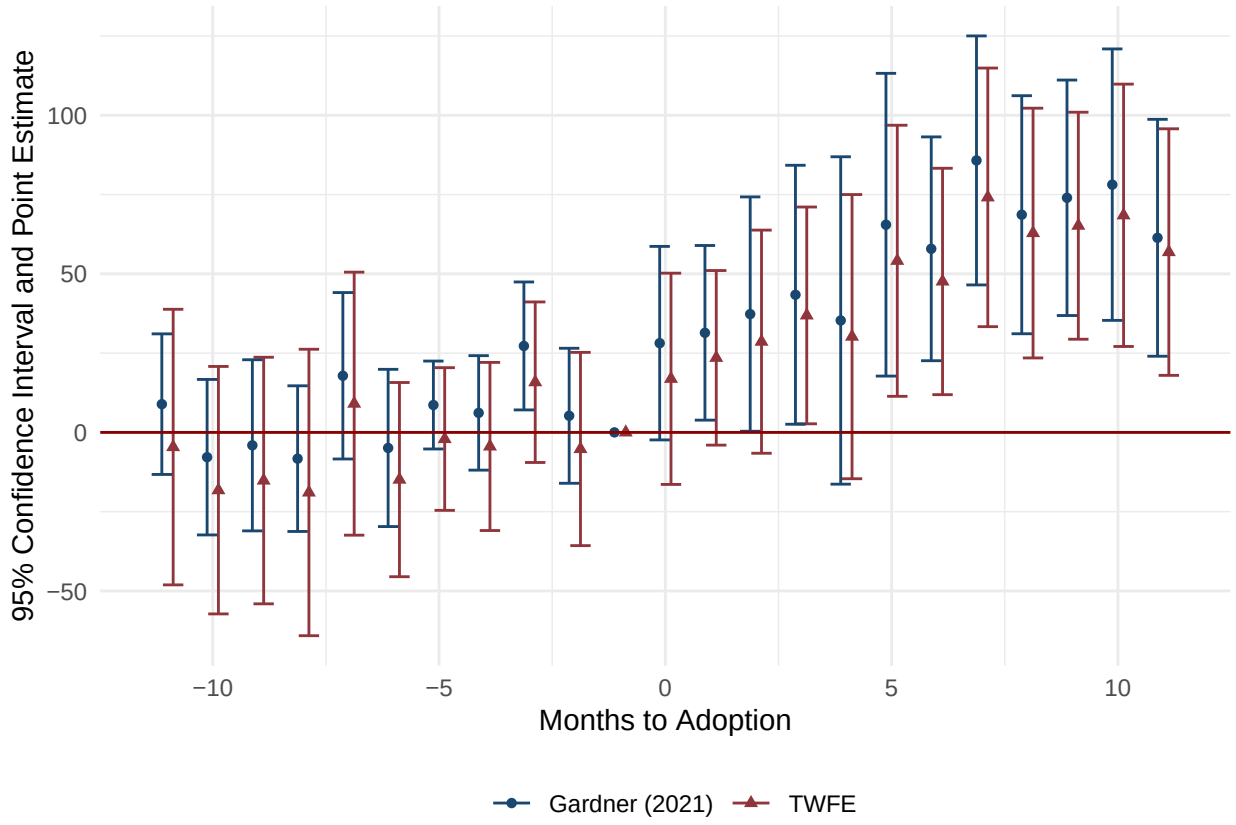


Figure 5: Event Study (Call-to-On-Scene)

Note: The x-axis denotes the number of months pre/post adoption of ShotSpotter technology. The y-axis denotes the 95% confidence intervals and point estimates (in seconds). The red errorbars/points represent confidence intervals/point estimates from OLS estimation while the blue are from Gardner (2021) two-stage difference-in-difference estimators which are robust to heterogeneous treatment effects in staggered adoptions. All pre/post periods are normalized by the month before ShotSpotter adoption. Controls are synonymous with the preferred specification. Standard errors are clustered at the district level.

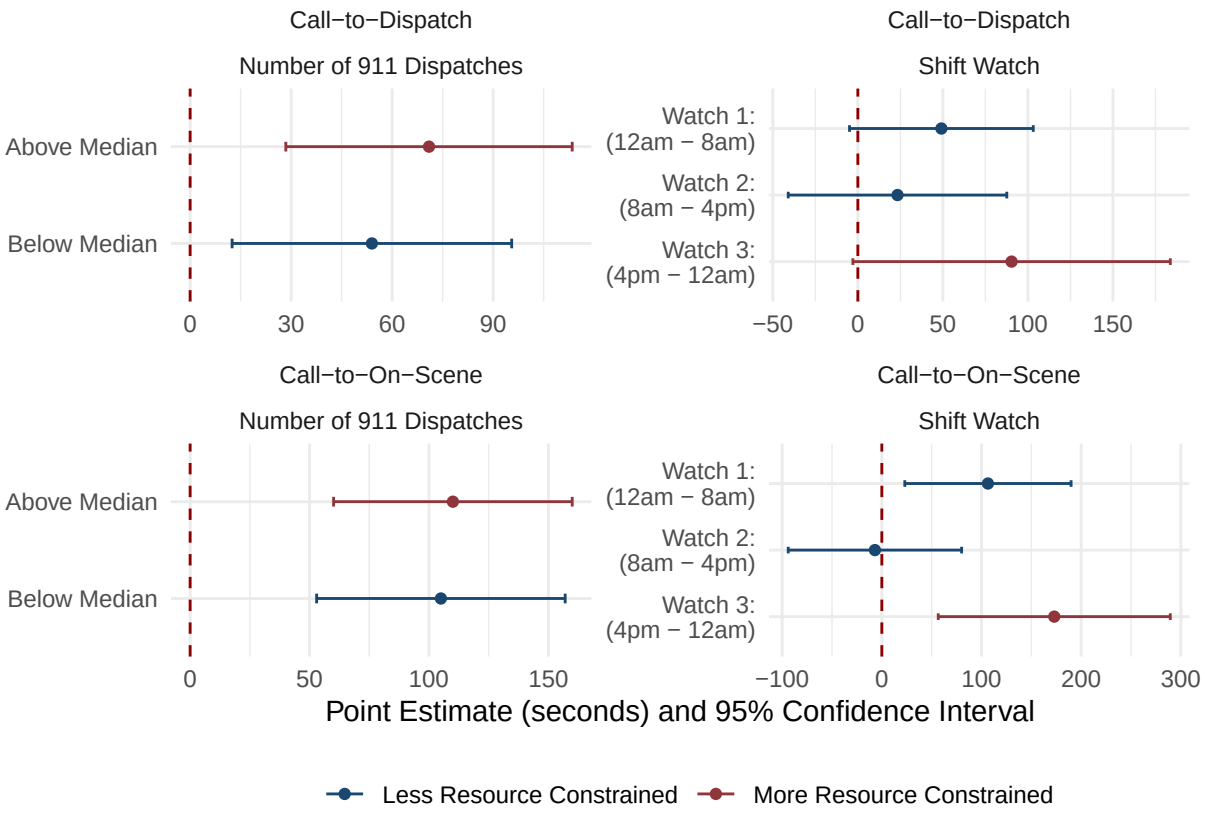


Figure 6: Effect of ShotSpotter by Watch and 911 Calls

Note: These notes need to be redone. First row denotes the aggregate effect from the preferred specification on call-to-dispatch times in seconds, by priority. Rows 2-6 denote the top five most frequent 911 call descriptions within each priority. Each errorbar represents the 95

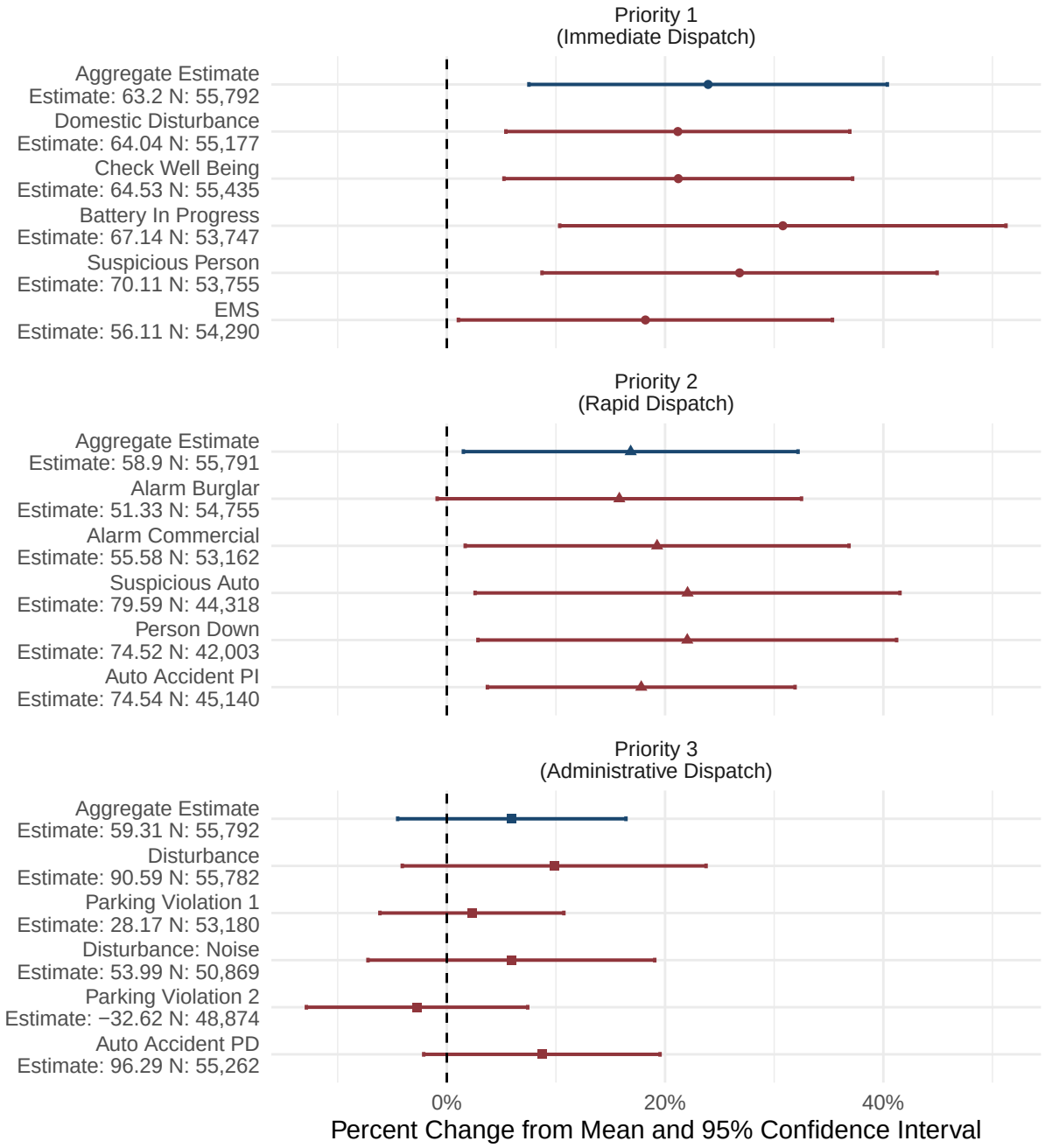


Figure 7: Effect of ShotSpotter on Call-to-Dispatch by Priority/Call Description
Note: The first row denotes the aggregate effect from the preferred specification on call-to-dispatch times in seconds, by priority. Rows 2-6 denote the top five most frequent 911 call descriptions within each priority. Each errorbar represents the 95

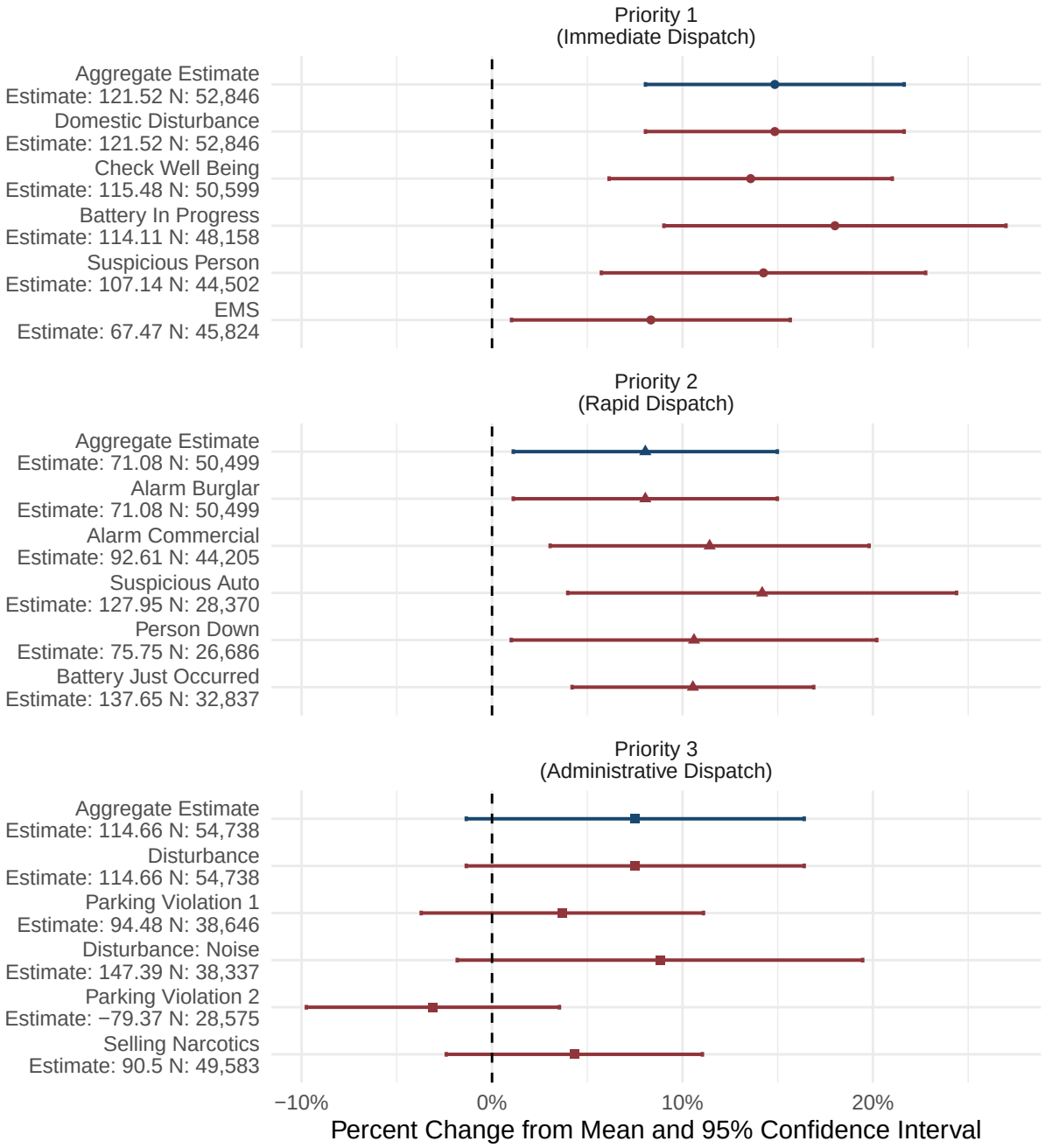


Figure 8: Effect of ShotSpotter on Call-to-On-Scene by Priority/Call Description
Note: The first row denotes the aggregate effect from the preferred specification on call-to-dispatch times in seconds, by priority. Rows 2-6 denote the top five most frequent 911 call descriptions within each priority. Each errorbar represents the 95

3 Tables

Table 1: Summary Statistics of Response Times (seconds)

	Mean	Std. Dev.	Median	Min	Max
Main Outcomes:					
Call to Dispatch (Priority 1)	263.94	147.97	220.50	40.82	1,298.17
	(4.40 mins)	(2.47 mins)	(3.67 mins)	(0.68 mins)	(21.64 mins)
Call to On-Scene (Priority 1)	769.28	248.77	723.62	103.00	5,577.00
	(12.82 mins)	(4.15 mins)	(12.06 mins)	(1.72 mins)	(92.95 mins)
Controls/Secondary Outcomes:					
Number Dispatches	151.84	48.97	145.00	34.00	449.00
Priority 1	64.21	23.77	61.00	8.00	223.00
Priority 2	28.76	11.04	28.00	0.00	126.00
Priority 3	58.86	23.86	55.00	8.00	278.00
Number Arrests	20.45	7.07	20.00	2.00	54.00
Arrest Rate	0.14	0.03	0.14	0.02	0.38
Number SST Alerts	2.57	4.46	0.00	0.00	71.00
Officer Hours	1,205.34	316.58	1,196.00	200.50	3,431.50
Number Gun Victimizations	0.36	0.70	0.00	0.00	8.00

Note:
Units are in seconds unless otherwise noted. Data is at the district-by-day level. Call to Dispatch represents the amount of time from the 911 call to the dispatcher finding and dispatching a police officer to the scene. Dispatch to On-Scene is the time from dispatch to the scene of the reported crime. Priority 1 refers to an immediate dispatch, Priority 2 a rapid dispatch, and Priority 3 a routine dispatch. Officer Hours are the number of working hours sworn police officers work. Number of SST Alerts is the number of ShotSpotter alerts. Note that New Years Eve/New Years Day/Fourth of July are excluded from the sample as ShotSpotter Alerts can be as high as 392 on these days.

Table 2: Effect of ShotSpotter Rollout on Response Times (OLS)

					Officer Hours	
					> Median	<= Median
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Call to Dispatch						
ShotSpotter Activated	64.208***	63.147***	71.915***	61.351***	26.509**	91.126***
	(21.640)	(20.824)	(21.646)	(20.282)	(11.608)	(29.647)
Border District Activated				12.534		
				(15.124)		
Mean of Dependent Variable	263.941	263.941	263.941	263.941	215.487	312.299
Observations	55,792	55,792	55,792	55,792	27,868	27,924
Wild Bootstrap P-Value	0.008	0.003		0.006	0.062	0.001
Panel B: Call to On-Scene						
ShotSpotter Activated	111.867***	108.269***	124.887***	105.919***	60.480***	143.476***
	(25.364)	(24.346)	(25.306)	(23.959)	(19.850)	(32.508)
Border District Activated				16.402		
				(17.654)		
Mean of Dependent Variable	769.284	769.284	769.284	769.284	710.531	827.917
Observations	55,791	55,791	55,791	55,791	27,867	27,924
Wild Bootstrap P-Value						
FE: Day-by-Month-by-Year	X	X	X	X	X	X
FE: District	X	X	X	X	X	X
Control Variables		X	X	X	X	X
Gardner (2021) Robust			X			

Note:
* p < 0.1, ** p < 0.05, *** p < 0.01
Standard errors are clustered by district. Shotspotter is activated in 12 of the 22 police districts in Chicago. Panel A shows the time from entry call to dispatched officer. Panel B shows time from the dispatched officer to on scene. Controls in all models include controls for officer hours and number of dispatches.

Table 3: Effect of Number of ShotSpotter Alerts on Response Times (OLS)

					Officer Hours	
					> Median	<= Median
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Call to Dispatch						
Number SST Alerts	6.770***	6.383***	9.647***	6.277***	3.881**	6.275***
	(1.884)	(1.938)	(2.796)	(1.870)	(1.429)	(1.398)
Border Police District				15.097		
				(14.726)		
Mean of Dependent Variable	263.941	263.941	263.941	263.941	240.245	287.635
Observations	55,792	55,792	55,792	55,792	27,895	27,897
Panel B: Call to On-Scene						
Number SST Alerts	9.959***	9.259***	15.414***	9.096***	6.841***	7.965***
	(2.109)	(2.140)	(3.044)	(2.078)	(1.838)	(1.644)
Border Police District				23.369		
				(16.990)		
Mean of Dependent Variable	769.284	769.284	769.284	769.284	723.041	815.525
Observations	55,791	55,791	55,791	55,791	27,895	27,896
FE: Day-by-Month-by-Year	X	X	X	X	X	X
FE: District	X	X	X	X	X	X
Control Variables		X	X	X	X	X
Gardner (2021) Robust			X			

Note:
* p < 0.1, ** p < 0.05, *** p < 0.01
Standard errors are clustered by district. Shotspotter is activated in 12 of the 22 police districts in Chicago. Panel A shows the time from entry call to dispatched officer. Panel B shows time from the dispatched officer to on scene. Controls in all models include controls for officer hours and number of dispatches.

Table 4: Effect of ShotSpotter Enactment on Arrest Rates (OLS)

		Arrest Rate by Most Frequent Arrest Calls				
	Arrest Rate	Domestic Battery	Domestic Disturbance	Robbery	EMS	Battery
	(1)	(2)	(3)	(4)	(5)	(6)
ShotSpotter Activated	-0.007***	-0.016**	-0.003	-0.018*	-0.006	-0.010**
	(0.002)	(0.007)	(0.005)	(0.009)	(0.005)	(0.004)
Mean of Dependent Variable	0.147	0.348	0.134	0.668	0.155	0.153
Observations	55,792	49,999	55,177	29,405	54,290	53,747
FE: Day-by-Month-by-Year	X	X	X	X	X	X
FE: District	X	X	X	X	X	X

Note:

* p < 0.1, ** p < 0.05, *** p < 0.01

Standard errors are clustered by district. Shotspotter is activated in 12 of the 22 police districts in Chicago. Panel A shows the time from entry call to dispatched officer. Panel B shows time from the dispatched officer to on scene. Controls in all models include controls for officer hours and number of dispatches.

Table 5: Effect of ShotSpotter on Gun Victimization (OLS)

	Gun-Related Victimization			
	All	Homicide	Robbery	Battery
	(1)	(2)	(3)	(4)
ShotSpotter Activated	-0.066**	-0.012*	-0.007**	-0.047*
	(0.031)	(0.006)	(0.003)	(0.026)
Mean of Dependent Variable	0.363	0.073	0.015	0.276
Observations	55792	55792	55792	55792
FE: Day-by-Month-by-Year	X	X	X	X
FE: District	X	X	X	X

Note:
* p < 0.1, ** p < 0.05, *** p < 0.01

4 Appendix Figures

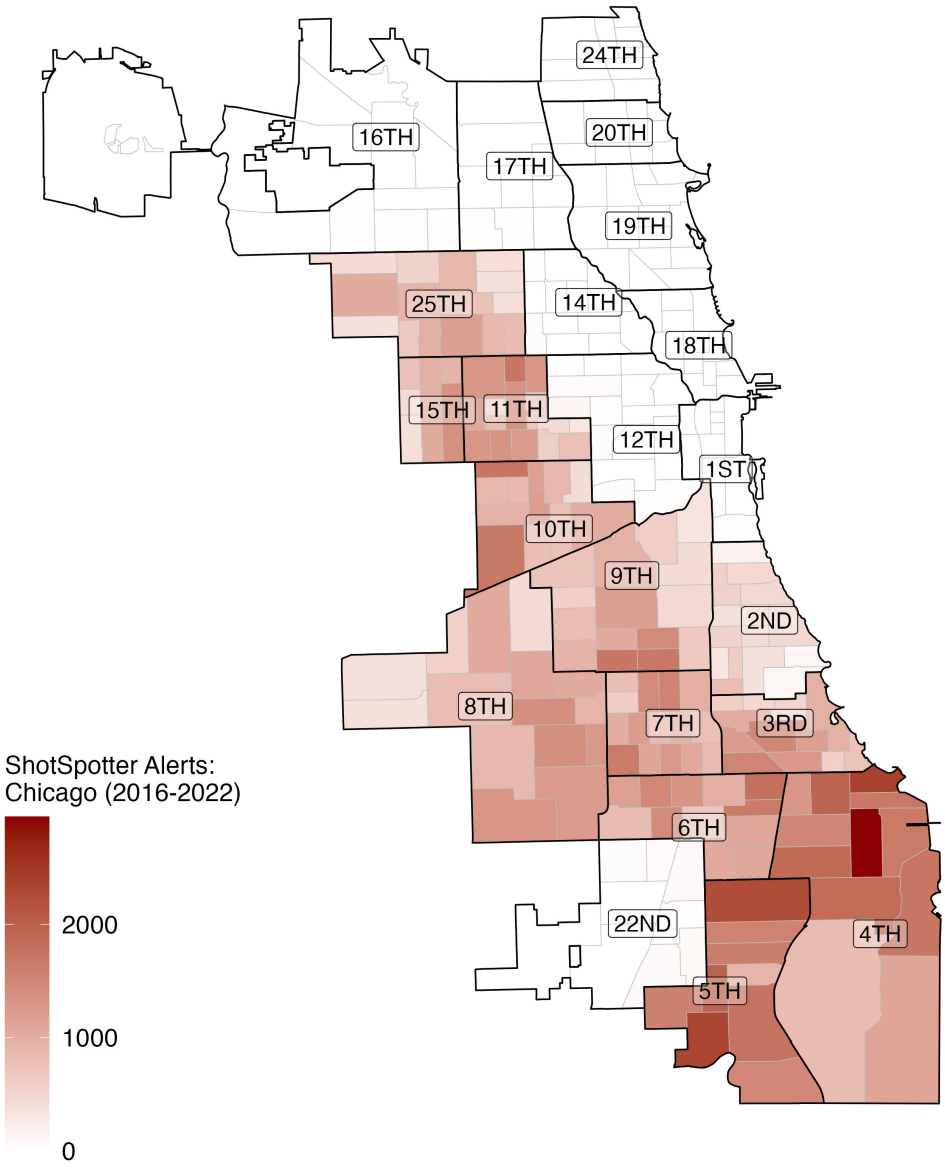


Figure 9: Raw Counts of Gun Arrests Over Time

Note: There are a total of 18 police districts in Chicago. Each of these districts contains beats which are designated by the boxes within the district lines. ShotSpotter began implementation in 2017 and rolled out over the next two years.

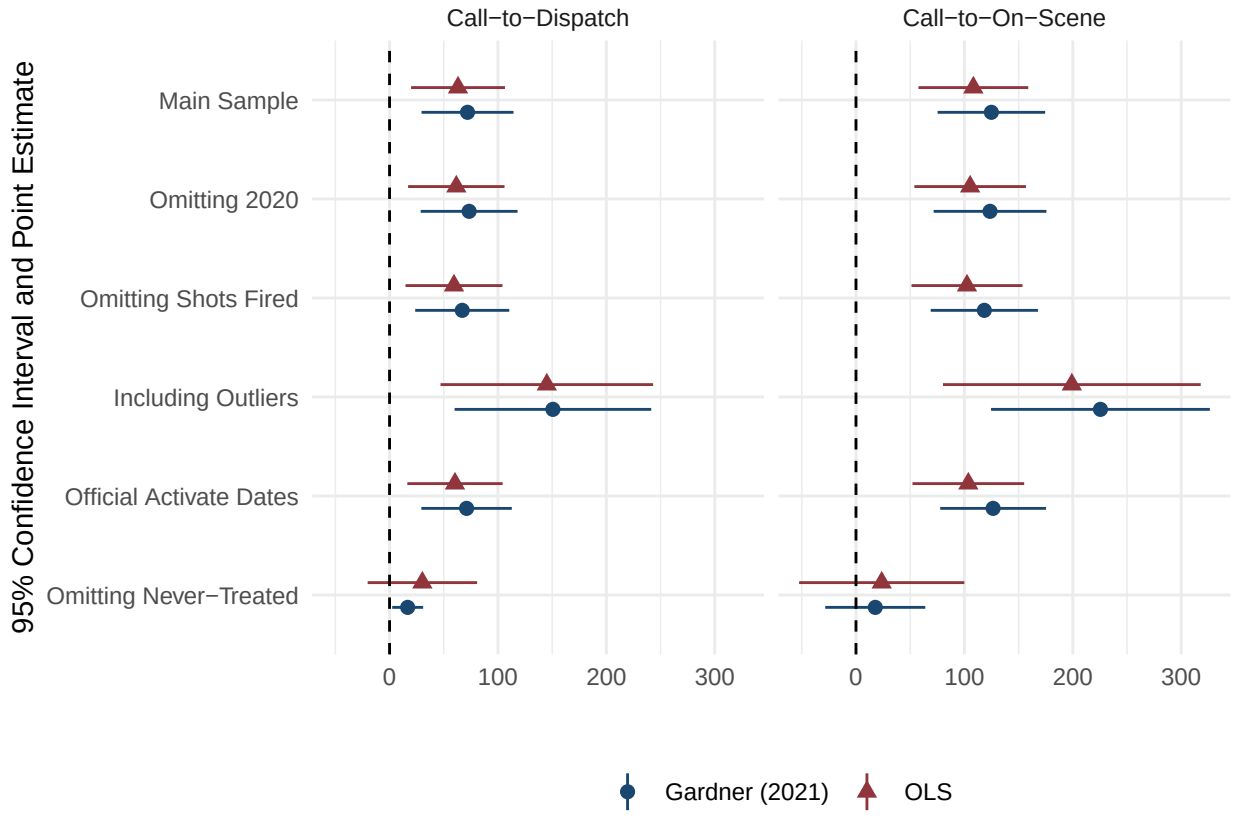


Figure 10: Robustness of Main Results

Note: This figure shows six different regression specifications for both call-to-dispatch and call-to-on-scene. Main Sample refers to the main sample used in the paper. Main Sample (2-Stage DID) uses the main sample, but uses the 2-Stage DID estimation technique as outlined in Gardner (2022). No Controls omits all controls, yet keeps day-by-month-by year and district fixed effects. Omitting 2020 uses the main specification in the paper, but omits the year 2020 due to Covid-19. Last, Omitting Never-Treated uses the full sample, but omits any police districts that did not receive ShotSpotter technology.

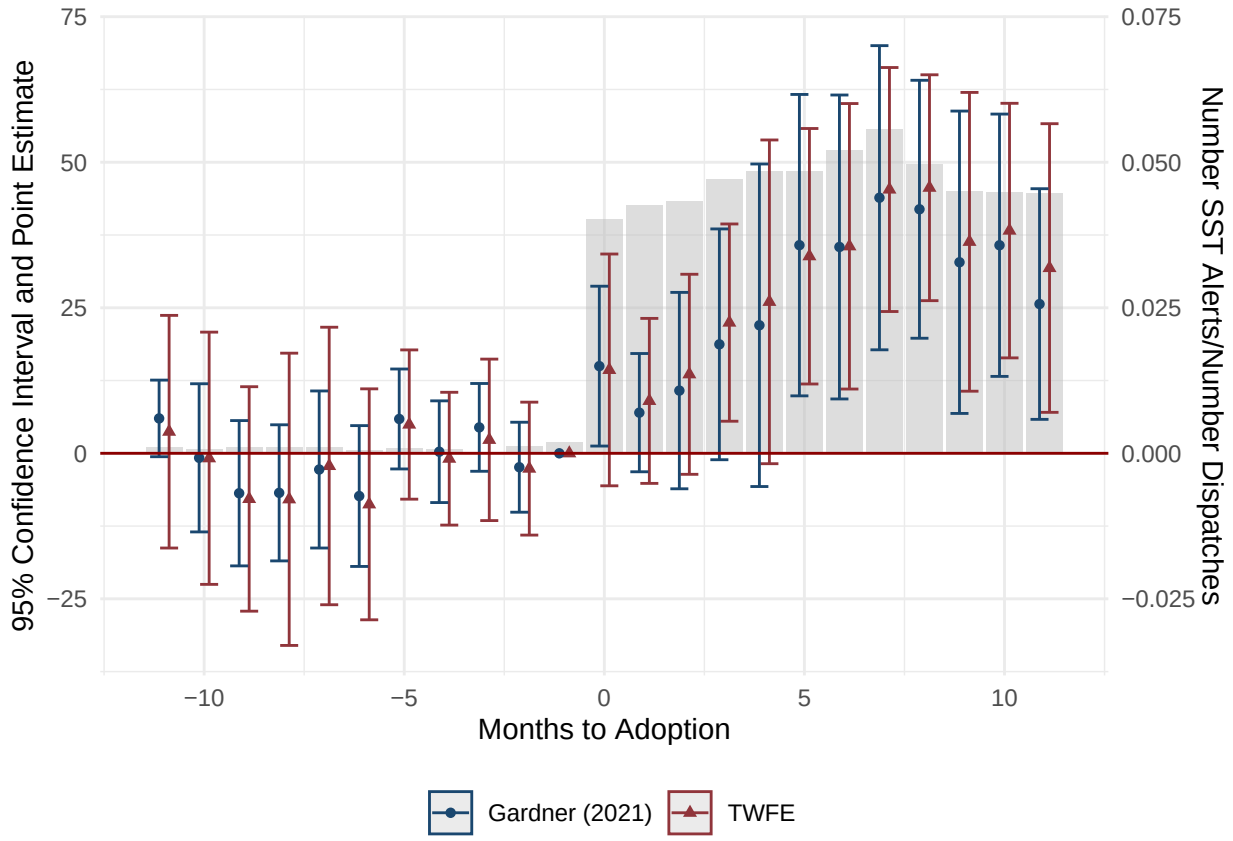


Figure 11: Robustness of Main Results

Note: This figure shows six different regression specifications for both call-to-dispatch and call-to-on-scene. Main Sample refers to the main sample used in the paper. Main Sample (2-Stage DID) uses the main sample, but uses the 2-Stage DID estimation technique as outlined in Gardner (2022). No Controls omits all controls, yet keeps day-by-month-by year and district fixed effects. Omitting 2020 uses the main specification in the paper, but omits the year 2020 due to Covid-19. Last, Omitting Never-Treated uses the full sample, but omits any police districts that did not receive ShotSpotter technology.

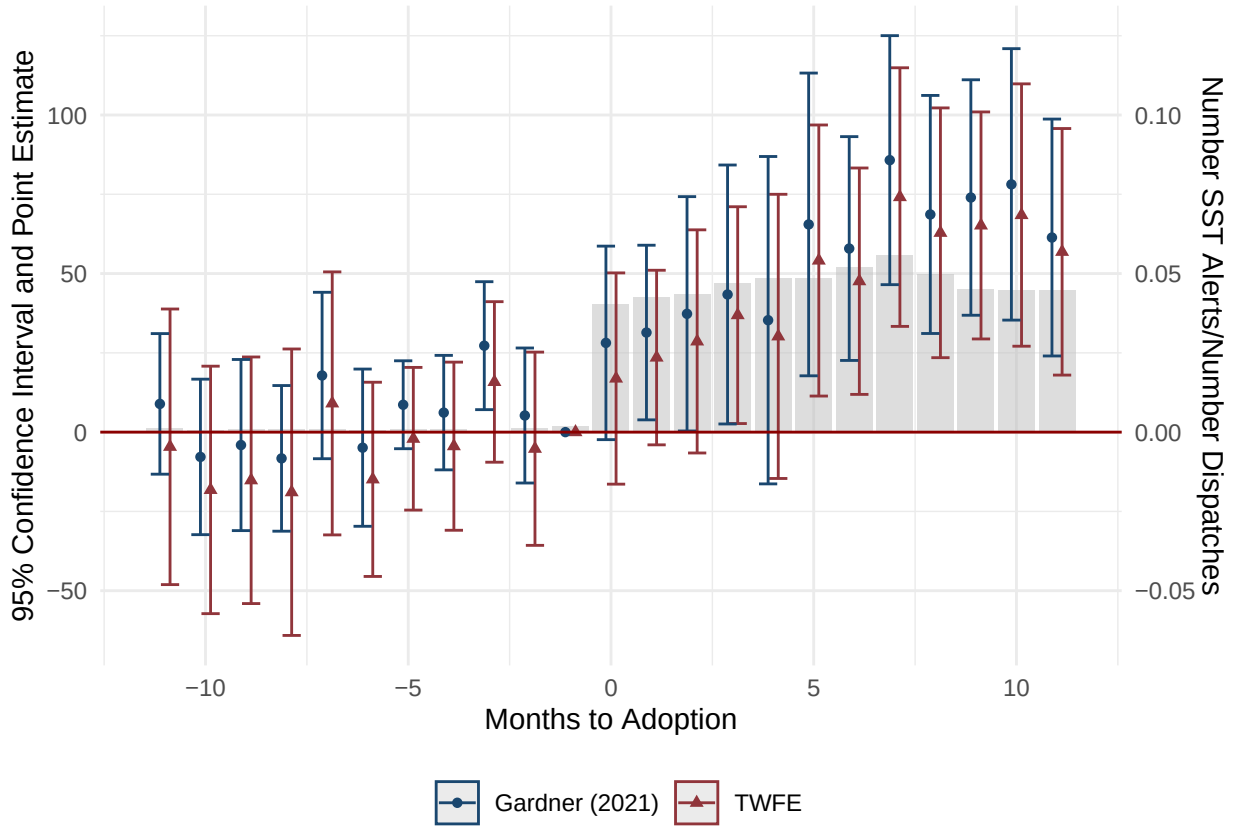


Figure 12: Robustness of Main Results

Note: This figure shows six different regression specifications for both call-to-dispatch and call-to-on-scene. Main Sample refers to the main sample used in the paper. Main Sample (2-Stage DID) uses the main sample, but uses the 2-Stage DID estimation technique as outlined in Gardner (2022). No Controls omits all controls, yet keeps day-by-month-by year and district fixed effects. Omitting 2020 uses the main specification in the paper, but omits the year 2020 due to Covid-19. Last, Omitting Never-Treated uses the full sample, but omits any police districts that did not receive ShotSpotter technology.

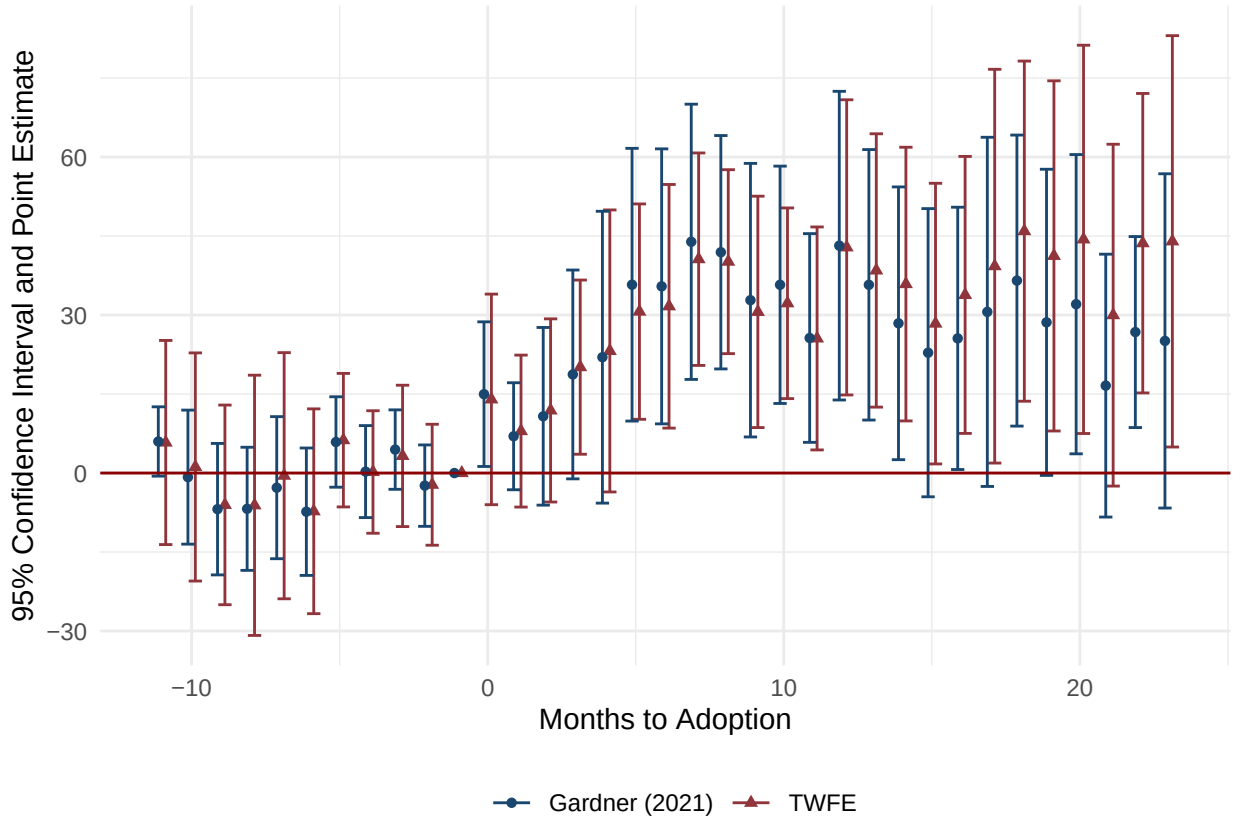


Figure 13: Robustness of Main Results

Note: This figure shows six different regression specifications for both call-to-dispatch and call-to-on-scene. Main Sample refers to the main sample used in the paper. Main Sample (2-Stage DID) uses the main sample, but uses the 2-Stage DID estimation technique as outlined in Gardner (2022). No Controls omits all controls, yet keeps day-by-month-by year and district fixed effects. Omitting 2020 uses the main specification in the paper, but omits the year 2020 due to Covid-19. Last, Omitting Never-Treated uses the full sample, but omits any police districts that did not receive ShotSpotter technology.

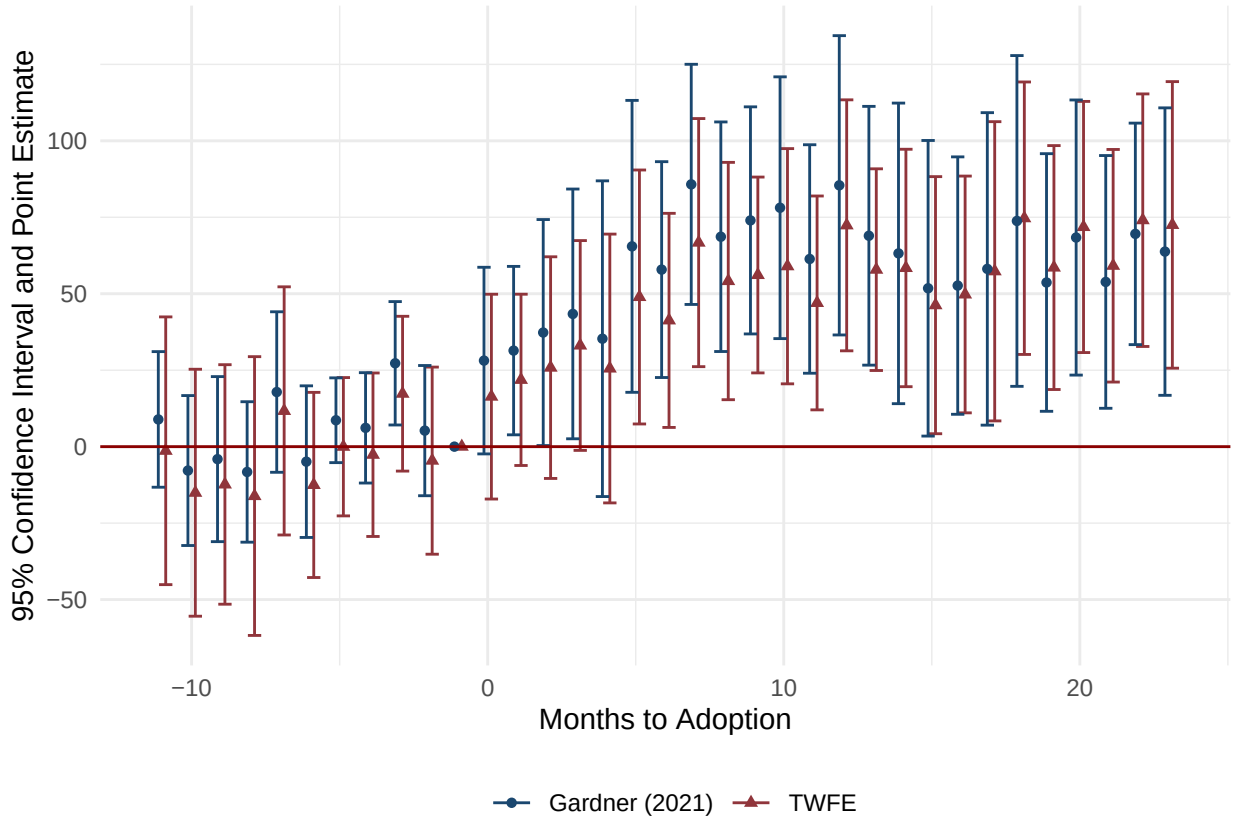


Figure 14: Robustness of Main Results

Note: This figure shows six different regression specifications for both call-to-dispatch and call-to-on-scene. Main Sample refers to the main sample used in the paper. Main Sample (2-Stage DID) uses the main sample, but uses the 2-Stage DID estimation technique as outlined in Gardner (2022). No Controls omits all controls, yet keeps day-by-month-by year and district fixed effects. Omitting 2020 uses the main specification in the paper, but omits the year 2020 due to Covid-19. Last, Omitting Never-Treated uses the full sample, but omits any police districts that did not receive ShotSpotter technology.

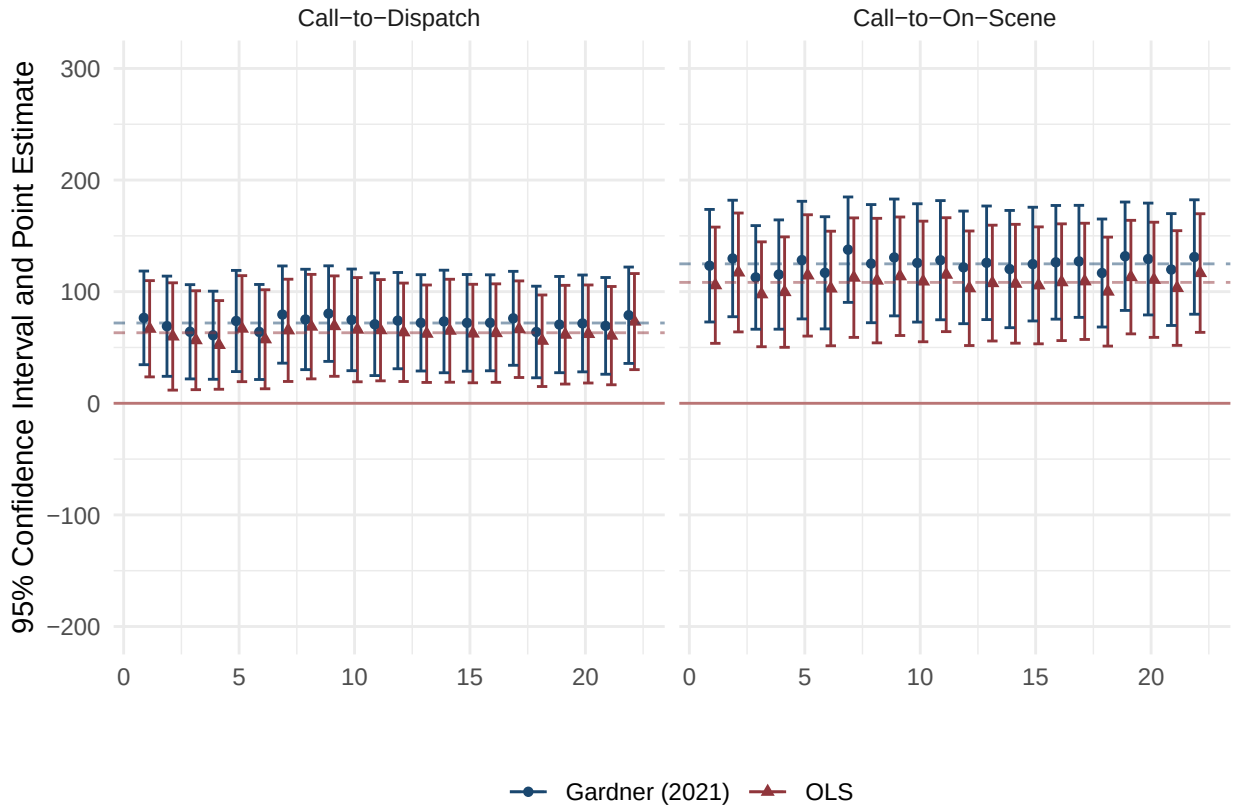


Figure 15: Leave-one-out Analysis of Outcomes

Note: This figure shows six different regression specifications for both call-to-dispatch and call-to-on-scene. Main Sample refers to the main sample used in the paper. Main Sample (2-Stage DID) uses the main sample, but uses the 2-Stage DID estimation technique as outlined in Gardner (2022). No Controls omits all controls, yet keeps day-by-month-by year and district fixed effects. Omitting 2020 uses the main specification in the paper, but omits the year 2020 due to Covid-19. Last, Omitting Never-Treated uses the full sample, but omits any police districts that did not receive ShotSpotter technology.

5 Appendix Tables

Table 6: Proportion of Missing Call-to-On-Scene Data (OLS)

	(1)	(2)
ShotSpotter Activated	0.031	0.033
	(0.020)	(0.023)
Mean of Dependent Variable	0.526	0.526
Observations	56,254	56,254
FE: Day-by-Month-by-Year	X	X
FE: District	X	X
Gardner (2021) Robust		X

Note:
* p < 0.1, ** p < 0.05, *** p < 0.01
Standard errors are clustered by district. Dependent variable is the proportion of 911 call dispatches that have missing on-scene times. ShotSpotter Activated refers to the timing in which each district receives ShotSpotter technology. The Gardner (2021) Robust estimator is robust to the heterogeneous treatment effects in staggered two-way-fixed-effects designs.