

# The Effect of ShotSpotter Technology on Police Response Times

Applied Micro Lunch

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# Motivation:

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- Artificial Intelligence (AI) → police forces
- License plate readers, facial recognition, predictive policing
- AI changes officer production function

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- Widespread (150+ cities world-wide)
- In Chicago: \$11 million a year

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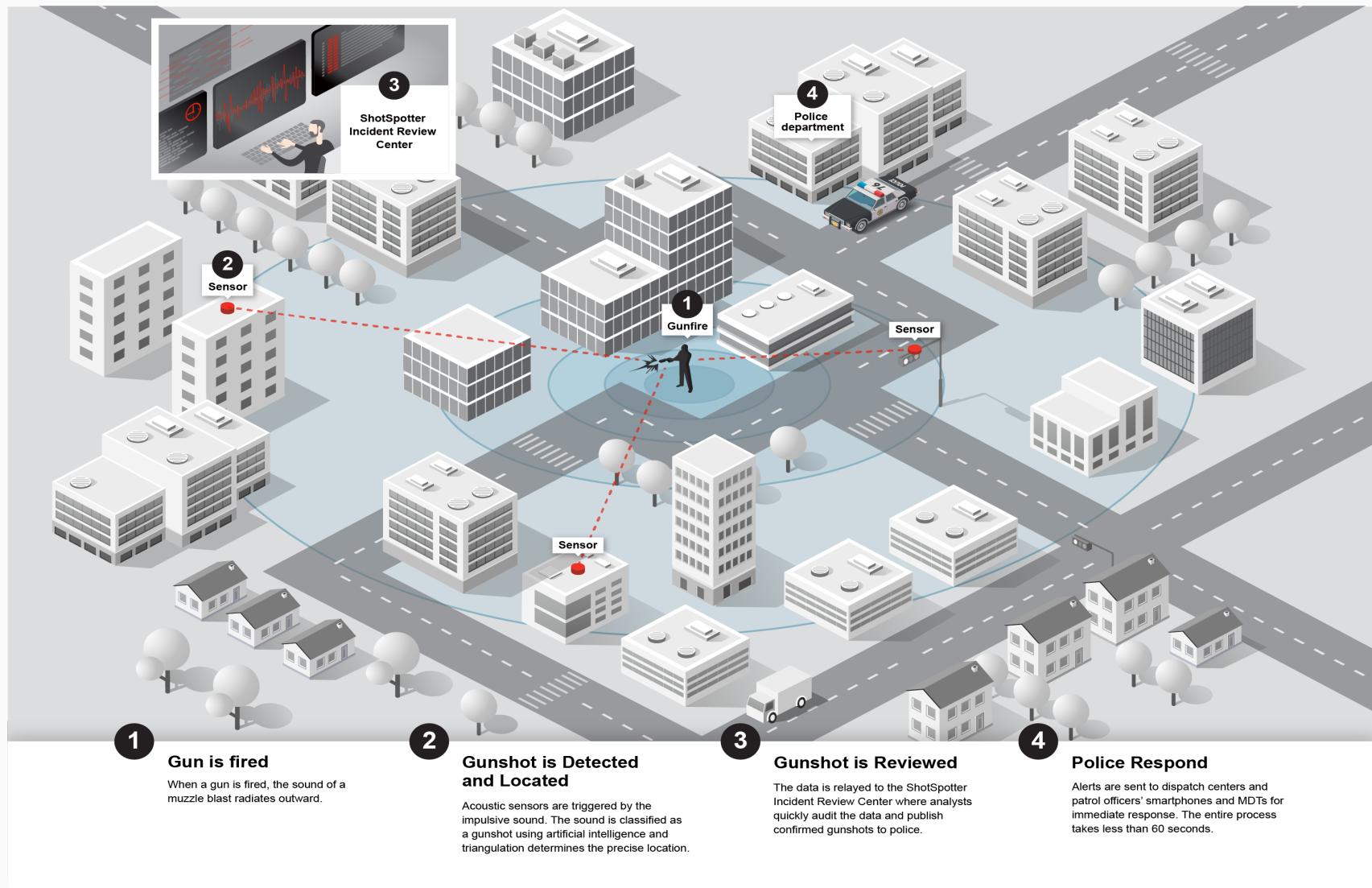
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## Research Question:

How does investment in ShotSpotter affect the time allocation of scarce police resources in terms of 911 response times?

- Two outcomes: Priority 1 911 Call-to-Dispatch / Call-to-On-Scene

# What is ShotSpotter and how does it work?



# Why do we care about response times?

“If police can arrive within one minute of the commission of an offense, they are more likely to catch the suspect. Any later and the chances of capture are very small, probably less than one in ten.”- (David H. Baley 1996)

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## Support for Response Times:

- Lower response times results in:
  - Higher crime clearance (Blanes i Vidal and Kirchmaier 2018)
  - Less likelihood of an injury (DeAngelo et al. 2023)
- Response → important component of investigation (College of Policing 2013)
- Health implications
  - Delayed treatment → worse patient outcomes (Wilde, 2013, Avdic, 2016)

# Why would ShotSpotter affect response times?

## Police Forces:

- A fixed amount of daily resources

## ShotSpotter Resource-Intensive:

- Respond to every *hypothesized* gunfire
  - Known as a *ShotSpotter Alert*
- ~60 daily dispatches
- ~20 min investigating the scene

## Time Wasted?

- Costly for other *confirmed* 911 calls from civilians?

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On an **average day** in Chicago,

there are more than  
**61 ShotSpotter-initiated police deployments** that turn up **no evidence of any crime, let alone gun crime.**

[EndPoliceSurveillance.com](http://EndPoliceSurveillance.com)

This study was conducted by the MacArthur Justice Center



# Summary of the Paper:

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## Setting:

- Chicago: 2016-2022
  - Second largest police force
  - Third largest city

## Data:

- All dispatched Priority 1 911 calls for police service
  - Police shifts
  - Arrests
  - Victim Injuries

# Summary of the Paper:

## Setting:

- Chicago: 2016-2022
  - Second largest police force
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## Empirical Strategy:

- Staggered difference-in-differences
  - Variation: ShotSpotter rollouts across police districts

## Data:

- All dispatched Priority 1 911 calls for police service
  - Police shifts
  - Arrests
  - Victim Injuries

## Main Results:

- When a civilian calls 911, a Priority 1 911 call experiences:
  - +1 minute Call-to-Dispatch (23%)
  - +2 minutes Call-to-On-Scene (13%)
  - Lower arrest probability (8%)

# Contribution:

In-depth, causal analysis on a wide-spread police technology, whose consequences are relatively unknown.

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## Related Literature

### ShotSpotter Specific

Police Technology

Rapid Response

AI in Workforce

We find unintended consequences due to large resource investment (increased response times/lower arrest rates).

- Economics:
  - Use ShotSpotter as data for alternative crime/mistrust measure (Carr and Doleac 2018; Ang et. al 2021)
- Non-Economics:
  - Better accuracy, little crime impact or case resolution (Piza et al., 2023; Mares and Blackburn, 2012; Choi et al., 2014)

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In-depth, causal analysis on a wide-spread police technology, whose consequences are relatively unknown.

## Related Literature

ShotSpotter Specific

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We find detrimental consequences of an expensive, resource-intensive, technology.

- Benefits of Police Technology:
  - Body Worn Cameras → lower use of force/complaints (Zamoff et al. 2021; Braga et al. 2022; Ferrazares 2023)
  - Predictive Policing → less crime (Mastrobuoni, 2020; Jabri, 2021; Heller et al., 2022)
  - Tactical Equipment → less crime (Bove and Gavrilova 2017; Harris et al. 2017))

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## Related Literature

ShotSpotter Specific  
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We identify a determinant of higher response times, and can quantify at a micro-level.

- Lower Response Times:
  - Higher crime clearance (Blanes i Vidal and Kirchmaier, 2018)
  - Less likelihood of an injury (DeAngelo et al., 2023)

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Our results imply that artificial intelligence cannot replace police officers.

- Substitutes:
  - AI operates better than human managers (Hoffman et al., 2018)
- Complements:
  - Human and algorithmic targeting work best together (Bhatt et al., 2023)

# Institutional Background and Setting

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# 911 Dispatch Procedure:

Pipeline:

Call-to-Dispatch

Call-to-On-Scene

## 911 Dispatch Pipeline:

1. Emergency call is made
  - Civilian reports crime to 911.
2. Dispatcher dispatches police
  - Dispatcher records info, finds available police to dispatch.
3. Police travel to crime scene
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# 911 Call Priorities in Chicago:

## Priority 1 (immediate dispatch):

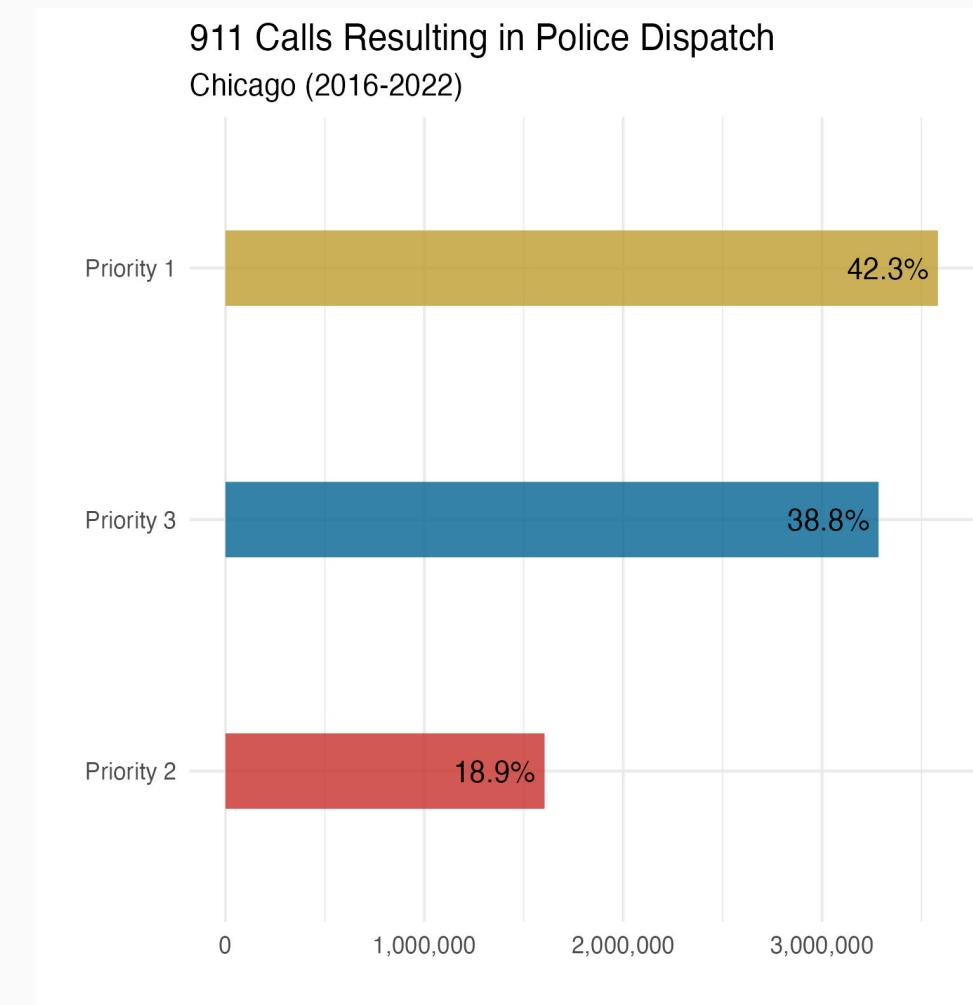
- Imminent threat to life, bodily injury, or major property damage/loss. Example: 'person with gun' 'domestic battery'

## Priority 2 (rapid dispatch):

- Timely police action has the potential to affect the outcome of an incident. Example: 'suspicious auto'

## Priority 3 (routine dispatch):

- Does not involve an imminent threat...a reasonable delay in police action will not affect the outcome of the incident.  
Example: 'parking violation'



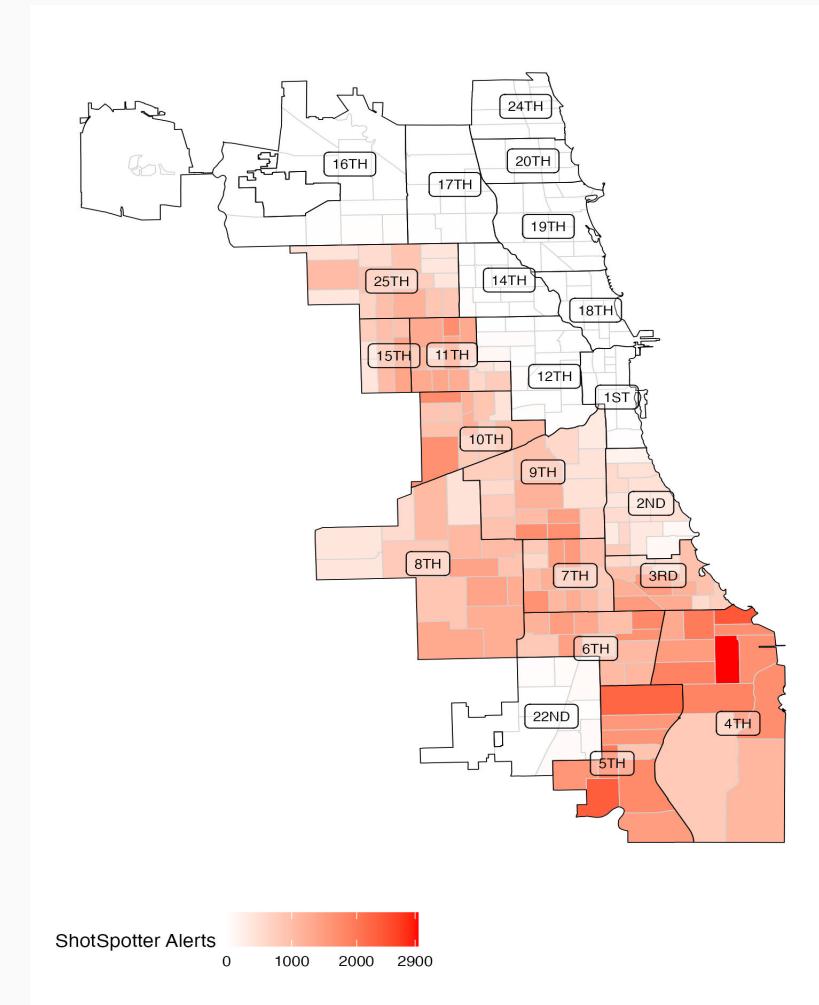
# ShotSpotter in Chicago:

## Staggered Rollout

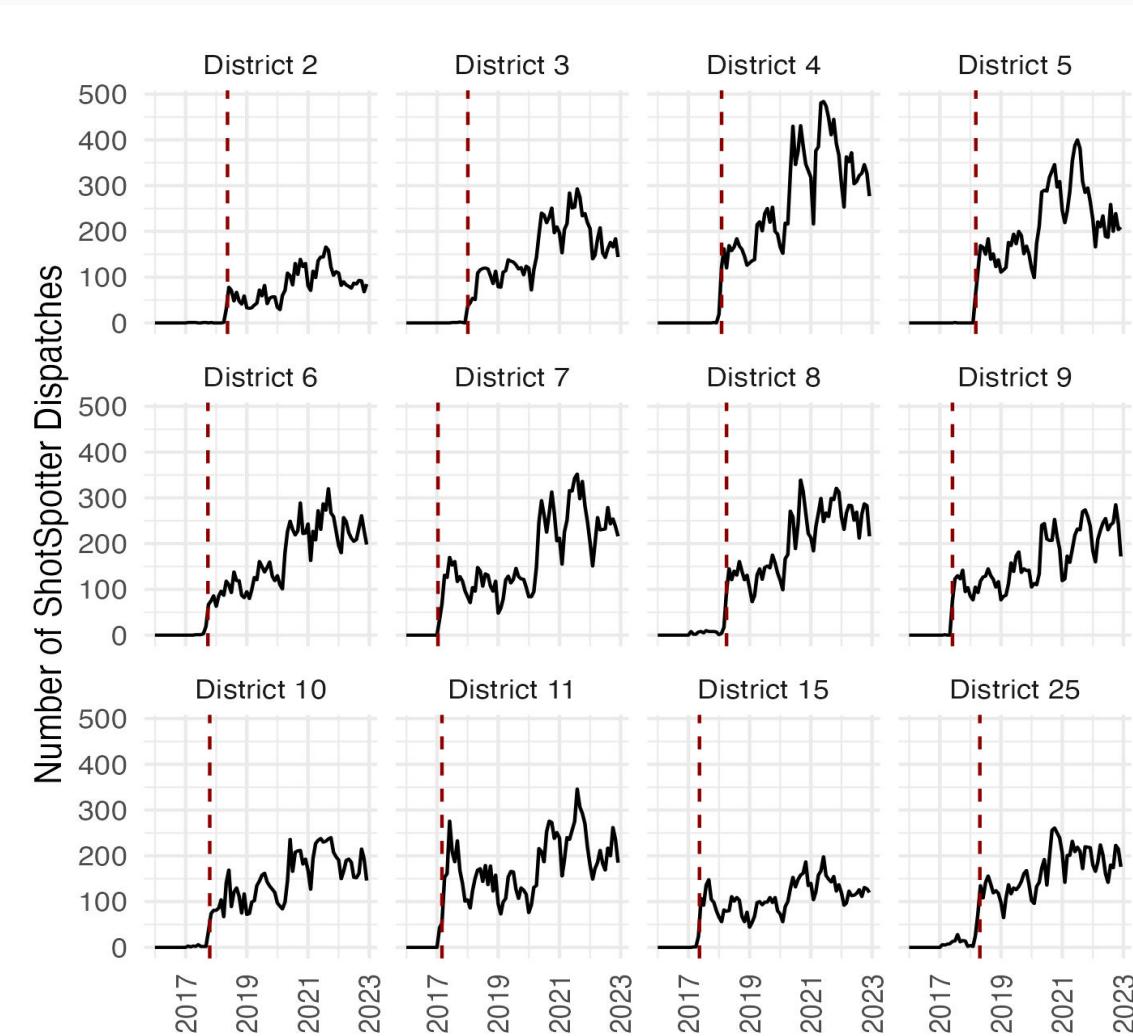
- 12 of 22 police districts in 2017-2018
- Implemented with full coverage across districts
- Rational: respond to high gun-crime

## Administrative Background

- Priority 1 - same as active shooter
- Same officers responding as 911 call
- Additional: canvass 25 meter radius, add information



# ShotSpotter Dispatch Trends:



District	Enactment
2	2018-05-16
3	2018-01-04
4	2018-02-01
5	2018-03-07
6	2017-09-24
7	2017-01-13
8	2018-04-01
9	2017-06-01
10	2017-10-16
11	2017-03-01
15	2017-05-13
25	2018-04-24

# Data and Empirical Strategy

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# Data and Sample Restrictions:

## Data Overview:

- Priority 1 911 Calls (2016-2022) with police dispatch
- ShotSpotter dispatches ≠ 911 call
- Freedom of Information Act

## Exclusions:

- Outliers (0.04%; 1.6%), Negative response times (.03%)
- January 1/July 4/December 31

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	Mean	Std.Dev.	Min	Max	N
Call-to-Dispatch	281.89 (4.70 mins)	436.53 (7.28 mins)	2.00 (0.03 mins)	3,111.00 (51.85 mins)	3,582,560
Call-to-On-Scene	770.86 (12.85 mins)	784.69 (13.08 mins)	11.00 (0.18 mins)	7,671.00 (127.85 mins)	1,997,102

# Estimation Strategy:

## Specification (OLS):

$$\text{ResponseTime}_{cdt} = \beta \text{ShotSpotter}_{dt} + \eta_{\bar{c}} + \delta_d + \gamma \mathbb{X}_{f(t)} + \varepsilon_{cdt}$$

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$$\text{ResponseTime}_{cdt} = \beta \text{ShotSpotter}_{dt} + \eta_c + \delta_d + \gamma \mathbb{X}_{f(t)} + \varepsilon_{cdt}$$

- $\text{ResponseTime}_{cdt}$  is call  $c$  in police district  $d$  in time  $t$ .
- $\text{ShotSpotter}_{dt}$  is the binary treatment
- $\eta_c$  is a call-type fixed effect
- $\delta_d$  is a police district-specific fixed effect
- $\mathbb{X}_{f(t)}$  is a vector of time-varying controls:
  - Hour-of-day and day-by-month-by-year
- Standard errors clustered by police district
- Intuitively, this is estimating the average change in response times on days with ShotSpotter accounting for expected differences in districts/time/call-types.

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- Standard operating procedures same for Priority 1 911 calls
- Specific call-type analysis

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## 3. Other policies that coincide that may affect response times:

- Strategic Decision Support Centers (SDSC) and Body-Worn Cameras (BWC)

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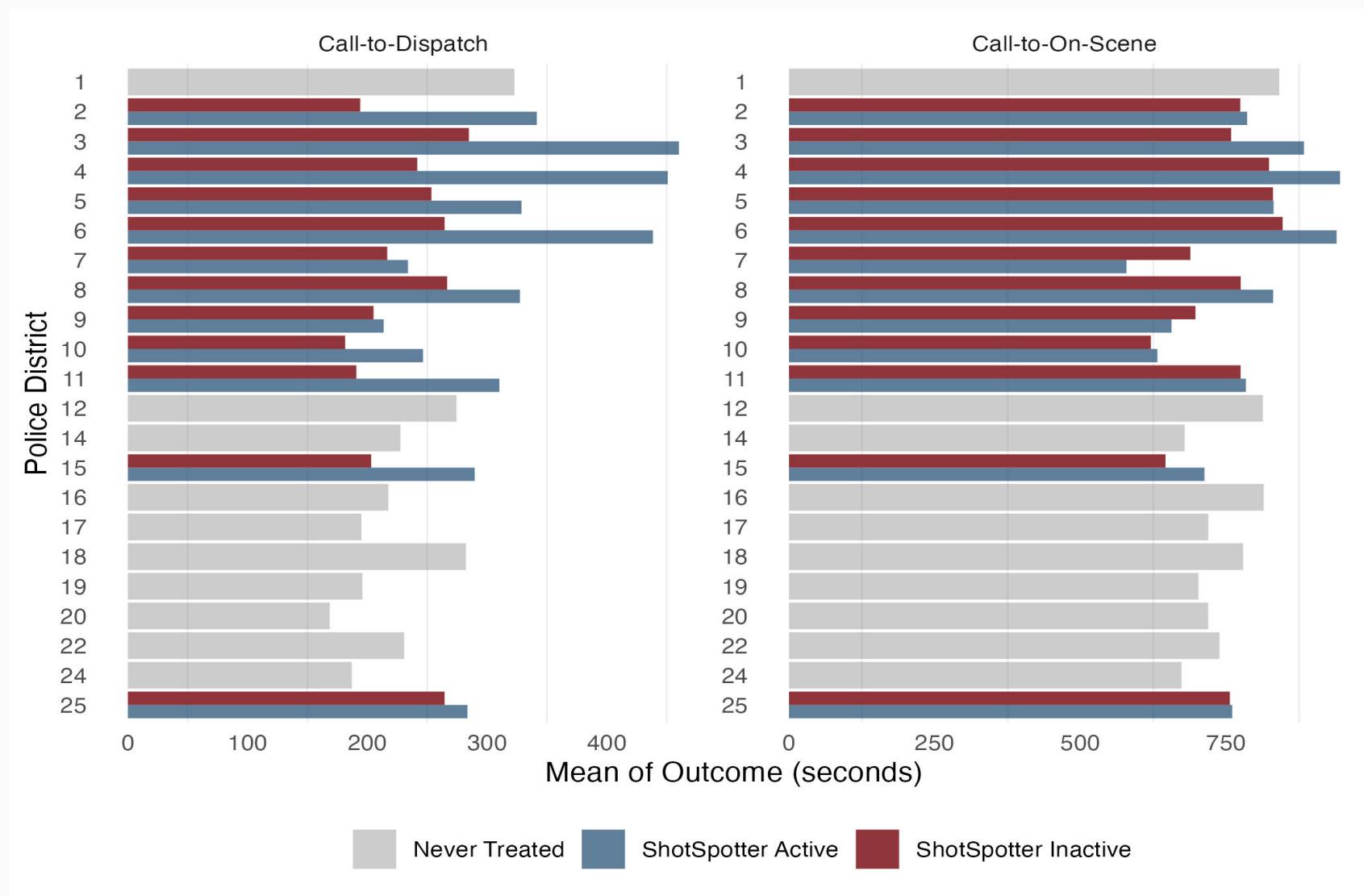
## 4. OLS with staggered rollouts:

- Two-stage difference-in-differences (Gardner 2022) similar to Borusyak et al. (2021)

# Results

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# Raw Data Preview:



# Main Results:

Call-to-Dispatch	Call-to-On-Scene	Arrest Probability	
Effect of ShotSpotter Enactment on Call-to-Dispatch (OLS)			
	(1)	(2)	(3)
ShotSpotter Activated	64.131*** (22.379)	72.063*** (22.356)	61.446*** (21.627)
Border District Activated			21.442 (16.503)
Mean of Dependent Variable	281.890	281.890	281.890
Observations	3,582,560	3,582,528	3,582,560
Wild Bootstrap P-Value	0.012		0.017
Gardner (2022) Robust	No	Yes	No
<i>Note:</i>			
* p < 0.1, ** p < 0.05, *** p < 0.01			

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Effect of ShotSpotter Enactment on Call-to-On-Scene (OLS)			
	(1)	(2)	(3)
ShotSpotter Activated	102.682*** (28.724)	120.389*** (27.913)	100.986*** (28.099)
Border District Activated			24.178 (17.847)
Mean of Dependent Variable	770.863	770.863	770.863
Observations	1,997,102	1,997,076	1,997,102
Wild Bootstrap P-Value	0.012		0.017
Gardner (2022) Robust	No	Yes	No

*Note:*

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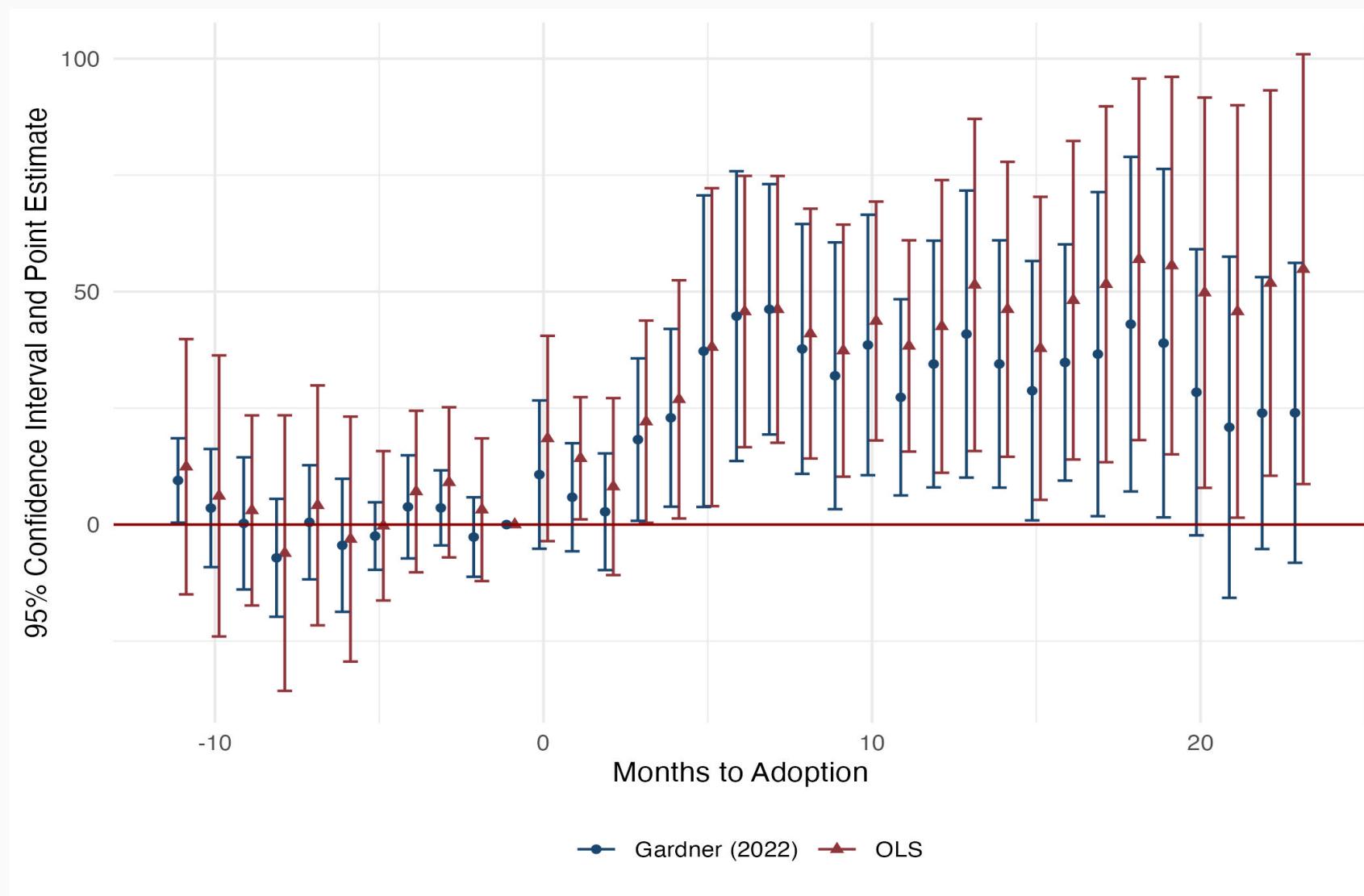
# Main Results:

Call-to-Dispatch	Call-to-On-Scene	Arrest Probability				
Effect of ShotSpotter Enactment on Arrest Probability (OLS)						
	Gun-Relation			Most Frequent Arrest Types		
	Pooled	Gun	Non-Gun	Domestic Disturbance	Domestic Battery	Robbery
	(1)	(2)	(3)	(4)	(5)	(6)
ShotSpotter Activated	-0.002*** (0.001)	-0.002 (0.002)	-0.002*** (0.001)	-0.008*** (0.002)	-0.003** (0.001)	-0.003 (0.002)
Mean of Dependent Variable	0.024	0.034	0.024	0.061	0.020	0.042
Observations	3,582,560	317,937	3,264,623	224,022	675,025	270,735
Wild Bootstrap P-Value	0.001	0.412	0.003	0.003	0.049	0.109

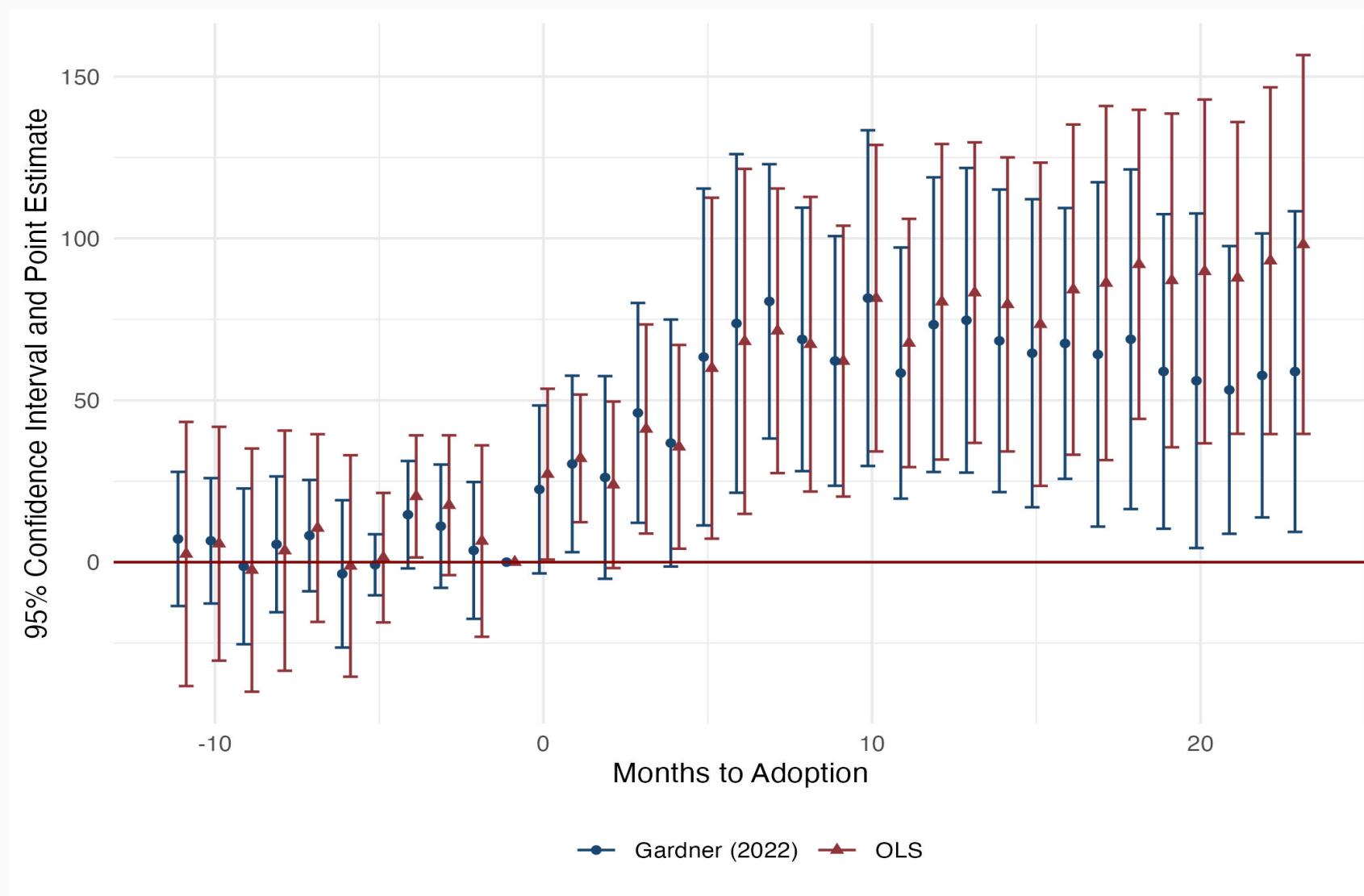
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# Dynamic Effects: Call-to-Dispatch



# Dynamic Effects: Call-to-On-Scene



# Robustness:

## Main Results:

- Leave-one-out analysis - ensure results are not driven by 1 district
- Sample restrictions:
  - Omit 2020 (Covid-19)
  - Reintroduce outliers
  - Reintroduce omitted days

## Event Studies:

- Rambachan and Roth (2023) sensitivity
- Robust to varying trend-types

# Mechanism

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# Potential Mechanism:

**ShotSpotter expands an officer's responsibilities and incapacitates them from attending to other tasks.**

## 1. Extensive Margin: Estimate most resource-constrained times

- Split by police-district median number of officer hours
- Separate by shift-type

## 2. Intensive Margin: Use ShotSpotter dispatches as intensity measure

- If we can assume the number of alerts within a district day is random, the following will estimate the marginal effect of an extra ShotSpotter dispatch:

$$\text{ResponseTime}_{cdt} = \beta \text{NumberSSTDispatches}_{dt} + \eta_c + \delta_d + \gamma \mathbb{X}_{f(t)} + \varepsilon_{cdt}$$

- $\text{NumberSSTDispatches}_{dt}$  is number of ShotSpotter dispatches in a police-district
- Restrict to only treated periods

# Extensive Margin: Less Officers

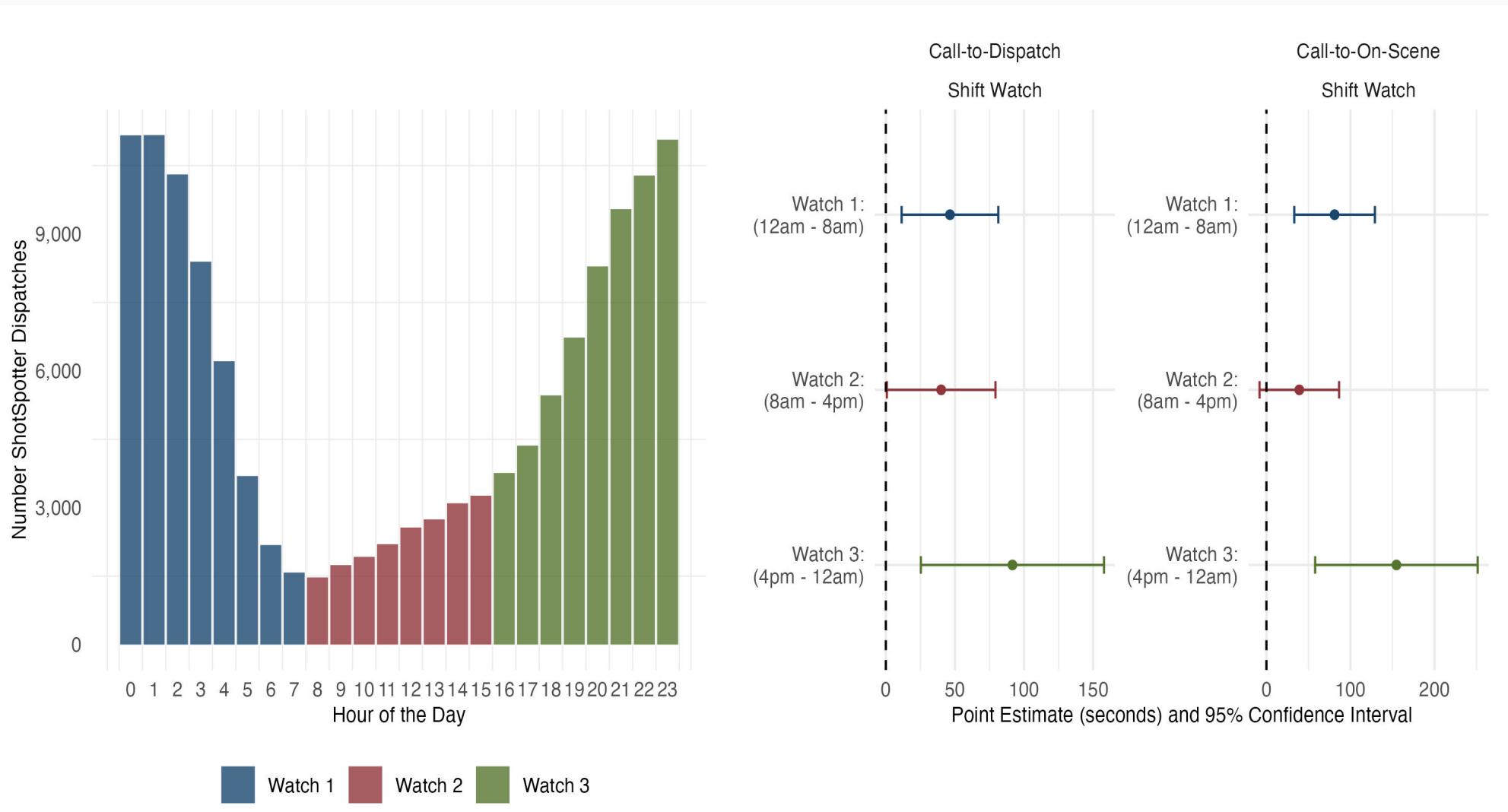
Extensive Margin: Effect of ShotSpotter Implementation

	Officer Hours		
	Pooled	> Median	<= Median
<i>Panel A: Call-to-Dispatch</i>			
ShotSpotter Activated	64.131*** (22.379)	27.222** (12.382)	93.794*** (31.497)
Mean of Dependent Variable	281.890	229.785	333.871
Observations	3,582,560	1,789,157	1,793,403
<i>Panel B: Call-to-On-Scene</i>			
ShotSpotter Activated	102.682*** (28.724)	55.508** (21.030)	141.492*** (38.611)
Mean of Dependent Variable	770.863	700.283	837.941
Observations	1,997,102	973,138	1,023,964

*Note:*

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

# Extensive Margin: Shift Times



# Intensive Margin: ShotSpotter Dispatches

Intensive Margin: Effect of Number of SST Dispatches

	Officer Hours		
	Pooled	> Median	<= Median
<i>Panel A: Call-to-Dispatch</i>			
Number SST Dispatches	5.272*** (1.490)	3.344*** (0.945)	4.237*** (0.879)
Mean of Dependent Variable	291.300	232.886	349.536
Observations	2,958,754	1,477,121	1,481,633
<i>Panel B: Call-to-On-Scene</i>			
Number SST Dispatches	7.053*** (1.885)	4.857*** (1.158)	5.152*** (1.133)
Mean of Dependent Variable	771.964	690.147	853.515
Observations	1,732,479	864,836	867,643

*Note:*

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# Heterogeneity

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# Two Types of Heterogeneity Analysis:

## 1. Analyze specific call-types

- Analyze a specific call for the most frequent offenses
- Large health implications with emergency medical services/domestic calls

## 2. Split by priority of call

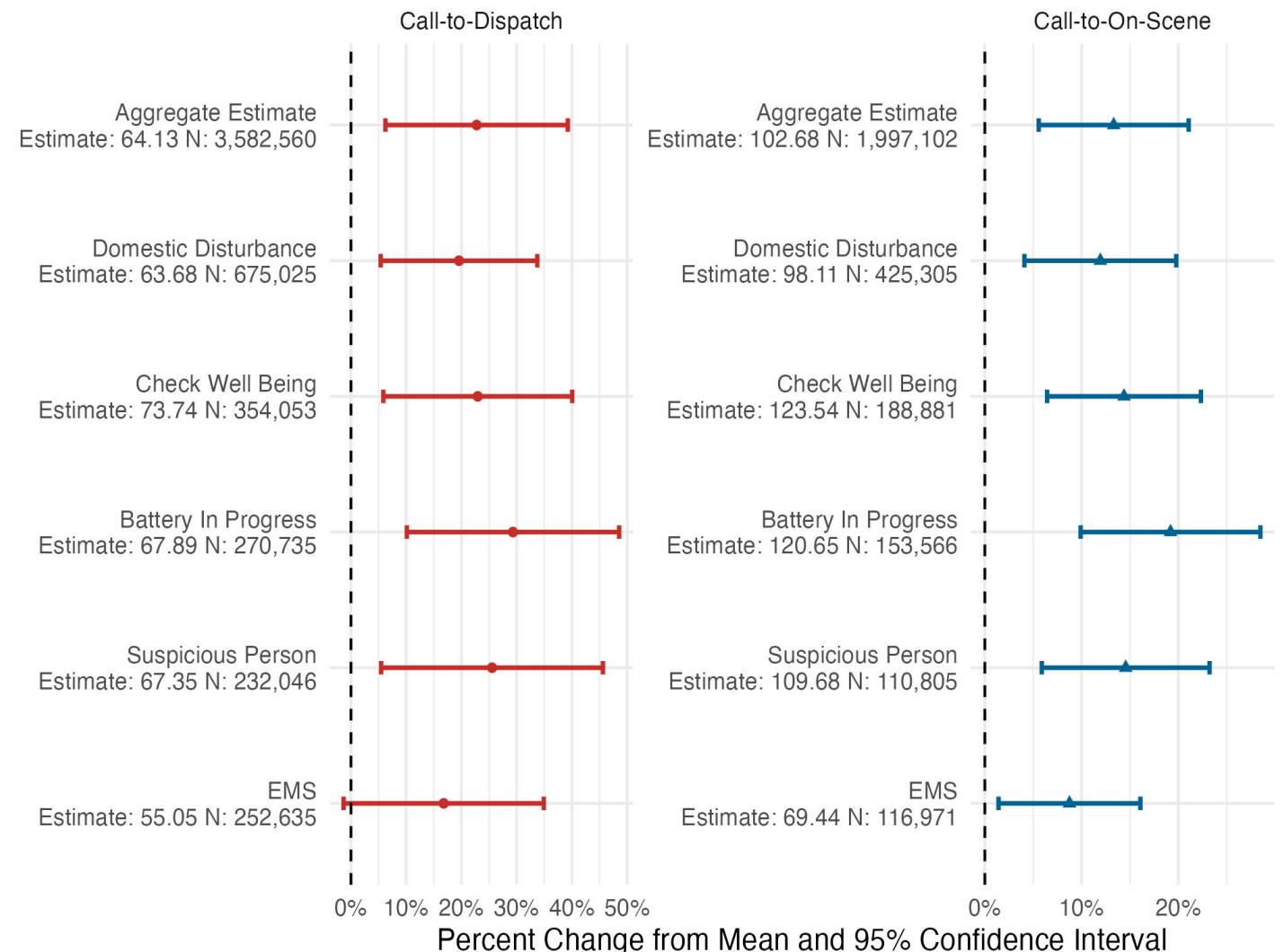
- A 'trickle down' effect in Priority 2, suggestive for Priority 3
- No time for high priority == no time for lower priorities
- Lends to the idea that officers are facing more responsibilities than they can handle

# Priority and Call-type Heterogeneity:

Priority 1 (Immediate)

Priority 2 (Rapid)

Priority 3 (Routine)

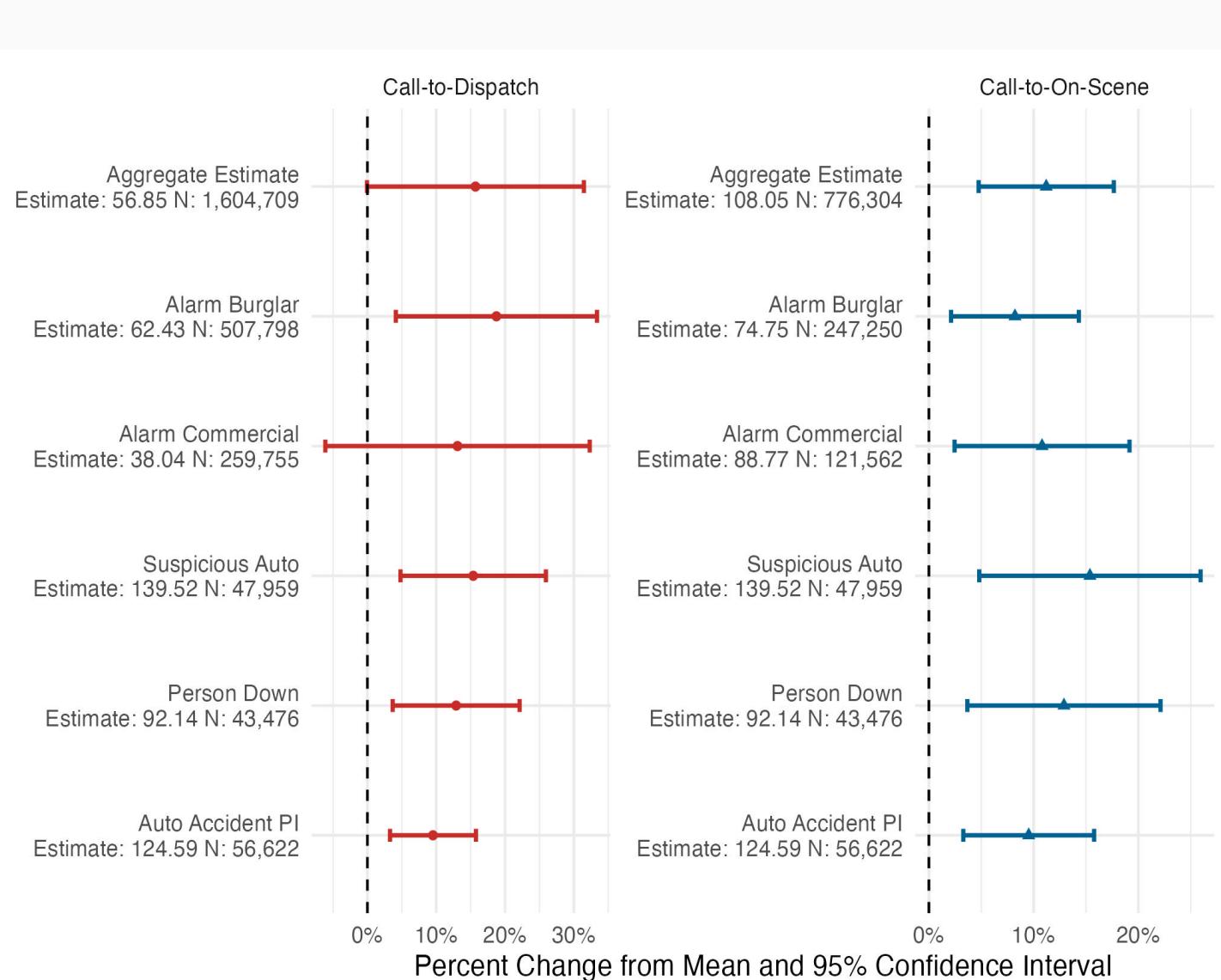


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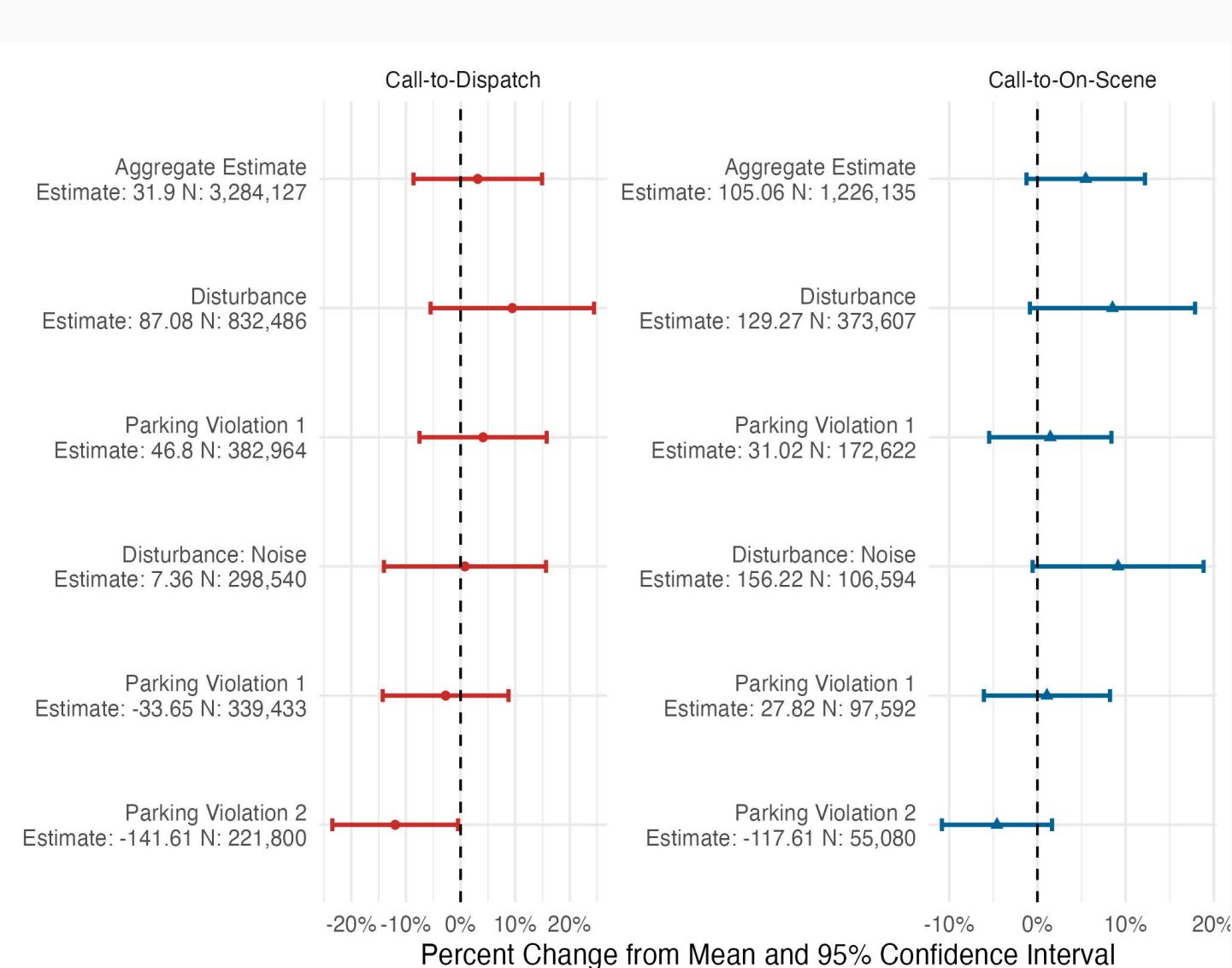


# Priority and Call-type Heterogeneity:

Priority 1 (Immediate)

Priority 2 (Rapid)

Priority 3 (Routine)



# Intended Consequence?

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# Possible Benefits?

## Does ShotSpotter provide benefits?

- Analyze the probability of a victim injury
  - Following DeAngelo et al. (2023)

## New Restrictions:

- Restrict data to only *unrealized* events → police intervention may affect outcome
- Examples:
  - Include: 'Call for Help' → unrealized
  - Exclude: 'Person Shot' → realized
- Main Result: Suggestive (not conclusive!) evidence of lower injury probability, driven by gun-related calls

# Effect on Victim Injury:

Effect of ShotSpotter Implementation on Probability of Injury (OLS)

	Probability of Victim Injury		
	Pooled	Gun Dispatch	Non-Gun Dispatch
	(1)	(2)	(3)
ShotSpotter Activated	-0.001*	-0.003	0.000
	(0.000)	(0.002)	(0.000)
Mean of Dependent Variable	0.014	0.024	0.012
Observations	2,434,526	304,544	2,129,982
Wild Bootstrap P-Value	0.123	0.114	0.751

*Note:*

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

# Conclusion:

## Main Takeaways:

- An in-depth analysis on consequences of ShotSpotter:
  - Unintended Consequences:
    - Higher response times
      - Call-to-Dispatch (+1 minute/ 23% increase)
      - Call-to-On-Scene (+2 minutes/ 13% increase)
    - Lower arrest rates (8% decrease)
  - Intended Consequence:
    - Suggestive evidence of effectiveness in probability of gun-related victim injury
- Mechanism: incapacitation and misallocation of officer resources
  - More officers needed to mitigate unintended consequences
- Other recommendations appreciated

Thank you

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