

The Effect of ShotSpotter Technology on Police Response Times

Job Market Talk

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Motivation:

AI in the Workforce:

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

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ShotSpotter Technology

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- Police respond to all detections
- Rationale: only 12% of gunfire reported (Carr and Doleac, 2017) → method to respond to others

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Research Question:

How does the implementation of ShotSpotter technology affect Priority 1 911 call response times?

- How does a police officer's production function change s.t. it affects response?

Why would ShotSpotter affect response times?

Resource-Intensive:

- Respond to every detected gunfire
- Chicago: ~70 daily dispatches, 20 min.
- Priority 1 - equivalent to active shooter

Police Scarcity:

- Fixed amount of resources ⇒ tradeoffs

Unintended consequences?

- Does this reallocation affect 911 call response times?

On an **average day** in Chicago,

there are roughly
**70 ShotSpotter-initiated
dispatches** that take **20
minutes** to investigate,
resulting in **23 hours of
officer time**.

Does this result in **unintended consequences**?

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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Evidence:

- 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)

Summary of the Paper:

Setting:

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 - 2nd largest police force
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 - Police shifts
 - Arrests
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Empirical Strategy:

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

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Main Results:

- When a civilian calls 911, a Priority 1 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 the unintended consequences of a wide-spread police technology.

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Related Literature

ShotSpotter Specific

We unpack the effects of this wide-spread police technology.

Police Technology

Rapid Response

AI in Workforce

- 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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Related Literature

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Unlike others, we find costly unintended consequences of a police 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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We identify a determinant of higher response times, and can quantify at a micro-level.

- Lower Response Times:
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 - Less likelihood of an injury (DeAngelo et al., 2023)

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AI in Workforce

The 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

911 Dispatch Procedure:

911 Dispatch Pipeline:

Call-to-Dispatch:

Call-to-On-Scene:

Arrest Made:

911 call ⇒ Dispatcher Assigns ⇒ Officer Travels ⇒ Officer Arrives

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Call-to-Dispatch

- Measure of officer availability

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Call-to-Dispatch

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Call-to-On-Scene

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Arrest Made:

- Only arrests in the 911 call pipeline: implication of rapid response

911 Call Priorities in Chicago:

Priority 1 (immediate dispatch):

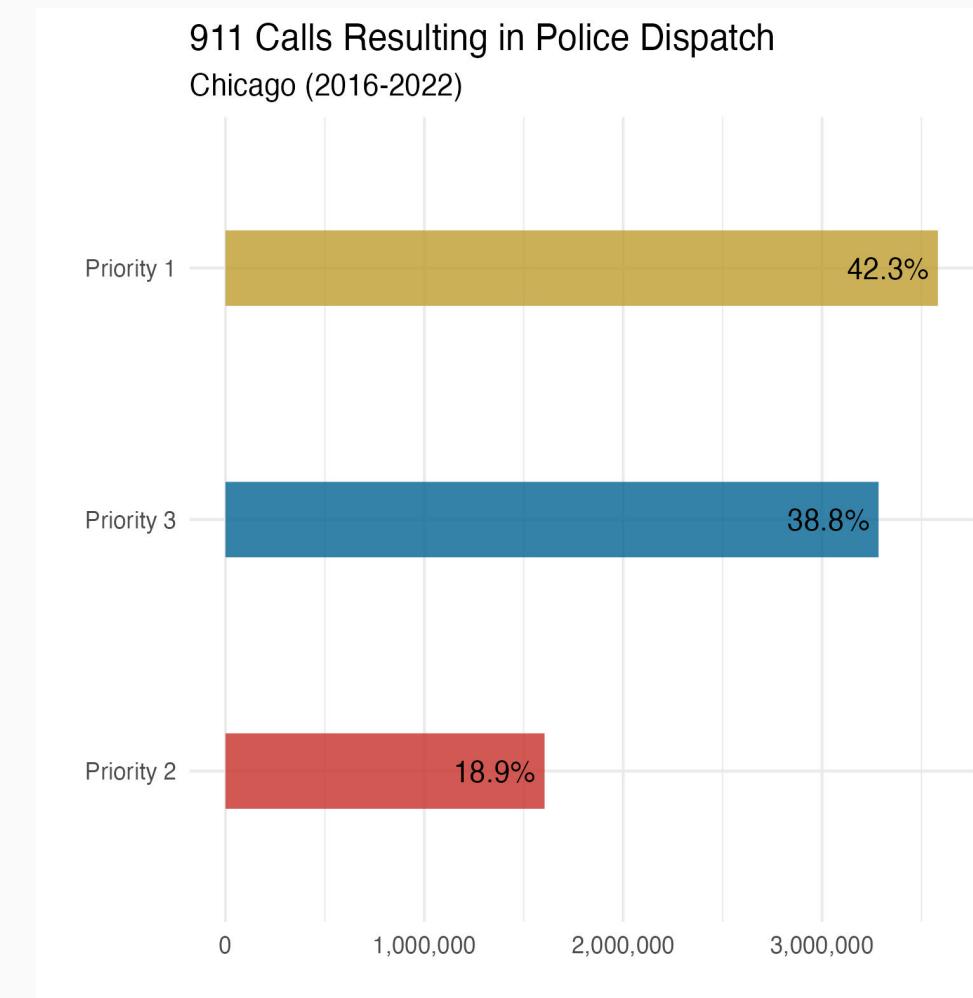
- Imminent threat to life, bodily injury, or major property damage/loss. Example: 'person with gun' 'domestic battery'

Priority 2 (rapid dispatch):

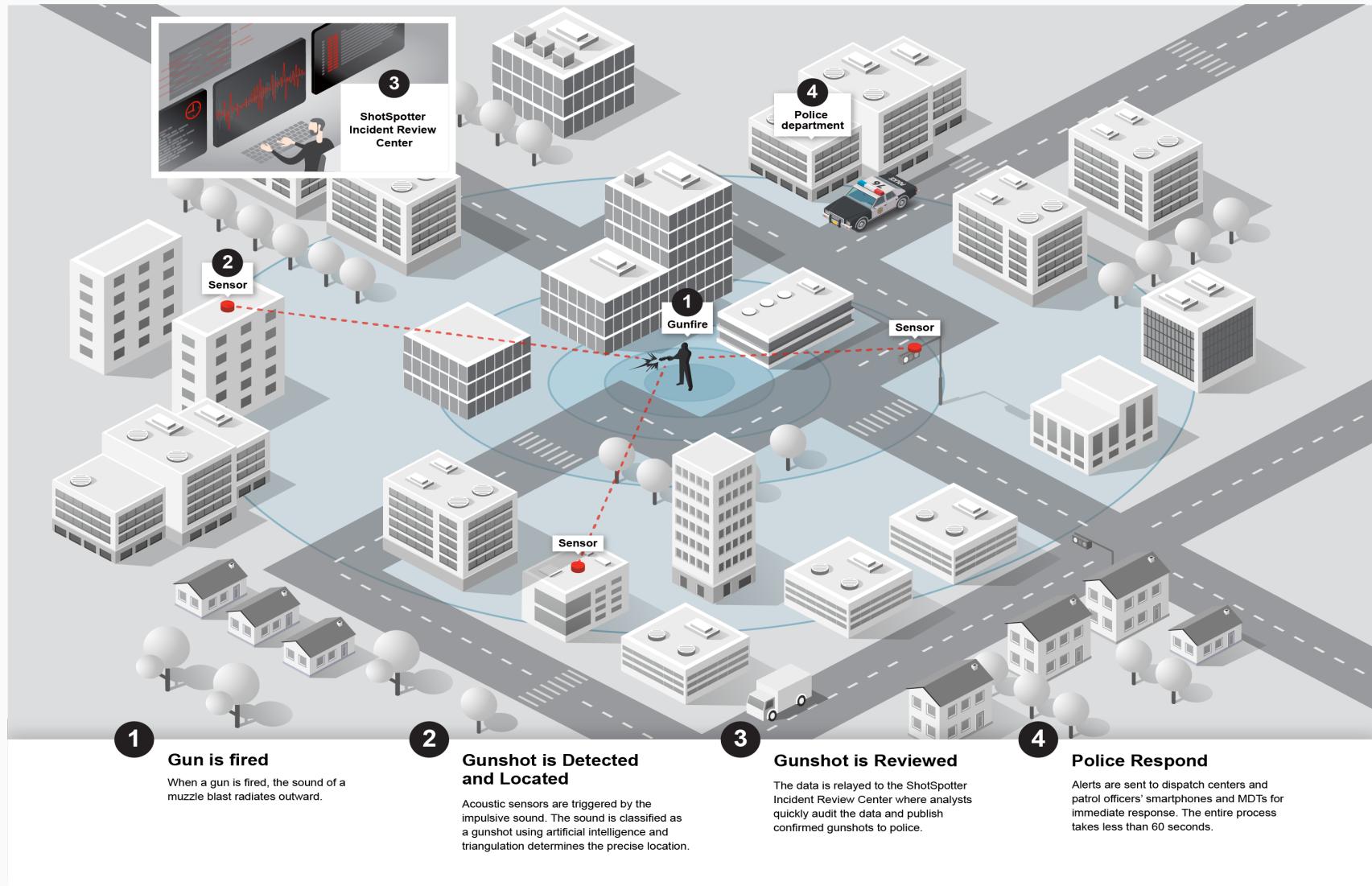
- Time-sensitive, no threat to life. Example: 'suspicious auto'

Priority 3 (routine dispatch):

- Not time-sensitive. Example: 'parking violation'



What is ShotSpotter and how does it work?



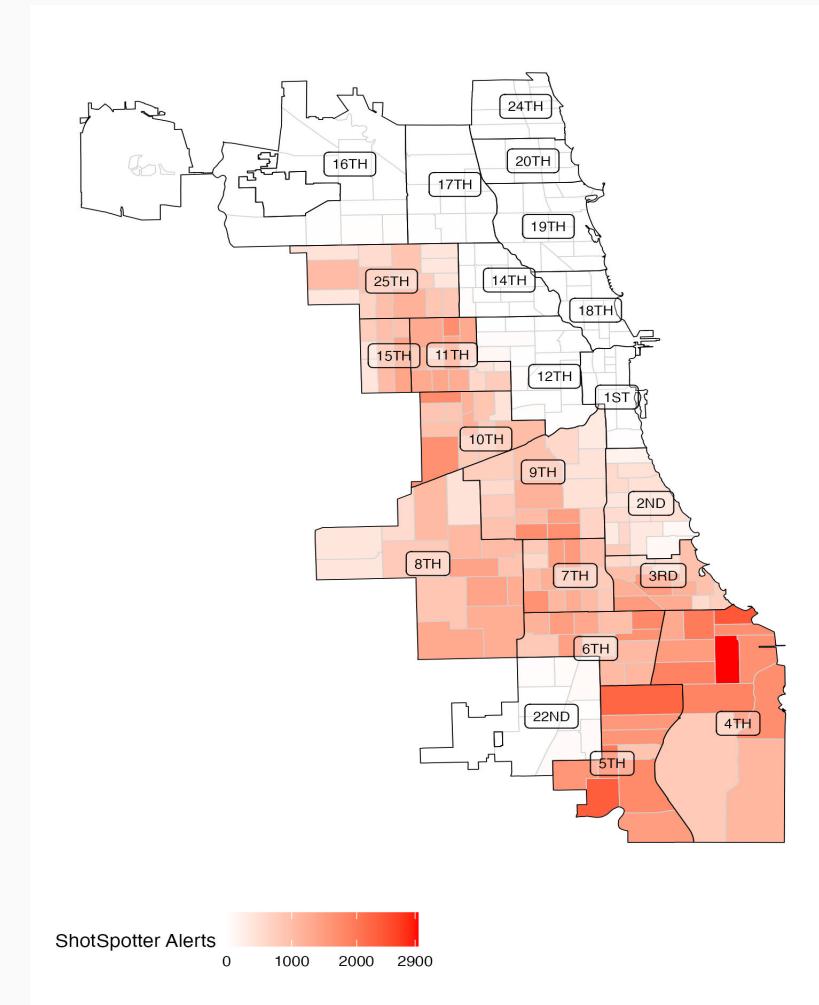
ShotSpotter in Chicago:

Staggered Rollout

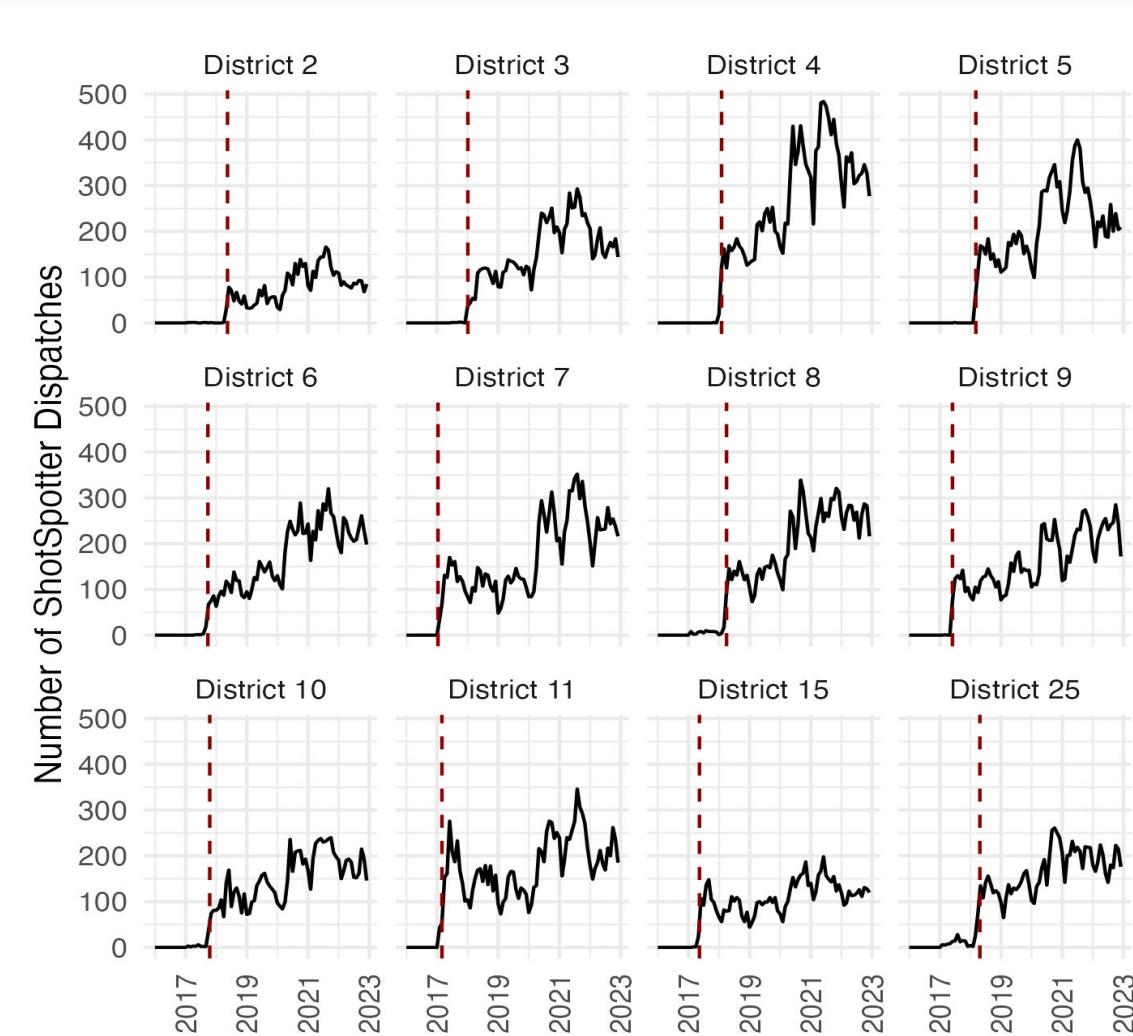
- 12 of 22 police districts in 2017-2018
- Implemented with full coverage across districts
- Rational: respond to high gun-crime

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

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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Specification (OLS):

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

- $\text{ResponseTime}_{cdt}$ is call c in police district d in time t .
- ShotSpotter_{dt} is the binary treatment
- η_c is a call-type fixed effect
- δ_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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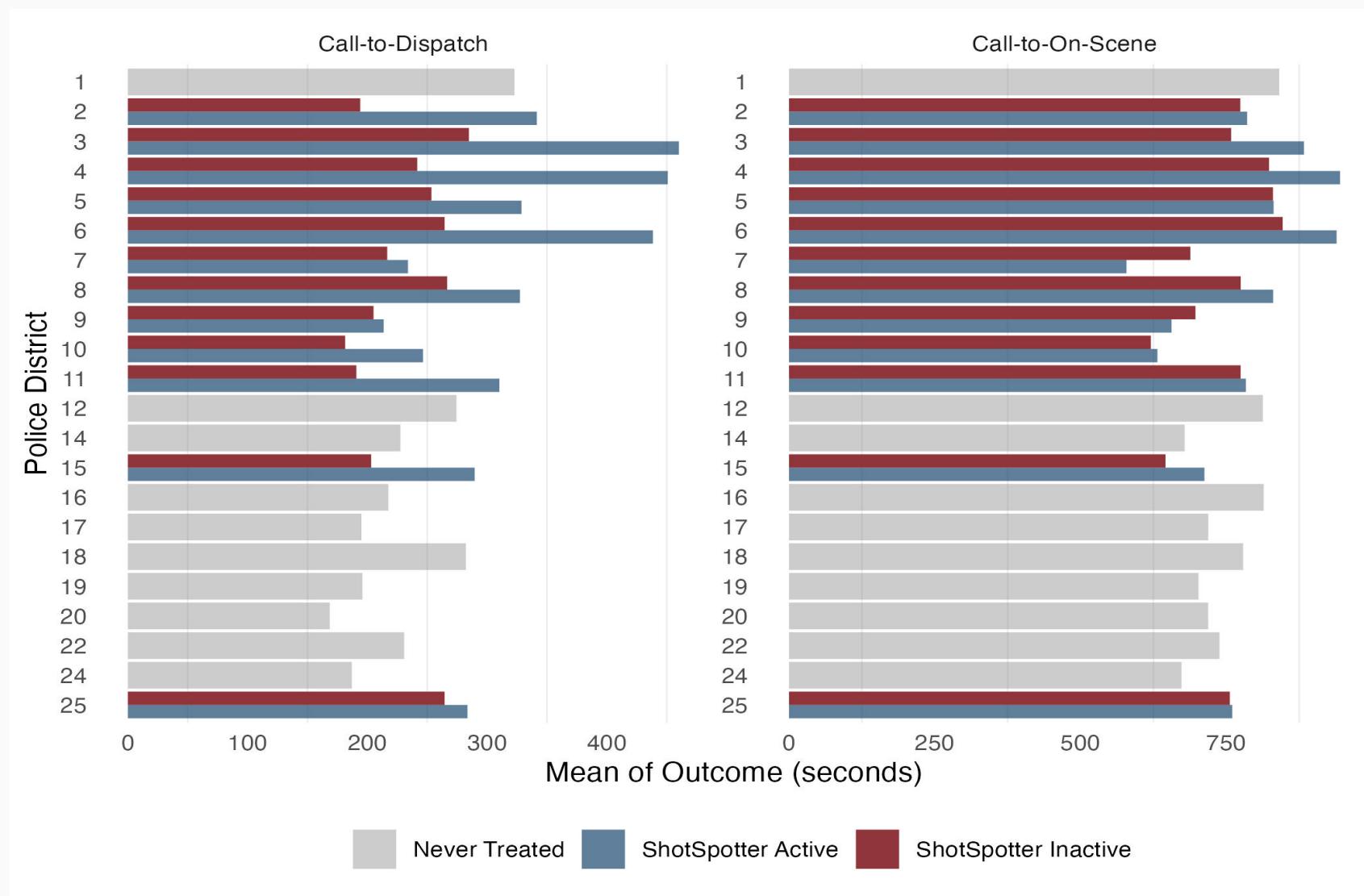
- Strategic Decision Support Centers (SDSC) and Body-Worn Cameras (BWC)

4. OLS with staggered rollouts:

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

Results

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			

Main Results:

Call-to-Dispatch	Call-to-On-Scene	Arrest Probability	
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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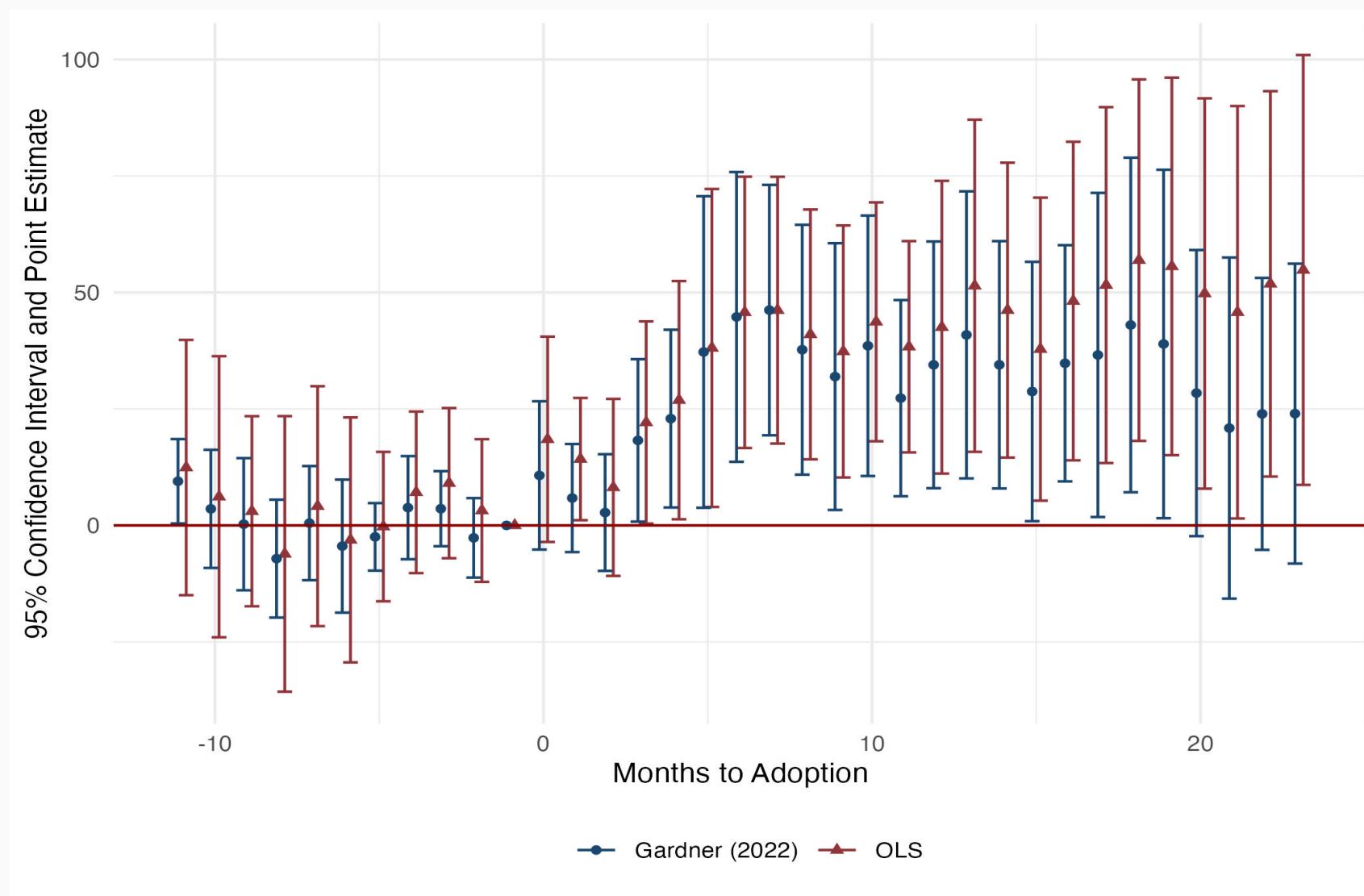
Main Results:

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

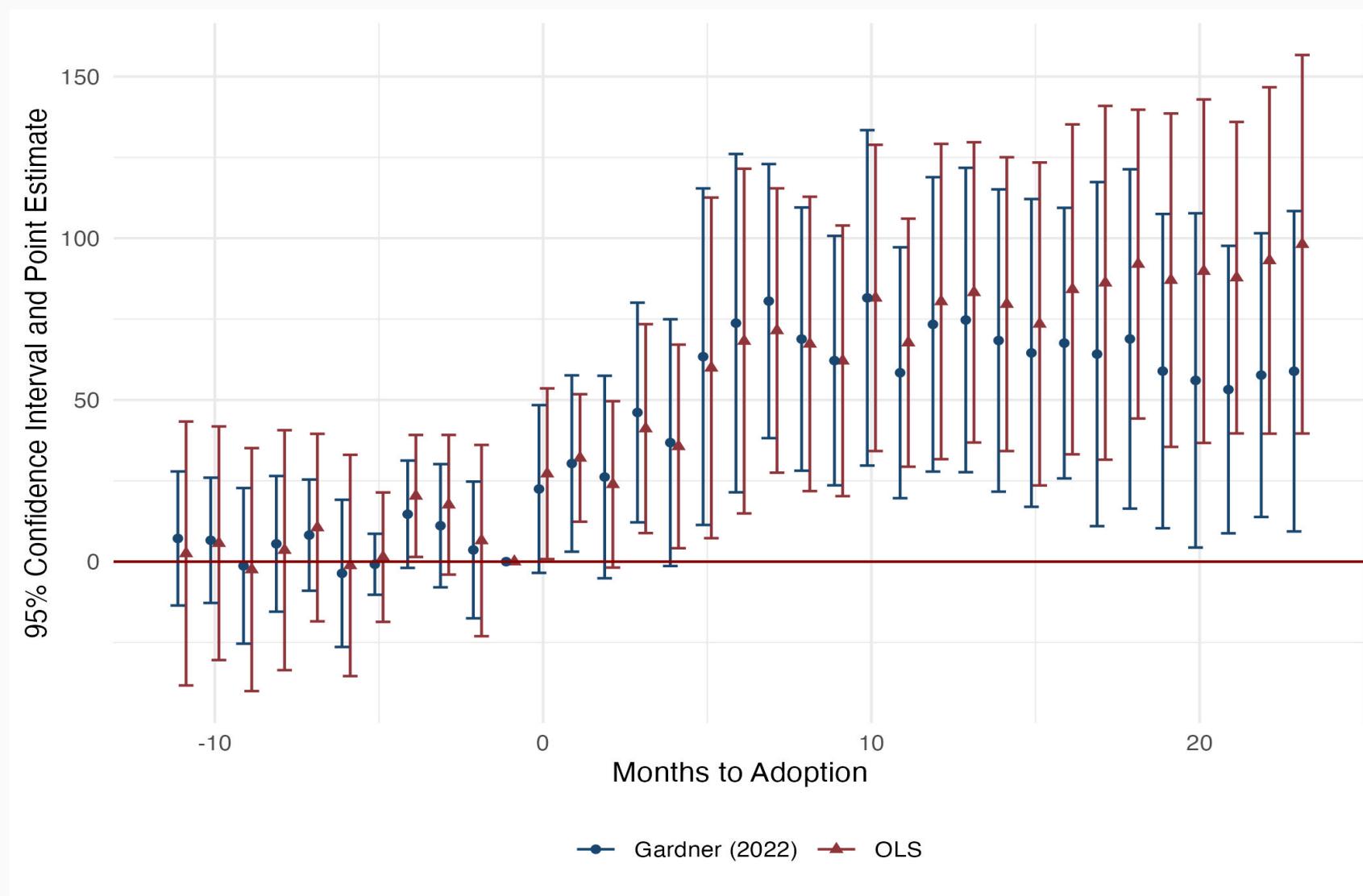
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Dynamic Effects: Call-to-Dispatch



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

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

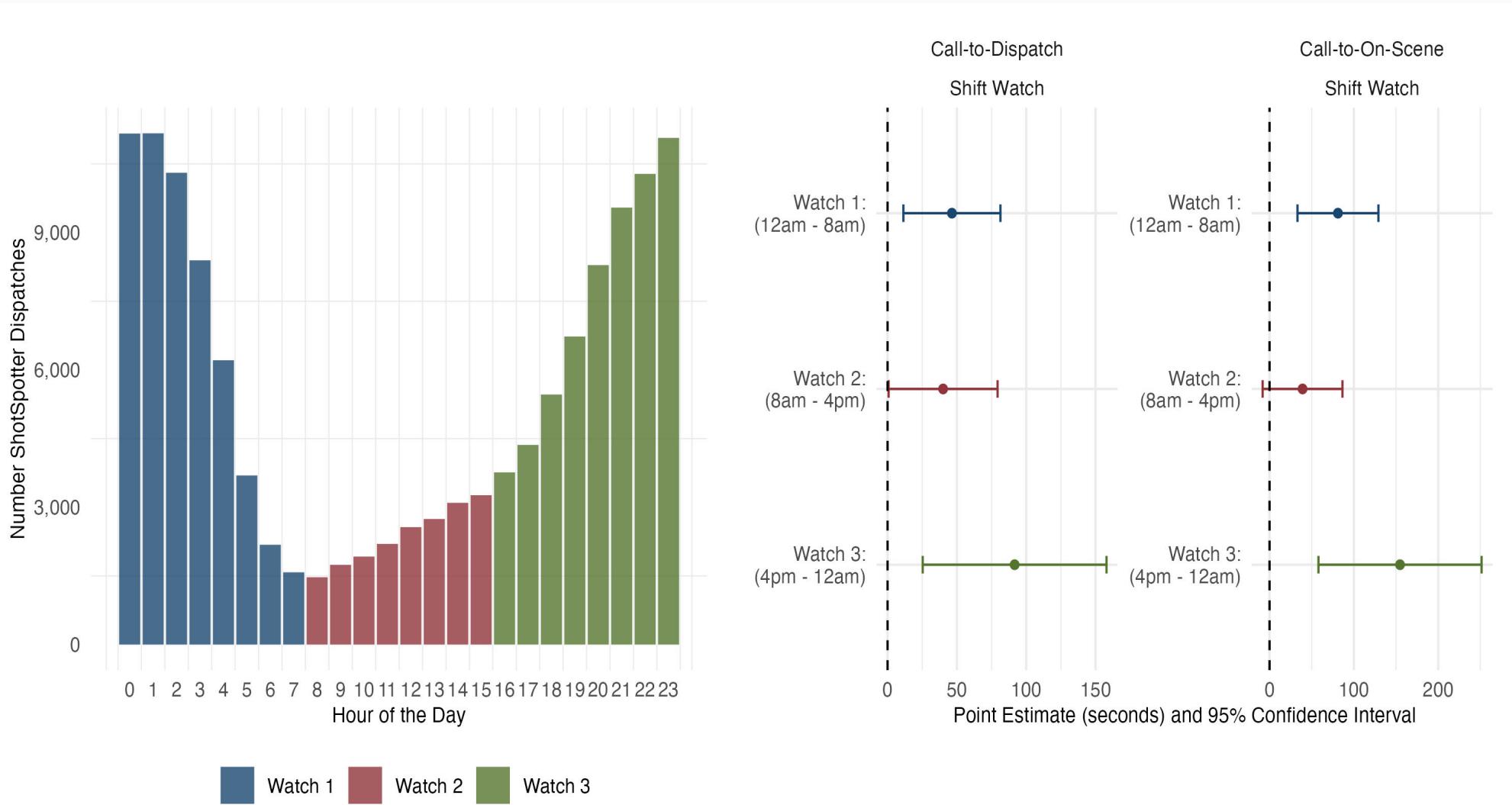
Extensive Margin: Effect of ShotSpotter Implementation

	Pooled	> Median	<= Median	Officer Hours
<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:

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

Heterogeneity

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

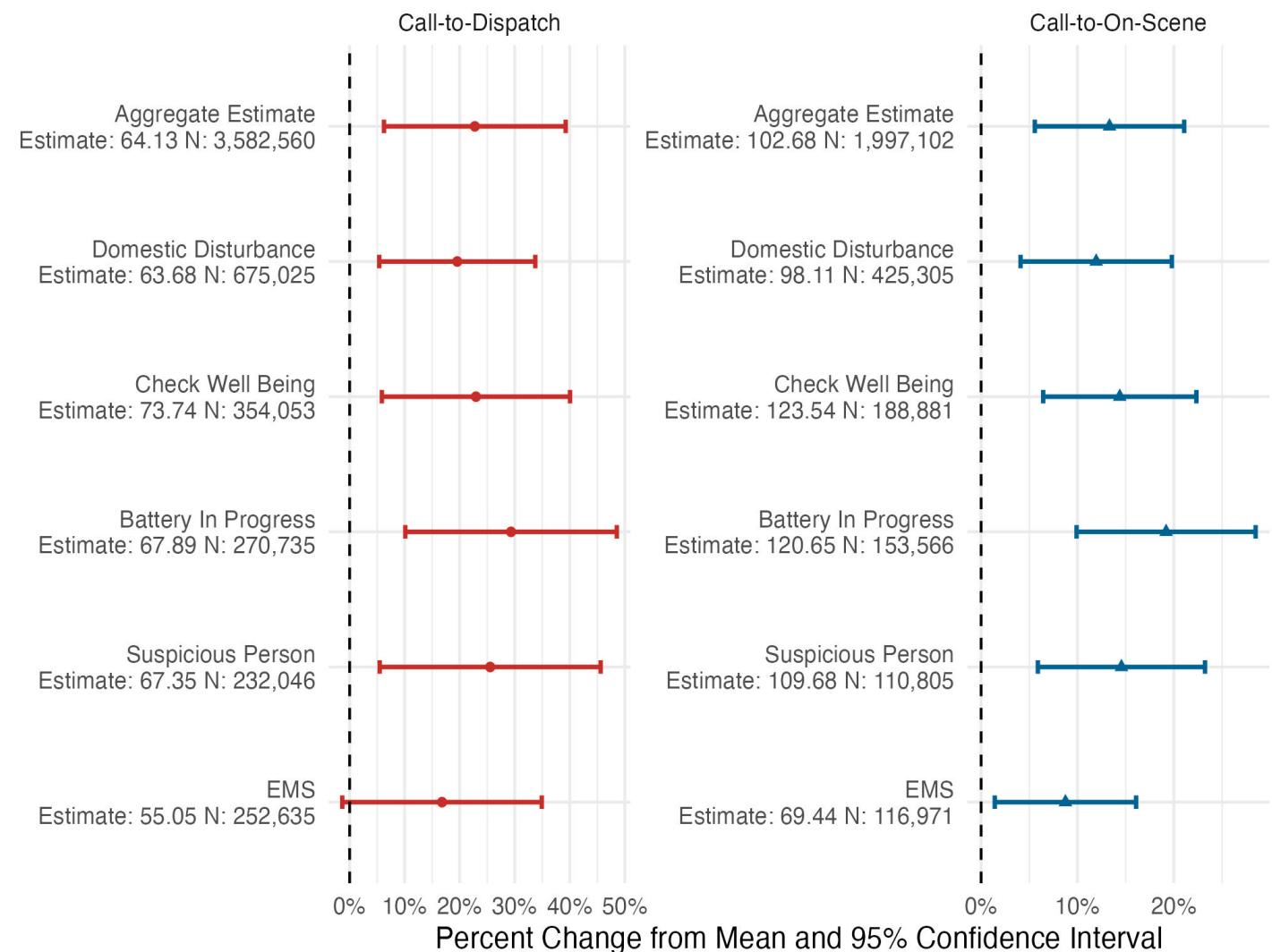
- A 'trickle down' effect in Priority 2, suggestive for Priority 3
- No time for high priority == no time for lower priorities
- Lends to the idea that officers are facing more responsibilities than they can handle

Priority and Call-type Heterogeneity:

Priority 1 (Immediate)

Priority 2 (Rapid)

Priority 3 (Routine)

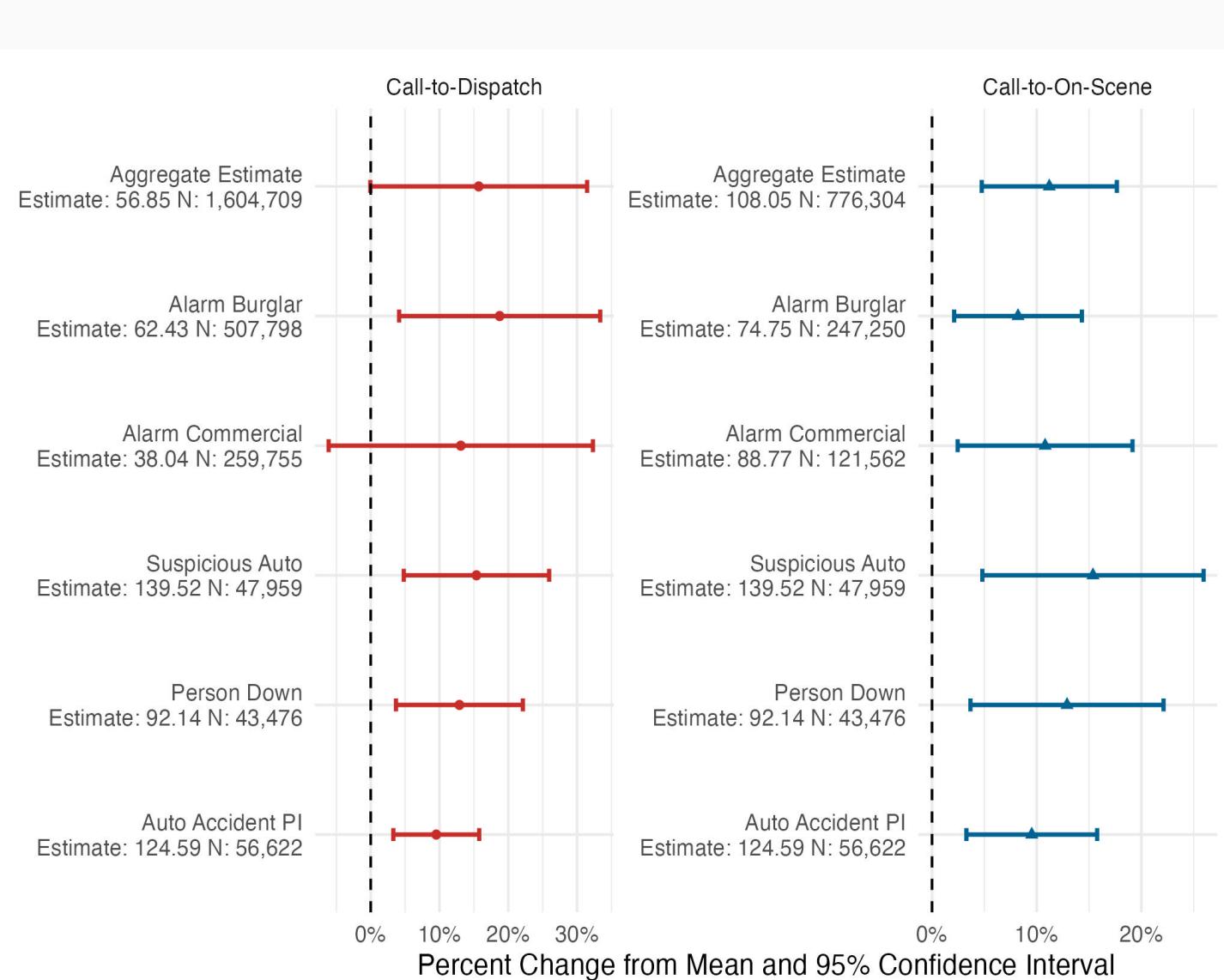


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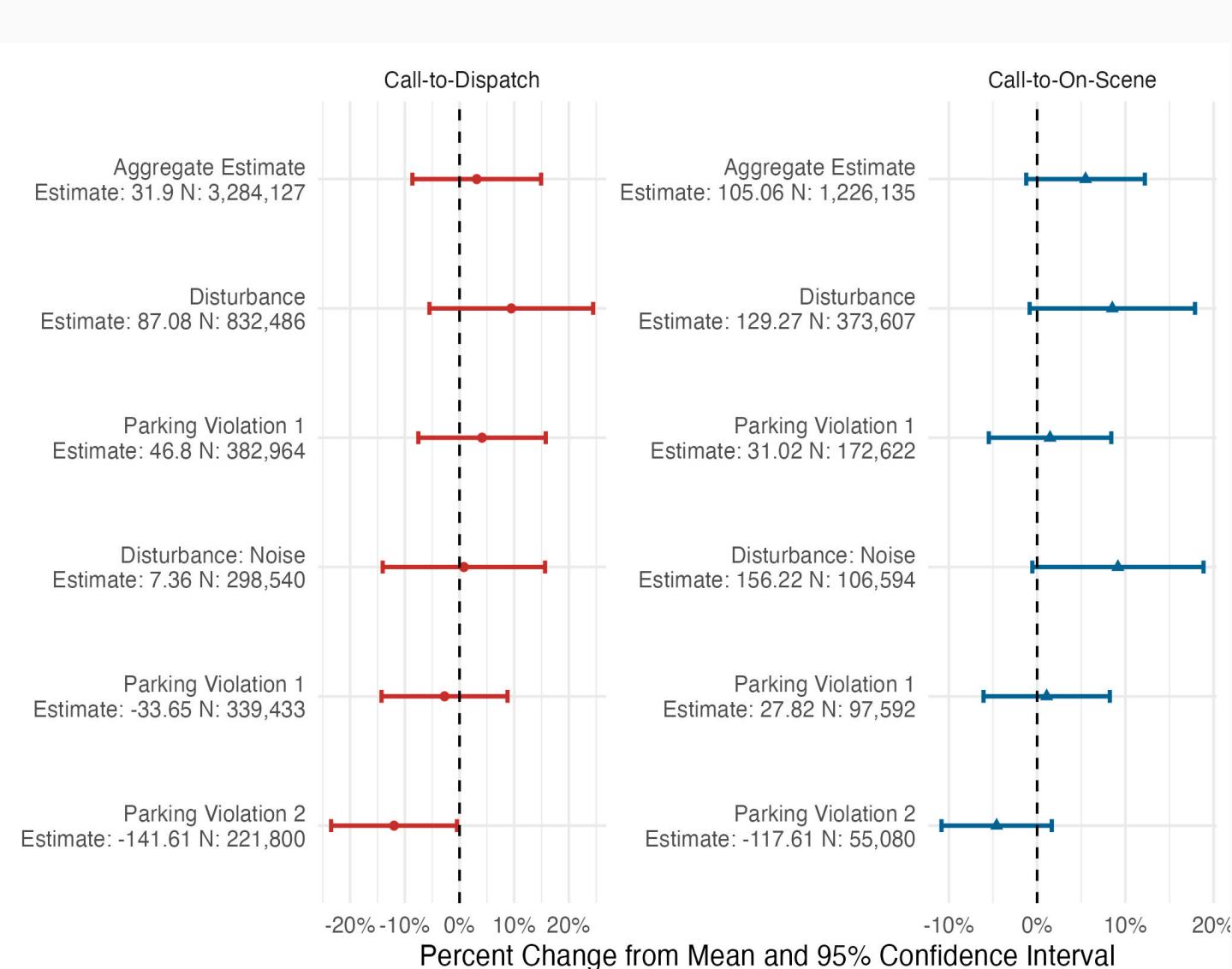


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Intended Consequence?

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
