

Evacuation Order Effectiveness and Community Behavior: Enabling Strategic Data-Driven Decision Making through Big Data

Harsh Anand, Majid Shafiee-Jood, Negin Alemazkoo

Systems and Information Engineering, University of Virginia, Charlottesville, VA 22903

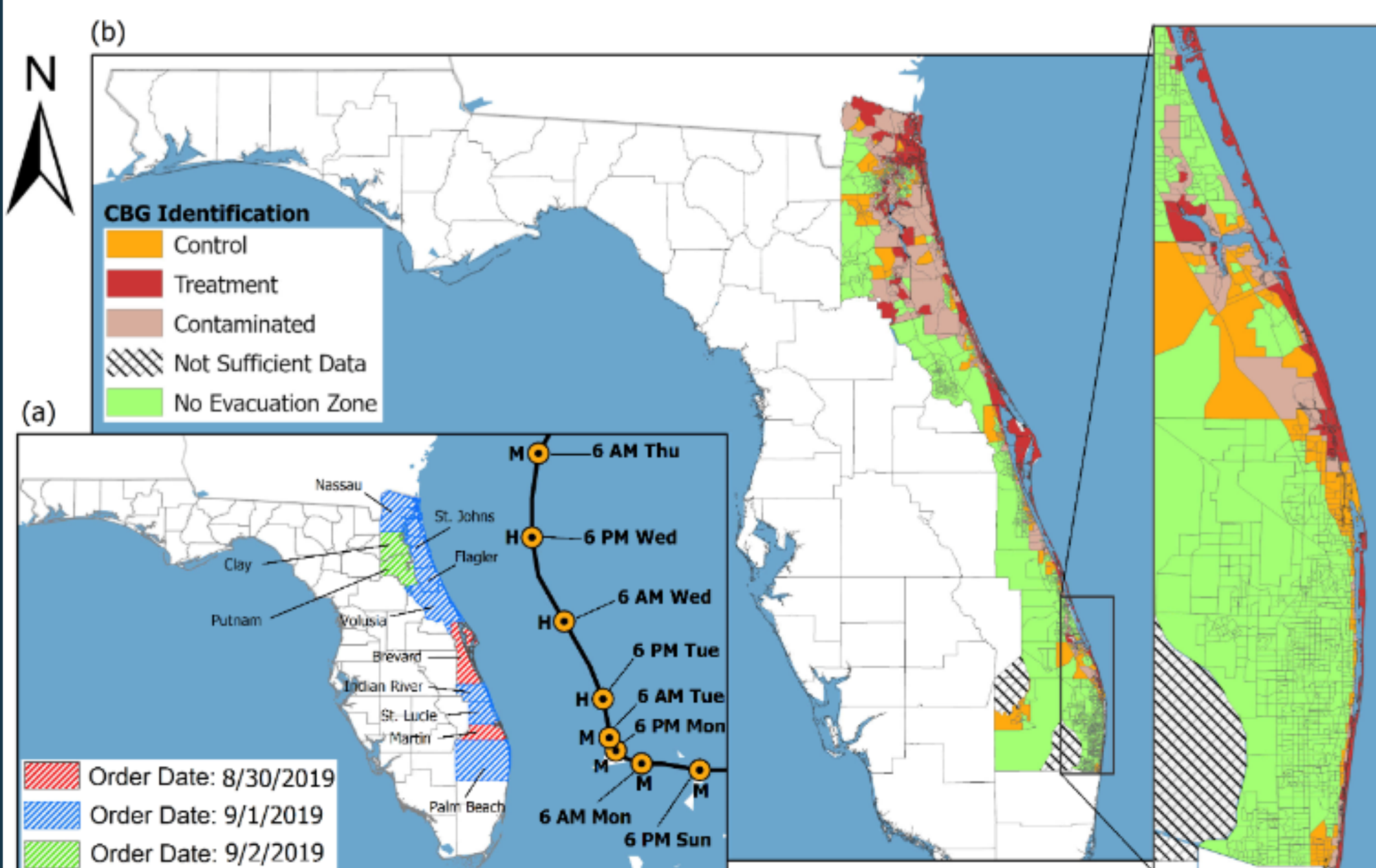
ABSTRACT

Enforcement of hurricane preparedness plans, such as the issuance of evacuation orders, is an imperative step toward reducing social vulnerability, in terms of both human suffering and economic loss. Yet are these evacuation orders actually effective? To address this question, our study (1) analyzes evacuation decisions as a function of government-issued evacuation orders and (2) examines how the evacuation behavior of communities varies based on socio-economic and demographic factors. We also investigate "shadow evacuation" patterns to understand evacuation order responses in areas without evacuation zones and areas with evacuation zones but no orders. Utilizing big data—comprising high-fidelity mobility and demographic information—our analysis aims to uncover the interdependence between emergency management and community mobility. The insights can help emergency managers and policymakers develop a strategic decision-support aid to maximize the effectiveness of evacuation orders.

INTRODUCTION

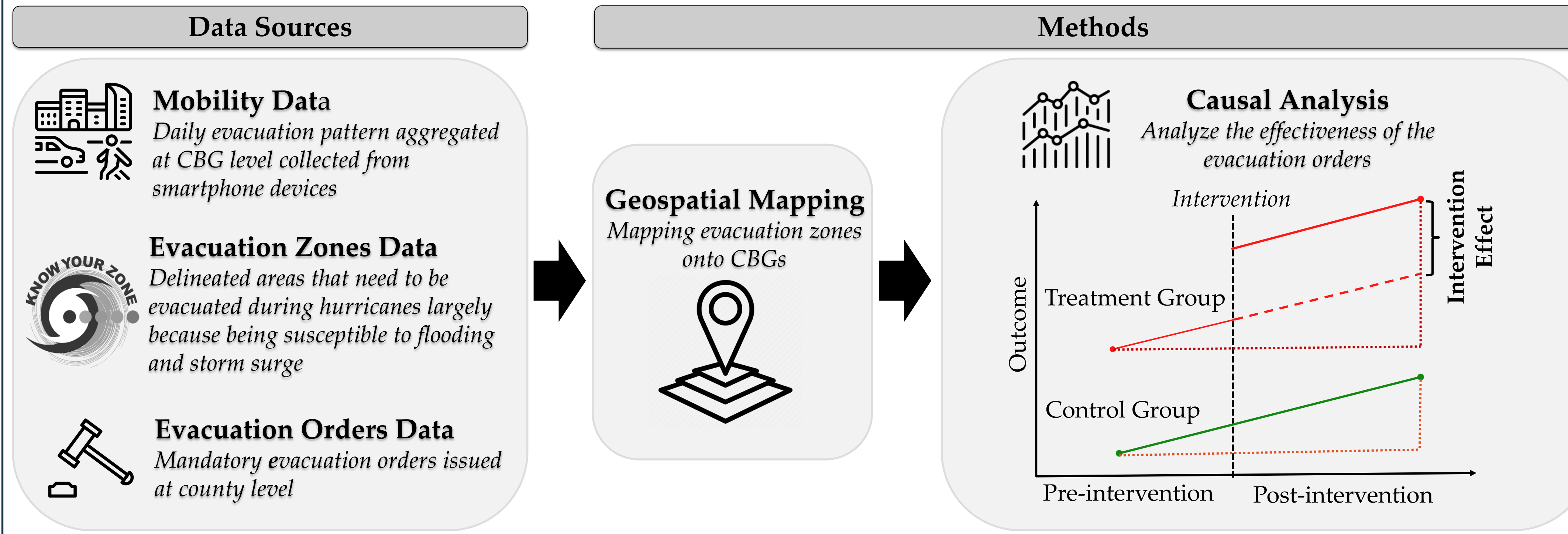
This study delves into the critical aspects of hurricane preparedness and response, with a specific focus on the impact of evacuation orders. Key areas of our study include:

- **Effectiveness of Evacuation Orders:** How orders influence evacuation decisions, questioning their actual impact in increasing evacuation rate.
- **Community Behavior Analysis:** How different communities, characterized by varied socio-economic and demographic profiles, respond to these orders.
- **Exploring Shadow Evacuation:** Explore the phenomenon of shadow evacuation, examining responses in regions both within and outside designated evacuation zones.
- **Data-Driven Insights:** Leverage large-scale high-resolution mobility and demographic data to draw insights.



This figure maps the extent of communities affected by evacuation orders during Hurricane Dorian in Florida, highlighting Census Block Groups (CBGs) by (a) evacuation order date and (b) CBG identification categorization.

METHODOLOGY



Evaluate the effectiveness of mandatory evacuation orders on actual evacuation rates within census block groups (CBGs) during Hurricane Dorian in Florida.

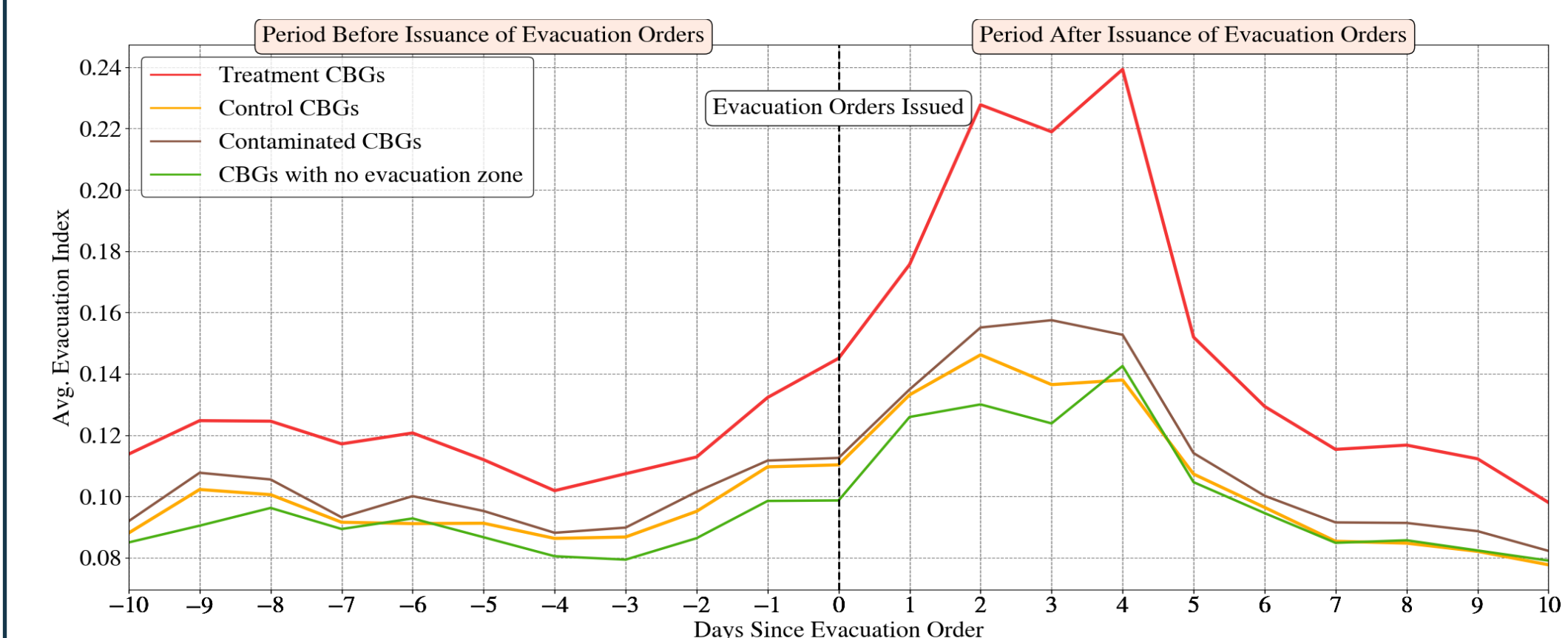
- **CBG Identification:** Identified CBGs as treatment or control groups based on the issuance of evacuation orders.
- **Behavior Assessment:** Assess evacuation in CBGs without orders to gauge the overall hurricane risk perception effect.

Empirical Approaches:

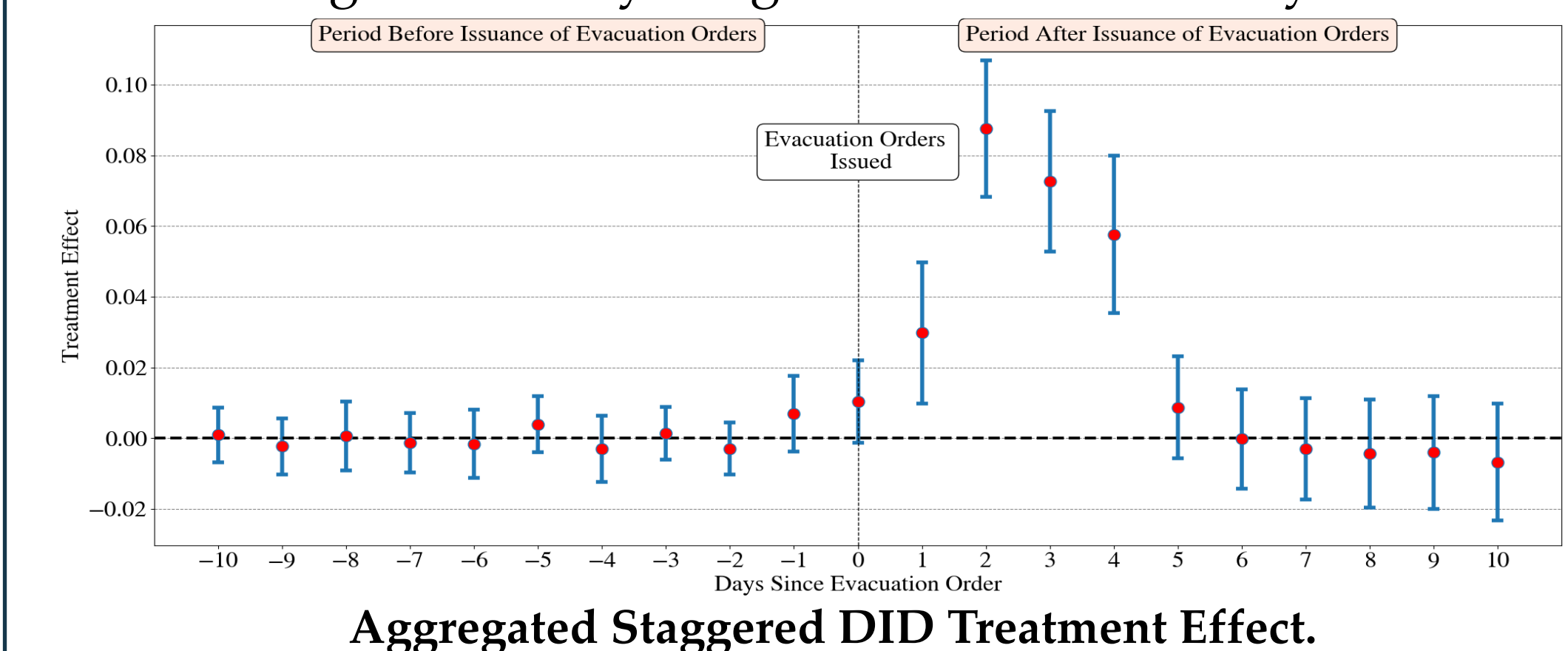
- Utilized *staggered difference-in-differences (DID)* method to address timing variations in evacuation orders.
- Estimated average treatment effect on the treated (ATT) for CBGs on evacuation order dates.
- Robustness checks were performed by considering the *two-way fixed effect (TWFE)* method and varying CBG identification categories.

EVACUATION ORDER EFFECTIVENESS ESTIMATIONS

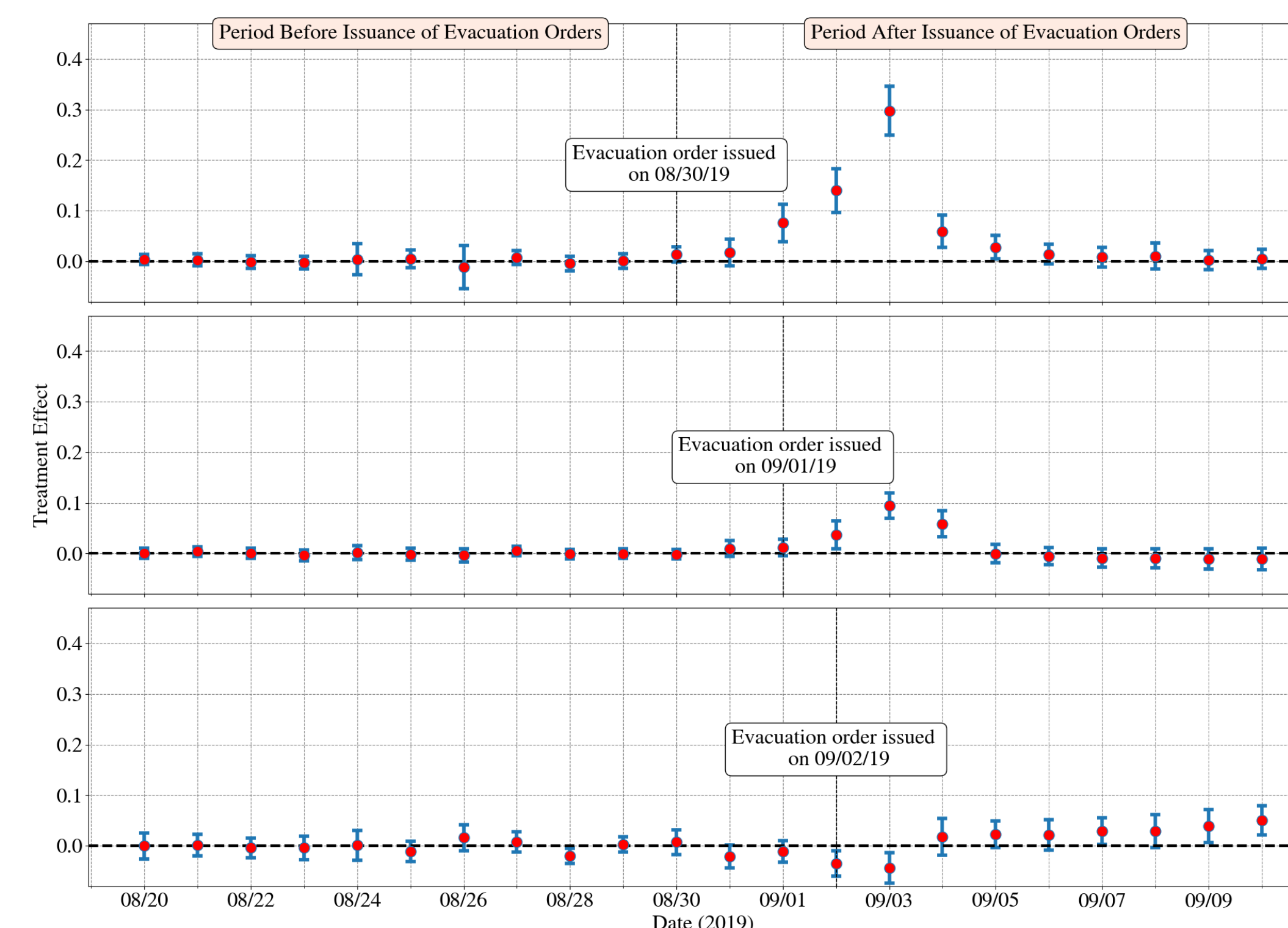
Aggregated mobility pattern indicates a rise from 10% to 23% in the number of individuals outside their home CBG post-evacuation orders. However, increases are also noted in non-ordered CBGs, suggesting broader hurricane-related movement.



- Using a staggered DID approach, we observe a 2% increase in evacuation rates the day after an order, with a more representative 7% rise by the second day ($t = 2$), factoring in both immediate and delayed evacuations.
- Trends in CBGs with and without orders prior to issuance support the DID's parallel trend assumption.
- Notably, the influence of evacuation orders wanes, becoming statistically insignificant after four days.



- Movement patterns across CBGs revealed a trend of increased out-of-CBG movements, such as Aug 24, 2019.
- While pre-order evacuation rates were consistent, post-order rates varied, with the earliest-ordered CBGs showing the most pronounced increase.
- CBGs in Brevard and Martin counties saw a 6% rise in evacuations on the second day post-order. However, CBGs receiving orders later, like on Sept 2nd, showed no significant increase, indicating a possible reduced perception of threat.
- Minimal impact of shadow evacuation, as CBGs within evacuation zones but without orders did not show increased evacuation rates.

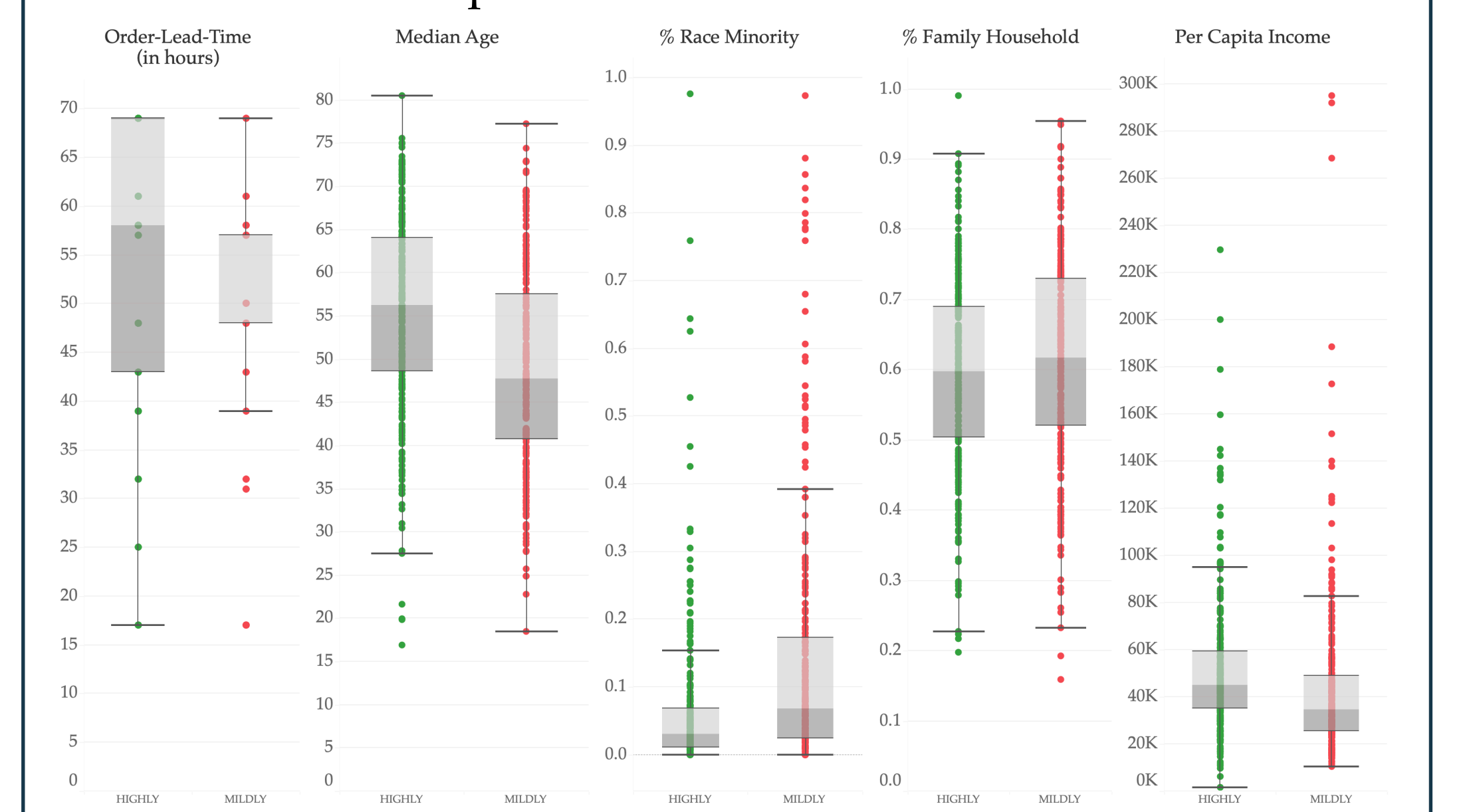


Staggered DID Treatment Effect for Order Date (a) 30th Aug, (b) 1st Sept, and (c) 2nd Sept.

EVACUATION COMPLIANCE FACTORS

Utilizing *machine learning classification models*, we predict CBG compliance (highly and mildly) with evacuation orders based on socio-demographic characteristics, geographic factors, and order-lead-time.

- Early evacuation orders significantly enhance compliance, with CBGs having an earlier order-lead-time showing higher evacuation rates.
- Factors such as younger median age, Zone A location, minority race percentage, family household prevalence, and higher per capita income significantly influence evacuation compliance.



CONCLUSIONS

- **Evacuation Order Impact:** Timely evacuation orders significantly influence compliance, with early orders resulting in higher evacuation rates.
- **Influence of Socio-Demographics:** Evacuation behaviors vary with socio-economic and demographic factors, with younger, higher-income CBGs showing higher compliance.
- **Shadow Evacuation Insight:** Minimal shadow evacuation observed, indicating evacuation orders are key in driving evacuation decisions.
- **Methodological Robustness:** Consistent findings across staggered DID and two-way fixed effects models validate the study's reliability.

REFERENCES

1. Brantly Callaway and Pedro HC Sant'Anna. Difference-in-differences with multiple time periods. *Journal of econometrics*, 225(2):200–230, 2021.
2. Alberto Abadie. Semiparametric difference-in-differences estimators. *The Review of Economic Studies*, 72(1):1–19, 2005.

ACKNOWLEDGEMENT

This research is partially supported by the University of Virginia's Environmental Institute and the Commonwealth Center for Advanced Logistics Systems, and conducted within the UVA Link Lab. We thank Spectus Inc. for providing the mobility data used in this study.