ASCENT Project 003

Cardiovascular Disease and Aircraft Noise Exposure

Boston University School of Public Health

PI: Junenette Peters

PM: Donald Scata and Sean Doyle

Cost Share Partner: Donators to Nurses' Health Study

Objective:

To evaluate the relationship between aircraft noise exposure and health including hypertension and sleep disturbance in existing health cohorts (Health Impacts)

Project Benefits:

Addresses gap of limited health and noise studies in the U.S., important for informing policy options.

Overall, contributes to the body of knowledge of potential health impacts of aircraft noise.

Responsive to Section 189 of the 2018 FAA Reauthorization.

Research Approach:

Exposure

Noise contours for 90 airports for 1995-2015 in five-year intervals; metrics day-night noise level (DNL) and nighttime sound level (Lnight)

Cohorts:

Nurses' Health Study (NHS) and NHS II

Study Areas

1. Sociodemographic patterns of noise
2. Associations between noise and hypertension and noise and cardiovascular disease (CVD)
3. Associations between noise and sleep markers

Major Accomplishments (to date):

1. Papers accepted for publication
   a. Sociodemographic patterns of exposure to civil aircraft noise in the United States – Accepted *Environmental Health Perspectives*
   b. Long-term aircraft noise exposure and risk of hypertension in the Nurses' Health Studies – Accepted *Environ Res*
2. Paper submitted for publication
   a. Associations between nighttime aircraft noise exposure and insufficient sleep in the US-based prospective Nurses' Health Study cohort

Future Work / Schedule:

1. Complete analysis on noise and CVD, develop manuscript and pass NHS & FAA review – 7/2022
2. Complete Noise trend analysis – 6/2022
3. Develop report to Congress – 9/2022

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 003 through FAA Award Number 13-C-AJFE-BU under the supervision of Sean Doyle and Donald Scata. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

Health Impacts – Project Outline
Project current scheduled end date October 31, 2022

Spring 2021

1 Finalize Phase I CVD Analysis (Ascent 3)

- **Analysis of sociodemographic patterning of noise exposures**
- *Analysis of trends of aircraft noise exposures*
- **Analysis of aircraft noise (DNL and Lnight) and hypertension**

2 Perform CVD Phase II Analysis (Ascent 3)

- **Analytical approaches and analysis of relationship of aircraft noise and CVD**
- *Analytical approaches and analysis of relationship of additional metrics of aircraft noise and health outcomes.*

+ 3 Develop Analytical Approach & Sleep Analysis (Section 189)

- **Assessment of potential approaches for analysis and appropriateness of sleep quality data.**
- **Analysis of annual average aircraft noise exposure with general sleep length and quality (NHS).**
- *Explore analysis of living under flight paths with sleep disturbance (WHISPER).*

Fall 2022

Sociodemographic Patterns of Noise

Status:

- **Published in peer-reviewed journal *Environmental Health Perspectives***

Highlights:

- Compared exposure of U.S. Census block groups by race/ethnicity, education, and income across three noise groups/thresholds (DNL 45 dB, 55 dB, 65 dB).
- Block groups with higher Hispanic population and proportion of residents with ≤ high school education had higher odds of noise exposure.

In progress:

- Analysis of trends in noise exposure over time

Sociodemographic Patterns - Results

Multinomial multivariable-adjusted odds ratio for block group exposure to day-night average sound level (DNL) exposure groups relative to base group (<45 dB)

Variables	45-<55 dB(A)	55-<65 dB(A)	≥65 dB(A)
% Race/Ethnicity			
Non-Hispanic Black	1.05 (1.04, 1.06)	1.03 (1.01, 1.05)	1.15 (1.06, 1.24)
Non-Hispanic Asian	1.10 (1.09, 1.12)	1.13 (1.10, 1.17)	0.49 (0.35, 0.69)
Hispanic	1.13 (1.11, 1.14)	1.12 (1.09, 1.15)	1.39 (1.25, 1.54)
Non-Hispanic Other	1.08 (1.03, 1.13)	1.12 (1.03, 1.22)	1.31 (0.92, 1.87)
Non-Hispanic White	*Reference*	*Reference*	*Reference*
% Education			
< High school/GED	1.00 (0.98, 1.02)	1.09 (1.05, 1.14)	0.89 (0.75, 1.04)
High school/GED	1.05 (1.03, 1.07)	1.19 (1.15, 1.23)	1.17 (1.01, 1.36)
> High school/GED	*Reference*	*Reference*	*Reference*

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*Stable across sensitivity analyses

Noise and Hypertension

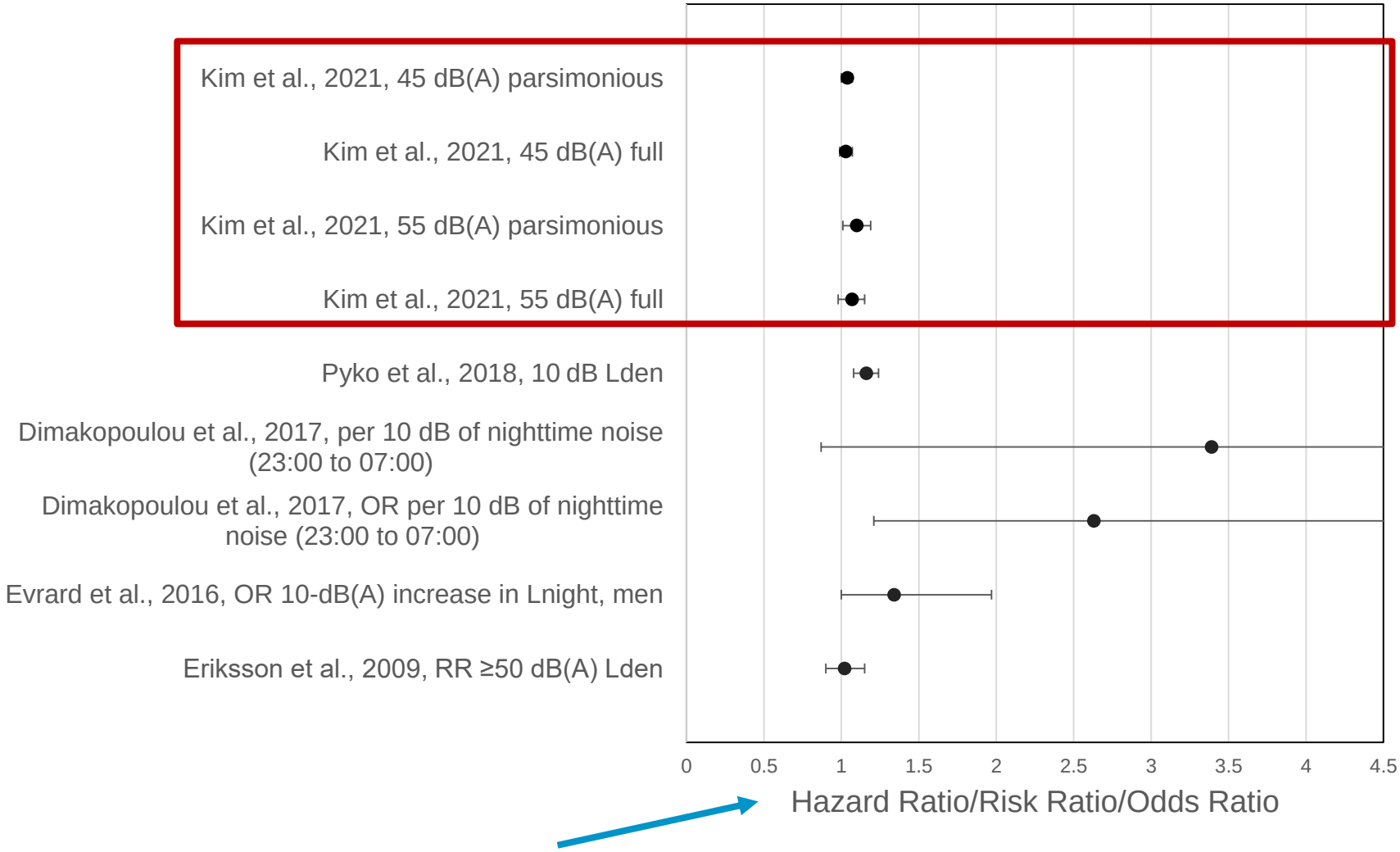
Status:

- Presented at International Commission on Biological Effects of Noise (ICBEN) 2021
- **Published in peer-reviewed journal *Environmental Research***

Highlights:

- Examined associations between aircraft noise (DNL) and incident hypertension in NHS and NHS II.
- In combined parsimonious model using a DNL 55 dB cut-point, participants in NHS and NHS II exposed to levels ≥55 dB had a 10% increased risk of hypertension compared to participants exposed to levels <55 dB, with a 95% confidence interval (CI) of 1% to 19%.
- In combined fully-adjusted model participants exposed to ≥55 dB had a 6% increased risk (95% CI: -2%, 15%) compared to the unexposed.
- Relationship between noise and hypertension was not affected by additional control for particulate matter air pollution.

Noise and Hypertension – Comparison with Other Studies



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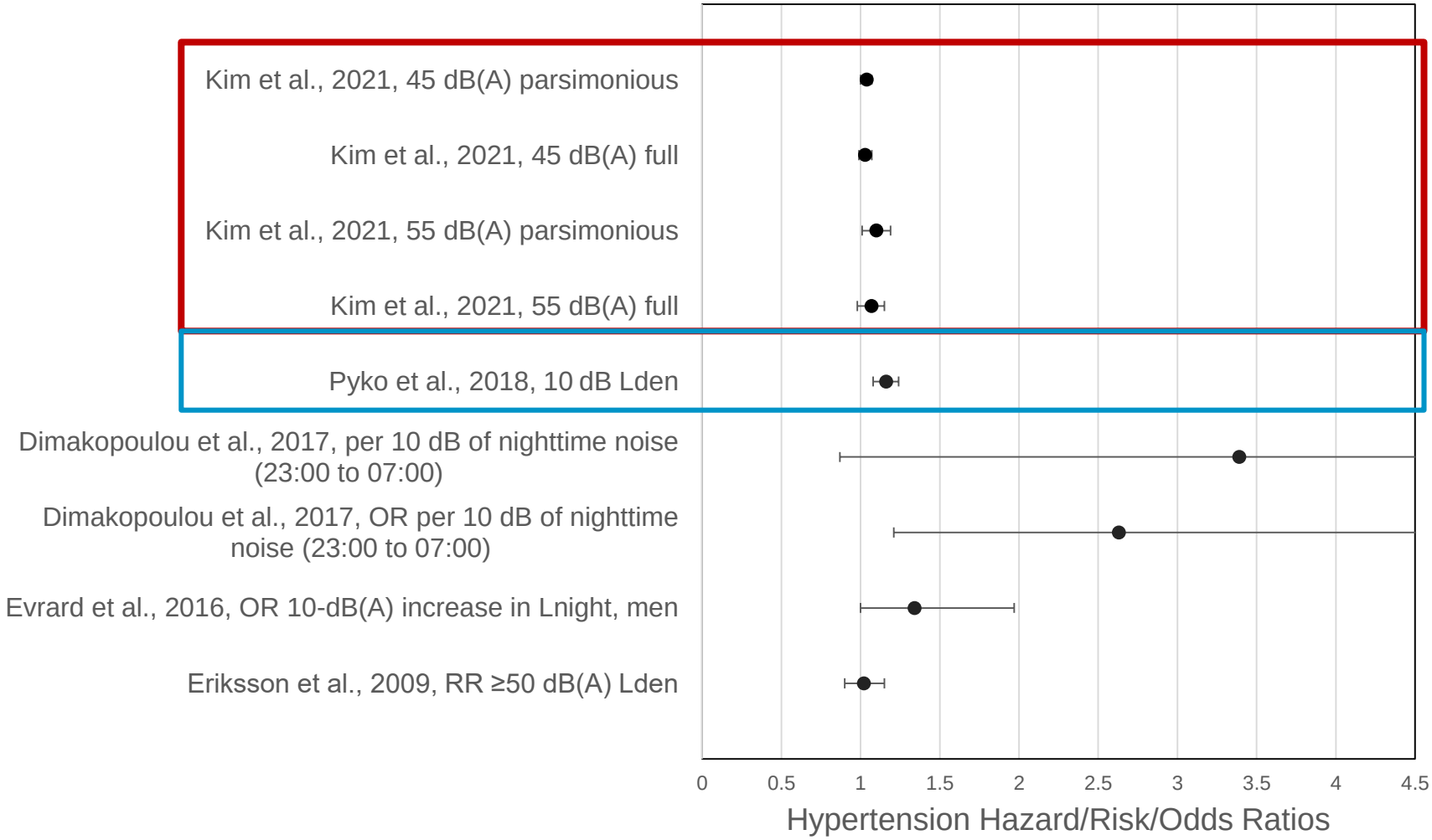

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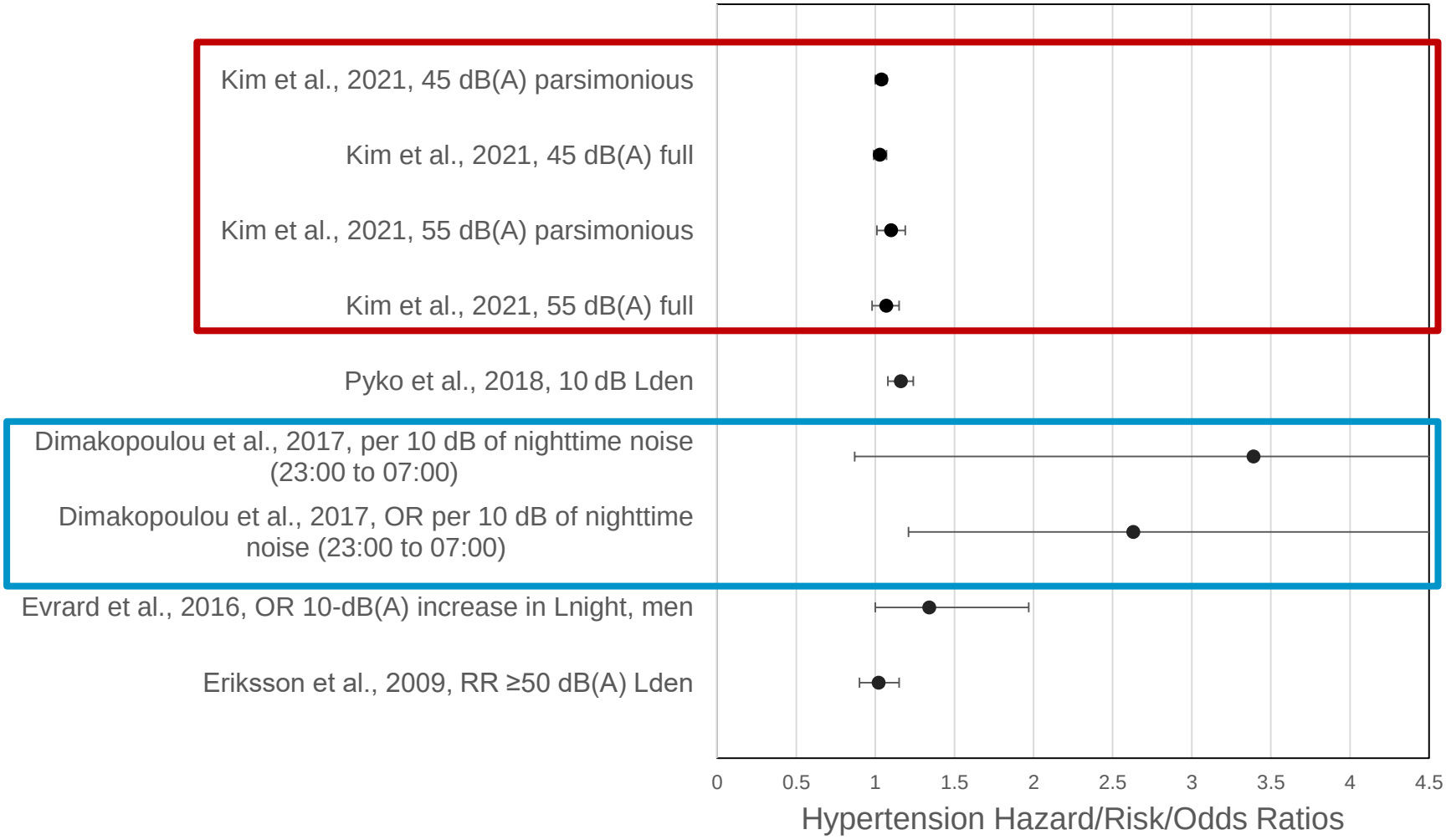

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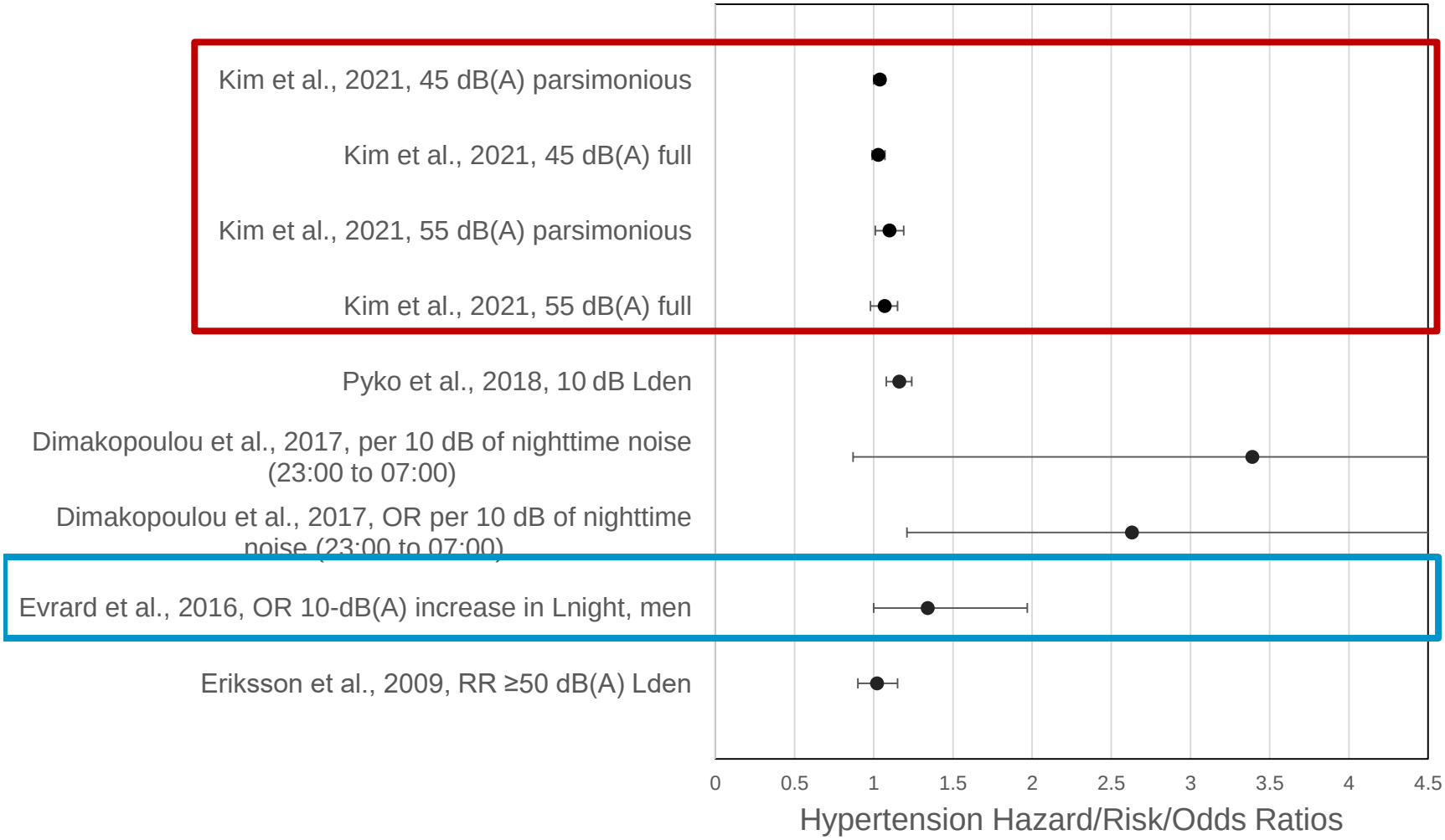

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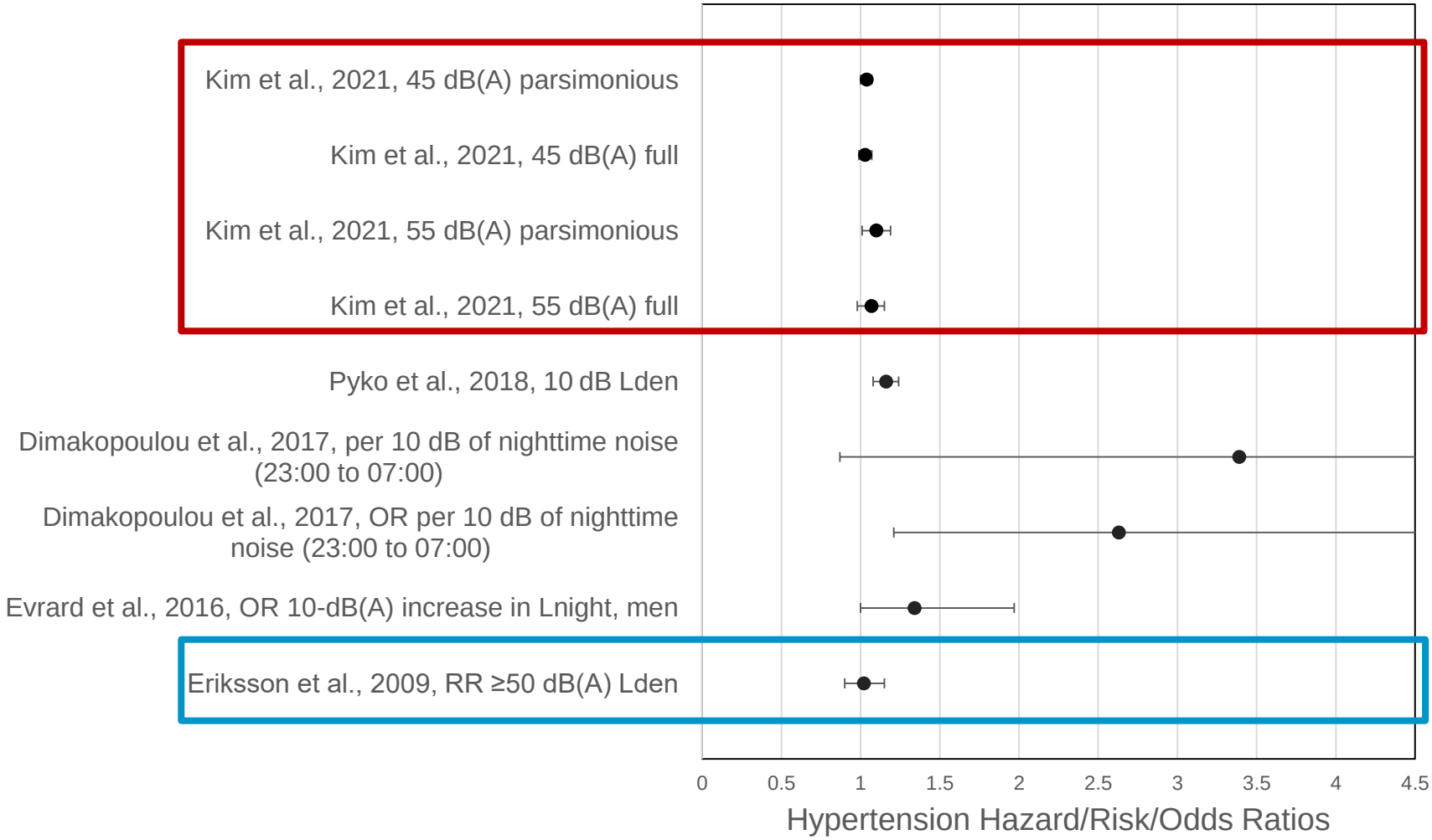
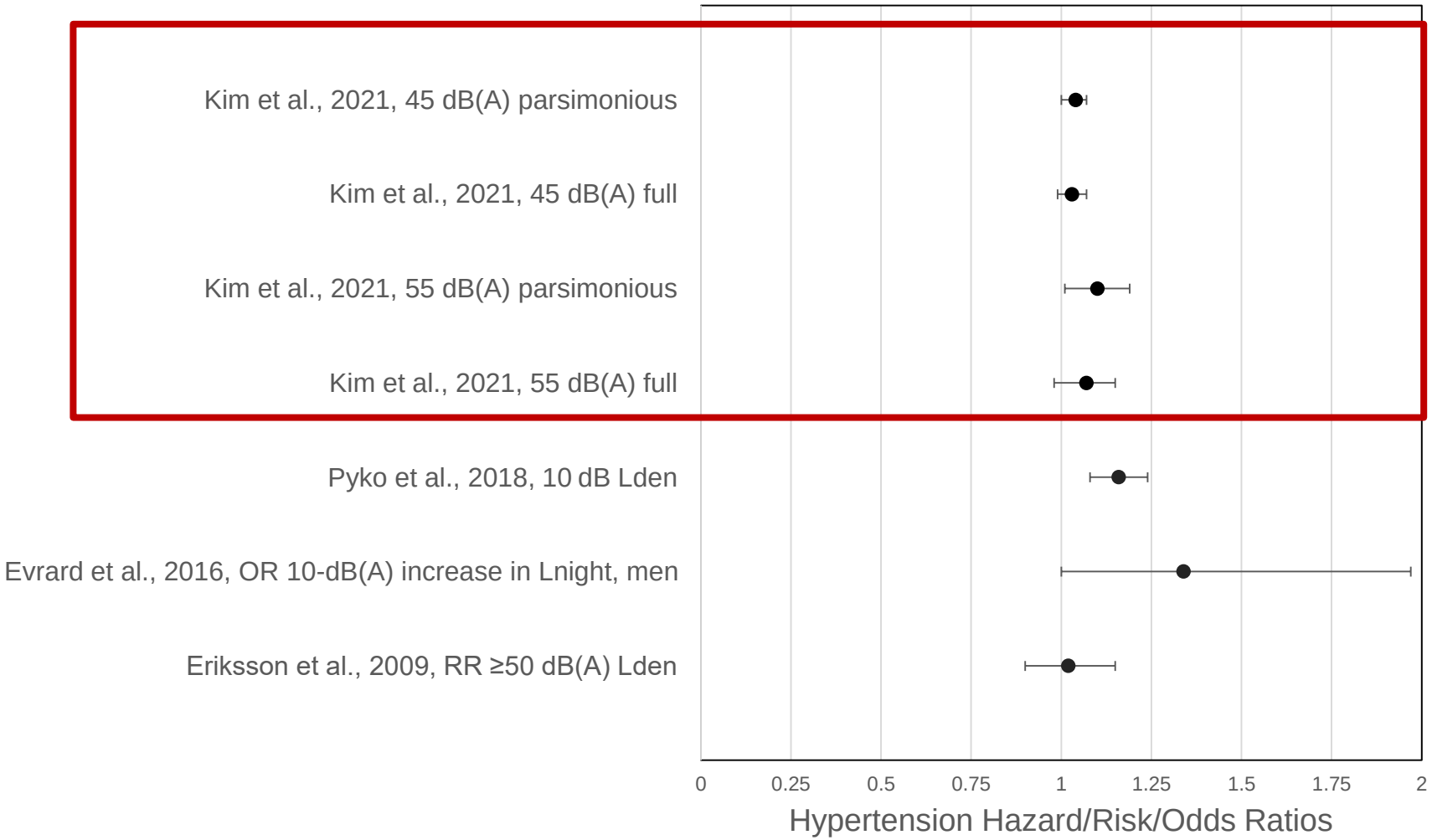


Noise and Hypertension – Comparison with Other Studies

*Without study with very wide confidence intervals (Dimakopoulou et al., 2017)



Noise and Sleep

Status:

- Passed NHS manuscript review process
- Submitted manuscript to peer-reviewed journal *Environmental Health Perspectives*

Highlights:

- Investigated associations between nighttime noise and insufficient sleep and poor sleep quality in NHS.
- In multivariable-adjusted longitudinal models those in block groups exposed to nighttime aircraft noise had higher odds of insufficient sleep compared with those not exposed.
- Relationship pronounced in participants living in the west, near cargo airports, and near water-adjacent airports

Next Step:

- Investigate noise and sleep markers in NHS II

Noise and Sleep - Results

Study Population
- NHS (original) participants
- Study period 2000-2014

Exposure
- Annualized daily and nightly averages (DNL and Lnight)

Outcome
- Sleep insufficiency defined as ≤6 hr/night (repeated measures)
- Poor sleep quality defined as poor sleep ≥ "a good bit of the time" (one-time measure)

Model	Sleep insufficiency	Poor sleep quality
Lnight ≥45 vs <45 dB(A)	**OR (95% CI)**	**OR (95% CI)**
Model 1: Crude	1.34 (1.17, 1.53)	0.94 (0.72, 1.21)
Model 2: Adjusted	1.27 (1.11, 1.45)	0.91 (0.70, 1.18)
Model 3; Adjusted + ambient environmental	1.23 (1.07, 1.41)	0.91 (0.70, 1.18)

* OR – Odds Ratio; CI – Confidence Interval
Models adjusted for 1) age, 2) add other demographics, behaviors, comorbidities 3) add ambient environmental factors - particulate matter of size equal to or smaller than 2.5 microns ($PM_{2.5}$), greenness (Normalized Difference Vegetation Index, NDVI), light at night (LAN).

Noise and Cardiovascular Disease

Status:

- Performing analysis and manuscript preparation

Highlights:

- Investigated associations between day night average noise level and risk of cardiovascular disease (CVD) in NHS and NHSII.
- Analysis dichotomized at the 45 dB cut-point - small numbers at higher exposure.

Next Step:

- Continue investigating noise and potential association with CVD as well as all-cause mortality
- Complete analysis and manuscript

Noise and CVD

Study Population
- NHS and NHSII participants
- Study periods 1994-2014 (NHS) and 1995-2013 (NHSII)

Exposure
- Annualized daily averages (DNL)

Outcome
- Cardiovascular disease incidence (heart attack and stroke)

DNL Distribution among Participants at Risk for CVD				
DNL, dB(A)	NHS I (n=109,432)		NHS II (n=114,746)	
	At risk	Cases	At risk	Cases
<44	100,890 (92.2%)	8,131	105,245 (91.7%)	1,372
45 – 54	7,381 (6.7%)	511	8,148 (7.1%)	94
55 – 64	1,114 (1.0%)	86	1,292 (1.1%)	16
≥65	47 (0.04%)	2	61 (0.05%)	0

Noise and CVD – Preliminary Results

DNL category, dB(A)	Cases	Person-Years	HR (95% CI)		
			Basic	Parsimonious	Fully Adjusted
≥45	709	288,167	0.95 (0.88, 1.02)	0.97 (0.90, 1.05)	0.96 (0.89, 1.04)
<45	9,503	3,528,900	*Reference*	*Reference*	*Reference*

*HR – Hazard Ratio; CI – Confidence Interval; AHEI – Alternate Healthy Eating Index; MI – myocardial infarction
Models adjusted for:
Basic model: age, time period
Parsimonious model: add other demographics and environmental factors (race/ethnicity, spouse's educational attainment, region, particulate matter of size equal to or smaller than 2.5 microns ($PM_{2.5}$), population density, neighborhood level socioeconomic status)
Fully Adjusted model: add lifestyle factors and medical history (physical activity, smoking status, alcohol use, AHEI diet score, menopausal status, and family history of MI)

Summary

Next Steps

- Continue analyzing noise and cardiovascular disease events and all-cause mortality in NHS and NHSII.
- Continue noise trends and noise and racial and economic segregation

New Project Ideas

- Investigate noise and additional health outcomes in NHS or/and WHI using existing noise measures
- Investigate noise and cardiovascular outcomes with newer (post 2015), more precise noise measures – including number of events
- Investigate noise and cardiometabolic outcomes in the NHS 3 (current recruitment) or the Hispanic Community Health Study / Study of Latinos (2008-present)
- Study joint effects of noise and air pollution (w/ ASCENT 18).

ASCENT Project 3 (MIT subaward)

Cardiovascular Disease and Aircraft Noise Exposure – *Impacts of Noise on Businesses*

Massachusetts Institute of Technology

PIs: *R. John Hansman, Florian Allroggen*

PMs: *Donald Scata & Sean Doyle*

Objective:

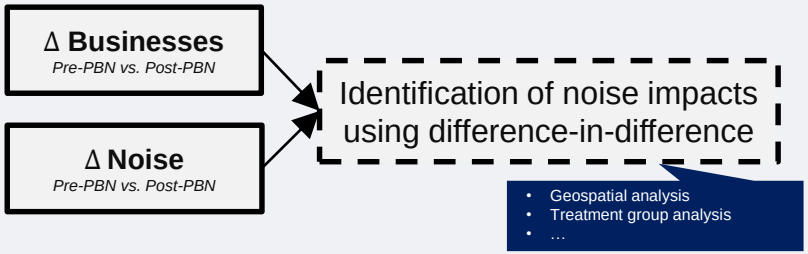
To conduct an empirical assessment of the **economic impacts of aircraft noise on businesses located underneath flight paths** at selected U.S. airports, incl. the trade-off between economic benefits and noise impacts on businesses

Project Benefits:

1. Empirical assessment of the impacts of aircraft noise on businesses
2. If impacts are identified: Identification of most affected communities, anticipate consequences of future procedural changes

Research Approach:

- ***Exploratory study*** of the impact of noise changes on businesses
- Leverage a ***natural experiment*** setting:
  Δ *flight procedures (new infrastructure, PBN)*
  → Δ *population noise exposure*
  → Δ *possible business closure & relocation?*
- **Empirical approach** *(with data at high resolution)*:



Major Accomplishments (to date):

I. ***Overview:*** *impacts of access to air transportation on economic activity close to airports*

II. ***Correlation analysis*** of noise change vs. business change for BOS and ORD and different economic sectors, including outlier analysis, revealing no obvious trends

III. ***Significance testing*** for treatment vs. non-treatment areas (both aggregate groups by city and contiguous geographic regions) showing no statistically significant impacts

Future Work:

- Documentation of results

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 3 through FAA Award Number 13-C-AJFE-BU (with subaward to MIT) under the supervision of Donald Scata and Sean Doyle. Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

Economic Impacts of Aircraft Noise – *Existing literature*

Economic growth effects of aviation

Demand-side impacts

*Quantify the contribution of the aviation sector to **macroeconomic demand** (for all goods and services):*

- *Direct impacts*
- *Indirect impacts*
- *Induced impacts*

Catalytic impacts

*Impacts resulting from the use of aviation as an **input factor to other economic production processes***

Economic option value

Value resulting from the availability of aviation services, but not related to the use of the services

Prior empirical work

- Studies find a **statistically significant positive impact** of access to the aviation system on economic outcomes, including growth, productivity and employment (while controlling for reverse causality) (For an overview, see Lenaerts, Allroggen, Malina, 2021)
- These effects **depend on access quality**: positive impacts tend to be concentrated close to airports and decline with distance; regions with low access can lose economic activity (e.g. due to relocations) (e.g.: Campante, Yanagaziwa-Drott, 2019; Lenaerts, Allroggen, Malina, 2022)

VS.

No prior empirical studies

Noise impacts on businesses

(to be analyzed in this study in an exploratory approach)

Research approach for empirical study

Noise changes

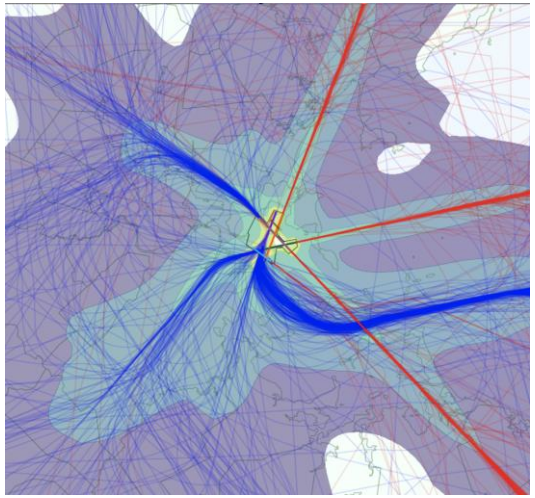
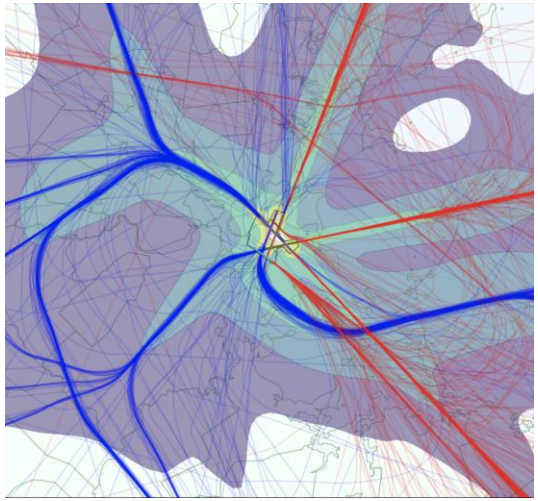
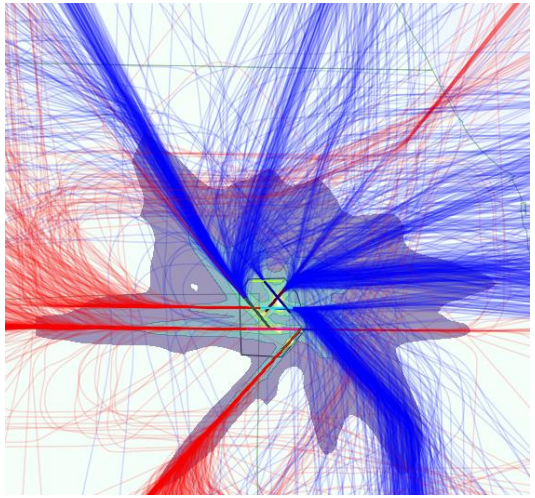
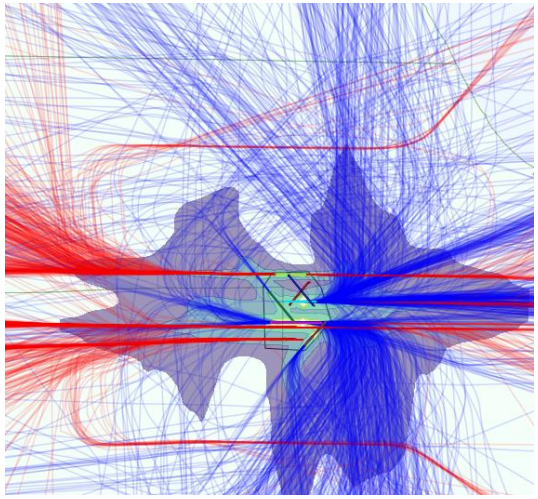
Changes in noise exposure (independent from economic development) due to:

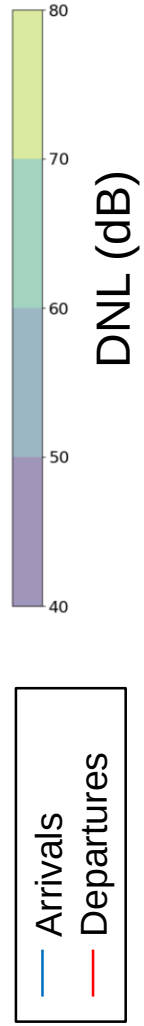
- **Implementation of PBN procedures** leading to concentration of flight paths
- **New runway configuration:** change in predominant flight paths

Business data

Empirical model

Changes in annual average noise exposure: *introduction of PBN and new runway configurations*

	2011	2016
Implementation of PBN: *concentration of flight paths (example: KBOS)*		
New runway configuration: *change in predominant flight paths (example: KORD)*		



PRELIMINARY RESULTS

Research approach for empirical study

Noise changes

Changes in noise exposure (independent from economic development) due to:

- **Implementation of PBN procedures** leading to concentration of flight paths
- **New runway configuration:** change in predominant flight paths

Business data

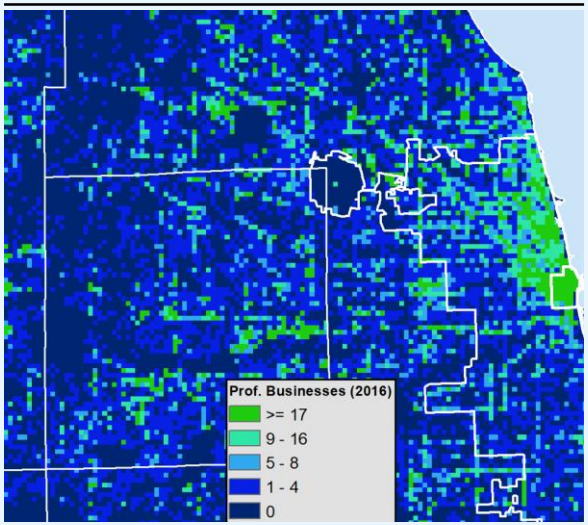
Info Group data on **business locations** (12-16m points), including data on sector, sales volume, and employees

Selected for analysis:

- retail
- professional, scientific, technical, and financial services ("professional")

Street address data gridded (200m (BOS), 400m (ORD)

Number of businesses (professional sector), *2016, Chicago*



Empirical model

Natural experiment:

ΔNoise
$\rightarrow \Delta$Population exposure
$\rightarrow$ ΔBusiness_activity (closures & relocation)

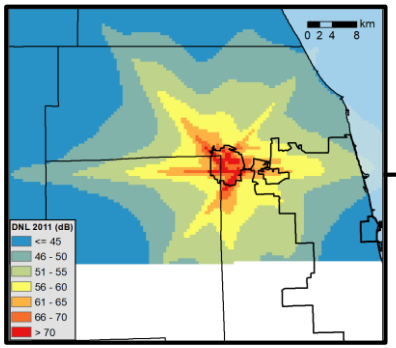
?

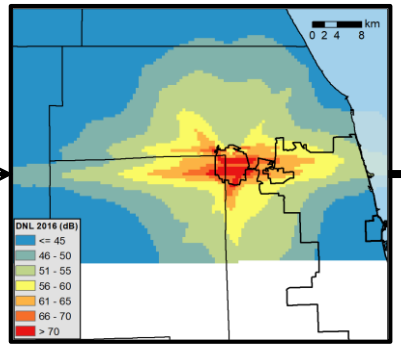
We analyze noise changes following changes in noise patterns in an exploratory approach:

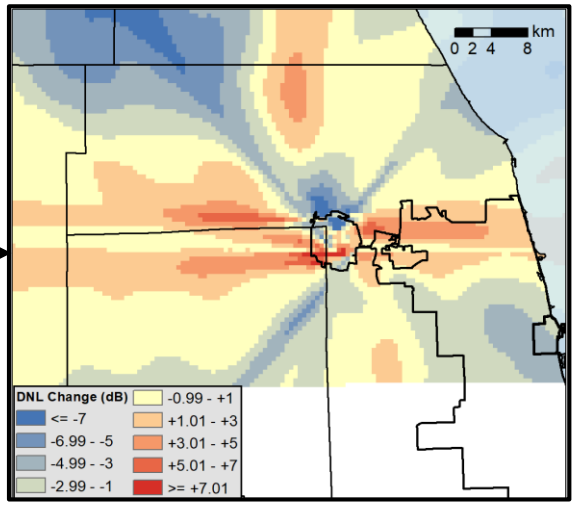
1. Geospatial analysis
2. Correlation analysis
3. Significance testing (control vs. treatment groups)

1 Geospatial Analysis KORD: *no obvious common trends in changes in noise and business activity*

Noise (DNL)





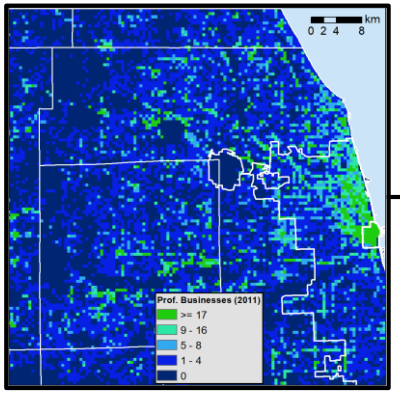


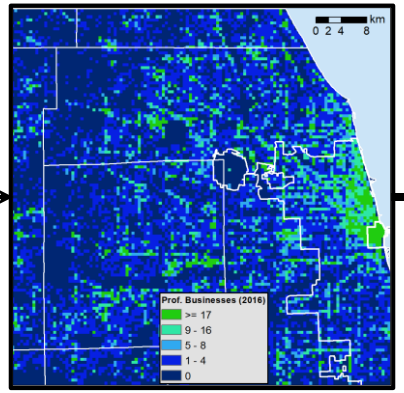
2011
(pre-PBN / runway changes)

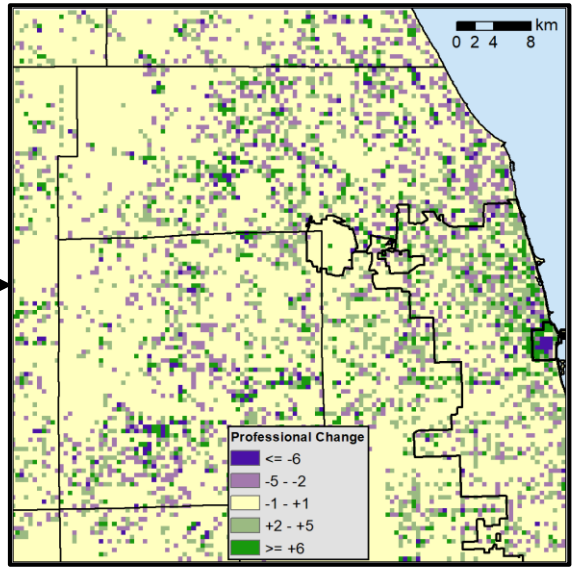
2016
(post-PBN / runway changes)

Δ

Businesses *(professional sector)*



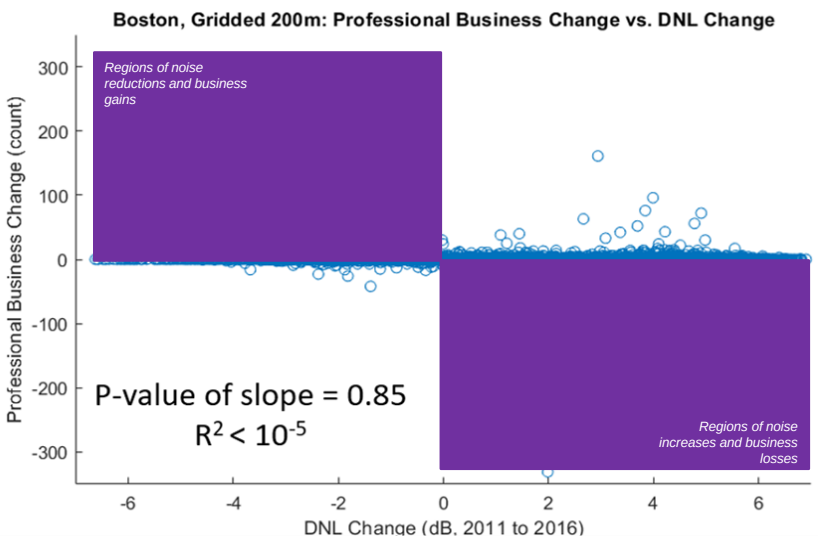
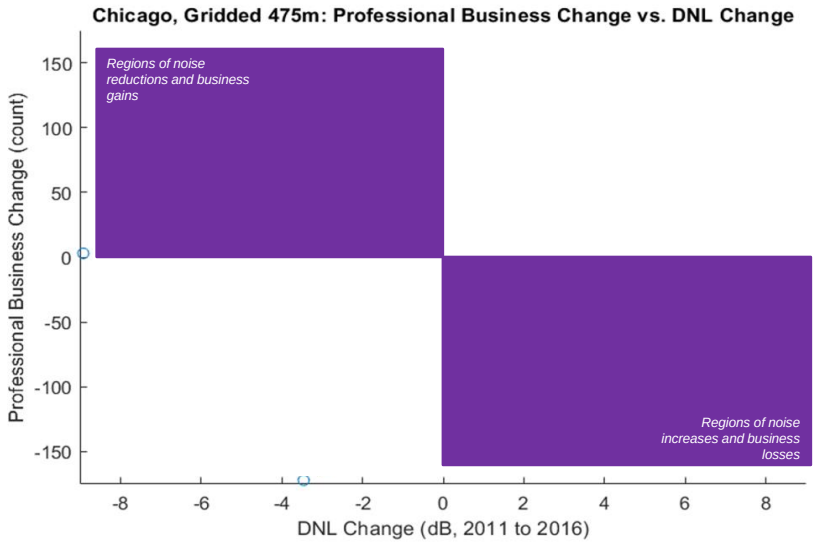
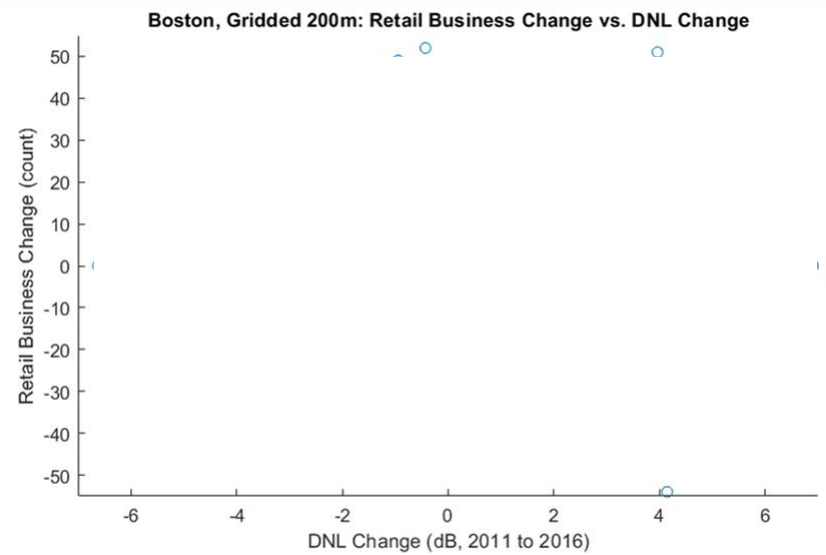
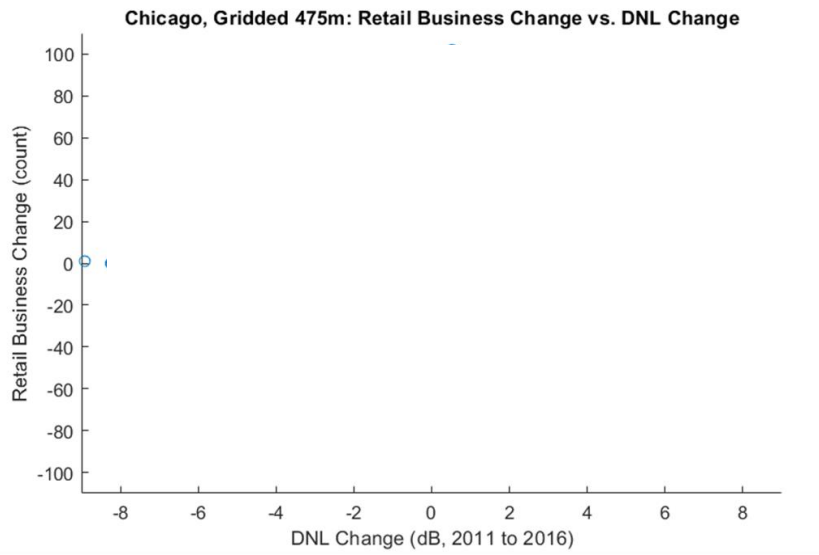




PRELIMINARY RESULTS

2 Correlation Analysis: *No broad trends across sectors and airports*

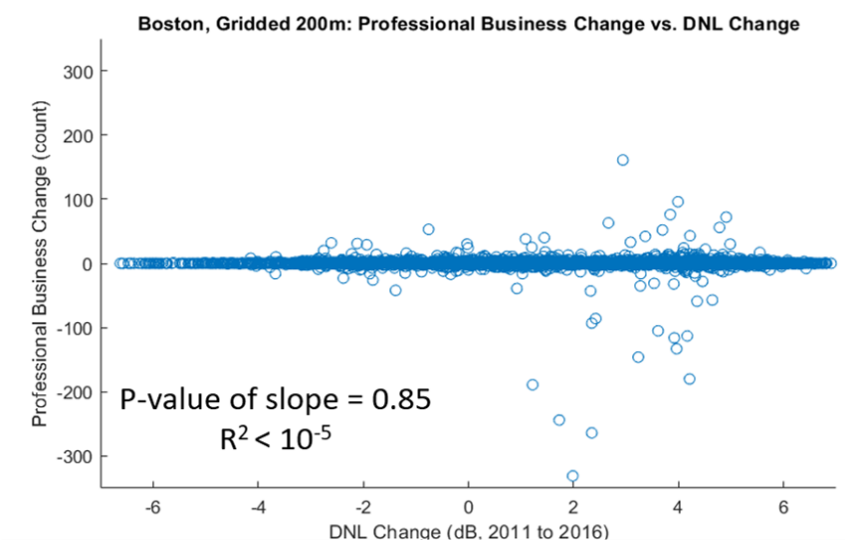
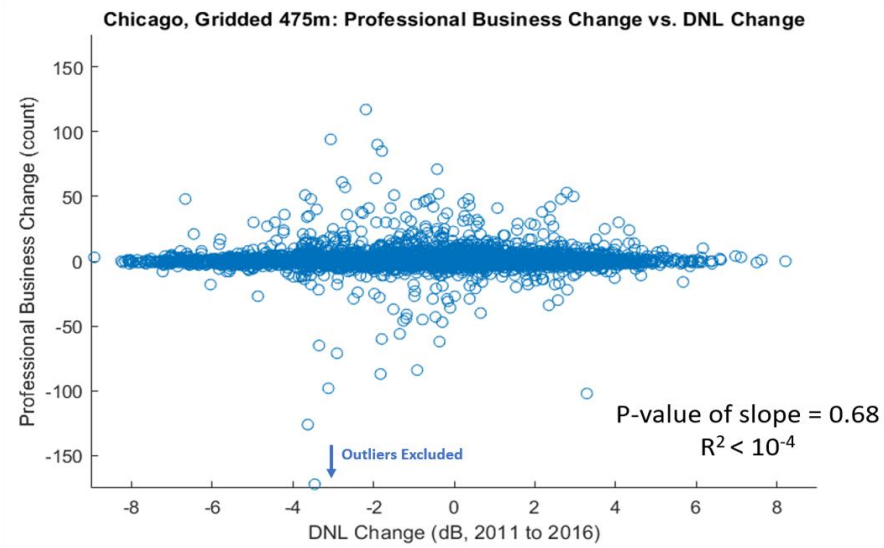
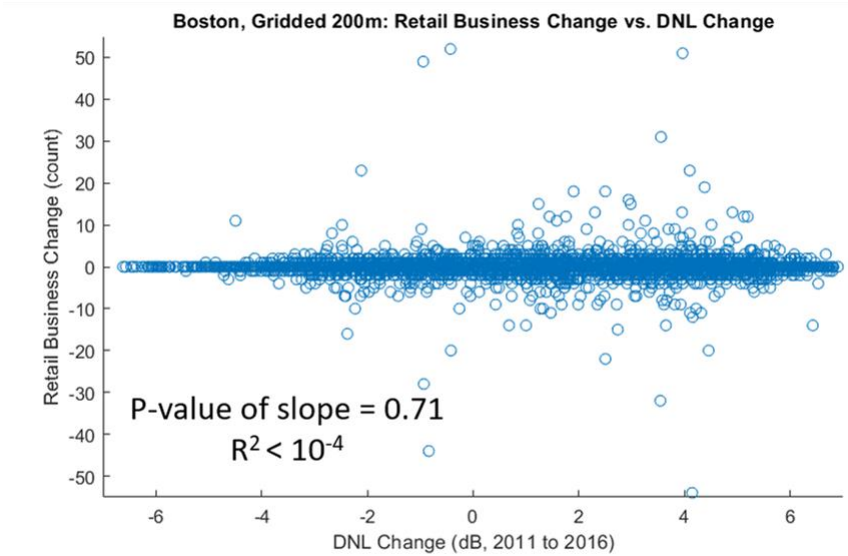
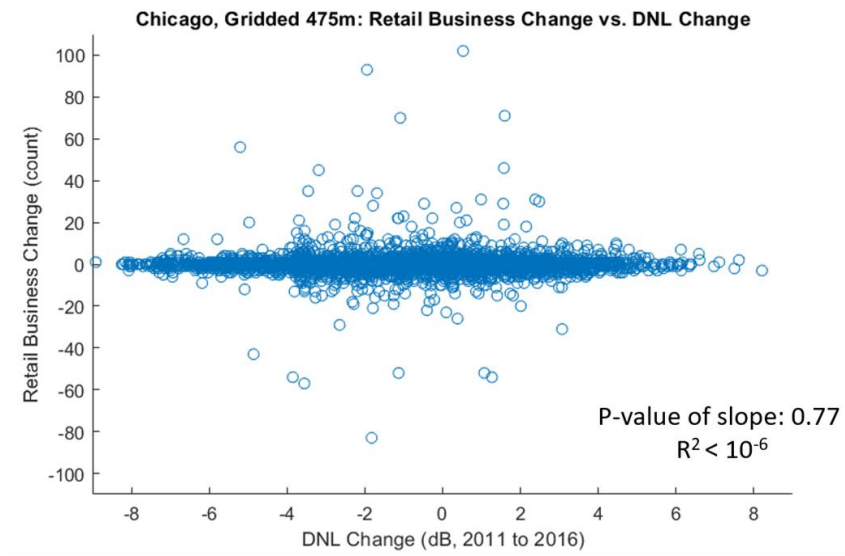
ASCENT AVIATION SUSTAINABILITY CENTER

	Boston Logan	Chicago O'Hare
Professional		
Retail		

PRELIMINARY RESULTS

2 Correlation Analysis: *No broad trends across sectors and airports*

ASCENT AVIATION SUSTAINABILITY CENTER

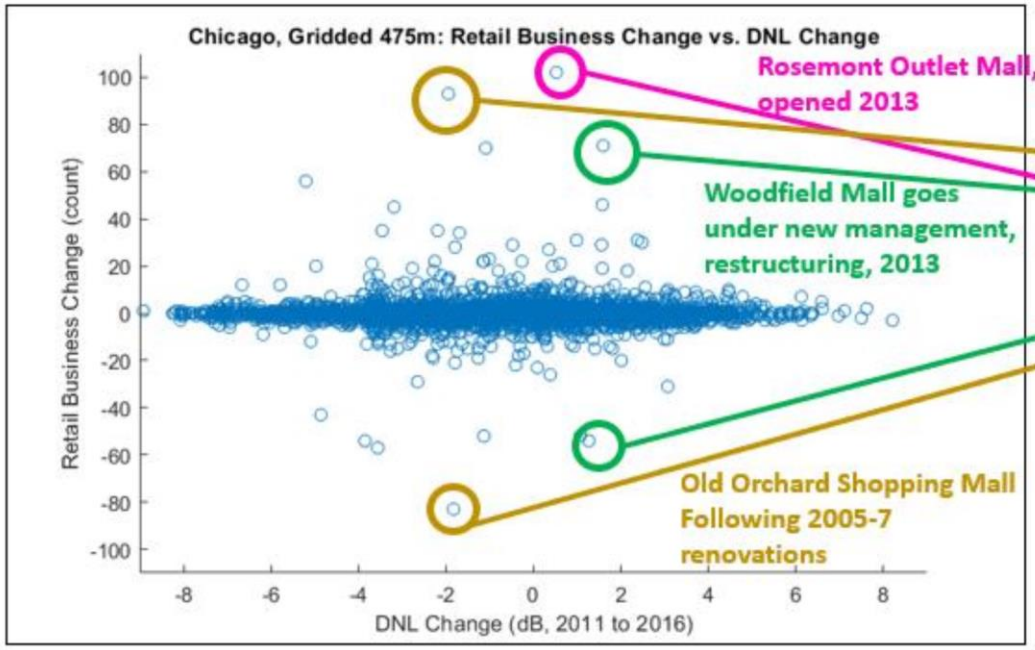
	Boston Logan	Chicago O'Hare
Professional		
Retail		

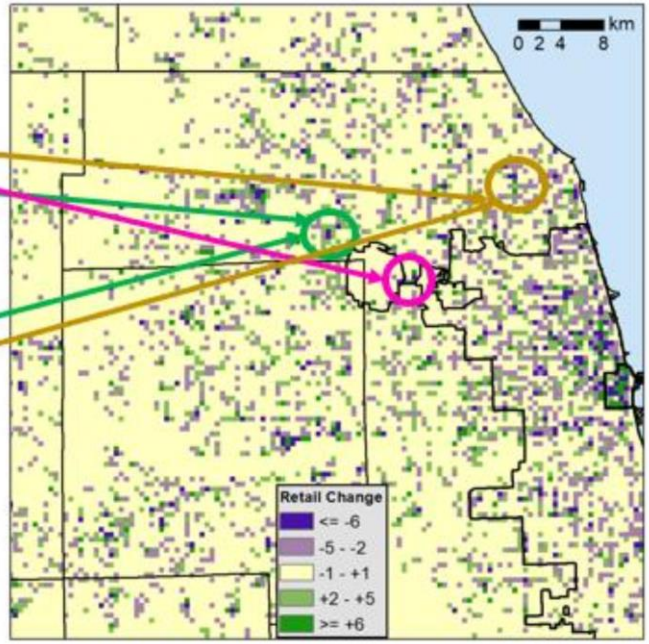
PRELIMINARY RESULTS

2 Correlation Analysis: *Outliers can be explained, no obvious impact of noise*

Motivation:
Outliers can skew the correlation and/or could serve as case studies for regions where noise changes have economic impacts (despite the overall trend not being statistically significant).

Example analysis: *Chicago, retail sector*

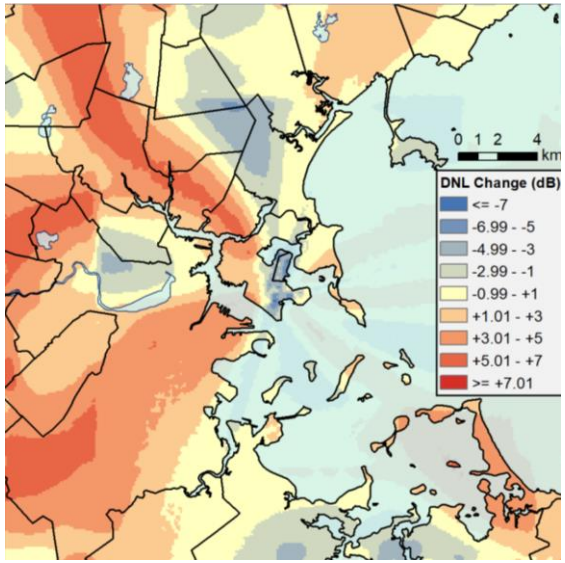




3 Significance testing: *Treatment group analysis shows no significant results (retail)*

Approach:
Comparison of areas with noise changes (beyond certain thresholds) with areas of no noise changes could reveal potential thresholding effects.

Example analysis: *Boston, professional sector*



Control:	***Treatment:***	***Treatment:***
Noise Change ≥ -1 and ≤ +1	Noise increase ≥ 2 dB	Noise decrease ≤ -2 dB
Mean: +0.34	Mean: +0.12 DoM: +0.22	Mean: +0.37 DoM: -0.02

Mean = Average change in business # by grid cell 2011-2016
DoM = Difference in mean control group vs. treatment

* α < 0.1 ** α < 0.05

Note:
- Sensitivity analyses with different noise thresholds lead to similar results.
- Similar results obtained for Chicago O'Hare and for professional sector

PRELIMINARY RESULTS

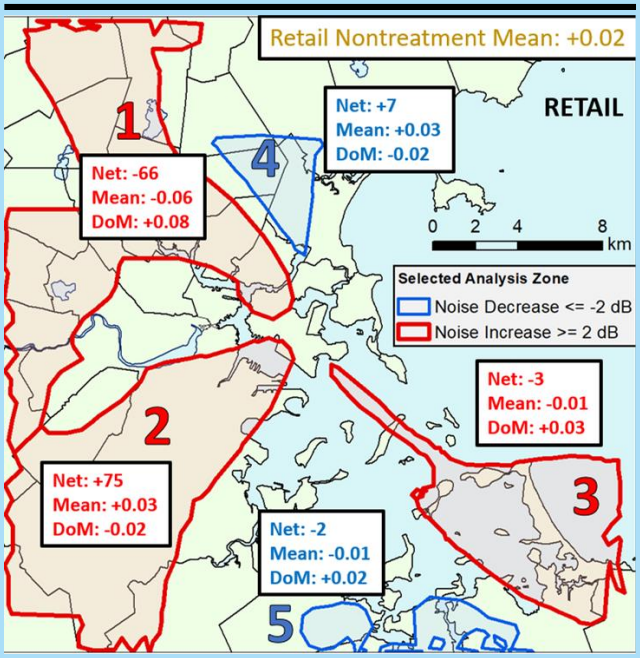
Significance testing: *Analysis of contiguous groups shows no significant results*

Defining treatment/non-treatment groups based purely on noise change might hide potential heterogeneities between regions.

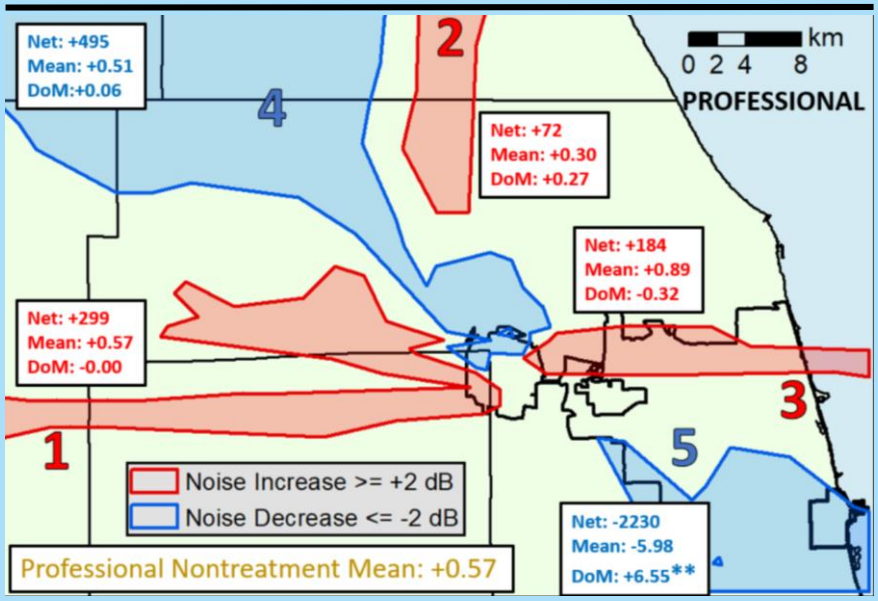
Geographically contiguous treatment/non-treatment groups

Business change and difference to control groups shown per regions, as indicated on map
2db threshold

Boston, retail



Chicago, professional



* α < 0.1 ** α < 0.05

Mean = Average change in business # by grid cell 2011-2016
DoM = Difference in mean between control group vs. treatment group

Publications

- Simon MC, Hart JE, Levy JI, VoPham T, Malwitz A, Nguyen DD, Bozigar M, Cupples LA, James P, Laden F, Peters JL. Sociodemographic Patterns of Exposure to Civil Aircraft Noise in the United States 2022; 130(2) https://doi.org/10.1289/EHP9307.
- Kim CS, Grady ST, Hart JE, Laden F, VoPham T, Nguyen DD, Manson JE, James P, Forman JP, Rexrode KM, Levy JI, **Peters JL**. Long-term aircraft noise exposure and risk of hypertension in the Nurses' Health Studies. Environmental Research, 2021; 207:112195. doi: 10.1016/j.envres.2021.112195.
- Peters JL, Zevitas CD, Redline S, Hastings A, Sizov N, Hart JE, Levy JI, Roof CJ, Wellenius GA. Aviation noise and cardiovascular health in the United States: a review of the evidence and recommendations for research direction. Current Epidemiology Reports 2018; 5(2):140–152. doi.org/10.1007/s40471-018-0151-2.

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