
*Evaluating exposure inequalities in
air pollution health science: state of
the science and current activities at
Health Canada*

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Air Program
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Upwind Downwind Conference,
May 26th, 2026
Hamilton



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Canada

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Outlines and Objectives



Describe the **Right to a Healthy Environment** under CEPA and its relevance to air pollution

Detail findings of two recent projects evaluating **national exposure inequalities**

Highlight **other relevant work** related to environmental justice and air pollution at Health Canada

Right to a Healthy
Environment under
the *Canadian Environmental
Protection Act, 1999* (CEPA)



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The right to a healthy environment under CEPA



CEPA was amended in June 2023 to recognize, in the preamble, that every individual in Canada has a right to a healthy environment as provided under the Act and require the Government to develop an implementation framework

- In July 2025, the Government published the implementation framework to set out what the right to a healthy environment means **in the context of CEPA**, and how Health Canada and Environment and Climate Change Canada staff will fulfill their duty to protect this right and uphold 3 new principles in their work.



Check out the [Implementation framework for the right to a healthy environment under the Canadian Environmental Protection Act, 1999 - Canada.ca](#)

Right to A Healthy Environment under CEPA

Substantive elements

- The right of every individual in Canada to live in an environment that is protected from harmful substances, pollutants, and waste, and where actions taken under CEPA contribute to:
 - clean and healthy air and water
 - a sustainable climate
 - healthy ecosystems and biodiversity

Procedural Elements

- Access to information
- Participation in decision-making

Indigenous Rights

New CEPA Principles

- Environmental justice
- Intergenerational equity
- Non-regression

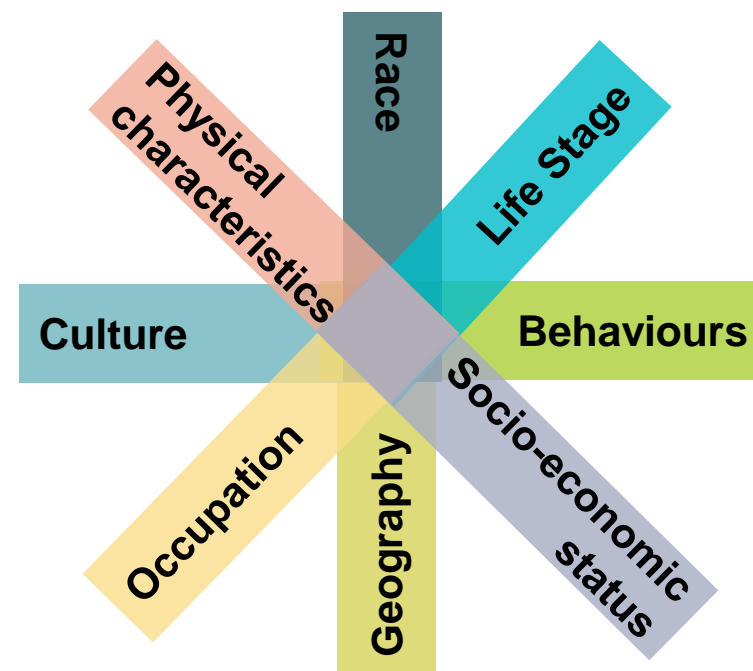
Factors

- Scientific
- Environmental
- Health
- Social
- Economic

Environmental Justice under CEPA

Seeks to advance the fair and equitable protection of all people in Canada from disproportionate environmental or health risks and to advance their equitable access to meaningful participation in decision-making under the Act.

Disproportionate impacts on populations can arise from greater exposure and/or greater susceptibility due to:



Environmental Justice as it Relates to the Air Program:

Research & Monitoring:

- **Identifying populations who may be disproportionately impacted**
- **Collecting and sharing disaggregated data (i.e. exposure broken down by sex, race, age, community etc.)**

Risk Assessment:

- Identify if risks are present for communities with a disproportionate susceptibility or exposure

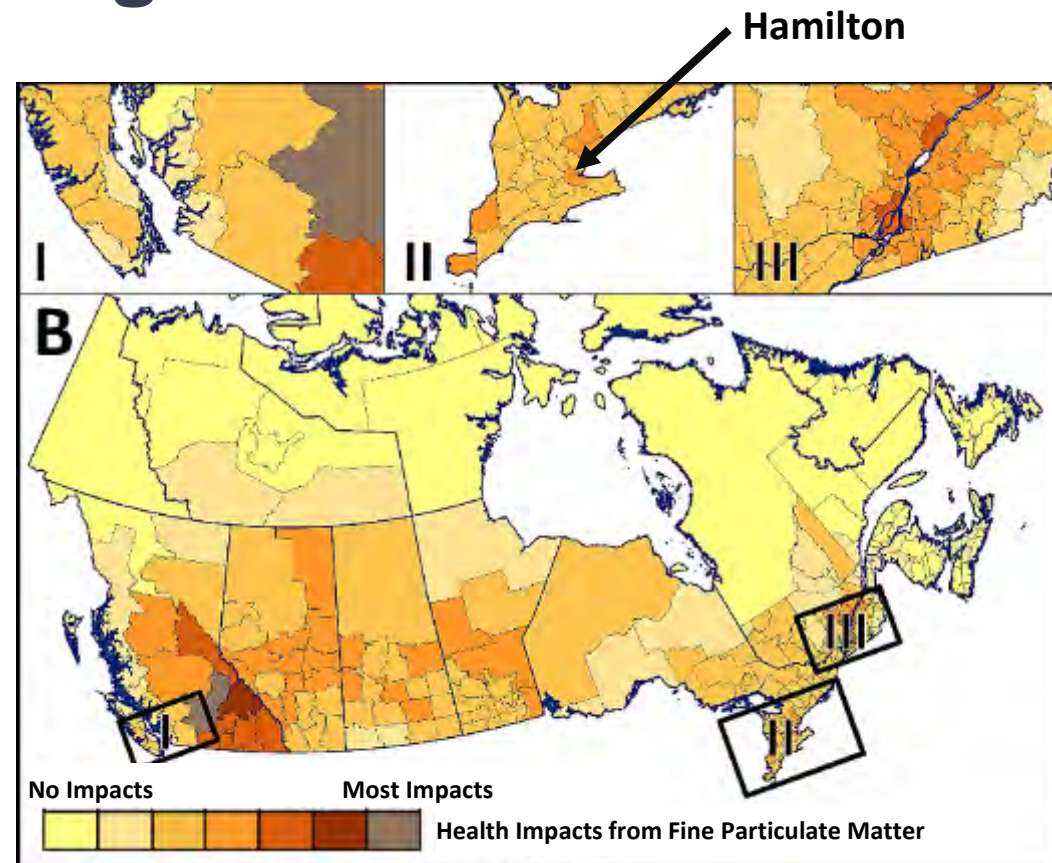
Risk Communication:

- Establishing outreach and risk communication strategies tailored for these populations
- Making efforts to include diverse voices in consultation and engagement activities.

R2HE: Research and Monitoring

Basis for understanding disproportionate impact

- Sources of air pollution are distinct geographically
- Air pollution varies substantially within and between urban centres
- Population characteristics and susceptibility are not uniform across individual cities nor nationally



Ref: Fuller-Thomson et al., 2024

Evaluating exposure inequalities

National PM_{2.5} Inequality under Multiple Exposure Models



The screenshot shows the top portion of a scientific article page. At the top left is the ACS ES&T Air logo. To the right, it states 'This article is licensed under CC BY 4.0' with a Creative Commons icon and a 'View Article' button. Below this is the URL 'pubs.acs.org/estair'. The main title is 'Variation in Fine Particulate Matter Exposure Models: Implications for Health, Equity, and Uncertainty Evaluation'. The authors listed are Amanda J. Pappin, Elysia G. Fuller-Thomson, Saeed Nadi, Hong Chen, Anas Alhusban, Y. Burak Oztaner, Amir Hakami, Nedka Pentcheva, Xihong Wang, Maxim Bulat, and Richard T. Burnett. There is a 'Cite This' section with the citation 'ACS EST Air 2026, 3, 681-696' and a 'Read Online' button. At the bottom of the screenshot are links for 'ACCESS', 'Metrics & More', 'Article Recommendations', and 'Supporting Information'.

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Variation in Fine Particulate Matter Exposure Models: Implications for Health, Equity, and Uncertainty Evaluation

Amanda J. Pappin,[†] Elysia G. Fuller-Thomson, Saeed Nadi, Hong Chen, Anas Alhusban, Y. Burak Oztaner, Amir Hakami, Nedka Pentcheva, Xihong Wang, Maxim Bulat, and Richard T. Burnett

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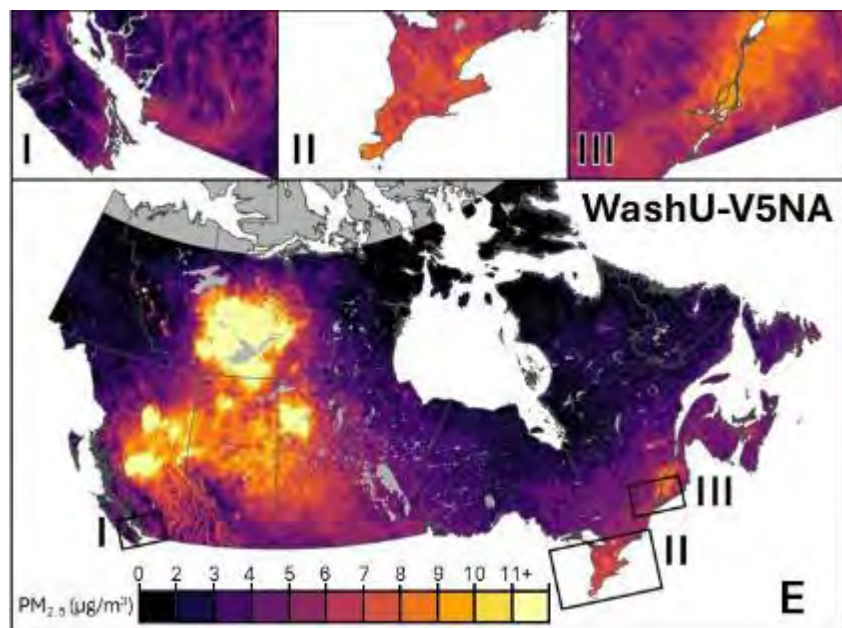
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Methods

7 Exposure Models, 2002-2014



7 total models encompassing modern techniques:

- Chemical Transport Modelling
- Machine Learning
- Satellite Information

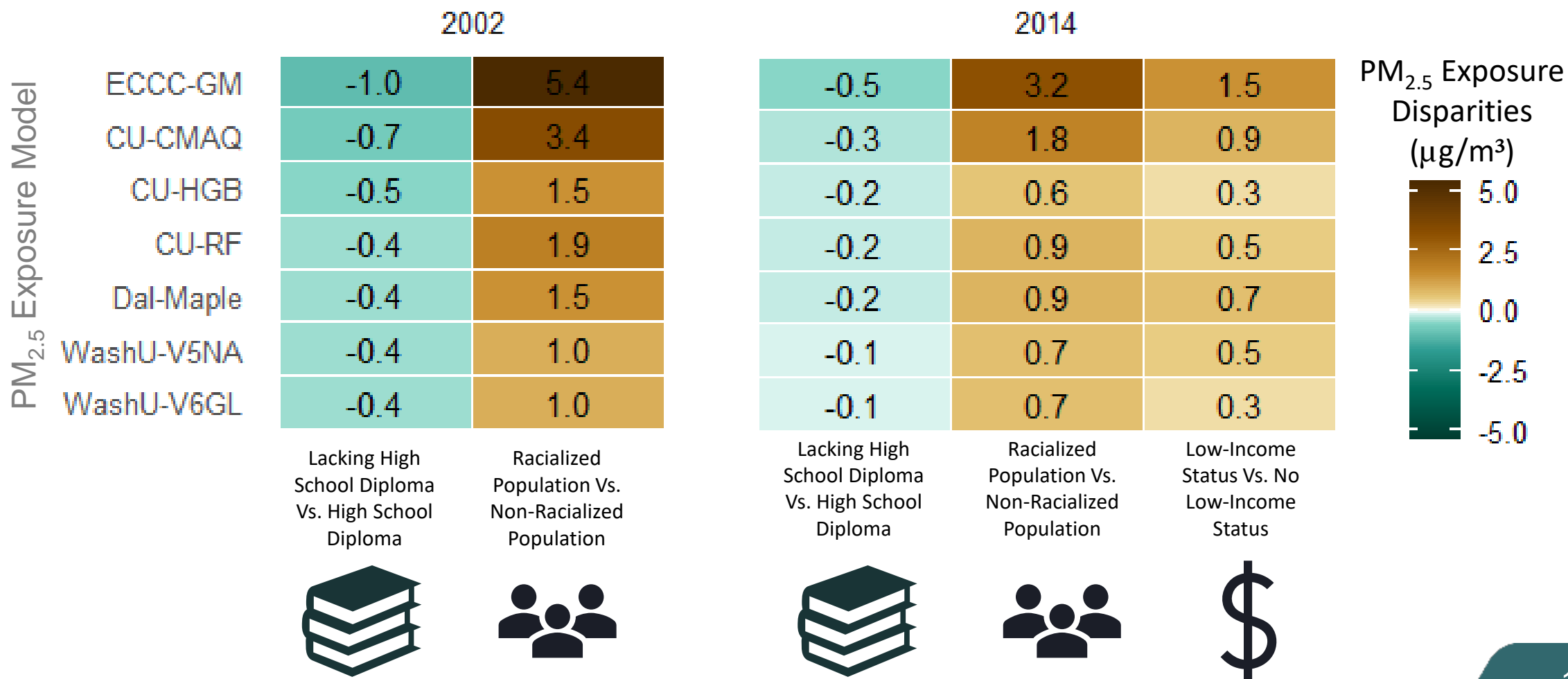
Three Measures of SES, Canadian Census

- Racialized Populations
- High School Education
- Low-Income Status



**Disparities
Assessed**

Results: PM_{2.5} Disparities Across Exposure Model Type



Key-Takeaways

- Consistent national PM_{2.5} disparities no matter the choice of exposure model
- Trends hypothesized to be linked to urban-rural gradients
- Absolute disparities decreases, very slight decrease to relative disparities

Analyses examining national nitrogen dioxide exposure inequalities

Elysia Fuller-Thomson^a

Mathieu Rouleau^a

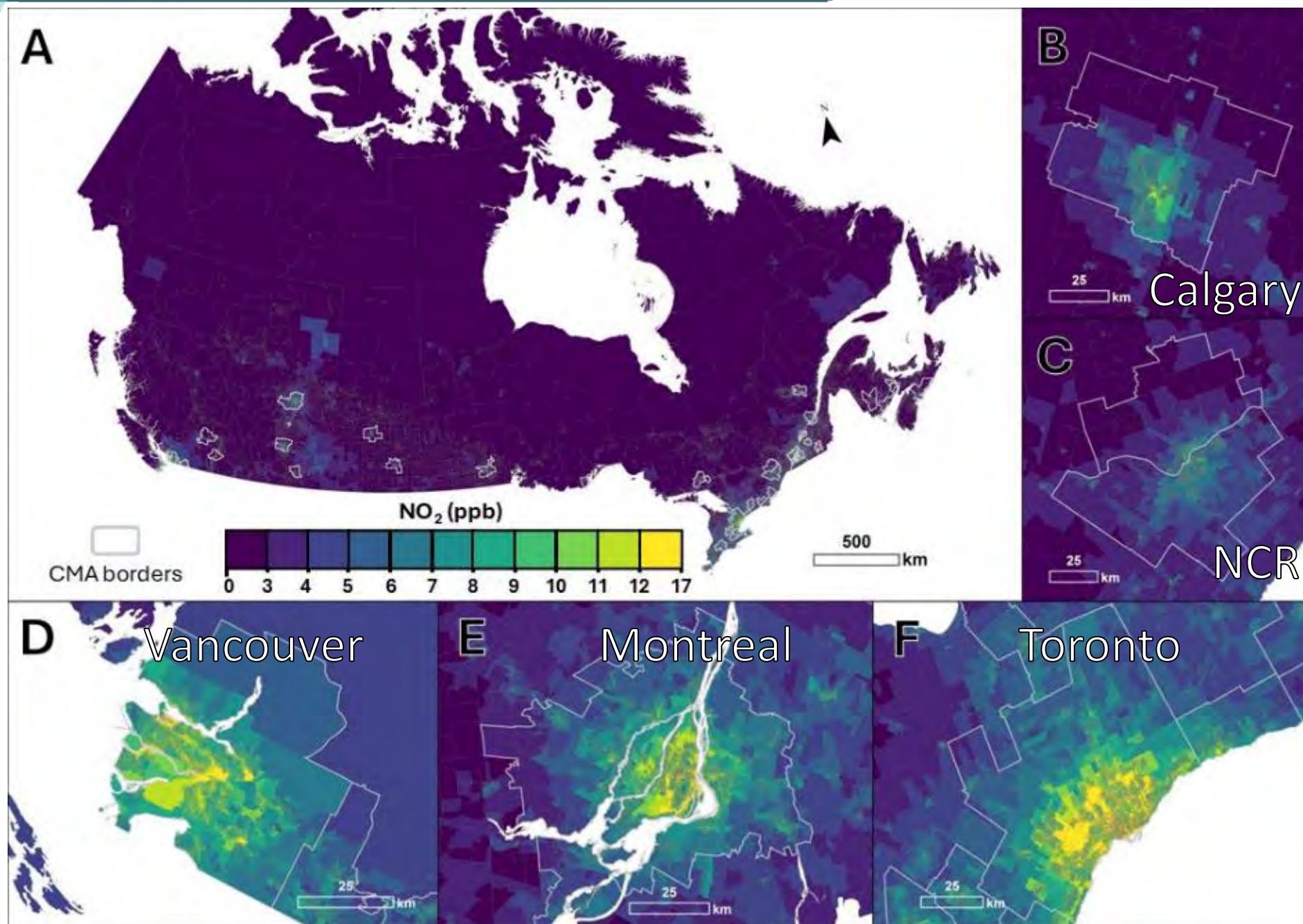
Toyib Olaniyan^b

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^bHealth Analysis and Modelling Division, Analytical Studies and Modelling Branch

Data Source: 2019 Land-Use Regression Exposure Model



Data Source: Area-Level Socioeconomic Data

Specific SES Measures from 2021 Census

- Precedence within Canadian literature
- Six Measures:
 - % Age 14-
 - % Age 65+
 - % Indigenous
 - % < High School Education
 - % < Low-Income Cut-Off (LICO)
 - % Racialized Population

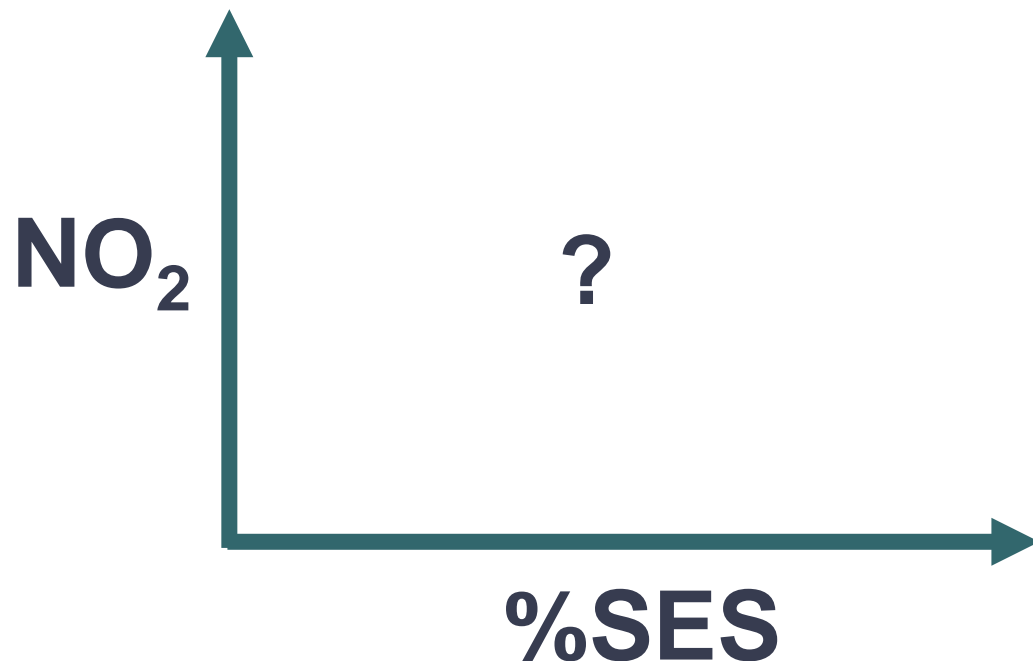
Canadian Index of Multiple Deprivation (CIMD) (2021)

- Commonly employed index of SES
- Statistics Canada product available freely
- Four dimensions

GOAL:







Evaluate the association between area-based measures of socioeconomic status and NO₂ exposure

$$\text{NO}_2 \propto \% \text{SES} (?)$$

**Methodology: Statistical Regression**

- Simultaneous Autoregressive Model (Spatial Lag) evaluates associations between SES and NO₂
 - Two modelling types: National + Stratified by Census Metropolitan Area
 - Separate models for census and CIMD
 - Accounts for common methodological concerns
 - Standardized by standard deviation to fairly compare SES

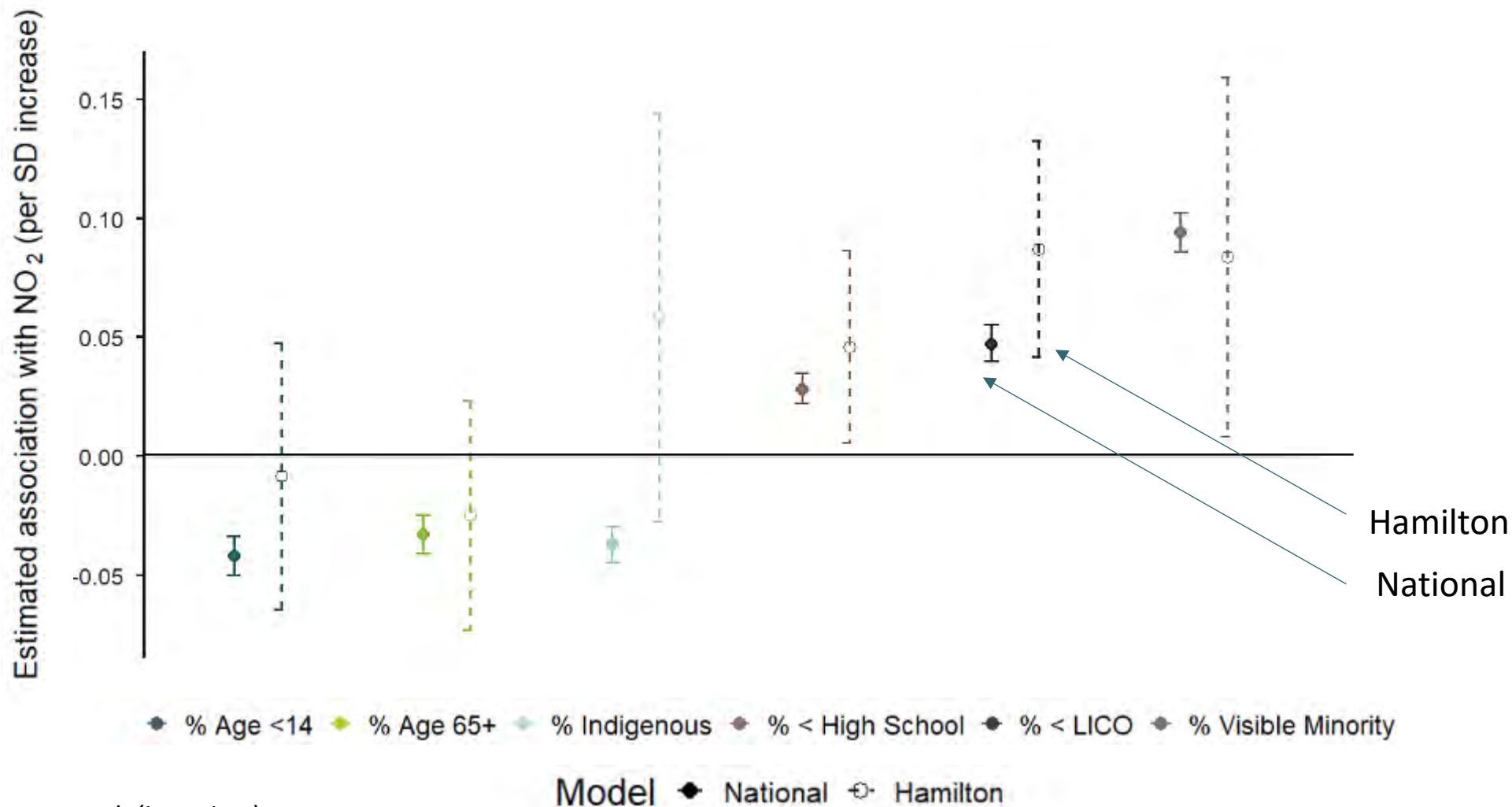
Results: Statistical Associations Between SES Census Variables and NO₂ Exposure

	SAR – Spatial Lag Model
% Age 14- (SD = 5.1%)	
% Age 65+(SD = 9.8%)	
% Indigenous (SD = 5.7%)	
% < High School (SD = 8.4%)	
% < LICO (SD = 5.2%)	
% Racialized (SD = 25.6%)	

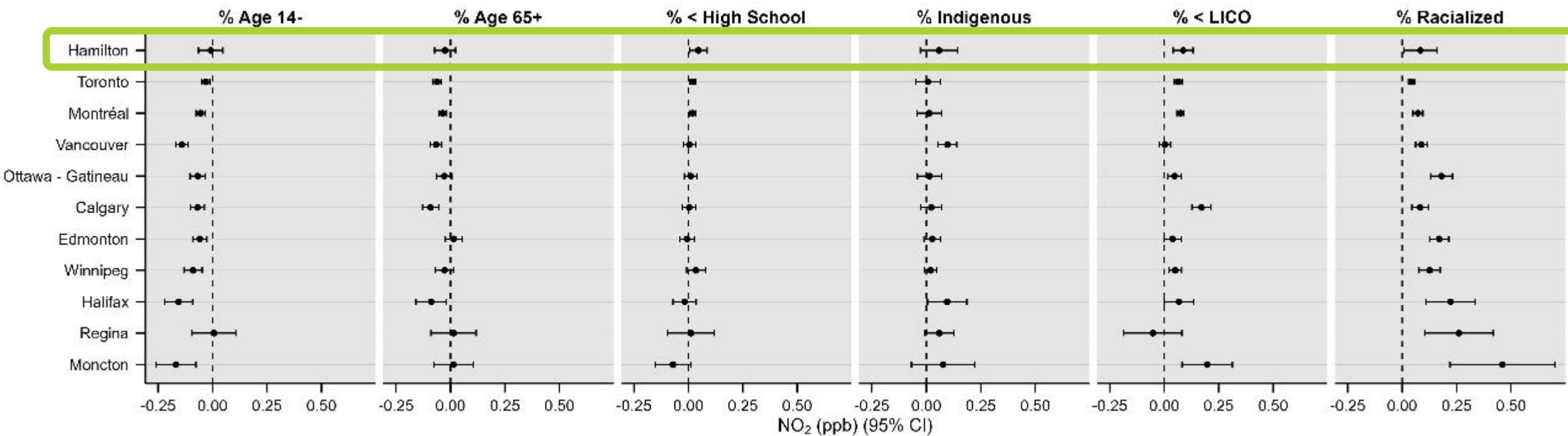
 **Positive**

 **Negative**

Associations Between SES Census Variables and NO₂ exposure (SAR Model)

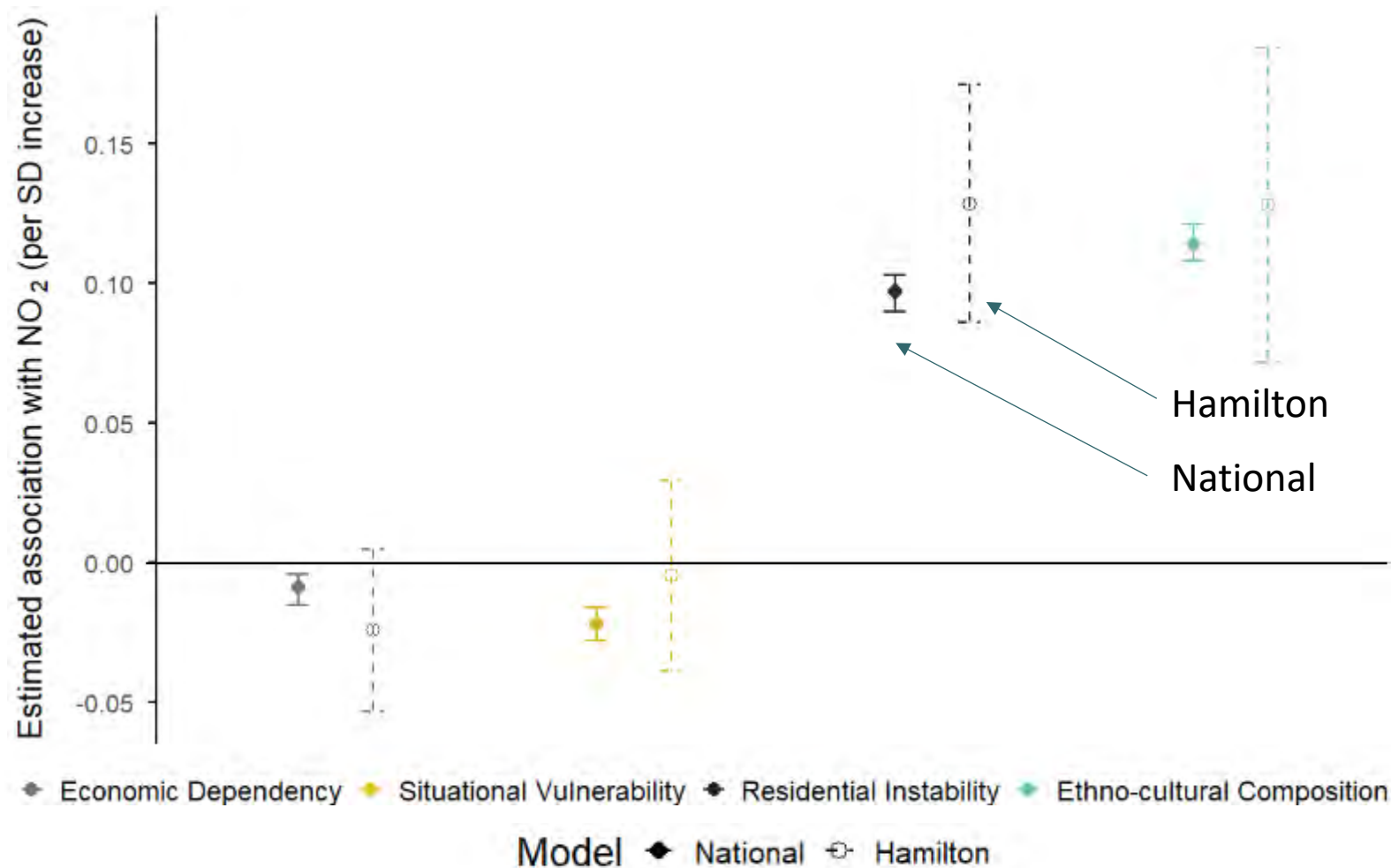


Associations Between SES Census Variables and NO₂ exposure SAR - Stratified Model

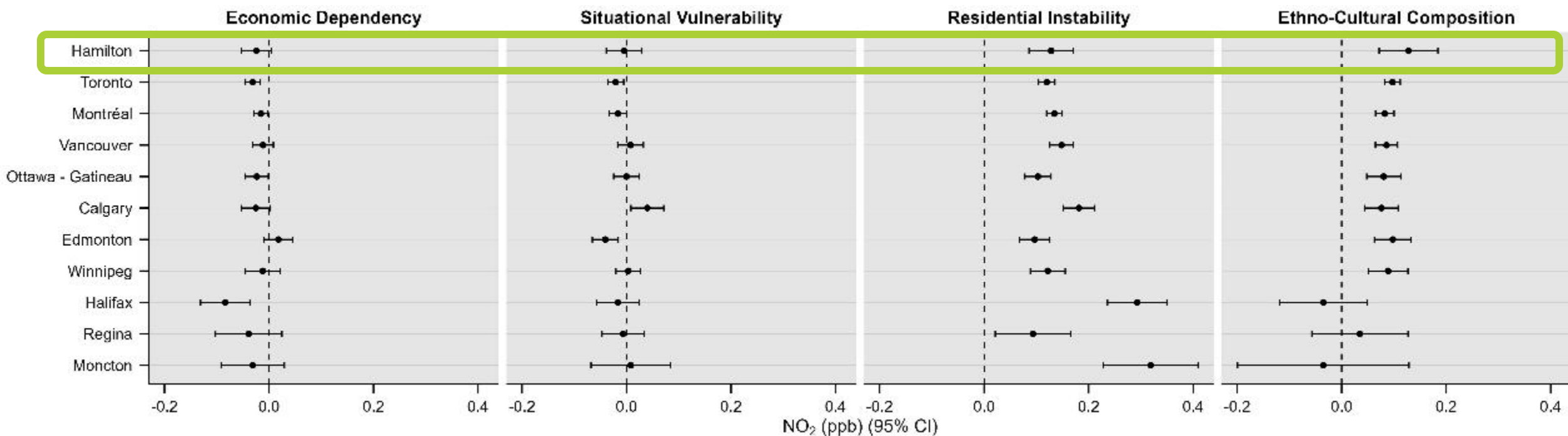


Associations Between CIMD and NO₂ exposure SAR Model

	SAR – Spatial Lag
<i>Economic Dependency</i>	▬
<i>Situational Vulnerability</i>	▬
<i>Residential Instability</i>	+
<i>Ethno-cultural Composition</i>	+



Associations Between CIMD and NO₂ exposure SAR - Stratified Model



Discussion: Key Takeaways

- Results suggest a tentative national pattern of poverty, racialized populations, and residential instability linked with higher NO₂ exposure
- Growing international picture of racialized populations & elevated NO₂ exposure in high-income countries

Other work related to environmental justice and air pollution at Health Canada

Inequality in the Distribution of Air Pollution Attributable Mortality Within Canadian Cities

David M. Stieb^{1,2,3,4}, Marc Smith-Doiron⁵, Matthew Quick⁶, Tanya Christidis⁴, Guoliang Xi⁷, Rosalind M. Miles^{8,9}, Aaron van Donckelaer², Randall V. Martin⁴, Perry Hystad¹⁰, and Michael Tjepkema⁴

¹Environmental Health Science and Research Bureau, Health Canada, Vancouver, BC, Canada; ²Environmental Health Science and Research Bureau, Health Canada, Ottawa, ON, Canada; ³School of Epidemiology and Public Health, University of Ottawa, Ottawa, ON, Canada; ⁴Health Analysis Division, Statistics Canada, Vancouver, BC, Canada; ⁵Faculty of Education, Indigenous Health & Physical Activity Program, University of British Columbia, Vancouver, BC, Canada; ⁶Physical Activity and Chronic Disease Prevention Unit, Faculty of Education, University of British Columbia, Vancouver, BC, Canada; ⁷Department of Energy, Environment and Physical Activity and Cultural Circle, Vancouver, BC, Canada; ⁸Department of Energy, Environment and Physical Activity and Cultural Circle, Vancouver, BC, Canada; ⁹Department of Energy, Environment and Physical Activity and Cultural Circle, Vancouver, BC, Canada; ¹⁰College of Public Health and Human Sciences, Oregon State University, Corvallis, OR, USA

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

Indoor air quality in remote first nations communities in Ontario, Canada

Gary Mallach, Liu (Sunny) Sun, Michael McKay, Thomas Kovesi, Gail Lawlor, Ryan Kulka, J. David Miller

Published: November 22, 2023 • <https://doi.org/10.1371/journal.pone.0294040>

Article	Authors	Metrics	Comments	Media Coverage
📄				

CHAPTER 3: POPULATION SUBGROUPS AT HIGHER RISK OF HEALTH EFFECTS

This chapter focuses on the susceptibility factors, i.e., factors that increase the risk of adverse outcomes. Available evidence indicates that a variety of factors can affect an individual's response to ambient PM_{2.5} exposure, increasing the risk of adverse health outcomes in certain population subgroups. A national analysis estimated the percentage of the total Canadian population (representative sample of over 120,000 participants in 110 administrative health regions) that has at least one risk factor, which is how susceptible population subgroups are defined by Stieb et al. (2019). The results indicated that the percentage of the population with at least one risk factor (i.e., less than 10, or 75 years old and older, individuals with heart disease, asthma, COPD, or diabetes, or pregnant women) was 32.0% (95% CI: 24.4 to 41.2%). The percentage increased to 69.2% (95% CI: 61.2 to 87.0%) when a broader range of potential susceptibility factors (i.e., less than 20, or 65 years old and older, outdoor workers, less than high school education, low vitamin C intake) was considered.

THE AIR QUALITY HEALTH INDEX FORECAST

EXPOSURE TO TRAFFIC-RELATED AIR POLLUTION IN CANADA: An assessment of population proximity to roadways

CANADIAN HEALTH SCIENCE ASSESSMENT FOR FINE PARTICULATE MATTER (PM_{2.5})

The AQHI uses a scale to show the health risk from air pollution we breathe.

The following table provides the health messages for 'at risk' individuals in each of the AQHI Health Risk Categories.

Health Risk	Air Quality Health Index	Health Messages At Risk Population*	General

Environmental Research

journal homepage: www.tandfonline.com/doi/full/10.1080/10401869.2023.2244442

Spatial associations between socioeconomic groups and NO₂ air pollution exposure within three large Canadian cities

Lauren Pinault^{1,2,3}, Daniel Crouse^{1,2,3}, Michael Jerrett^{1,2,3}, Michael Brauer^{1,2,3}, Michael Tjepkema^{1,2,3}

¹Health Analysis Division, Statistics Canada, 100 University Parkway, 10th Floor, Ottawa, ON, Canada K1A 0S6; ²Department of Environmental Health Science, University of British Columbia, 2180 East Mall, Vancouver, BC, Canada V6T 1Z2; ³Canadian Centre for Air Quality Modelling, University of British Columbia, 2180 East Mall, Vancouver, BC, Canada V6T 1Z2

Thank You – Any Questions?

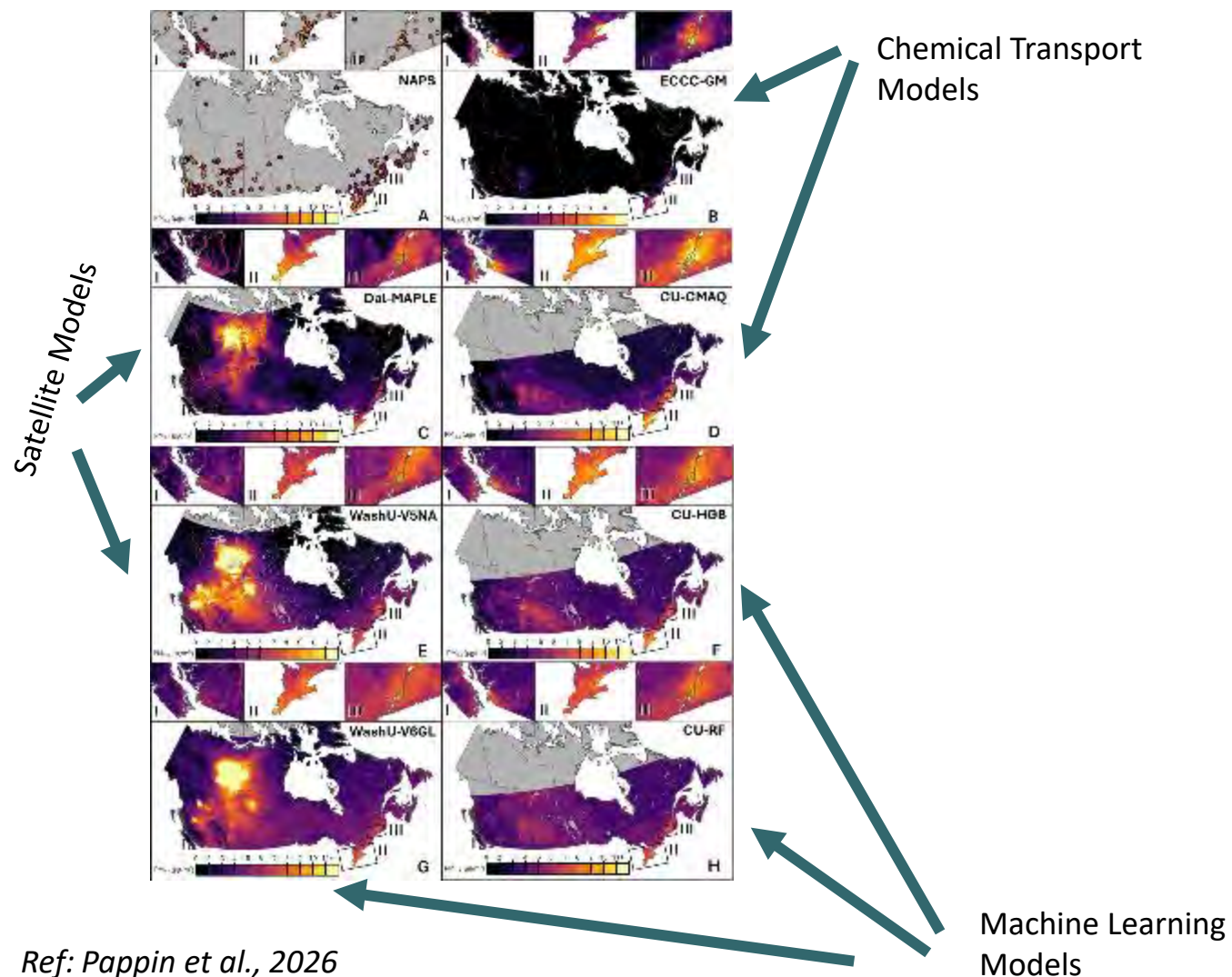
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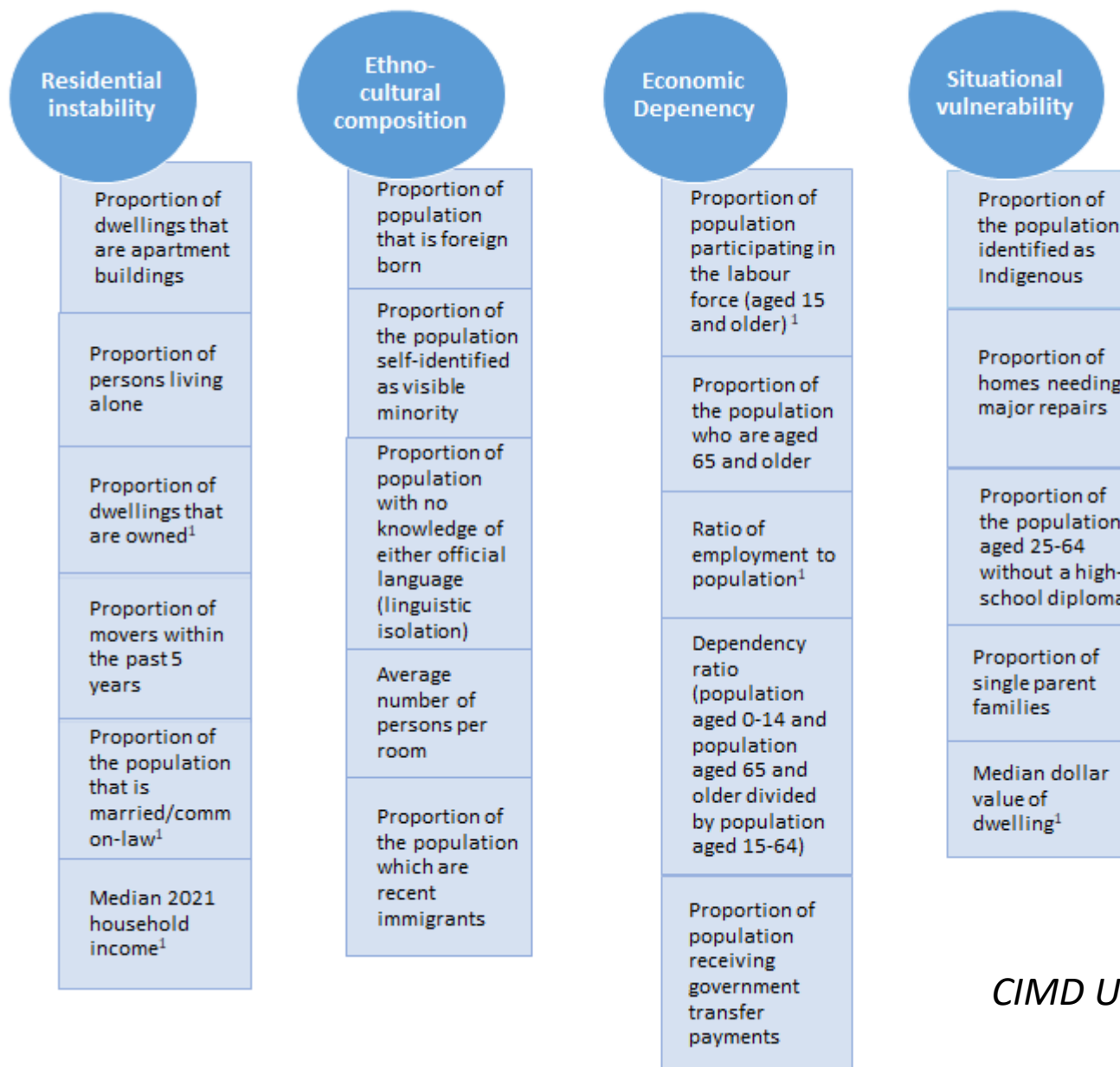
Methods

7 Exposure Models, 2002-2020

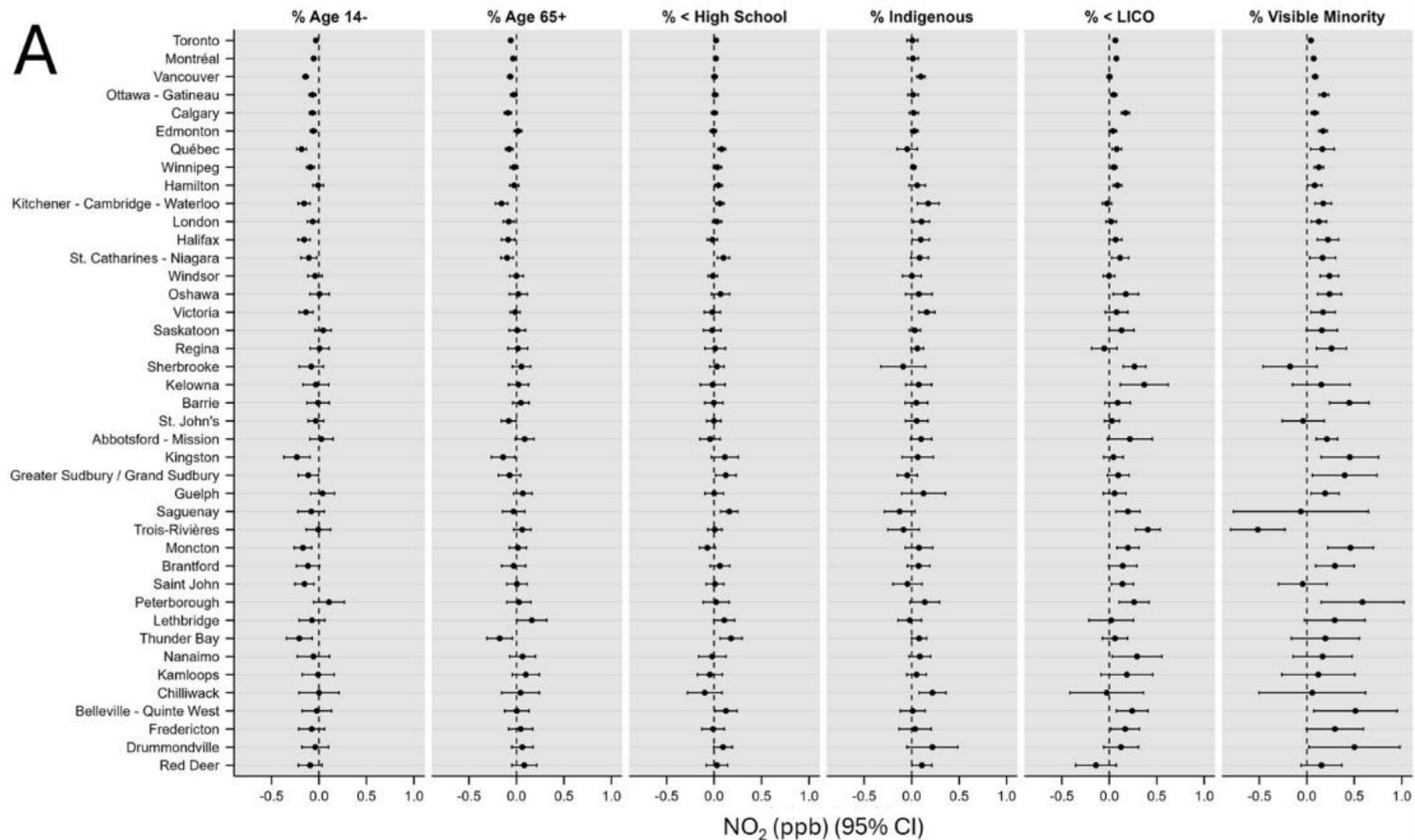


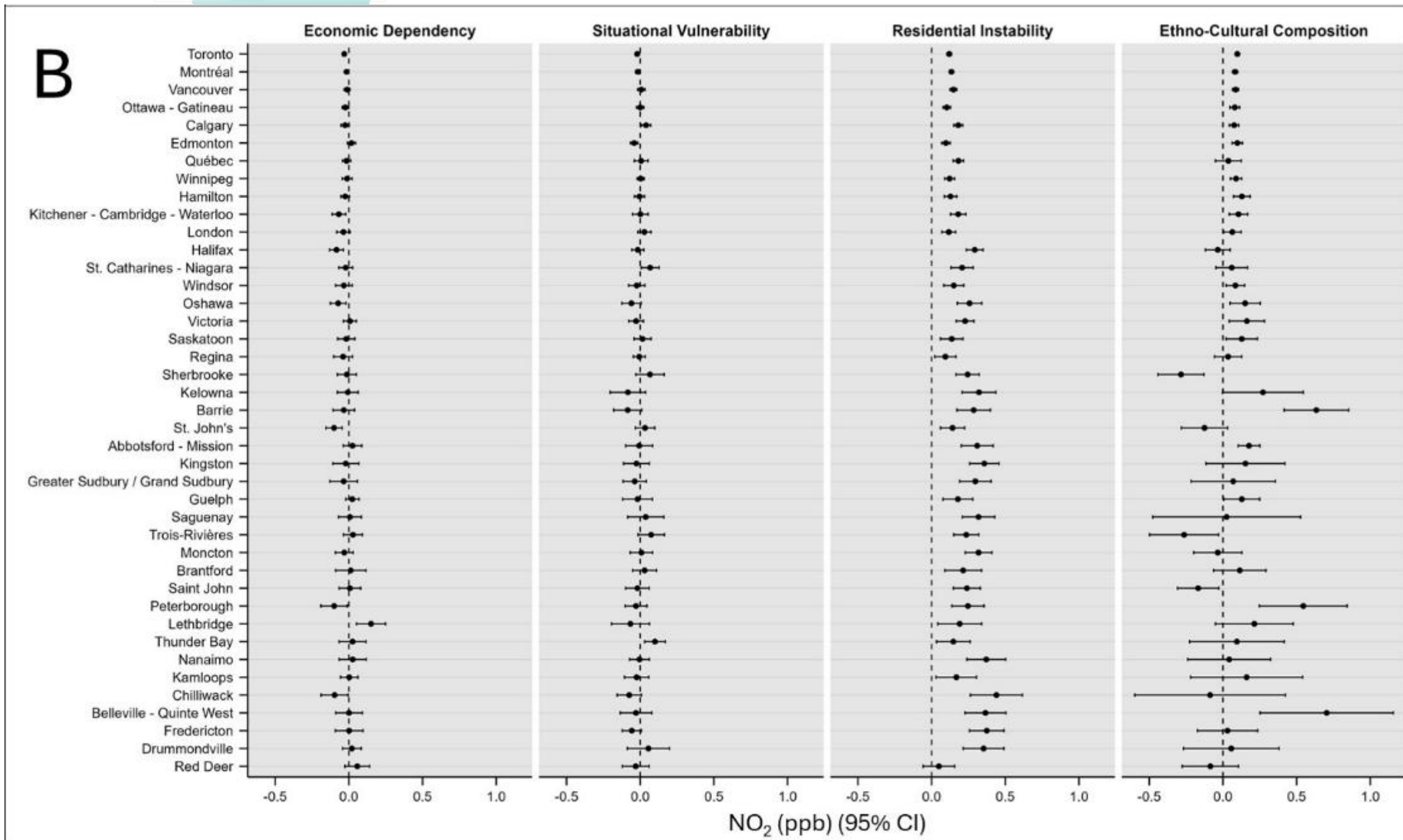
Ref: Pappin et al., 2026

The four dimensions of multiple deprivation and their corresponding indicators, Canada, 2021



A





Methodology: Four Types of Regression Models

Ordinary Least Square Regression (OLS)

- Goal: Base case regression model
- Starting place for all regression modelling

Linear Mixed Effects Regression (LME)

- Goal: To see associations beyond CMA-level differences
- Adds a random intercept for CMAs

Simultaneous Autoregressive Model (Spatial Lag) (SAR)

- Goal: To see associations remain when accounting for spatial autocorrelation
- Adds a spatial lag component:
- $NO_2 = \beta(\%SES) + \rho W_y + \varepsilon$

Simultaneous Autoregressive Model by CMA (SAR - Stratified)

- Goal: Evaluate consistency of CMA-specific associations
- Stratifies analysis
- Keeps a spatial lag component

NOTE:

- Area-based analysis
- Z-score standardization
- Within CMAs Only