Regional Variation in the Effects of Built Environment on Driving

A Reproducible Research Project

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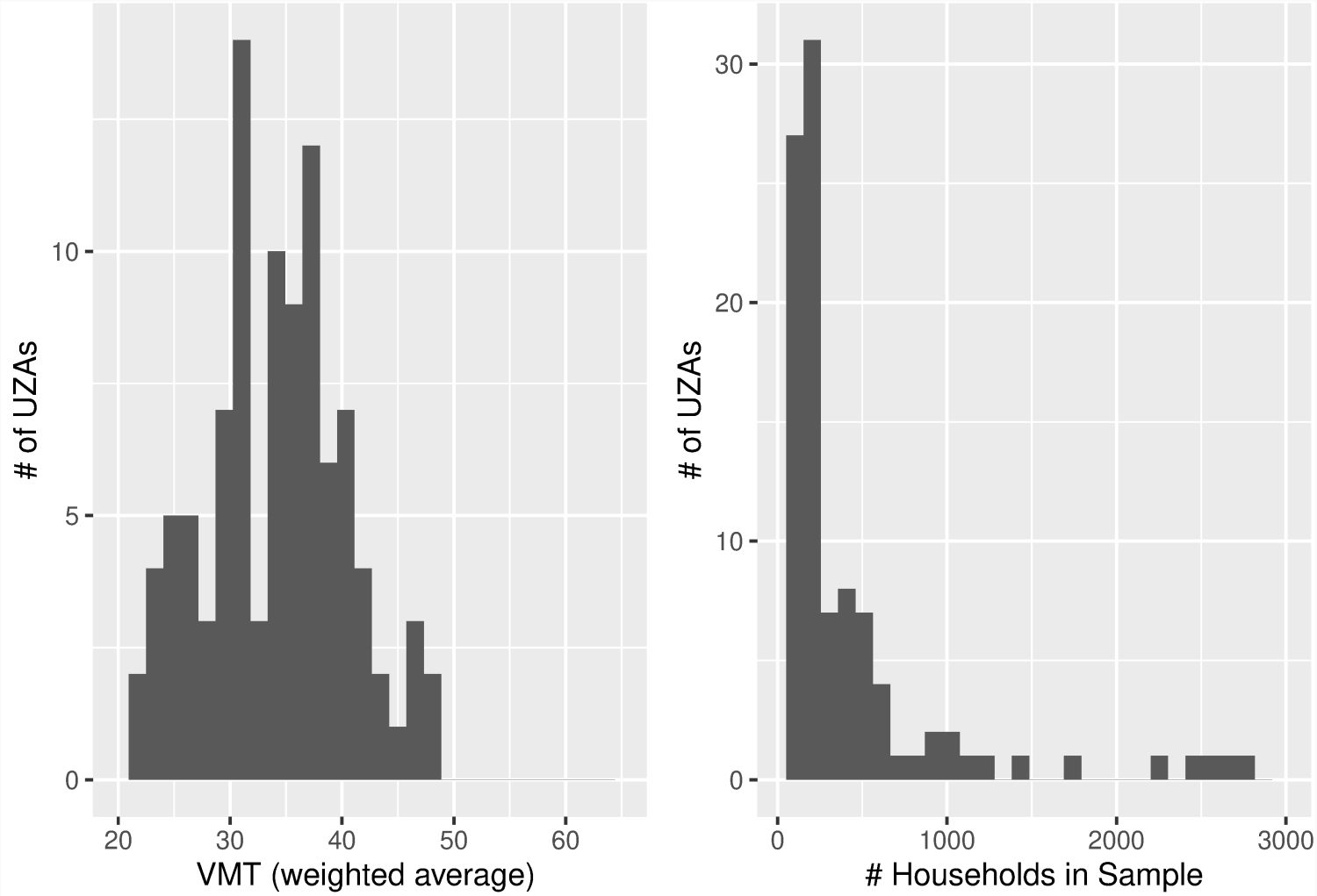
Motivation and Research Questions

- Numerous previous studies focusing on producing point estimates of effects (elasticities) and ended up with a wide range of estimates for the elasticity of the built environment on travel outcomes.
    - For example, In the papers reviewed in Ewing & Cervero (2010), estimates for elasticity of Vehicle Miles Traveled with respect to population density range from -1.05 to +0.03 (with weighted average=-0.04)
- How do we reconcile these different estimates?
    - Most previous studies use data from a single region, collected by different agencies
    - Used different models, sometimes with different dependent/independent variables
    - Regional variation?

Data and Methods

- Data used including the 2009 U.S. National Household Travel Survey (NHTS) and high-resolution built environment measures from the EPA Smart Location Database (SLD)
    - NHTS Socio-demographic characteristics
    - NHTS Travel behavior outcomes, including household VMT on survey day
    - SLD Diverse set of built environment measures organized by 5D variables
- Include 44,000 households across 100 UZAs

Descriptives



Histograms of UZA-level weighted average VMT and Number of household obser- vations by UZA

Methods/Models

- Fixed Effects Models

$$\Pr(VMT_{iu} = 0) = \frac{\exp(V_{iu})}{1 + \exp(V_{iu})},$$
$$\text{where } V_{iu} = \alpha_u + \beta X_{iu}^{SES} + \gamma_u X_{iu}^{BE}$$

$$\log(VMT_{iu}) \sim N(a_u + bX_{iu}^{SES} + c_u X_{iu}^{BE}, \sigma)$$
$$\text{for } VMT_{iu} > 0$$

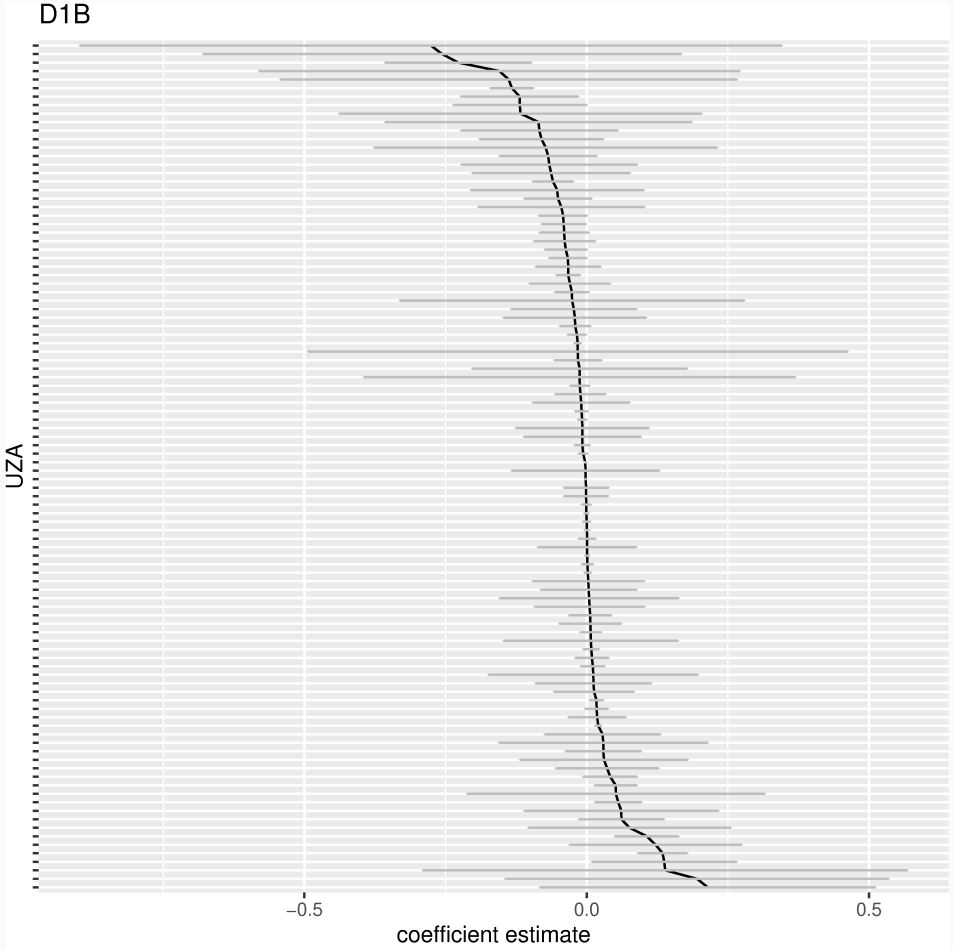
- Hierarchical Mixed Effect Models

$$V_{iu} = \alpha_{iu} + \beta X_{iu}^{SES} + \gamma_{iu} X_{iu}^{BE},$$
$$\text{where } \alpha_{iu} \sim N(\bar{\alpha}, \sigma_\alpha),$$
$$\text{and } \gamma_{iu} \sim N(\bar{\gamma}, \Sigma_\gamma)$$

$$VMT_{iu} \sim N(a_{iu} + bX_{iu}^{SES} + cX_{iu}^{BE}, \sigma),$$
$$\text{where } a_{iu} \sim N(\bar{a}, \sigma_a),$$
$$\text{and } c_{iu} \sim N(\bar{c}, \Sigma_c)$$

Findings (1)

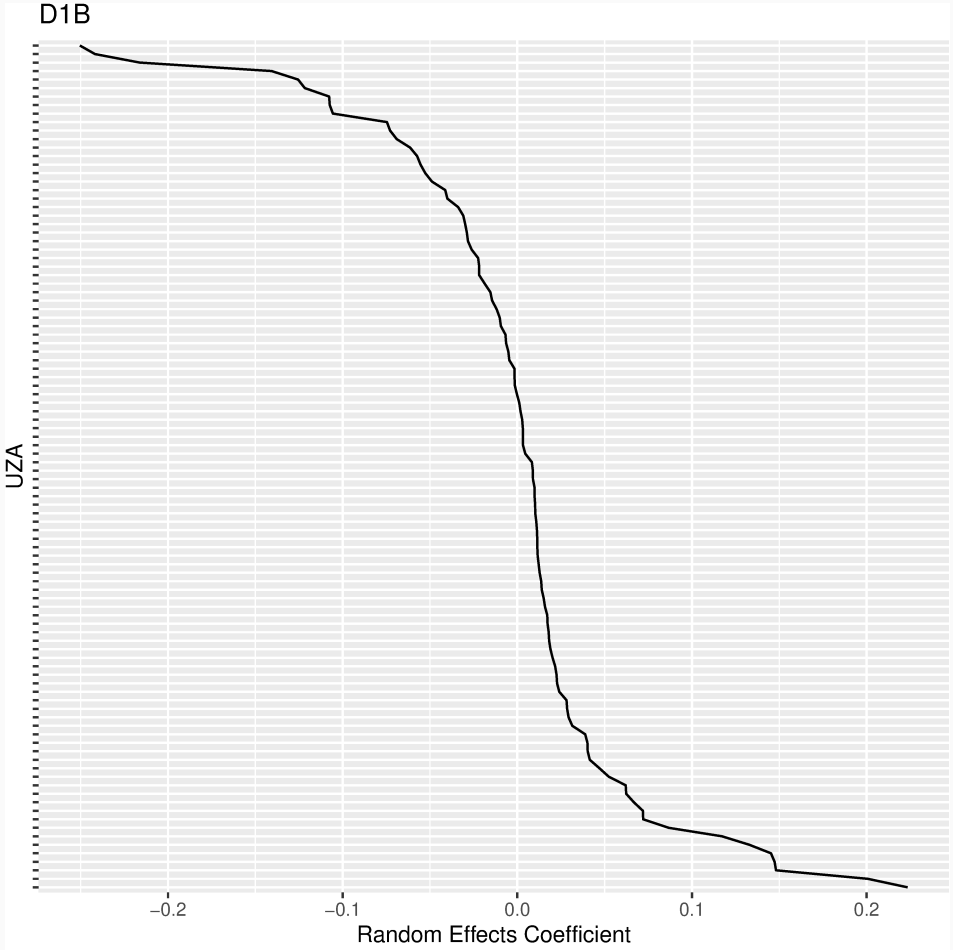
- For the elasticity estimate of VMT wrt population density (D1B) = **-0.086** in pooled fixed effect model, in line with Ewing & Cervero's estimate of -0.04
- Likelihood ratio test rejects the fixed effect model (no UZA-specific slopes) and favors the full fixed effect model with UZA-specific coefficient (χ^2 =1620.883, p < 0.000), although most UZA-specific coefficients are not significant.



Point estimates and confidence intervals for D1B (population density) variable by UZA

Findings (2)

- Likelihood ratio test also favors full mixed effect model with both random slopes and intercepts ($p<0.0000$).
- Notably, in the mixed effect model, all fixed effect coefficients for 5D variables are not significant.



Random coefficients for D1B variable by UZA

Conclusions and Discussion

Conclusions

- Significant regional variation in the estimates of built-environment effects on VMT, even as the mean estimate in line with synthesized weighted average
- With NHTS and SLD data, estimates of UZA-specific effect are mostly unusable (highly variable and statistically insignificant)
- Mixed-effect model provides a solution to the problem by allowing partial pooling
- After considering random effects, there is no statistically significant fixed effects.

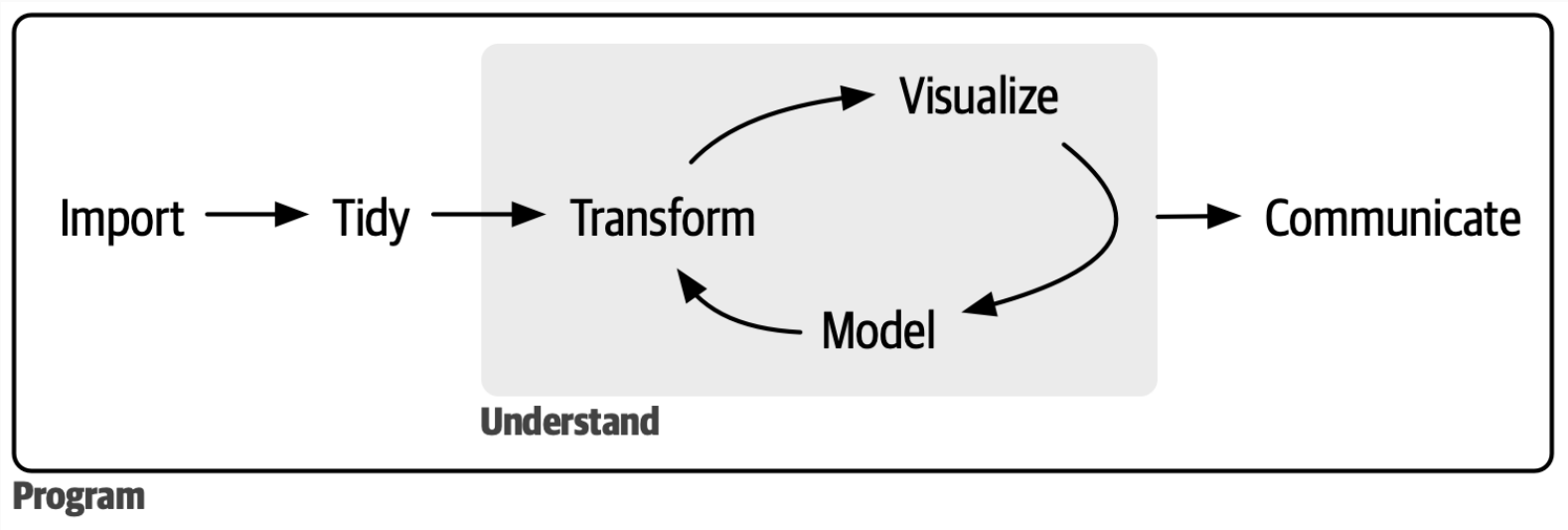
Implications

- Maybe we should not have been so fixated with producing a single estimate after all?
- Both sides of the debate miss some part of the big picture

Experience on Reproducible Research

- The work conducted for the project using R and the `tidyverse` suite of packages, reproducible from raw data to final products
- Project reports and papers written using RMarkdown
  - including my TRB paper and the RMarkdown is available at https://github.com/cities/nhts-mxlm
- Product of the project including an open source R package `VETravelDemandMM` (https://github.com/cities-lab/VETravelDemandMM) contributed to the VisionEval project (https://visioneval.org), a strategic planning model under active development led by FHWA.

Tidy workflow and R for Reproducible Research



Credit: Wickham and Grolemund, 2023

Reflections on Reproducible Research

- Personally, I cannot imagine (myself) doing research any other way; "You have at least one collaborator for any project - at the very least, yourself in 3 months".
- Making code available can only go so far; live documentation and literal programming is an essential, but often neglected, step in reproducible research.
- Tools (in R, Python) supporting reproducible research have improved tremendously over the last a few years, but the learning curve is still steep and most students and researchers have not been trained or exposed in reproducible research.
- Combining reproducible research with open data facilitates dissemination of research and speeds up scientific investigation

Questions + Acknowledgements

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