2023 INDIANA HOUSING CONFERENCE

Innovations in Housing Research

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Does Affordability Status Matter in 'Who Wants Multifamily Housing in their Backyards?'

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Motivation

Neighborhoods Matter for Children

- Better neighborhood benefits children (Watson, 2009; Chetty, Hendren, and Katz, 2016)
- Chetty et al., 2022 (Nature): Low-SES child grow up in high-SES parents occupied counties, adulthood income would increase by 20% on average
- Nuance effect on adult for inter-city relocation (Chyn and Katz, 2021)

Majority of Low-Income Children Still Remain in Lower Opportunity Neighborhoods

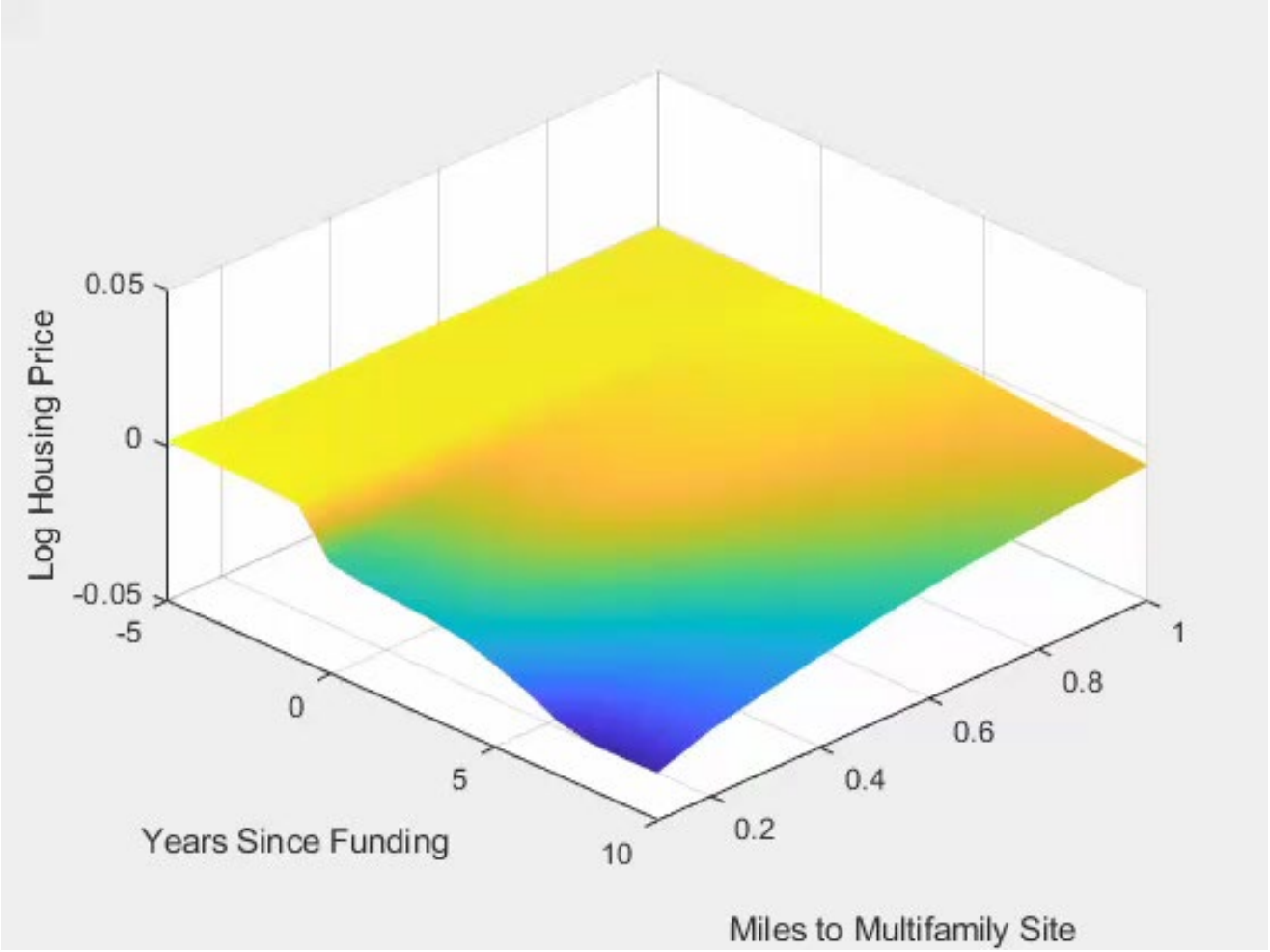
- Metro-wide Fair Market Rent (FMR) Voucher Subsidy Structure Reinforces

Costly on Neighbors to Build LIHTC Housing in Moderate-/High-Income Areas

- LIHTC is Nation's Largest Place-Based Program, 2.5million Units since 1987
- Diamond & McQuade (DM, 2019) Show LIHTC Units Decrease Surrounding Residential Property Values in Such Neighborhoods

Key Result of Earlier Research

LIHTC – All Income Neighborhoods



Research Question

Is the Diamond & McQuade (2019) Result Unique to Affordable Housing or Common for all Multifamily Housing?

- NIMBYism of Apartments is Well Established
- Large Unsubsidized Apartments Decrease Rents by 6% in Lower-income Areas (Asquith et al, 2021)

How Do Effects Differ Based Upon a Neighborhood's Existing Density?

- Area Income is Highly Correlated with Density
- Potentially Easier to "hide" Affordable Status in Dense Areas

LIHTC Program

Only Place-Based Subsidy

- Originated through passage of the Tax Reform Act of 1986
- Awarding private developers tax credits which use to offset federal income tax liabilities
- At least 2.5 million units subsidized since 1987

Two Main Variants

- Awards developers tax credits up to 5.2% of the project's development costs minus land for 10-years for operating rent-restricted units for at least 15 years
- Awards up to 11.7% of the project's development costs minus land for 10-years but requires either new construction or a substantial rehabilitation, with restricted use of municipal bond financing

In This Paper…

Create a Database of New Multifamily Developments from Yardi Matrix

- Focuses on Multifamily Buildings w/ 50+ Units in Major US Metros

Replicate and Extend Original DM Study using Identical Non-Parametric Estimator and Similar Data Supplemented with New Data (Yardi)

- Follow Diamond & McQuade (2019) as Closely as Possible
- 1995-2012, Expand to 350 Counties across 35 States
- Expand additional 4 years of housing transactions data, 1995-2016

Explore Supply and Demand Mechanisms

- Focus on Rehabs to Control for Supply and Congestion Effects

Re-Calculate Welfare Effects Using New Estimates

Data – Similar to Original Study

LIHTC Database

- Originally Assembled by HUD, Annual Updates
- Downloaded Exact DM Version from Website

U.S. Census Bureau Data (1990)

- Block-Group Level, Within-Metro Relative Ranking

Home Mortgage Disclosure Act (HMDA)

- Home Buyer Income & Race to Recover Welfare Effects

Residential Price Transactions (Corelogic)

- Original Study Uses DataQuick; Acquired by Corelogic in 2013
- Unable to Exactly Match DataQuick Sample, Coverage Expands Over Time
- Focus on All Available Counties using the Same Standard (>1,000 transactions per year, Available as of 1996)

New Data - Yardi Matrix

Monthly Property-level Information

- Physical attributes, rent histories, year of development, exact address location
- Specializes in Rental Developments with more than 50 Units
- Drop Buildings Known to be Subsidized (Most Likely LIHTC)

Tracks over 3.69 Million Rental Units

- Focus on 1995-2012 like Original DM Study
- 82.4% Coverage as Compared to Census Buildings w/ 5+ Unit Completions

Combined Sample Attributes

- Focus on LIHTC & Market-Rate (Yardi) in 350 counties across 35 states
- 6,640 LIHTC and 8,566 Market-Rate Multifamily Properties
- 16 million residential transactions within 1.5 miles of Building from 1995-2016

Endogeneity

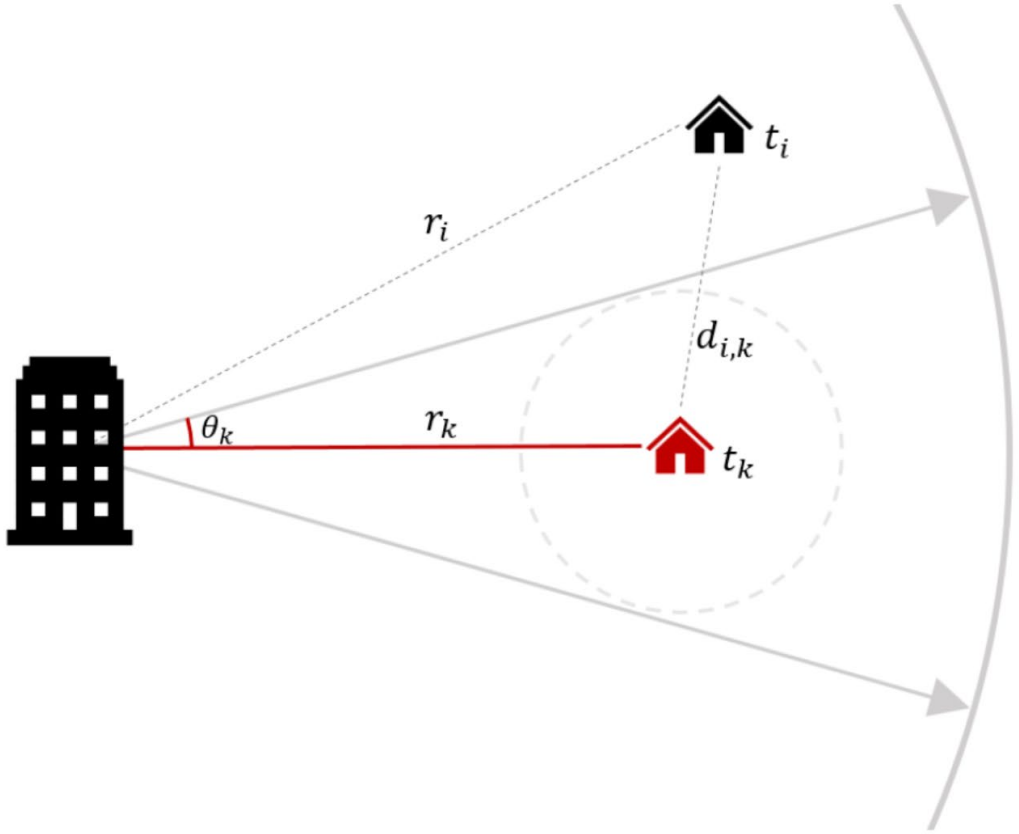
Empirical Problem

- LIHTC Developers Locate Projects in Already Improving Areas
- This Called Omitted Variable Bias (Correlation ≠ Causation)

Control for Hyperlocal Price Trend

- Precise location of new development is plausible exogenous due to highly local lot supply and constrained local land supply
- Though general neighborhood decision is endogenous, it is difficult for developers to time the market due to external and unpredictable regulation delays
- Our flat price surface (w/ large CIs) before the LIHTC treatment helps validate our identification strategy

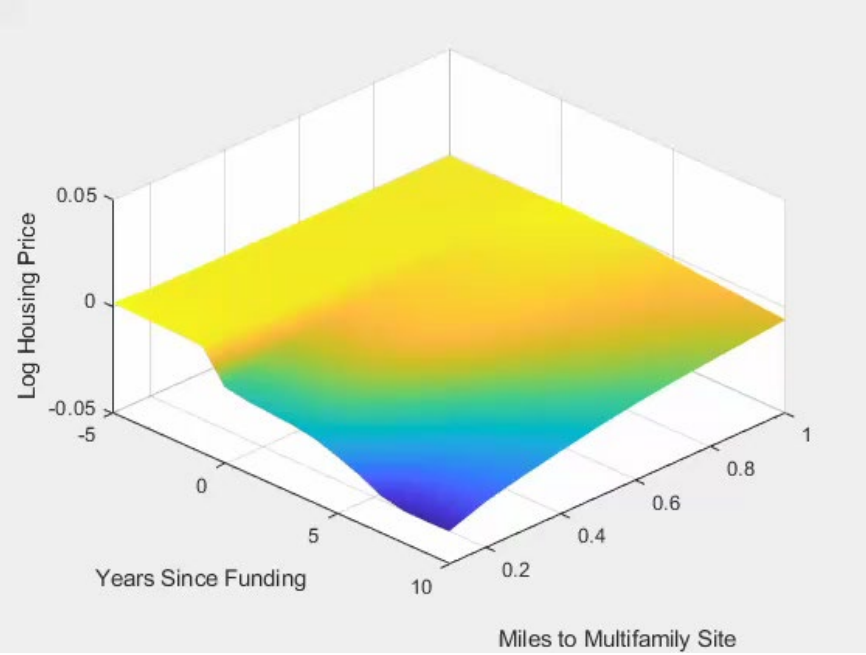
Diagram of Empirical Strategy



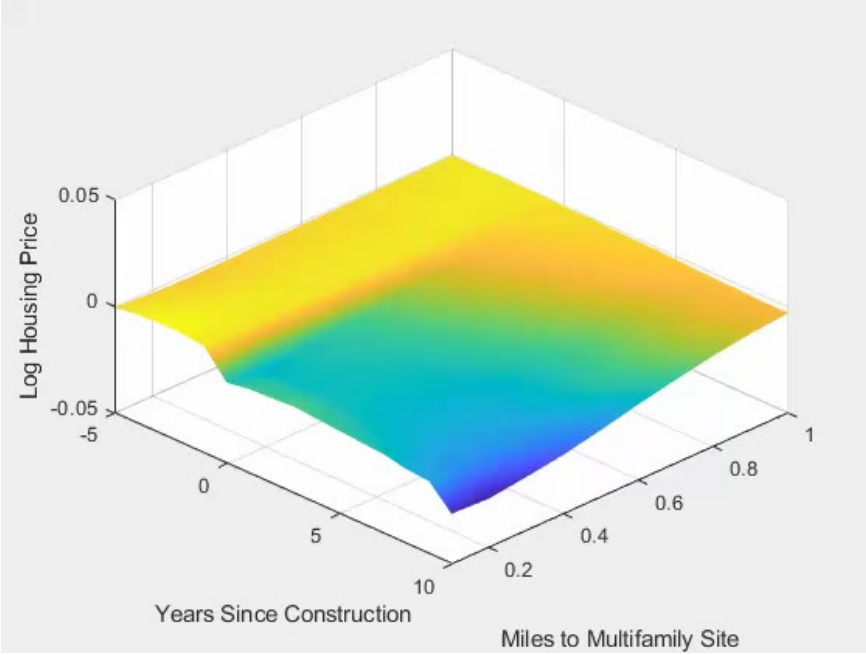
k represents the point that estimating the empirical derivative
i represents the selected housing transaction to calculate the derivative

Main Effect: All Neighborhoods

LIHTC



Market-Rate Multifamily (Yardi)



Neighborhood Income Status

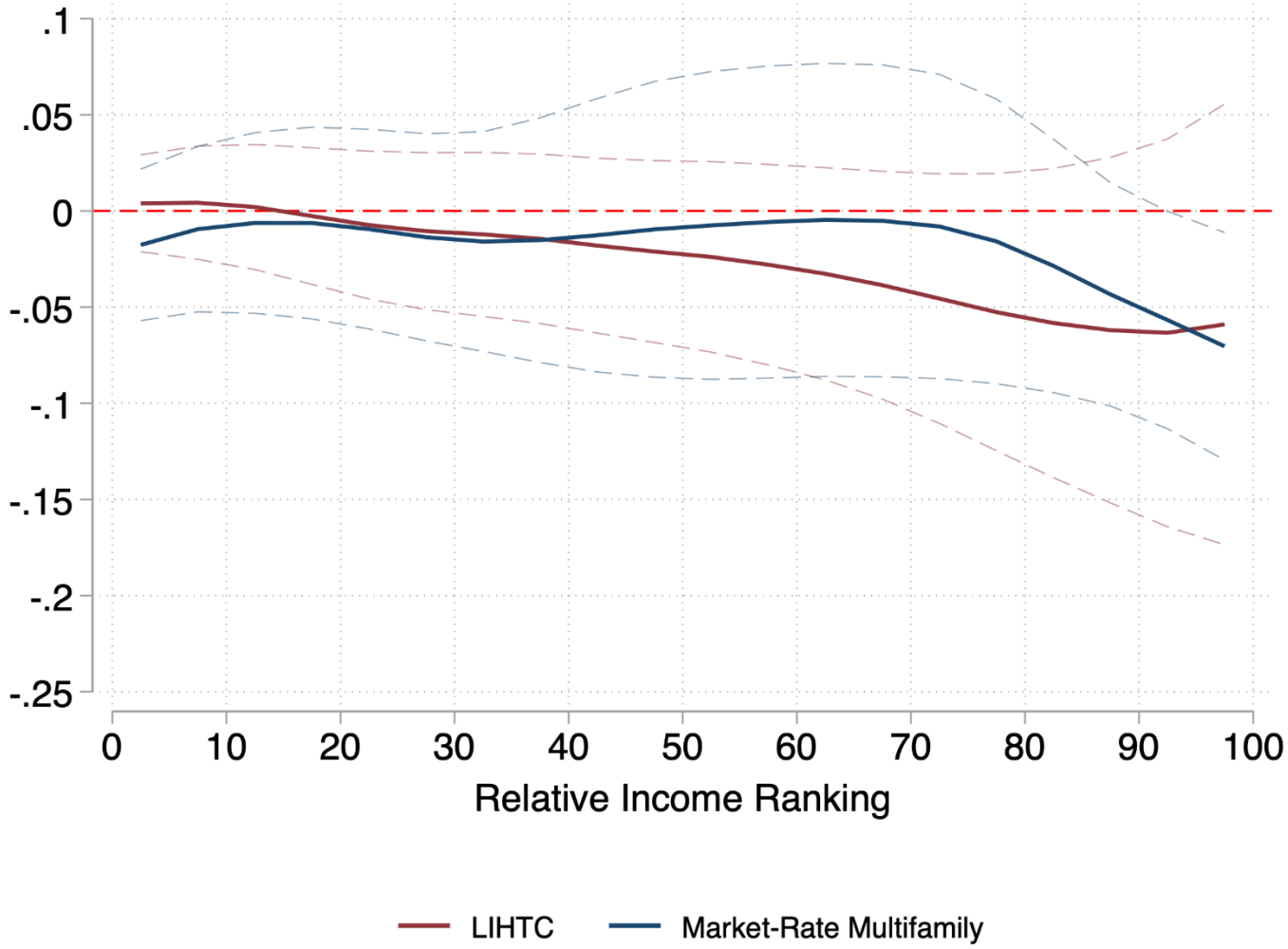
Previous Research Used National Dollar Cutoffs

- Ranked All Block Groups with LIHTC Units in Entire United States
- Even the 75th Pct of Income ($38,177) is Relatively Low
- Some Metros Had Only High- or Low-Income Neighborhoods

Prefer to Use Within-Metro Relative Ranking

- Rank All Block Groups by Median Income For Each Metro Area
- Define Four Income Quartiles (Q1 is Lowest, Q4 Highest)
- Fewer LIHTC Units in Above Median Income Neighborhoods
- Show Net Price Effect After Differencing Any Pre-Trends

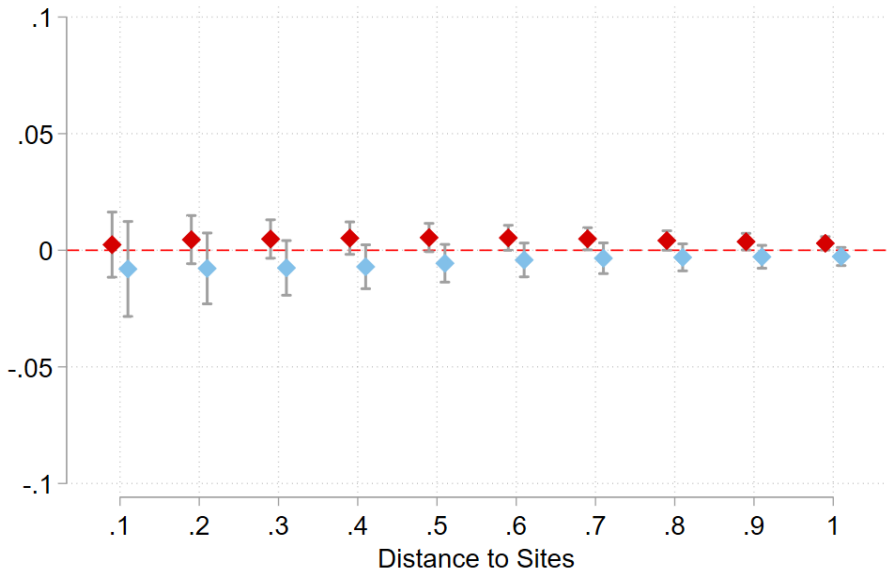
Price Effect w.r.t Income



Net Price Effect by Distance

Q1 Income (lowest)
BG Median HHs Income < 25th Percentile

Q4 Income (Highest)
BG Median HHs Income > 75th Percentile



90% CI LIHTC Market-Rate Multifamily

Net Price Effect by Distance

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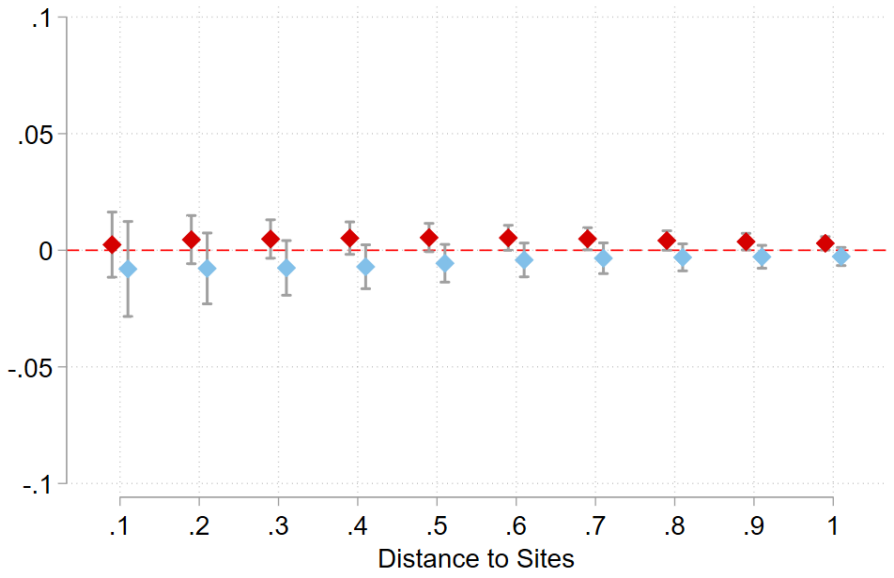
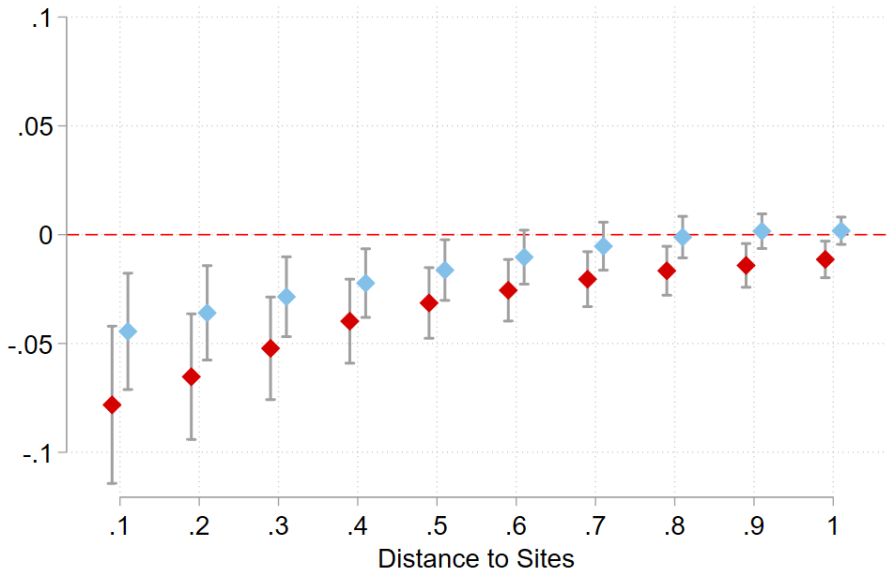
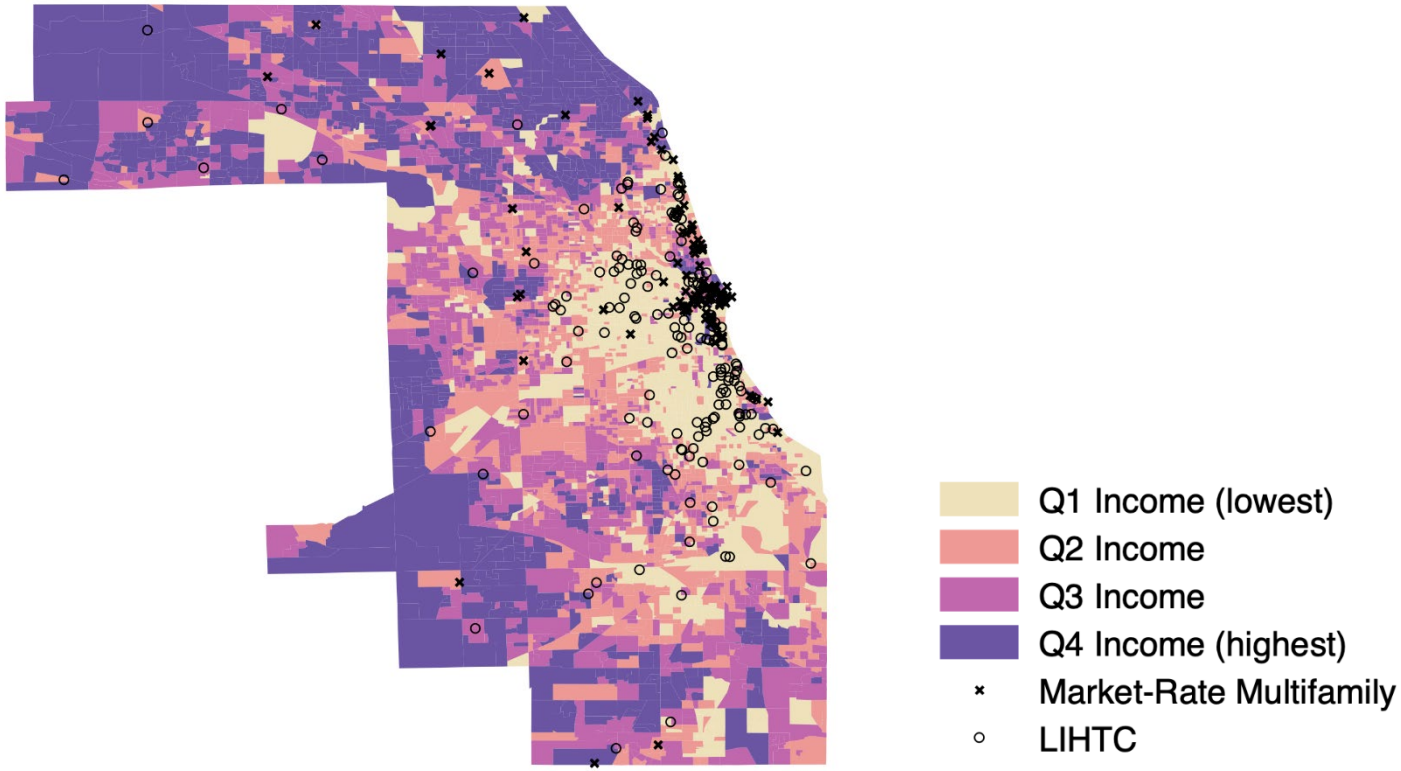


Q4 Income (Highest)
BG Median HHs Income > 75th Percentile

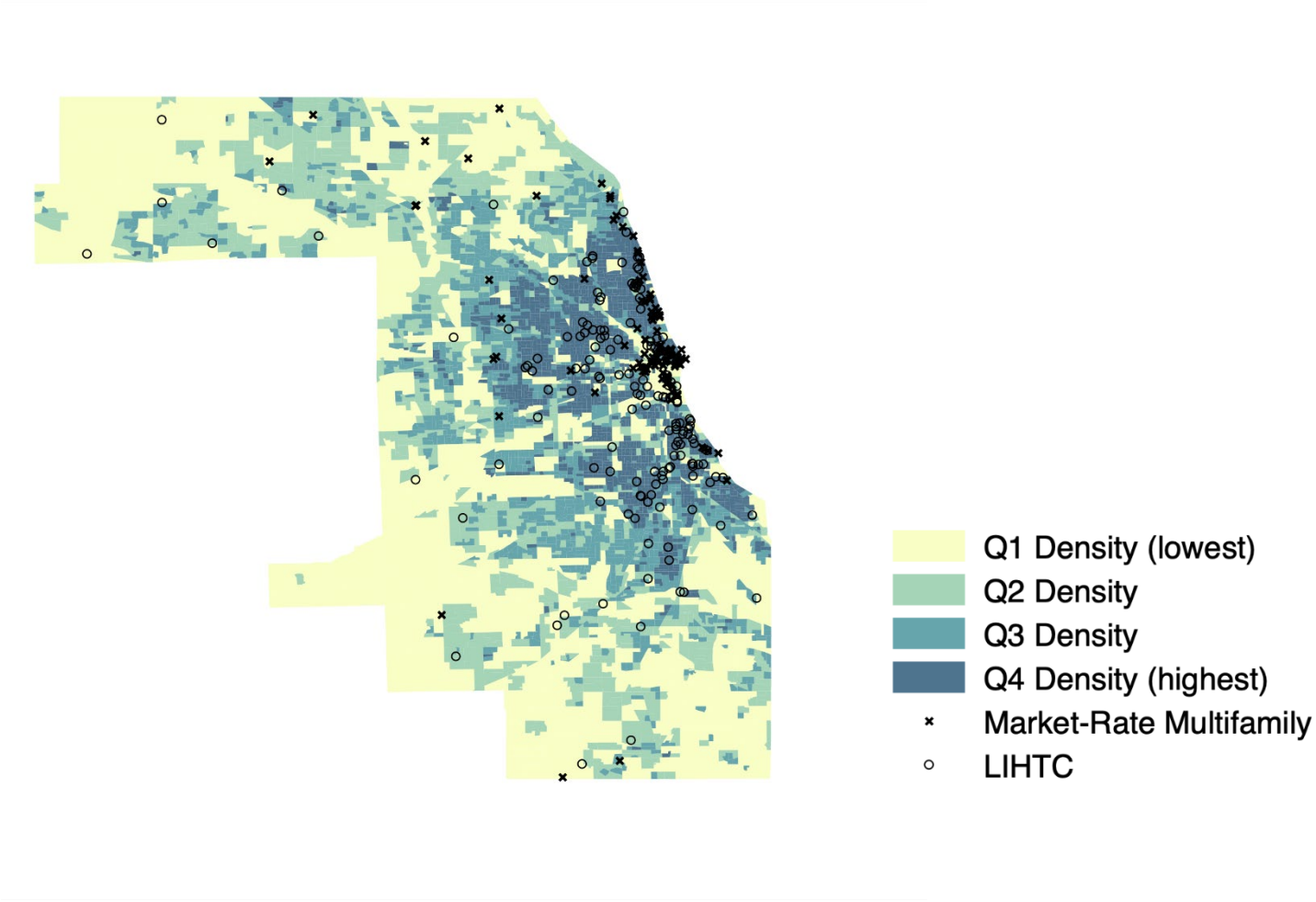


90% CI LIHTC Market-Rate Multifamily

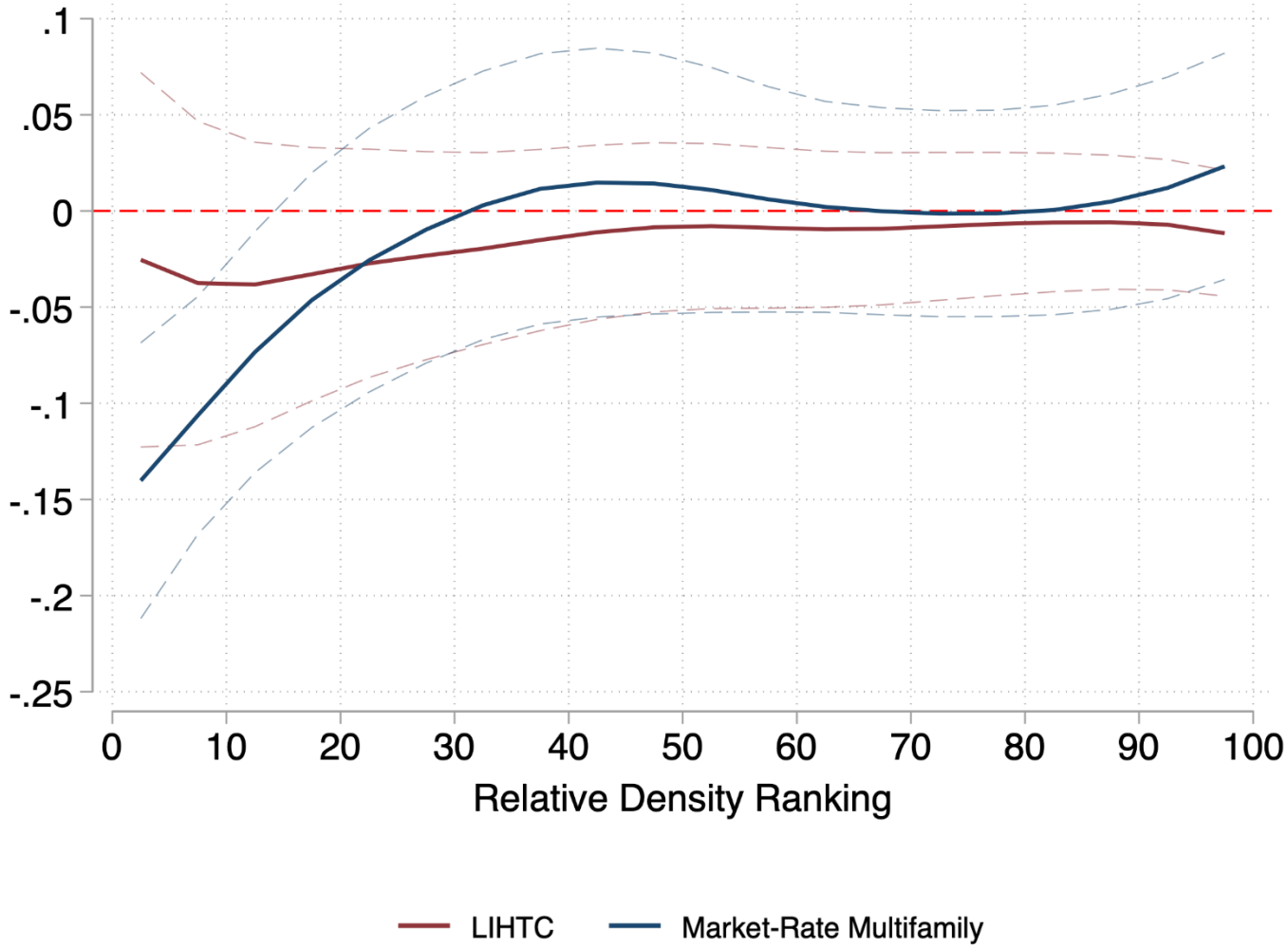
Income Map: Chicago



Density Map: Chicago

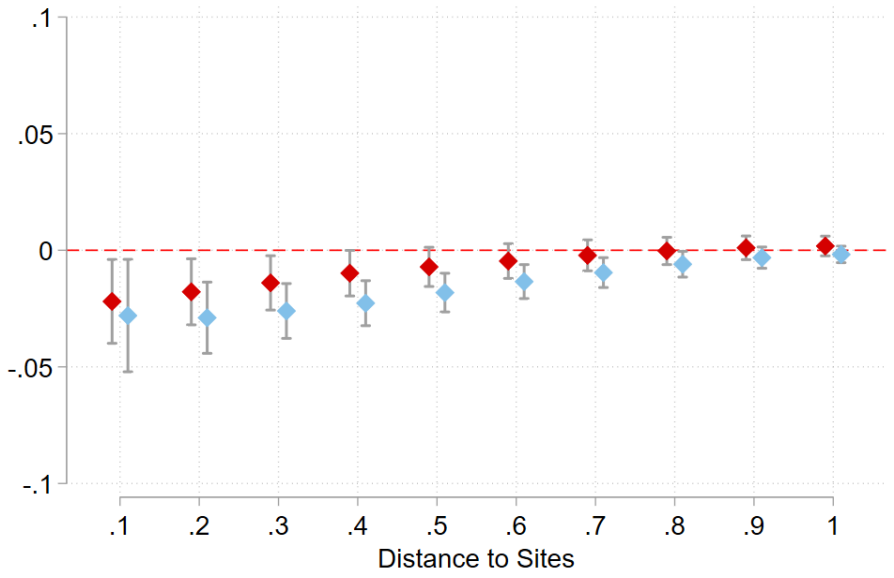


Price Effect w.r.t Density

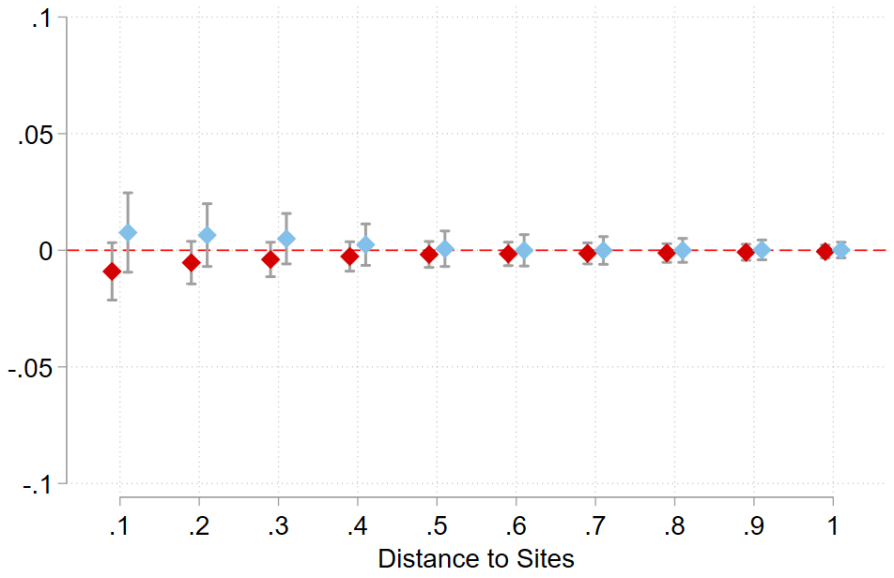


Net Price Effect by Distance

Low Density
BG Density < 50 Percentile



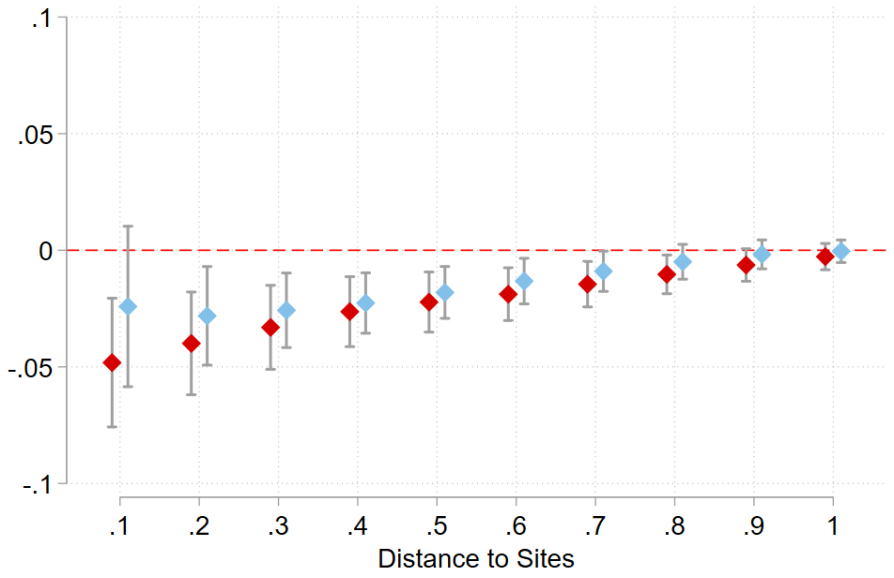
High Density
BG Density > 50 Percentile



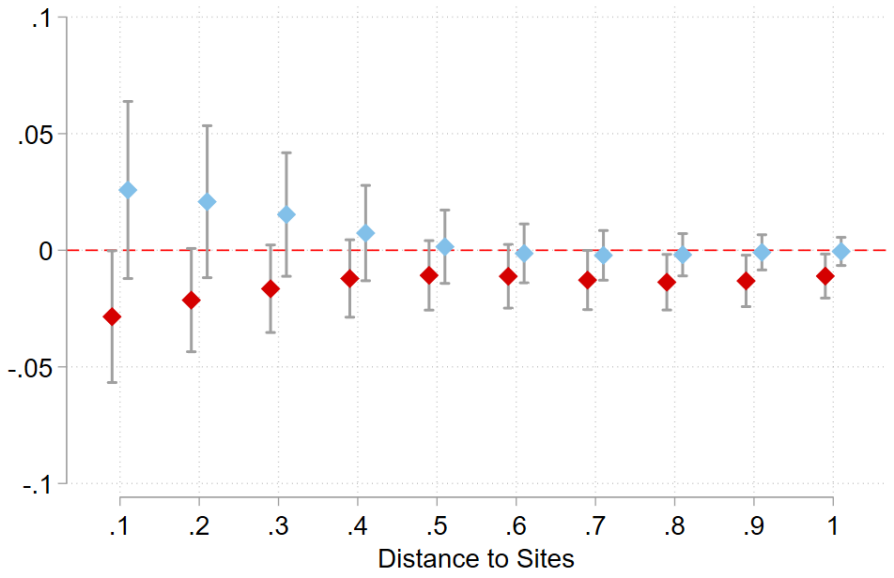
90% CI LIHTC Market-Rate Multifamily

Above-Median Income Areas

High Income & Low Density
Block Group Median HHs Income > 50th Pct
BG Density < 50th Percentile



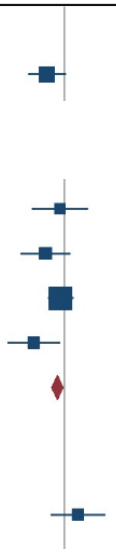
High Income & High Density
Block Group Median HHs Income > 50th Pct
BG Density > 50th Percentile



90% CI LIHTC Market-Rate Multifamily

Above Median Inc & Density

Study	N	Effect size with 90% CI
LIHTC		
Main Result	384	-0.0178 [-0.0369, 0.0012]
Q1/Q4 as Low/High Income or Density		
DM Cutoffs		
Renter Share as Density	242	-0.0046 [-0.0334, 0.0243]
Single Family Detached Unit Share as Density	385	-0.0195 [-0.0445, 0.0056]
Within Metro Ranking for In-Sample Block Groups	918	-0.0038 [-0.0163, 0.0086]
Matched Sample	237	-0.0318 [-0.0581, -0.0056]
		-0.0072 [-0.0137, -0.0006]
Market-Rate Multifamily		
Main Result	557	0.0142 [-0.0131, 0.0414]
Q1/Q4 as Low/High Income or Density		
DM Cutoffs		
Renter Share as Density		
Single Family Detached Unit Share as Density		
Within Metro Ranking for In-Sample Block Groups		
Matched Sample		



Test of group differences: $Q_b(1) = 3.85$, $p = 0.05$

High Income and Dense Areas

Study	N	Effect size with 90% CI
LIHTC		
Main Result	384	-0.0178 [-0.0369, 0.0012]
Q1/Q4 as Low/High Income or Density	22	-0.1027 [-0.2516, 0.0463]
DM Cutoffs	1309	-0.0006 [-0.0107, 0.0094]
Renter Share as Density	242	-0.0046 [-0.0334, 0.0243]
Single Family Detached Unit Share as Density	385	-0.0195 [-0.0445, 0.0056]
Within Metro Ranking for In-Sample Block Groups	918	-0.0038 [-0.0163, 0.0086]
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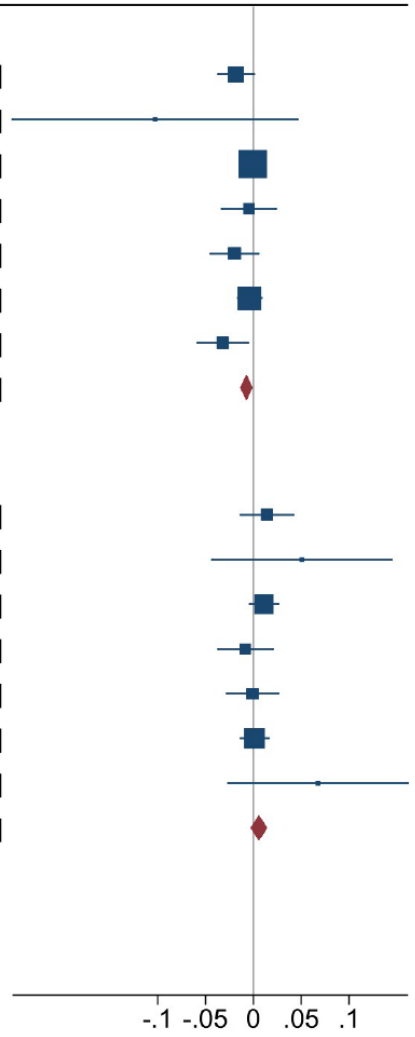
		-0.0072 [-0.0137, -0.0006]
Market-Rate Multifamily		
Main Result	557	0.0142 [-0.0131, 0.0414]
Q1/Q4 as Low/High Income or Density	57	0.0511 [-0.0429, 0.1452]
DM Cutoffs	1142	0.0111 [-0.0041, 0.0263]
Renter Share as Density	623	-0.0081 [-0.0371, 0.0208]
Single Family Detached Unit Share as Density	936	-0.0007 [-0.0275, 0.0261]
Within Metro Ranking for In-Sample Block Groups	1220	0.0014 [-0.0133, 0.0161]
Matched Sample	122	0.0676 [-0.0262, 0.1614]
		0.0058 [-0.0029, 0.0146]

Test of group differences: $Q_b(1) = 3.85$, $p = 0.05$



Welfare Calculation

Recover MWTP

- Using empirical derivative to recover the MWTP and preference parameters
- Identical procedure and assumptions of original DM study
- Average and aggregate by neighborhood type: Amenity & Dis-amenity

Average Willingness to Pay

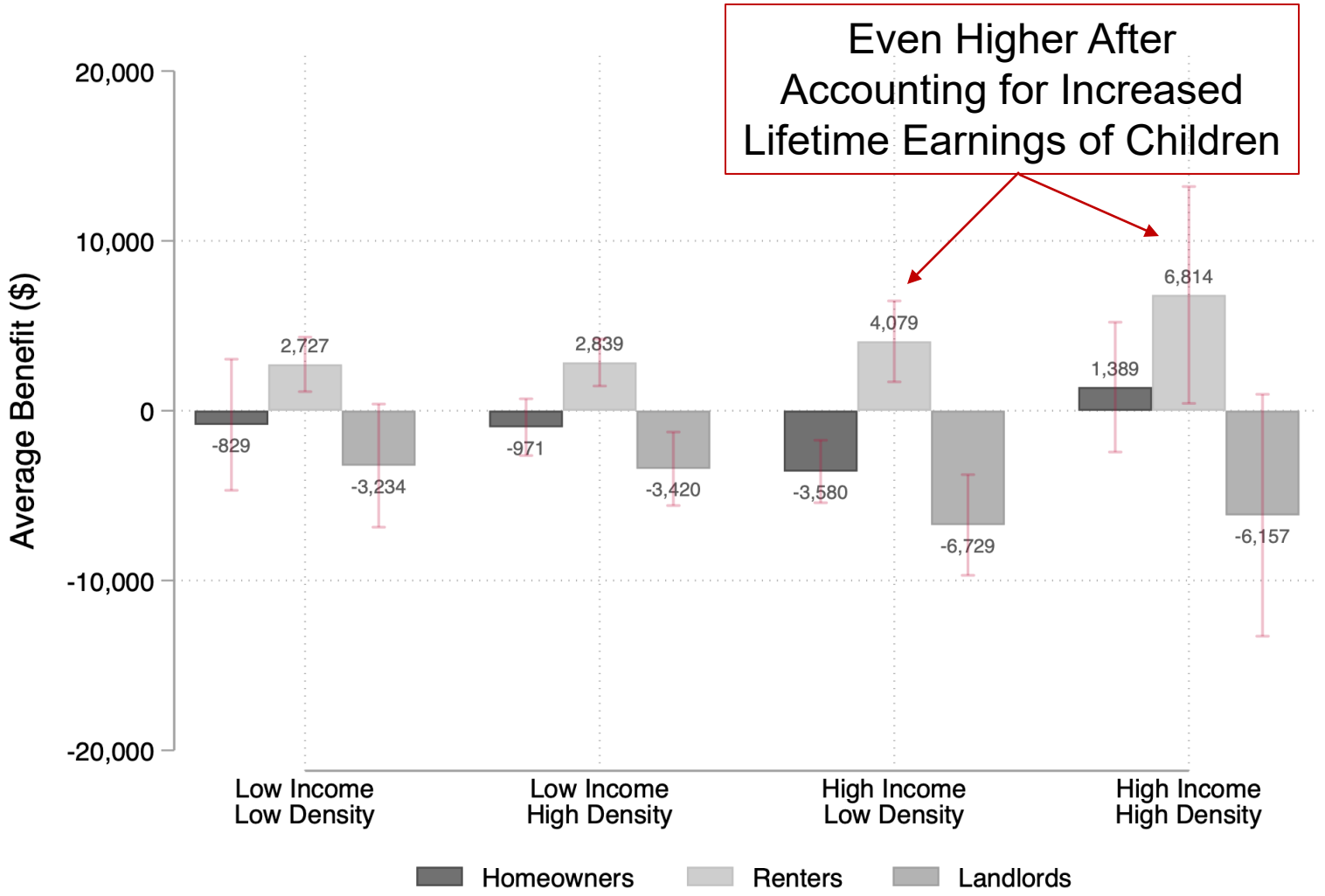
- Homeowners: varies by (dis)amenities for living close to sites
- Absentee landlords: mostly utility loss fully due to (-) price effect
- Renters: always better off due to combine two effects

Aggregate Benefits to Society

- Less harm of LIHTC Properties in Abv Median Density Areas (Large CIs)
- Multifamily properties bring $105 million benefits in high-income high-density area

Calculation Does <u>Not</u> Account for ↑ Lifetime Earnings

Average Benefit from LIHTC



Summary and Implications

Similar Spillover Effects from Multifamily Developments Regardless of LIHTC Subsidy

- Subsidized Status Matters Less in Sufficiently Dense Neighborhoods
- Consistent with Earlier NIMBY Evidence Against Any Multifamily in Less Dense Areas
- Our results suggest a demand story instead of supply or congestion

Target LIHTC Housing to Above-Median-Income Areas with Existing Density (ie, not suburbs)

- Minimizes Negative Spillovers, Maximizes Benefits
- Provides Children Access to Higher Quality Education and Social Networks
- Aggregate Benefits should be much Larger after accounting for increases in lifetime earnings of children (less subsidies, higher income taxes paid, etc.)

Considering automated vehicle deployment uncertainty in the design of optimal parking garages using real options

2023 Indiana Housing Conference

Presentation: Claudio Martani [1]

Authors: Arnor Elvarsson [2], Claudio Martani [1], Bryan T. Adey [2]

[1] F*u*RI Lab, School of Construction Management Technology, Purdue University

[2] Institute of Construction and Infrastructure Management, ETH Zürich (ETHZ)

September, 26. 2023

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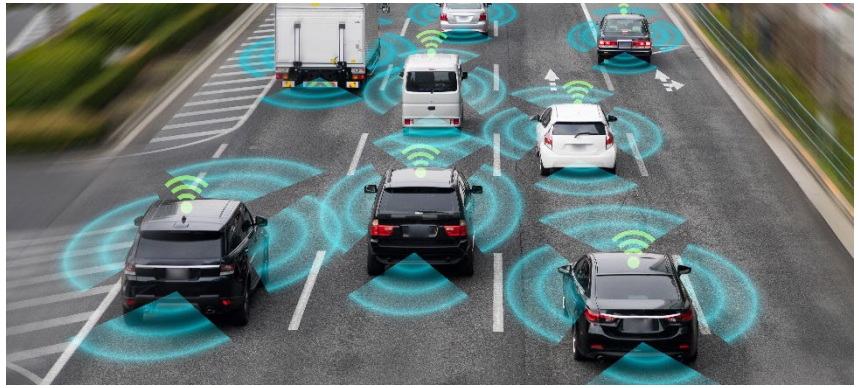
Context

Electrical vehicles

Autonomous vehicles

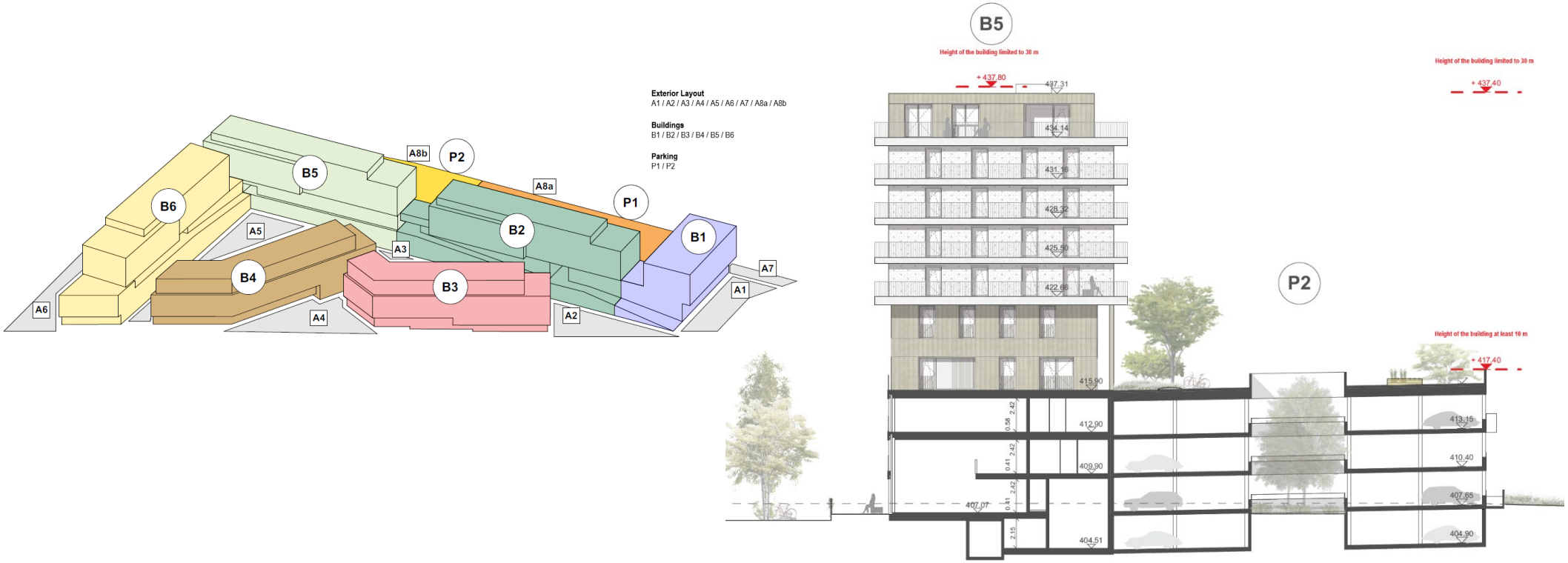


Future of parking garage

Scope

Research Question

With the uncertainty of AV deployment and its effect on parking demand, to what extent is the implementation of flexibility in infrastructure design beneficial?



Elvarsson, Arnór B., Claudio Martani, and Bryan T. Adey. "Considering automated vehicle deployment uncertainty in the design of optimal parking garages using real options." Journal of Building Engineering 34 (2021): 101703.

Steps

1. Define service and expected level of service

2. Build the objective function

3. Model the uncertainty related to key variables

4. Describe the possible intervention options

5. Evaluate the intervention options

1. Define service and expected level of service

Stakeholder
Owner
User

Elvarsson, Arnór B., Claudio Martani, and Bryan T. Adey. "Considering automated vehicle deployment uncertainty in the design of optimal parking garages using real options." Journal of Building Engineering 34 (2021): 101703.

1. Define service and expected level of service

Stakeholder	Cost	Description
Owner	Construction cost	Initial cost of building is dependent on the excavation costs, needed construction materials and the labor efforts required. The largest difference between parking and residential facilities is the cost of interior.
	Development cost	Costs of use transition include the different instalments to the interior required as well as to the exterior. They also include the labor efforts and material costs.
	Demolition cost	Includes removing the building, and the resulting debris, at the end of a building's life-time
	Rent income	Owner's positive cost due to the user's use of the infrastructure
	Operational costs	A cost dependent on the use and interior of the building
User	Cost of no parking	If parking is removed, users that want to park will be affected, both economically and in terms of comfort

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1. Define service and expected level of service

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	Development cost	Costs of use transition include the different instalments to the interior required as well as to the exterior. They also include the labor efforts and material costs.	Variable. Dependent on the design
	Demolition cost	Includes removing the building, and the resulting debris, at the end of a building's life-time	Variable. Dependent on the design
	Rent income	Owner's positive cost due to the user's use of the infrastructure	1'452 CHF/year per parking spot*
			263 CHF/year/sq.m. for residential use*
	Operational costs	A cost dependent on the use and interior of the building	600 CHF/year per parking spot**
			35 CHF/year/sq.m. for residential use**
User	Cost of no parking	If parking is removed, users that want to park will be affected, both economically and in terms of comfort	500 CHF/person**

* Source: Wüest & Partner, 2016 | ** Source: Estimate made by authors

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2. Build the objective function

Objective function: difference between benefits and costs over the garage's life-time (T)

$$Z_i = \sum_{t=0}^{T} (d_t \cdot \sum_i (B_{i,t} - C_{i,t}))$$

$$B_{i,t} = B_{p,t} + B_{r,t}$$

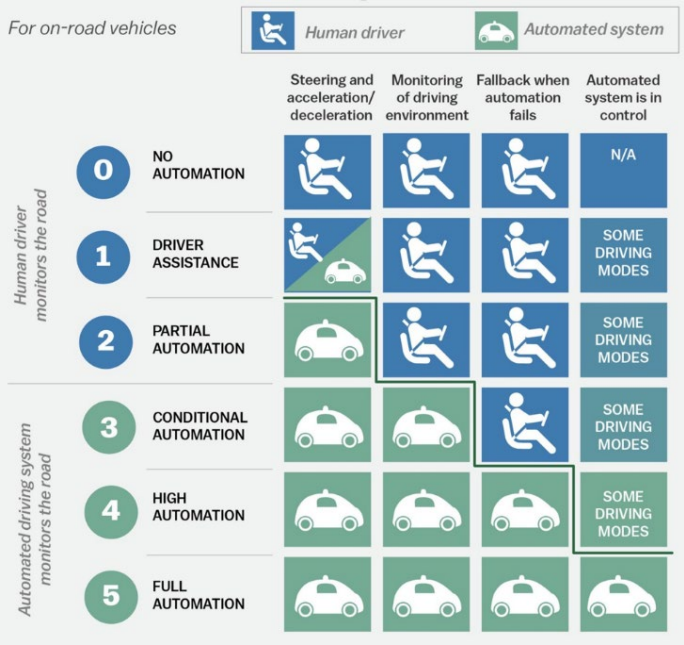
Where: (p) is the income from the rent of parking spots and (r) is the rent from the rent of apartments

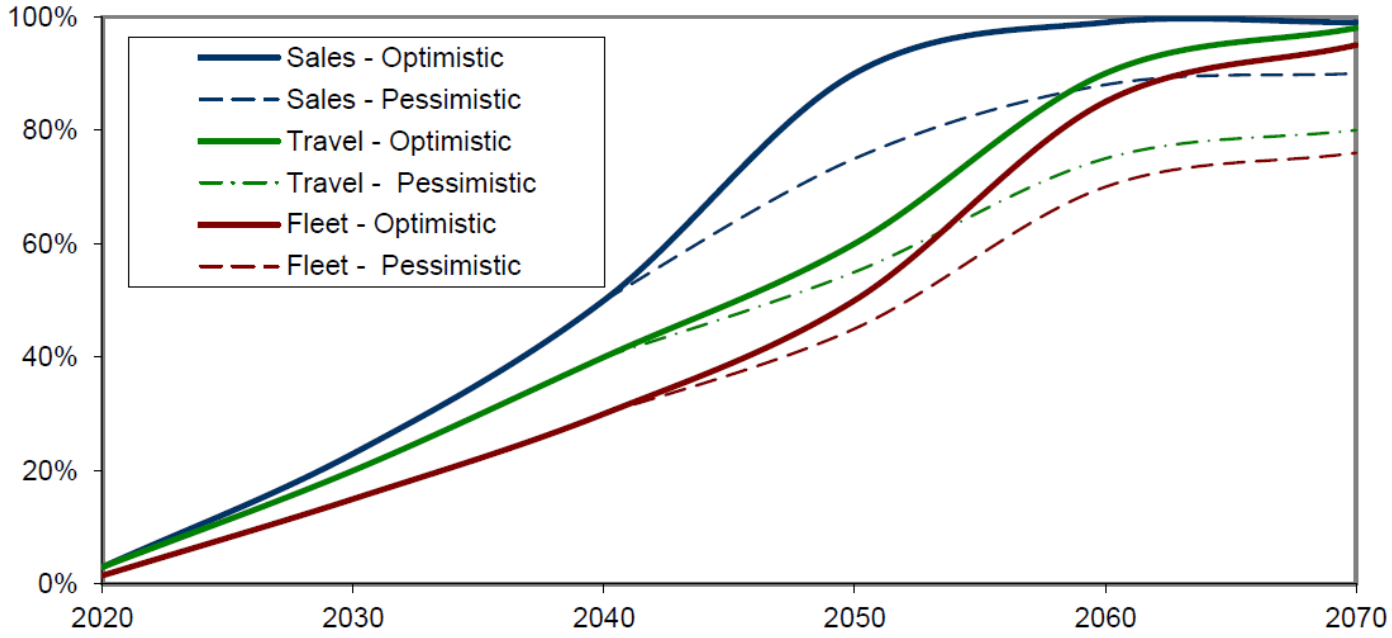
$$C_t = C_{c,t} + C_{dem,t} + C_{dev,t} + C_{op,t} + C_{user,t}$$

Where: Construction (c), demolition (dem), development (dev), operational (op) and user (user) costs

Elvarsson, Arnór B., Claudio Martani, and Bryan T. Adey. "Considering automated vehicle deployment uncertainty in the design of optimal parking garages using real options." Journal of Building Engineering 34 (2021): 101703.

3. Model the uncertainty related to key variables



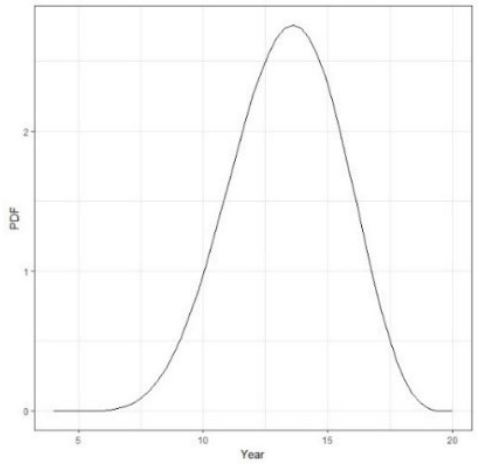


Technology → Legislation → Drop in parking

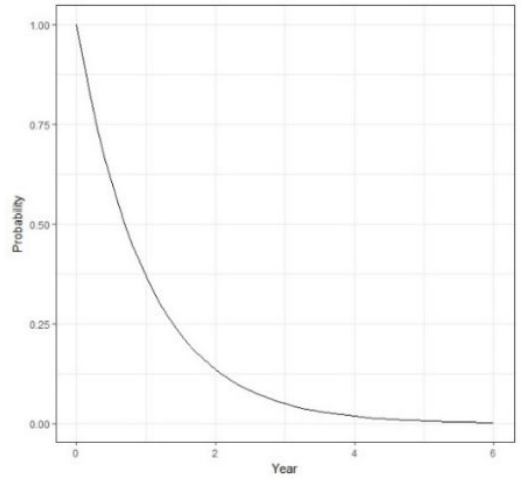
Litman, T. (2018) *Autonomous vehicle implementation predictions*, Victoria Transport Policy Institute.

3. Model the uncertainty related to key variables

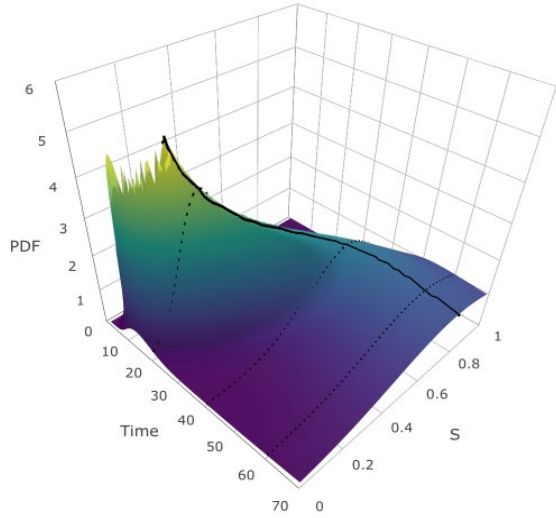
Technology



Legislation



Drop in parking



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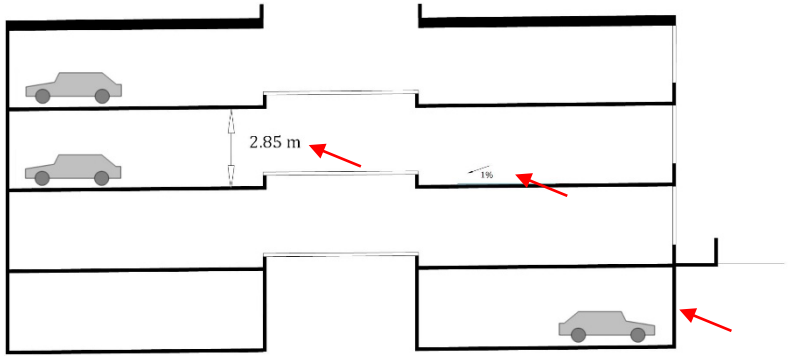
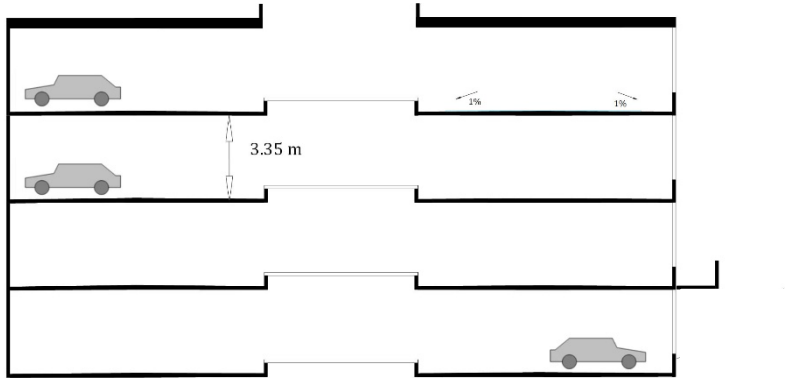
4. Describe the possible intervention options

Traditional design



Flexible design



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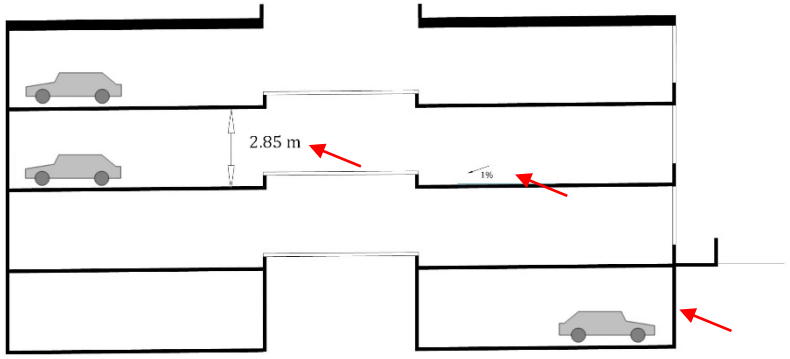
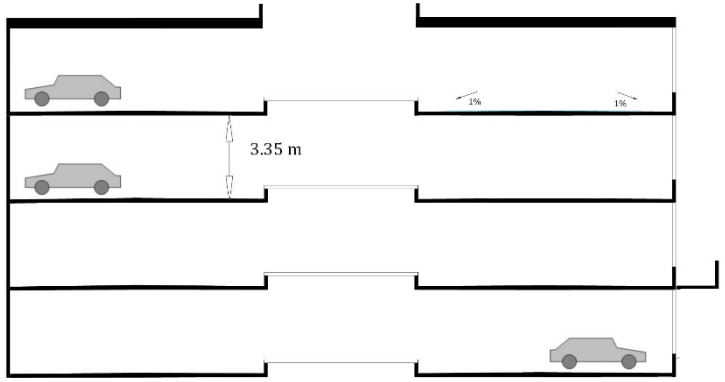
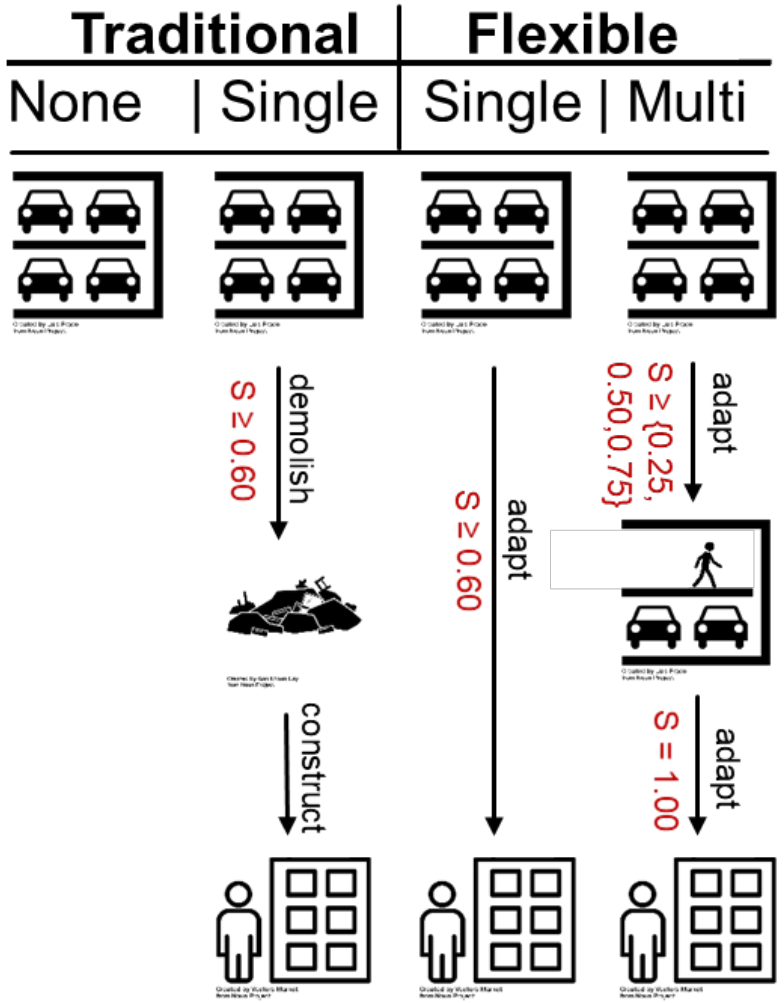


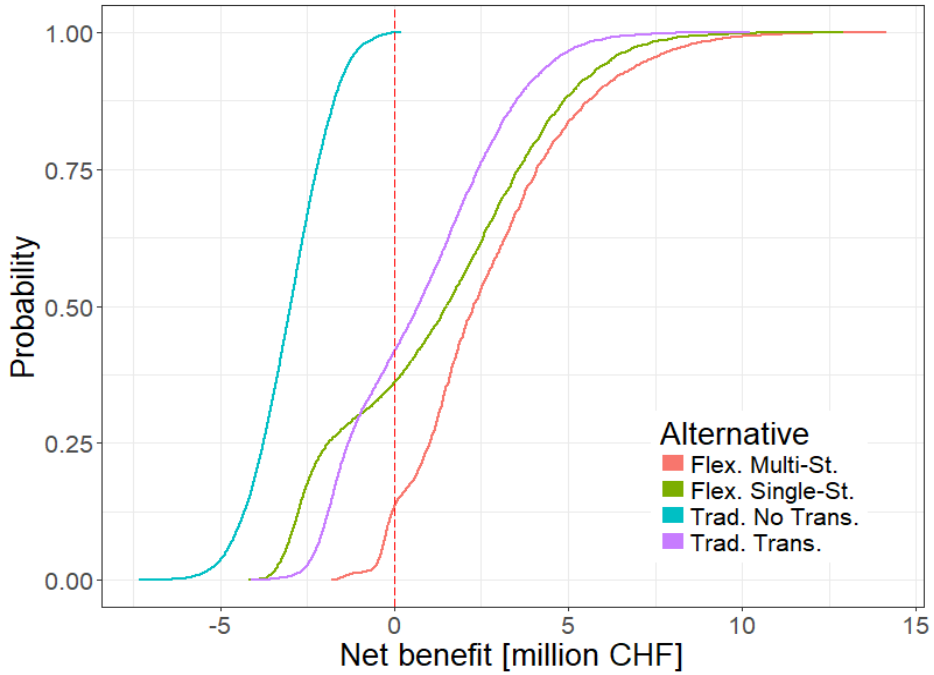
Flexible design

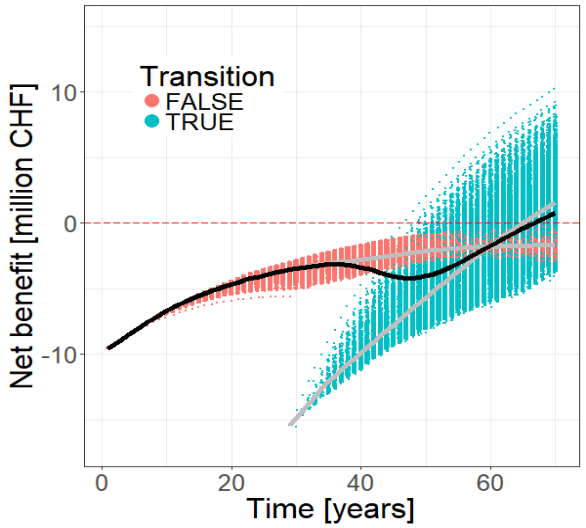


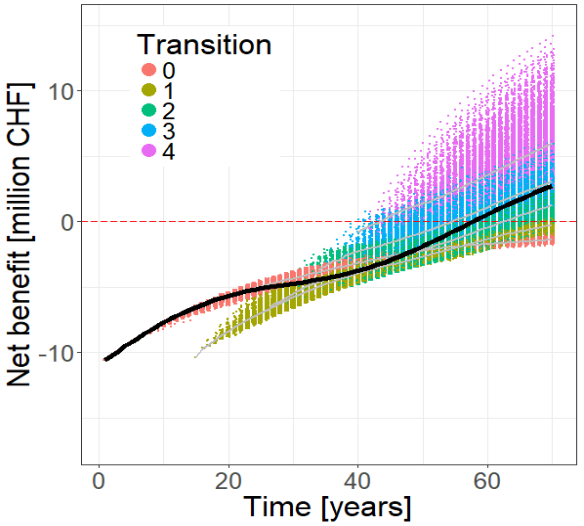


Elvarsson, Arnór B., Claudio Martani, and Bryan T. Adey. "Considering automated vehicle deployment uncertainty in the design of optimal parking garages using real options." Journal of Building Engineering 34 (2021): 101703.

5. Evaluate the intervention options







	Traditional		Flexible	
Use transition	No transition	Transition	Single-Stage (SS)	Multi-Stage (MS)
Net benefit	-3’005’697 CHF	756’504 CHF	1’260’248 CHF	2’722’191 CHF
Mean transition time [years]	-	47.6	47.6	34.2 / 44.5 /52.1 / 58.6

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Conclusions

This research advances the domain of infrastructure management by **introducing a methodology grounded in Real Options theory**. This approach aims to identify potential designs and intervention strategies for parking garages in response to the uncertainties surrounding the future of mobility.

Following the proposed methodology, owners can **enhance their capacity to assess the net benefits of their decisions** while considering the potential changes in critical uncertain contextual conditions.

The findings from the case study of the Swiss parking garage indicate that the infrastructure owner would gain advantages by proactively **preparing for the shift to autonomous vehicles through a flexible design and a multi-stage intervention strategy**, despite the need of a more substantial initial investments.

Elvarsson, Arnór B., Claudio Martani, and Bryan T. Adey. "Considering automated vehicle deployment uncertainty in the design of optimal parking garages using real options." Journal of Building Engineering 34 (2021): 101703.

Thank you

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CENTER FOR HIGH PERFORMANCE BUILDINGS AT PURDUE

MySmartE – A software platform for smart and connected energy-aware residential communities

September 26th, 2023

Team

Principal Research Investigators

- *Panagiota Karava (Civil)*
- *Ilias Bilionis (Mechanical)*
- *James Braun (Mechanical)*
- *Thanh Nguyen (Management)*
- *Leigh Raymond (Political Science)*
- *Julia Rayz (CIT)*
- *Torsten Reimer (Communication)*

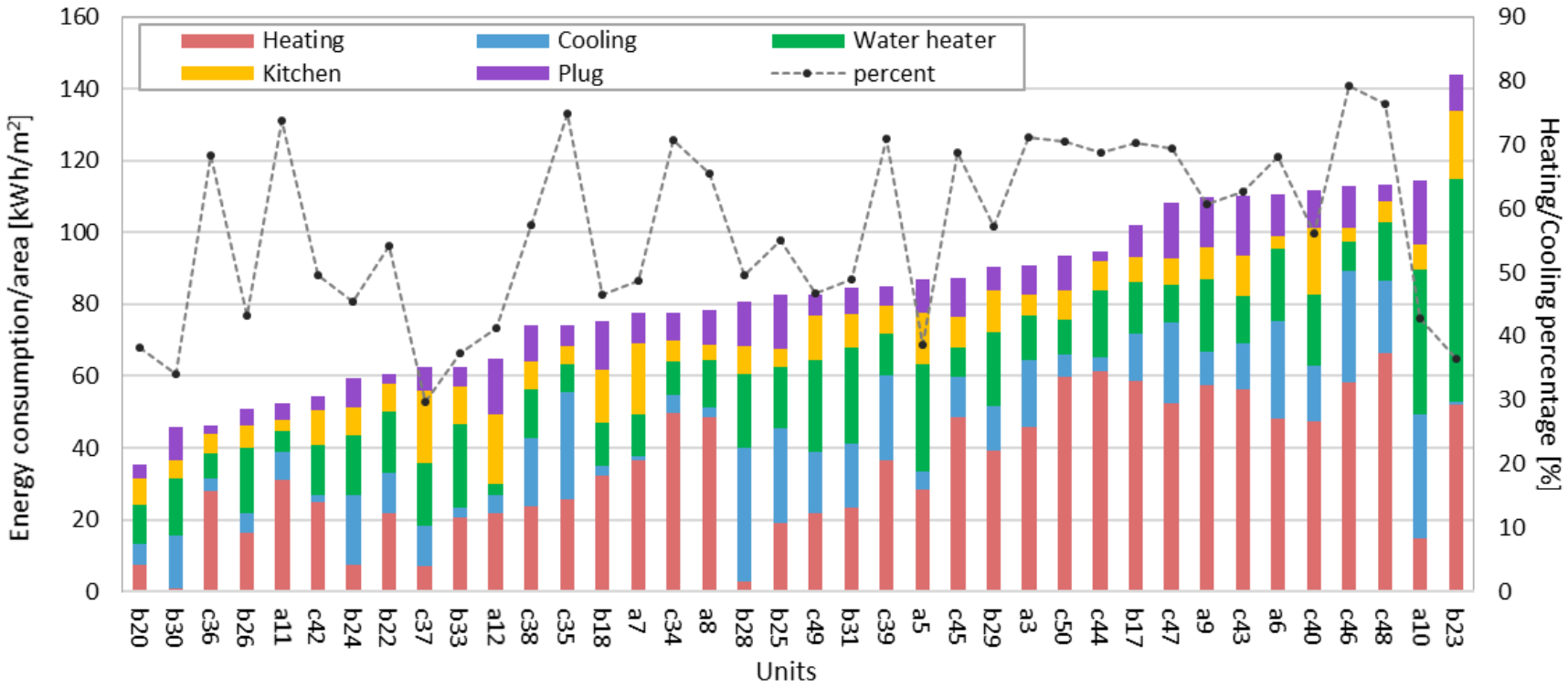
Community Partners

- *Jacob Sipe (IHCDA)*
- *Gary Hobbs (BWI)*

Why focus on residential sector?

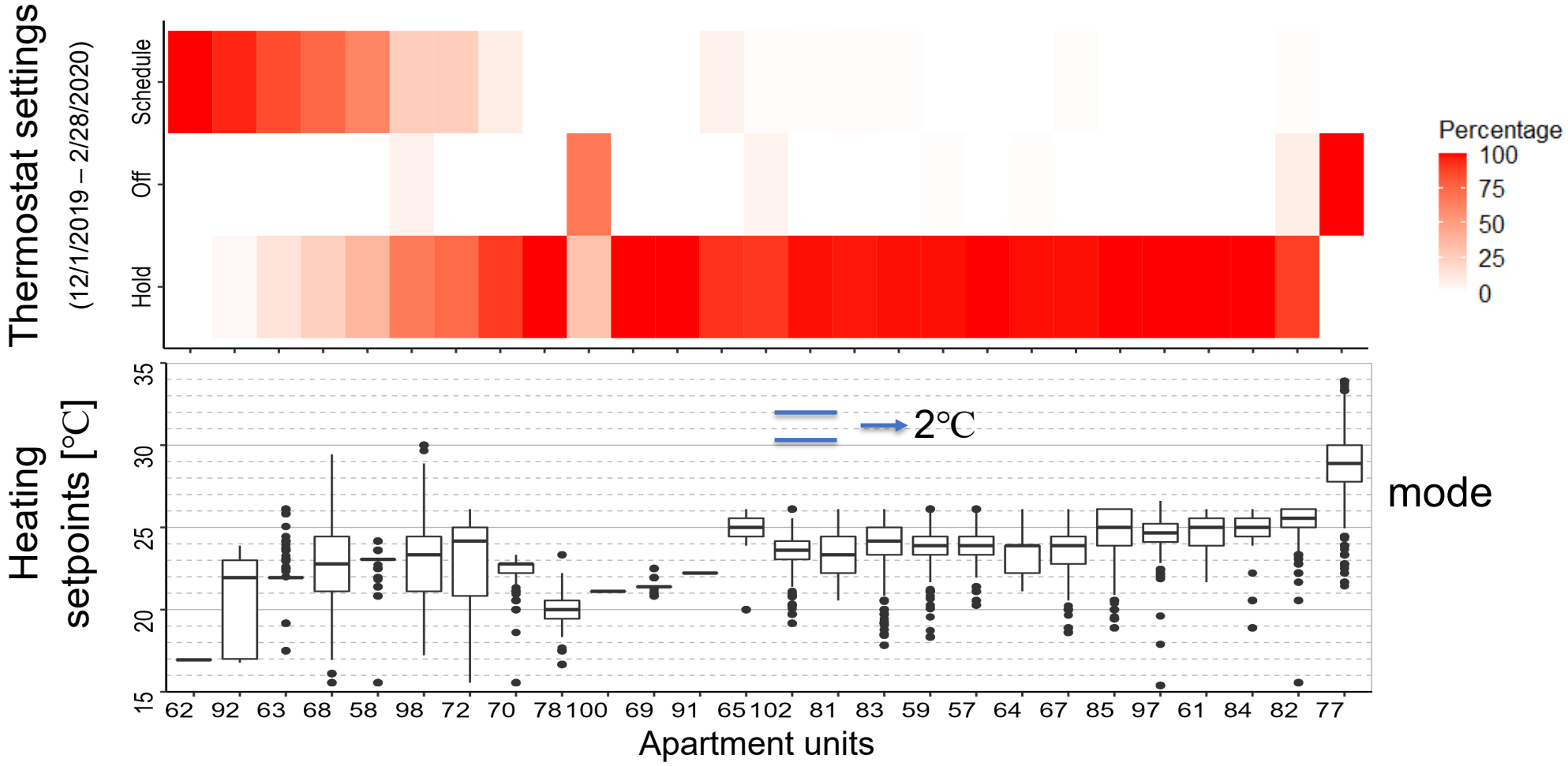
- 20% of total energy use and GHG emissions in the US
- Significant investments on energy efficiency programs

Why focus on resident engagement?



- Large variations (38–143 kWh/m^2) in total unit-level energy consumption
- HC ranges from 30 to 80% (average 56%) of the total energy consumption.

Why focus on thermostat-adjustment behavior?



- High usage of **fixed setpoints**

MySmartE – A software platform for smart and connected energy-aware residential communities

ihcda
Indiana Housing & Community Development Authority

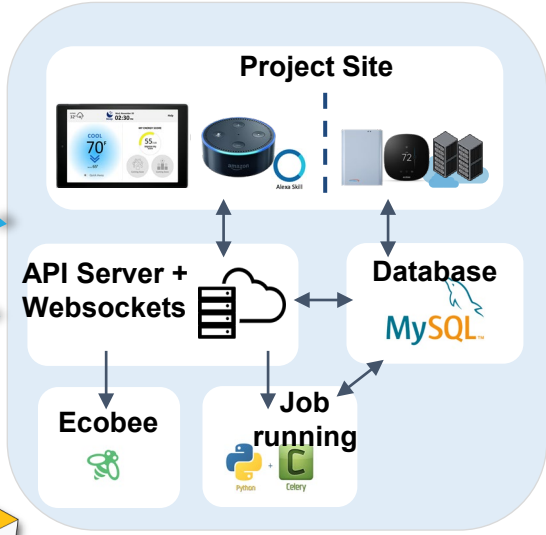
*Launches **Moving Forward program***

BWi

*Builds innovative **housing communities***

PURDUE UNIVERSITY

*Conducts **sociotechnical** research and develops new **S&C resident engagement** technology*



MySmartE app is a home energy management system that works with a tablet and amazon alexa and helps residents in understanding and reducing their home energy use

Our Pilot S&CC

Community 1
(50 households, Indianapolis)

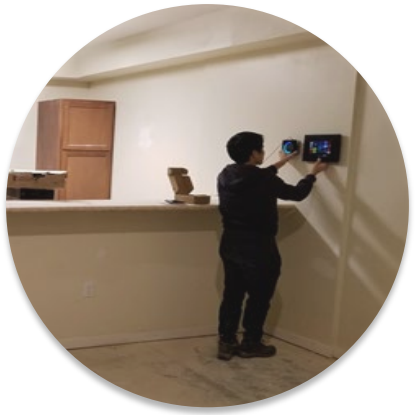
Community 2
(44 households, Fort Wayne)

Community 3
(11 households, South Bend)

Community 4
(25 households, New Albany)

Smart thermostat &
Wifi-enabled power meter

App development



Installation &
Virtual onboarding

Resident on-site
onboarding

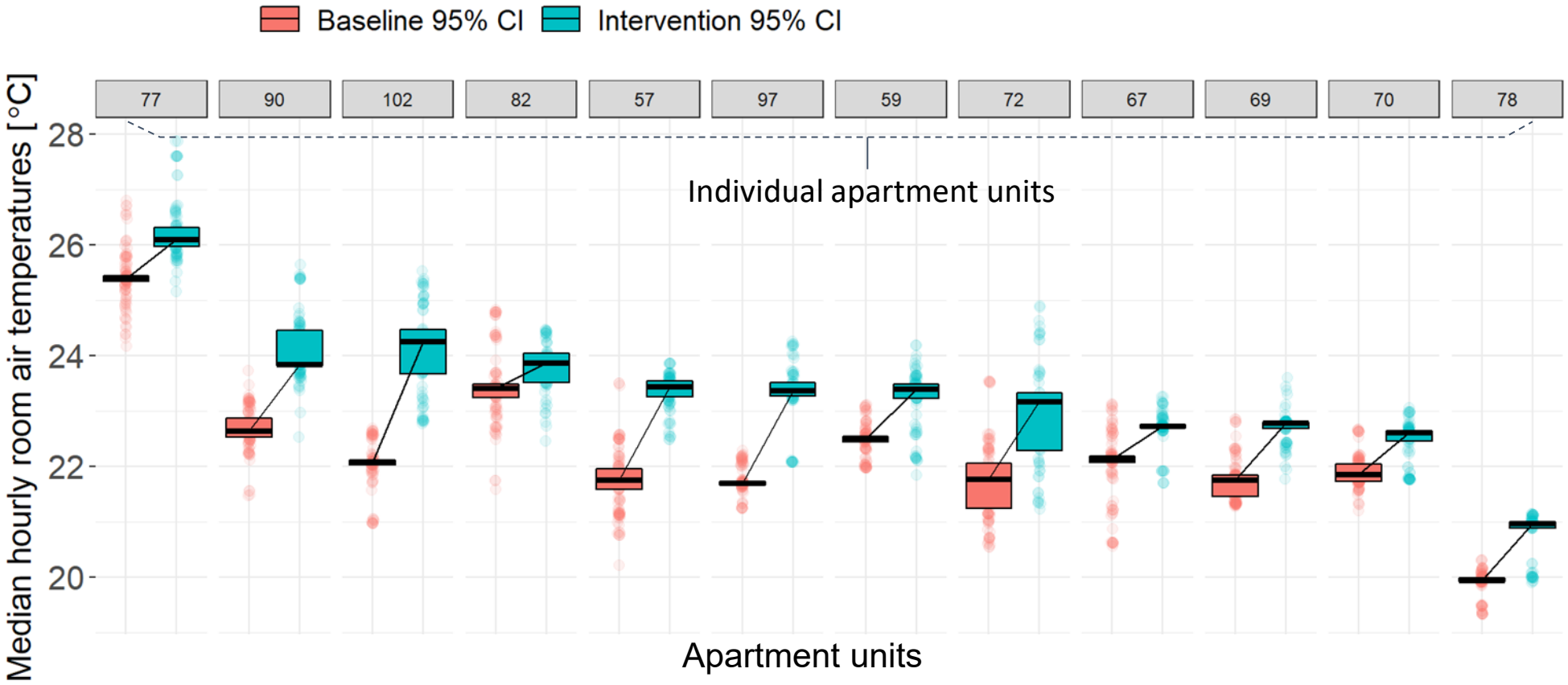
MySmartE

What is MySmartE?

Community Games

Before and after intervention

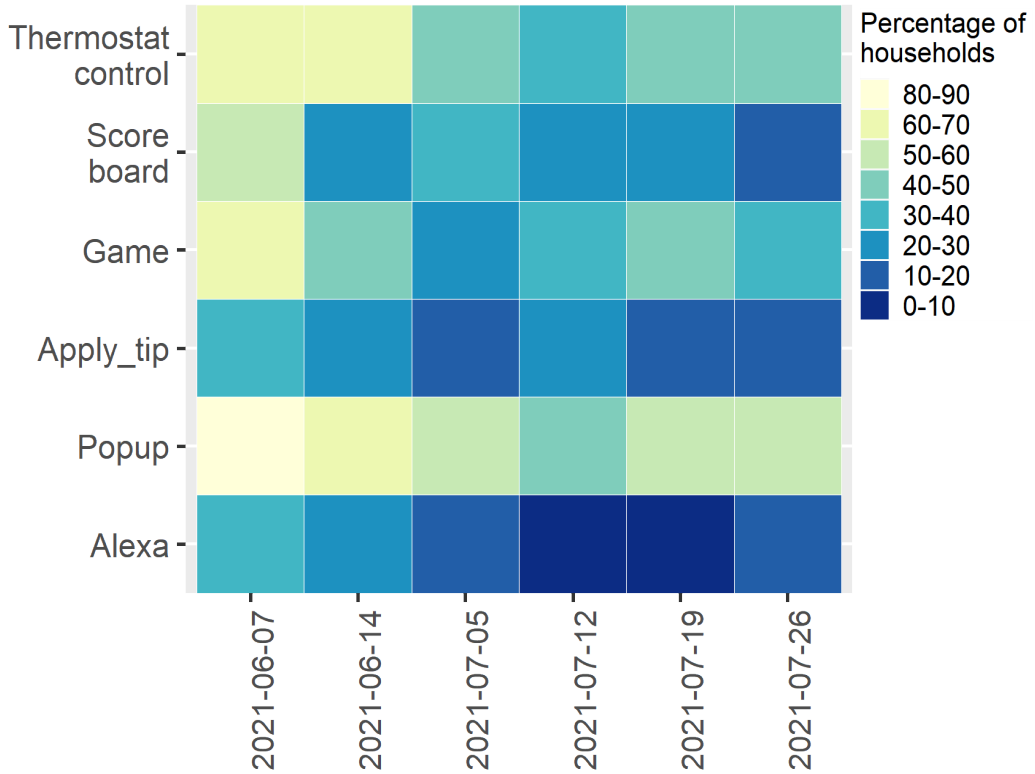
- Household room air temperatures increased after the intervention in cooling season



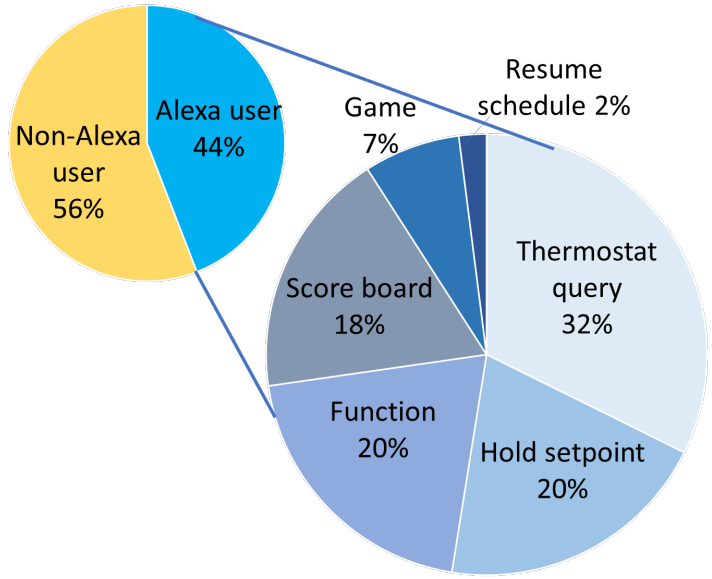
- *Positive effect of the intervention for all participating units with baseline data*

User interactions

❑ Tablet user interactions



❑ Alexa user interactions



❑ 19 tried Alexa (~44%)

❑ Thermostat query > Function = Hold > Score board> Game

Current steps

SCALE-UP DEPLOYMENT

different construction types & population demographics

New Community Partners

- Housing agencies
- Cities
- Utility providers
- Foundations
- Real Estate /Housing developers

Thank you

Q&A

Huijeong Kim
kim2683@purdue.edu

Field Data

- Participants: **36 households**
- Timeline:
  - **Baseline:** Dec. 2019 - Dec. 2020
  - **Intervention:** Jan. ~ Aug. 2021

    (Summer game: June 7th ~ 20th, July 5th ~ August 2nd)

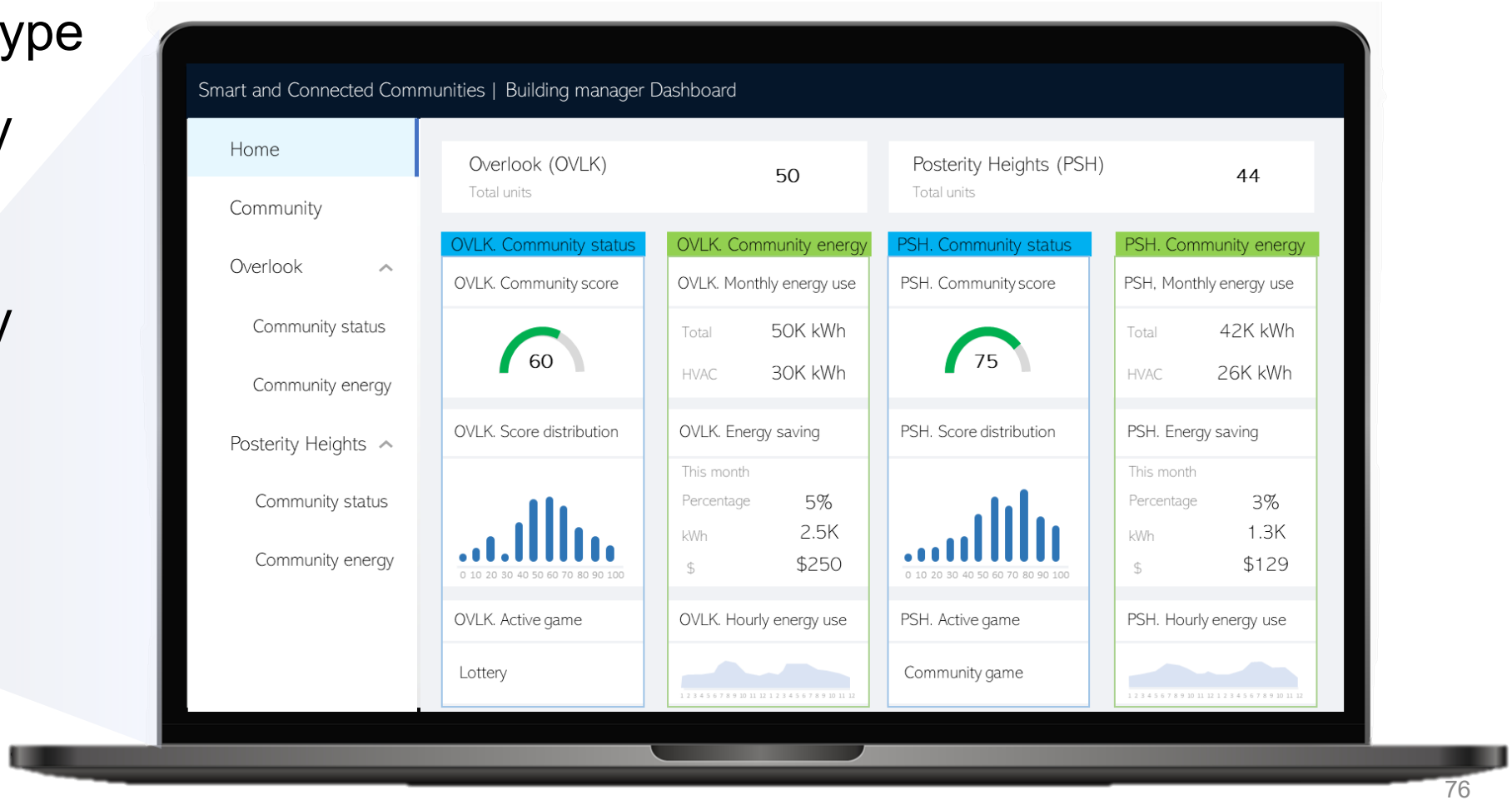
Before VS. After (12)

User interactions (36)

Post-experiment interviews (13)

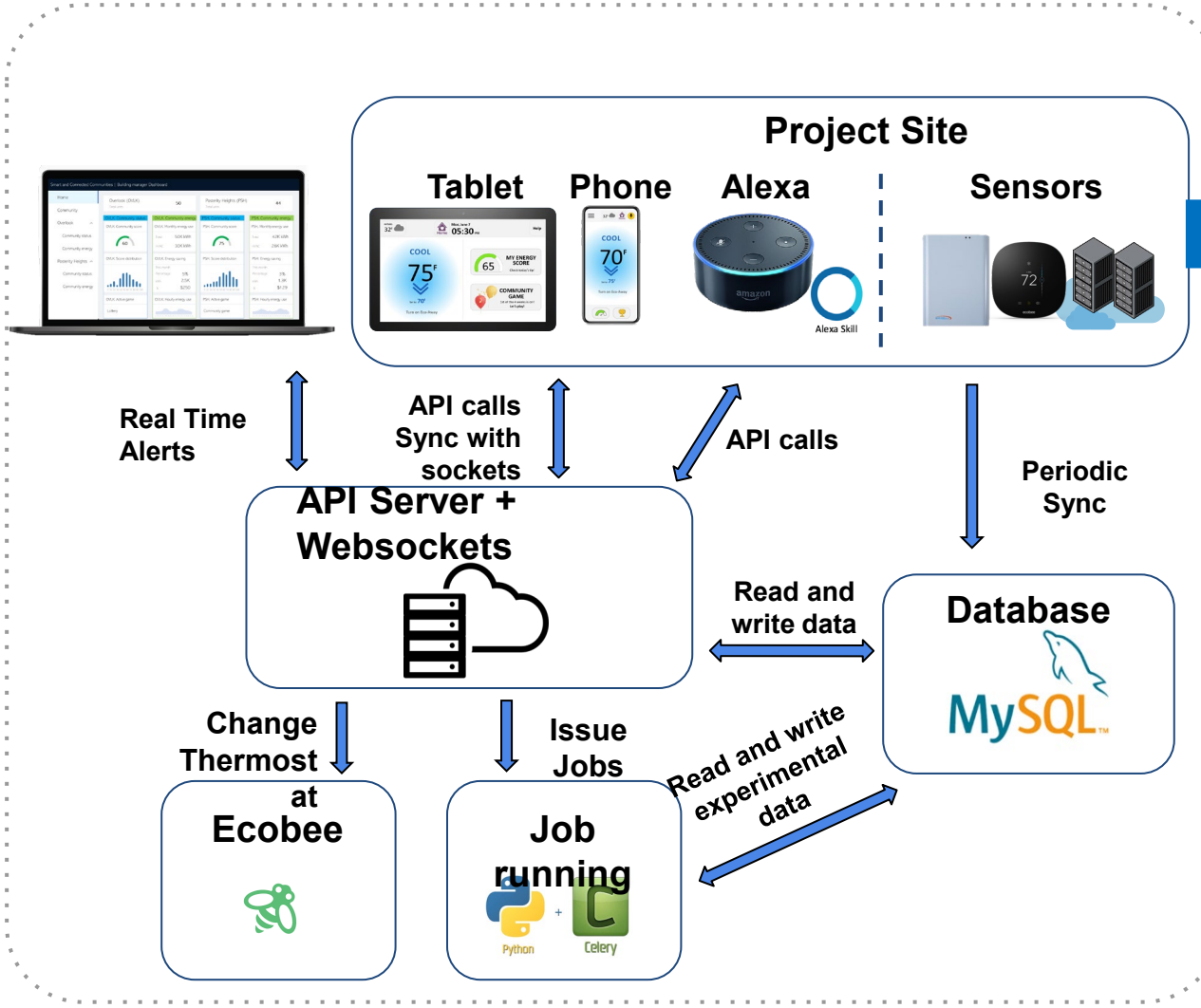
Facility Manager Portal

- Add/remove project site
- Assign intervention type
- Overview community status
- Overview community energy usage

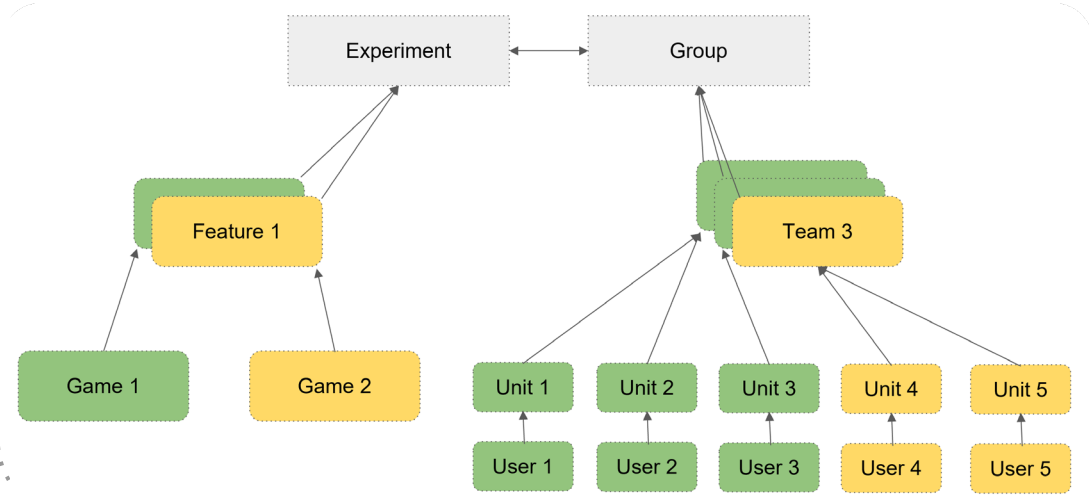


Facility Manager Portal

Software infrastructure



Portofolio management



Post-experiment Interview

30-min phone interviews with 13 residents:

- ❑ MySmartE improves thermostat accessibility (tablet location, Alexa's remote-control function)
- ❑ Social game excites users (e.g., avatars, social proof information)
- ❑ Users have different learning curves
- ❑ Alexa adoption is slower

Summary

- Developed an eco-feedback and gaming platform (MySmartE) to promote energy-conserving thermostat-adjustment behaviors

- Deployed MySmartE in a multi-unit residential community
  - **Positive effect** of the intervention during the cooling season
  - **Popups** and **social game elements** play a key role in **triggering user interactions**
  - **Simple and intuitive UIs** and **software maintenance** are important