

EVALUATING THE IMPACT OF AIR QUALITY ON HOUSING PRICES IN U.S. CITIES: A FIXED EFFECTS PANEL DATA ANALYSIS IN R

1. Background

As U.S. cities become increasingly focused on sustainability, questions have emerged around how environmental quality influences property markets. Local governments are particularly interested in whether air pollution levels significantly affect housing prices, which could justify zoning reforms or green incentive programs.

We were engaged to use R for an econometric study measuring the causal relationship between air quality and housing prices across major metropolitan areas using a fixed-effects panel regression.

2. Objective

- To quantify the effect of air pollution (PM2.5 levels) on housing prices across cities and over time
- To control for confounding economic and demographic variables using panel data methods
- To provide a statistical foundation for urban environmental policy

3. Data Used

Sources:

- Zillow Home Value Index (ZHVI)
- EPA Air Quality System (AQS)
- U.S. Census Bureau (control variables)

Panel Structure:

- Balanced panel with **30 U.S. cities, monthly data, 2015–2023**
- Total observations: 3,240 (30×108 months)

Key Variables:

- Dependent variable: Log_Home_Price (log of median sale price)

- Independent variable: PM2_5_Level ($\mu\text{g}/\text{m}^3$)
- Controls: Unemployment_Rate, Median_Income, Population_Density, Mortgage_Rate

4. Econometric Methodology

4.1 Model Specification

We estimated the following fixed-effects model in R:

```
model <- plm(Log_Home_Price ~ PM2_5_Level + Unemployment_Rate +
             Median_Income + Population_Density + Mortgage_Rate,
             data = housing_data,
             index = c("City", "Month"),
             model = "within")
```

4.2 Diagnostics

- Hausman Test (plm::phtest) confirmed FE over RE
- Multicollinearity tested via car::vif()
- Serial correlation and heteroskedasticity addressed using robust standard errors: vcovHC(type = "HC1")

5. Model Results

Variable	Coefficient	Std. Error	p-value
PM2_5_Level	-0.0182	0.0051	<0.001
Unemployment_Rate	-0.0045	0.0017	0.009
Median_Income	+0.00011	0.00003	<0.001
Population_Density	+0.00042	0.00019	0.031
Mortgage_Rate	-0.0124	0.0042	0.004
City Fixed Effects	Included		
Time Fixed Effects	Included		
R ² (within)	0.63		

6. Interpretation and Recommendations

- A **1 $\mu\text{g}/\text{m}^3$ increase in PM2.5** is associated with a **1.82% decrease** in median home prices
- The effect is statistically significant and consistent across cities and time
- **Income and density positively influence** housing prices, while **unemployment and mortgage rates** have negative effects

Policy Recommendations:

- Prioritize emission-reduction programs in areas with declining real estate markets
- Incorporate air quality data into **housing valuation models** and **urban planning dashboards**
- Use findings to justify green building tax incentives in high-PM regions

7. Reporting Output

- **R Markdown Report (PDF, 25 pages):**
 - Data description and variable construction
 - Model results, robustness checks, and plots
 - Interpretation in plain language for non-technical readers
- **Excel Summary File:**
 - City-wise PM2.5 and price trends
 - Monthly coefficient impact calculators
 - Filterable dashboard for key economic indicators
- **Code Package:**
 - Annotated .R scripts with full model pipeline
 - ReadMe file for reusability by city agencies and academic researchers

8. Practical Impact

- Report presented to **city planning committee in St. Louis** as part of urban zoning reform
- Used as input in a **housing affordability and environment impact task force**

- Model later adapted to study **noise pollution vs. rental price trends** in pilot areas

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