# ECONOMETRIC TIME-SERIES ANALYSIS OF HOUSING PRICES AND AIR POLLUTION IN FIVE U.S. METROPOLITAN AREAS

## 1. Introduction

Housing affordability and urban livability are deeply influenced by environmental quality. With increasing attention on air pollution's impact on health and real estate desirability, this project aimed to quantify how air pollution (as measured by AQI) affects residential property prices over time.

The client—a real estate consultancy serving institutional investors—sought a Python-powered econometric analysis to inform pricing models, portfolio strategy, and ESG-aligned investment planning in high-growth metro areas.

## 2. Objective

- To evaluate whether monthly air pollution levels have a measurable effect on residential housing prices
- To implement time-series econometric techniques in Python including stationarity testing, lag structures, and multi-metro comparisons
- To provide evidence-backed insights that support dynamic pricing, zoning, and investment strategy

## 3. Data Used

**Source**:

- AQI: U.S. EPA AirNow API
- Median Home Prices: Zillow Home Value Index (ZHVI)
- Controls: BLS (Unemployment Rate), FRED (Interest Rate, Inflation)

**Timeframe**:

- Jan 2015 to Dec 2022 (96 months)

**Geographies**:

- Los Angeles, CA

- Chicago, IL
- Phoenix, AZ
- Atlanta, GA
- Denver, CO

**Variables (monthly time series)**:

- Median_House_Price (USD)
- AQI (monthly average)
- Unemployment_Rate (%)
- Interest_Rate (%)
- Inflation_Rate (%)

# 4. Methodology

### 4.1 Data Preparation

- Merged time-aligned series using pandas
- Checked for missing months, interpolated where necessary (max 1 month gap)
- Inflation-adjusted housing prices using CPI to compute real values
- Created lagged variables (1, 3, and 6 months) for AQI and macroeconomic controls

### 4.2 Econometric Modeling

- Conducted **ADF tests** on all series to check for stationarity
- Differenced non-stationary variables as needed
- Applied **Multivariate Time Series Regression (OLS)** per metro
- Model:

$$\Delta \log(HousePrice)_t = \alpha + \beta 1 AQI_t - 1 + \beta_2 UnempRate_t + \beta_3 InterestRate_t + \beta_4 InflationRate_t + \epsilon_t$$

- Controlled for autocorrelation using Newey-West HAC standard errors
- Conducted Granger causality tests between AQI and housing prices (2–6 month lags)

# 5. Key Results

**Consistent Results Across Cities**:

- **AQI** lagged by 1 month negatively impacted **real house prices** in all five metros
- **Los Angeles** and **Phoenix** showed the strongest pollution-price relationship

| Metro | Coeff. on AQI (lag 1) | P-Value | $R^2$ |
|---|---|---|---|
| Los Angeles | –0.0048 | 0.002 | 0.72 |
| Phoenix | –0.0039 | 0.010 | 0.68 |
| Chicago | –0.0021 | 0.047 | 0.63 |
| Atlanta | –0.0017 | 0.051 | 0.60 |
| Denver | –0.0019 | 0.043 | 0.59 |

**Granger Causality** (2 lags):

- AQI → Housing Price confirmed for **3 of 5 cities** ($p < 0.05$)

# 6. Econometric Interpretation

- A one-point increase in AQI (worsening air quality) led to an **approximate 0.4–0.5% monthly decrease** in home prices in LA and Phoenix
- The relationship was **stronger in car-dependent cities** with high pollution sensitivity
- **Economic controls (interest and inflation)** behaved as expected; higher rates depressed real prices
- Newey-West adjustments confirmed no residual autocorrelation in final models

# 7. Report Output

- **Report (Harvard Format, 22 pages)**:
    - Executive summary, methodology, full results tables
    - Lag comparison plots, Granger causality test charts
    - Interpretation sections written for both technical and non-technical readers
    - Appendix: ADF test results and stationarity diagnostics
- **Python Notebook**:

    - Structured with function blocks for time-series cleaning, testing, and regression
    - Custom plot_time_series() and run_granger_tests() methods included
    - Final coefficients exported to CSV for investor dashboards
- **Interactive Graphs (Optional Add-on)**:
    - Built using plotly.express and dash to explore AQI vs Price per city

# 8. Strategic Recommendations

- Investors should apply **location-level AQI risk premiums** when pricing portfolios in high-pollution metros
- Real estate listings and builders in affected areas should integrate **environmental disclosures and mitigation narratives**
- City-level policy teams can use this model to simulate the **housing impact of pollution control efforts** (e.g., EV subsidies, zoning reforms)
- Further research can integrate **property type**, **proximity to highways/green spaces**, and **buyer segment (first-time vs investor)**