# Air Quality and Housing Price: An Empirical Analysis in Beijing

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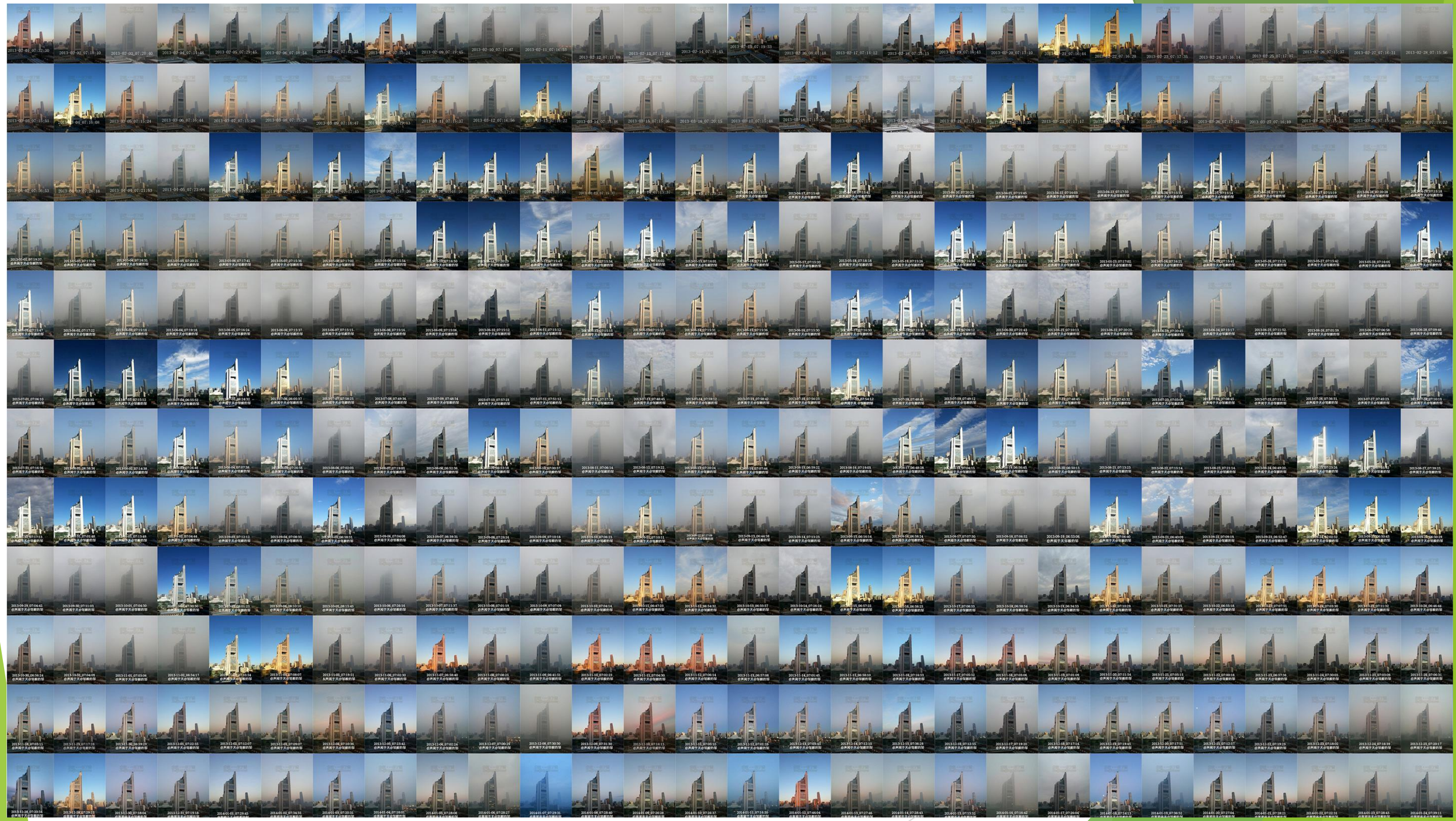
# Background

- Air quality and housing price have been investigated for a long time
  - Since Ridker and Henning (1967)



# Background

- Air quality and housing price have been investigated for a long time
  - Since Ridker and Henning (1967)
- Air pollution is negatively associated with housing prices
- Several methodological issues remain to be addressed

# Research Focus

- How to include an air quality variable to hedonic house price models?
  - Measure of pollution: a few monitor stations in a region
  - Home sales: spatially distributed across the whole region

# Matching Housing Price and Air Quality

## Housing Data

Kim, Phipps, and Anselin (2003)

Xiao et al. (2017)

Individual Housing Units

Chattopadhyay (1999)

↓

Aggregated Units
(communities, census tracts)

Ridker and Henning (1967)

Liu et al. (2018)

Mei et al. (2020)

## Air Quality

Monitoring Stations

↓

Anselin and Gallo (2006): use previous year

Time Aggregation
(current year annual mean)

↓ interpolation

- Nearest station
- Inverse Distance
- Kriging
- Spline

Imputed Space

# Considerable differences between interpolators (Anselin and Gallo, 2006)

**Table 7.** Analytical marginal willingness to pay, by interpolator[a]

| Model | Thiessen | IDW | Kriging | Spline |
|---|---|---|---|---|
| OLS | $3,028 | $4,889 | $6,468 | $4,925 |
| | ($2,699–3,357) | ($4,519–5,241) | ($6,127–6,808) | ($4,592–5,258) |
| | 1.26% | 2.04% | 2.70% | 2.06% |
| | (1.13–1.40%) | (1.89–2.19%) | (2.56–2.84%) | (1.92–2.20%) |
| Lag-IVR | $4,087 | $6,031 | $7,444 | $5,899 |
| | ($3,609–4,566) | ($5,496–6,567) | ($6,920–7,969) | ($5,394–6,404) |
| | 1.71% | 2.52% | 3.11% | 2.46% |
| | (1.51–1.91%) | (2.29–2.74%) | (2.89–3.33%) | (2.25–2.67%) |

[a] Uniform 1 ppb $O_3$ improvement, assuming average house price. Two standard error bounds are given in parentheses.

# Data Source

## Housing Data

Lianjia.com

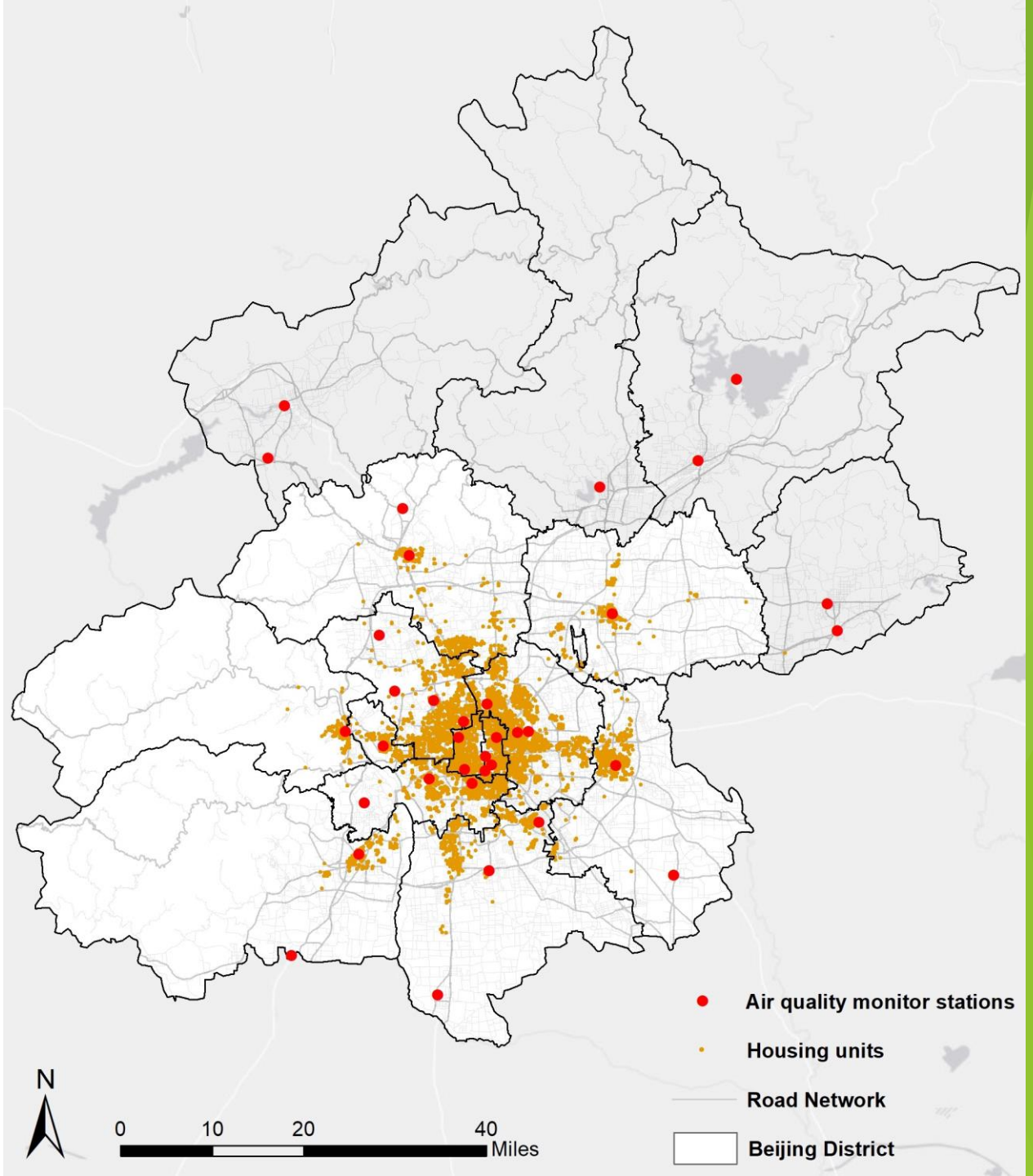
- The largest resale home agency in Beijing
- 557,998 resale home transactions 2014-2018

## Air Quality Data

PM 2.5

- Beijing Municipal Environmental and Monitoring Center (BJMEMC)
- 35 in-situ monitoring stations from December 5th, 2013, to December 31st, 2018

# Resale Home Sample & Monitoring Station

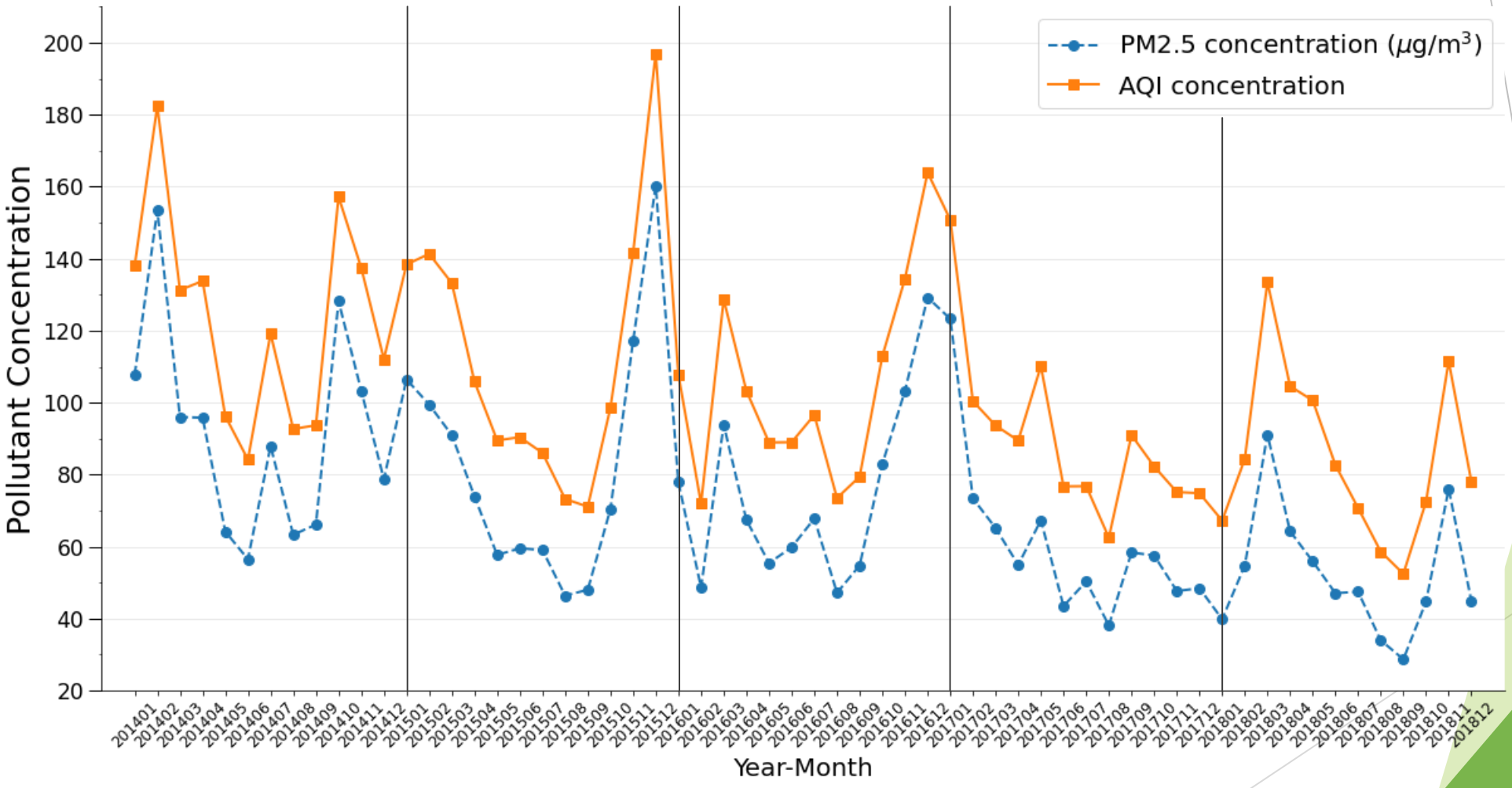


# PM2.5

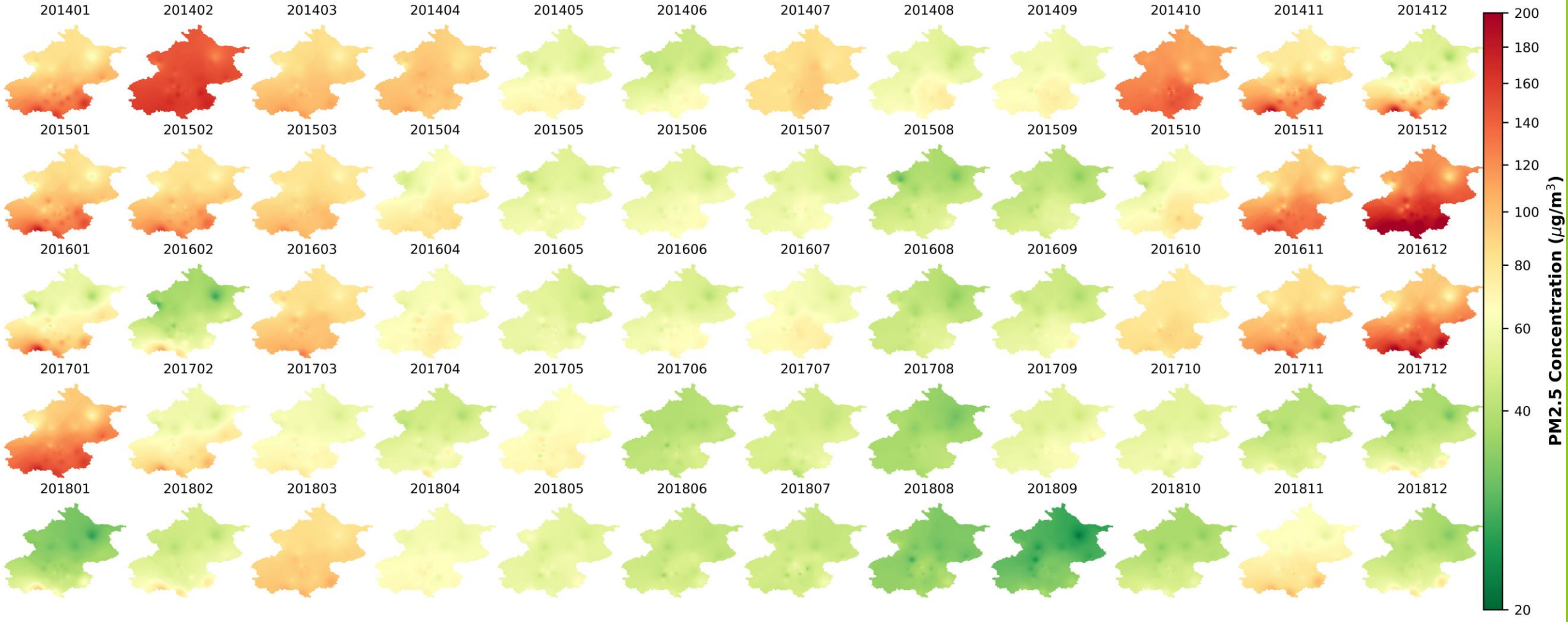
- Fine particles (diameter<2.5 mm)

- More hazardous than larger particles (2.5 mm< diameter<10 mm, PM10) in terms of mortality, cardiovascular and respiratory endpoints, and PM2.5 is considered to be the best indicator of the level of health (Freeman et al., 2019)

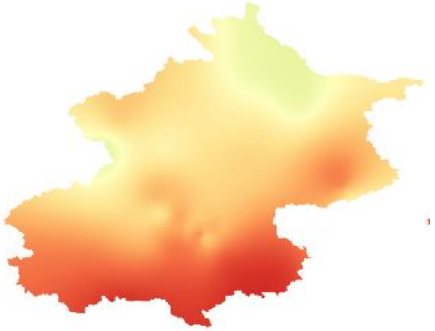
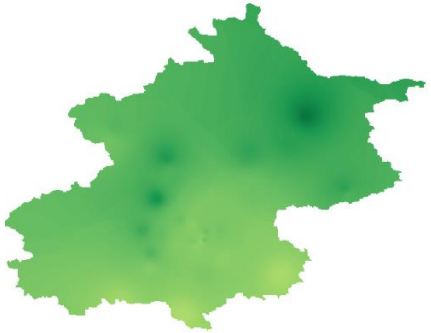
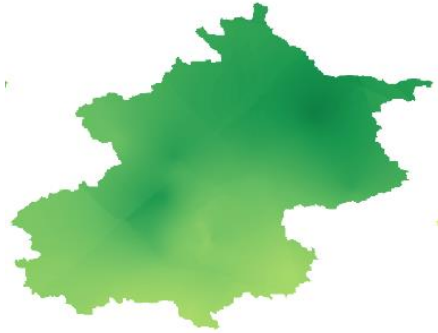
# PM2.5 and AQI (2014-2018)



# Spatial Interpolation



# Difference in Spatial Interpolation Methods

| IDW | Kriging | Spline |
| --- | --- | --- |
| 201401 | 201401 | 201401 |
|  |  |  |
| 201809 | 201809 | 201809 |
|  |  |  |

# Model Specification

$$\boldsymbol{ln(P)} = \beta_0$$

| | |
|---|---|
| $+ \beta_1 \boldsymbol{Air\ Quality}$ | PM2.5 with different specifications |
| $+ \boldsymbol{\beta_2\ Housing\ Attribute}$ | bedroom, living room, bathroom, floor area, floor level, facing, total number of floor, year built, elevator; distance to subway, school level, hospital, distance to CBD, distance to park |
| $+ \boldsymbol{\beta_3\ Time\ \ FE}$ | month, year, month * year |
| $+ \boldsymbol{\beta_4\ District\ FE}$ | |
| $+ \boldsymbol{\varepsilon}$ | |

# Estimation Results (PM2.5/100)

| Days | Nearest Station (NN) | IDW | | | Kriging | | | Spline | | | Dist_Nearest Station (NN) | Dist_IDW | Dist_Kriging | Dist_Spline |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1000m | 2000m | 3000m | 1000m | 2000m | 3000m | 1000m | 2000m | 3000m | | | | |
| 0 | -0.001 | -0.000 | -0.000 | -0.000 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | -0.001 | 0.002*** | 0.002*** | 0.003*** | 0.003*** |
| | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) |
| 3 | -0.004*** | -0.003** | -0.002** | -0.002** | -0.004*** | -0.004*** | -0.004*** | -0.004** | -0.004** | -0.004** | 0.001* | 0.002*** | 0.002** | 0.002** |
| | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.001) | (0.002) | (0.002) | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) |
| 10 | -0.024*** | -0.021*** | -0.021*** | -0.021*** | -0.025*** | -0.025*** | -0.024*** | -0.024*** | -0.024*** | -0.024*** | -0.007*** | -0.007*** | -0.007*** | -0.006*** |
| | (0.005) | (0.003) | (0.003) | (0.003) | (0.004) | (0.004) | (0.004) | (0.005) | (0.005) | (0.005) | (0.002) | (0.002) | (0.002) | (0.002) |
| 15 | -0.033*** | -0.030*** | -0.029*** | -0.029*** | -0.035*** | -0.035*** | -0.034*** | -0.033*** | -0.033*** | -0.033*** | -0.007*** | -0.007*** | -0.006*** | -0.005** |
| | (0.007) | (0.005) | (0.005) | (0.005) | (0.006) | (0.006) | (0.006) | (0.008) | (0.008) | (0.008) | (0.002) | (0.002) | (0.002) | (0.002) |
| 30 | -0.058*** | -0.055*** | -0.055*** | -0.054*** | -0.068*** | -0.068*** | -0.066*** | -0.059*** | -0.059*** | -0.060*** | 0.007 | 0.011** | 0.009 | 0.011** |
| | (0.017) | (0.012) | (0.012) | (0.012) | (0.014) | (0.014) | (0.014) | (0.019) | (0.018) | (0.018) | (0.005) | (0.005) | (0.005) | (0.005) |
| 60 | -0.140*** | -0.163*** | -0.163*** | -0.162*** | -0.178*** | -0.177*** | -0.175*** | -0.143*** | -0.144*** | -0.147*** | -0.011 | -0.011 | -0.009 | -0.003 |
| | (0.031) | (0.026) | (0.026) | (0.026) | (0.030) | (0.030) | (0.030) | (0.035) | (0.035) | (0.035) | (0.010) | (0.010) | (0.009) | (0.009) |
| 90 | -0.222*** | -0.301*** | -0.303*** | -0.303*** | -0.305*** | -0.304*** | -0.302*** | -0.229*** | -0.233*** | -0.238*** | -0.033*** | -0.039*** | -0.029** | -0.019 |
| | (0.044) | (0.043) | (0.043) | (0.043) | (0.047) | (0.047) | (0.047) | (0.051) | (0.051) | (0.051) | (0.014) | (0.015) | (0.013) | (0.013) |
| 180 | -0.349*** | -0.509*** | -0.513*** | -0.517*** | -0.522*** | -0.521*** | -0.519*** | -0.364*** | -0.372*** | -0.385*** | -0.061*** | -0.051* | -0.042* | -0.027* |
| | (0.069) | (0.076) | (0.076) | (0.077) | (0.081) | (0.081) | (0.081) | (0.080) | (0.081) | (0.082) | (0.027) | (0.030) | (0.025) | (0.023) |
| 270 | -0.477*** | -0.727*** | -0.735*** | -0.744*** | -0.761*** | -0.760*** | -0.758*** | -0.509*** | -0.522*** | -0.543*** | -0.129*** | -0.118*** | -0.102*** | -0.079** |
| | (0.088) | (0.102) | (0.103) | (0.104) | (0.110) | (0.110) | (0.110) | (0.103) | (0.104) | (0.106) | (0.040) | (0.042) | (0.037) | (0.033) |
| 360 | -0.551*** | -0.861*** | -0.871*** | -0.882*** | -0.915*** | -0.914*** | -0.912*** | -0.598*** | -0.614*** | -0.641*** | -0.149*** | -0.114** | -0.105** | -0.083** |
| | (0.102) | (0.123) | (0.124) | (0.127) | (0.133) | (0.133) | (0.134) | (0.122) | (0.124) | (0.126) | (0.050) | (0.050) | (0.046) | (0.041) |
| District FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year × Month FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

*The dependent variable is the housing price per square meter, *Standard errors clustered at the Jiedao level in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

# Individual Housing Units

| | IDW | | | Kriging | | | Spline | | |
|---|---|---|---|---|---|---|---|---|---|
| | Prior-360-Day | Current-Year | Previous-Year | Prior-360-Day | Current-Year | Previous-Year | Prior-360-Day | Current-Year | Previous-Year |
| Air Quality | -0.0086*** | -0.0083*** | -0.0103*** | -0.0091*** | -0.0074*** | -0.0090*** | -0.0060*** | -0.0044*** | -0.0056*** |
| | (0.0012) | (0.0015) | (0.0017) | (0.0012) | (0.0015) | (0.0017) | (0.0012) | (0.0010) | (0.0012) |
| Observations | 498318 | 557998 | 493935 | 498318 | 557998 | 493935 | 498318 | 557998 | 493935 |
| $R^2$ | 0.788 | 0.790 | 0.790 | 0.790 | 0.790 | 0.791 | 0.787 | 0.788 | 0.788 |
| Adjusted $R^2$ | 0.788 | 0.790 | 0.790 | 0.790 | 0.790 | 0.791 | 0.787 | 0.788 | 0.788 |
| *AIC* | -182398 | -201406 | -185343 | -186189 | -202998 | -187271 | -181328 | -196252 | -180895 |
| *BIC* | -182164 | -201170 | -185110 | -185956 | -202763 | -187038 | -181095 | -196016 | -180662 |
| District FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year × Month FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

*The dependent variable is the housing price per square meter, *Standard errors clustered at the Jiedao level in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Mei et al (2020)**
Unit price (/m2) increase by 0.8% - 1.2% for 1μg/m3 decrease of annual PM2.5 value

# Aggregated Communities (*XiaoQu*)

| | IDW | | | Kriging | | | Spline | | |
|---|---|---|---|---|---|---|---|---|---|
| | Prior-360-Day | Current-Year | Previous-Year | Prior-360-Day | Current-Year | Previous-Year | Prior-360-Day | Current-Year | Previous-Year |
| Air Quality | -0.0023*** | -0.0073*** | -0.0076*** | -0.0027*** | -0.0072*** | -0.0072*** | -0.0021*** | -0.0041*** | -0.0045*** |
| | (0.0004) | (0.0011) | (0.0012) | (0.0005) | (0.0011) | (0.0012) | (0.0005) | (0.0009) | (0.0010) |
| Observations | 25716 | 27904 | 23754 | 25716 | 27904 | 23754 | 25716 | 27904 | 23754 |
| $R^2$ | 0.833 | 0.832 | 0.835 | 0.834 | 0.833 | 0.836 | 0.833 | 0.831 | 0.833 |
| Adjusted $R^2$ | 0.833 | 0.832 | 0.834 | 0.834 | 0.833 | 0.836 | 0.833 | 0.831 | 0.833 |
| *AIC* | -14689 | -15935 | -13827 | -14787 | -16151 | -13979 | -14717 | -15721 | -13656 |
| *BIC* | -14559 | -15803 | -13698 | -14657 | -16019 | -13850 | -14587 | -15589 | -13527 |
| District FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Year × Month FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

*The dependent variable is the housing price per square meter, *Standard errors clustered at the Jiedao level in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

# Conclusion

- The relationship between air quality and housing price is sensitive to the choice of spatial interpolation methods, the aggregation strategy, the time for air quality

- Unit price (/$m^2$) increase by 0.72% for 1μg/$m^3$ decrease of annual PM2.5 value

# Thank you very much!

Any questions or comments are welcome!

**Chen and Chen (2017)**
Unit price (/m2) increase by 46 yuan/m2 (or $6.6/m2) for 1μg/m3 decrease in annual PM2.5 value.

**Freeman (2019)**
The median household is willingness to pay $21.70 for 1μg/m3 decrease in annual PM2.5 concentration

**Mei et al (2020)**
Unit price (/m2) increase by 0.8% - 1.2% for 1μg/m3 decrease of annual PM2.5 value

**Qin et al (2019)**
Unit price (/m2) increase by 0.18%(OLS) or 0.32% (2SLS) for 100μg/m3 increaseof PM2.5 value on transaction day.