Understanding Spatial House Price Dynamics in a Housing Boom

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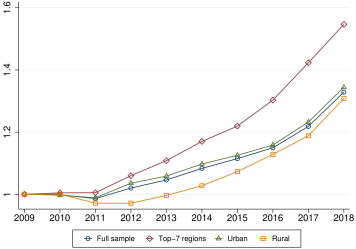
Motivation

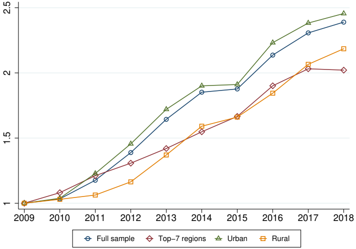
- Large and rising dispersion of house prices across locations
  - ↑ wealth inequality between households
  - ↑ residential segregation and spillovers on children's human capital (Fogli, Guerrieri, Ponder and Prato 2023)
  - ↑ regional misallocation of capital and labor (Herkenhoff et al. 2018, Hsieh and Moretti 2019)
- Explore house price dispersion at more granular level (unlike Van Nieuwerburgh and Weil 2010, Gyorko et al. 2013)

House Prices in Germany, 2009-2018

Mean



Spatial variance



Note: Based on residuals of hedonic regressions of sales listings. Spatial dispersion - variance across postal codes.

- No house price boom prior to 2010
- Large house price increase since 2010
- Large increase of spatial dispersion

What We Do

1. We use millions of sales listings data from 2009-2018 to document that

    - House price dispersion across postal codes ↑ over time

        - More than 3/4 of the increase is between and less than 1/4 within labor market regions

        - In the Top-7 regions, 1/2 of the increase is within regions (Berlin, Munich, Frankfurt, Hamburg, Cologne, Dusseldorf, Stuttgart)

2. A stylized spatial directed search model

    - Estimate the model and quantify the sources of rising dispersion across postal codes (demand, supply, rent sharing)

    - Demand changes account for the majority of the rise in house price dispersion

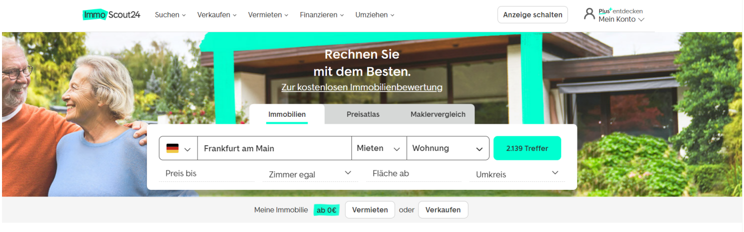
▸ Literature

Outline

1. Data
2. House Price Dispersion Across Space and Time
3. Model
4. Estimation
5. Model-Based Results

Data

German Housing Dataset - ImmobilienScout24



- Sales listings of residential housing units on the ImmobilienScout24 online platform
- Accessed via RWI-GEO-RED dataset of RWI Essen
- Millions of ads from January 2009 until December 2018

Variables

Variables about each listing:

- posted price
- housing characteristics
- location on a km^2 grid
- duration of a listing in days
- number of views
- number of contact attempts

▸ Data Cleaning ▸ Limitations ▸ GREIX

Control for Characteristics

- Interested in the spatial variation of house prices over time
  - deal with changes in the composition of sales listings
- Control for observable differences in the characteristics of housing units

$$\log p_{ht} = const + X_{ht}^{'}\beta_X + \varepsilon_{ht}$$

  - $\log p_{ht}$: inflation-adjusted listed price per m^2 of unit h posted at time t
  - X_{ht}: rooms/toilets/cellar, 22 property type categories, quarterly dummies
- Use estimated residuals ε_{ht}
  - capture location premia across space and time

Baseline Sample

- Geographical units:
  - LOCATIONS = Postal codes (8200 units, around 5000 households per unit)
  - REGIONS = Labor market regions (141 units, Kosfeld and Werner 2012)
- Construct a quarterly house price panel
- Aggregate estimated residuals ε_{ht} and other measures at location/region
- Restrict to locations that contain at least 10 listings in all quarters and regions with at least 14 locations
- **Result:** 2,161 locations in 99 regions over 40 quarters

Means across Locations and Time

Variable	2009-10	2011-12	2013-14	2015-16	2017-18
Log price $\ln p$	7.28	7.29	7.35	7.48	7.59
Price residual ε	-0.13	-0.12	-0.07	0.03	0.17
Listings S	71	69	73	58	46
Duration in days d	56	52	44	48	45
Contacts C	169	209	280	305	292
Flow tightness $\frac{C}{dS}$	0.05	0.07	0.11	0.16	0.19
Observations	17,288	17,288	17,288	17,288	17,288

NOTES: Means of selected variables for the baseline sample of location-quarter observations. Prices are in euros and adjusted for inflation using the CPI of the federal states in Germany.

- Prices ↑ 36% from €1451 to €1978
- Listings ↓ 35%, duration ↓ 20%, contacts ↑ 73%
- Contacts per listing day ↑↑: substantial tightening of the German housing market

House Price Dispersion Across Space and Time

The Increase of the House Price Dispersion

- Go back to the 2009-2018 sample of individual listings
- ε_{ht}: residual posted price per m^2 for listing h posted at t

	$\text{var}\varepsilon_h$		
	2009	2013	2018
Full Sample	0.190	0.237	0.290
West-Germany	0.187	0.234	0.283
East-Germany	0.188	0.239	0.295
Top-7 regions	0.184	0.199	0.230
Urban	0.193	0.246	0.298
Rural	0.180	0.208	0.265

- $\text{var}\varepsilon_h \uparrow$ 50+%

Within- and Between-Location Variance

$$\underbrace{var\varepsilon_h}_{\text{total variance}} = \underbrace{\sum_{i \in L} s_i var_i(\varepsilon_h)}_{\text{within locations}} + \underbrace{\sum_{i \in L} s_i(\bar{\varepsilon}_i - \bar{\varepsilon})^2}_{\text{between locations}}$$

- L: set of locations
- $\bar{\varepsilon}_i$: average residual price in location i
- s_i: listing share of location i
- $\bar{\varepsilon}$: average residual price across all of Germany
- **Within locations**: listing-weighted average of the within-location variances
- **Between locations**: listing-weighted variance of location-level prices

Within- and Between-Location Variance

	Total variance			Within locations			Between locations		
	2009	2013	2018	2009	2013	2018	2009	2013	2018
Full Sample	0.190	0.237	0.290	0.115	0.113	0.111	0.075	0.123	0.179
West Germany	0.187	0.234	0.283	0.114	0.112	0.107	0.073	0.122	0.176
East Germany	0.188	0.239	0.295	0.132	0.136	0.161	0.055	0.103	0.134
Top-7 regions	0.184	0.199	0.230	0.115	0.101	0.091	0.069	0.098	0.139
Urban	0.193	0.246	0.298	0.117	0.114	0.109	0.077	0.132	0.189
Rural	0.180	0.208	0.265	0.111	0.113	0.114	0.069	0.095	0.151

- **Full Sample**: between-location component for $\text{var}\varepsilon_h \uparrow$
- **East Germany**: within-location component also important
  - unaccounted disparities btw unrenov. and renov. housing
- **Urban and Top-7**: Within-location component $\downarrow$

PDFs across Locations

Within- and Between-Region Variance

$$\underbrace{\sum_{i \in L} s_i (\bar{\varepsilon}_i - \bar{\varepsilon})^2}_{\text{between-location variance}} = \underbrace{\sum_{r \in R} \sigma_r var_r(\bar{\varepsilon}_i)}_{\text{within regions}} + \underbrace{\sum_{r \in R} \sigma_r (\bar{\varepsilon}_r - \bar{\varepsilon})^2}_{\text{between regions}}$$

- R: set of regions
- $\sigma_r = \sum_{i \in r} s_i$: listing weight of region r
- $\bar{\varepsilon}_r = \sum_{i \in r} \frac{s_i}{\sigma_r} \bar{\varepsilon}_i$: mean residual price in region r
- **Within regions**: listing-weighted average of the within-region variances
- **Between regions**: listing-weighted variance of average regional prices

Within- and Between-Region Variance

	Between-location			Within regions			Between regions		
	2009	2013	2018	2009	2013	2018	2009	2013	2018
Full Sample	0.075	0.123	0.179	0.032	0.048	0.054	0.043	0.076	0.125
West Germany	0.073	0.122	0.176	0.032	0.047	0.055	0.041	0.075	0.121
East Germany	0.055	0.103	0.134	0.031	0.053	0.048	0.024	0.049	0.086
Top 7 regions	0.069	0.098	0.139	0.044	0.060	0.073	0.025	0.037	0.066
Urban	0.077	0.132	0.189	0.034	0.049	0.053	0.043	0.083	0.136
Rural	0.069	0.095	0.151	0.018	0.027	0.033	0.051	0.068	0.118

- **Full Sample**: 70% of between-location var accounted by between-region variance in 2018
  - More than 3/4 of the 2009-2018 rise in between-location variance due to between-region dispersion ↑
- **Top-7**: 1/2 of the 2009-2018 rise in between-location variance due to within-region dispersion ↑
  - Top-7 regions are more comparable ⇒ share of between-location variance (and its increase) better accounted by within-region dispersion

Model

Environment

- Labor market region with a finite number of locations (postal codes) i
- Discrete time periods $t \geq 1$ (quarters)
- Populated by house buyers and sellers subject to search frictions who
  - maximize discounted utility values
  - quarterly discount factor β
- Prices, values, costs: inflation-adjusted and per m^2

Model Preview Limitations

Sellers

- Free entry of sellers with a housing unit with
  - exogenous outside value K_{it} in location i and period t
  - captures construction cost or value of alternative use
- Free entry implies that the endogenous value of a seller

$$V_{it}^{S} = K_{it}, \text{ for all } i, t$$

- Per period cost of housing unit for sale c
  - captures utility costs of a vacant unit / sale costs

Buyers I

- Given stock of buyers in the region in $t = 1$, B_1
- Exog. inflow of new buyers into the region at $t \geq 2$, B_t^n
- Total number of buyers in the region, B_t
  - unmatched buyers from last period
  - new buyers
- Every buyer chooses in which location i to search in t
- Utility value of search in location i, $V_{it}^B + \varphi_{it} + \tau_i$
  - V_{it}^B : discounted utility value of a buyer searching in (i, t)
  - φ_{it}: type-I extreme taste shock with zero mean
  - τ_i: time-invariant location premium for location i

Buyers II

- If a buyer remains unmatched in (i, t)
  - decides where to search next period $t + 1$
  - drawing new taste shocks for $t + 1$
- If a buyer is matched in (i, t)
  - pays the posted price
  - leaves market with discounted utility value A_{it}
- A_{it} exogenous to the model
- r_t: cost of searching in a period (rental cost in the region)

Search and Matching

- Sellers post prices, buyers direct search to listings (Moen 1997, Wright et al. 2021)
- Submarkets diff. by posted prices and buyer-seller ratios
- Sellers and buyers trade off matching probs and prices
  - θ: buyer-seller ratio (tightness) in a submarket
  - seller matched with prob. $q_t(\theta)$
  - buyer matched with prob. $f_t(\theta) = q_t(\theta)/\theta$
  - matching efficiency varies over time
- All Ss and Bs in (i, t) share same values $\Rightarrow$ only one submarket active in a location
  - posted price p_{it}
  - market tightness θ_{it}

Value Functions

- Bellman equations for sellers and buyers in (i, t) are

$$V_{it}^{S} = -c + \beta V_{i,t+1}^{S} + q_t(\theta_{it}) \left(p_{it} - \beta V_{i,t+1}^{S} \right)$$
$$V_{it}^{B} = -r_t + \beta \bar{V}_{i,t+1}^{B} + f_t(\theta_{it}) \left(A_{it} - p_{it} - \beta \bar{V}_{i,t+1}^{B} \right)$$

- Unmatched buyer's continuation value is

$$\bar{V}_{t+1}^{B} = \mathbb{E} \max_{j} \left[V_{j,t+1}^{B} + \varphi_{j,t+1} + \tau_j \right] = \ln \left[\sum_{j} e^{V_{j,t+1}^{B} + \tau_j} \right] \quad (1)$$

Determining Price-Tightness (p, θ)

- A seller choose (p, θ) to maximize expected gain from trade

$$\max_{p,\theta} q_t(\theta)[p - \beta V^S_{i,t+1}] \qquad \text{s.t.} \qquad f_t(\theta)[A_{it} - p - \beta \bar{V}^B_{i,t+1}] \geq \Omega_{it}$$

  - Ω_{it}: expected buyer surplus from searching in (i, t)
  - buyers offered at least Ω_{it} to to search in submarket (p, q)

- First-order condition is

$$\Omega_{it} = q'_t(\theta)[A_{it} - \beta \bar{V}^B_{i,t+1} - \beta V^S_{i,t+1}]$$

- $q_t(\cdot)$ strictly concave $\Rightarrow$ all sellers choose the same p_{it} $\Rightarrow$ only one submarket active with tightness θ_{it}

Pricing and Bellman Equations

- Use $\Omega_{it} = f_t(\theta_{it})[A_{it} - p_{it} - \beta \bar{V}^B_{i,t+1}]$ and $f_t(\theta)\theta = q_t(\theta)$

  to get the equilibrium price

$$p_{it} = \zeta_t(\theta_{it})\beta V^S_{i,t+1} + (1 - \zeta_t(\theta_{it}))\left[A_{it} - \beta \bar{V}^B_{i,t+1}\right] \quad (2)$$

- $\zeta_t(\theta) = q_t'(\theta)\theta / q_t(\theta) \in (0,1)$: matching function elasticity

Bellman equations are

$$V^S_{it} = -c + \beta V^S_{i,t+1} + (q_t(\theta_{it}) - \theta_{it} q_t'(\theta_{it}))\left[A_{it} - \beta \bar{V}^B_{i,t+1} - \beta V^S_{i,t+1}\right] \quad (3)$$

$$V^B_{it} = -r_t + \beta \bar{V}^B_{i,t+1} + q_t'(\theta_{it})\left[A_{it} - \beta \bar{V}^B_{i,t+1} - \beta V^S_{i,t+1}\right] \quad (4)$$

Distribution of Buyers

- At the start of a period, all buyers B_t in a labor market region draw idiosyncratic taste shocks φ_{it}
- Share of buyers searching in location i is

$$\pi_{it} = \frac{e^{V_{it}^B + \tau_i}}{\sum_j e^{V_{jt}^B + \tau_j}} \tag{5}$$

- Number of buyers in a region evolves according to

$$B_{t+1} = \sum_i [1 - f_t(\theta_{it})] \pi_{it} B_t + B_{t+1}^n \tag{6}$$

▸ Equilibrium

Estimation

Parameters Calibrated Outside the Model

- Quarterly frequency discount factor $\beta = 0.995$
  - match an annual interest rate of 2%
- Seller flow cost per quarter $c = 6.50$ euros
  - match service charges per m^2
- Buyer flow cost per quarter $r_t =$ average inflation-adjusted rental rate per m^2 in the region

Baseline Sample Data

- Observe for a given labor market region with $i = 1, \ldots, N$ locations (postal codes) and $t = 1, \ldots, T$ quarters
  - residualized average hedonic prices p_{it}
  - number of listings (sellers) S_{it}
  - average duration of a listing in days d_{it}
  - number of buyer contacts C_{it}
- Not observed
  - number of buyers in a given market B_{it}
  - market tightness $\theta_{it} = B_{it} / S_{it}$

Auxiliary Matching Function

- Use auxiliary flow-based market tightness $\vartheta_{it} = C_{it}/(d_{it}S_{it})$
- Estimate for all locations and quarters in a region

$$\ln d_{it} = a_0 + a_1 \ln \vartheta_{it} + g_t + \epsilon_{it}$$

- Time fixed effects g_t take care of trends and seasonality in the listing duration relationship

Results

Mapping Estimates

- Daily matching prob. of a seller is the inverse of average duration
$$q^d_{it} = 1/d_{it}$$
- Map the estimates
$$q^d_{it} = q_t \vartheta^{\mu}_{it}$$
where $q_t = e^{-a_0 - g_t}$ and $\mu = -a_1$
- Not observed
  - number of buyers B_{it}
  - buyer daily matching prob. f^d_{it}

Link between Flow and Stock Tightness Measures

- Assume a buyer contacts k listings per day
- Total number of contacts in market (i, t) is

$$C_{it} = kB_{it}\frac{1}{f_{it}^d}$$

as buyer searches on average $1/f_{it}^d$ days

- Contacts-per-listing-day ratio is

$$\vartheta_{it} = \frac{C_{it}}{d_{it}S_{it}} = k\frac{B_{it}}{S_{it}}\frac{q_{it}^d}{f_{it}^d} = k\left(\frac{B_{it}}{S_{it}}\right)^2$$

where we use that $q_{it}^d S_{it} = f_{it}^d B_{it}$

Matching Functions

- Buyer-seller ratio (market tightness)

$$\theta_{it} = (\vartheta_{it}/k)^{1/2}$$

- Number of buyers

$$B_{it} = S_{it}(\vartheta_{it}/k)^{1/2}$$

- Use the estimated daily matching prob of a seller to get

$$q_t(\theta) = 1 - \left(1 - q_t k^{\mu} \theta^{2\mu}\right)^{90}$$

$$f_t(\theta) = q_t(\theta)/\theta$$

Estimation Procedure

Left to estimate

- Time-invariant location premia τ_i
  - pinned down by matching the average buyer shares in all locations i
- Time-varying buyer and seller valuations A_{it} and K_{it}
  - pinned down by matching exactly p_{it} and θ_{it}

Minimization Problem

- Buyer shares diff. in the data and in the model according to

$$\hat{\pi}_{it} = \pi_{it} e^{\eta_{it}}$$

  - $\hat{\pi}_{it} = \frac{\hat{B}_{it}}{\hat{B}_t}$: share of buyers in market (i, t) in the data
  - η_{it}: error term

- Solve

$$\min_{\tau_i} \sum_{i,t} \eta_{it}^2$$

subject to

$$\sum_i \tau_i = 0 \tag{7}$$

- First-order conditions

$$\tau_i = \frac{1}{T} \sum_{t=1}^{T} [\ln \hat{\pi}_{it} + \bar{V}_t^B - V_{it}^B] - \frac{\lambda}{2T} \tag{8}$$

▸ Terminal Values ▸ Linear System

Model-Based Results

Model-Based Decomposition

- Building on the pricing equations

$$p_{it} = \underbrace{\zeta_{rt}(\theta_{it})}_{\text{Rent Sharing}} \underbrace{\beta K_{i,t+1}}_{\text{Supply}} + \underbrace{(1 - \zeta_{rt}(\theta_{it}))}_{\text{Rent Sharing}} \underbrace{[A_{it} - \beta \bar{V}^B_{r,t+1}]}_{\text{Demand}}$$

i. Fix demand and rent-sharing to $A_{i,1} - \beta \bar{V}^B_{r,2}$ and $\zeta_{r,1}(\theta_{i,1})$

- allow housing supply to evolve $\beta K_{i,t+1}$
- derive counterfactual p_{it}^{supply}

ii. Fix supply and rent-sharing to $\beta K_{i,2} \text{ and } \zeta_{r,1}(\theta_{i,1})$

- allow housing demand to evolve $A_{it} - \beta \bar{V}^B_{r,t+1}$
- derive counterfactual p_{it}^{demand}

iii. Fix demand and supply to $A_{i,1} - \beta \bar{V}^B_{r,2}$ and m $\beta K_{i,2}$

- allow rent-sharing to evolve $\zeta_{rt}(\theta_{it})$
- derive counterfactual p_{it}^{rent}

Top-7 Cities - Average Price Changes

	$\bar{p}_T - \bar{p}_1$	$\bar{p}_T^{supply} - \bar{p}_1$	$\bar{p}_T^{demand} - \bar{p}_1$	$\bar{p}_T^{rent} - \bar{p}_1$
Munich	0.643	0.185	0.520	-0.014
	(100)	(29)	(81)	(-2)
Frankfurt	0.312	0.012	0.268	-0.044
	(100)	(4)	(86)	(-14)
Berlin	0.574	0.049	0.505	-0.073
	(100)	(9)	(88)	(-13)
Stuttgart	0.491	0.158	0.361	-0.015
	(100)	(32)	(74)	(-3)
Cologne	0.285	0.022	0.241	-0.030
	(100)	(8)	(85)	(-11)
Hamburg	0.446	0.115	0.369	0.009
	(100)	(26)	(83)	(2)
Dusseldorf	0.262	0.048	0.221	0.001
	(100)	(18)	(84)	(1)

NOTES: The supply, demand and rent-sharing contributions to the change of average log prices between 2008 and 2019 in Top-7 labor market regions. Percentages of the total log price change for each region are shown in parentheses.

- Heterogeneity across cities
- Price changes are mostly demand-driven

Top-7 Cities - Changes in House Price Dispersion

	$\text{var}(p_T) - \text{var}(p_1)$	$\text{var}(p_T^{\text{supply}}) - \text{var}(p_1)$	$\text{var}(p_T^{\text{demand}}) - \text{var}(p_1)$	$\text{var}(p_T^{\text{rent}}) - \text{var}(p_1)$
Munich	0.003	-0.014	0.011	-0.007
	(100)	(-467)	(367)	(-233)
Frankfurt	0.035	0.002	0.031	-0.002
	(100)	(6)	(89)	-6
Berlin	-0.011	-0.018	-0.007	-0.007
	(100)	(164)	(64)	(64)
Stuttgart	0.076	0.002	0.021	0.001
	(100)	(3)	(28)	(1)
Cologne	0.086	0.016	0.071	0.007
	(100)	(19)	(83)	(8)
Hamburg	0.020	-0.003	0.022	-0.001
	(100)	(-15)	(110)	(-5)
Dusseldorf	0.062	0.011	0.053	0.003
	(100)	(18)	(85)	(5)

NOTES: The supply, demand and rent-sharing contributions to the change of average log prices between 2008 and 2019 in Top-7 labor market regions. Percentages of the total variance change for each region are shown in parentheses.

- Heterogeneity across cities
- Large heterogeneity of the contributions of diff. factors
- Demand changes are the most important
- Rent sharing negligible for changes in price dispersion

Additional

Summary

- New dataset on sales listings for Germany
  - quality- and inflation-adjusted prices
- Price movements are heterogeneous across
  - narrow geographical units: postal codes
  - broader geographical units: labor market regions
- Variance decomposition
  - more than 3/4 of the increase in price heterogeneity across postal codes comes between regions
- Estimate a simple frictional spatial housing search model
  - demand side accounts for the majority of the increase in average prices and price dispersion

Appendix

Housing Literature

- Spatial dispersion
  - Across US metropolitan areas
    Rosen 1979, Roback 1982, Van Nieuwerburgh and Weil 2010, Gyorko et al. 2013
  - Differential house price trends during a housing boom
    Kindermann et al. 2021, Amaral et al. 2023
- Housing market search
  - Directed search
    Albrecht et al. 2016, Hedlund 2016, Rekkas et al. 2022, Moen et al. 2021, Kotova and Zhang 2021, Garriga and Hedlund 2022
  - Online listings data to study role of frictions
    Vanhapelto and Magnac 2024, Ben-Shahar and Golan 2022, Kotova and Zhang 2021, Guren 2018

back

Data Cleaning

Basic data cleaning:

- Problem: phishing or fraud listings, often below market price
  Solution: remove ultra-popular listings with contacts beyond the 99-th percentile

Further censoring based on:

- Price below €10,000 and above €6,000,000
- Price per m^2 below €150 and above €20,000
- Flats(houses) below 25(45) m^2 and above 400(800) m^2
- Flats(houses) with more than 8(15) rooms
- Duration longer than 99-th percentile

back

Limitations

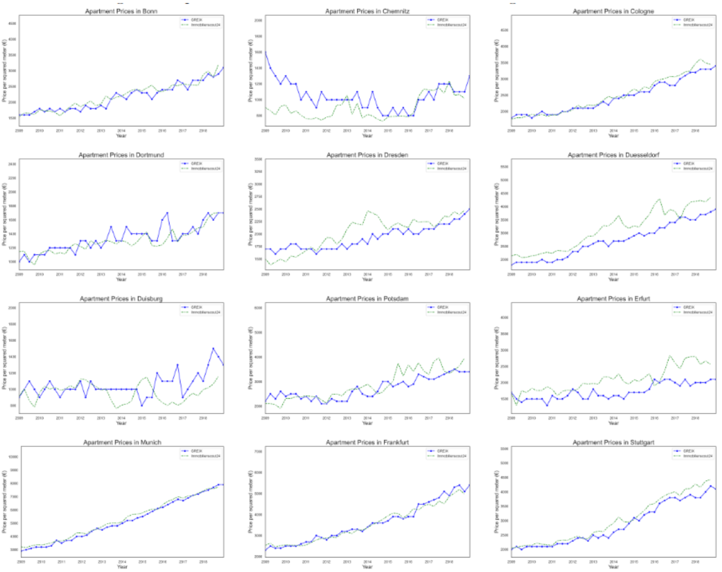
- Listed prices are not transaction prices
- Representative enough?

Checks:

- ImmobilienScout24 is the largest real estate listing website with a self-reported share of over 50%
  Georgi and Barkow 2010
- Transaction prices from a private provider at a district level
  Bulwiengesa
- Transaction prices for 18 cities from the newly created German Real Estate Index GREIX project
  Amaral, Dohmen, Schularick and Zdrzalek 2024

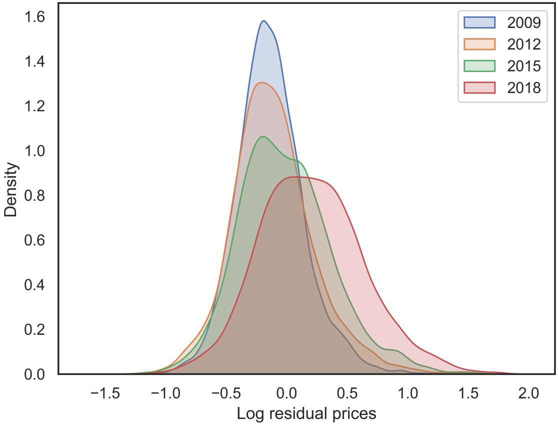
back

GREIX vs. ImmobilienScout24



back

Distribution of Residual Prices Across Locations, $\bar{\varepsilon}_i$



NOTES: Between-location distributions of residual log prices in the years 2009 (blue), 2012 (orange), 2015 (green) and 2018 (red). The residuals are obtained from hedonic house price regressions and averaged in each location.

- Mode is stable for 2009-2015
- Distribution widens in the upper part

back

Model - Preview

- Simple model estimatable on our baseline sample data
- Analyze the driving forces behind the diverging house prices: supply, demand and rent-sharing shifters
- Model describes a region divided into locations
- In each location, potential sellers decide about entry and the posted price of the housing unit for sale
- Buyers decide in whether to search in this location and which sellers to contact at their posted price
- Trade is subject to search frictions: directed search (Moen 1997, Wright et al. 2021)
- Buyers' location decisions respond to taste shocks (Aguirregabiria and Mira 2010, Caliendo et al. 2019)

back

What is not in the Model?

- Abstracting from:
  - tenure choice
  - mortgage financing
  - differentiation of housing units by size and quality
  - migration between labor market regions
- This strategy permits estimation of all key parameters using the listings data

back

Equilibrium

- Given an initial stock of buyers B_1 and buyer inflow B_t^n in periods $t \geq 2$
- A spatial competitive search equilibrium is a list for all periods $t \geq 1$ and all locations i of
  - posted house prices p_{it}, market tightness θ_{it}
  - discounted values V_{it}^S, $\bar{V}_t^B$, V_{it}^B
  - location choices π_{it}
  - total buyer stock B_t

such that

equations (1)–(6) and the free-entry conditions for sellers $V_{it}^S = K_{it}$ are satisfied

back

Auxiliary Matching Function Estimation

y=ln(d_{it})	Berlin	Munich	Hamburg	Frankfurt	Stuttgart	Dusseldorf	Cologne
a_1	-0.32***	-0.41***	-0.31***	-0.25***	-0.35***	-0.28***	-0.24***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
a_0	2.70***	2.70***	2.97***	3.04***	3.06***	3.02***	3.21***
	(0.05)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.216	0.419	0.330	0.306	0.501	0.361	0.433
N	5,440	3,440	3,760	3,960	2,800	3,680	2,720

NOTES: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

- a_1: doubling of contacts per listing day $\Rightarrow$ 24-41% $\downarrow$ in listing duration
- a_0: listing duration varies between regions in the reference quarter 2009q1

back

Extrapolation Values

- Need forecasts of continuation values of buyers and sellers in the last observation period T

- Linearly extrapolating

$$V_{i,T+1}^{S} = \frac{2}{T(T-1)} \left\{ \sum_{t=1}^{T} V_{it}^{S} \left[3t - (T+2) \right] \right\} \quad (9)$$

$$V_{i,T+1}^{B} = \frac{2}{T(T-1)} \left\{ \sum_{t=1}^{T} V_{it}^{B} \left[3t - (T+2) \right] \right\} \quad (10)$$

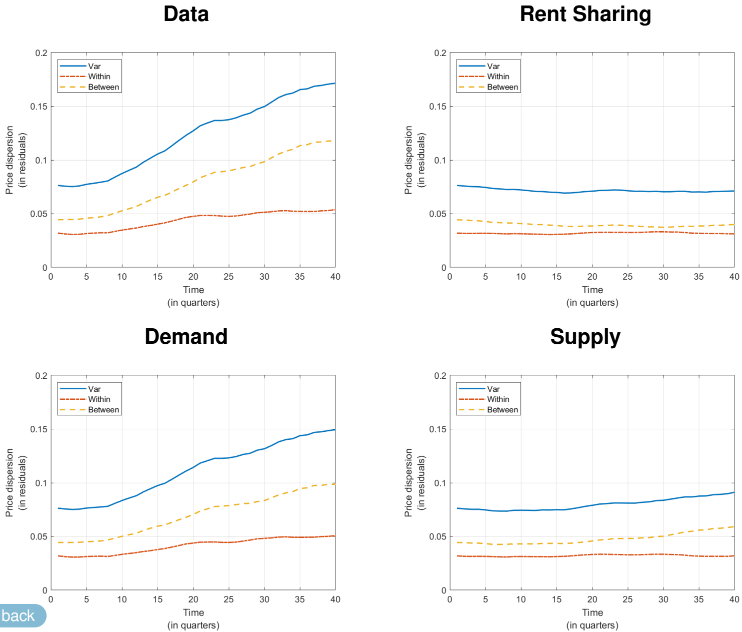
back

Near-Linear System of Equations

- Use data on p_{it}, θ_{it}, estimated matching functions , buyer shares $\hat{\pi}_{it}$
- $(3N+1)(T+1)+1$ equations: pricing (2), Bellman (3) and (4), extrapolation (9) and (10), minimization (7) and (8), continuation utilities of unmatched buyers (1)
  - linear except for $T+1$ equations (1)
- $(3N+1)(T+1)+1$ unknowns: $(A_{it})_{t=1}^{T}$, $(V_{it}^{B}, V_{it}^{S})_{t=1}^{T+1}$, τ_i for $i=1,\ldots,N$, λ, and $(\bar{V}_t^{B})_{t=1}^{T+1}$
- Solution gives buyers and sellers valuations A_{it}, $K_{it}=V_{it}^{S}$

back

Within- and Between-Region Dispersion in the Model



back