Mortgage Rates and the Price-to-Rent Ratio Across Space

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Introduction

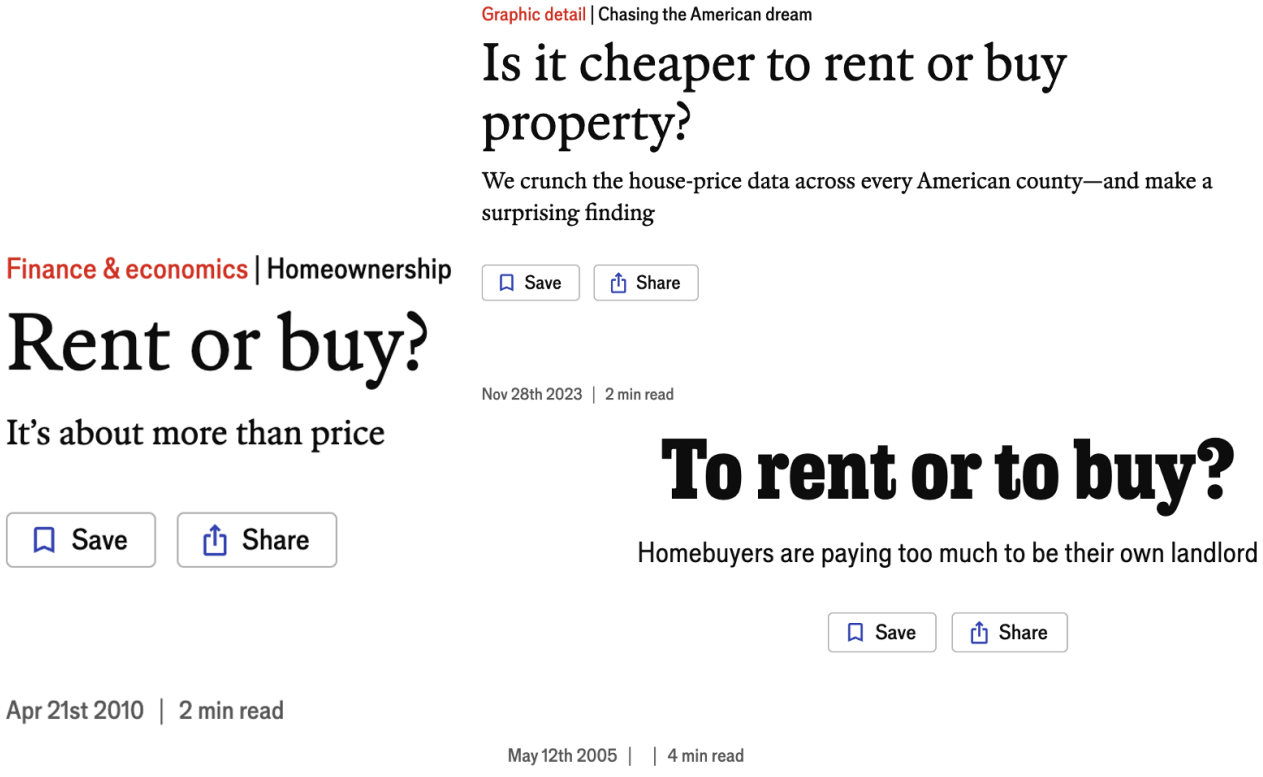
Residential properties can be traded on two markets: **the real estate market and the rental one**.

- Transaction market $\rightarrow$ transaction price.
- Rental market $\rightarrow$ rent.

What forces drive the **price-to-rent ratios** and their geographic heterogeneity?

- **Financial returns** for local real estate assets (cap-rate).
- **Tenure preferences** of households.
- **Location preferences** through location fundamentals.

To Buy or to Rent?



Graphic detail | Chasing the American dream

Is it cheaper to rent or buy property?

We crunch the house-price data across every American county—and make a surprising finding

Save Share

Nov 28th 2023 | 2 min read

Finance & economics | Homeownership

Rent or buy?

It's about more than price

Save Share

Apr 21st 2010 | 2 min read

To rent or to buy?

Homebuyers are paying too much to be their own landlord

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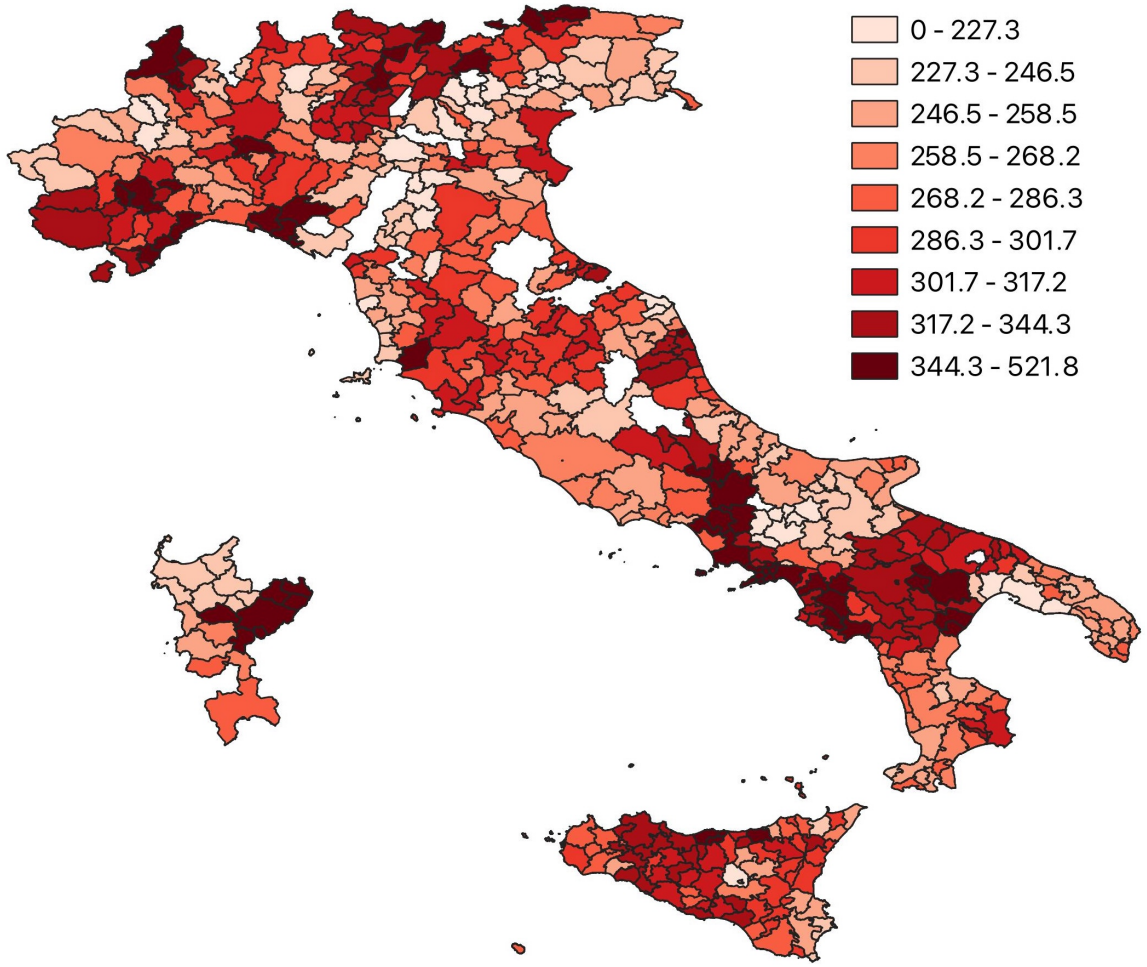
May 12th 2005 | | 4 min read

Can the price-to-rent ratio convey information on the **relative welfare?**

Geographic Heterogeneity in Price-to-Rent Ratios

Local price-to-rent ratios Italian local labor markets in 2019.



Granularity

Financial Returns - Gordon Growth Valuation

The **financial returns** rely on:

- Price = asset price.
- Rent = asset returns.

Thus, under perfectly competitive markets:

$$\text{Price}_i^0 = \sum_{t=0}^{+\infty} \left(\text{Rent}_i^t * \left(\frac{1}{1 + \text{Rate}_i^t} \right)^t \right)$$

Which is the **standard Gordon Growth Valuation formula** for assets.

Consistent with structural modeling.

[Vanhapelto, 2022, Amaral, Dohmen, Kohl, and Schularick, 2023, and Greaney, Parkhomenko, and Van Nieuwerburgh, 2025]

Tenure Preferences

Differences between shares of home-owners vs. renters.

Thus different demand for owning and renting $\rightarrow$ **price-to-rent ratio variation**.

Consistent with empirical results.

[Gete and Reher, 2018 and Akgündüz, Dursun-de Neef, Hacihasanoğlu, and Yılmaz, 2023]

This Paper

This paper will:

- Develop a **parsimonious model**:
  - Housing market with **all three forces**.
  - **Augmented Gordon Growth Valuation** formula.
- Measure the **local responses of prices and rents** to a mortgage rate shock:
  - The responses of prices and rents **vary in magnitude and sign**.
  - The three forces **are necessary** to explain the results.
- Run a structural exercise:
  - Recreate the **distribution of responses**.
  - Show that a mortgage rate hike **reduces geographic and tenure inequalities**.

Methodology

Common issues when estimating responses to mortgage rate shocks for both prices and rents:

- Difficult to compare properties for sale and for rent.
  $\rightarrow$ **Granular Italian dataset** which provides local prices and rents for properties of similar quality.
- Endogeneity between prices, rents, and mortgage rates.
  $\rightarrow$ **Novel SSIV identification strategy** leveraging local demographic differences.

Literature Review

I contribute to three strands of literature:

- **Price-to-Rent Ratios:**
  [Sommer et al. (2013) and Vanhapelto (2022)]
  → General mechanism explaining the local divergence in price-to-rent ratios.
- **Mortgage Rates and Prices**
  [Karlman (2022) and Akgündüz et al. (2023)]
  → Heterogeneous local responses of prices and rents to mortgage rate shocks.
- **Quantitative Spatial Models**
  [Redding and Rossi-Hansberg (2017) and Greaney et al. (2025)]
  → Incorporate the three price-to-rent forces in quantitative spatial models.

Environment

- The model is **static**. There are **I locations**, indexed $i \in \{1, \ldots, I\}$.
- Households consume a **generic consumption good** and **housing**
- Households can either be **renters** or **home-owners**, indexed by $t \in \{owner, renter\}$.
  - Renters rent housing by paying a rental price r_i.
  - Home-owners buy properties at price p_i and decide **how much to consume** and **how much to supply** on the rental market.
  - Home-owners enjoy a **warm glow bequest motive** for owning.
- Households choose **location, tenure and consumption**.
- Wages and the common consumption prices are given.

Household Problem - Renter

The renter problem is:

$$\max_{\{c_i, H_i^r\}} \ln A_i + \phi_1 \ln c_i + (1 - \phi_1) \ln H_i^r + \varepsilon_{i,renter}$$

$$\text{s.t. } w_i = c_i + r_i H_i^r$$

$$c_i, H_i^r \geq 0$$

- A_i is the value of local amenity in location i.
- c_i is the household consumption choice at price 1
- H_i^r is the housing consumption obtained on the rental market at price r_i.
- $\varepsilon_{i,t} \sim$ Nested Gumbel(σ_l, σ_t). Gumbel

Household Problem - Home-Owner

The home-owner problem is:

$$\max_{\{c_i, H_i, H_i^r, H_i^c\}} \ln A_i + \ln A_{i,owner} + \phi_1 \ln c_i + (1-\phi_1) \ln H_i^c + \beta \ln H_i^b + \varepsilon_{i,owner}$$

$$\text{s.t. } w_i + r_i H_i^r = c_i + (1+\tau) p_i H_i^b$$

$$H_i^b = H_i^r + H_i^c$$

$$c_i, H_i^r, H_i^c, H_i^b \geq 0$$

- Owners receive an additional local home-ownership amenity $A_{i,owner}$.
- τ is a wedge for house prices $\rightarrow$ Mortgage interest rates.
- $\beta > 0$.

Solutions Builders

Equilibrium

I define the equilibrium as a set $\{p_i, r_i\}_i$ for all $i \in \{1, \ldots, I\}$ such that:

- Buyers and renters maximize their utility.
- Builders maximize their profits.
- Transaction housing market clears.
- Rental housing market clears.

Define:

- $\text{Pop}_{i,t} = \lambda_i \, \lambda_{t|i} \, \text{Pop}$: the population which chooses location choice i and tenure choice t.

Equilibrium Price and Rent

Rearranging the market clearing conditions:

Local Rents

$$r_i = (1 - \phi_1)\frac{w_i}{H_i}\left(\text{Pop}_{i,\text{renter}} + \frac{1}{1+\beta}\text{Pop}_{i,\text{buyer}}\right)$$

Augmented Gordon Growth Valuation Formula

$$(1+\tau)p_i = r_i + \frac{w_i}{H_i}\frac{\beta}{1+\beta}\text{Pop}_{i,\text{buyer}}$$

What is driving the deviation from the standard Gordon's formula? The **local relative difference in utility**.

Price-to-Rent Ratio

Price-to-Rent Ratio

$$\frac{p_i}{r_i} = \underbrace{\frac{1}{(1+\tau)}}_{1.} + \frac{\beta}{(1-\phi_1)(1+\beta)(1+\tau)} \underbrace{\frac{\text{Pop}_{i,\text{buyer}}}{\left(\text{Pop}_{i,\text{renter}} + \frac{1}{1+\beta}\text{Pop}_{i,\text{buyer}}\right)}}_{2.}$$

The price-to-rent ratio captures the three forces:

1. **Financial returns**: the standard Gordon Growth Valuation formula.
2. **Location and tenure preferences**.

Is the model able to replicate the behavior of prices and rents?

Theoretical predictions

The standard Gordon Growth Valuation formula predicts ($\beta = 0$):

$$\frac{p_i}{r_i} = \frac{1}{1+\tau} \implies \frac{\partial p_i / r_i}{\partial \tau} = -\frac{1}{(1+\tau)^2}$$

Predictions:

- Price-to-rent ratio responses are **exclusively negative**.
- Net of mortgage rate levels $\rightarrow$ no price-to-rent ratio responses.

Additionally, without tenure-location equilibrium responses:

- Price responses are **negative**.
- Rent responses are **positive or null** through supply side responses.

OMI Dataset

Empirical analysis of price-to-rent ratios had one issue: **different types of properties are selected in different markets**.

How to compare properties for sale and properties for rent?

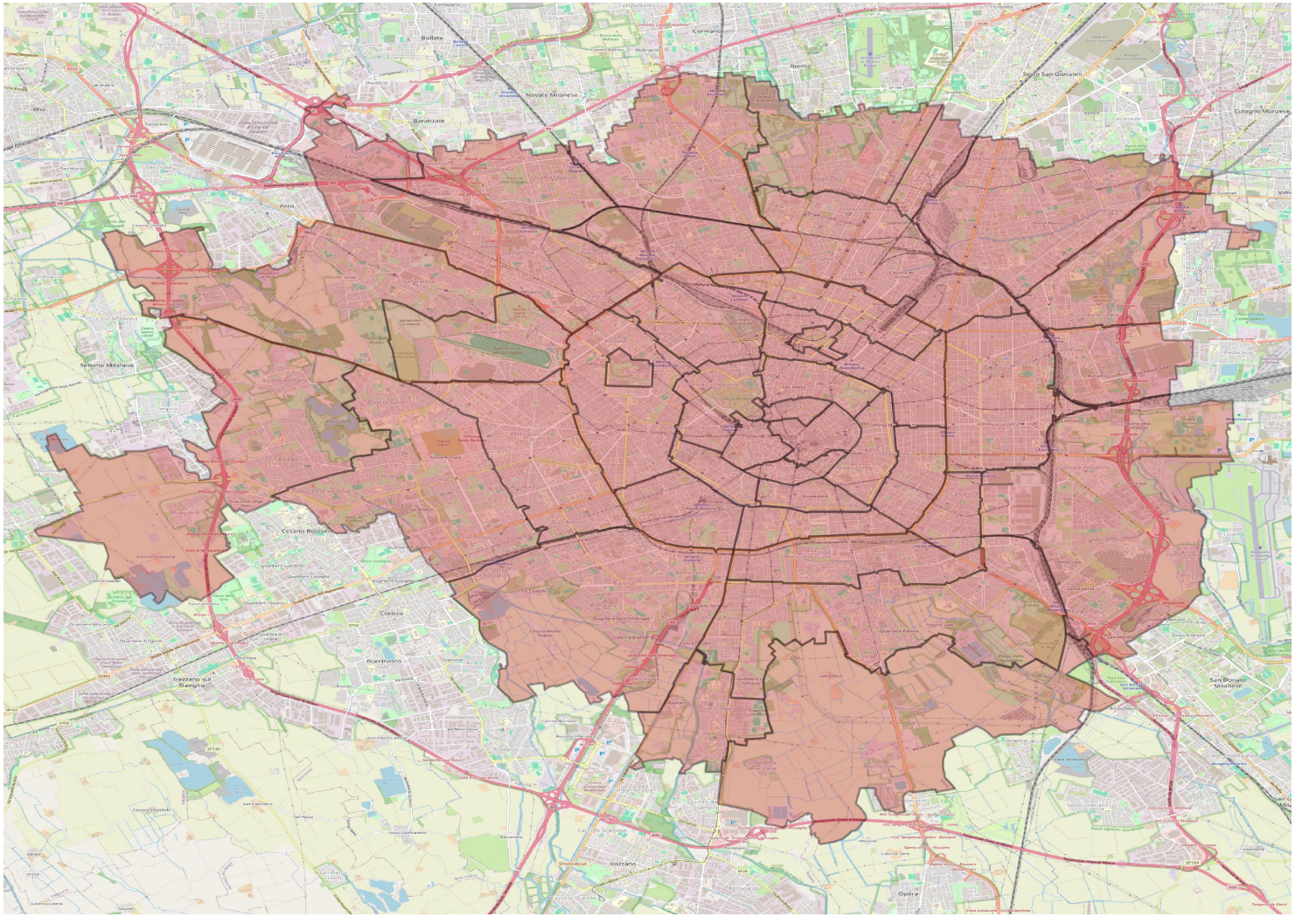
The Italian Tax Agency provides data on prices and rents, based on contract data, aggregated by:

- Sub-municipal homogeneous locations (OMI zones).
- Different categories of residential properties (i.e. 'affordable housing'.)
- Different quality levels.

Thus allowing for a correct comparison between prices and rents.

Data Collected

OMI Zones



Milan OMI zones between 2014 and 2023 overlayed on the city map. Nationally there are >20000 OMI zones.

OLS Estimation - Formula

We aim to estimate the **relationship between mortgage rates and both price and rents**:

$$y_{i,t,q} = \gamma \ln \tau_{R,t} + \mu_m + \mu_q + \mu_{t,LLM} + \varepsilon_{R,t}$$

Where:

- i indexes omi zone, t is a time index (every semester), q indexes the housing quality, m indexes municipalities R indexes the administrative region.
- $\tau_{R,t}$ is the Italian local mortgage interest rates.
- $\varepsilon_{R,t}$ is the error term, clustered at the R, t level.
- μ_q, μ_m, $\mu_{t,LLM}$ are sets of fixed effect per quality, municipality, and time interacted with local labor markets.

OLS Estimation Results

OLS Estimation - Local Heterogeneity Formula

To capture the geographic dimension, I evaluate the OLS regression allowing for different slopes based on local income.

$$y_{i,t,q} = \gamma \ln \tau_{R,t} + \gamma_m W_{m,2012\,S1} \ln \tau_{R,t} + \mu_m + \mu_q + \mu_{t,LLM} + \varepsilon_{m,t}$$

- W_m stands for income as measured in 2012.

OLS Estimation Results

Bartik Shift Share Instrument (SSIV)

The parameter of interest is the **response of prices and rents to mortgage rates**.

An SSIV identification strategy requires a variation in **the exposure to a shock**.

Local Demographic Composition

Different age groups have different mortgage pick up rates. $\rightarrow$ **Different local demographic compositions create variation in exposure**.

I further instrument the dependent variable with: **a composition of European mortgage interest rates**.

Source of Variation

SSIV Model - Assumptions

Key Assumptions:

- The shock is **quasi-randomly distributed** given shares and local unobservables.
  - The shock is common across each region for every year.
  - The shock is instrumented by a composition of European mortgage interest rates.
- The observations of the effective instrument (shocks) are **large in numbers and mutually uncorrelated**.
  - Respected across locations and years.

The quasi-random assignment of shocks $\Longrightarrow$ consistent and unbiased estimation.

Formal Assumptions

SSIV Model - Estimation

I estimate:

$$y_{i,q,t}^{e_m} = \gamma \ln \tau_{R,t}^{e_m} + \gamma_m W_{m,2012\,S1}\, \tau_{R,t}^{e_m} + \mu_m + \mu_q^{s_m} + \mu_{t,LLM}^{s_m} + \varepsilon_{m,t}$$

Where:

- Superscript e_m states the interaction with the exposure share for municipality m to a mortgage rate shock, s_m with the incomplete sum of age shares.
- $e_m = \sum_a s_{m,a}\, \kappa_a$, where κ_a is the mortgage pick up rate for age a.
- $\tau_{R,t}^{e_m}$ is the mortgage interest rate, instrumented by a composition of European mortgage interest rates.

Instrument and Shares Definitions | National Estimates

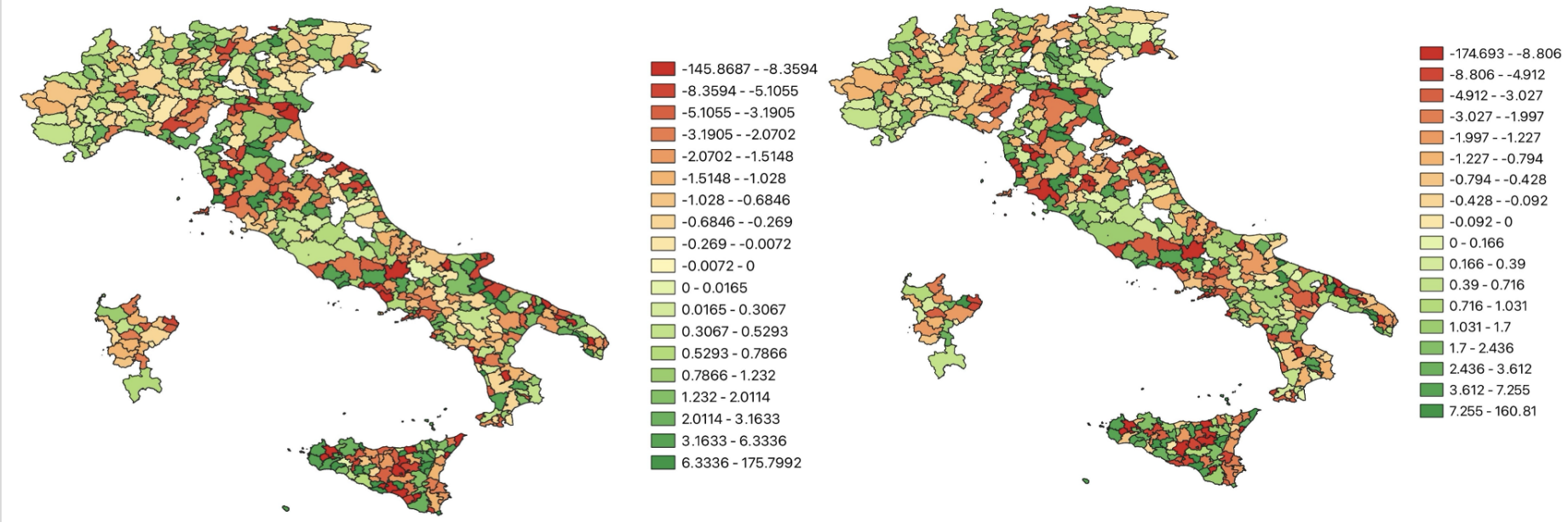
SSIV Analysis - Local Heterogeneity

	Prices	Rents	Price-to-Rent Ratio
Interest Rates	-0.633^{***}	-0.594^{**}	-0.0382
	(0.205)	(0.236)	(0.175)
Interest Rates	0.0526^{***}	0.0458^{**}	0.00682
$\times$ Log of Income	(0.0174)	(0.0197)	(0.0169)
Quality FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Semester $\times$ LLM FE	Yes	Yes	Yes
20^{th} Percentile	-0.133	-0.159	0.0265
80^{th} Percentile	-0.113	-0.141	0.0292
N	2'226'042	2'226'042	2'226'042
R-sq	0.9440	0.874	0.937

All variables are in log terms. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors clustered at the municipality - year level.

Regression Formula Pre-Trend Test

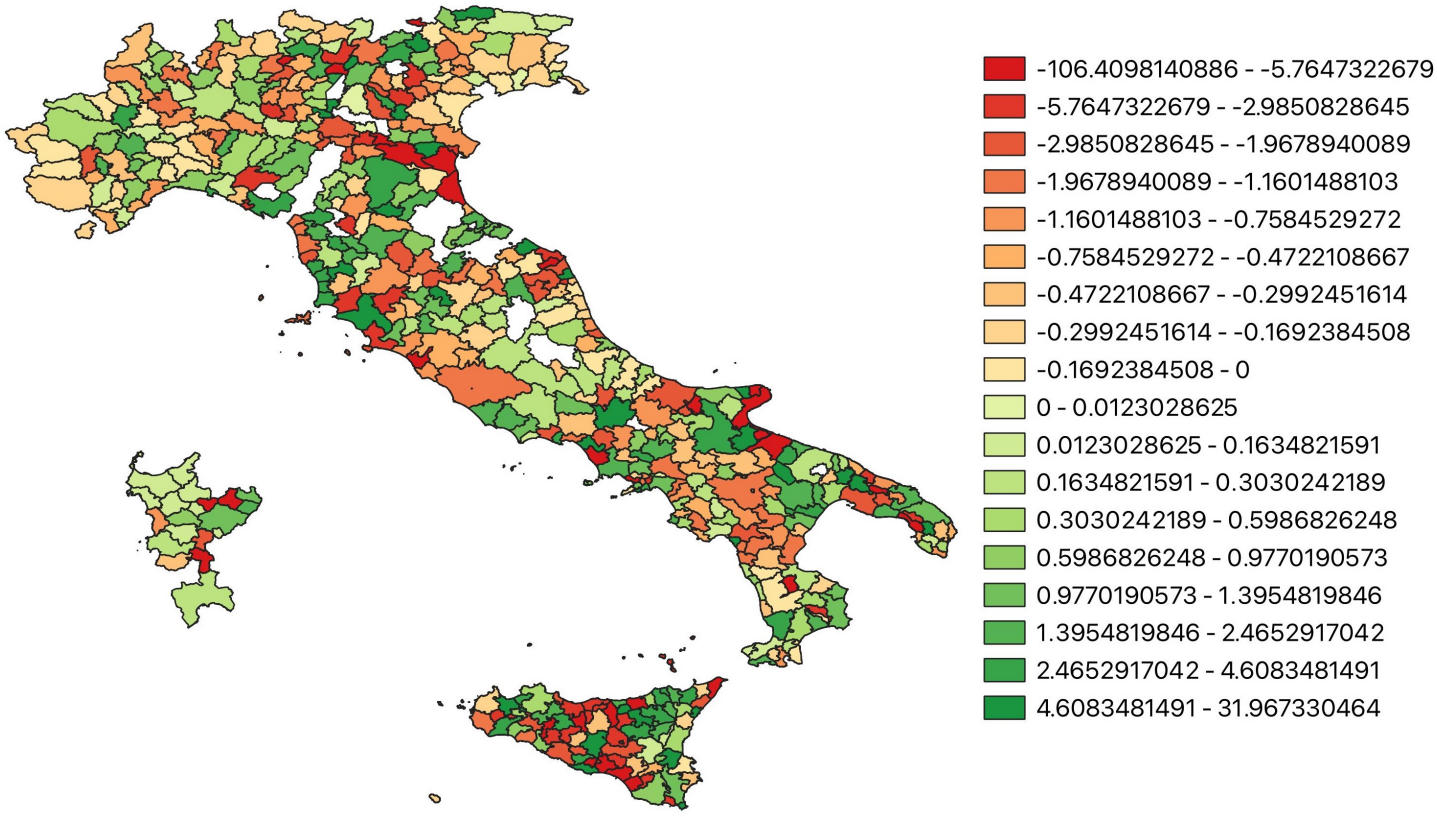
Distributions of Responses - Prices & Rents



On the left: local **price** elasticities. On the right: local **rent** elasticities

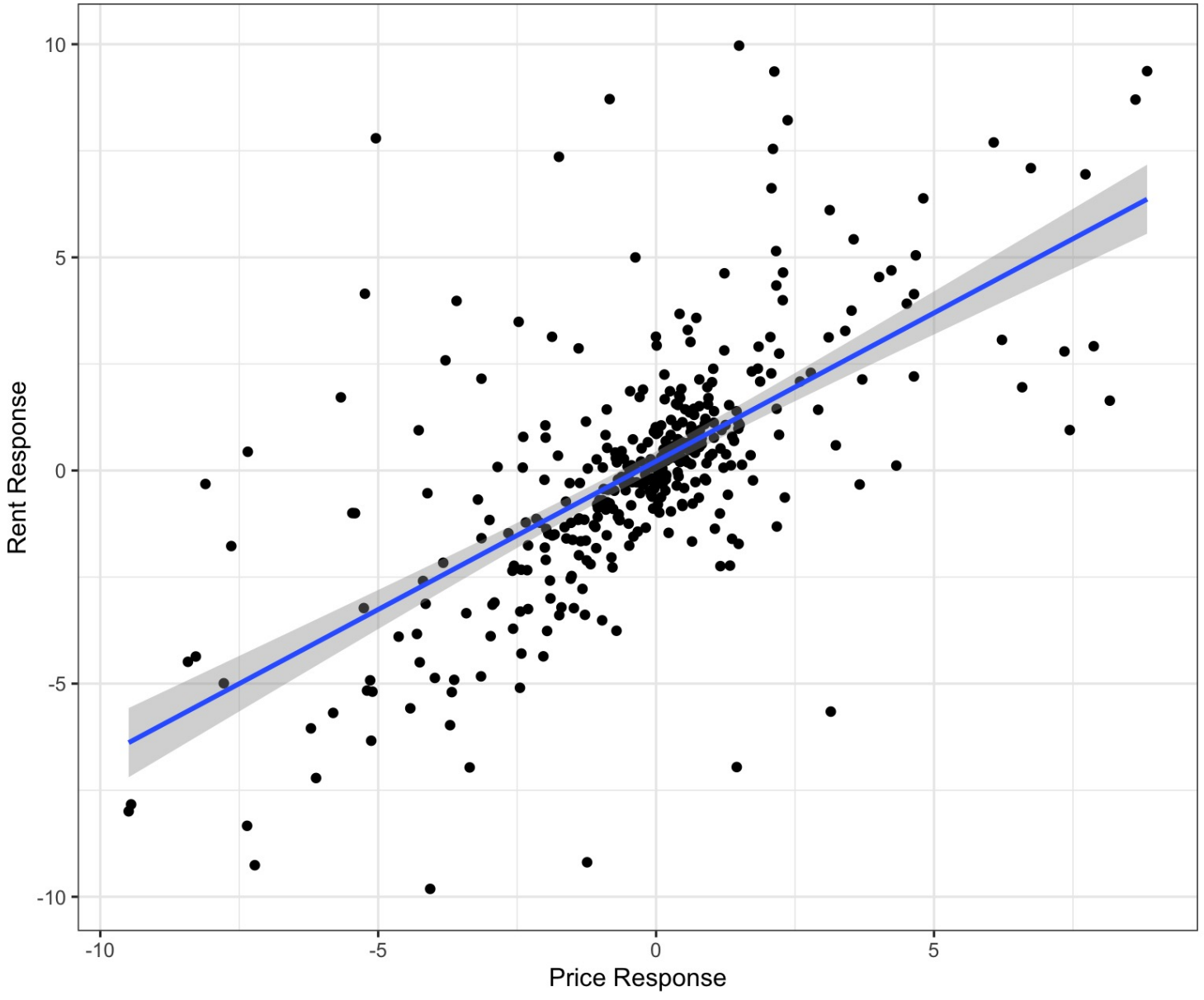
Local Labor Markets | Distribution of Population Responses

Distribution of Responses - Price-to-Rent Ratios



◂ Forward to Predictions

Price and Rent Local Elasticities Correlation



SSIV Analysis - Local Heterogeneity Additional Results

	Population	Share of Renters
Interest Rates	0.752^{***}	-1.159^{***}
	(0.120)	(0.0453)
Interest Rates	-0.189^{***}	0.00905^{*}
$\times$ Log of Income	(0.0209)	(0.00482)
Municipality FE	Yes	Yes
Semester $\times$ LLM FE	Yes	Yes
20^{th} Percentile	-1.043	-1.073
80^{th} Percentile	-1.117	-1.070
N	282'242	282'236
R-sq	0.999	0.996

All variables are in log terms. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors clustered at the municipality - year level.

Pre-Trend Test

Empirical Results

- **Prices and rents responses** to positive mortgage rate shock are
  - **heterogeneous** across location.
  - **positively correlated** within locations.
- **Share of renters** is less affected in high income locations.

The key model assumptions are **necessary** to account for these results.

- Location/tenure choice.
- Additional ownership utility.

Theoretical Predictions Tested

If $\beta = 0 \rightarrow (1+\tau)p_i = r_i$. It implies:

$$\frac{p_i}{r_i} = \frac{1}{1+\tau} \implies \frac{\partial p_i / r_i}{\partial \tau} = -\frac{1}{(1+\tau)^2}$$

Which cannot explain:

- Positive responses in price-to-rent ratios.

Similarly, absence of location-tenure responses would imply:

- Negative price responses.
- Positive or null rent responses.

Observe **positive correlation** in responses.

Price-to-Rent Responses Distribution | Simple Dynamic Behaviour

Aim of the Structural Estimation

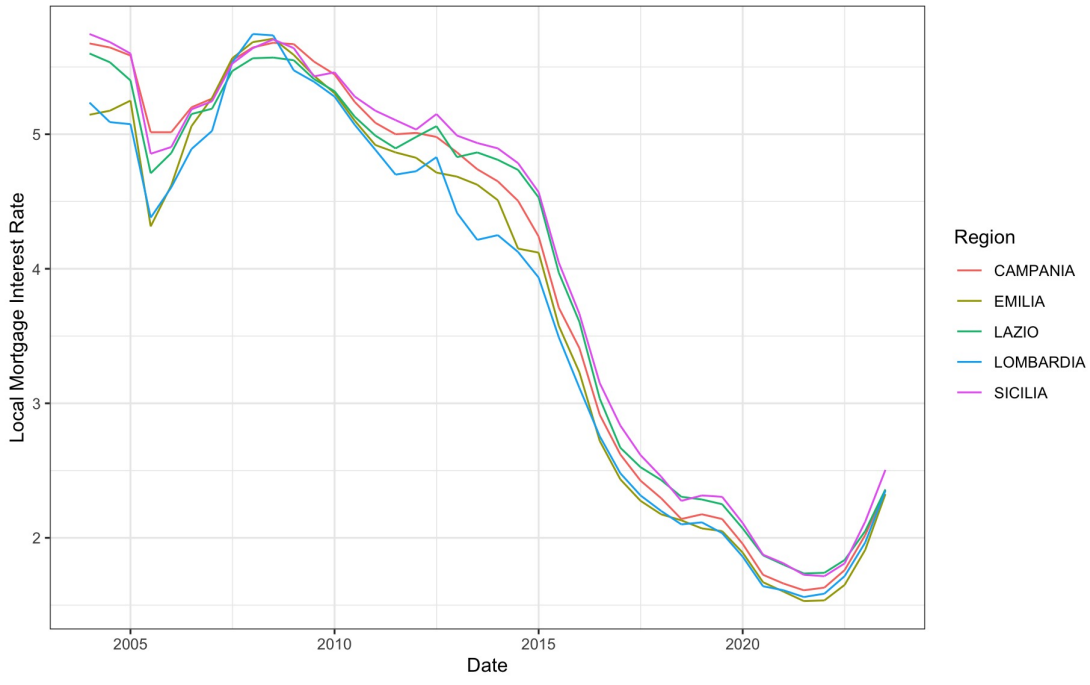
The aim of the estimation is threefold:

- The model generates a **similar distribution of prices and rents** as the one observed.
- The model generates a set of **heterogeneous responses** for prices and rents to a mortgage rate hike with respect to local wages as in the empirical estimation.
- Whether there is an **heterogeneous local response** in welfare for both buyers and renters.

I run a simple counterfactual, isolating the effect of a large **mortgage rate hike** on the economy.

Counterfactual Estimation

The rates of outstanding mortgage loans have increased sharply between 2021 and 2023.



I estimate the price, rents, and welfare effects of the increase in observed mortgage interest rates.

Structural Parameters

I recover the following time-specific parameters for both 2014 and 2021:

- Location amenities A_i.
- Location specific home-ownership amenities $A_{owner,i}$.
- Location land availability $\bar{H}_i$.
- Local construction elasticity parameter ρ_i.

I also estimate the following parameters:

- Individual preference parameters ϕ_1 and β.
- Gumbel shock parameters σ_l and σ_t.

Algorithm Locations Targeted Moments

Price and Rent Estimation

Does the model generate a realistic price and rent distribution?

Year	Price correlation	Rent correlation
2014	0.217	0.319
2021	0.193	0.361

I report the correlations between

- The **model-generated** prices and rents.
- The **real-world** local prices and rents.

Local Responses Distribution w.r.t Local Wages

In the table the direction of the correlation between:

- **Model simulated** responses and the local observed wages.
- **Real-world data estimated** responses and the local observed wages

Response	Simulated correlation	Observed correlation
Price	$>$	$>$
Rent	$>$	$>$
Price-to-Rent (Net of interest rate)	$<$	$\sim$
Population	$<$	$<$
Share of Renters	$>$	$>$

Local Welfare Responses Distribution

Response	Simulated correlation
Home-Owner Welfare	$<$
Renter Welfare	$<$

The responses in local welfare:

- **reduce** relative spatial inequalities.
- **reduce** national inequalities between buyers and renters.

Conclusion

The current research finds:

- I incorporate the three forces determining price-to-rent ratios in a spatial model $\rightarrow$ **augmented Gordon Growth Valuation Formula**.

- Different locations have **different responses in prices and rents w.r.t. mortgage rate shocks** $\rightarrow$ reconcilable only with the three forces.

- The model estimates that the national mortgage rate increase between 2021 and 2023 **reduced spatial inequalities** and **buyers-renters inequalities**.

Thank you for following.

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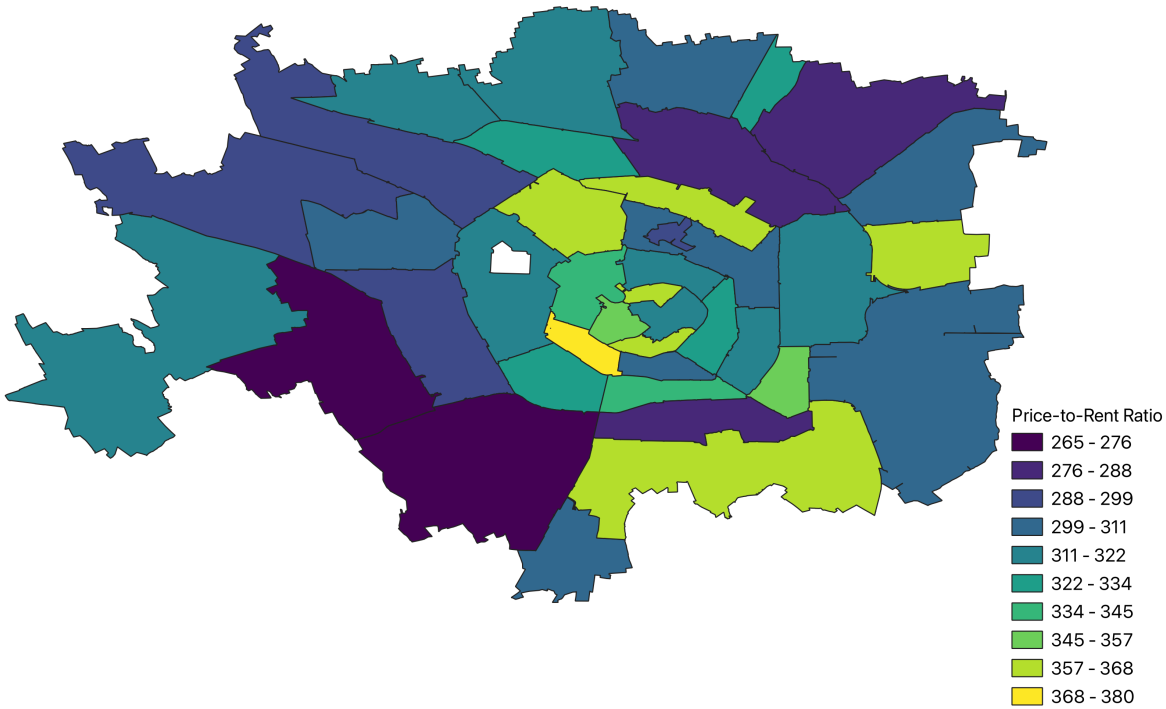
Local Geographic Heterogeneity in Price-to-Rent Ratios

Local price-to-rent ratios across the municipality of Milan in 2019.



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Household Problem - Solution

The renter's problem solution:

$$c_{i,\text{Renter}} = \phi_1 \, w_i, \quad H^r_{i,\text{Renter}} = (1-\phi_1)\,\frac{w_i}{r_i}$$

The home-owner's problem solution:

$$c_{i,\text{Owner}} = \frac{\phi_1}{1+\beta}\, w_i, \quad H^c_{i,\text{Owner}} = \frac{1-\phi_1}{1+\beta}\,\frac{w_i}{r_i},$$

$$H_{i,\text{Owner}} = \frac{\beta}{1+\beta}\,\frac{w_i}{(1+\tau)p_i - r_i},$$

$$H^r_{i,\text{Owner}} = \frac{\beta}{1+\beta}\,\frac{w_i}{(1+\tau)p_i - r_i} - \frac{1-\phi_1}{1+\beta}\,\frac{w_i}{r_i}$$

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Population Distribution

Gumbel idiosyncratic shocks $\rightarrow$ probability of a household to pick tenure choice k given location choice j:

$$\lambda_{k|j} = \frac{\exp(U_{j,k})^{\frac{1}{\sigma_t}}}{\exp(U_{j,k})^{\frac{1}{\sigma_t}} + \exp(U_{j,k'})^{\frac{1}{\sigma_t}}}$$

While the choice of moving to j irrespective of tenure choice is:

$$\lambda_j = \frac{(\exp(U_{j,k})^{\frac{1}{\sigma_t}} + \exp(U_{j,k'})^{\frac{1}{\sigma_t}})^{\frac{\sigma_t}{\sigma_l}}}{(\sum_{i=1}^{I} \exp(U_{i,k})^{\frac{1}{\sigma_t}} + \exp(U_{i,k'})^{\frac{1}{\sigma_t}})^{\frac{\sigma_t}{\sigma_l}}}$$

Back

Existence of the Rental Market

A location i has a rental market if

$$H^b_{i,\text{Owner}} \geq H^r_{i,\text{Owner}}$$

Rearranging:

$$(1+\beta)r_i \geq (1-\phi_1)(1+\tau)p_i$$

Given that $(1+\tau)p_i \geq r_i$, the existence of a rental market is guaranteed if the relative desire for housing consumption for home-owners (ϕ_2) is lower with respect to the desire for ownership (β).

Otherwise the rental market collapses and the location has only homeowners with $H^b_{i,\text{Owners}} = H^c_{i,\text{Owners}}$.

Builder Problem

Properties are supplied by a competitive local construction sector.

$$\text{Max}_{\{n_i\}}\ p_i H_i - w_i n_i - p_i^L \bar{H}_i$$

$$\text{s.t. } H_i = n^{\rho_i} \bar{H}_i^{1-\rho_i}$$

- n is the labor input.
- $\bar{H}_i$ is the local land input and p_i^L is its price.
- Under $\rho_i = 0$ the housing supplied is inelastic and equal to $\bar{H}_i$.

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Builder Problem - Solution

The builder's problem solution is:

$$n = \left(\frac{\rho_i \, p_i}{w_i} \right)^{\frac{1}{1-\rho_i}} \bar{H}_i$$

Given that all the available land is traded, the housing supplied is equal to:

$$H_i = \left(\frac{\rho_i \, p_i}{w_i} \right)^{\frac{\rho_i}{1-\rho_i}} \bar{H}_i$$

Data

- **House prices and rents:** collected by the Italian fiscal agency and aggregated in sub municipal homogeneous territories (OMI zones). Provided for houses of similar purposes and quality. Collected between 2004 and 2023.
- **Residential properties supply:** collected by the Italian fiscal agency and provided in units and number of rooms. Collected between 2013 and 2020.
- **Wages:** Provided by the Ministry of the Economy and Finance at the municipal level based on income declarations. Collected between 2012 and 2021.
- **Population per age:** provided at the municipal level by ISTAT. Collected between 2004 and 2023.
- **Share of renters:** provided at the provincial level by ISTAT. Collected between 2004 and 2023.

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OLS Estimation

	Prices	Rents	Price-to-Rent Ratio
Interest Rates	0.263	0.271	−0.00805
	(0.228)	(0.235)	(0.145)
Quality FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Semester FE	Yes	Yes	Yes
N	2'226'042	2'226'042	2'226'042
R-sq	0.855	0.824	0.620

All variables are in log terms. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors clustered at the region - year level.

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OLS Estimation - Population Weights

	Prices	Rents	Price-to-Rent Ratio
Interest Rates	0.188	0.161	0.0275
	(0.192)	(0.256)	(0.188)
Quality FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Semester FE	Yes	Yes	Yes
N	2'226'042	2'226'042	2'226'042
R-sq	0.827	0.803	0.560

All variables are in log terms. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors clustered at the municipality - year level. Observations are weighted on average local population per OMI zone.

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OLS Estimation - Local Heterogeneity

	Prices	Rents	Price-to-Rent Ratio
Interest Rates	−0.119	0.0847	−0.204
	(0.154)	(0.166)	(0.137)
Interest Rates	0.0479***	0.0203	0.0276*
× Log of Income	(0.0157)	(0.0178)	(0.0152)
Quality FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Semester × LLM FE	Yes	Yes	Yes
20^{th} Percentile	0.336	0.277	0.0581
80^{th} Percentile	0.355	0.285	0.0689
N	2'226'042	2'226'042	2'226'042
R-sq	0.888	0.864	0.754

All variables are in log terms. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors clustered at the municipality - year level.

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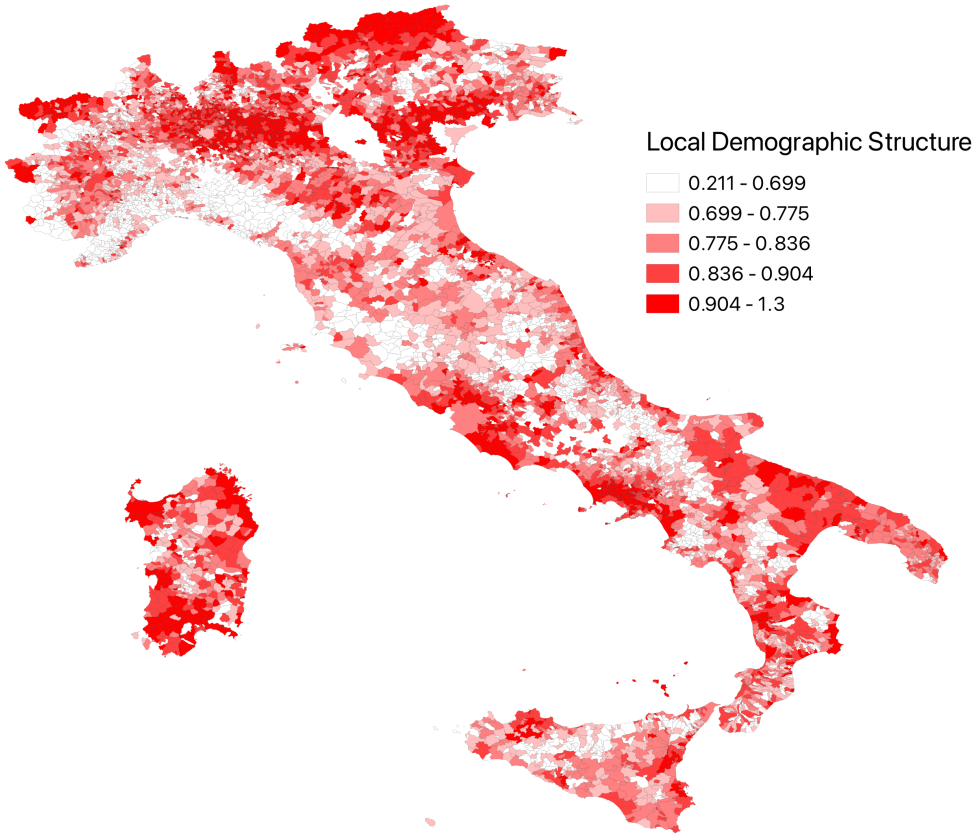
Variation Source - Mortgage Pick Up Rates

Age class	Percentage of borrowers
Up to 30	64%
31 - 40	70%
41 - 50	56%
51 - 60	36%
61 - 70	18%
Over 70	5%

Distribution of buyers per age class who take a mortgage when buying a residential property. Source: *Quaderni dell'Osservatorio - December 2023*, published by the OMI, based on transaction level data.

Variation Source - Local Demographic Composition

Local municipal population between 18 and 50 divided by the remaining municipal population.



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Boryusak et al. (2022) - Assumptions

I consider two assumptions by Borusyak, Hull, and Jaravel, 2022 which allow for a correct estimation of the SSIV model.

Assumption 3: Conditional quasi-random shock assignment

$$\mathbb{E}[g_n|\bar{\varepsilon}, q, s] = q_n' \mu, \forall n.$$

Where g_n is the shock (mortgage interest rates), q_n is a cluster (in our case regions) and μ is a given value.

Assumption 5: Many uncorrelated shock clusters

There exists a partition of shocks into clusters $c(n)$ such that $\mathbb{E}[\sum_c s_c^2] \to 0$ for $s_c = sum_{n:c(n)=c} s_n$ and $\text{Cov}[\tilde{g}_n, \tilde{g}_{n'}|\bar{\varepsilon}, q, s] = 0$ for all (n, n') with $c(n) \neq c(n')$.
Where s_n are the exposure shares.

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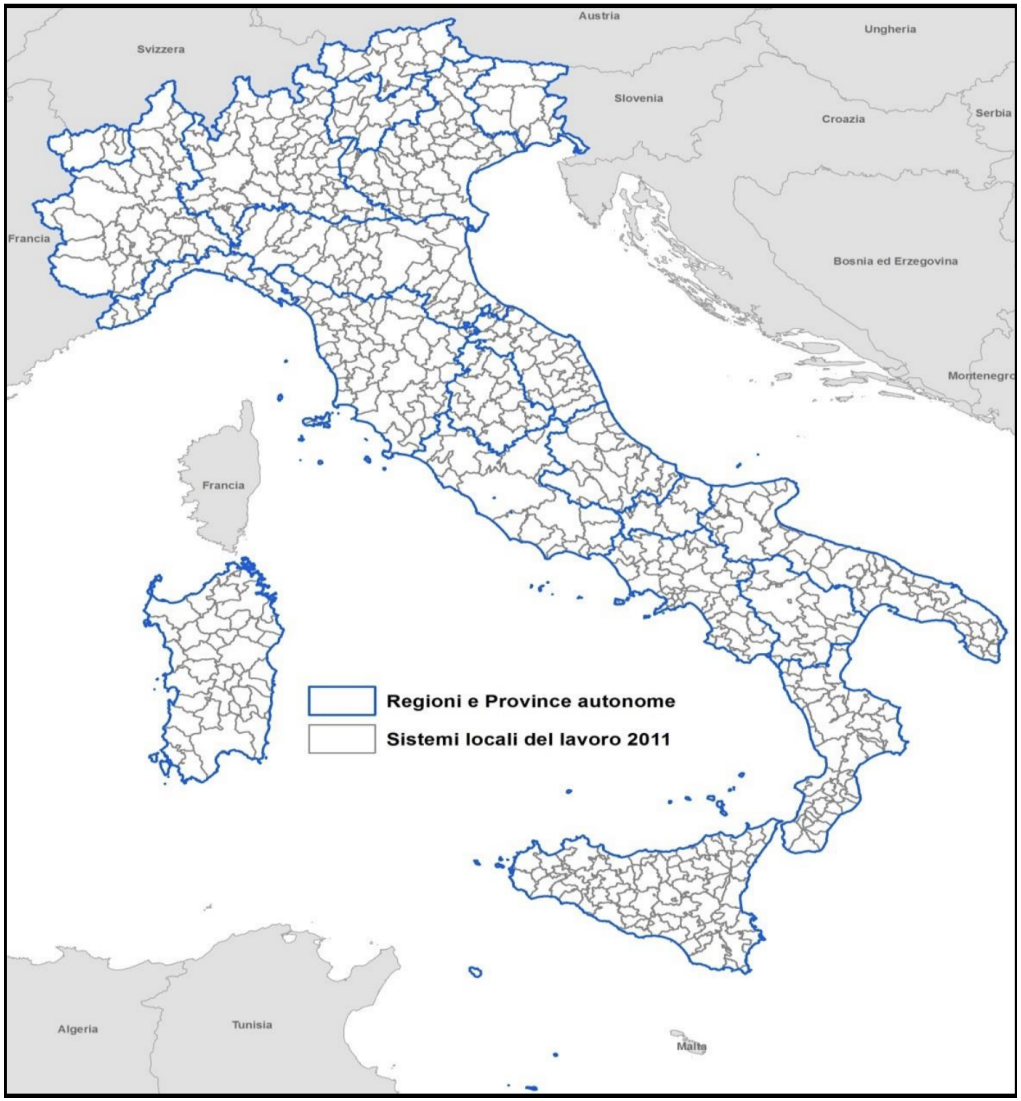
Local Labor Markets in Italy



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SSIV - Share definition and Instrument

I define the following:

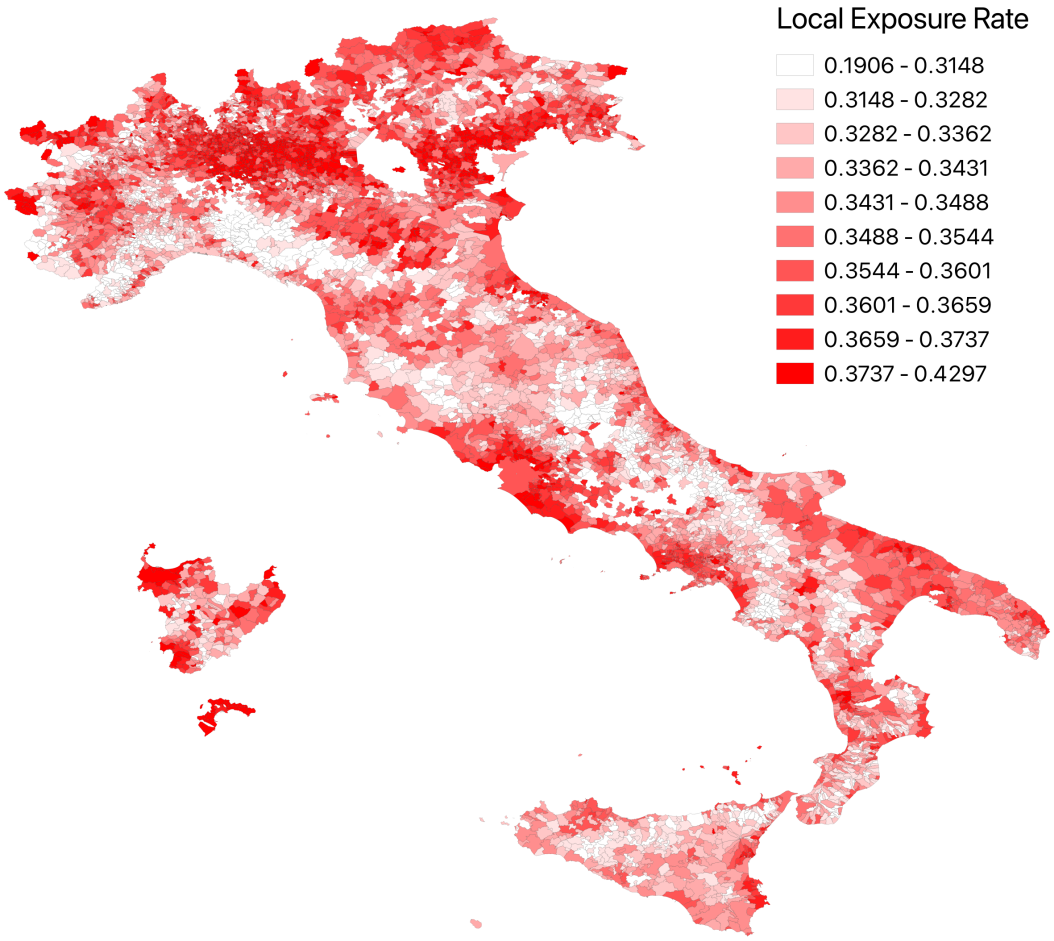
- $s_m = \sum_a s_{a,m}$, sum of the local population shares.
- $e_m = \sum_a s_{a,m}\, p_a$, linear combination of the local population shares and the mortgage take up rates.

The variable of interest is then: $\tau_{R,t}^{e_m} = \tau_{R,t}\, e_m$.

Where I index with a the age shares, with m the municipalities, with R the regions and with t the semester. All shares are defined with respect to 2004 S1.

In addition I further instrument the mortgage interest rates with a composition of European national mortgage interest rates.

SSIV - Spatial Distribution of e_m



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SSIV - Local Heterogeneity Formula

To test local heterogeneity with respect to income:

$$y_{i,q,t}^{e_m} = \gamma \ln \tau_{R,t}^{e_m} + \gamma_m W_{m,2012\,S1}\, \tau_{R,t}^{e_m} + \mu_m + \mu_q^{s_m} + \mu_{t,LLM}^{s_m} + \varepsilon_{m,t}$$

To further assess the local heterogeneity, for each local labor market:

$$y_{i,q,t}^{e_m} = \gamma_{LLM} \ln \tau_{R,t}^{e_m} + \mu_m + \mu_q^{s_m} + \mu_t^{s_m} + \varepsilon$$

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SSIV Analysis - National Level

	Prices	Rents	Price-to-Rent Ratio
Interest Rates	−0.117	−0.146	0.0287
	(0.136)	(0.144)	(0.0543)
Quality FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Semester × LLM FE	Yes	Yes	Yes
N	2'226'042	2'226'042	2'226'042
R-sq	0.874	0.874	0.937

All variables are in log terms. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors clustered at the region - year level.

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SSIV Analysis - National Level Population Weighted

	Prices	Rents	Price-to-Rent Ratio
Interest Rates	-0.372^{**}	-0.543^{***}	0.171
	(0.168)	(0.173)	(0.143)
Quality FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Semester FE	Yes	Yes	Yes
N	2'226'042	2'226'042	2'226'042
R-sq	0.892	0.843	0.882

All variables are in log terms. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors are clustered at the region - year level. Observation are weighted on local population levels

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SSIV Analysis - First Stage

	(1)	(2)
Eurozone Interest Rates	0.191^{***}	-11.399^{***}
	(0.00917)	(0.130)
Eurozone Interest Rates		1.391^{***}
$\times$ Log of Income		(0.0115)
N	2'217'900	2'217'900
F-statistics	6'422	80'986
R-sq	0.997	0.997

All variables are in log terms. Column (1): national estimations. column (2): estimation accounting for local income differences. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors are clustered at the OMI zone level.

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SSIV Analysis - Pre-Trend Local Heterogeneity

	Prices	Rents	Price-to-Rent Ratio
Interest Rates	4.093	3.604	−1.016
	(148899)	(166246)	(39406)
Interest Rates	−0.0581	0.00337	−0.0613
× Log of Income	(12.962)	(14.471)	(3.44)
Quality FE	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes
Semester × LLM FE	Yes	Yes	Yes
N	51'724	51'724	51'724
R-sq	0.730	0.653	0.739

All variables are in log terms. '*': significance at the 0.1 level. '**': significance at the 0.05 level. '***': significance at the 0.01 level. Standard errors are clustered at the municipality - year level.

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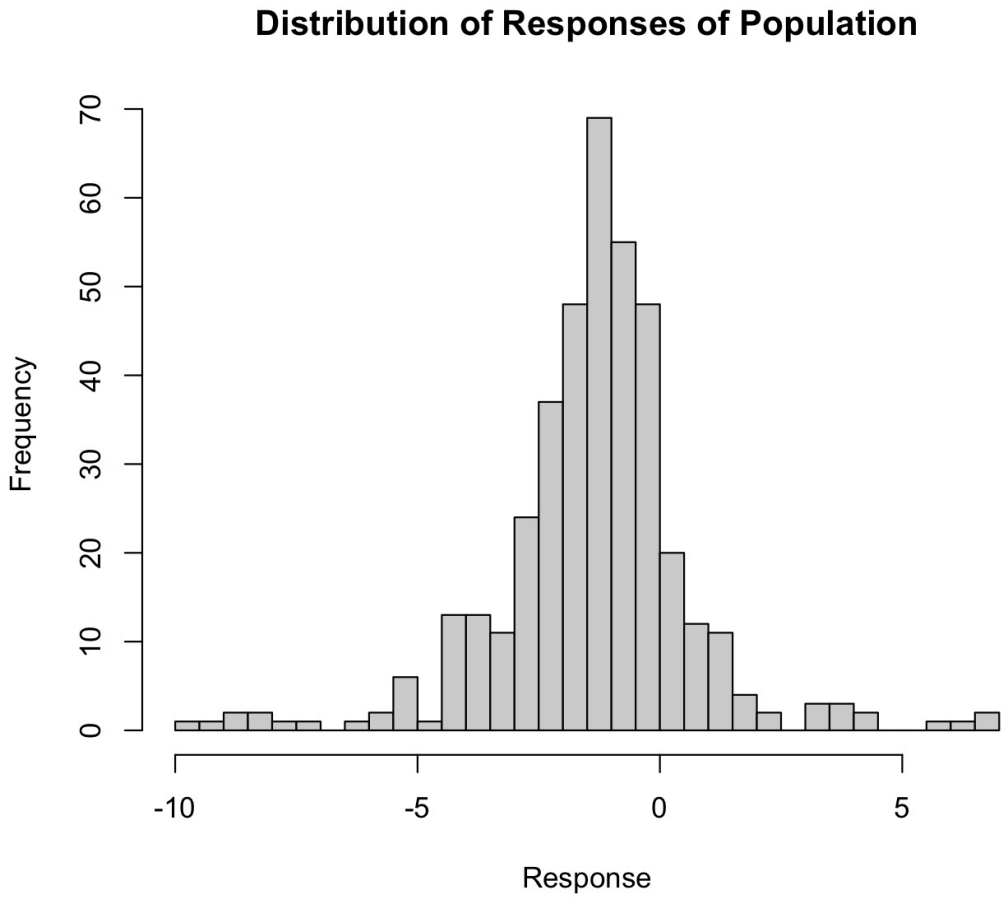
Distributions of Responses - Population



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SSIV Analysis - Pre-Trend Additional Results

	Population	Share of Renters
Interest Rates	−0.444	−2.532
	(0.980)	(1.498)
Interest Rates	0.0400	0.214
× Log of Income	(0.0929)	(0.159)
Municipality FE	Yes	Yes
Year × LLM FE	Yes	Yes
N	51'724	51'724
R-sq	0.968	0.899

All variables are in log terms. A '*' indicates coefficients significant at the 0.05 level. A '**' indicates coefficients significant at the 0.01 level. A '***' indicates coefficients significant at the 0.001 level. Standard errors are clustered at the municipal - year level.

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Dynamic Model with $\beta = 0$

Let us consider the Gordon Growth Formula as stated by Amaral et al., 2023:

$$(1 + \tau_{t=0})\,\text{Price}_{i,t=0} = \sum_{t=0}^{+\infty} \frac{\text{Rent}_{i,t}}{(1 + r_{i,t})^t}$$

Where $r_{i,t}$ is the local real interest rate. Assuming rents are expected to grow at constant local rate g_i, that $r_{i,t} = r_i$ for all t, and that $r_i < g_i$:

$$\frac{\text{Price}_i}{\text{Rent}_i} = \frac{1 + g_i}{(r_i - g_i)(1 + \tau)}$$

Thus, even in a simple dynamic model, an increae in mortgage rates that does not affect g_i, cannot explain the observed price-to-rent ratio responses.

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Locations Map

I restrict the model to:

- 400 local labor markets.
- The remaining municipalities are aggregated into 20 residual regional locations.

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Algorithm

The algorithm is made by the following general steps:

- Set ϕ_1 and ϕ_2 externally.
- Set inner loop to estimate β, σ_l and σ_t.
- Iterate inner loop for A_i, $A_{i,b}$, $\bar{H}_i$, and ρ_i matching the location choices, tenure choices and the price responses for 2014.
- Recover A_i, $A_{i,b}$, $\bar{H}_i$, and ρ_i for 2021.
- Run the counterfactual by increasing the interest rates similar to the 2021-2023 mortgage rate hike.

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Targeted Moments

- Static shares of:
  - Local population.
  - Local shares of buyers vs. renters
- Responses to a mortgage rate shock (in 2014):
  - Local prices.
- Average magnitude of responses to a mortgage rate shock (in 2014):
  - Local rents.
  - Local population.
  - Local shares of buyers vs. renters

Moments of interest

I am interested in the **correlation of responses** of prices, rents, population and share of buyers with respect to local wages.

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