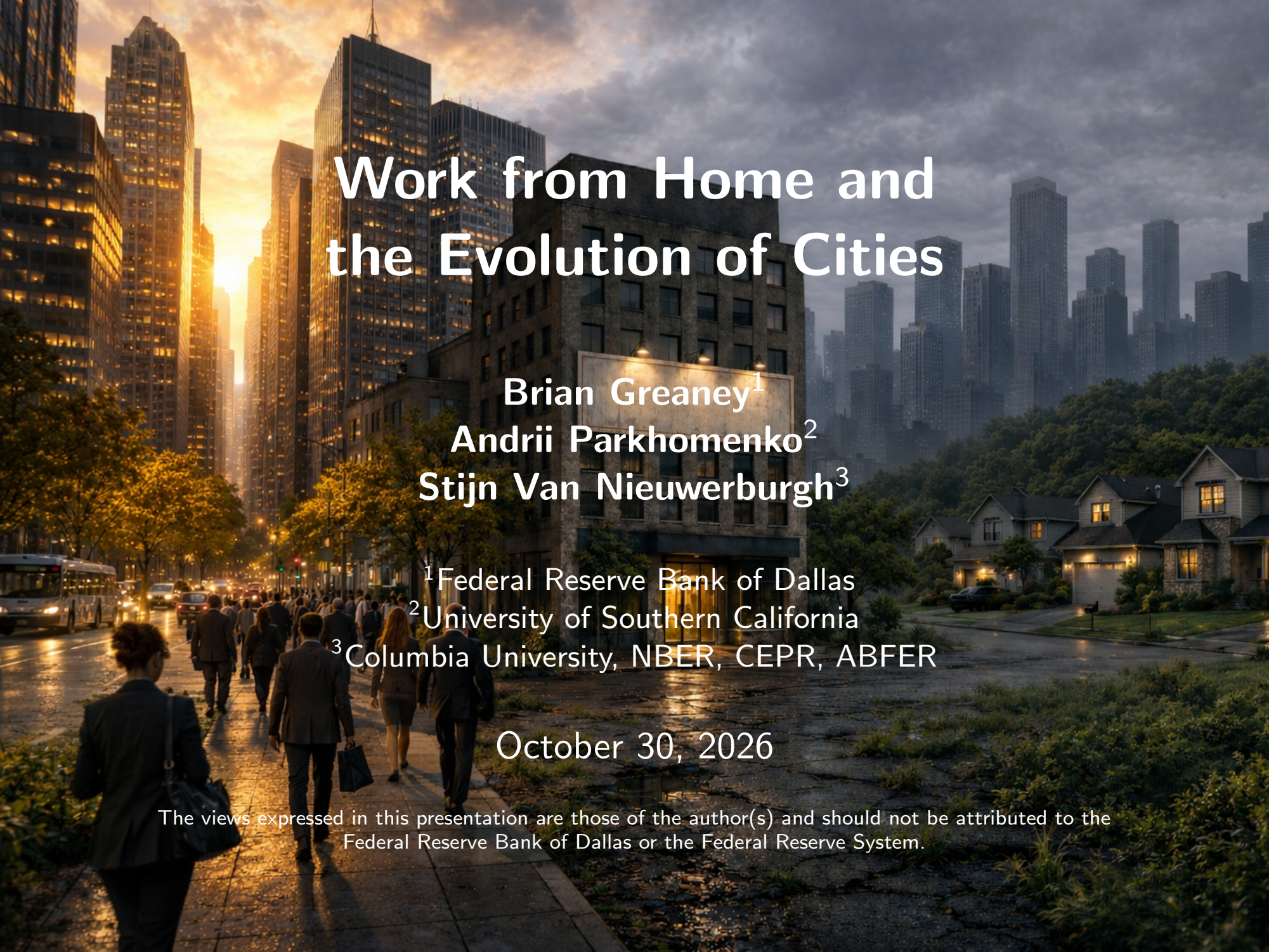


Work from Home and the Evolution of Cities

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Andrii Parkhomenko[2]
Stijn Van Nieuwerburgh[3]

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The views expressed in this presentation are those of the author(s) and should not be attributed to the Federal Reserve Bank of Dallas or the Federal Reserve System.

WFH and cities

- Work from home (WFH) days are 4x their pre-COVID level ▸ figure
- 1/4 of working days are done from home ▸ figure
- The distance between employers and employees is growing ▸ figure
- The premium to live close to the center has largely disappeared ▸ figure
- Office vacancies are high ▸ figure

WFH and cities

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- A **dynamic spatial model** with **frictions** and **heterogeneity** is required to study these questions

This paper

- Dynamic spatial model of a city with WFH ▸ literature
  - urban economics: many locations, commuting, migration, amenities
  - macro-housing: life cycle, uninsurable income risk, homeownership
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  - high average welfare gains, but 27% of households lose
  - local public finance and agglomeration reduce the gains
  - office-to-residence conversions can increase gains

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Model

Model: households

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- "Mixed time" of shocks and choices:
  - *discrete* "shock ages": preference and productivity shocks; residence, workplace, housing, and WFH frequency choices
  - *continuous* time: consumption-saving choices

▸ households ▸ timing ▸ computation

Model: firms, real estate

- Production: competitive firms in each j use labor and office space
  - on-site and remote work are imperfect substitutes
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- Production: competitive firms in each j use labor and office space
  - on-site and remote work are imperfect substitutes
  - *extension*: productivity depends on on-site labor
- Real estate: housing and offices
  - construction is irreversible
  - prices are present values of rents
  - households own owner-occupied housing
  - REITs own rental housing and offices

▸ real estate

WFH in the model: households

- WFH type $\varsigma \geq 0$: benefit of working on site
- Workers choose commuting frequency $x \in [0, 1]$. Costs and benefits:

$$\underbrace{-x^{\beta}\kappa T_{ij}}_{\text{cost}} + \underbrace{x\varsigma}_{\text{benefit}}$$

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- Optimal commuting frequency:

$$x(\varsigma, i, j) = \min \left\{ \left(\frac{\varsigma}{\beta \kappa T_{ij}} \right)^{\frac{1}{\beta - 1}}, 1 \right\}$$

  - $\varsigma = 0$: full-time remote
  - $0 < \varsigma < \beta \kappa \max T_{ij}$: hybrid
  - $\varsigma \geq \beta \kappa \max T_{ij}$: full-time on-site

WFH in the model: firms and offices

- Competitive firms in each j combine on-site and remote work:

$$Y_{jt} = Z_j \left(\theta_j (Y_{jt}^{\text{ofc}})^{\frac{\sigma-1}{\sigma}} + (1-\theta_j)(Y_{jt}^{\text{wfh}})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

  - on-site: $Y_{jt}^{\text{ofc}} = \left(\alpha_j L_{jt}^{\frac{\omega-1}{\omega}} + (1-\alpha_j) \left(H_{Cjt} - \bar{h}^C L_{jt} \right)^{\frac{\omega-1}{\omega}} \right)^{\frac{\omega}{\omega-1}}$
  - remote: $Y_{jt}^{\text{wfh}} = \tilde{L}_{jt}$

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  - remote: $Y_{jt}^{\text{wfh}} = \tilde{L}_{jt}$

- Workers earn pooled wage $w_{jt} = (w_{jt}^{\text{ofc}} L_{jt} + w_{jt}^{\text{wfh}} \tilde{L}_{jt})/(L_{jt} + \tilde{L}_{jt})$
  - w_{jt}^{ofc}, w_{jt}^{wfh}: marginal products of on-site and remote labor

- Office demand: on-site labor only, at least $\bar{h}^C$ per eff. unit ▸ offices

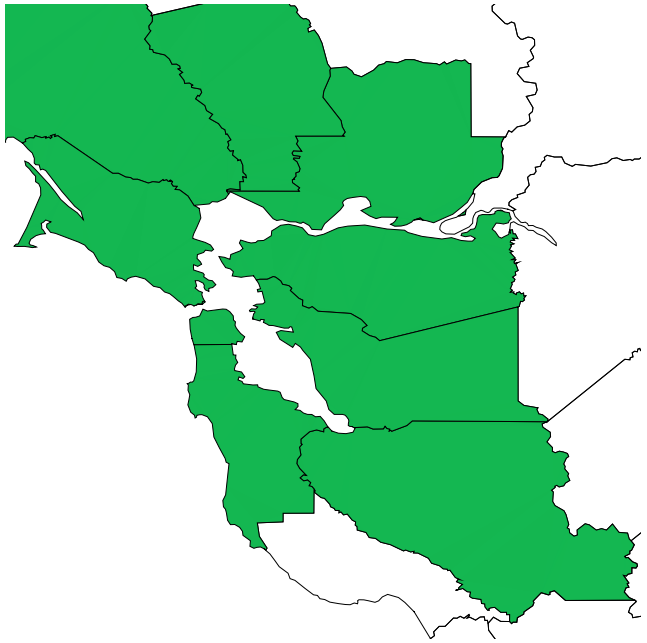
- Leases: firms pay the rent r_{Cjt}^e, repriced at rate λ^L ▸ leases

Quantitative Analysis

Calibration: San Francisco Bay Area

- 9 counties, closed city
- Pre-COVID baseline: 2012–2016, 2019
- Data: ACS, SCF, CTPP, LODES, LEHD, SIPP, SWAA, Zillow, Compstak ▸ data
- Supply elasticities: Saiz (2010), Baum-Snow & Han (2024)
- Parameters:

▸ external ▸ internal ▸ untargeted moments



Quantitative experiment

- WFH shock is a permanent shift in the distribution of WFH types:

WFH type	before 2020	after 2020
Remote	5%	12%
Hybrid	5%	26%
On-site	90%	62%

  - sources: SIPP (before), SWAA (Barrero, Bloom & Davis, 2021) (after)
  - at impact: on-site workers draw a new type; remote and hybrid do not
  - unanticipated shock in 2020, perfect foresight afterwards

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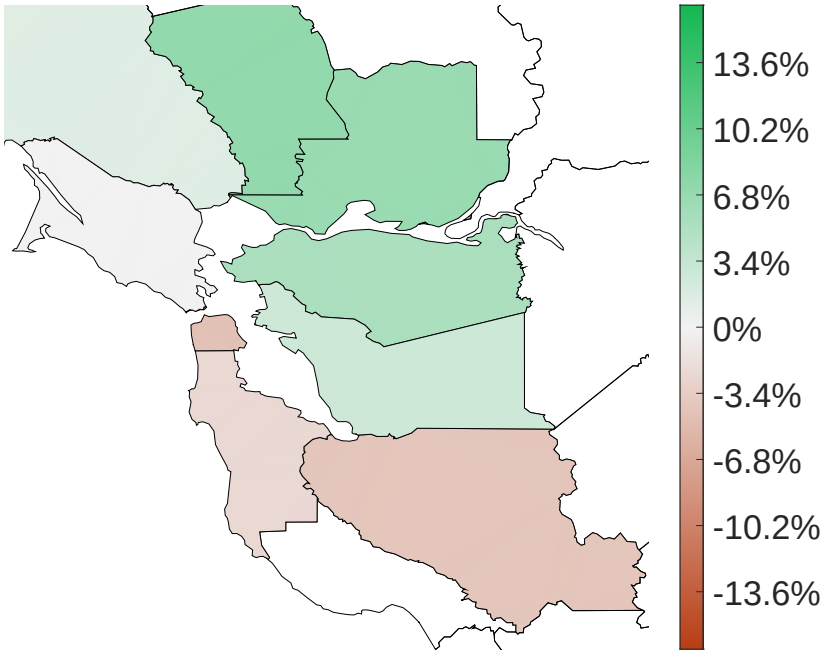
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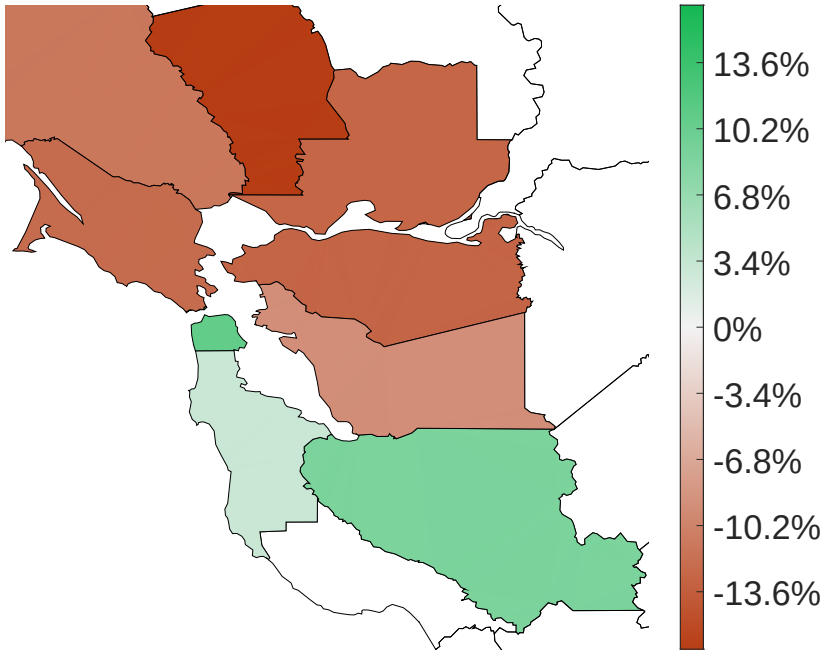
  - sources: SIPP (before), SWAA (Barrero, Bloom & Davis, 2021) (after)
  - at impact: on-site workers draw a new type; remote and hybrid do not
  - unanticipated shock in 2020, perfect foresight afterwards
- We compute
  - transition dynamics: population, employment, prices, etc.
  - welfare effect of the shock on every household in the initial steady state

Long-run results: residents and jobs

Residents, % chg



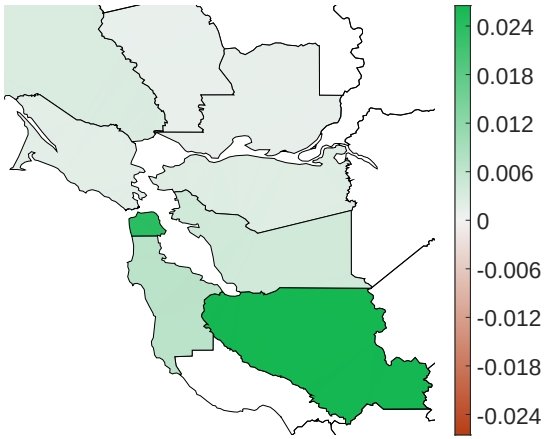
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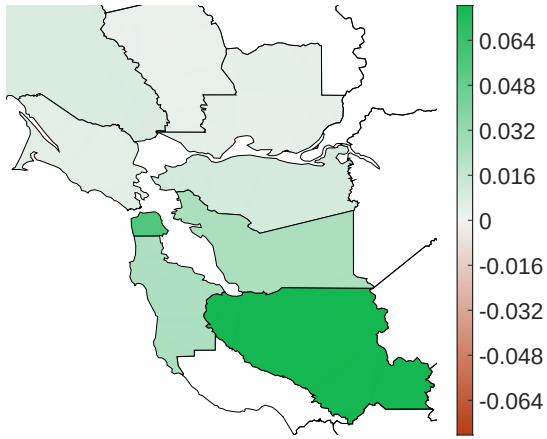
▸ wages

Long-run results: jobs by WFH type

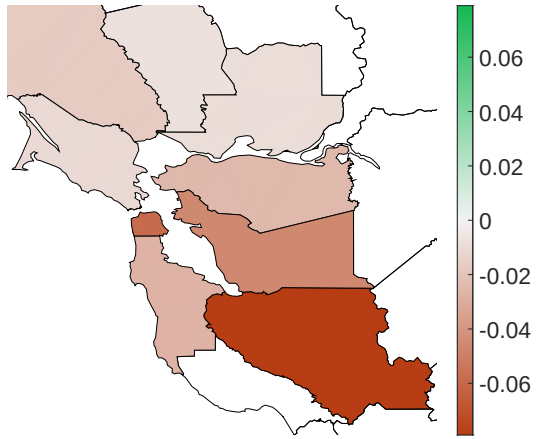
Panel A: Remote jobs



Panel B: Hybrid jobs



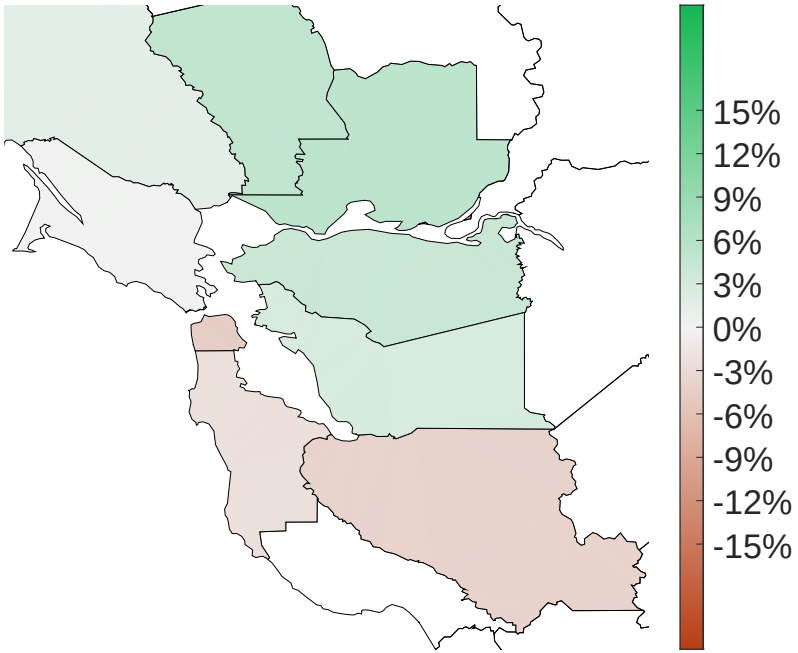
Panel C: On-site jobs



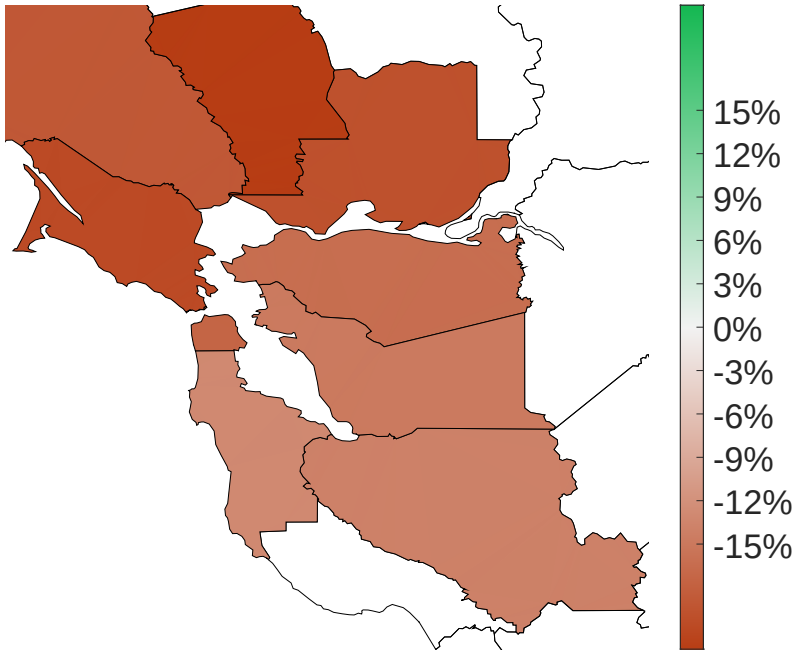
Note: change in each type's share of all jobs (fraction of jobs; 0.01 = 1 p.p.)

Long-run results: real estate prices

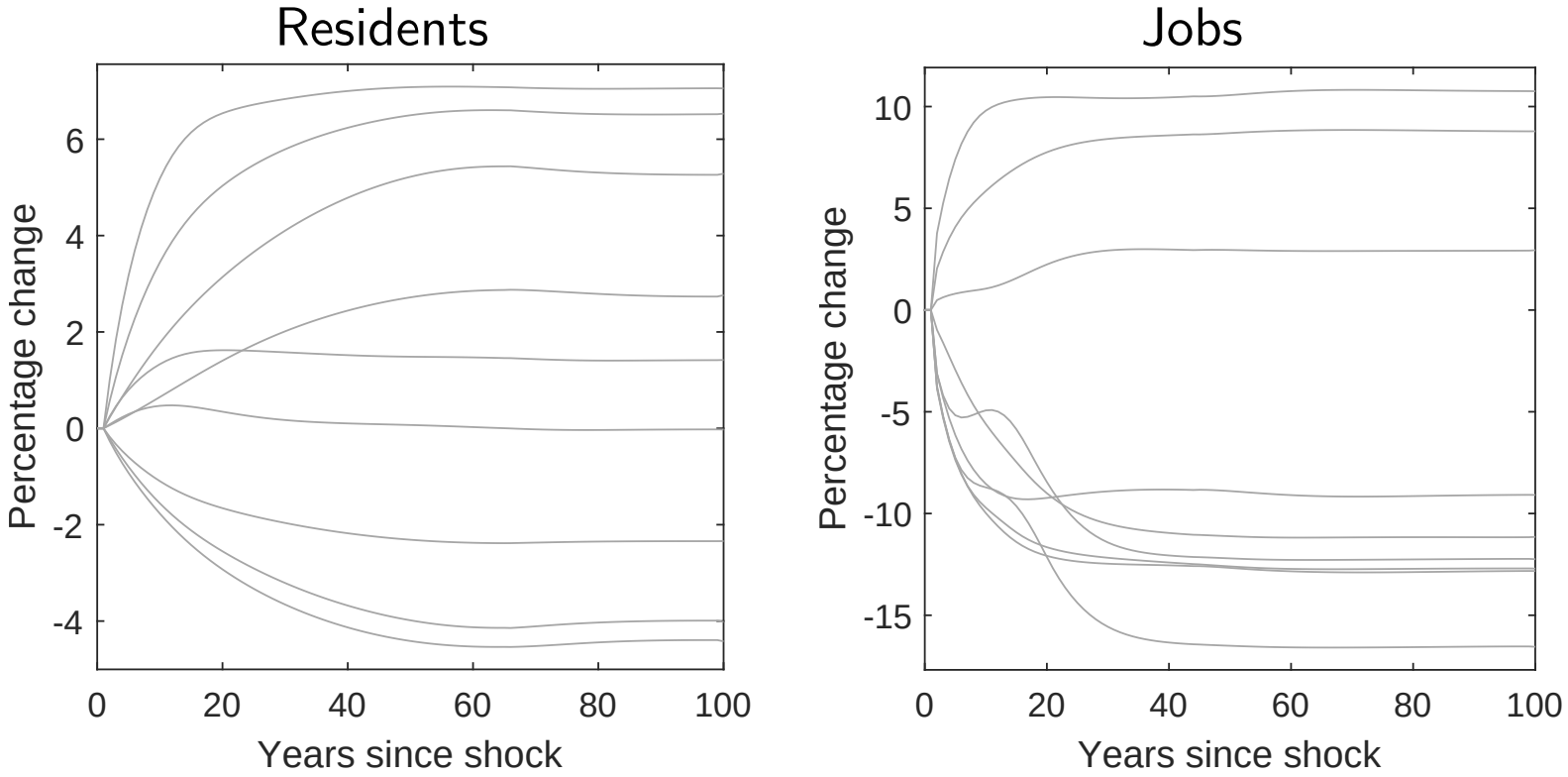
Residential prices, % chg



Commercial prices, % chg



Transitional results: residents and jobs

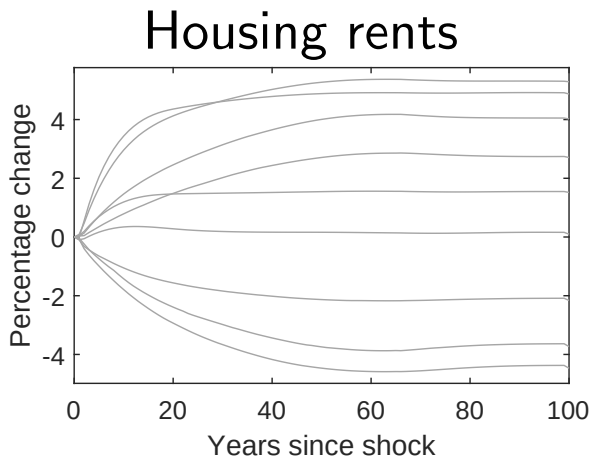


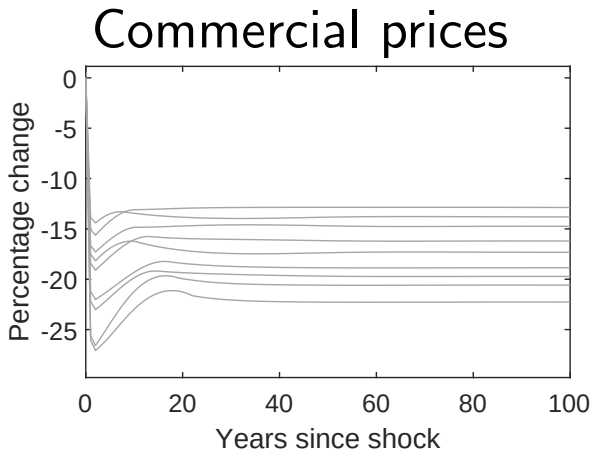
Note: each line is one of the 9 counties. Half of the long-run change takes 6 years for jobs and 13 years for residents (medians across counties).

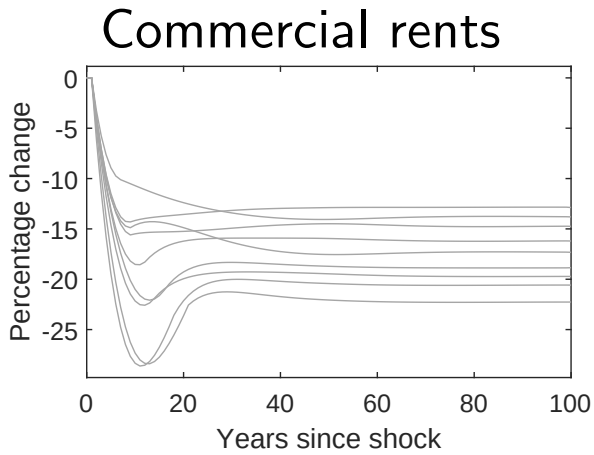
▸ housing supply

Transitional results: real estate prices and rents



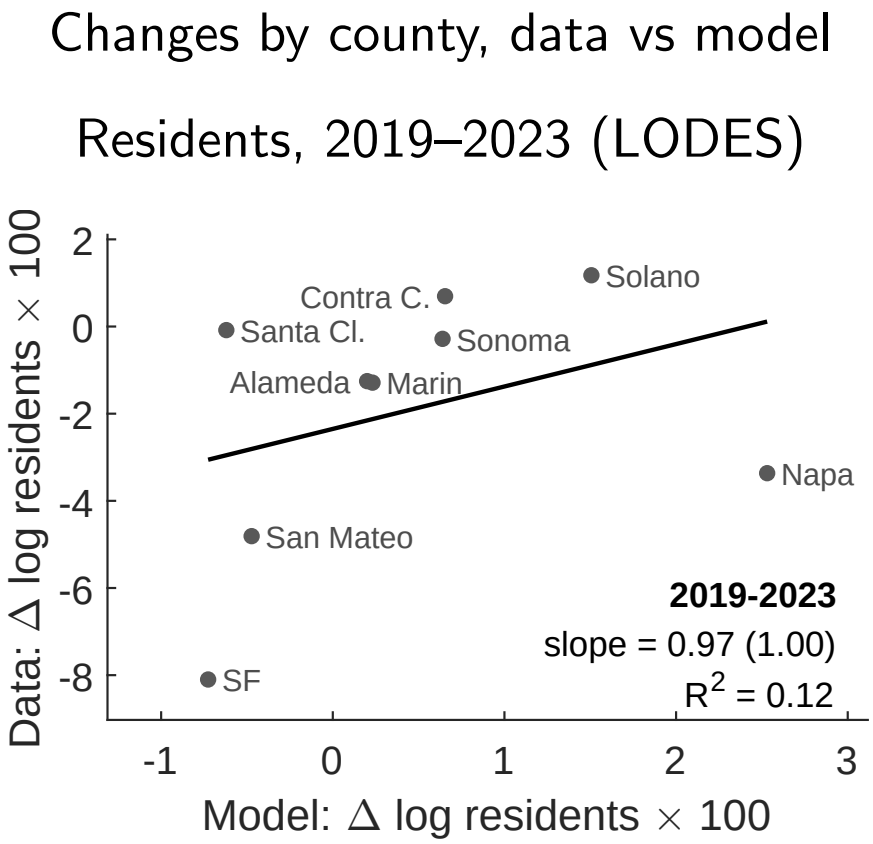






▸ wages ▸ price-rent ratios, homeownership ▸ gradients

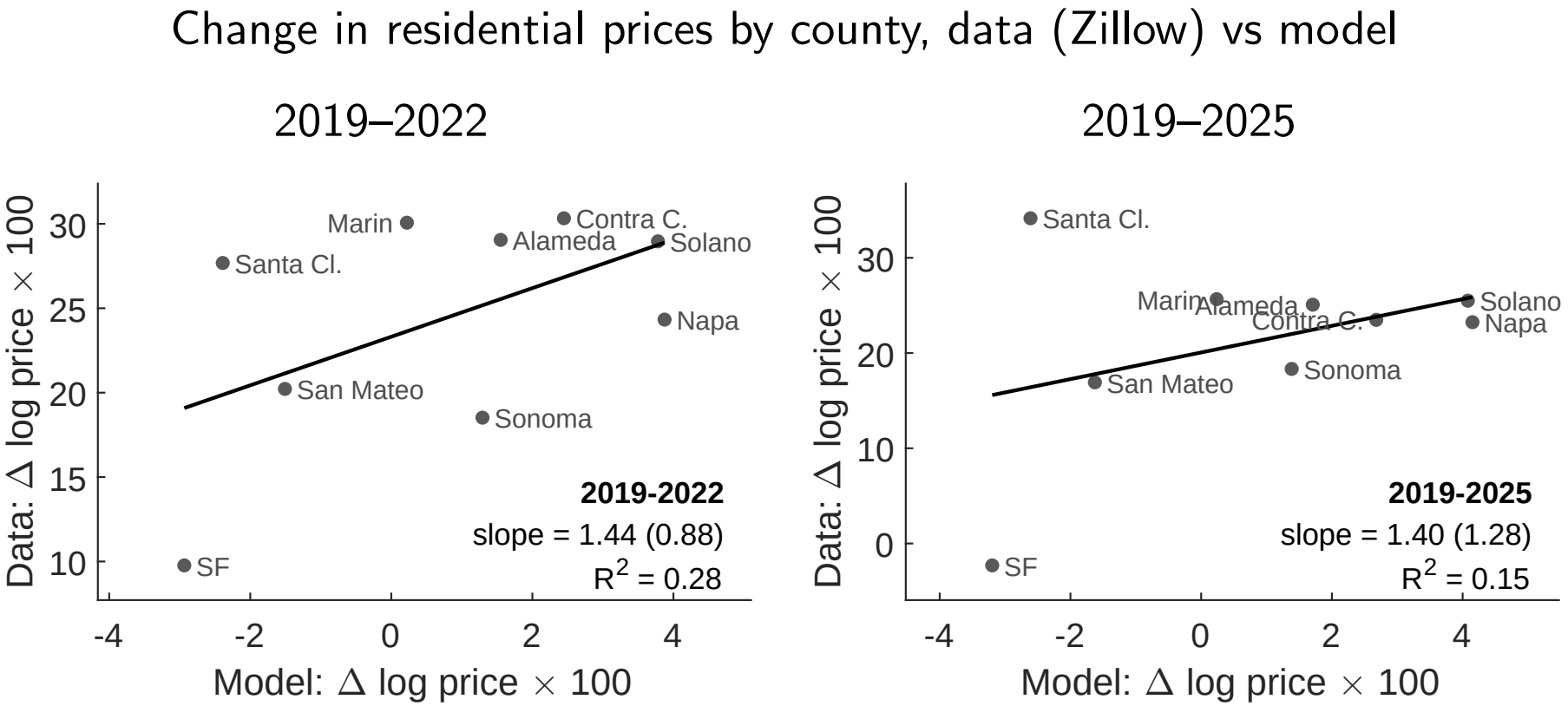
Validation: Residents



▸ SF share of residents

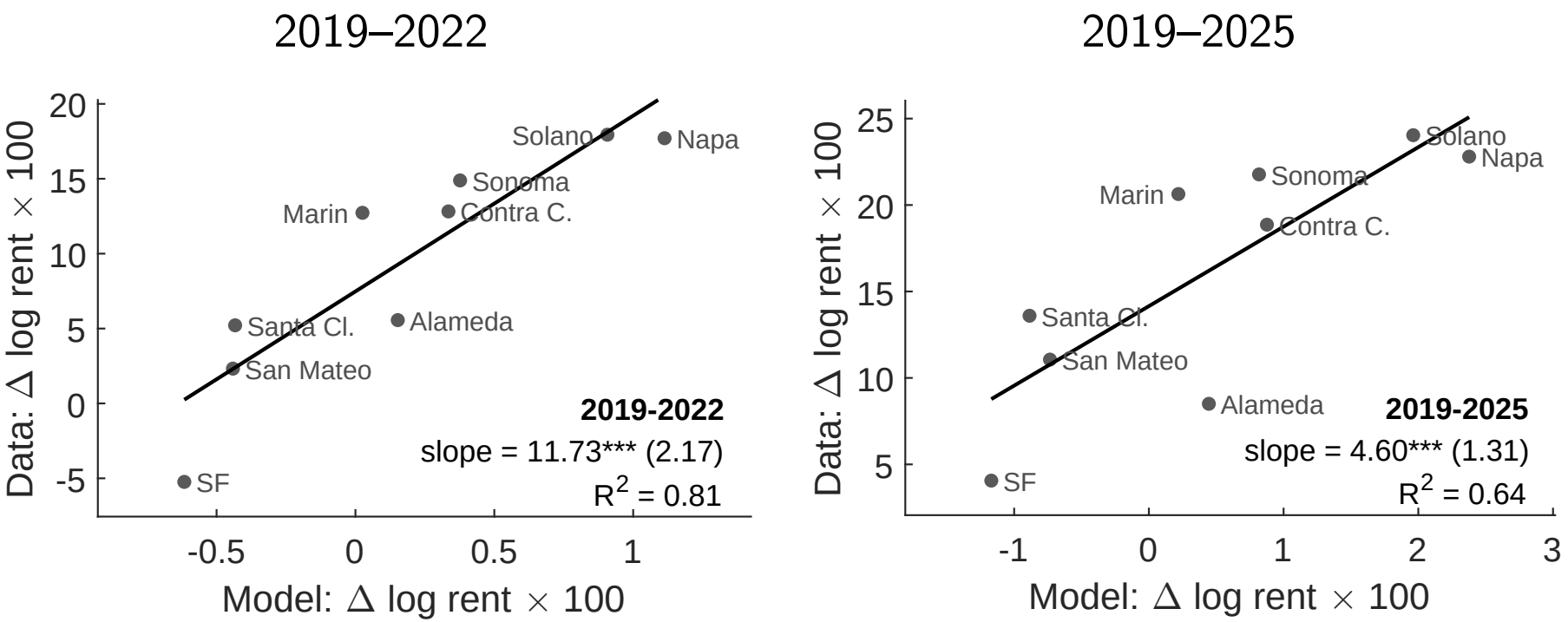
Validation: residential prices

Change in residential prices by county, data (Zillow) vs model



Validation: residential rents

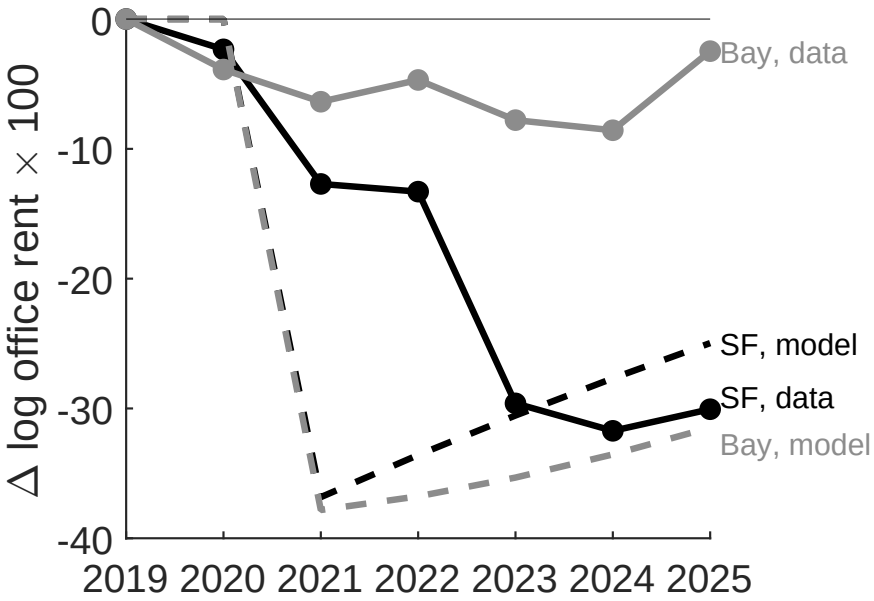
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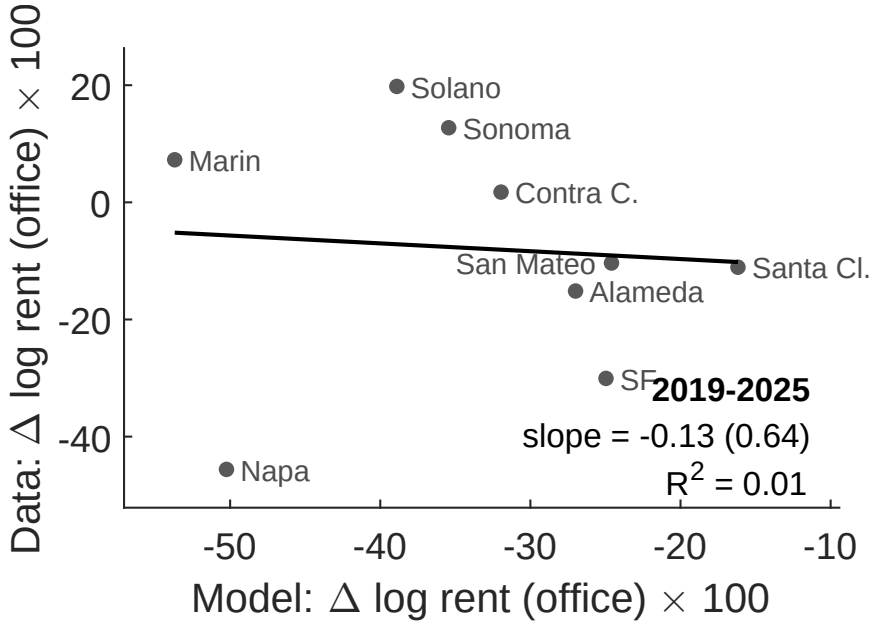
Validation: office rents

Change in office rents, data (Compstak) vs model

SF vs rest of the Bay Area



By county, 2019–2025



▸ all variables

Welfare gains

	Main model
Welfare gain, %	3.43

- Large differences by WFH type, tenure, wealth, and age ▸ decomposition

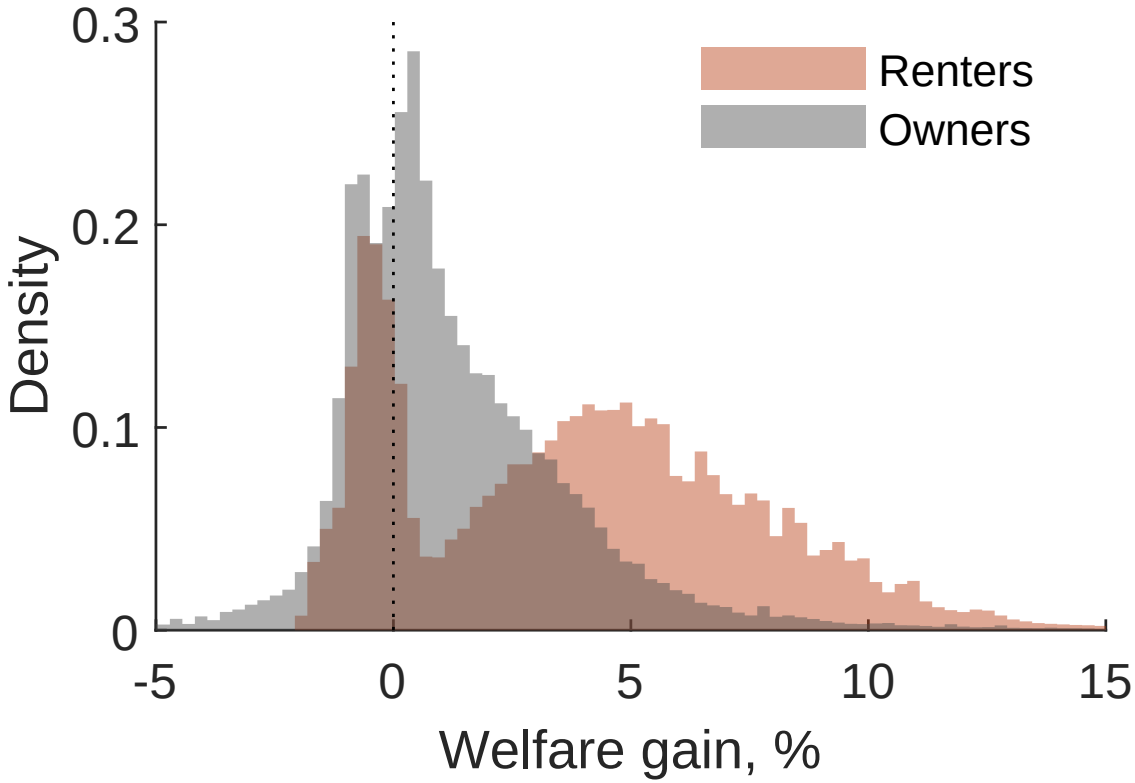
Welfare gain: percentage increase in the consumption aggregate $c^{1-\eta}(\mathbf{h}-\bar{h})^{\eta}$ for the rest of a household's life in the initial steady state that makes it indifferent to the WFH transition. Includes the WFH-type lottery at impact and the revaluation of housing and REIT wealth. Excludes the commuting-benefit term $x\varsigma$ (a taste shifter).

Welfare gains by pre-2020 WFH type

WFH type	Welfare gain, %
Remote	-0.41
Hybrid	-0.58
On-site	3.87

- **Key result:** gains are concentrated among on-site workers

Distribution of welfare gains



- Median gain: 3.9% for renters, 0.7% for owners
- 27% of households lose

▸ by residence and tenure ▸ by age ▸ by wealth ▸ by WFH type and age

Role of local public finance

	Main model	Endog. amen.
Welfare gain, %	3.43	2.85

- Local public finance: amenities respond to property tax revenues, which fall by 6–19% across counties ▸ model
- **Key result:** the deterioration in amenities lowers the welfare gain

Role of agglomeration externalities

	Main model	Endog. amen.	Aggl. effects
Welfare gain, %	3.43	2.85	2.93

- Agglomeration: $Z_{jt} = \bar{Z}_j L_{jt}^{\lambda}$ with L_{jt} on-site labor and $\lambda = 0.05$. Remote work does not contribute
- **Key result:** weaker agglomeration lowers the welfare gain

Office-to-residence conversions

- Many cities have vacant offices and a shortage of housing
- OTR conversions turn offices into housing, but are costly
  Gupta, Martinez & Van Nieuwerburgh (2023)
- Many are under way
  - NYC: 30% of large office buildings are candidates
  - NYC: 40+ projects, 14,000+ apartments
  - U.S.: 90,300 apartments in the 2026 pipeline
  - SF: only three major proposals, about 310 units

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- Quantitative experiment: offices and housing become perfectly convertible (one rent). An upper bound on OTR conversions

Office-to-residence conversions

	Main model	Conversion	Conversion, main-model wages
Welfare gain, %	3.43	2.86	4.06
renters, mean individual gain	3.94	3.72	5.06
owners, mean individual gain	1.25	-0.06	0.45

- **Key results:**
  - conversions lower gains because scarcer office space lowers wages
  - absent the wage effect, conversions increase welfare gains
  - renters are better off, owners worse off vs. main model

Summary and Next Steps

Summary

- Dynamic urban model with commuting, migration, forward-looking households, frictions, risk, homeownership, local public finance, **WFH**
- Welfare gains on average, but large variance; 27% households lose
- Transition dynamics and homeownership shape the welfare effects
- Accounting for local public finance and agglomeration lowers gains
- Office-to-residence conversions may bring further gains, but only if changes in office supply don't lower wages

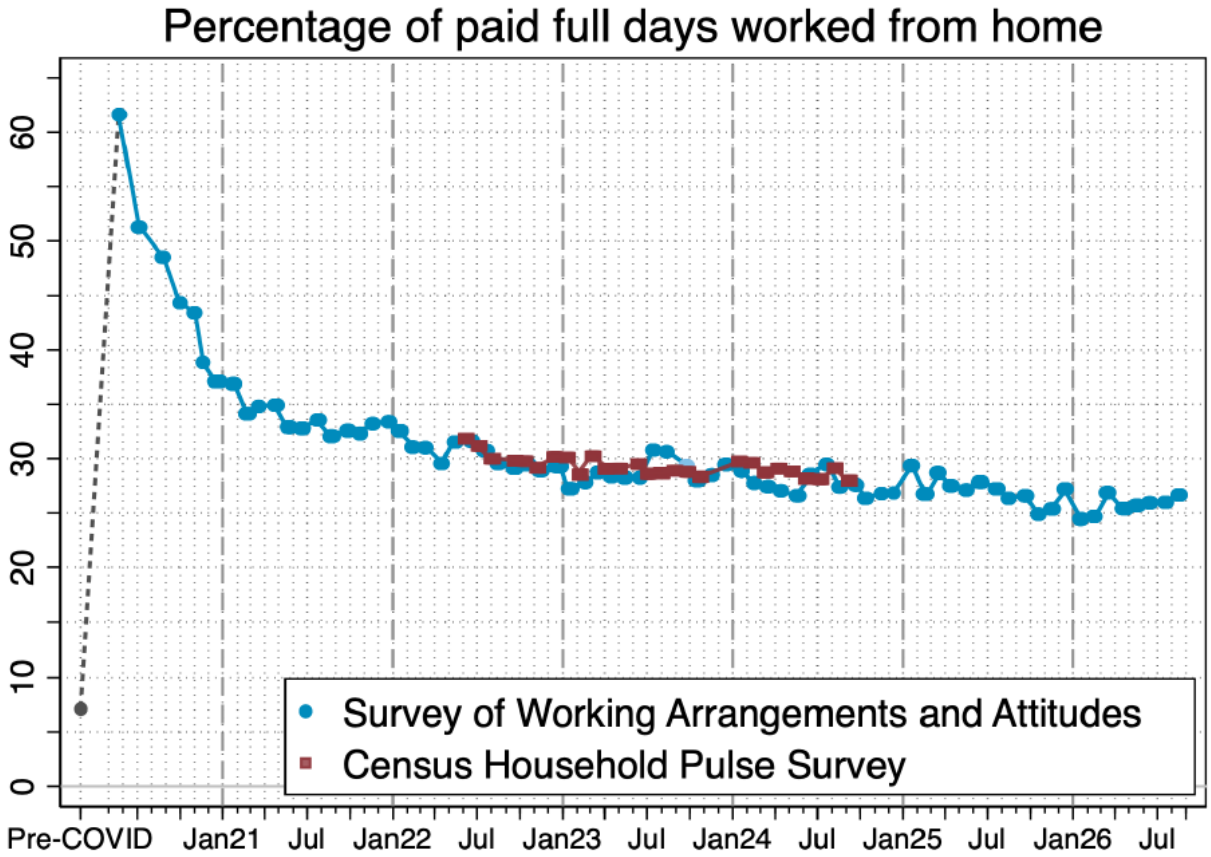
Next steps

- Comparison with other major metro areas
- Model: allow migration in and out of the Bay Area (open city), uncertainty regarding WFH
- Policies: return-to-office mandates and fiscal redistribution ▸ RTO

Appendix

Motivation

Work from home (WFH) days are 4x their pre-COVID level

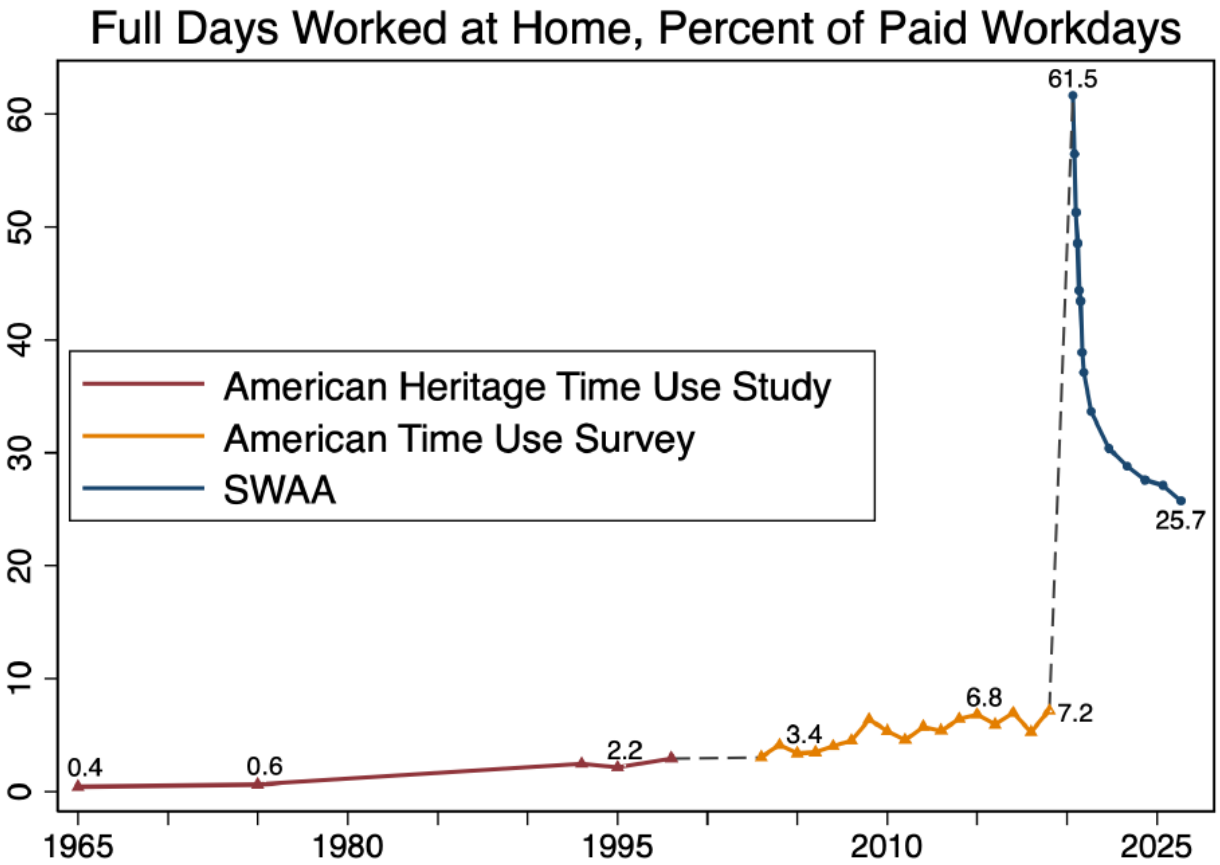


Source: Barrero, Bloom & Davis (2021) and www.wfhresearch.com

▸ back

Motivation

1/4 of working days are done from home

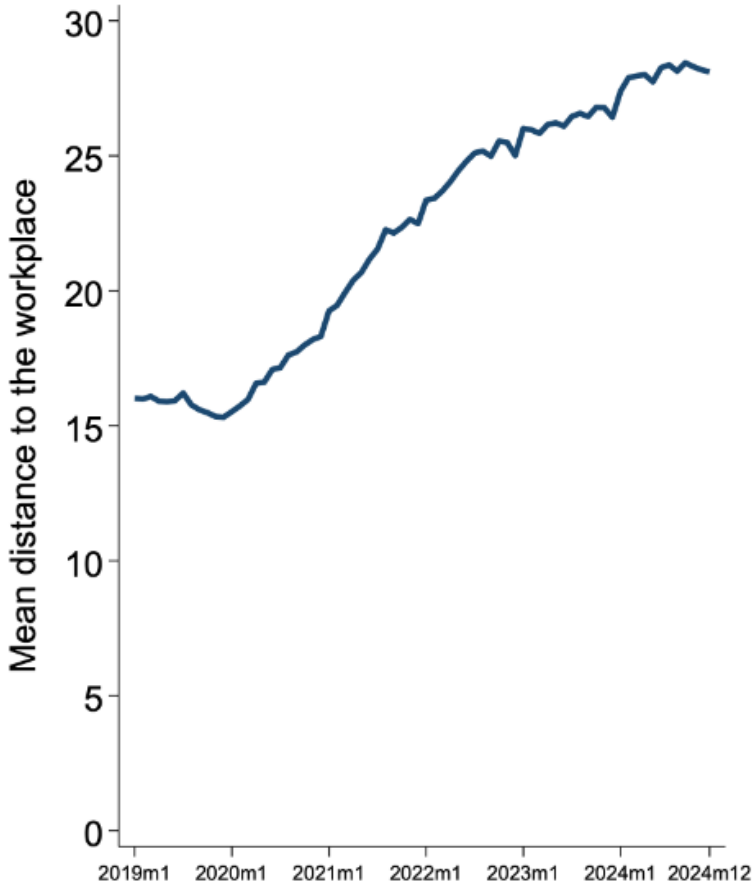


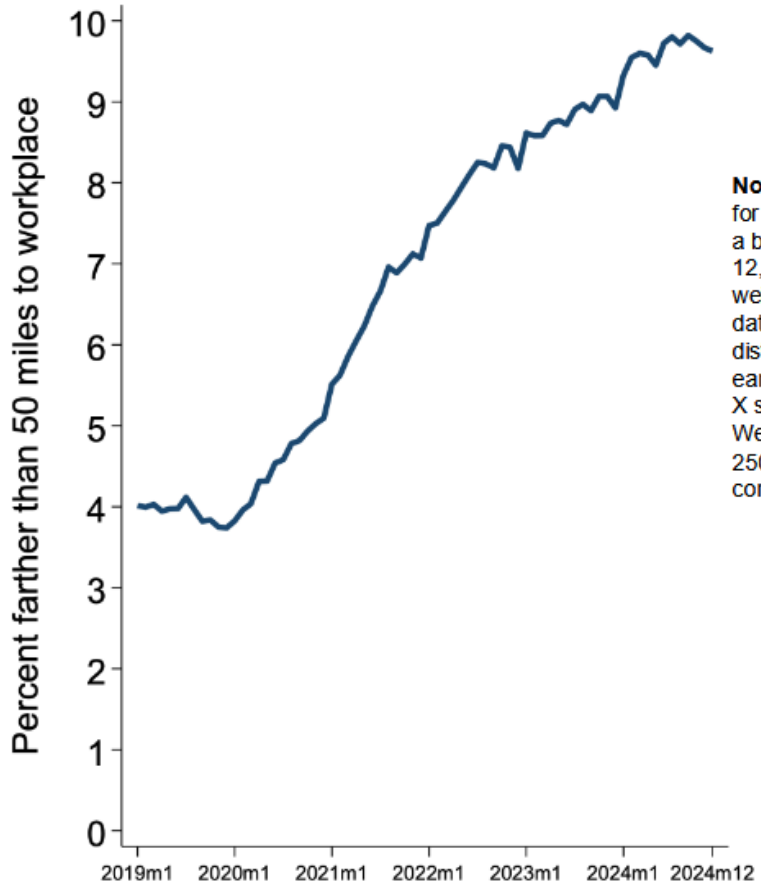
Source: Barrero, Bloom & Davis (2021) and www.wfhresearch.com

▸ back

Motivation

The distance between employers and employees is growing





Notes: Gusto payroll data for 371,849 employees in a balanced panel of 12,454 firms. We re-weight the employee-level data to match the CPS distribution by (annualized earnings bin) X (age bin) X sex X major industry. We winsorize distance at 250 miles when computing mean distance.

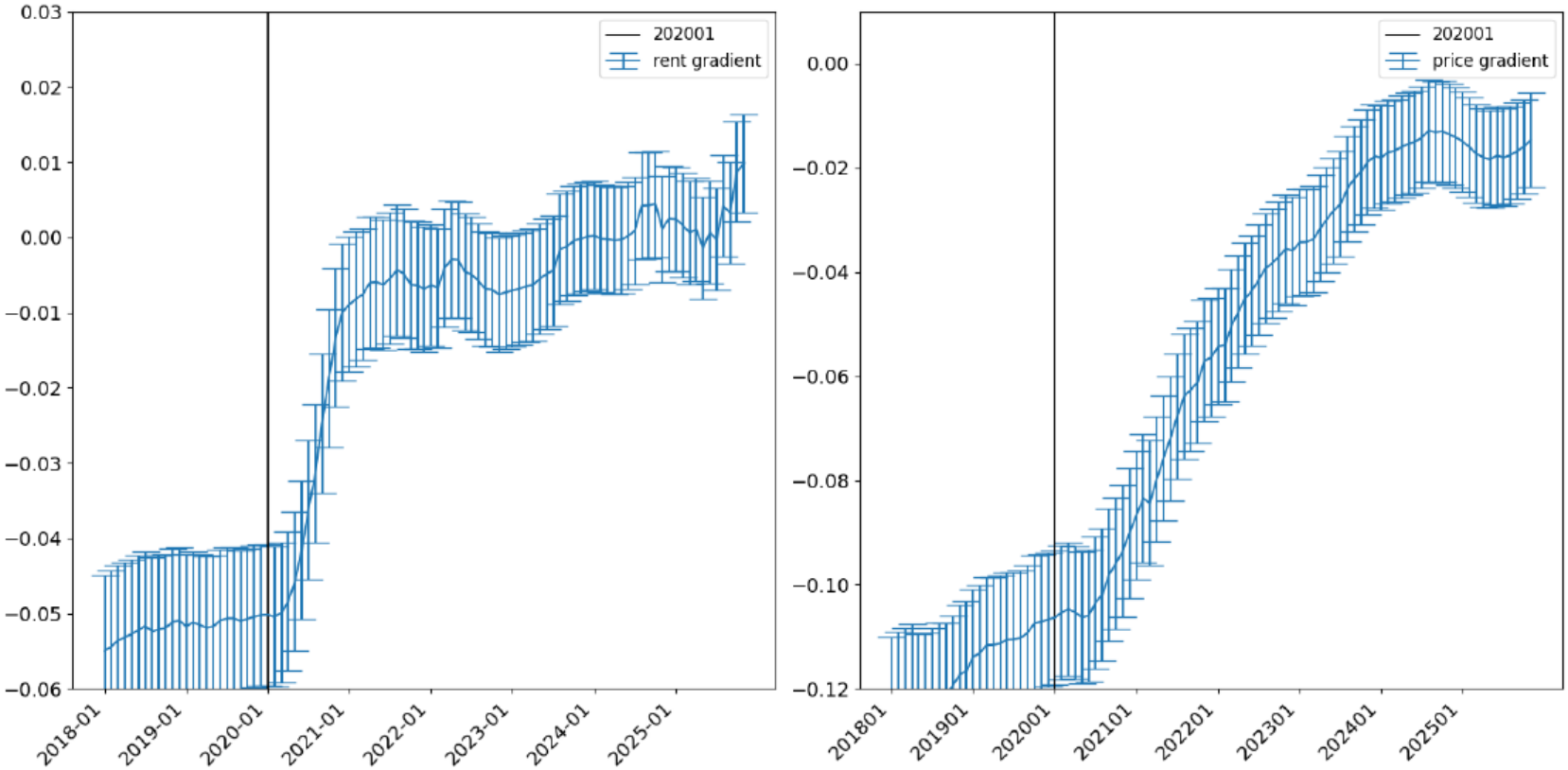
Source: Akan et al (2025) and www.wfhresearch.com

▸ interstate migration ▸ back

Motivation

The premium to live close to the center has largely disappeared

Figure 2: Rent and Price Gradients across top 30 MSAs

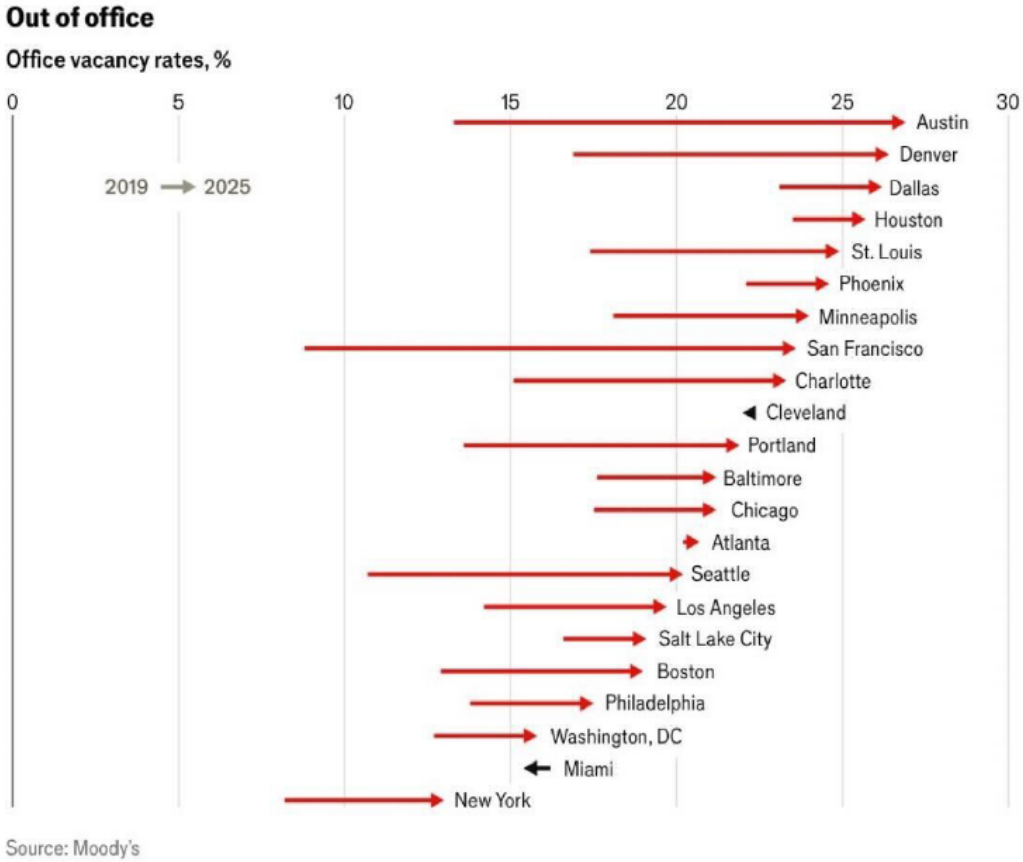


Source: Van Nieuwerburgh (2026)

▸ back

Office vacancies are growing

Figure 4: Office Vacancy Rates



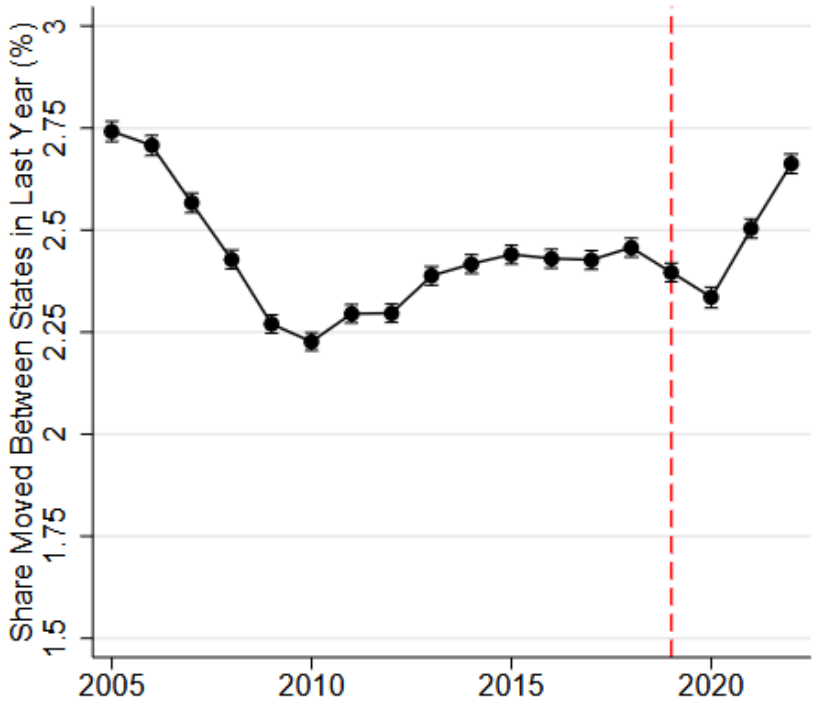
Source: Van Nieuwerburgh (2026) and Moody's Analytics

▸ back

Motivation

Interstate migration increased since 2020

(c) Interstate Migration: 2005-2022



Source: Bick et al (2024)

▸ back ▸ motivation

What **we know** about the impact of WFH on cities

- Empirical evidence on migration, changes in real estate values, commuting, etc.
  - Barrero, Bloom & Davis (2021); Althoff, Eckert, Ganapati & Walsh (2021); Bick, Blandin & Mertens (2021); Liu & Su (2021); Gupta, Peeters, Mittal & Van Nieuwerburgh (2021); De Fraja, Matheson & Rockey (2021); Rosenthal, Strange & Urrego (2021); Gupta, Mittal & Van Nieuwerburgh (2022); Howard & Liebersohn (2022); Dalton, Dey & Loewenstein (2022); Duranton & Handbury (2023); Mondragon & Wieland (2022); Brueckner, Kahn & Lin (2023); Li & Su (2023); Haslag & Weagley (2024); Bick, Blandin, Mertens & Rubinton (2024); Qian & Su (2024); Akan et al (2025); Van Nieuwerburgh (2026)
- Predictions from "stylized" models
  - Larson & Zhao (2017); Behrens, Kichko & Thisse (2021); Kyriakopoulou and Picard (2021); Agrawal & Brueckner (2022); Brueckner, Kahn & Lin (2023); Brueckner (2024)
- Predictions from calibrated quantitative spatial models
  - Delventhal, Kwon & Parkhomenko (2022); Davis, Ghent & Gregory (2024, 2026); Delventhal & Parkhomenko (2025); Monte, Porcher & Rossi-Hansberg (2025); Richard (2025); Zavarzin (2025); Ghinami (2023)

▸ back

Contribution

Feature	Why important?	Davis et al (2024, 2026)	Delventhal & Parkhomenko (2025)	Monte et al (2025)	Richard (2025)	**THIS PAPER**
Transition dynamics	short vs long run; welfare			✓	✓	✓
Homeowner-ship	wealth and welfare				✓	✓
Rich heterogeneity	distr. of welfare gains				✓	✓
Many locations	realism, heterogeneity	✓	✓	✓		✓
Flexible geography	most jobs are not in CBD		✓			✓
Local public finance	large changes in revenues					✓
Multiple equilibria	path dependence			✓		

▸ back

Households

- Fixed number of finitely-lived households
- Work during $a \in [0, A_{\text{ret}})$, retired during $a \in [A_{\text{ret}}, A)$, die at $a = A$
- Preferences:
  - $u(c, \mathbf{h}) = \left(c^{1-\eta}(\mathbf{h} - \bar{h})^{\eta}\right)^{1-\gamma} / (1-\gamma)$
  - $\mathbf{h} = \chi h_{\text{own}} + h_{\text{rent}}$, $\bar{h}$: subsistence housing (Stone-Geary)
  - bequest motive over terminal wealth $v\big(b + (1-\psi)ph\big)$
- Earnings:
  - earnings depend on age, individual productivity ζ (AR1), local wage
  - retirees earn a pension $\flat$

▸ budget and mobility ▸ back

Households

- Budget and portfolio:
  - risk-free return q (exogenous)
  - down payment, collateral constraint for owners
  - housing transaction costs upon sale
- Mobility:
  - residence & workplace choices depend on fundamentals (amenities, wages, housing costs), EV1 shocks, and commuting costs
  - moving across residence locations has cost $\mu(a)$
  - moving across workplaces has cost μ^W

▸ back

Timing and household problem

- Time t is continuous
- At "shock ages" $\mathcal{A}^s \equiv \{0, 1, ..., A-1\}$:
  - productivity shock
  - residence preference shocks $\leftarrow$ residence choice
  - choose to own vs rent
  - workplace preference shocks $\leftarrow$ workplace choice, WFH frequency
- Between "shock ages":
  - flow of income, consumption and saving choices

▸ timing details

- Household problem is a sequence of logit and HJB equations

▸ household problem details

▸ computational challenges and solutions

▸ back

Real estate

- Floorspace supply curves, $m \in \{S, C\}$ (residential, commercial):

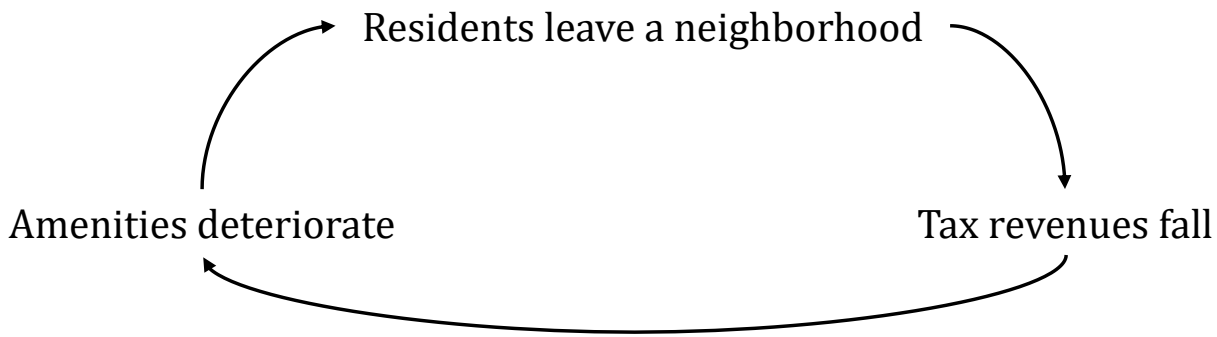
$$r_{mit} = \bar{r}_{mi} \left(H_{mit} / H_{mi0} \right)^{1/\varepsilon_{mi}}$$

- ε_{mi}: Saiz (2010) and Baum-Snow & Han (2024) supply elasticities
- Construction is irreversible: $H_{mit} \geq (1 - \delta) H_{mi,t-1}$ (annual updating). When it binds, rents fall below the supply curve
- Prices are present values of rents: $r_{mit} = (q + \delta + \tau_h) p_{mit} - \dot{p}_{mit}$
- Comm. floorspace demand depends on how much work is done on site

▸ more details ▸ back

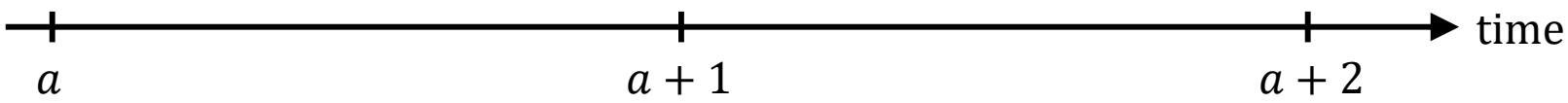
Local public finance

- Local government levies property taxes to fund local services (schools, sanitation, police, fire dept., parks, libraries, etc.)
- Tax revenues: $T_{it} = \tau_h \left(p_{Sit} H_{Sit} + p_{Cit} H_{Cit} \right)$
- Residential amenities: $E_{it}^R = \bar{E}_i^R + \varphi^R \ln T_{it}$ (baseline: $\varphi^R = 0$)
- Possibility of "urban doom loop":



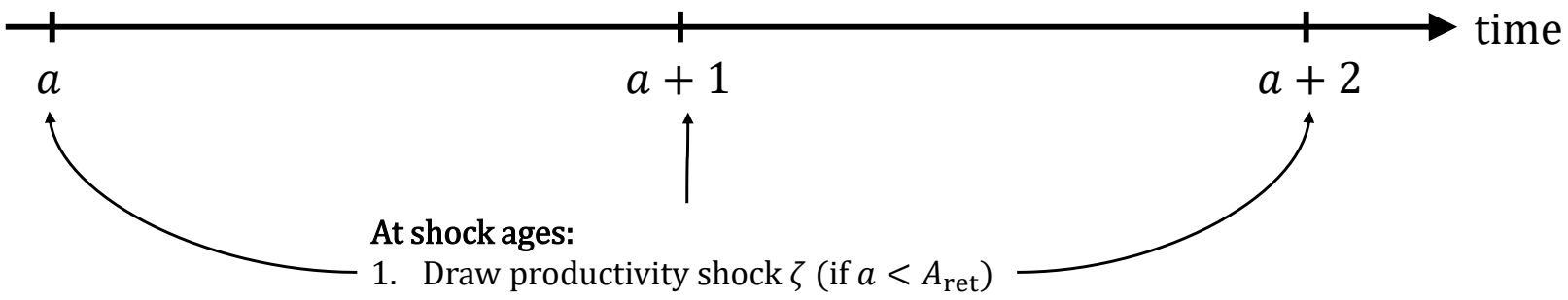
▸ back: results ▸ back: model

Time



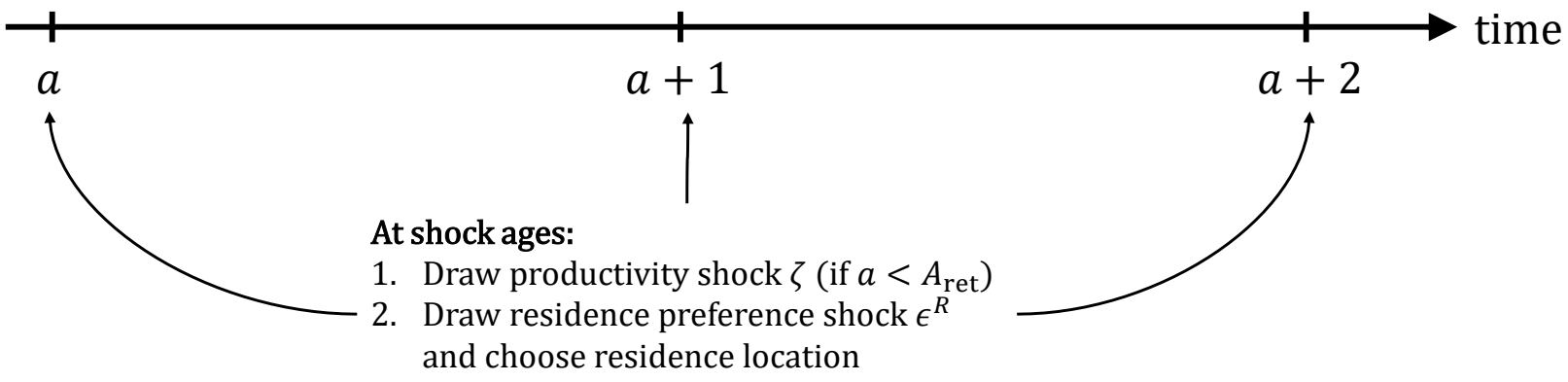
▸ back

Time


time
a
$a+1$
$a+2$
At shock ages:
1. Draw productivity shock ζ (if $a < A_{\text{ret}}$)

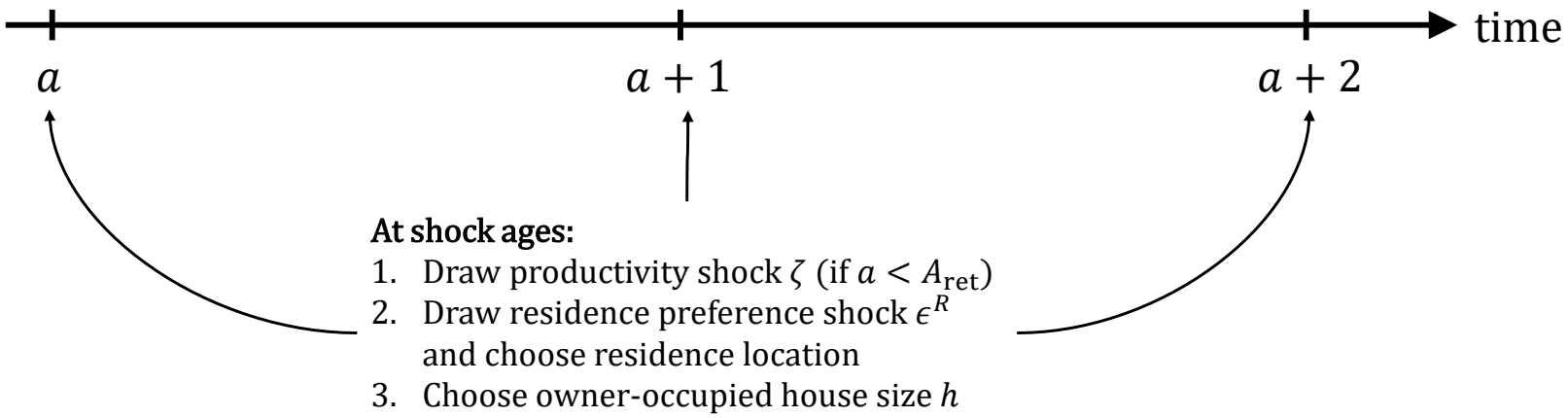
▸ back

Time


time
a
$a+1$
$a+2$
At shock ages:
1. Draw productivity shock ζ (if $a < A_{\text{ret}}$)
2. Draw residence preference shock ϵ^R
and choose residence location

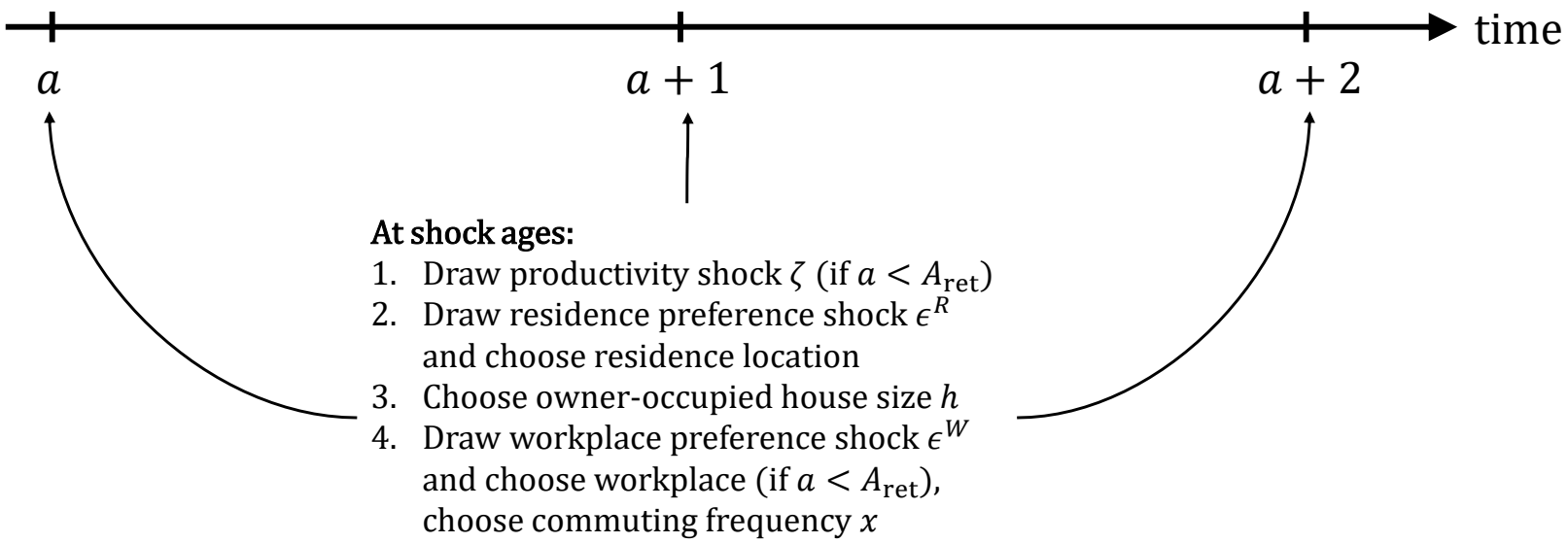
▸ back

Time


time
a
$a+1$
$a+2$
At shock ages:
1. Draw productivity shock ζ (if $a < A_{\text{ret}}$)
2. Draw residence preference shock ϵ^R and choose residence location
3. Choose owner-occupied house size h

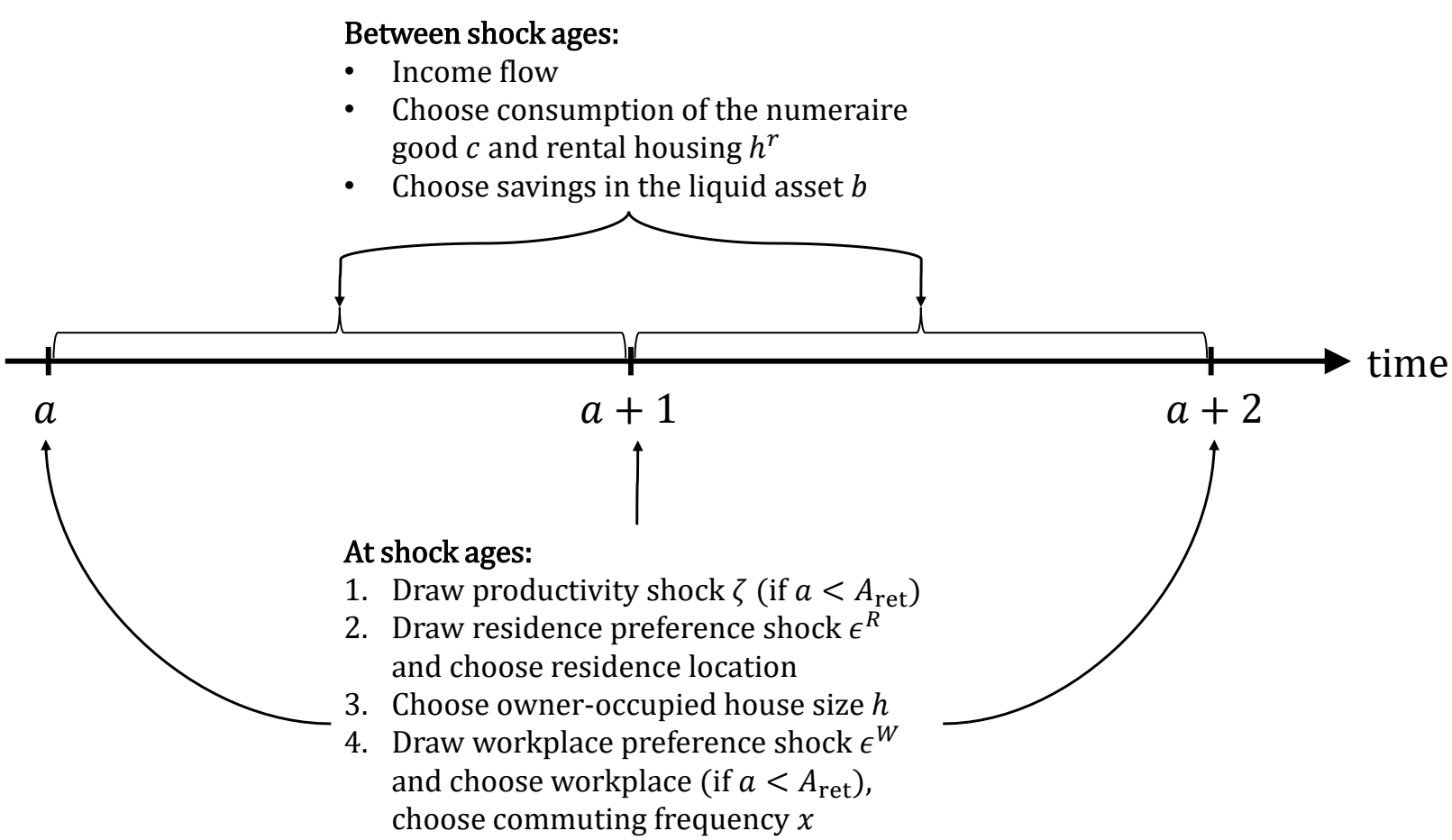
▸ back

Time


time
a
$a+1$
$a+2$
At shock ages:
1. Draw productivity shock ζ (if $a < A_{\text{ret}}$)
2. Draw residence preference shock ϵ^R and choose residence location
3. Choose owner-occupied house size h
4. Draw workplace preference shock ϵ^W and choose workplace (if $a < A_{\text{ret}}$), choose commuting frequency x

▸ back

Time


Between shock ages:
• Income flow
• Choose consumption of the numeraire good c and rental housing h^r
• Choose savings in the liquid asset b
time
a
$a+1$
$a+2$
At shock ages:
1. Draw productivity shock ζ (if $a < A_{\text{ret}}$)
2. Draw residence preference shock ϵ^R and choose residence location
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▸ back

Household problem

- State variables $\Omega \equiv (b, h, \zeta, a, \varsigma, i, j^{-})$, j^{-}: previous workplace

Household problem

- State variables $\Omega \equiv (b, h, \zeta, a, \varsigma, i, j^-)$, j^-: previous workplace
- **At shock ages.** Four recursive value functions, one before each shock/choice. Example: before the workplace shock, with $V_{t+\iota}(\,\cdot\,; j)$ the value of working in j this year (earnings accrue as a flow):

$$V_t^W(\Omega) = \nu^W \ln\Big(\sum\nolimits_j \exp([V_{t+\iota}(b, h, i, \zeta, \varsigma, a+\iota; j) + E_j^W - x(\varsigma, i, j)^\beta \kappa T_{ij} + x(\varsigma, i, j)\varsigma - \mu^W \mathbf{1}\{j \neq j^-\}]/\nu^W)\Big)$$

Household problem

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- **Between shock ages.** Hamilton-Jacobi-Bellman (HJB) equation:

$$\rho V_t(\Omega) = \max_{c, h^r} \; u(c, \mathbf{h}) + \underbrace{\partial_b V_t(\Omega)\dot{b}_t(\Omega, c, h^r)}_{\text{saving}} + \underbrace{\partial_a V_t(\Omega) + \partial_t V_t(\Omega)}_{\text{age and time}}$$

$$\text{s.t. } \dot{b} \geq 0 \text{ if } b \leq -\phi p_{it} h \;\text{ and }\; h^r = 0 \text{ if } h > 0$$

▸ more details

▸ back

Computational challenges and solutions

- Challenges:
  1. Large state space:
     - ★ 7 state variables
     - ★ wealth-housing-productivity-age-WFH type distr. in each location pair
     - ★ transitions
  2. Dozens of location-specific parameters to estimate
  3. Housing frictions $\Rightarrow$ household problem is non-convex

Computational challenges and solutions

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     - ★ transitions
  2. Dozens of location-specific parameters to estimate
  3. Housing frictions $\Rightarrow$ household problem is non-convex

- Solutions ("mixed time"):
  - Separate timing of discrete and continuous choices (Greaney, 2023; Greaney, Parkhomenko & Van Nieuwerburgh, 2025)
  - At shock ages: discrete-choice methods (Ahlfeldt et al., 2015)
  - Between shock ages: continuous-time methods (Achdou et al., 2022)
  - No workplace dynamics between shock ages: j^- matters only through the switching cost

▸ benefits of continuous time ▸ benefits of shock ages ▸ other solutions in the literature

▸ back: model ▸ back: timing

Benefits of continuous time

- Achdou, Han, Lasry, Lyons & Moll (2022) show how heterogeneous-agent macro models can be solved efficiently in continuous time

- Four reasons:
  1. FOCs are sufficient
  2. FOCs are contemporaneous
  3. discretized HJB and KF are sparse matrix equations (finite differences method)
  4. solution to HJB equation $\approx$ gives solution to KF equation

▸ back

Benefits of shock ages

- Workplace j is chosen only at shock ages
  - no workplace dynamics between shock ages
  - amenity, commuting cost, and the switching cost μ^W are applied at shock ages; earnings accrue as a flow at the chosen workplace's wage
  - only the previous workplace j^- is carried as a state

- Alternative: Poisson arrival of shock ages
  - time until j can be adjusted not known *ex ante*
  - can't apply amenity and commuting cost at shock ages
  - need to keep track of j between shock ages

- Robustness check with shock ages 1/2-years apart (Greaney, Parkhomenko & Van Nieuwerburgh, 2025)

▸ back

Other solutions in the literature

- Bilal (2023):
  - master equation approach in continuous time
  - extremely fast computation
  - requires continuously differentiable value functions (hard to satisfy when there are housing frictions)
  - first/second-order approximation (may be problematic when shocks are large and there are non-linearities)
- Sun (2024):
  - sequential structure of the household problem (modular stages)
  - machine learning approach to solving value functions

back

Households: optimal choices at shock ages

- Expected value of residence choice (movers sell their house):

$$V_t^R(\Omega) = \nu^R \ln\left(\sum_{i'} \exp\left([V_t^H(\tilde{b}_t^R(\Omega;i'),\tilde{h}^R(\Omega;i'),i',\zeta,\varsigma,a,j^-) + E_{i'}^R - \mu_{ii'}(a)]/\nu^R\right)\right)$$

- Expected value of tenure and house-size choice (keep h, or buy/sell at $\tilde{b}^H$):

$$V_t^H(\Omega) = \max\left\{V_t^W(\Omega),\ \max_{h'} V_t^W(\tilde{b}_t^H(\Omega;h'),h',i,\zeta,\varsigma,a,j^-)\right\}$$

- Expected value of workplace choice, with net commuting cost $d_{ij}(\varsigma) \equiv x(\varsigma,i,j)^\beta \kappa T_{ij} - x(\varsigma,i,j)\varsigma$ and $V_{t+\iota}(\,\cdot\,;j)$ the value of working in j (earning w_{jt} as a flow) during the year:

$$V_t^W(\Omega) = \nu^W \ln\Big(\sum\nolimits_j \exp\big([V_{t+\iota}(b,h,i,\zeta,\varsigma,a+\iota;j) + E_j^W - d_{ij}(\varsigma) - \mu^W \mathbf{1}\{j \neq j^-\}]/\nu^W\big)\Big) \quad \text{if } a < A_{\text{ret}},$$

$$V_t^W(\Omega) = V_{t+\iota}(b,h,i,\zeta,\varsigma,a+\iota) \quad \text{otherwise}$$

- Value function at shock ages:

$$V_t(\Omega) = \begin{cases} \int V_t^R(b,h,i,\zeta',\varsigma,a,j^-)\, f(\zeta'|\zeta)\, \mathrm{d}\zeta' & \text{if } a < A_{\text{ret}}, \\ V_t^R(\Omega) & \text{otherwise} \end{cases}$$

▸ back

Households: density of state variables at shock ages

- After productivity shocks have occurred, the density of state variables is:

$$g_t^z(\Omega) = \begin{cases} \int \lim_{\iota \downarrow 0} g_{t-\iota}(b, h, i, \zeta', \varsigma, a - \iota)\, f(\zeta|\zeta')\, \mathrm{d}\zeta' & \text{if } a < A_{\text{ret}}, \\ \lim_{\iota \downarrow 0} g_{t-\iota}(b, h, i, \zeta, \varsigma, a - \iota) & \text{if } a \geq A_{\text{ret}}. \end{cases}$$

- After residential locations are chosen:

$$g_t^R(\Omega) = \sum_{i'} \iint \mathbf{1}_t^R(b', h', i'; b, h, i) \pi_t^R(b', h', i', \zeta, \varsigma, a, j^-; i) g_t^z(b', h', i', \zeta, \varsigma, a, j^-) \mathrm{d}b' \mathrm{d}h'$$

- After housing adjustments:

$$g_t^H(\Omega) = \iint \mathbf{1}_t^H(b', h', i, \zeta, \varsigma, a, j^-; b, h)\, g_t^R(b', h', i, \zeta, \varsigma, a, j^-)\, \mathrm{d}b' \mathrm{d}h'$$

- After workplaces are chosen ($g_t = g_t^H$ for retirees); j becomes next year's j^-:

$$g_t(b, h, i, \zeta, \varsigma, a; j) = \sum_{j^-} \pi_t^W(b, h, i, \zeta, \varsigma, a, j^-; j)\, g_t^H(b, h, i, \zeta, \varsigma, a, j^-) \quad \text{if } a < A_{\text{ret}}$$

▸ KF equation and logit probabilities ▸ back

Density of state variables

- **Between shock ages**. Kolmogorov Forward (KF) equation:

$$\partial_t g_t(\Omega) = -\partial_b[\dot{b}_t(\Omega) g_t(\Omega)] - \partial_a g_t(\Omega)$$

- **At shock ages**. Closed-form logit expressions, e.g., the workplace choice probability of a worker with previous workplace j^-:

$$A^W_{jt} \equiv \left[V_{t+\iota}(b, h, i, \zeta, \varsigma, a + \iota; j) + E^W_j - d_{ij}(\varsigma) - \mu^W \mathbf{1}\{j \neq j^-\}\right]/\nu^W$$

$$\pi^W_t(\Omega; j) = \frac{\exp(A^W_{jt})}{\sum_{j'} \exp(A^W_{j't})}$$

▸ back

Real estate: floorspace demand and supply

- Residential floorspace demand:
  $$H_{Sit} = \int\int\int\int\int [h_t^r(b,h,i,\zeta,\varsigma,a) + h]\, g_t(b,h,i,\zeta,\varsigma,a)\, \mathrm{d}b\, \mathrm{d}h\, \mathrm{d}\zeta\, \mathrm{d}\varsigma\, \mathrm{d}a$$
- Commercial floorspace demand (firm's first-order condition):
  $$H_{Cjt} = \bar{h}^C L_{jt} + k_j L_{jt} \left(\frac{w_{jt}^{\mathsf{ofc}} + \bar{h}^C r_{Cjt}}{r_{Cjt}} \right)^{\omega}$$
  L_{jt}: on-site labor; k_j: 2019 space per unit of on-site labor; $\bar{h}^C$: share of the leanest county's 2019 ratio
- Floorspace supply: on the supply curve $r_{mit} = \bar{r}_{mi}(H_{mit}/H_{mi0})^{1/\varepsilon_{mi}}$ whenever construction is positive. When demand falls, irreversibility $H_{mit} \geq (1-\delta)H_{mi,t-1}$ binds and rents fall below it

▸ prices, rents, and leases ▸ back: model ▸ back: real estate

Real estate: prices, rents, and leases

- Rental housing and commercial real estate are owned by perfectly competitive REITs
- Prices are present values of rents, $r_{mit} = (\delta + q + \tau_h)p_{mit} - \dot{p}_{mit}$; steady state price-rent ratio $p_{mit}/r_{mit} = 1/(\delta + q + \tau_h)$
- Commercial leases are long-term: the rent firms pay, r^e_{Cjt}, reprices toward the spot rent r_{Cjt} as leases are renewed,

$$r^e_{Cjt} = (1 - \lambda^L)\, r^e_{Cj,t-1} + \lambda^L\, r_{Cjt},$$

  with $\lambda^L = 0.135$ per year (7.4-year leases); $\lambda^L = 1$ recovers spot rents
- Zero profits at the paid rent: the gap $(r_{Cjt} - r^e_{Cjt})H_{Cjt}$ comes out of the pooled wage bill during the transition

▸ back: model ▸ back: real estate

Data

- Socioeconomic characteristics, rent burden: ACS; wealth: SCF
- Wages: CTPP and ACS
- Commuting flows and times: LODES and ACS; cross-metro job switching: LEHD
- Local employment: LODES
- Real estate prices and rents: Zillow, Compstak, and ACS
- Housing supply elasticities: Saiz (2010) and Baum-Snow & Han (2024)
- Office leases: Gupta, Mittal & Van Nieuwerburgh (2026); office requirement: SF office rents 2019–23
- WFH type distribution before 2020: SIPP
  after 2020: Barrero, Bloom & Davis (2021)

▸ back

Externally calibrated parameters

Parameter	Description	Value	Source
q	interest rate	0.02	data
γ	risk aversion	2	standard value
ϑ_1	bequest motive curvature	0.01	see the text
θ_ζ	labor prod. persistence term	0.914	Floden & Linde (2001)
σ^2_ζ	labor prod. variance term	0.0426	Floden & Linde (2001)
ω	EOS betw. labor & floorspace	0.30	Oberfield & Raval (2021)
σ	EOS betw. on-site & remote work	3.60	Davis, Ghent & Gregory (2024)
δ	housing depreciation rate	0.011	BEA and Davis, Larson, Oliner & Shui (2021)
ψ	housing transaction fee	0.06	standard value
τ_h	property tax	0.0071	Brookings data
τ_z	payroll tax	0.179	OECD
ϕ	collateral constraint	0.8	standard value
β	commuting cost curvature	1.58	commuting frequency vs. travel time
φ^R	amenity response to log tax revenue (local public finance version)	0.0643	see the text
λ^L	commercial lease renewal rate	0.135	7.4-year leases, GMVN (2026)
$\bar{h}^C$	office space requirement per unit of on-site labor (19% of leanest county's 2019 ratio)	0.38	SF office rents 2019–23 (Compstak)
$\bar{h}$	subsistence housing (Stone-Geary)	1.6	rent burden by income (ACS)
Π_ς^{2019}	WFH types, remote / hybrid / on-site	0.05 / 0.05 / 0.90	SIPP
Π_ς^{2020+}	WFH types, remote / hybrid / on-site	0.12 / 0.26 / 0.62	Barrero, Bloom & Davis (2021)
$\min \mathbb{H}$	smallest own. size	4.22	p5 own. value / median wage
$\max \mathbb{H}$	largest size	14.1	p90 own. / p10 own. size
f^S	share of resid. REIT	0.103	SCF data
f^C	share of comm. REIT	0.0688	SCF data

▸ back

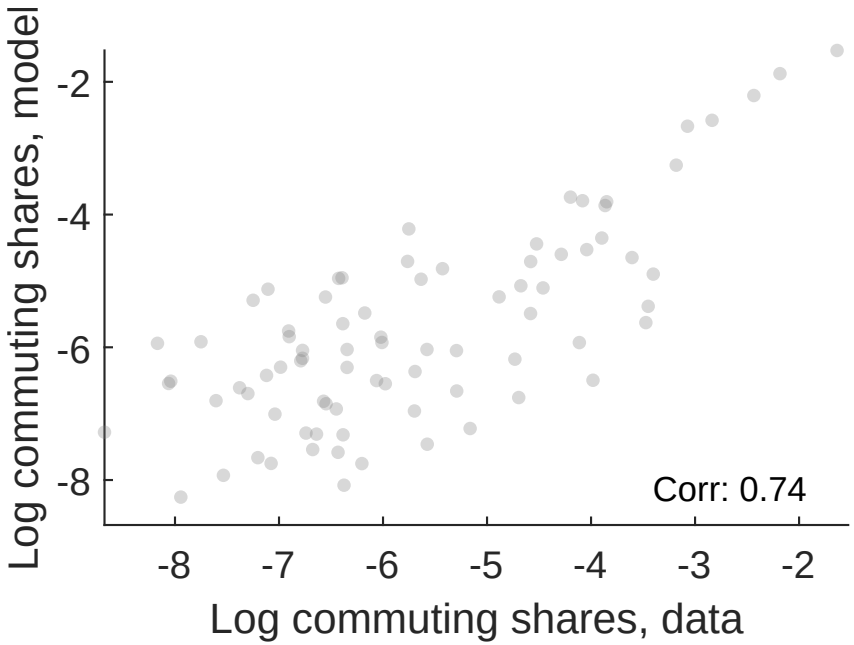
Internally calibrated parameters

Parameter	Description	Value	Target or source	Value
ρ	discount rate	0.0187	median wealth-earnings ratio	1.7
η	weight of housing in utility	0.164	housing expenditure share	0.24
χ	preference for homeown.	1.09	homeownership rate	0.532
ϑ_0	bequest motive	1.093	homeown., ages 80–84 vs 20–24	0.642
ν^R	Gumbel scale, resid. shocks	8.05	$100\times$ variance of log earnings across locations	1.03
ν^W	Gumbel scale, work. shocks	1.41	value of commuting time / wage	1
κ	cost of commuting	0.0104	commuting gravity coeff.	-0.0491
μ^0	res. moving cost, intercept	33.3	cross-county migration rate	0.0257
μ^a	res. moving cost, age coeff.	0.416	migration, ages 20–24 vs 80–84	0.0837
μ^W	job moving cost	6.58	cross-metro (CBSA) job switching rate	0.0252
$\bar{w}$	wage scale	0.934	median earnings (normalization)	1
ς_2	commuting benefit for hybrid workers	0.575	comm. frequency of hybrid workers	0.535
α_j	labor weight in on-site composite	0.13–0.66	labor share, Valentinyi & Herrendorf (2008)	0.82
θ_j	weight on on-site composite	0.64–0.73	on-site and remote MPL equal in 2019	

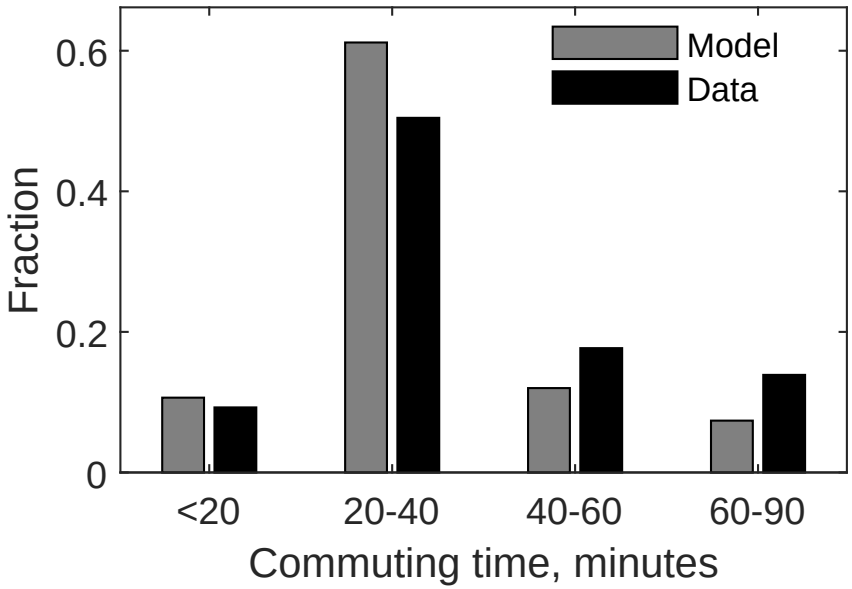
▸ back

Untargeted moments

Commuting flows



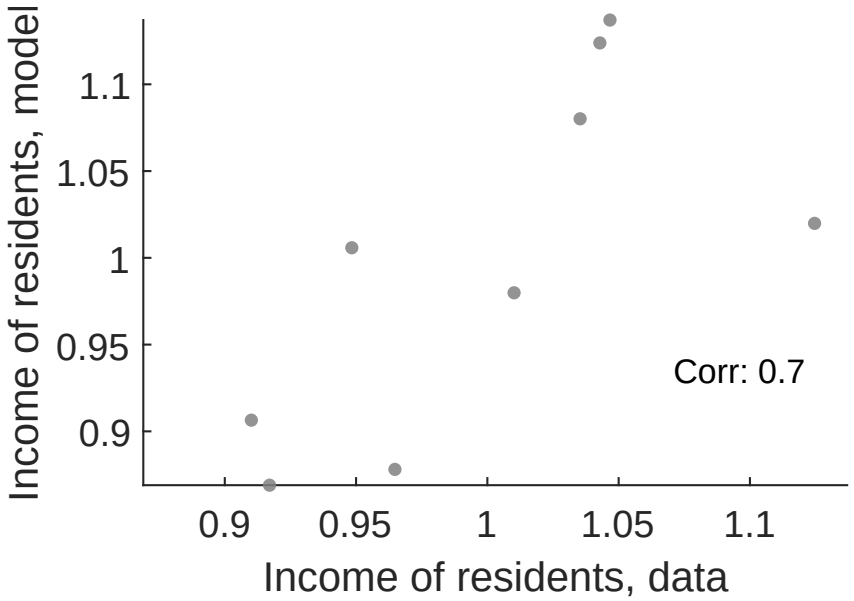
Commuting times



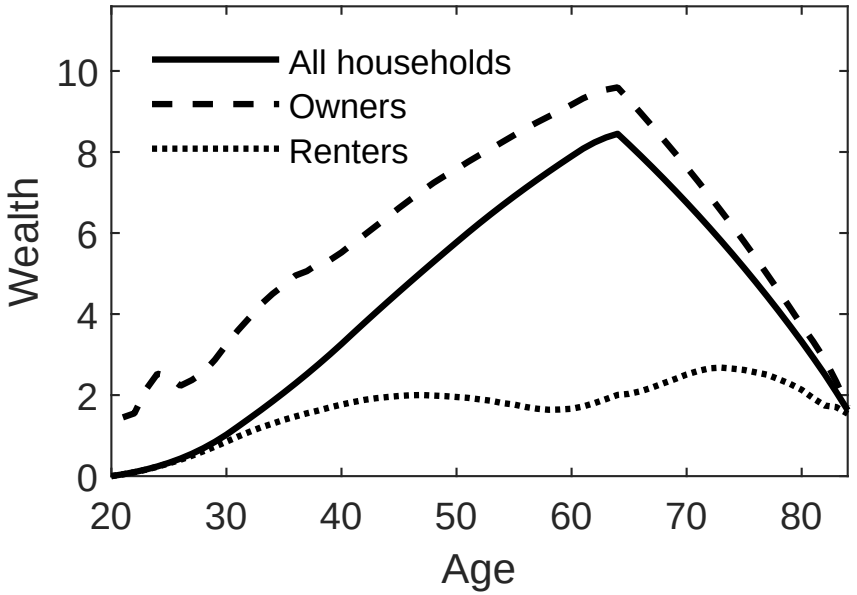
▸ back

Untargeted moments

Income by location

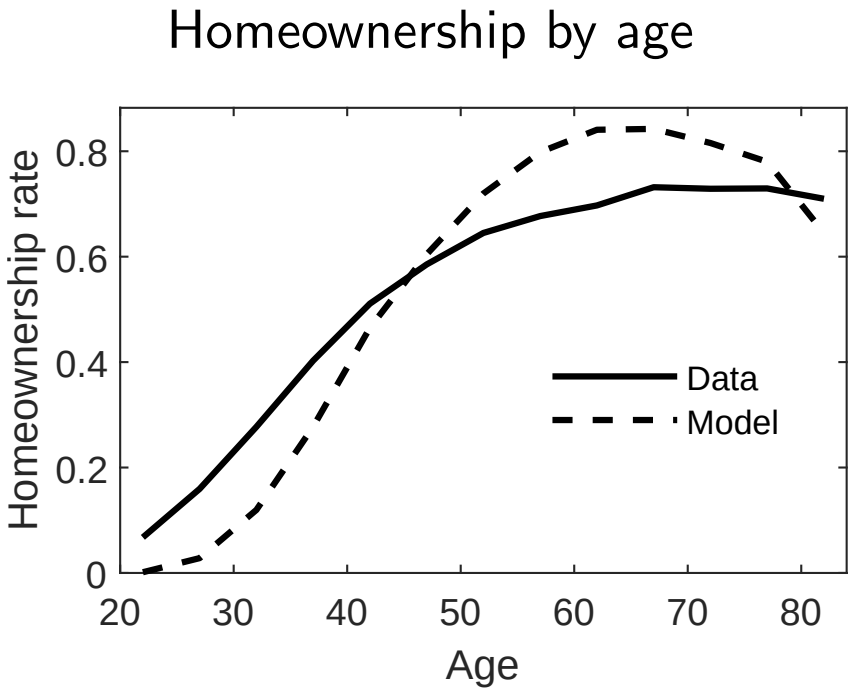


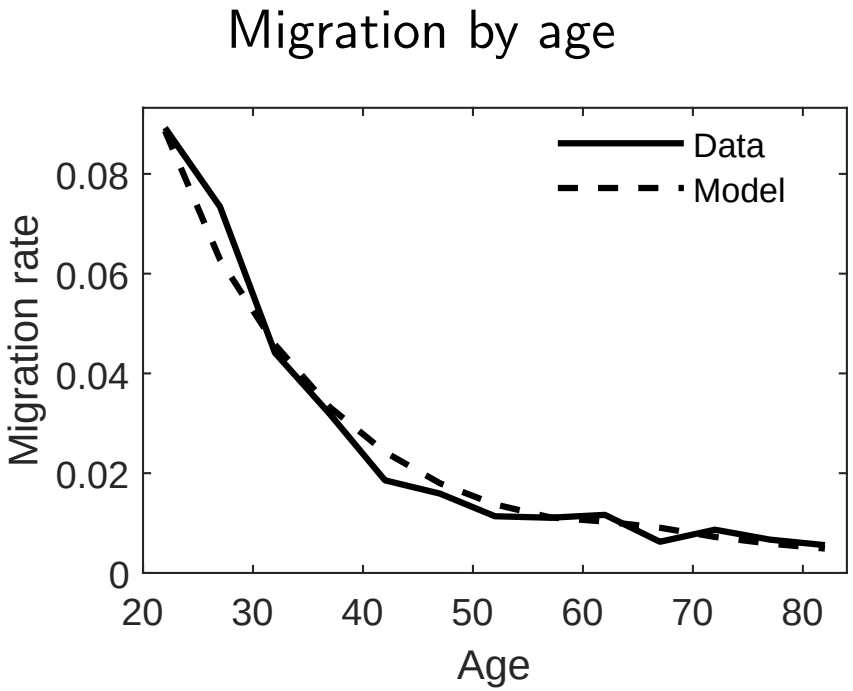
Wealth by age



▸ back

Untargeted moments

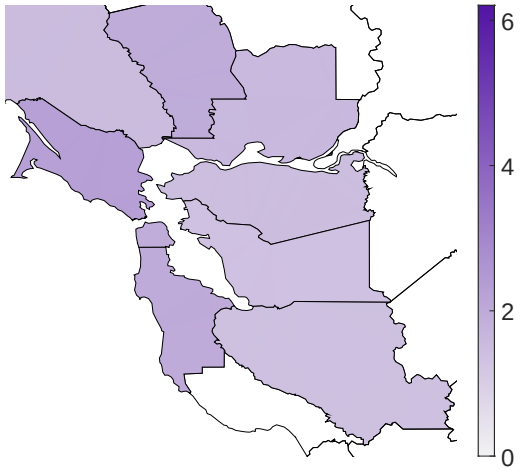




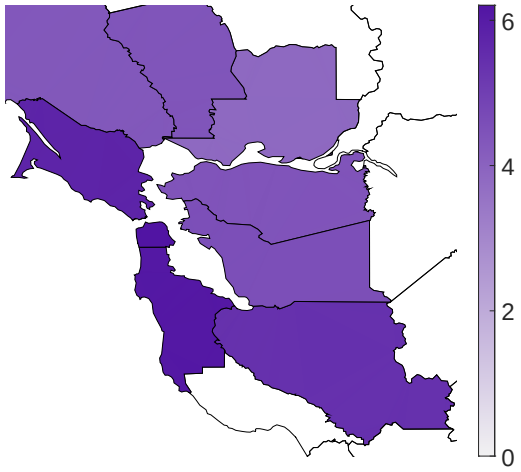
▸ back

Wealth in the model

Panel A: Financial wealth

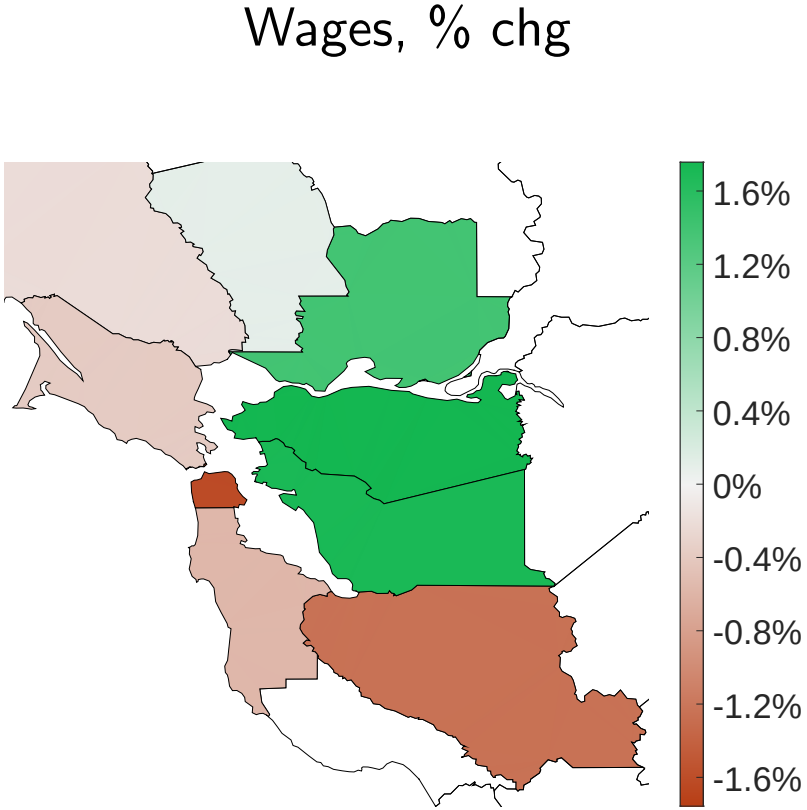


Panel B: Housing wealth, owners



▸ back

Long-run results: wages



▸ back

Transitional results: wages



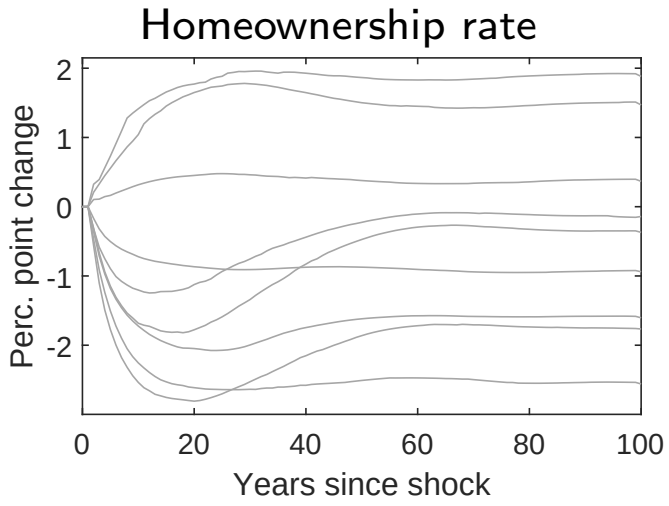
Note: wages fall on impact because firms still pay pre-2020 rents on in-force leases. As leases reprice, lower office rents pass through to wages, which overshoot before settling.

▸ back

Transitional results: price-rent ratios and homeownership



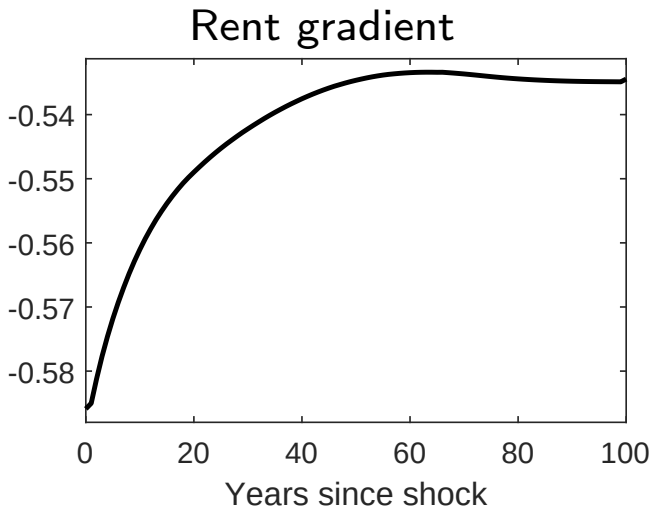




▸ back

Transitional results: price and rent gradients

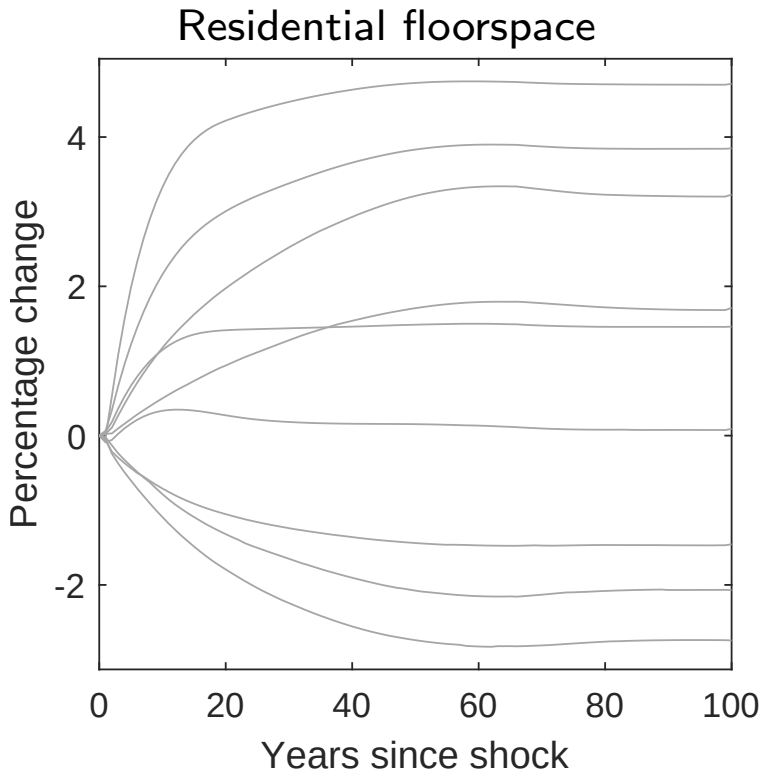




Note: gradient = coefficient from the regression of log prices or rents on log travel time to city center.

▸ back

Transitional results: housing supply

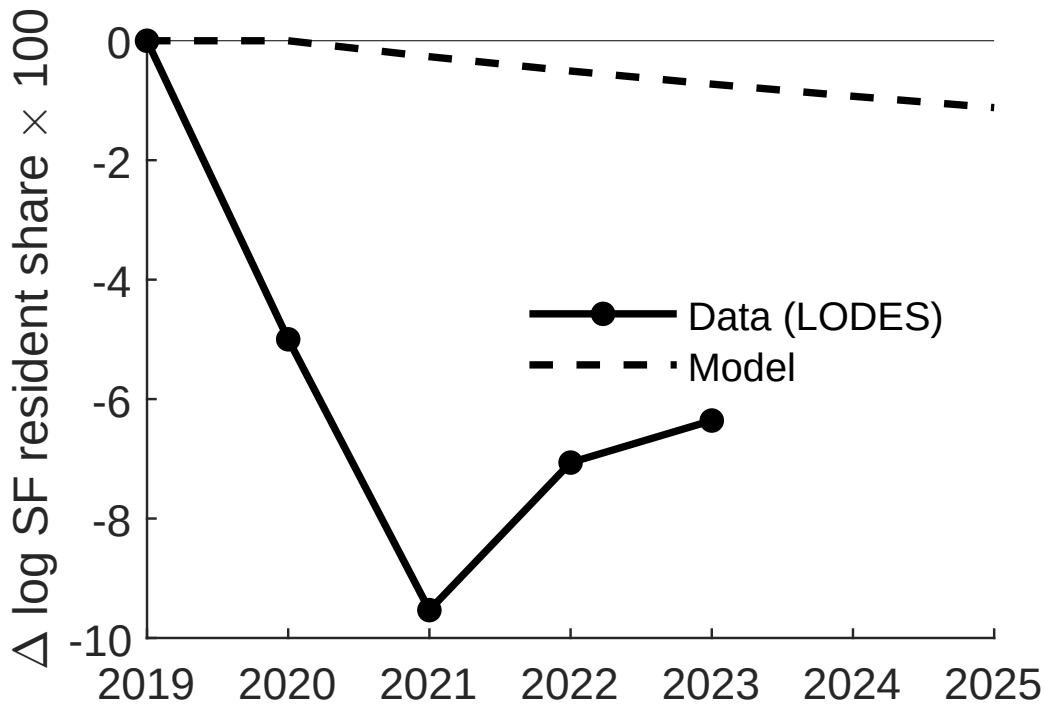


Note: where demand falls, the stock declines only through depreciation (irreversible construction).

▸ back

Validation: SF share of residents

SF share of the Bay Area's employed residents, data (LODES) vs model



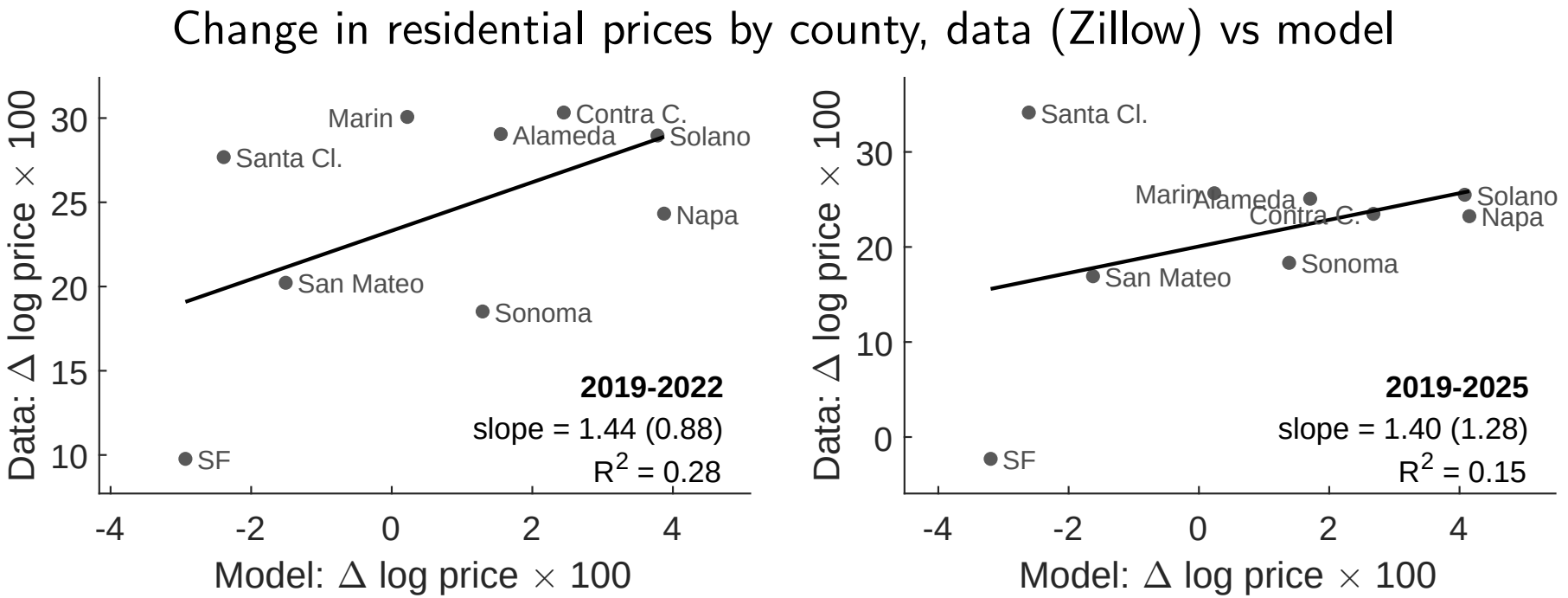
▸ back

Validation: all variables

	2019–2022			2019–2025 (LODES 2023, ACS 2024)		
	slope	s.e.	R^2	slope	s.e.	R^2
Res. price	1.44	(0.88)	0.28	1.40	(1.28)	0.15
Res. rent	11.73	(2.17)	0.81	4.60	(1.31)	0.64
Comm. rent (indust.)	-0.39	(0.48)	0.10	-0.24	(0.58)	0.02
Comm. rent (retail)	0.50	(0.89)	0.05	-0.34	(0.50)	0.06
Comm. rent (office)	0.18	(0.64)	0.01	-0.13	(0.64)	0.01
Residents (LODES)	1.47	(1.48)	0.12	0.97	(1.00)	0.12
Jobs (LODES)	0.09	(0.17)	0.04	0.01	(0.17)	0.00
Jobs (QCEW)	0.14	(0.21)	0.06	-0.30	(0.16)	0.32
Homeownership (ACS)	-0.04	(1.78)	0.00	-0.99	(0.87)	0.16
Travel time (LODES)	0.03	(0.09)	0.02	0.07	(0.09)	0.06
WFH share (ACS)	-75.96	(27.70)	0.52	-5.48	(3.53)	0.26

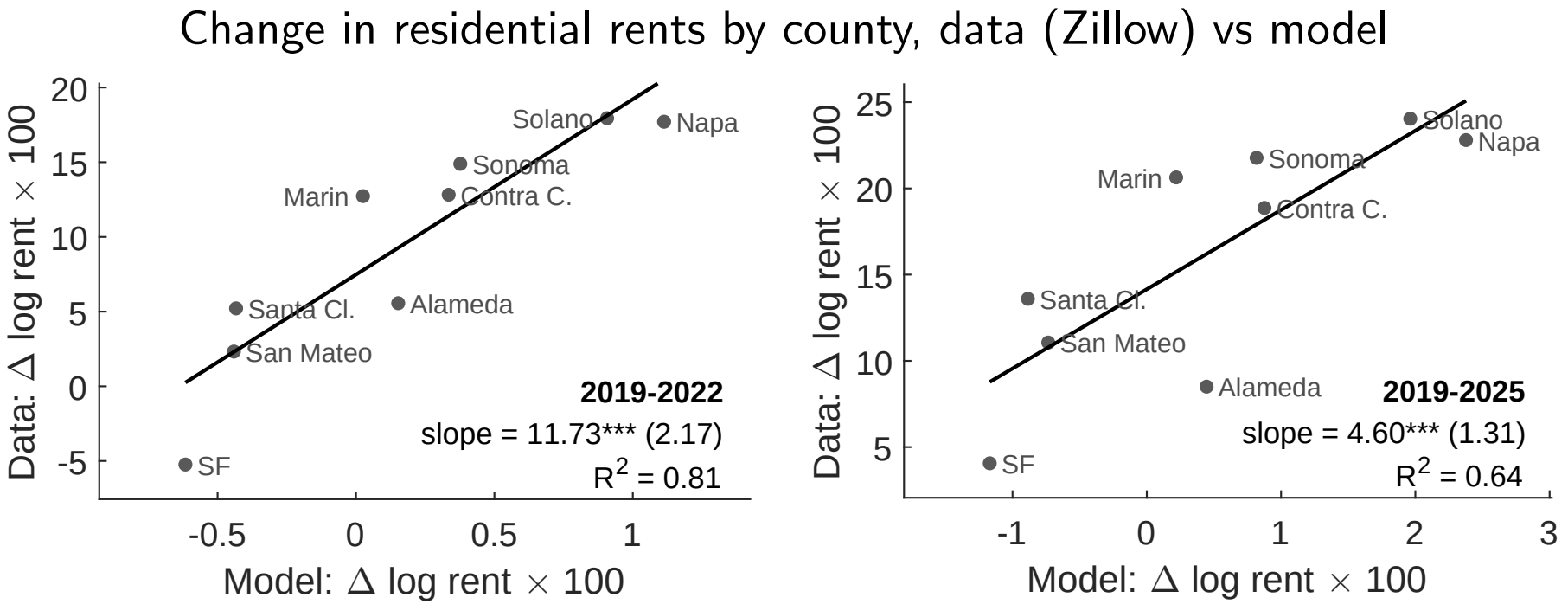
▸ scatterplots ▸ back

Validation: residential prices



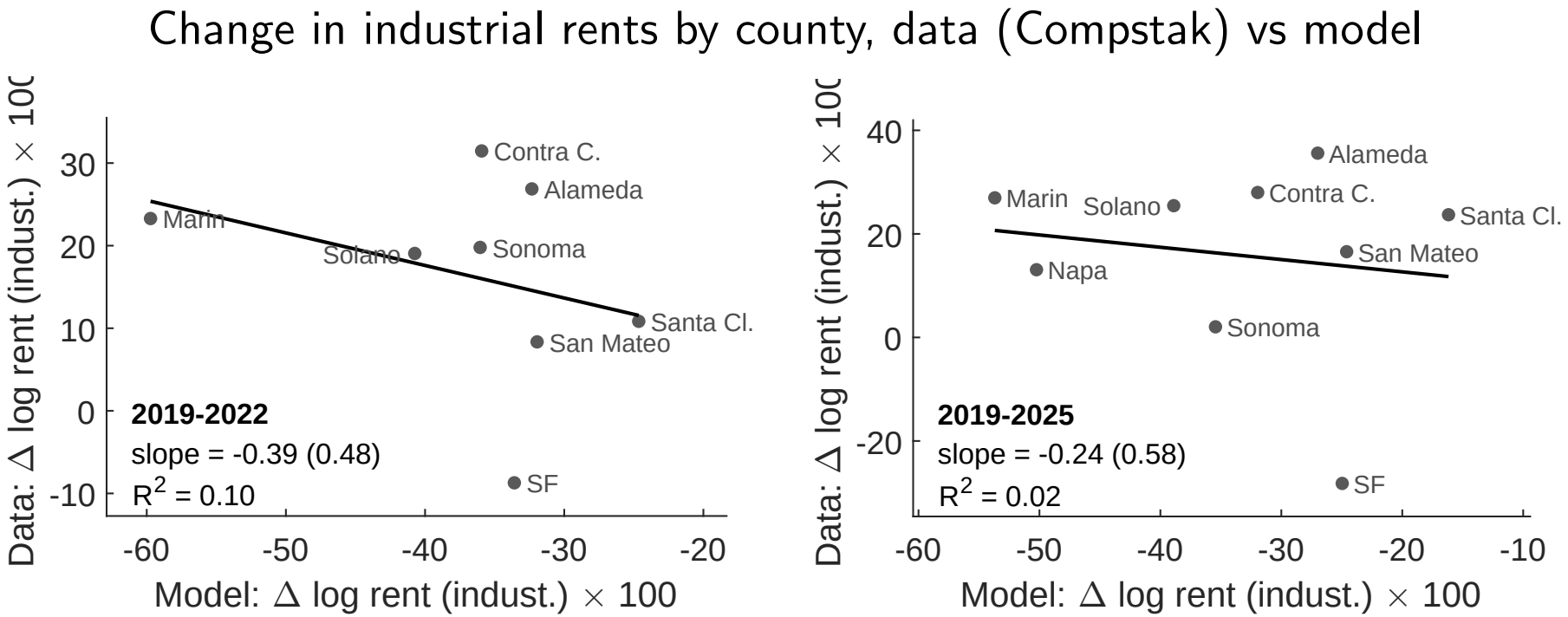
▸ back

Validation: residential rents



▸ back

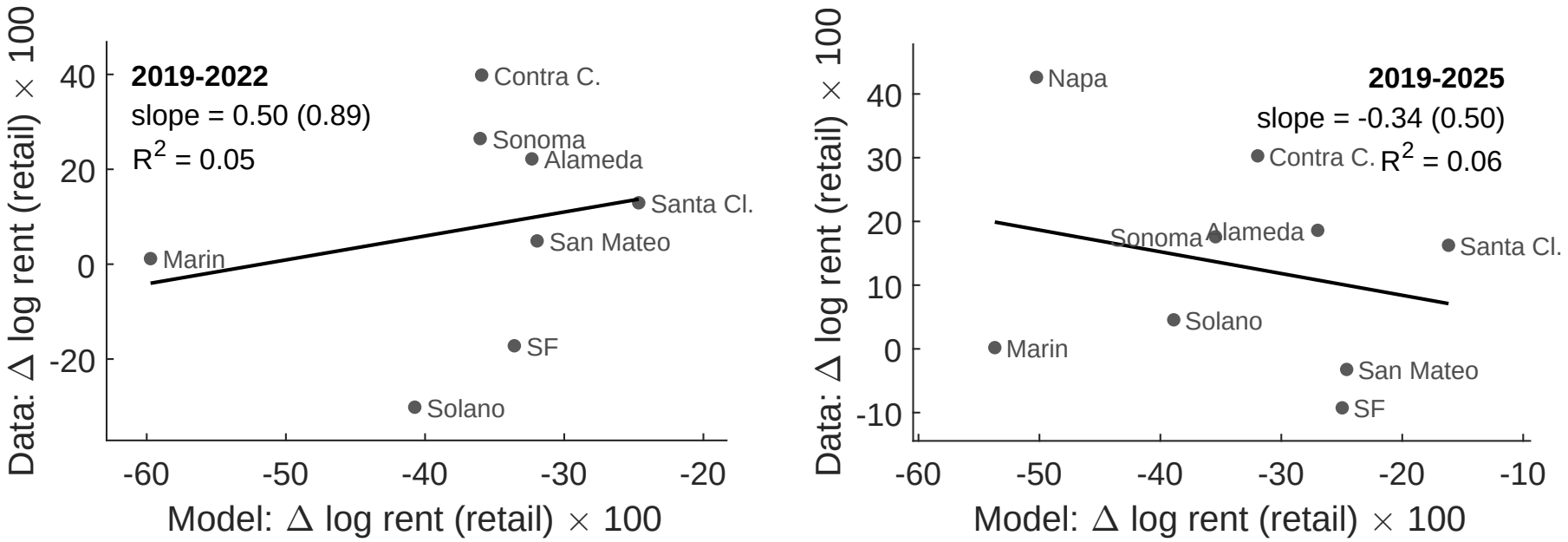
Validation: industrial rents



▸ back

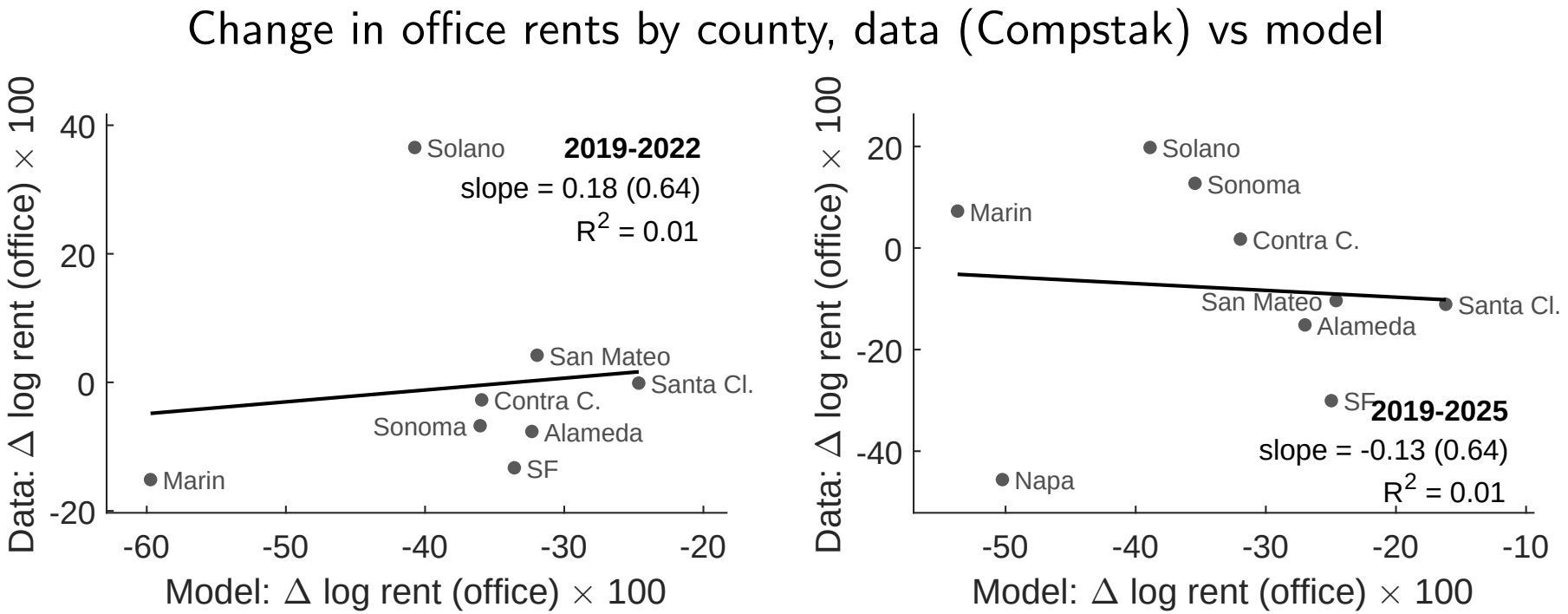
Validation: retail rents

Change in retail rents by county, data (Compstak) vs model



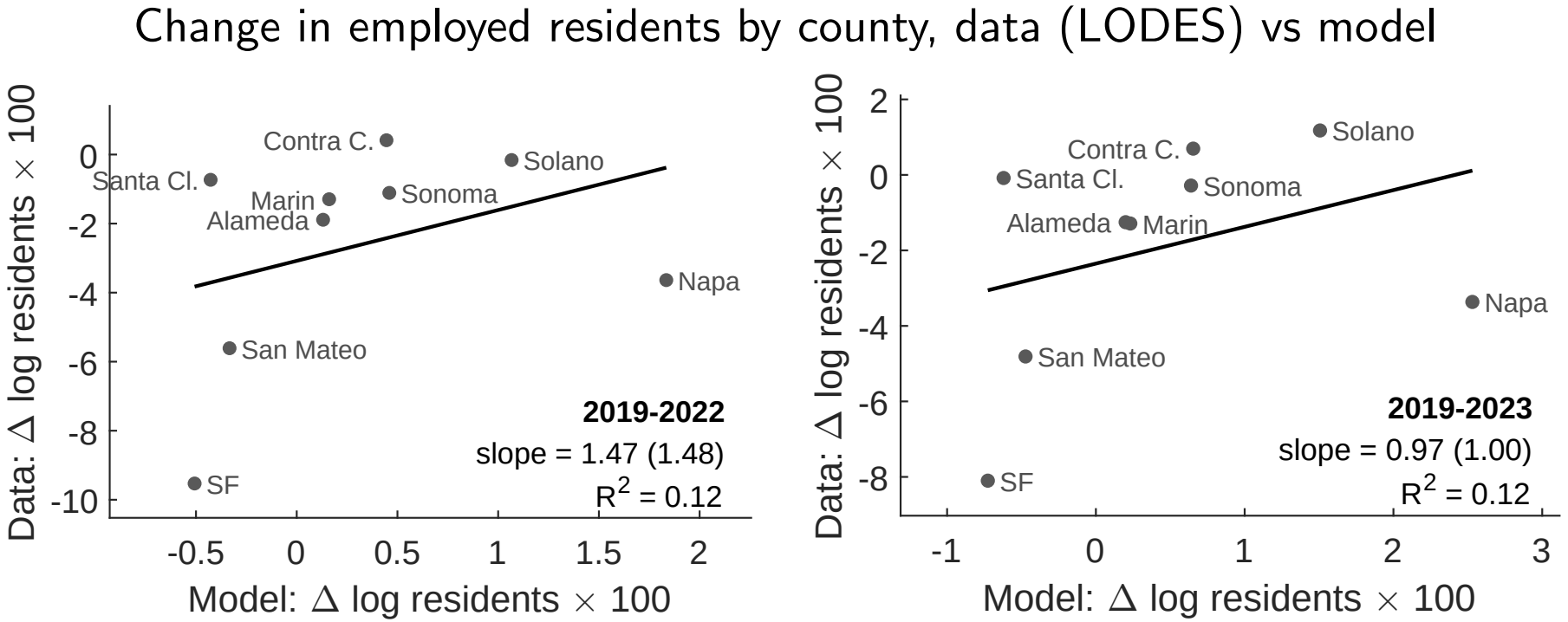
▸ back

Validation: office rents



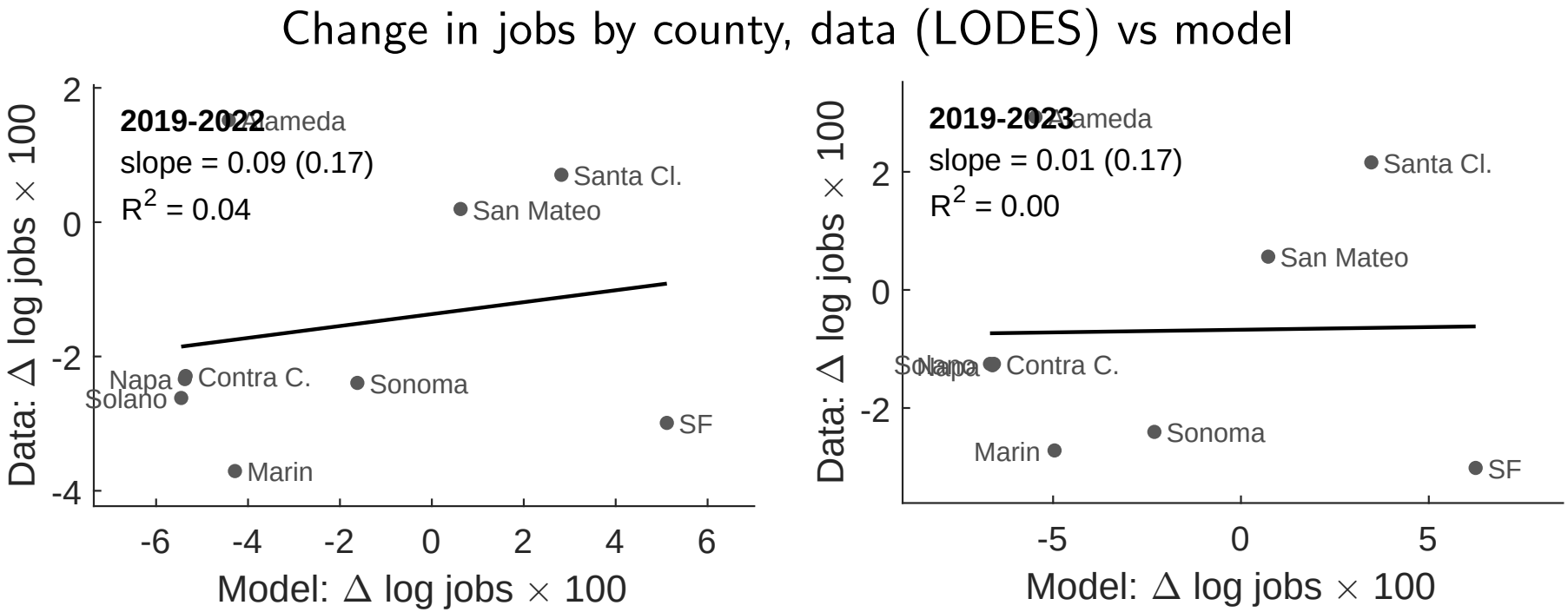
▸ back

Validation: employed residents



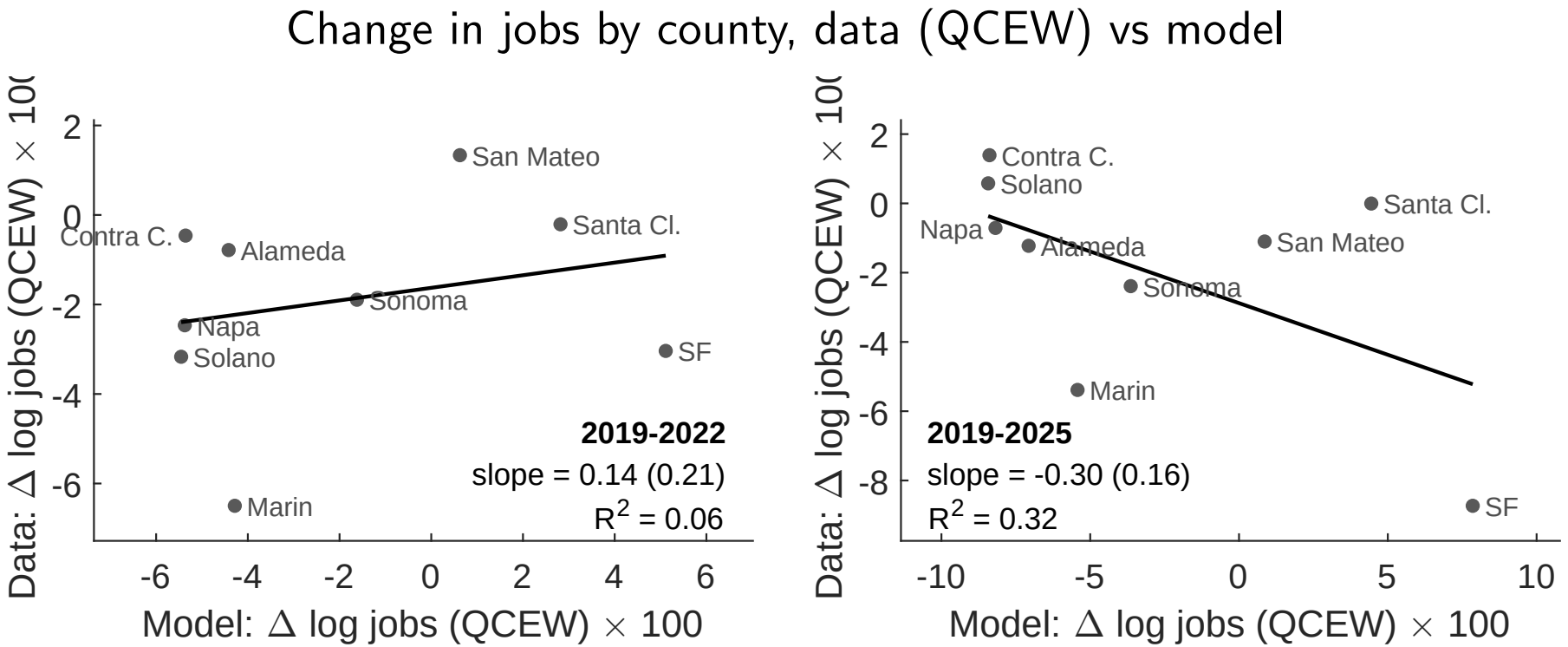
▸ back

Validation: jobs (LODES)



▸ back

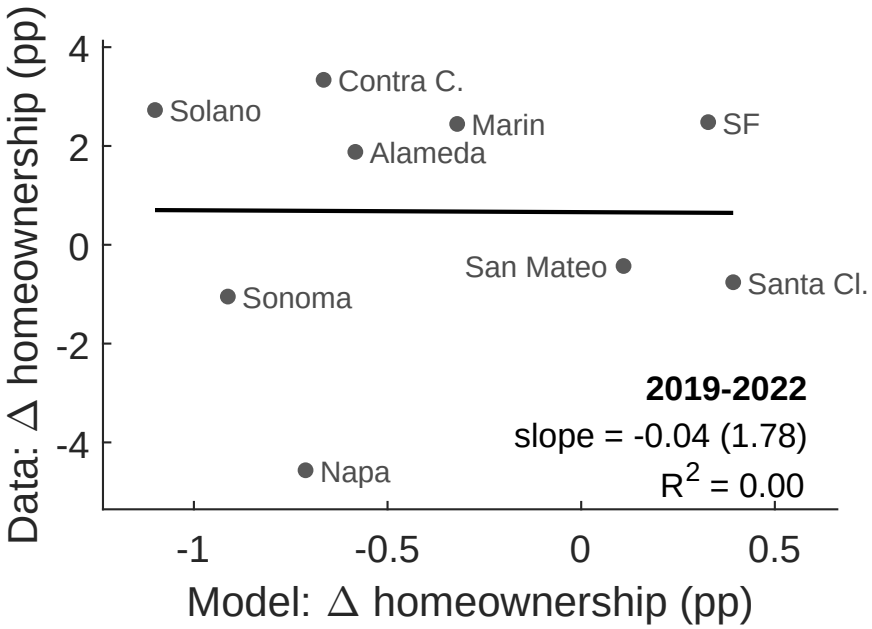
Validation: jobs (QCEW)

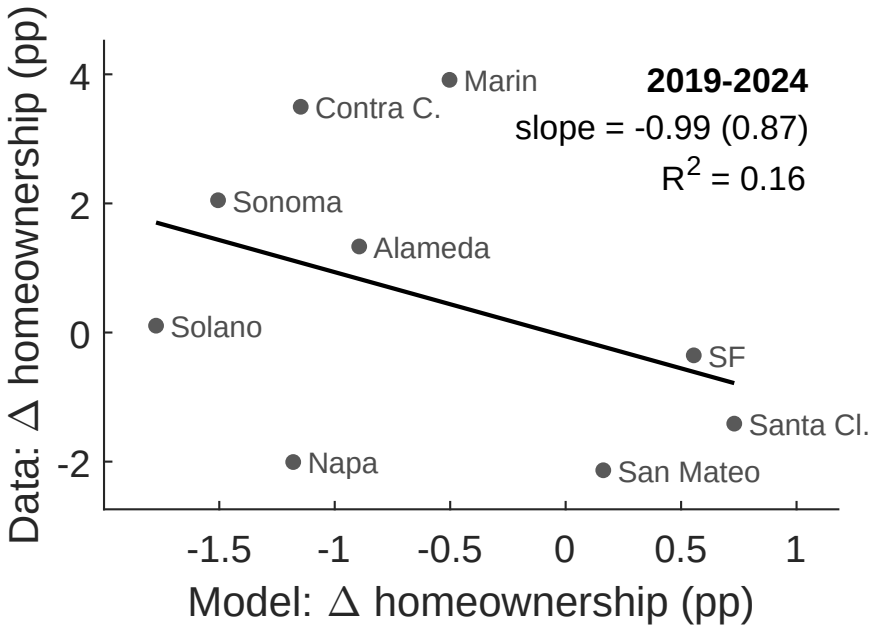


▸ back

Validation: homeownership

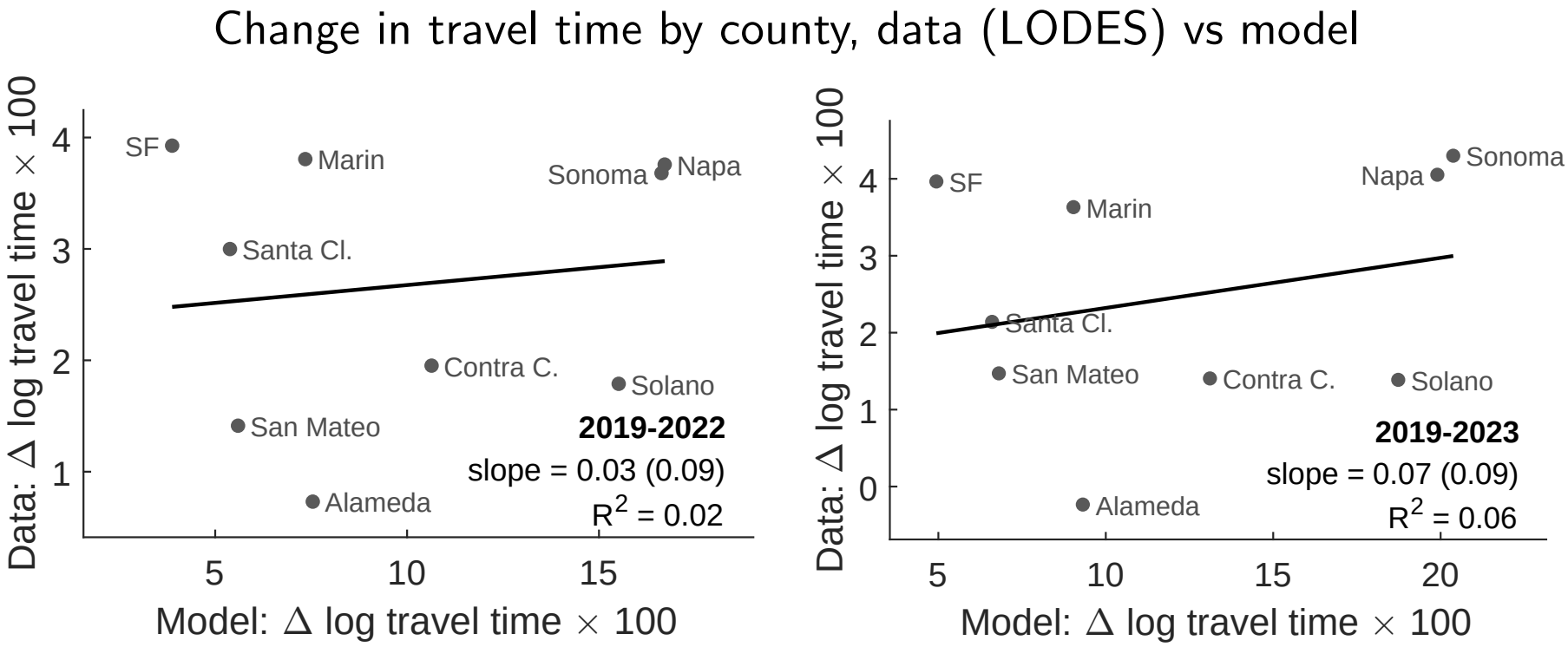
Change in the homeownership rate by county, data (ACS) vs model





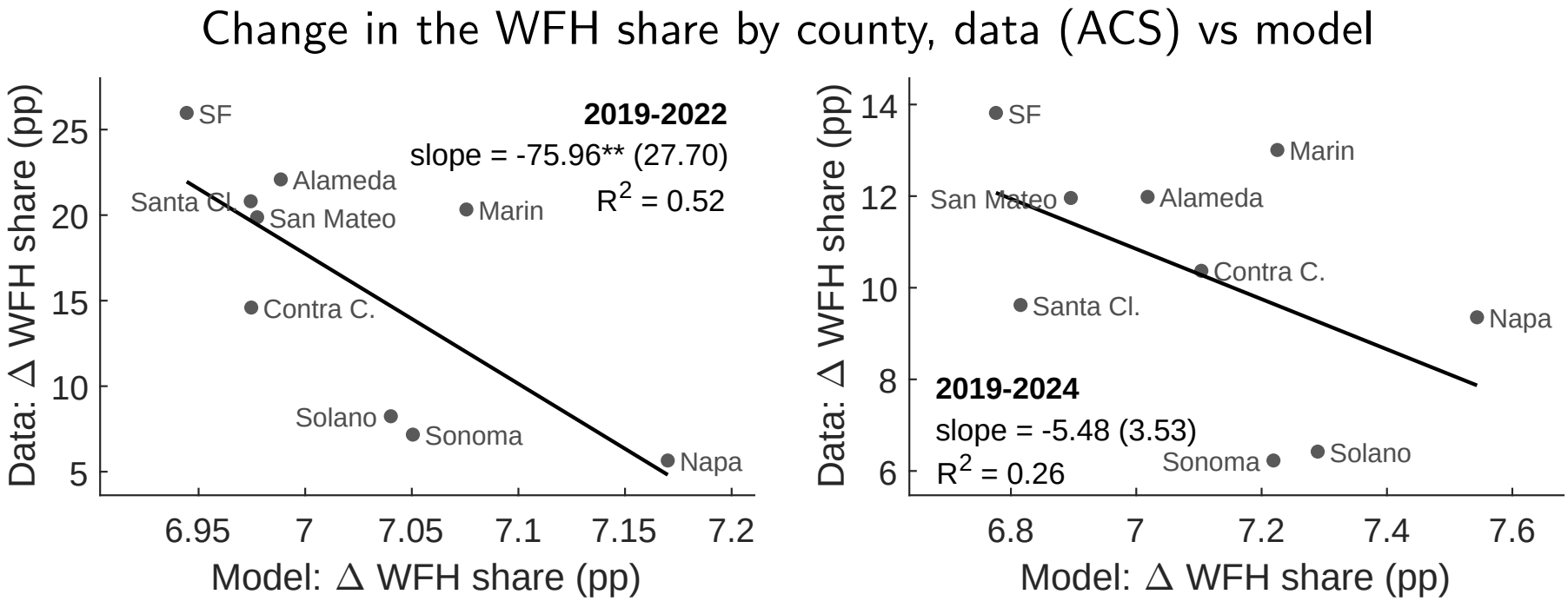
▸ back

Validation: travel time



▸ back

Validation: WFH share



back

Decomposition of welfare gains

	All workers	Remote	Hybrid	On-site
Commuting costs	2.24	0.00	-0.11	2.49
Consumption (tradable)	0.33	0.99	0.47	0.29
Housing (incl. ownership)	0.02	-0.03	-0.00	0.02
Residential amenities	-0.11	0.09	0.08	-0.13
Residual	0.89	-1.43	-1.01	1.13
Total	3.43	-0.41	-0.58	3.87

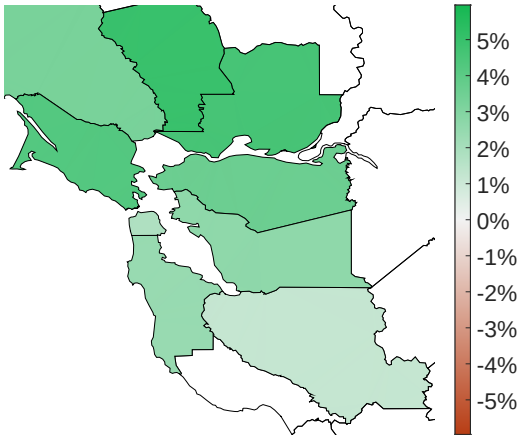
- **Key result:** two thirds of the gains come from lower commuting costs

Note: columns = pre-2020 WFH types; consumption-equivalent % over the transition. Residual: location tastes, moving costs, bequests, changes in states valued at baseline utility.

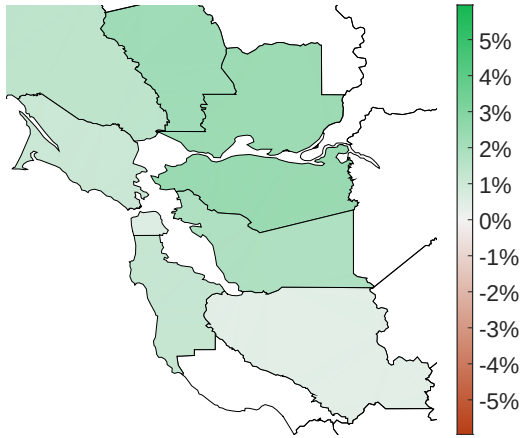
Welfare gains by residence and tenure

Key result: renters gain more. Owners gain least where house prices fall

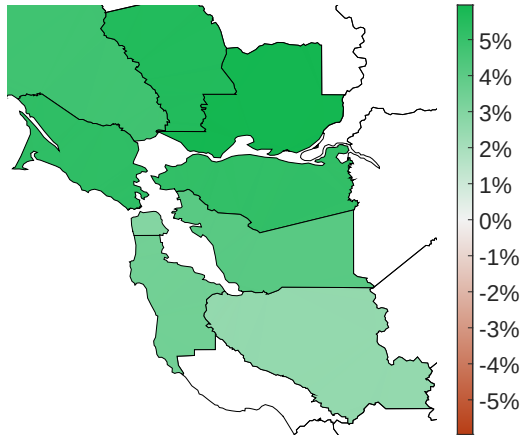
All individuals



Owners

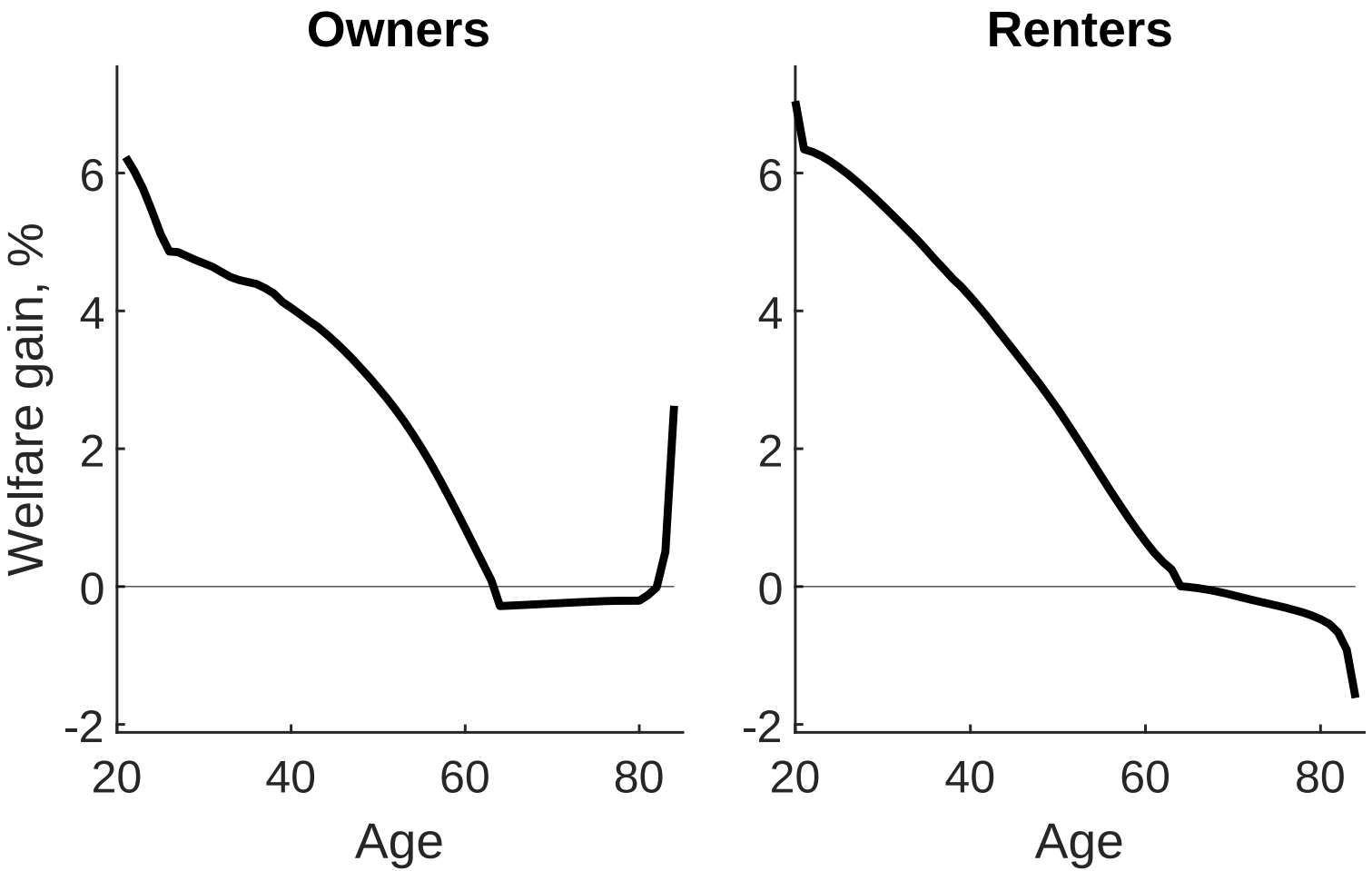


Renters



▸ back

Welfare gains by age



▸ back

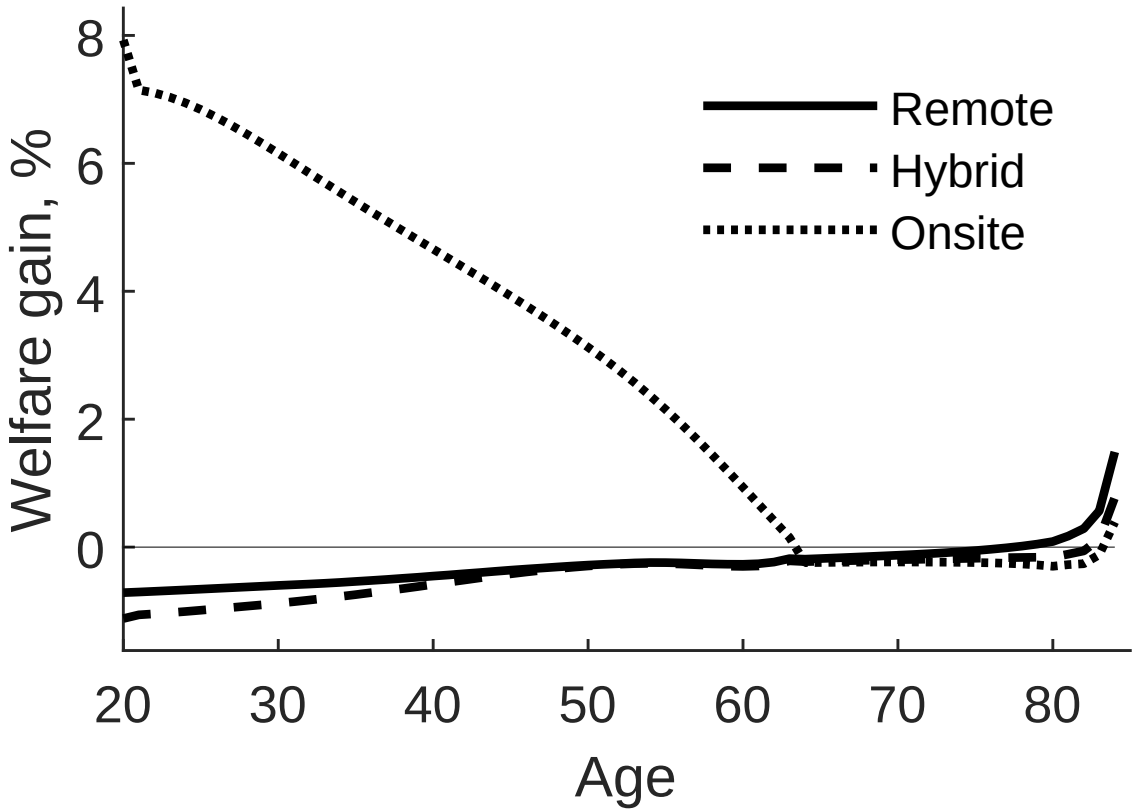
Welfare gains by wealth



Note: wealth in units of median annual earnings.

▸ back

Welfare gains by pre-2020 WFH type and age



▸ back

Office-to-residence conversions: decomposition

Welfare gain, %	Main model	Conversion	Conversion, main-model wages
Commuting costs	2.24	2.23	2.24
Consumption (tradable)	0.33	0.45	2.10
Housing (incl. ownership)	0.02	0.24	0.29
Residential amenities	-0.11	-0.10	-0.10
Residual	0.89	0.02	-0.53
Total	3.43	2.86	4.06

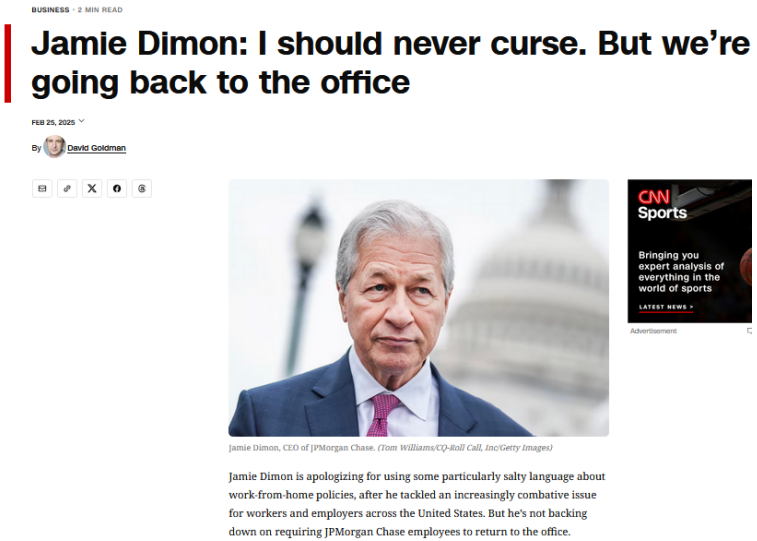
- Floorspace channel (conversion at main-model wages vs. main model): $+0.6$. Consumption $+1.8$ and housing $+0.3$, partly offset by the residual (-1.4)
- Wage channel (conversion vs. conversion at main-model wages): -1.2. Consumption -1.7, residual $+0.6$

Note: consumption-equivalent % over the transition, all workers.

▸ back

Return-to-office mandates (in progress)

- Many firms have imposed RTO mandates



BUSINESS · 2 MIN READ

Jamie Dimon: I should never curse. But we're going back to the office

FEB 25, 2025

By David Goldman

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Jamie Dimon, CEO of JPMorgan Chase. *(Tom Williams/CQ-Roll Call, Inc/Getty Images)*

Jamie Dimon is apologizing for using some particularly salty language about work-from-home policies, after he tackled an increasingly combative issue for workers and employers across the United States. But he's not backing down on requiring JPMorgan Chase employees to return to the office.



BBC

Elon Musk declares end to remote working at Tesla

2 June 2022

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- Reasons: higher perceived productivity, corporate culture
- Even if true, RTO mandates may not be welfare-improving. Workers have already paid to move farther from work
- We will study equilibrium and welfare effects of RTO mandates

▸ back

Decomposition of welfare gains across model versions

Welfare gain, %	Main model	Endog. amen.	Aggl. effects
Commuting costs	2.24	2.24	2.24
Consumption (tradable)	0.33	0.35	0.11
Housing (incl. ownership)	0.02	0.02	0.00
Residential amenities	-0.11	-0.66	-0.10
Residual	0.89	0.88	0.66
Total	3.43	2.85	2.93

Note: components in consumption-equivalent % over the transition, all workers.

▸ back: public finance ▸ back: agglomeration