Living in a Ghost Town: The Geography of Depopulation and Aging

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Motivation

- Increasing dispersion of population across **regions** within Japan
  - Population $\uparrow$ 10% in urban vs $\downarrow$ 30% in rural Japan from 1980-2010
- Widespread concerns about **nationwide** aging and depopulation
  - Median age $\uparrow$ 13 years from 1980-2010
  - Population decreased by 3million from 2010-2020
- **Questions**
  - What drives the large geographic variation?
  - How is this process related to nationwide demographic transition?
  - How will the aggregate aging and depopulation shape rural areas?
  - What are the policy implications?

This Paper

- Documents spatial pattern of depop & aging in Japan since 1980
  - Faster depop & aging rural areas; driven by (youths') migration beyond birth & death
- Develops a framework to unpack the forces behind lifecycle migration decisions
  - Wages/employment, housing cost, amenity (local non-tradable services)
  - **Amenity** is key; especially for young
  - Elasticity of amenity w.r.t population density is not constant
- Embeds the migration decisions into a quantitative dynamic spatial GE model to conduct future simulation and counterfactual analysis
  - Rich spatial heterogeneity + life-cycle elements + migration decision $\leftrightarrows$ local economic conditions (wages, housing, amenity)
  - *Nationwide* depop & aging + **endogenous amenity** $\Rightarrow$ *Rural* depop & aging

Outline

1. Data & Motivating Facts
2. Unpacking Migration Decisions
3. General Equilibrium Model
4. Quantitative Analysis: Decline of Fertility Rate

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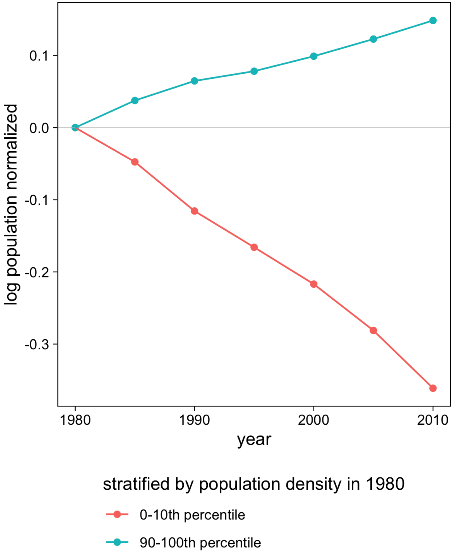
Data (1719 municipalities across 47 prefectures)

- Population Changes & Migration
  - Population count by municipality, age, gender, residence 5 years ago (Population Census)
  - Birth & death by age and prefecture (Vital Statistics)
- Income & Employment
  - Average taxable income by municipality (Ministry of Internal Affairs)
  - Wage by age and prefecture (Basic Survey on Wage Structure)
  - Employment by age and municipality (Economic Census)
- Land Prices & Housing
  - Land prices for designated plots (Ministry of Land, Infrastructure, Transport, and Tourism)
  - Housing stock and construction by urban municipality (Housing and Land Survey)
- Amenity (Various Sources)
  - Classify: retail, health/medical, elderly service, child/education, environment/transport
  - Create a PCA index for each category (Diamond '16) detail

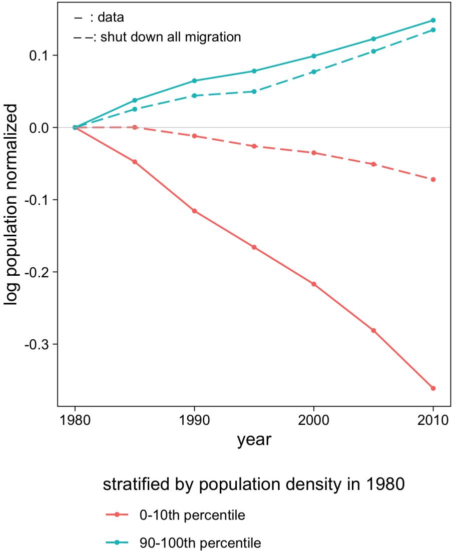
Faster depopulation in rural areas



- 0-10th percentile in 1980 - rural
- 90-100th percentile in 1980 - urban

scatter plots

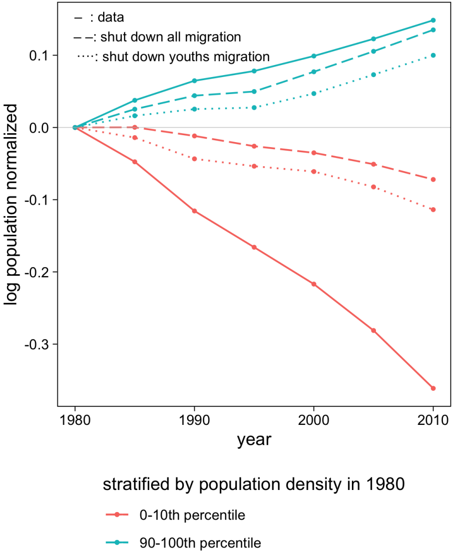
Migration accelerated rural depopulation beyond birth & death



- Starting from 1980, construct hypothetical population if there were no migration
- Remaining variation is mostly driven by differences in reproductive-age population (rather than fertility or death rates)

net out-migration rates

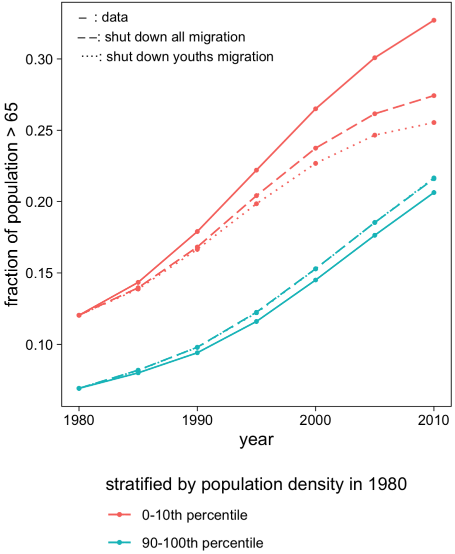
Youths' outmigration accelerated rural depopulation



- Same counterfactual, only shut down migration of youths (15-24 years old)

net out-migration rates by age

Youths' out-migration accelerated rural aging



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Migration Decision

- Agent of age a that lives in location n in period t earns period utility $u_t^n(a)$
- Decide where to migrate at the end of period t

$$\max_{\ell} s_t^{\ell}(a)\beta V_{t+1}^{\ell}(a+1) - \tau_t^{n\ell}(a) + \nu\varepsilon_t^{\ell}(a)$$

  - $V_t^l(a)$: value if age a lives in location l in period t
  - $s_t^{\ell}(a)$: survival rate
  - $\tau_t^{n\ell}(a)$: migration cost
  - $\varepsilon_t^l(a)$: i.i.d. preference shocks; ν: dispersion of preference shocks

- Value function

$$V_t^n(a) = u_t^n(a) + \mathbb{E}\left[\max_{\ell}\{s_t^{\ell}(a)\beta V_{t+1}^{\ell}(a+1) - \tau_t^{n\ell}(a) + \nu\varepsilon_t^{\ell}(a)\}\right]$$

Migration Decision

- Assume $\{\epsilon_t^l(a)\}$ is i.i.d Type 1-EV
- Migration share of moving from n to i

$$\mu_t^{ni}(a) = \frac{\exp\left[s_t^i(a)\beta V_{t+1}^i(a+1) - \tau_t^{ni}(a)\right]^{1/\nu}}{\sum_\ell^N \exp\left[s_t^\ell(a)\beta V_{t+1}^\ell(a+1) - \tau_t^{n\ell}(a)\right]^{1/\nu}}$$

- Value function

$$V_t^n(a) = u_t^n(a) + \nu \log \sum_\ell^N \exp\left[s_t^\ell(a)\beta V_{t+1}^\ell(a+1) - \tau_t^{n\ell}(a)\right]^{1/\nu}$$

Estimating Flow Utility

- **Goal**: using migration flow data to infer flow utility $u_t^n(a)$

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- Invert continuation values $\{V_{t+1}^i(a+1)\}$ from migration flows data

$$\mu_t^{ni,data}(a) = \frac{\exp\left[s_t^n(a)\beta V_{t+1}^i(a+1) - \tau_t^{ni}(a)\right]^{1/\nu}}{\sum_\ell \exp\left[s_t^\ell(a)\beta V_{t+1}^\ell(a+1) - \tau_t^{n\ell}(a)\right]^{1/\nu}}$$

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- From Bellman equation, recover $\{u_t^n(a)\}$

$$V_t^n(a) = u_t^n(a) + s_t^n(a)\beta V_{t+1}^n(a+1) - \nu \ln \mu_t^{nn,data}(a),$$

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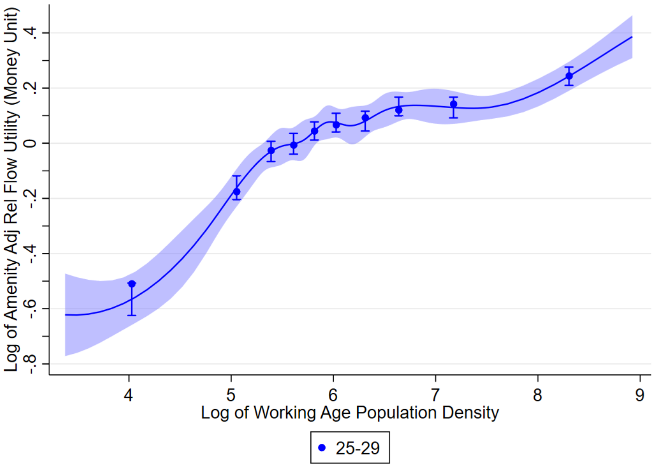
- Decompose $u_t^n(a)$ into:
  1. Income
  2. Housing cost
  3. Amenity (residual): accessibility of non-tradable services, crime, environment etc

Flow Utility vs Population Size in 2010



Large spatial dispersion of young's flow utility

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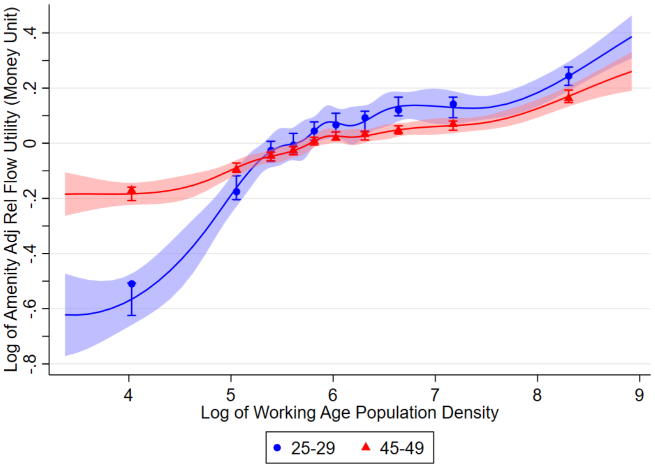

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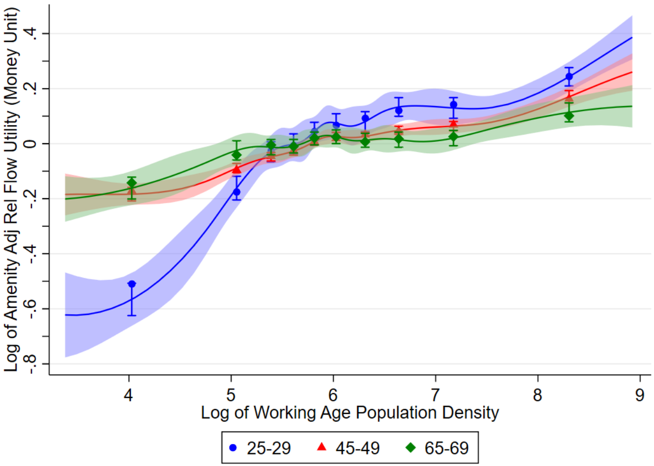
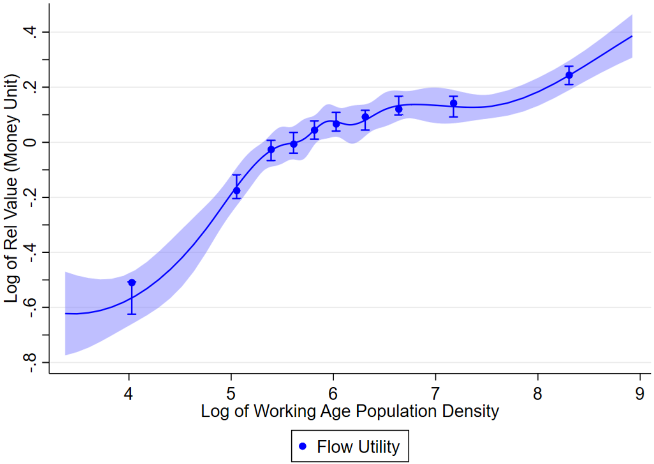


Large spatial dispersion of young's flow utility

Unpacking Youth's (Age 25-29) Flow Utility in 2010

Age 45-49 | Remove 10% | Housing cost | Correlation | Taxable Income



Large spatial dispersion of young's flow utility, mostly driven by amenity

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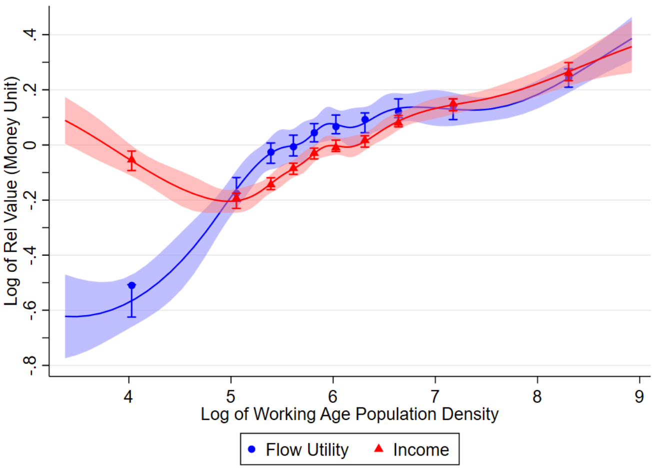

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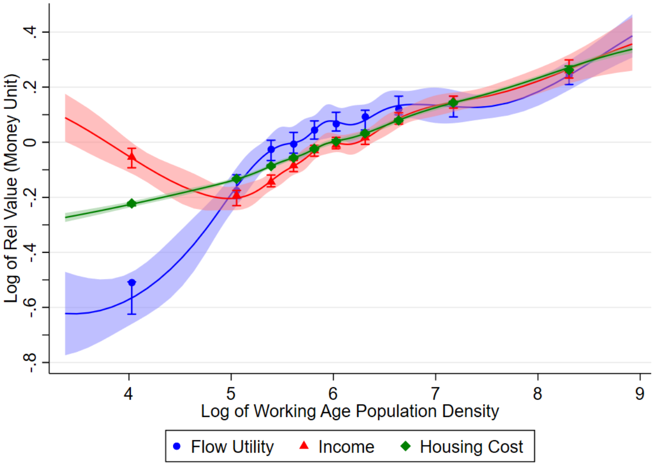

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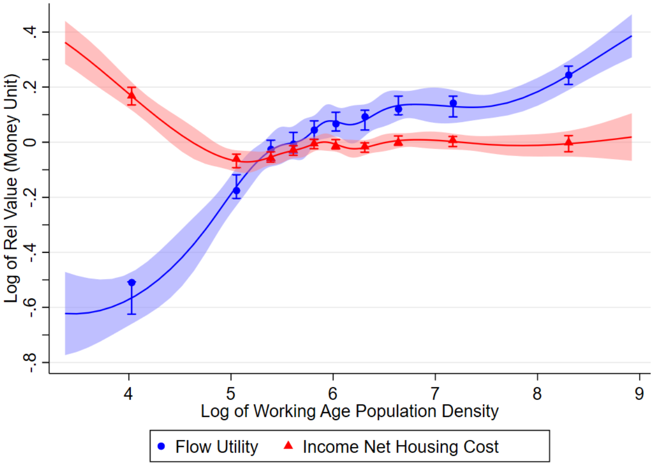

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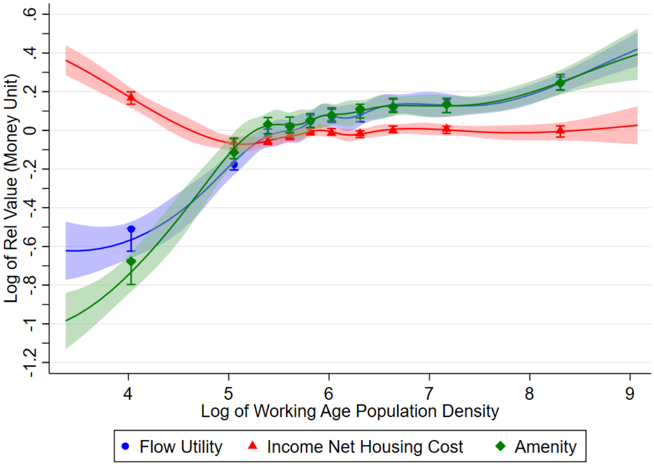

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Non-linear Effect of Population Density on Amenity

VARIABLES	(1) 2010 15-64 OLS $\ln \text{Amenity}_{nt}(a)$	(2) 2010 15-64 OLS $\ln \text{Amenity}_{nt}(a)$	(3) 2010 15-64 No-Mig IV $\ln \text{Amenity}_{nt}(a)$	(4) 2010 15-64 Pull-Push IV $\ln \text{Amenity}_{nt}(a)$
$\ln$(Working-Age Pop Density)	0.0973***	0.320***	0.338***	0.249***
	(0.00669)	(0.0132)	(0.0233)	(0.0202)
$(\ln(\text{Working-Age Pop Density}))^2$		-0.0207***	-0.0185***	-0.0233***
		(0.00103)	(0.00178)	(0.00159)
Observations	17,310	17,310	17,310	17,310
R-squared	0.928	0.931	0.596	0.589
FE	Pref-Age	Pref-Age	Pref-Age	Pref-Age
Control	Yes	Yes	Yes	Yes
Kleibergen-Paap F			1160	858.7

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Note: We control for the share of secondary industry, the share of tertiary industry, the log of working age population density, and the log of the area in 1985 and include prefecture-age group fixed effects.

Non-constant population elasticity of amenity, larger elasticity in rural areas

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Quantitative Dynamic Spatial Lifecycle GE Model detail

Caliendo, Dvorklin, Parro ’19 + lifecycle dimension (Suzuki ’21) + housing & amenity

- **Space**: $n \in N$ locations; differ by productivity, amenities, and fertility/death rates
- **Migration**
- **Demographics (life-cycle)**: age a; die stochastically; newborn from local population

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  - Location-age-specific labor income + land ownership income + pension (after 65)
  - Pensions financed by labor income tax
  - Labor income depends on location-age productivity

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  - Labor income depends on location-age productivity
- **Preferences**
  - Consumption good c (freely-traded good + non-tradable) and housing services h
  - Non-tradable features endogenous variety effect from IRS (Krugman '80)
  - Location-age-specific residential amenities χ

Quantitative Dynamic Spatial Lifecycle GE Model

- Preference

$$u^n(a) = (1-\theta)\ln c^n(a) + \theta \ln h^n(a) + \ln \chi^n(a),$$

$$c^n(a) = \left(c_T^n(a)^{\frac{\eta-1}{\eta}} + c_{NT}^n(a)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}},$$

$$c_{NT}^n(a) = \left(\int_{\Omega_{NT}^n} c_{NT}^n(\omega; a)^{\frac{\sigma-1}{\sigma}} d\omega\right)^{\frac{\sigma}{\sigma-1}},$$

where $\eta > 0, \sigma > 1$

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  where $\eta > 0, \sigma > 1$

- Indirect utility:

$$u^n(a) = \ln I^n(a) - \theta \ln R^n \underbrace{- \frac{1-\theta}{1-\eta} \ln\left(1 + (P_{NT}^n)^{1-\eta}\right) + \ln \chi^n(a)}_{\ln B^n(a)\text{: amenity}}$$

Quantitative Dynamic Spatial Lifecycle GE Model

- Endogenous spillover from varieties (Krugman '80):

$$P_{NT}^{n} \sim \left(N_{NT}^{n}\right)^{\frac{1}{1-\sigma}} \sim \left(L^{n}\right)^{\frac{1}{1-\sigma}} \implies P_{NT}^{rural} > P_{NT}^{urban}$$

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- Complementarity between tradable and non-tradable

$$0 < \eta < 1 \Longrightarrow s_{NT}^{rural} > s_{NT}^{urban}$$

Quantitative Dynamic Spatial Lifecycle GE Model

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$$P^n_{NT} \sim (N^n_{NT})^{\frac{1}{1-\sigma}} \sim (L^n)^{\frac{1}{1-\sigma}} \Longrightarrow P^{rural}_{NT} > P^{urban}_{NT}$$

- Complementarity between tradable and non-tradable

$$0 < \eta < 1 \Longrightarrow s^{rural}_{NT} > s^{urban}_{NT}$$

- Non-constant elasticity

$$\frac{\partial \ln B^n(a)}{\partial \ln L^n} \downarrow \text{ in } L^n,$$

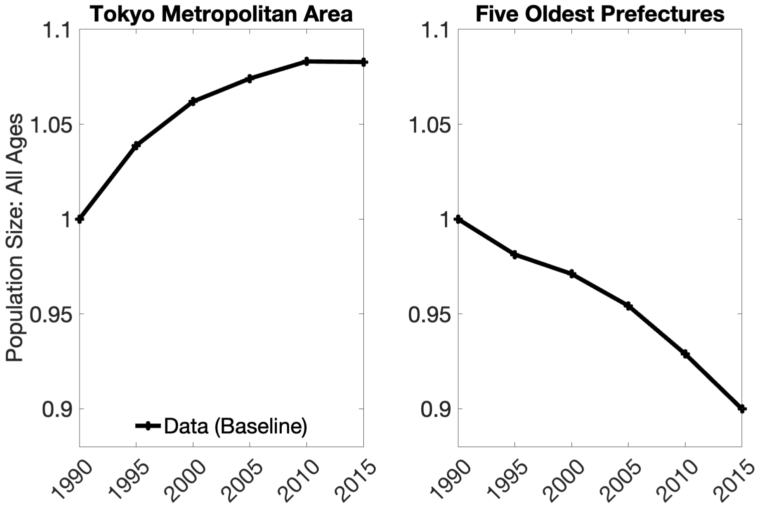
same percentage decline of population hurts rural areas relative more!

Calibration

- 47 prefectures; 5 year time interval
- Choose location-age-specific fundamentals to exactly fit data in 1990-2015 (CDP '19)
  - Productivity: labor compensation
  - Amenity and migration costs: population transition
- Calibrate other parameters

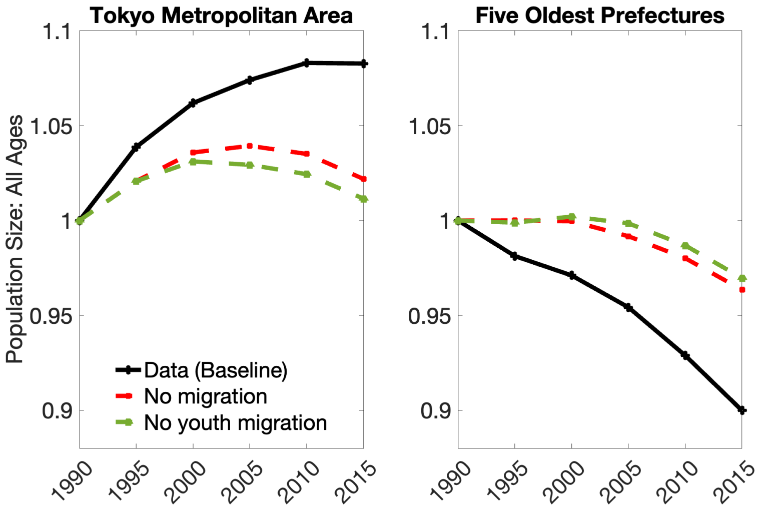
Parameters	Description	Values / Sources
ν	shape parameter for migration preference shocks	0.4
β	discount factor	0.97^5
θ	consumption expenditure share of housing	0.33
μ	labor share in housing construction	0.9
σ	elasticity of substitution among non-tradable varieties	5
η	elasticity of substitution between tradable and non-tradable	0.5
$\{s_t^n(a)\}$	survival rates by age and year	official statistics (past and projection)
$\{\varkappa_t^n(a)\}$	fertility rates by age, year, locations	official statistics (past and projection)
T_t	pension payment per elderly population	aggregate pension payment = 110% of elderly labor income
κ_t	income tax rate	set to finance pension payment

Calibration: Regional Depopulation 1990-2015



Faster depopulation in rural prefectures (model exactly calibrated to population changes)

Calibration: Regional Depopulation 1990-2015



Significantly slower rural depopulation by shutting down migration fraction of elderly share of 25-29 spillover

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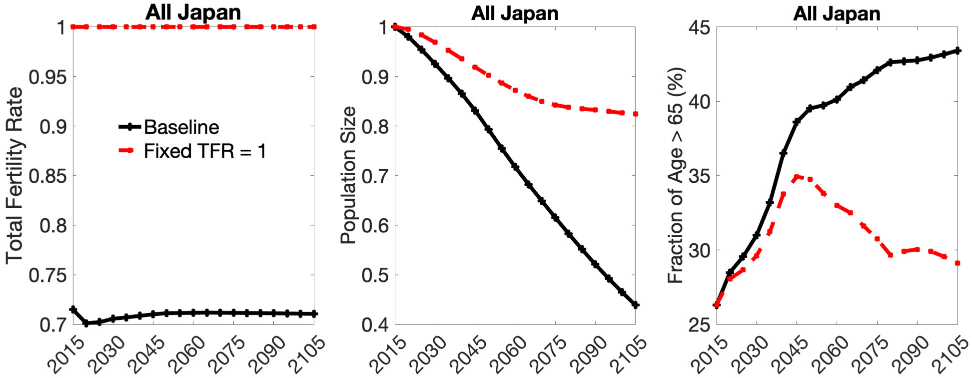
Aging and Depopulation: 2015 onwards

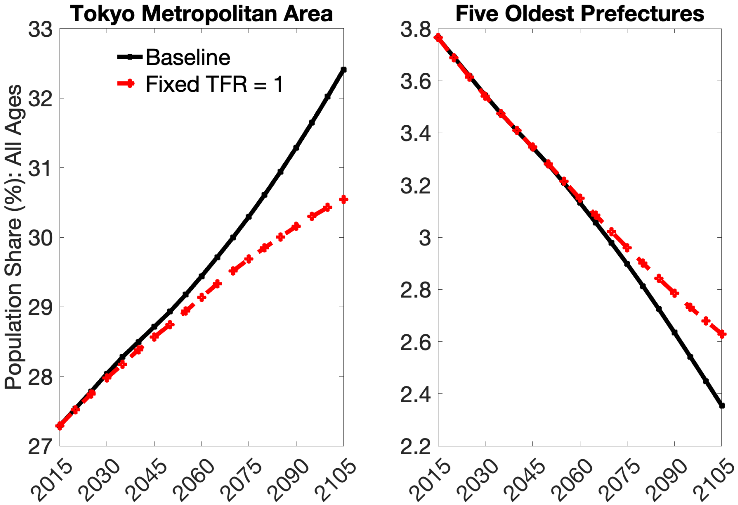
- Total fertility rate:

$$\text{TFR}_t = \sum_{a \in [15,45]} \sum_{n}^{N} \frac{L_t^n(a)}{\sum_n^N L_t^n(a)} fr_t^n(a)$$

- Counterfactual: what will happen if we adjust fertility rates across location homogeneously so that TFR is fixed at 1?



Uneven Regional Depopulation: 2015 onwards



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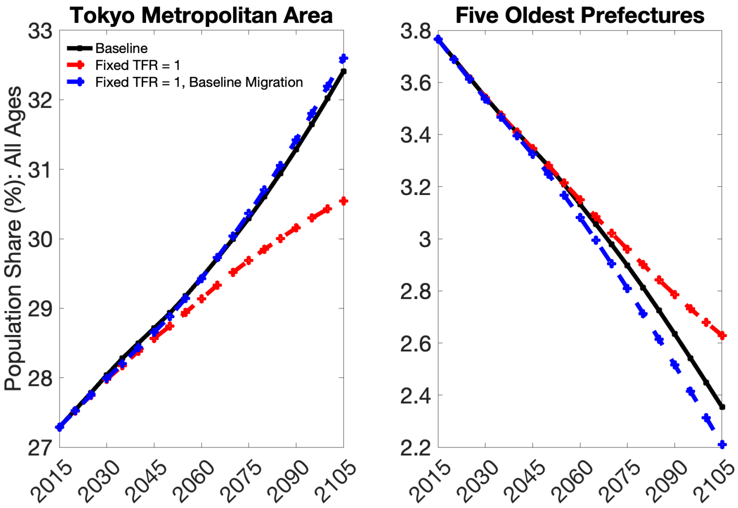

More pop. share in rural areas if depopulation will not progress that much aggregately, driven mostly by migration

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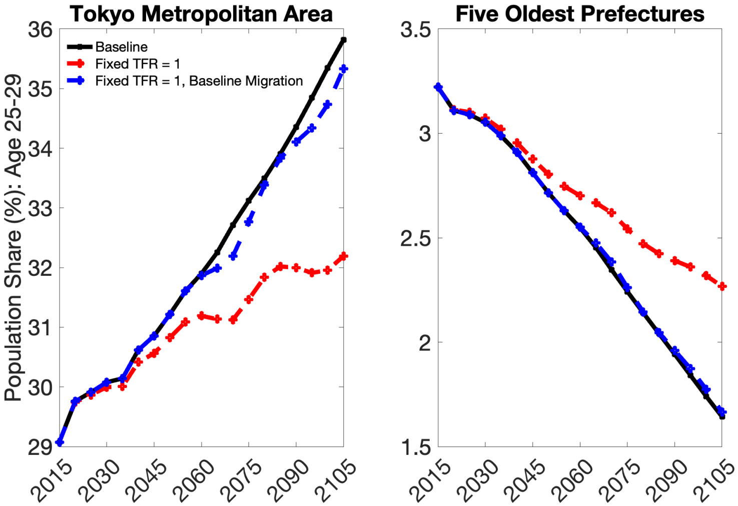

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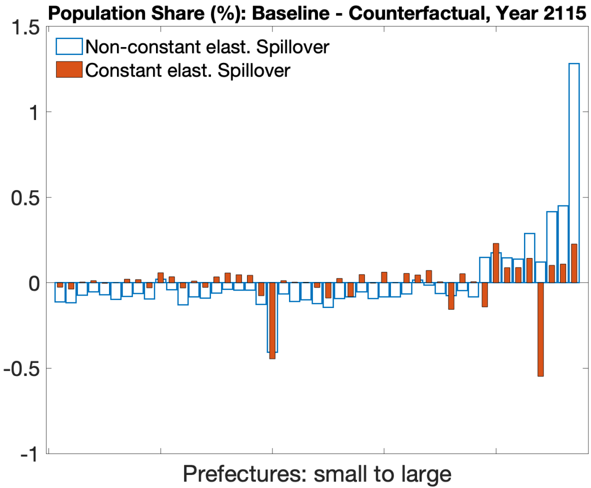

Non-constant elasticity is crucial for the regional impact of aggregate aging and depopulation

Conclusions and Current Work

- **Q:** How do depopulation and aging progress across regions within a country?
- **Reduced-form evidence** about the role of amenity-driven migration
- **Quantitative dynamic spatial GE model** to unpack mechanism and project future
  - Endogenous migration and non-constant elasticity of amenities are crucial
- **Upcoming**: Welfare analysis & Policy implication for ongoing migration subsidy

Appendix

Life Expectancy and Fertility Rates

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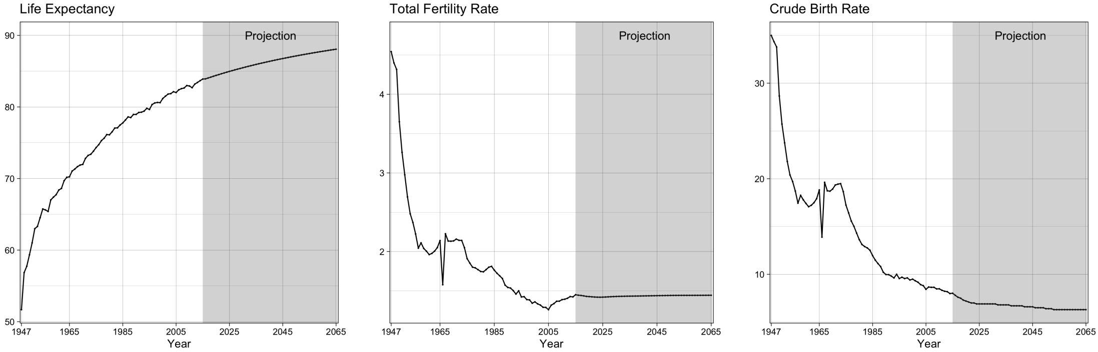


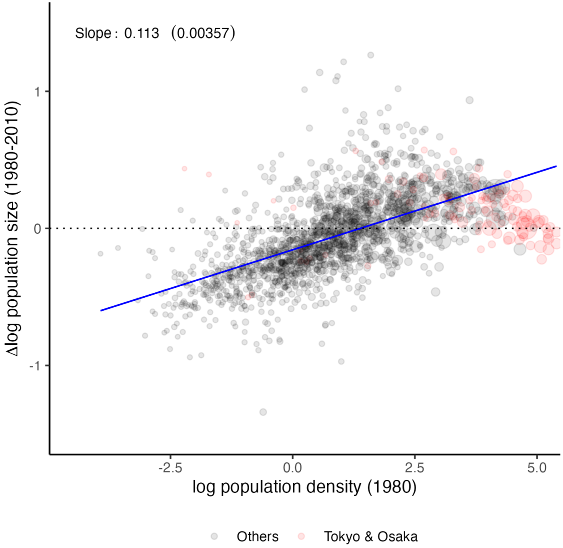
Amenity Proxies

go back

	Loading
Panel A. Retail	
Number Of Retail Stores	.418
Number of Clothing Stores	.411
Number of Food and Beverage Retail Stores	.411
Number Of Restaurants	.411
Number Of Large Retail Stores	.384
Number Of Barber Shops And Beauty Parlors	.413
Panel B. Health Medical	
Number Of General Hospitals	.477
Number Of General Clinics	.505
Number Of Medical Doctors	.517
Number Of Nurses	.499
Panel C. Elderly Service	
Number Of Community Centers	.547
Number Of Senior Citizen Clubs	.632
Number Of Nursing Homes	.550
Panel D. Child Education	
Number Of Daycares	.567
Number Of Schools (Elementary, Middle, and High)	.576
Number Of Teachers (Elementary, Middle, and High)	.589
Panel E. Environment / Transportation	
Road Length	.526
Paved Road Length	.564
Number Of Parks	.394
Number of Police Stations	.500

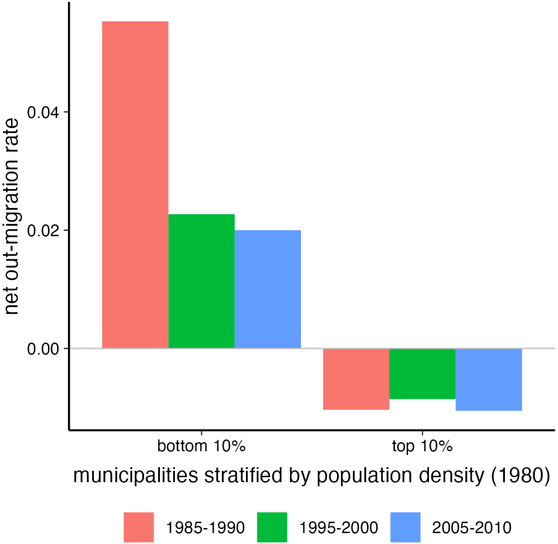
Depopulation and Baseline Population Density

go back



Higher net out-migration rate in rural areas

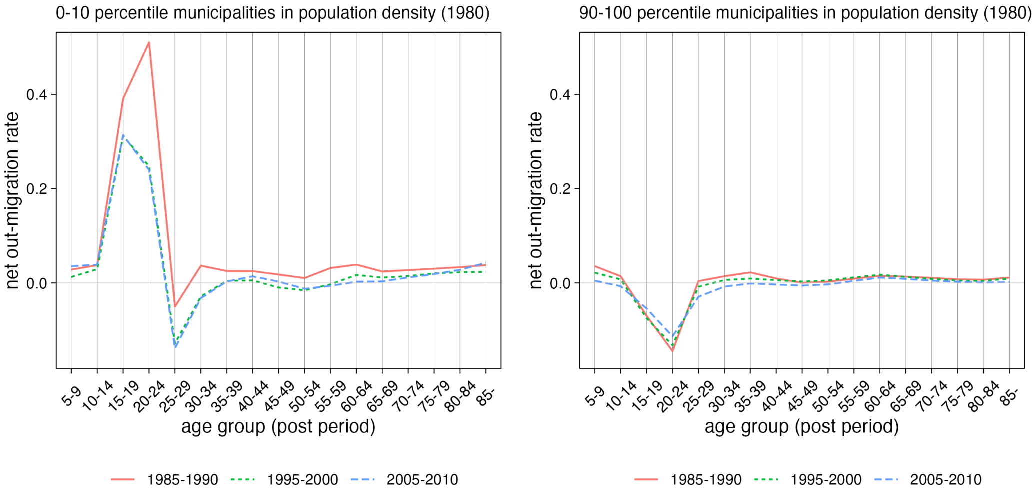
go back



$$\text{Net Outmigration Rate}_t^n = \text{Net Outmigration}_{t-5\to t}^n / L_{t-5}^n$$

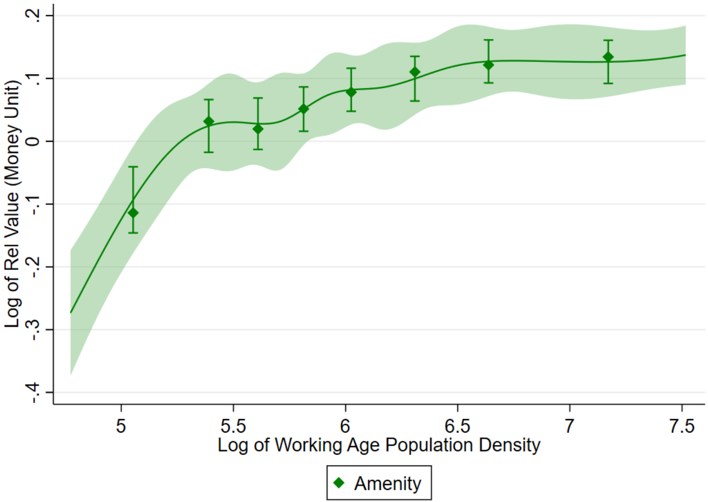
Youths' net out-migration is higher in rural areas

go back



$$\text{Net Outmigration Rate}_t^n(a) = \text{Net Outmigration}_{t-5\to t}^n(a) / L_{t-5}^n(a-5)$$

Youth’s Amenity in 2010 without the Top & Bottom 10%



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Validation of Imputed Housing Cost

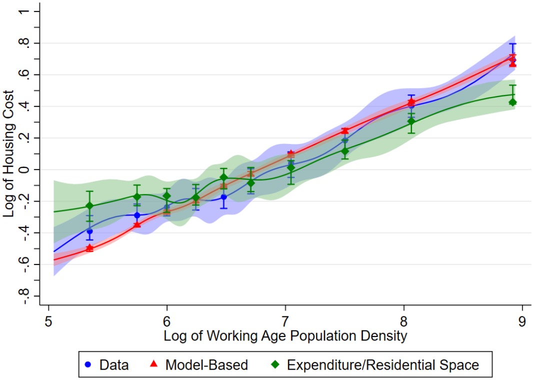


Figure: 1985

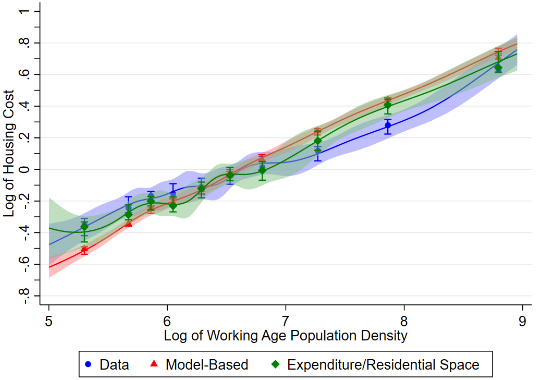


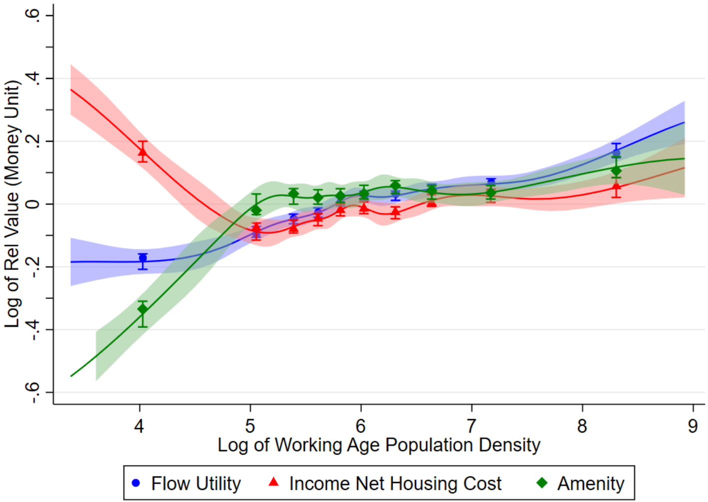
Figure: 2010

go back

Imputed Income vs. Taxable Income Per Capita

go back

Unpacking Age 45-49's Flow Utility in 2010



go back

Association between Amenity and PCAs in 2010

VARIABLES	(1) 2010 20-39 $\ln \text{Amenity}_{nt}(a)$	(2) 2010 40-59 $\ln \text{Amenity}_{nt}(a)$	(3) 2010 60-69 $\ln \text{Amenity}_{nt}(a)$
Retail PCA	0.0993***	0.0345***	0.0150***
	(0.00243)	(0.00211)	(0.00388)
Child Education PCA	0.166***	0.0662***	0.0413***
	(0.00234)	(0.00186)	(0.00335)
Elderly Service PCA	0.124***	0.0449***	0.0240***
	(0.00275)	(0.00213)	(0.00400)
Health Medical PCA	0.0845***	0.0231***	0.00190
	(0.00221)	(0.00185)	(0.00350)
Environment Transport PCA	0.122***	0.0432***	0.0264***
	(0.00285)	(0.00226)	(0.00425)

Each row shows the results of separate regressions
Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

go back

Association between Amenity and PCAs in 1985

VARIABLES	(1) 2010 20-39 $\ln \text{Amenity}_{nt}(a)$	(2) 2010 40-59 $\ln \text{Amenity}_{nt}(a)$	(3) 2010 60-69 $\ln \text{Amenity}_{nt}(a)$
Retail PCA	0.0805***	0.0382***	0.0227***
	(0.00417)	(0.00330)	(0.00609)
Child Education PCA	0.134***	0.0520***	0.0354***
	(0.00223)	(0.00183)	(0.00346)
Elderly Service PCA	0.122***	0.0467***	0.0302***
	(0.00349)	(0.00273)	(0.00516)
Health Medical PCA	0.0810***	0.0290***	0.0201***
	(0.00270)	(0.00218)	(0.00409)

Each row shows the results of separate regressions
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

go back

Push and Pull Migration IV

go back

- Pull IV:

$$\tilde{\mathcal{I}}^d(a) = \sum_{o \neq d} \sum_{s=1990,2000,2010} \tilde{\mu}^{od}_{1980}(a-(2010-s))\mathcal{O}^o_s(a-(2010-s)),$$

  - $\mathcal{O}^o_t(a)$: the observed outflow of age group a in municipality o in t
  - $\tilde{\mu}^{od}_{1980}(a)$: share of out-migrants from o to d from 1980 to 1985

- Push IV:

$$\tilde{\mathcal{O}}^o(a) = \sum_{d \neq d} \sum_{s=1980,1990,2000} \breve{\mu}^{od}_{1980}(a-(2010-s))\mathcal{I}^o_s(a-(2010-s)),$$

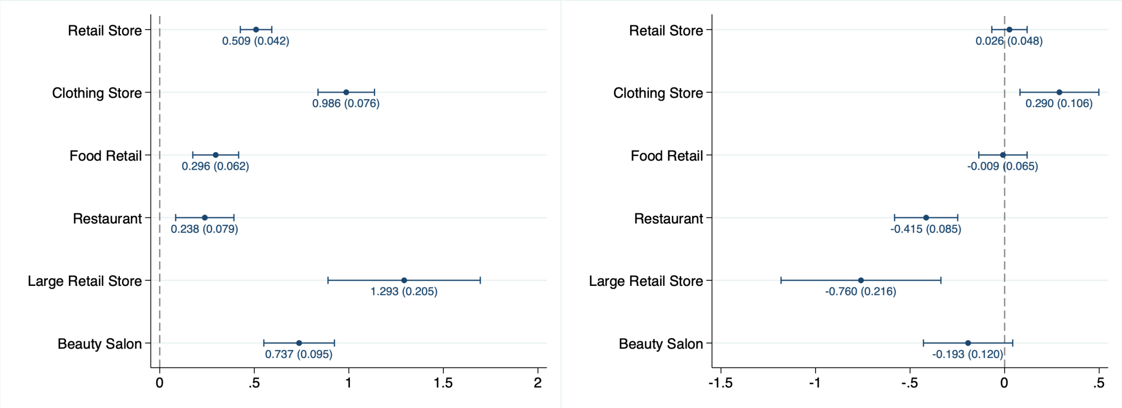
- Use these variables to predict changes in working-age and elderly population size; convert the changes into percentiles

Impacts on Depop & Aging: Retail

go back

(a) Δ log Population

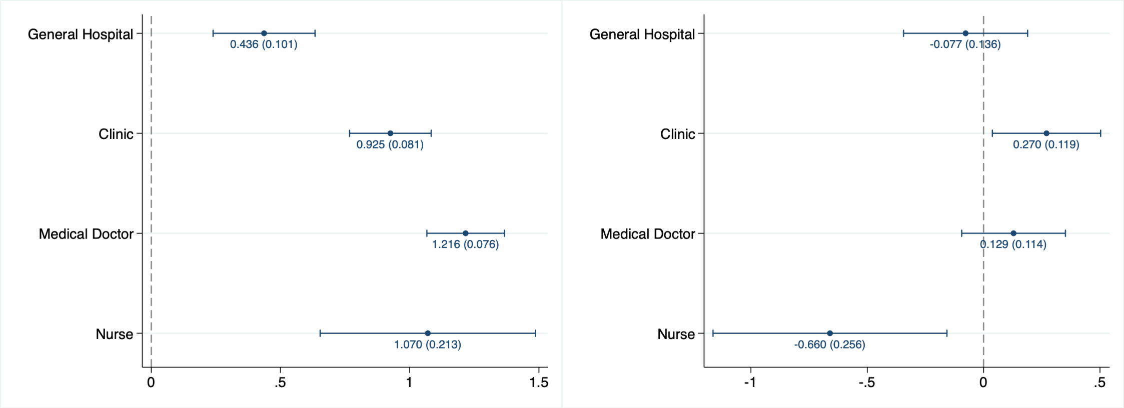
(b) Δ log Fraction on Elderies



Impacts on Depop & Aging: Health/Medical

go back

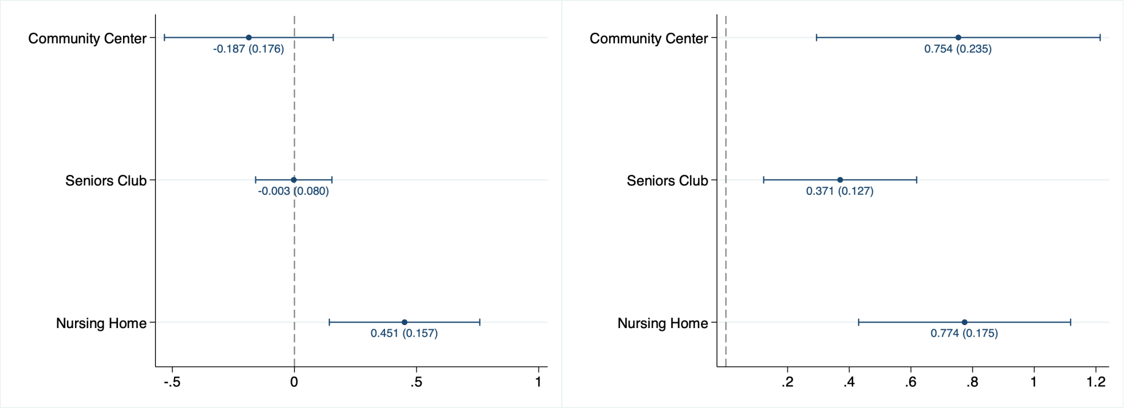
(a) Δ log Population (b) Δ log Fraction on Elderies



Impacts on Depop & Aging: Elderly Services

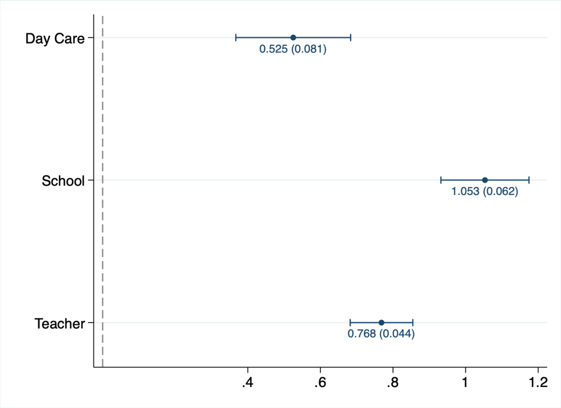
go back

(a) Δ log Population (b) Δ log Fraction on Elderies

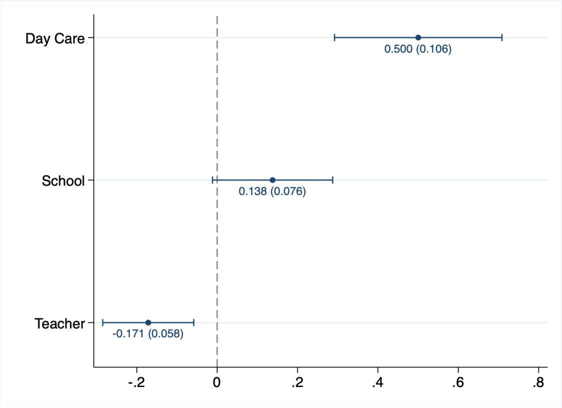


Impacts on Depop & Aging: Child/Education go back

(a) Δ log Population

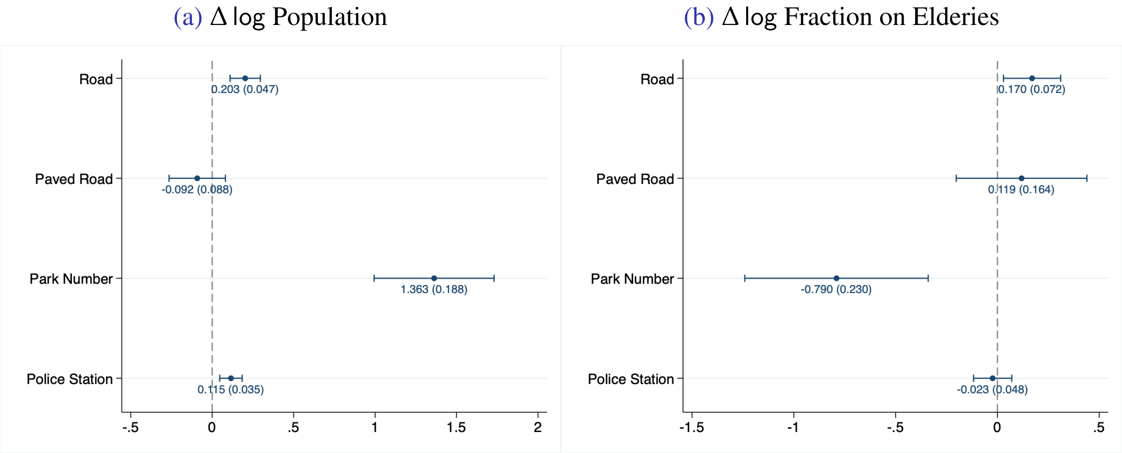


(b) Δ log Fraction on Elderies



Impacts on Depop & Aging: Environment/Transportation

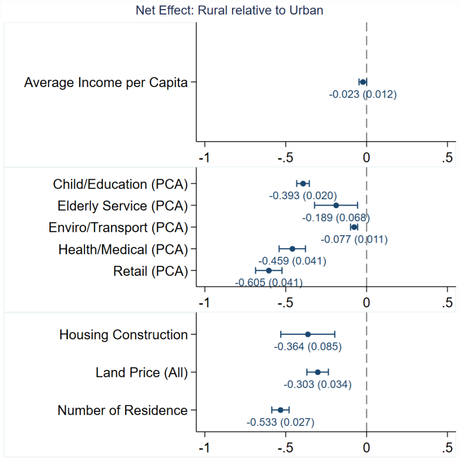
go back



Imputed Net Effects on Rural vs Urban

go back

$$\hat{\beta}_1 \underbrace{\Delta \ln Pop(15 \leq age \leq 64)_n}_{-0.72=-0.59(\text{rural})-0.13(\text{urban})} + \hat{\beta}_2 \underbrace{\Delta \ln Pop(age \geq 65)_n}_{-0.77=0.59(\text{rural})-1.36(\text{urban})}$$



Population Change

- Agents of age a, location n, year t give birth to age 0 agents at fertility rate $\varkappa_t^n(a)$
- Agents of age a dies at an exogenous probability $1 - s_t^n(a)$
- If she survives, advances her age to $a+1$ (stay at $\bar{a}$ if $a = \bar{a}$)

- Population change absent migration

$$L_{t+1}^n(a) = \begin{cases} \sum_{a'} \varkappa_{t+1}^n(a') L_{t+1}^n(a') & \text{if } a = 0 \\ s_t^n(a-1) L_t^n(a-1) & \text{if } 0 < a < \bar{a} \\ s_t^n(\bar{a}-1) L_t^n(\bar{a}-1) + s_t^n(\bar{a}) L_t^n(\bar{a}) & \text{if } a = \bar{a} \end{cases},$$

- Population change with migration

$$L_{t+1}^n(a) = \begin{cases} \sum_{a'} \varkappa_{t+1}^n(a') L_{t+1}^n(a') & \text{if } a = 0 \\ s_t^n(a-1) \sum_{\ell} \mu_t^{\ell n}(a-1) L_t^{\ell}(a-1) & \text{if } 0 < a < \bar{a} \\ s_t^n(\bar{a}-1) \sum_{\ell} \mu_t^{\ell n}(\bar{a}-1) L_t^{\ell}(\bar{a}-1) + s_t^n(\bar{a}) \sum_{\ell} \mu_t^{\ell n}(\bar{a}) L_t^{\ell}(\bar{a}) & \text{if } a = \bar{a} \end{cases}$$

  - Microfoundation for "demographic balancing equation" (e.g., Smith-Tayman-Swanson '13) go back

Income

- Linear production technology

$$Y_t = \sum_a \phi_t^n(a) L_t^n(a)$$

- Income - Working age

$$y_t^n(a) = w_t^n \times \varphi_t^n(a)$$

  - Location-specific wage per efficient unit of labor (endogenously determined)

- Income - Retirees

$$y_t^n(a) = w_t^n \varphi_t^n(a) + T_t, \quad a \geq a^*$$

$$T_t = \frac{\sum_n \sum_{\underline{a} \leq a < a^*} \tau y_t^n(a) L_t^n(a)}{\sum_n \sum_{a \geq a^*} L_t^n(a)}$$

go back

Housing and Amenity

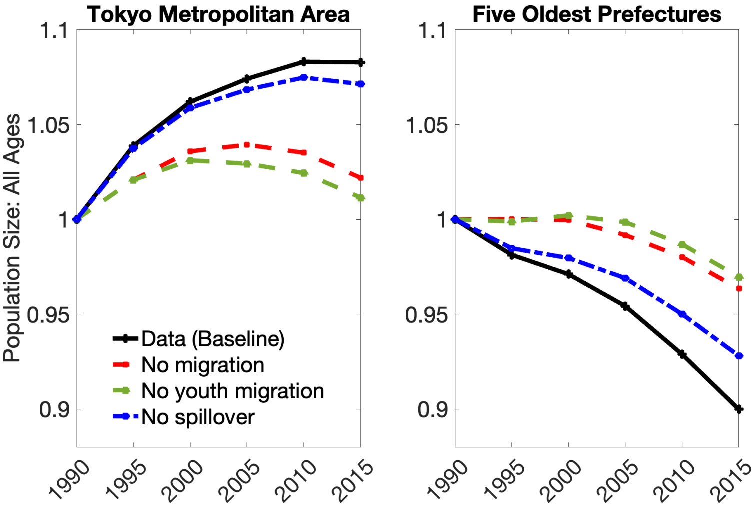
- Housing supply function

$$H_t^n = \tilde{H}_t^n \left(R_t^n\right)^{\mu}$$

  - $\tilde{H}_t^n$: exogenous housing supply shifter
  - Market clearing determines the rents R_t^n

go back

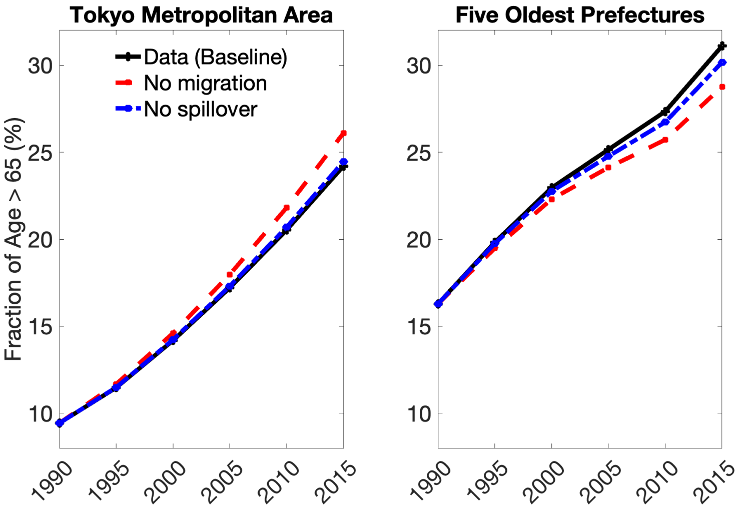
Calibration: Regional Depopulation 1990-2015



Spillover explains an important fraction of migration responses

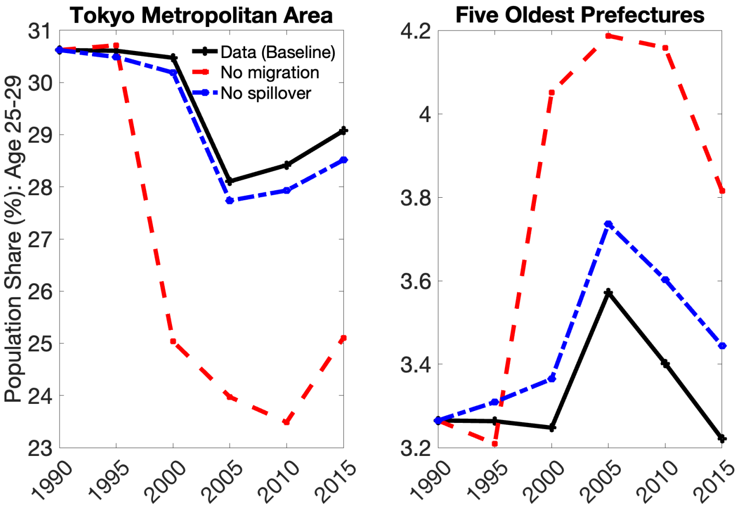
go back

Calibration: Regional Depopulation 1990-2015



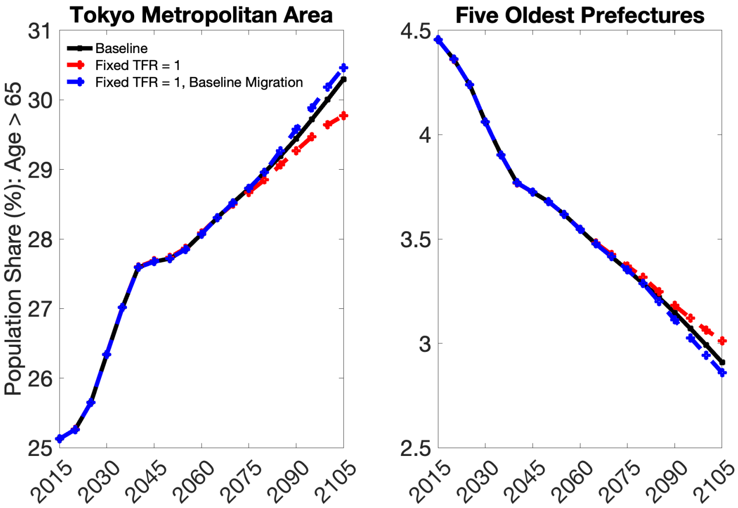
go back

Calibration: Regional Depopulation 1990-2015



go back

Uneven Regional Depopulation: 2015 onwards



go back