A dynamic equilibrium model of commuting, residential and work location choices

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Methodology and applications of dynamic structural models with strategic interactions

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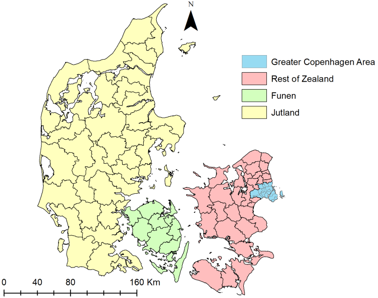
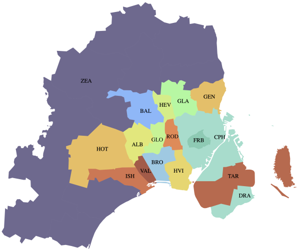
We model commuting, residential and work location choices in Denmark

Figure 1: Definition of regions

(a) Entire Denmark



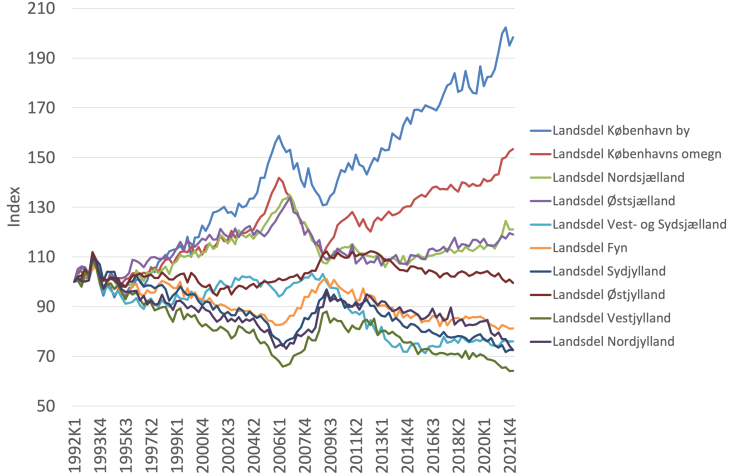
(b) Greater Copenhagen Area



Note: The abbreviations denote the following regions: Copenhagen (CPH), Frederiksberg (FRB), Ballerup (BAL), Broendby (BRO), Dragoer (DRA), Gentofte (GEN), Gladsaxe (GLA), Glostrup (GLO), Herlev (HEV), Albertslund (ALB), Hvidovre (HVI), Hoeje-Taastrup (HOT), Roedovre (ROD), Ishoej (ISH), Taarnby (TAR), Vallensbaek (VAL), rest of Zealand (ZEA). Figure 25b only displays subset of ZEA.

Regional house prices in Denmark

Figure 2: Price index (2021 prices, base: 1992K1) of single-family homes by region



Note: Source: Finans Danmark, Boligmarkedsstatistikken. Prices deflated by 2021 price index of single-family homes and apartments, respectively from Statistics Denmark table EJ5.

Cities are growing and thriving due to agglomeration ... but rural areas are in decline

- Increased spatial concentration of economic activity
  - ...rural areas declining in terms of population, labor demand and house prices
  - ...urban areas experience large increases in traffic congestion and house prices
  - $\rightarrow$ demographic composition at locations change and increased regional inequality

- Policies considered in Denmark
  - Increasing housing supply in urban areas
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- Understanding dynamic equilibrium effects of such spatial policies is crucial .. but challenging

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- Choice of residence, work location, housing demand and commuting...
- ...while allowing life cycle aspects to play a key role
- Sorting of heterogeneous consumers and equilibrium in the housing market

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- Model fits key aspects of data well, incl. regional house price trends

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We simulate effects on house prices, job mobility, residential sorting and commuting in two counterfactual equilibria:

1. [FOCUS TODAY] Extended use of telecommuting for highly skilled (HS) workers
   - HS workers workers move out of city → prices drop in center → LS move there
   - Non-employment drops and HS better off while LS indifferent
2. 10% increase in supply of housing stock in central Copenhagen
   - Actually planned policy of constructing the artificial island Lynetteholm which we have analyzed for the Danish Ministry of Transportation as part of this project

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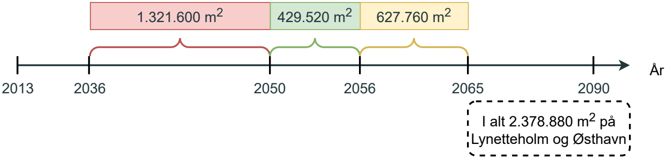
Lynetteholm in the harbour of Copenhagen

- Expanding housing supply in central Copenhagen by 2.4 mio m^2 from 2036-2065
- Large public investment: $>$ 16 bn DKK (2.3 bn USD)

Figure 3: Map of Lynetteholm

Figure 4: Timeline for increased housing stock at Lynetteholm



The Choice Model

Individuals solve the following optimization problem:

$$EV = \max_{\{d_{it}^{rl}, d_{it}^{wl}, h_{it}\}_{t=t_0}^{T}} \sum_{t=t_0}^{T} \rho_t(x_{it})^t \mathbb{E}_t \Big[u_t(x_{it}, wl_{it}, rl_{it}, d_{it}', \mathrm{h}_{it}) \Big]$$

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s_{it}	$\{x_{it}, wl_{it}, rl_{it}\}$

Utility specification

$$u_t(x, d, d^{rl}, d^{wl}, h) =$$

$$\kappa(inc, s)\ \underbrace{\left[inc(s) - \psi_{uc}\, p^h(d^{rl}) \cdot h\right]}_{\text{consumption}} - swcost_r^p(x) + \underbrace{\phi_{h1}(s) h + \phi_{h2} h^2}_{\text{utility housing}}$$

$$+\ \text{ttimecost}(x, d) + \text{amenities}(d^{rl}) + u_r$$

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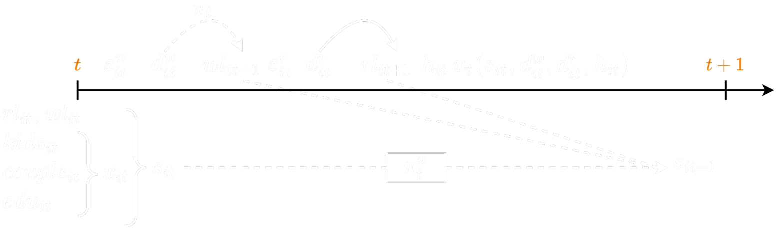
ttimecost	depends on travel-time between d^{rl} and d^{wl} and on year
amenities	depend on regional attributes of residential location, d^{rl}
u_r	utility of retiring for those eligible (≥ 60)

Functional forms

Model structure

Model is based on ▸ Bellman equations whose content is illustrated in the following:

Figure 5: Timeline of decisions and states



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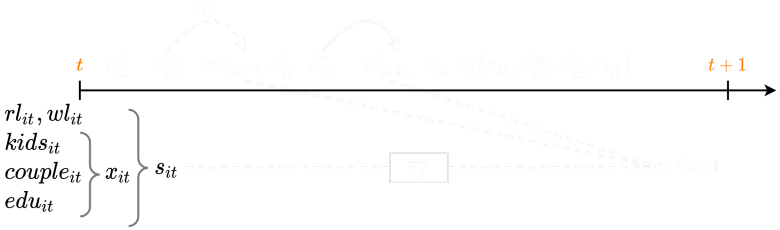

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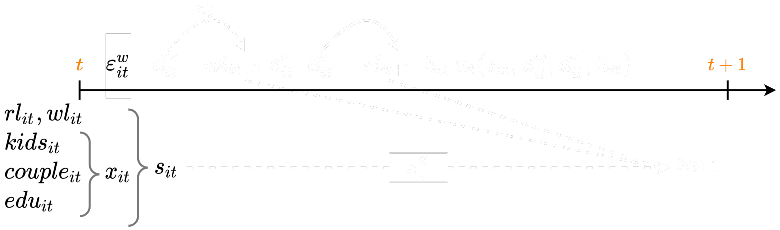

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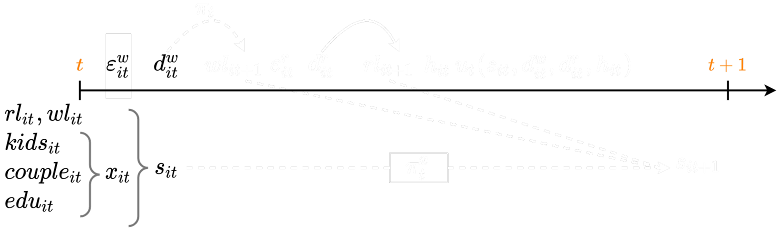

- R regions, $d_{it}^{w} \in R+1$ (voluntary and involuntary unemployment: $\emptyset$)

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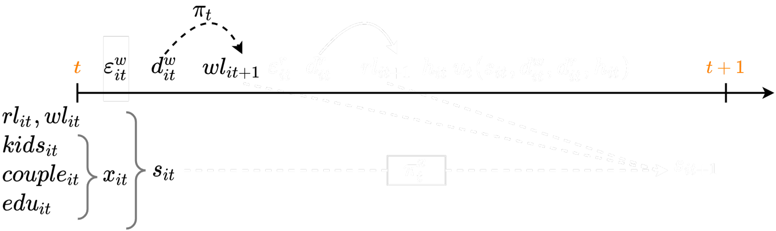

- $\pi_t(d^w_t, wl_t, x_t)$ informs about transition from desired work location to work location outcome ▸ Details

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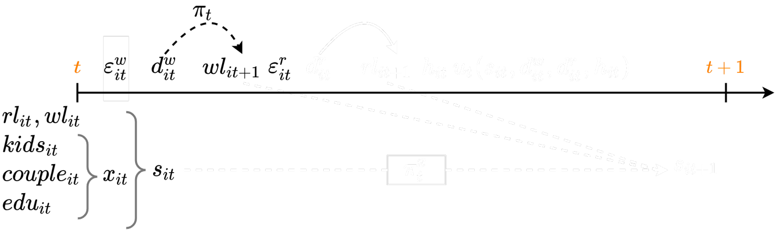

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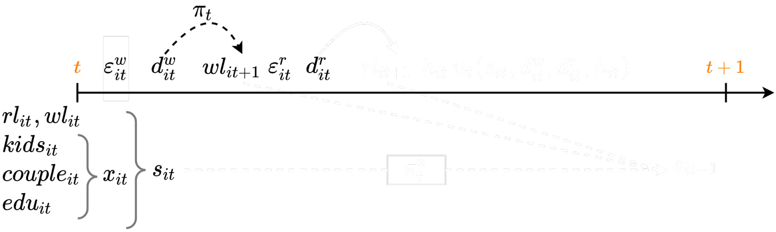

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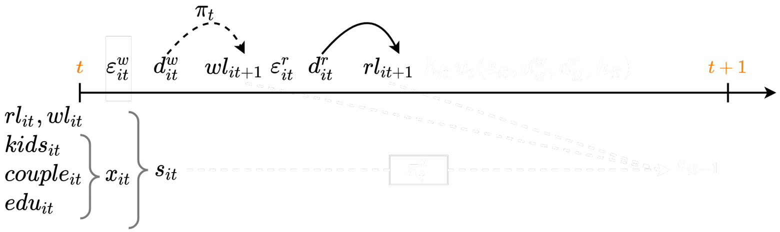

- $d^r_{it} \in R$ and perfect control over residential decision: $d^r_{it} = rl_{it+1}$

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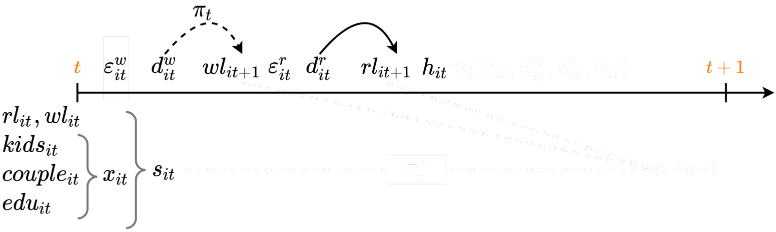

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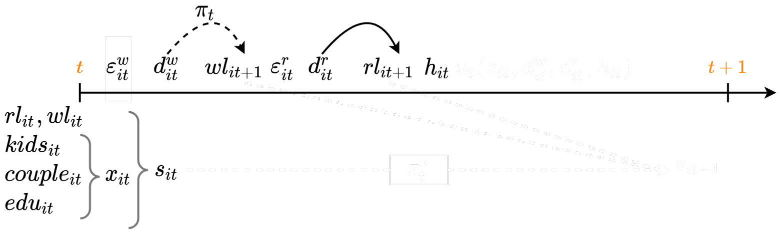

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- $\Rightarrow$ Next period value function $V_{t+1}(x, d, \varepsilon)$ independent of h

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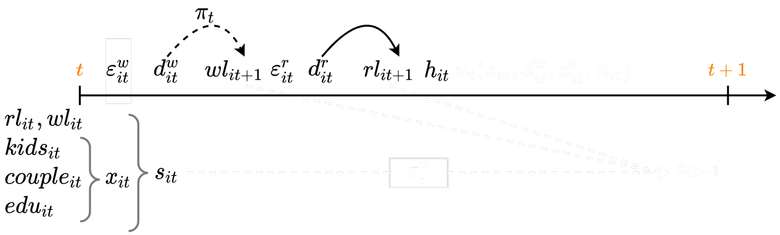

- $\Rightarrow$ Optimal housing demand given by FOC

$$\frac{\partial u_t(\cdot)}{\partial h} = \phi_{h1}(s) + 2\phi_{h2}h - \kappa(s)p^h(d^{rl}) = 0 \quad \Rightarrow$$

$$h^*_t = \frac{\phi_{h1}(s) - \kappa(s)p^h(d^{rl})}{-2\phi_{h2}} \tag{1}$$

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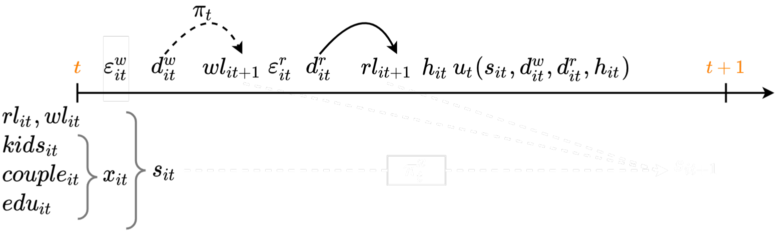

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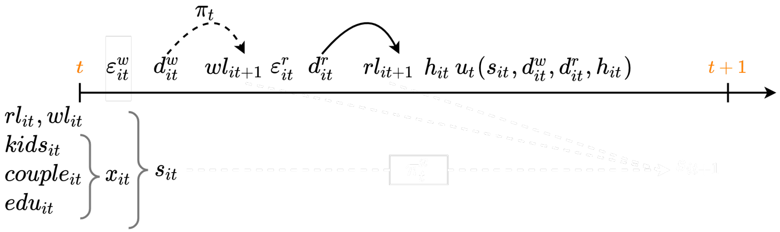

- Substituting expression of optimal housing demand into the utility function defined above, we obtain the *indirect utility function* $u(s_{it}, w_{it+1}, rl_{it+1})$
- Pure discrete choice model conditional on housing demand

Model structure

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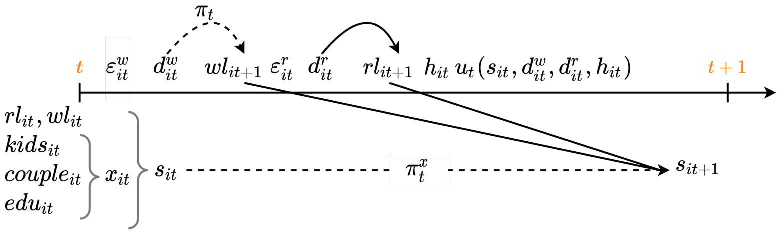

- Location states transition as a deterministic function of decisions

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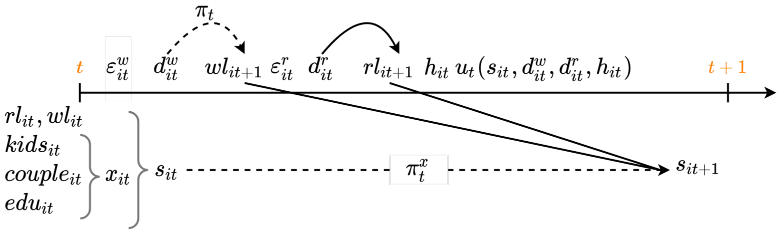

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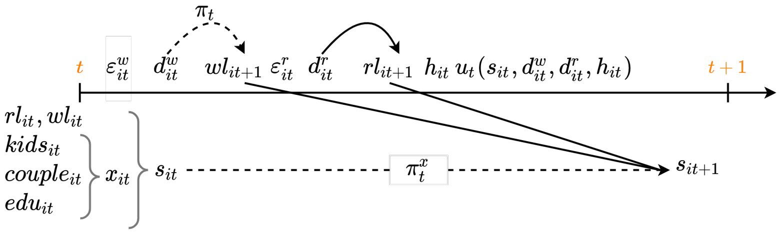

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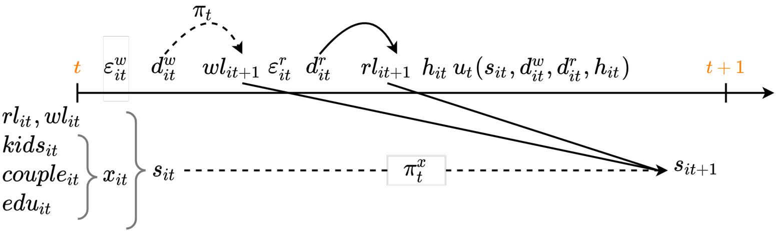

- Location states transition as a deterministic function of decisions
- edu_i is time-constant
- Non-location states:

$$(cs_{it+1}, ms_{it+1}) \sim \mu_{cs,ms}(\cdot|cs_t, ms_t, edu, age_t) \equiv \pi^x(x_t, x_{t+1}) \qquad (2)$$

Estimation strategy

We estimate the model sequentially in three separate steps:

1. Estimate the parameters governing the pre-tax income equations, income tax system, transition probabilities of children and marital status and survival rates

   ▸ Income ▸ Tax ▸ States ▸ Survival

▸ Functional forms

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$$\hat{\theta} = \text{argmax}_{\theta} \frac{1}{N} \sum_{i} \sum_{t} \{ \log P_t^r(rl_{it+1} | wl_{it}, rl_{it}, wl_{it+1}, x_{it}; \theta) + \log \sum_{d^w} P_t^w(d^w | wl_{it}, rl_{it}, x_{it}; \theta) \pi_t(d^w, wl_{it}, x_{it}, wl_{it+1}; \theta) \}, \tag{3}$$

where N is the number of individuals

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On top of this comes an equilibrium solver in the counterfactual simulations

▸ Functional forms

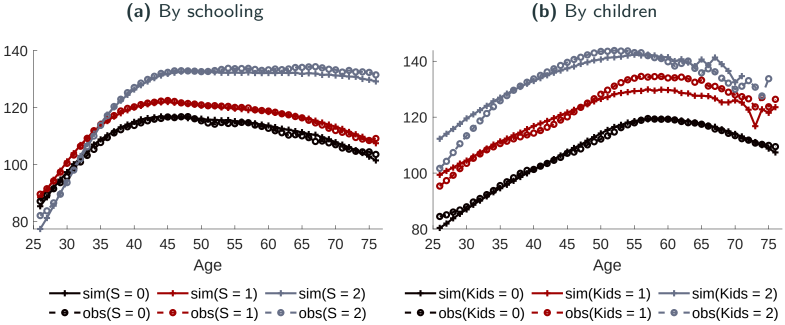
Data sources

We use full population Danish administrative panel data for 2000-2013

- Population register: residential info (98 municiapalities), moving in dates, personal info (SSN, age, spouse, kids)
- Housing register: house characteristics (house id, m^2 of home, whether house or apartment)
- Employee register: employer-employee match (SSN, job industry, employment period, employment location (municipality)
- Income register: annual income of various types (SSN, pre-tax wage income, transfers, pensions, tax payments)
- Education register: educational attainment (SSN, degree level)
- Sales register: population of sold properties (house id, transaction price)
- Property ownership register: population of properties (SSN, takeover date, property id)
- Commute time: travel time and distances between 907 traffic zones of Denmark (2002 and 2010)

Model fit: Housing demand

Figure 6: House size in square meters over the life cycle



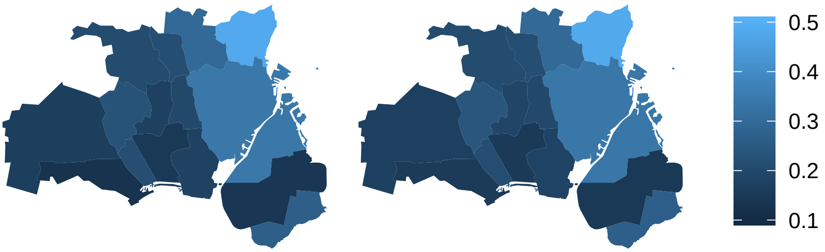
- Clear demographic differences in housing demand over the life cycle
- The reduced form model captures the crucial dependence between household composition and housing demand and difference over the life cycle
- Though some challenges capturing differences in demand at the beginning of the life cycle

Spatial | Marital status | Params housing | Params user costs

Model fit: Spatial educational sorting

Figure 7: Residential sorting by home region

(a) Share highly educated (obs.) **(b)** Share highly educated (sim.)



Residential sorting driven mainly by:

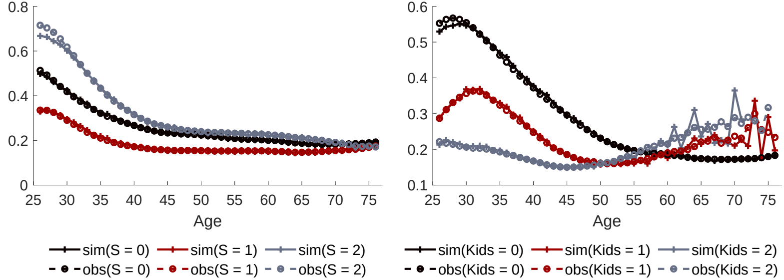
- Regional variation in house prices and regional-specific amenities
- Individual differences in housing demand
- Individual differences in marginal utility of money (main channel of educational sorting)
- Distance to local labor markets

▸ Params cafes ▸ Params amenities FE

Model fit: Sorting over the life cycle

Figure 8: Share living in Copenhagen over the life cycle

(a) By schooling **(b)** By children

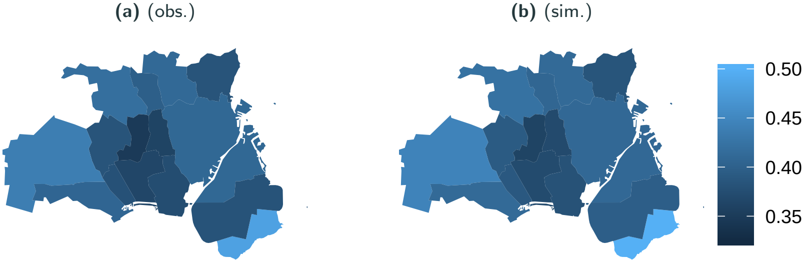


- Slight under-prediction for the youngest cohorts
- Reason: not modelling educational choice. Poorer fit only evident for highly-educated

▸ Marital status ▸ Moving ▸ Params moving costs

Model fit: Commuting across space

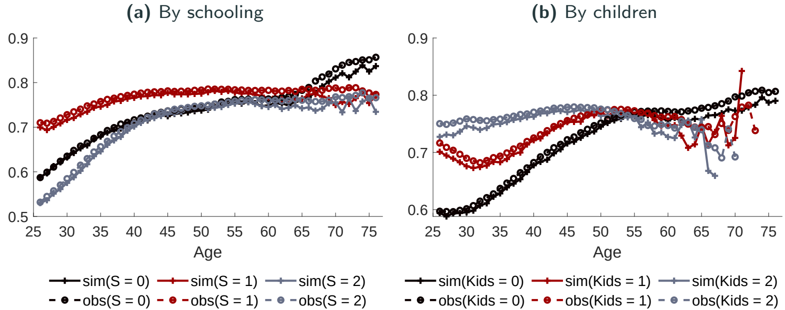
Figure 9: Commute times (hours) by residential location



▸ Work in Cph ▸ Job moves ▸ Params commute costs ▸ Params job finding/dismissal

Model fit: Commute time over the life cycle

Figure 10: Commute time (hours)



- Model captures shorter commute by highly educated as they can afford housing close to dense labor markets
- Above age 60 harder to explain the strong selection among working individuals at that age

Marital status

Equilibrium house prices

To compute the housing market equilibrium, P^h is set to solve

$$\begin{aligned} S_t(1) &= D_t(1, P^h) \\ &\vdots \\ S_t(R) &= D_t(R, P^h) \end{aligned}$$

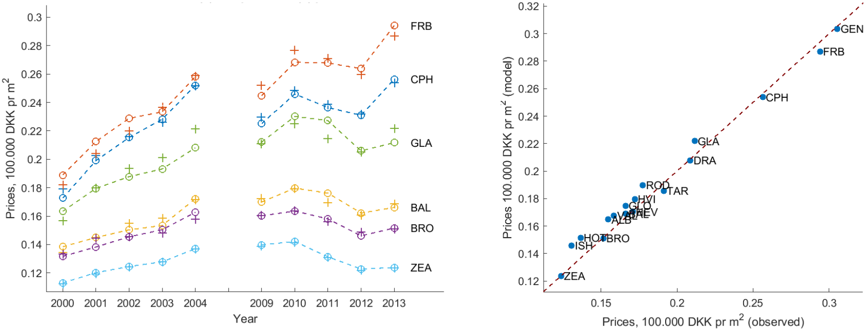
where

- $P^h = (P^h(1), .., P^h(R))$ s the R-dimensional vector of regional square meter prices
- $S_t(rl)$ the micro aggregated exogenously fixed supply of m^2 of housing in region rl
- $D_t(rl, P^h)$ is the micro aggregated demand for available m^2 of housing in region rl
- We solve the R equilibrium equations with R unknowns using Newton's Method.

Empirical vs. model equilibrium prices

Figure 11: Observed and predicted equilibrium house prices per m^2

(a) Selected regions, 2000-2004 and 2009-2013 **(b)** All regions, 2013



Baseline fit

Counterfactual: increased access to telecommuting - effects on locations

Lowering commute time by 50% for highly-educated

Table 1: Counterfactual I: % change of home and work locations by schooling (2013)

	$rl(s_0)$	$wl(s_0)$	$rl(s_1)$	$wl(s_1)$	$rl(s_2)$	$wl(s_2)$
Center of CPH	3.77	0.44	4.52	0.39	-10.79	3.95
West of CPH	3.46	0.05	4.13	0.01	-13.23	-0.41
North of CPH	7.31	-0.06	7.51	-0.05	-9.62	-0.21
East of CPH	2.08	-0.11	4.81	-0.51	-10.40	1.07
RestOfZealand	-3.95	-0.44	-3.09	-0.76	11.69	7.64
Non-employment	-	-0.27	-	-0.20	-	-8.38

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- Easier for highly educated to keep high-paying jobs in city centre while living in attractive suburban areas

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- Easier for highly educated to keep high-paying jobs in city centre while living in attractive suburban areas
- Lower-income households better chance to reside closer to dense labor markets
- All regions more mixed on sociodemographics

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- Highly-educated more likely to work in Cph and RoZ as they only have to commute half of the week
- Main part of extra workers in RoZ come from reduction in non-employment
- Less educated only slight increase in tendency to work in more urbanized areas

Counterfactual: increased access to telecommuting - effects on prices

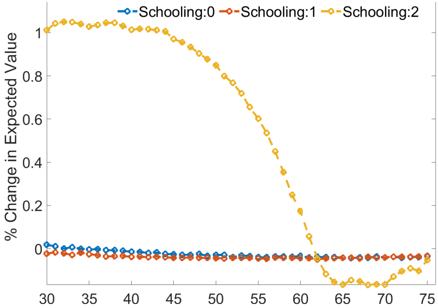
Table 2: Counterfactual I: % change in equilibrium prices 2009-2013

	2009	2010	2011	2012	2013
Center of CPH	-0.53	-1.01	-1.35	-1.64	-1.95
West of CPH	-0.36	-0.64	-0.93	-1.15	-1.60
North of CPH	-0.57	-1.08	-1.46	-1.58	-1.75
East of CPH	-0.06	-0.10	-0.79	-1.04	-1.66
RestOfZealand	0.79	1.55	2.08	2.45	3.03

- Dynamic model $\rightarrow$ Gradual changes in prices
- Lower demand for living in Cph for highly-educated $\rightarrow$ prices fall by 0.53% immediately
- Over time prices lower by 1.6-2.0% in the GCA while higher by 3.0% in RoZ
- $\rightarrow$ affordable for lower-income hhs to live in GCA

Counterfactual: increased access to telecommuting - welfare effects

Figure 12: Simulated change in welfare (%)



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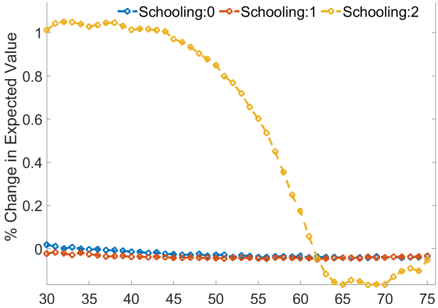

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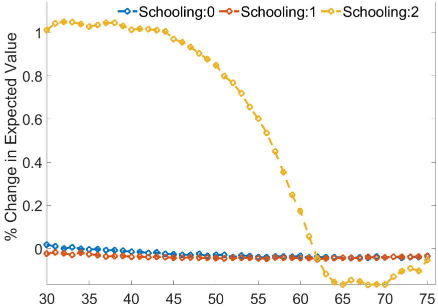

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- As they age, their marginal utility of money declines $\rightarrow$ welfare effects drop to 0 around retirement
- At retirement-eligible age: most not working $\rightarrow$ no benefit of telecommuting but facing increased house prices in their popular regions
- ≈ 0 welfare effect for less educated: gain from lower commute times, but only by paying higher house prices

Concluding remarks on counterfactual simulation

Reduction in commute time for highly educated

- Highly educated move out of the city to peripheral regions $\rightarrow$ consume larger homes at a reduced price
- $\rightarrow$ freed up space in the center $\rightarrow$ lower educated people could afford living closer by their jobs in the new equilibrium
- Reducing commute times allows locations to become more specialized in either jobs or residence
- Welfare gains positive in total, but unequally distributed across household types with higher educated being better off and lower educated indifferent

STOP!!!

The residential choice

Let EV^r be the *ex ante* expected value of residence r,
... but conditional on the employment location outcome wl'
... and before learning about the residential location shocks $\epsilon^r(d^r)$.

EV^r is given by the usual log-sum formula

$$EV^r(wl, rl, wl', x) =$$
$$\sigma_r \log\left(\sum_{d^r} \exp\{[u(wl, rl, wl', d^r, x) + \beta EV(wl', d^r, x)]/\sigma_r\}\right).$$

Residence location choice probabilities are given by logit formulas

$$P^r(d^r|wl, rl, wl', x) = \frac{\exp\{[u(wl, rl, wl', d^r, x) + \beta EV(wl', d^r, x)]/\sigma_r\}}{\sum_{d^r} \exp\{[u(wl, rl, wl', d^r, x) + \beta EV(wl', d^r, x)]/\sigma_r\}}.$$

◂ Timeline

The work location choice

- Let $EV^w(wl, rl, x)$ be the *ex ante* expected value of location (wl, rl)
  ...before learning about the work location shocks $\epsilon^w(d^w)$
  ...and the outcome of the job search process

$$EV^w(wl_t, rl_t, x) = \sigma_w \log \left(\sum_{d^w} \exp\left\{ v^w(wl, rl, x, d^w)/\sigma_w \right\} \right).$$

- $v^w(wl, rl, x, d^w)$ is the expected choice-specific value corresponding to the particular choice of job location d^w.

$$v^w(wl, rl, x, d^w) = \sum_{wl} \pi(d^w, wl, x, wl') EV^r(wl, rl, wl', x).$$

- $\pi(d^w, wl, x, wl')$ governs how job search location d^w translates into the realized one wl'

- The work location *choice* probabilities are given by logit formulas

$$P^w(d^w | wl, rl, x) = \frac{\exp\{v^w(wl, rl, x, d^w)/\sigma_w\}}{\sum_{d^w} \exp\{v^w(wl, rl, x, d^w)/\sigma_w\}}.$$

◂ Timeline

Job finding and dismissal probabilities

- $\pi_t^n(d_t^w, wl_t, x_t)$, $d_t^w \neq wl_t$: probability of finding a new job in the region d_t^w given household characteristics x_t

Timeline

Job finding and dismissal probabilities

- $\pi_t^n(d_t^w, wl_t, x_t)$, $d_t^w \neq wl_t$: probability of finding a new job in the region d_t^w given household characteristics x_t
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- If searching for a new job in a different region ($d_t^w \neq wl_t$):

$$wl_{t+1} = \begin{cases} d_t^w & \text{with probability } \pi_t^n(d_t^w, wl_t, x_t), \\ wl_t & \text{with probability } (1 - \pi_t^n(d_t^w, wl_t, x_t))\pi_t^k(wl_t, x_t), \\ \emptyset & \text{with probability } (1 - \pi_t^n(d_t^w, wl_t, x_t))(1 - \pi_t^k(wl_t, x_t)). \end{cases} \tag{4}$$

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- If hoping to keep existing job, $d_t^w = wl_t$: $\pi_t^n(d_t^w, wl_t, x_t) = 0$

$$wl_{t+1} = \begin{cases} wl_t & \text{with probability } \pi_t^k(wl_t, x_t), \\ \emptyset & \text{with probability } 1 - \pi_t^k(wl_t, x_t). \end{cases} \tag{5}$$

Timeline

Job finding and dismissal probabilities

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- If $d_t^w = wl_t$: $\pi_t^n(wl_t, wl_t, x_t) \equiv \pi_t^k(wl_t, x_t)$ is the probability of keeping the existing job in location wl_t
- If searching for a new job in a different region ($d_t^w \neq wl_t$):

$$wl_{t+1} = \begin{cases} d_t^w & \text{with probability } \pi_t^n(d_t^w, wl_t, x_t), \\ wl_t & \text{with probability } (1-\pi_t^n(d_t^w, wl_t, x_t))\pi_t^k(wl_t, x_t), \\ \emptyset & \text{with probability } (1-\pi_t^n(d_t^w, wl_t, x_t))(1-\pi_t^k(wl_t, x_t)). \end{cases} \tag{4}$$

- If hoping to keep existing job, $d_t^w = wl_t$: $\pi_t^n(d_t^w, wl_t, x_t) = 0$

$$wl_{t+1} = \begin{cases} wl_t & \text{with probability } \pi_t^k(wl_t, x_t), \\ \emptyset & \text{with probability } 1-\pi_t^k(wl_t, x_t). \end{cases} \tag{5}$$

- For currently unemployed individuals, $\pi_t^k(\emptyset, x_t) = 1$:

$$wl_{t+1} = \begin{cases} d_t^w & \text{with probability } \pi_t^n(d_t^w, \emptyset, x_t), \\ \emptyset & \text{with probability } 1-\pi_t^n(d_t^w, \emptyset, x_t). \end{cases} \tag{6}$$

Timeline

Job finding and dismissal probabilities

- $\pi_t^n(d_t^w, wl_t, x_t)$, $d_t^w \neq wl_t$: probability of finding a new job in the region d_t^w given household characteristics x_t
- If $d_t^w = wl_t$: $\pi_t^n(wl_t, wl_t, x_t) \equiv \pi_t^k(wl_t, x_t)$ is the probability of keeping the existing job in location wl_t
- If searching for a new job in a different region ($d_t^w \neq wl_t$):

$$wl_{t+1} = \begin{cases} d_t^w & \text{with probability} \;\; \pi_t^n(d_t^w, wl_t, x_t), \\ wl_t & \text{with probability} \;\; (1 - \pi_t^n(d_t^w, wl_t, x_t))\pi_t^k(wl_t, x_t), \\ \emptyset & \text{with probability} \;\; (1 - \pi_t^n(d_t^w, wl_t, x_t))(1 - \pi_t^k(wl_t, x_t)). \end{cases} \tag{4}$$

- If hoping to keep existing job, $d_t^w = wl_t$: $\pi_t^n(d_t^w, wl_t, x_t) = 0$

$$wl_{t+1} = \begin{cases} wl_t & \text{with probability} \;\; \pi_t^k(wl_t, x_t), \\ \emptyset & \text{with probability} \;\; 1 - \pi_t^k(wl_t, x_t). \end{cases} \tag{5}$$

- For currently unemployed individuals, $\pi_t^k(\emptyset, x_t) = 1$:

$$wl_{t+1} = \begin{cases} d_t^w & \text{with probability} \;\; \pi_t^n(d_t^w, \emptyset, x_t), \\ \emptyset & \text{with probability} \;\; 1 - \pi_t^n(d_t^w, \emptyset, x_t). \end{cases} \tag{6}$$

- If voluntary unemployed, $d_t^w = \emptyset$,: $\pi_t^n(\emptyset, wl_t, x_t) = 1$

Timeline

Utility function

Parsimonious utility function:

$$u = u_m + u_r + u_h + \underbrace{amenities - swcost_r^p - ttimecost}_{u_o} \tag{7}$$

- u_m: *monetary utility* (disposable income net of housing expenditures)
- u_r: utility of retirement for the eligible individuals ($t \geq 60$)
- u_h: *housing utility* obtained from the utilization of a chosen home size
- *amenities*: *regional-specific* attractiveness of housing options
- $swcost_r^p$: *psychological costs* of changing the location of residence
- *ttimecost*: *cost of commuting* between the chosen locations of work and residence

◂ Econometrics ◂ Utility

Housing demand

Quadratic utility of housing

$$u_m + u_h = \kappa(inc_t)(inc_t - hcost_t) + \Phi(x_t)h_{t+1} + \frac{1}{2}\phi_{h2}\, h_{t+1}^2,$$

where $\phi_{h2} < 0$ (diminishing returns to house size)

Marginal utility of money depends on income, year and x

$$\kappa(inc_t) = \kappa_0 + \sum_{\tilde{y}=1}^{Y} \kappa_{year,\tilde{y}} \mathbb{1}_{\{year=\tilde{y}\}} + \kappa_y\, inc_t + \kappa_{ms}\, ms_t +$$

$$+ \sum_{k=1}^{2} \kappa_{c,k} \mathbb{1}_{\{cs_t=k\}} + \kappa_a\, age_t + \sum_{j=1}^{2} [(\kappa_{s,j} + \kappa_{as,j}\, age_t)\mathbb{1}_{\{edu_t=j\}}]$$

Housing demand

$\Phi(x_t)$ allows for heterogeneity in marginal utility of housing

$$\Phi(x_t) = \phi_0 + \sum_{y=1}^{Y} \phi_{year,y} \mathbb{1}_{\{year=y\}} + \phi_a age_t + \phi_{a2} age_t^2 + \phi_{ms} ms_t$$

$$+ \sum_{k=1}^{2} \phi_{c,k} \mathbb{1}_{\{cs_t=k\}} + \sum_{j=1}^{2} \phi_{s,j} \mathbb{1}_{\{edu_t=j\}} + \sum_{rl=1}^{R} \phi_{rl} \mathbb{1}_{\{rl_{t+1}=rl\}}.$$

Housing costs are given by

$$hcost_t(rl_{t+1}, h_{t+1}) = \psi_{uc} p^h(rl_{t+1}) h_{t+1},$$

Implied housing demand (linear regression).

$$h_{t+1} = \frac{\kappa(inc_t) p^h(rl_{t+1}) \psi_{uc} - \Phi(x_t)}{\phi_{h2}}.$$

◂ Econometrics ◂ Utility

Regional amenities

Amenities of regions come as a bundle of attributes that each contributes to the experienced utility of a region.

$$
\begin{aligned}
amenities(rl_{t+1}) =& \left(\alpha_0^{cafe} + \alpha_a^{cafe} age_t + \sum_{k=1}^{2} \alpha_{c,k}^{cafe} \mathbb{1}_{\{cs_t = k\}}\right) cafes_{rl_{t+1}} \\
& + \sum_{rl=1}^{R} \boldsymbol{\alpha}_{rl} \mathbb{1}_{\{rl_{t+1} = rl\}}
\end{aligned}
$$

- We can include a rich set of amenities almost without any additional computational cost associated with solving the model.
- This may require more parameters as number of amenities increases, but the number of parameters in the chosen specification is independent of the number of regions

◂ Econometrics ◂ Utility

Job arrival and dismissal

Probability of getting a new job

$$\pi_t^n(d^w, wl, x) = \Bigg[1 + exp\bigg(- \Big(\beta_0^{\pi(n)} + \beta_a^{\pi(n)} age + \beta_{ø}^{\pi(n)} 1_{wl=ø} + \beta_{jobdens}^{\pi(n)} jobdens(d^w) + \sum_{k=1}^{2} (\beta_s^{\pi(n)}(k) 1_{edu=k})\Big)\bigg)\Bigg]^{-1}, \tag{8}$$

Probability of keeping current job

$$\pi^k(wl, x) = \Bigg[1 + exp\bigg(- \Big(\beta_0^{\pi(k)} + \beta_a^{\pi(k)} age + \sum_{k=1}^{2} (\beta_s^{\pi(k)}(k)\{1_{edu=k})\Big)\bigg)\Bigg]^{-1}. \tag{9}$$

◂ Econometrics ◂ Utility

Utility cost of moving, $swcost_r^p(x_t)$

The utility cost of moving residence

$$swcost_r^p(x_t) = \mathbb{1}_{\{rl_t \neq rl_{t+1}\}}[\gamma_0 + \gamma_a age_t + \sum_{k=1}^{2} \gamma_{c,k} \mathbb{1}_{\{cs_t = k\}} + \gamma_{ms} ms_t + \sum_{j=1}^{2} \gamma_{s,j} \mathbb{1}_{\{edu_t = j\}}]$$

◂ Econometrics ◂ Utility

Travel time costs

The commuting cost between d^{rl} and d^{wl}

$$ttimecost = (\eta_0 + \sum_{y=1}^{Y} \eta_{year,y} \mathbb{1}_{\{year=y\}}) f^{tt}(rl_{t+1}, wl_{t+1})$$

where

- The $f^{tt}(\cdot)$ function denotes the shortest travel-time by any means of transportation between locations.
- Commute cost are zero when unemployed

Commute cost are assumed to be a function of

- Travel time between the two destinations.
- Year (allowing disutility of commuting to change over time)

◂ Econometrics ◂ Utility

Pre-tax income equations

Conditional on working, we specify the income process for an individual as a function of her states at age t, realized work location and calendar year, *year* according to

$$
\begin{aligned}
y = & \beta_0 + \beta_1 \cdot t + \beta_2 \cdot t^2 + \beta_3 \cdot t^3 + \beta_4 \cdot t^4 \\
& + \sum_{rw \in R} \beta_{rw} \cdot \mathbb{I}[wl_{t+1} = rw] + \beta_{\emptyset,rw} \mathbb{I}[wl_t = \emptyset] \cdot \mathbb{I}[wl_{t+1} = rw] \\
& + \sum_{yr \in \{[1993;s2013] \setminus \{2011\}\}} \beta_{yr} \cdot \mathbb{I}[year = yr],
\end{aligned} \tag{10}
$$

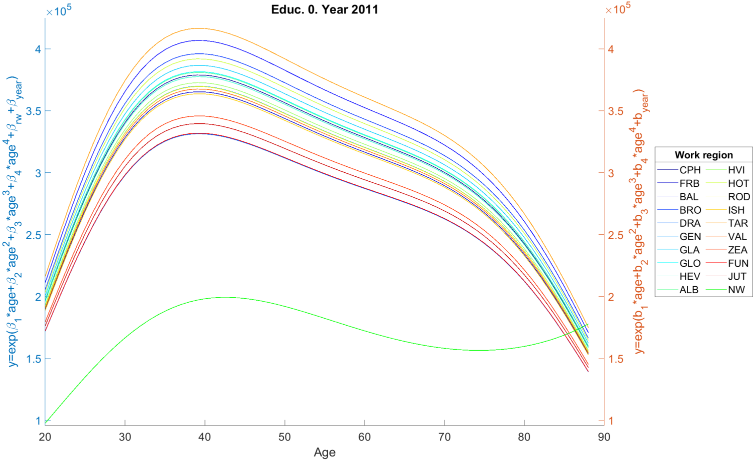
For non-working individuals, we have estimated a corresponding specification by level of schooling:

$$
\begin{aligned}
y^{nw} = & b_0 + b_1 \cdot t + b_2 \cdot t^2 + b_3 \cdot t^3 + b_4 \cdot t^4 \\
& + \sum_{yr \in \{[1993;2013] \setminus \{2011\}\}} b_{yr} \cdot \mathbb{I}[year = yr].
\end{aligned} \tag{11}
$$

◂ Estimation

Predicted income: low schooling

Figure 13: Total income prediction for low level of schooling (2011 real DKK)

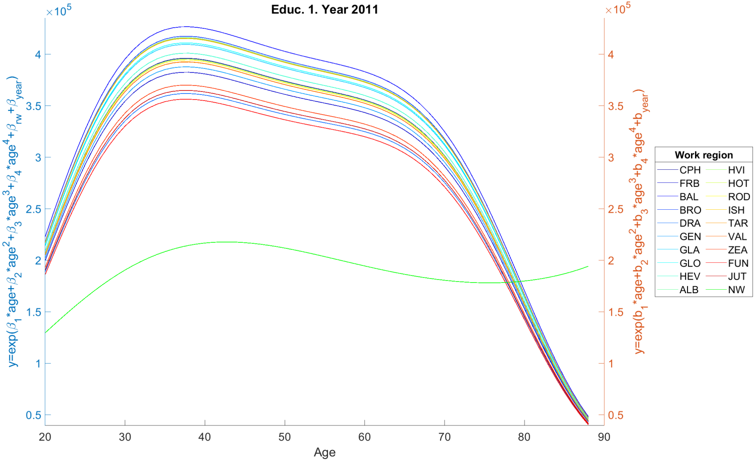


Note: Non-work income (NW) illustrated on right axis.

◂ Estimation

Predicted income: medium schooling

Figure 14: Total income prediction for medium level of schooling (2011 real DKK)

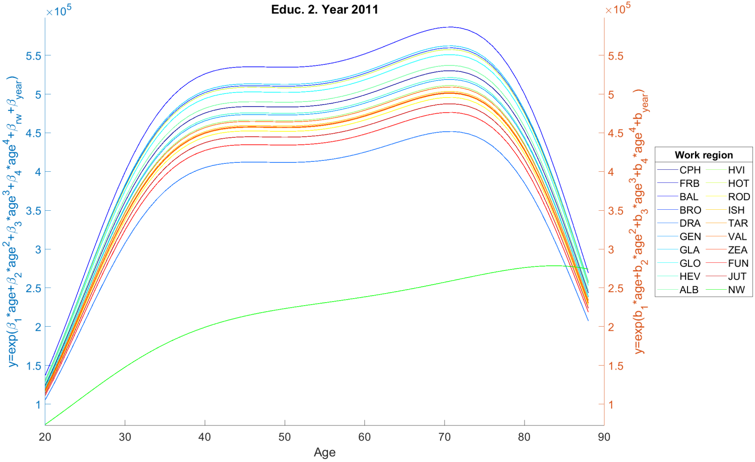


Note: Non-work income (NW) illustrated on right axis.

Estimation

Predicted income: high schooling

Figure 15: Total income prediction for high level of schooling (2011 real DKK)



Note: Non-work income (NW) illustrated on right axis.

◂ Estimation

Income tax equations

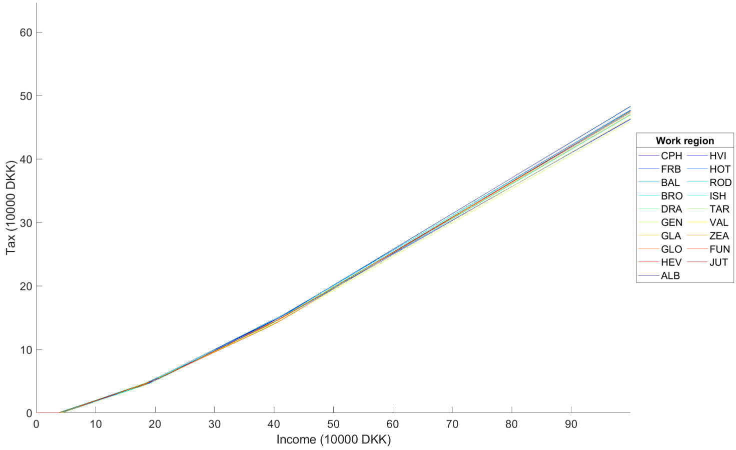
We use OLS to estimate a tax system with income thresholds and tax rates.

$$tax = \begin{cases} 0 & \text{if } y < thr_1 \\ rt_1 \cdot (y - thr_1) & \text{if } thr_1 \geq y < thr_2 \\ rt_1 \cdot (y - thr_1) + rt_2 \cdot (y - thr_1 - thr_2) & \text{if } thr_2 \geq y < thr_3 \\ rt_1 \cdot (y - thr_1) + rt_2 \cdot (y - thr_1 - thr_2) + rt_3 \cdot (y - thr_1 - thr_2 - thr_3) & \text{if } thr_3 \geq y. \end{cases} \tag{12}$$

◂ Estimation

Tax predictions

Figure 16: Tax schedule by home region



Estimation

State transitions: children and marital status

- We use a straightforward multinomial extension of the local logit model for binary choice developed in Frölich, 2006 to model the simultaneous transition of (cs_t, ms_t) conditional on current number of children, marital status and level of schooling
- Estimate the parameters for each group of states $s_t = (cs_t, ms_t, edu_t)$ and allow the simultaneous transition probability to be a function of $x = (x_0, x_1)$, which is a 2×1 vector with a constant and age
- Transitions for cs_t are indexed by tr_k and can take values in $\{-1, 0, 1\}$

◂ Estimation

State transitions: children and marital status

We obtain the parameter estimates for each possible transition (tr_k, tr_m) conditional on x by maximizing the local likelihood function as

$$\hat{\mu}_{cs,ms}(x) =$$

$$\arg\max_{\mu_{cs,ms}(x)} \sum_{i=1}^{N} \sum_{tr_k \in \{-1,0,1\}} \sum_{tr_m \in \{-1,0,1\}} \mathbb{I}[Tr_i = (tr_k, tr_m)] \log(P_{tr}(X_i' \mu_{cs,ms}(x))\mathbb{K}_H(X_i, x), \tag{13}$$

where N is the number of individuals in state s, Tr_i is the $N \times 1$ vector of a set of transition indices, X_i the $N \times 2$ matrix of covariates, and P_{tr} the conditional probability of transition (tr_k, tr_m) as a function of $X_i' \mu_{cs,ms}(x)$, which is specified as

$$P_{tr} = \frac{\exp(X_i' \mu_{cs,ms}(x))}{\sum_{tr_k \in \{-1,0,1\}} \sum_{tr_m \in \{-1,0,1\}} \exp(X_i' \mu_{cs,ms}(x))} \tag{14}$$

$\mathbb{K}_H(X_i, x)$ is the product of k Gaussian Kernel functions for (x_0, x_1) for a vector of bandwidths $H = (h_1, h_2)'$. We use Silverman's rule to compute the global bandwidth, but use the idea outlined in Jennen-Steinmetz and Gasser, 1988 to transform this into a local bandwidth by use of a local smoothing parameter $\eta = 0.5$

◂ Estimation

Survival rates

For survival rates, we use a local logit with adaptive bandwidth $\eta = 0.5$ for the $0/1$ outcome of survival.

We estimate each life cycle profile of survival probabilities by couple and schooling states.

◂ Estimation

Reduced form housing demand

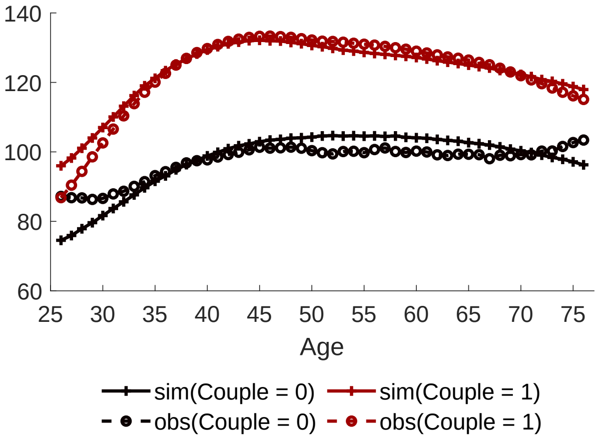
- Optimal choice of the housing size characterized by the first order condition and is a static sub-problem independent of the dynamic location choices
- Using the pooled micro data we estimate the following demand for housing equation by OLS

$$\begin{aligned} h_{it+1} = \tilde{\phi}_0 + \sum_{y=1}^{Y} \tilde{\phi}_{year,y} \mathbb{1}_{\{year=y\}} + \tilde{\phi}_a age_t + \tilde{\phi}_{a2} age_t^2 + \tilde{\phi}_{ms} ms_t + \sum_{k=1}^{2} \tilde{\phi}_{c,k} \mathbb{1}_{\{cs_t=k\}} \\ + \sum_{j=1}^{2} \tilde{\phi}_{s,j} \mathbb{1}_{\{edu_t=j\}} + \sum_{rl=1}^{R} \tilde{\phi}_{rl} \mathbb{1}_{\{rl_{t+1}=rl\}} + \tilde{\kappa}_y [inc_t \cdot \psi_{uc} P(rl_{it+1})] \\ - \Bigg(\tilde{\kappa}_0 + \sum_{y=1}^{Y} \tilde{\kappa}_{year,y} \mathbb{1}_{\{year=y\}} + \tilde{\kappa}_{ms} ms_t + \sum_{k=1}^{2} \tilde{\kappa}_{c,k} \mathbb{1}_{\{cs_t=k\}} + \tilde{\kappa}_a age_t \\ + \sum_{j=1}^{2} [(\tilde{\kappa}_{s,j} + \tilde{\kappa}_{as,j} age_t) \mathbb{1}_{\{edu_t=j\}}] \Bigg) \psi_{uc} P(rl_{it+1}) + \varrho_{it}, \quad (15) \end{aligned}$$

where ϱ_{it} is a random error. $\tilde{\phi}$ and $\tilde{\kappa}$ in the *reduced-form demand equation* are proportional to the structural parameters that index marginal utility of money $\kappa(\cdot)$ and heterogeneous housing utility parameters in $\Phi(\cdot)$. The respective scale factors $-1/\phi_{h2} > 0$ and $-\psi_{uc}/\phi_{h2} > 0$ are identified together with the remaining structural

Model fit: Housing demand by marital status

Figure 17: House size in square meters over the life cycle



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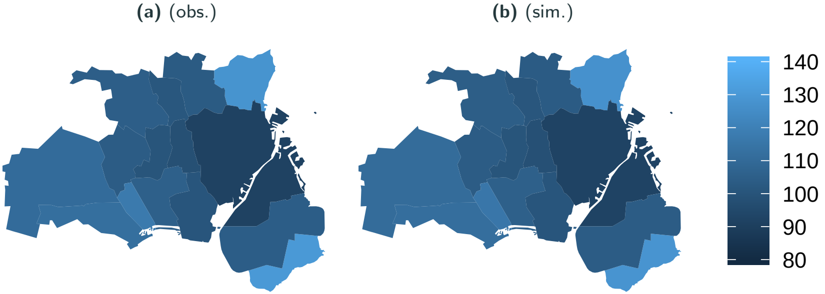
Model fit: Housing demand by region

Figure 18: House size by home region



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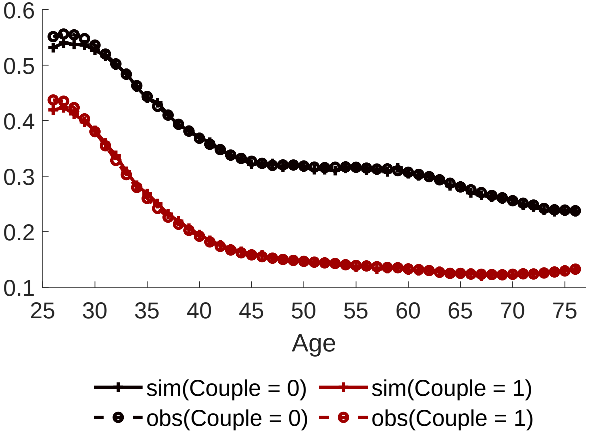
Model fit: Share living in Copenhagen by marital status

Figure 19: Share living in Copenhagen over the life cycle by marital status



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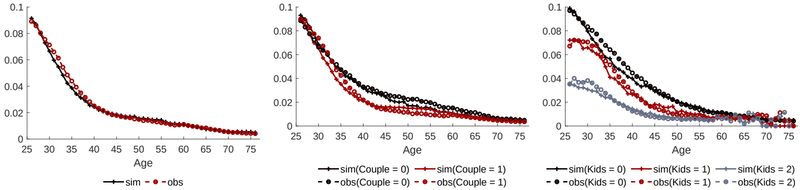
Model fit: Moving propensity

Figure 20: Share moving residential location over the life cycle

(a) Overall **(b)** By marital status **(c)** By children



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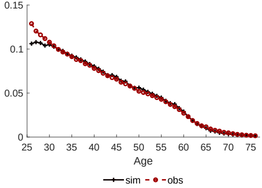
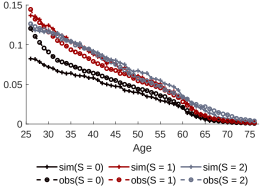
Model fit: Sorting on workplace over the life cycle

Figure 21: Job moves

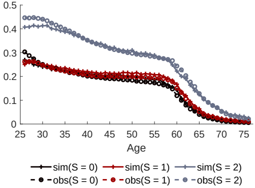
(a) Move job



(b) Move job by schooling



(c) Working in CPH by schooling



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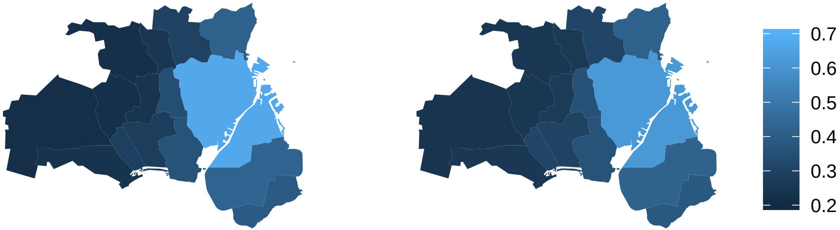
Model fit: Working in Cph by home location

Figure 22: Work in Copenhagen by residential location

(a) (obs.) **(b)** (sim.)



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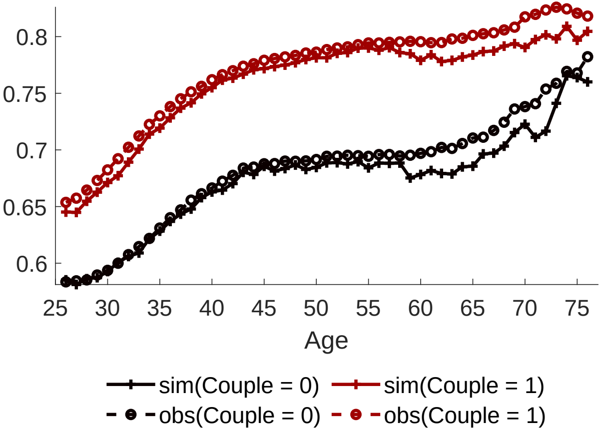
Model fit: Commuting by marital status

Figure 23: Commute time (hours) by marital status



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Model parameters: Housing demand

Table 3: First Stage Parameter Estimates, Reduced form Housing Demand

	Coeff. Estimates	Standard Error	Z-statistic
Const., $\tilde{\phi}_0$	70.2740	0.16419	428.0
Married, $\tilde{\phi}_{ms}$	27.8578	0.03868	720.2
Children, $\tilde{\phi}_c$ (1)	5.7386	0.05149	111.4
Children, $\tilde{\phi}_c$ (2)	14.6098	0.04911	297.5
Age, $\tilde{\phi}_a$	2.1723	0.00348	624.8
$\text{Age}^2/1000$, $\tilde{\phi}_{a2}$	-19.1718	0.03074	-623.6
Price pr. sqm, $\tilde{\kappa}_0$	-296.2954	0.91043	-325.4
Price pr. sqm $\times$ Income, $\tilde{\kappa}_y$	20.2790	0.07002	289.6
Price pr. sqm $\times$ Age, $\tilde{\kappa}_a$	0.0209	0.00853	2.4
Price pr. sqm $\times$ Age x Schooling, $\tilde{\kappa}_{a,s}$ (1)	1.0073	0.00476	211.5
Price pr. sqm $\times$ Age x Schooling, $\tilde{\kappa}_{a,s}$ (2)	2.9563	0.00529	558.4
Price pr. sqm $\times$ Schooling, $\tilde{\kappa}_s$ (1)	-51.7247	0.24317	-212.7
Price pr. sqm $\times$ Schooling, $\tilde{\kappa}_s$ (2)	-95.3167	0.25080	-380.1
Price pr. sqm $\times$ Children, $\tilde{\kappa}_c$ (1)	0.4389	0.29673	1.5
Price pr. sqm $\times$ Children, $\tilde{\kappa}_c$ (2)	13.4067	0.28757	46.6
Price pr. sqm $\times$ Married, $\tilde{\kappa}_{ms}$	-63.4794	0.22117	-287.0

Dependent variable: House size in square meters

Other controls: Regional dummies, $\tilde{\phi}_{rl}$ and time effects $\tilde{\phi}_{year}$ and $\tilde{\kappa}_{year}$

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Model parameters: User costs of housing demand curvature

Table 4: User Cost of Housing and Curvature Parameter of Housing Demand

	Coeff. Estimates	Standard Error	Z-statistic
Coef. on h^2, $\phi_{h2} \times 1000$	-0.0465	0.00036	-127.4
Baseline user cost of housing, ψ_0	0.0239	0.00024	99.9
Time effect, ψ_{2001}	-0.0052	0.00015	-34.9
Time effect, ψ_{2002}	-0.0045	0.00016	-28.8
Time effect, ψ_{2003}	-0.0063	0.00015	-41.0
Time effect, ψ_{2004}	-0.0090	0.00016	-57.3
Time effect, ψ_{2009}	-0.0035	0.00015	-23.6
Time effect, ψ_{2010}	-0.0076	0.00015	-50.2
Time effect, ψ_{2011}	-0.0089	0.00015	-57.7
Time effect, ψ_{2012}	-0.0088	0.00015	-57.1
Time effect, ψ_{2014}	-0.0110	0.00016	-67.4

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Model parameters: Amenities (time-varying)

Table 5: Taste Variation in Regional Amenities

	Coeff. Estimates	Standard Error	Z-statistic
Taste for cafes and bars, α^{cafe}			
Constant, α_0^{cafe}	0.0118	0.00005	257.9
Age, α_a^{cafe}	-0.0002	0.00000	-257.5
Children, α_c^{cafe} (1)	-0.0047	0.00005	-97.8
Children, α_c^{cafe} (2)	-0.0074	0.00003	-254.4

Other controls: Regional dummies, $\alpha_{rl_{t+1}}$, shown in online appendix.

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Model parameters: Amenities (fixed effects)

Table 6: Time-Constant Regional Amenities

	Coeff. Estimates	Standard Error	Z-statistic
α_{rl} (1)	-0.0976	0.00045	-219.3
α_{rl} (2)	-0.0827	0.00095	-87.0
α_{rl} (3)	-0.1244	0.00107	-115.8
α_{rl} (4)	-0.2733	0.00207	-131.9
α_{rl} (5)	-0.1956	0.00126	-155.7
α_{rl} (6)	-0.0721	0.00081	-89.4
α_{rl} (7)	-0.1329	0.00127	-104.5
α_{rl} (8)	-0.1086	0.00116	-93.6
α_{rl} (9)	-0.1246	0.00121	-102.7
α_{rl} (10)	-0.0713	0.00088	-81.5
α_{rl} (11)	-0.1310	0.00101	-129.9
α_{rl} (12)	-0.0801	0.00094	-85.3
α_{rl} (13)	-0.1888	0.00139	-135.9
α_{rl} (14)	-0.1037	0.00099	-104.6
α_{rl} (15)	-0.2247	0.00163	-137.8
α_{rl} (16)	-0.0274	0.00127	-21.6

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Model parameters: Moving costs

Table 7: Utility Cost of Moving Residence

	Coeff. Estimates	Standard Error	Z-statistic
Const., γ_0	1.8750	0.00521	360.0
Age, γ_a	0.0579	0.00012	495.1
Children, γ_c (1)	0.4934	0.00382	129.2
Children, γ_c (2)	1.1926	0.00450	265.0
Married, γ_{ms}	-0.0368	0.00291	-12.6
Schooling, γ_s (1)	0.0163	0.00309	5.3
Schooling, γ_s (2)	-0.1803	0.00317	-56.9

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Model parameters: Commuting

Table 8: Commute Cost

	Coeff. Estimates	Standard Error	Z-statistic
Cost of travel time, η_0	0.1789	0.00149	120.3
Time effect, η_{2001} (1)	-0.0014	0.00174	-0.8
Time effect, η_{2002} (2)	-0.0081	0.00178	-4.5
Time effect, η_{2003} (3)	-0.0210	0.00184	-11.4
Time effect, η_{2004} (4)	-0.0451	0.00181	-24.9
Time effect, η_{2009} (5)	0.0406	0.00191	21.2
Time effect, η_{2010} (6)	0.0323	0.00190	17.0
Time effect, η_{2011} (7)	0.0450	0.00194	23.2
Time effect, η_{2012} (8)	0.0484	0.00195	24.8
Time effect, η_{2013} (9)	0.0202	0.00197	10.2

Back

Model parameters: Job arrival and dismissal

Table 9: Job Arrival and Dismissal

	Coeff. Estimates	Standard Error	Z-statistic
Probability of keeping job: $\pi_t^k(wl_t, x_t; \beta^k)$			
Const., $\beta_0^{\pi(keep)}$	0.3066	0.01085	28.3
Age, $\beta_a^{\pi(keep)}$	0.0558	0.00030	186.7
Schooling, $\beta_s^{\pi(keep)}$ (1)	0.9288	0.00536	173.4
Schooling, $\beta_s^{\pi(keep)}$ (2)	1.0818	0.00575	188.0
Probability of new job: $\pi_t^n(d_t^w, wl_t, x_t : \beta^n)$			
Const., $\beta_0^{\pi(new)}$	-1.0998	0.00466	-235.9
Age, $\beta_a^{\pi(new)}$	-0.0431	0.00010	-415.9
Schooling, $\beta_s^{\pi(new)}$ (1)	0.1980	0.00253	78.3
Schooling, $\beta_s^{\pi(new)}$ (2)	0.2264	0.00278	81.5
Job density $\beta_{jobdensity}^{\pi(new)}$	0.2608	0.00045	583.9
Prev. unempl., $\beta_{unemp}^{\pi(new)}$	1.0474	0.00236	443.9

Back

Model parameters: Baseline fit

Table 10: Baseline fit: Change in home and work locations (share by schooling) and equilibrium prices (100,000 DKK)

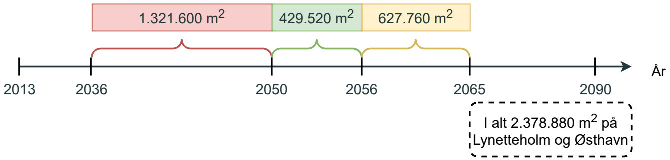
(data - baseline)	$rl(s_0)$	$rl(s_1)$	$rl(s_2)$	$wl(s_0)$	$wl(s_1)$	$wl(s_2)$	P^{eq}
Center of CPH	0.000	0.006	-0.048	0.003	0.033	-0.009	-0.023
West of CPH	-0.005	-0.003	0.012	0.119	0.120	0.111	0.010
North of CPH	-0.004	0.000	0.006	0.019	0.019	0.007	0.000
East of CPH	0.001	-0.001	0.003	0.024	0.025	0.024	0.004
RestOfZealand	0.008	-0.002	0.027	-0.142	-0.222	-0.170	0.012
Unemployment	-	-	-	-0.024	0.024	0.037	-

◂ Back

Artificial island Lynetteholm

Expanding housing supply in central Copenhagen by 2.4 mio m^2 from 2036-2065
Large public investment: $>$ 16 bn DKK (2.3 bn USD) ▸ Map ▸ m^2 over time

Figure 24: Timeline for increased housing stock at Lynetteholm



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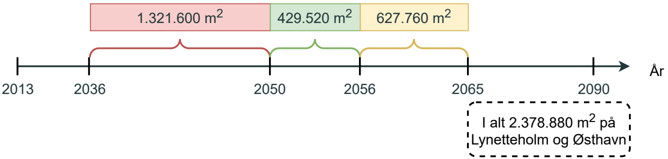

Evaluating effects in 2 counterfactual baseline cases:

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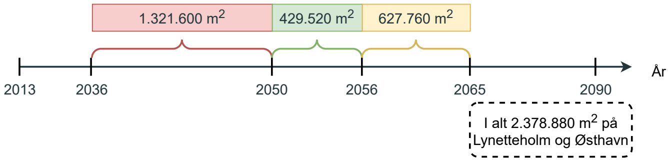

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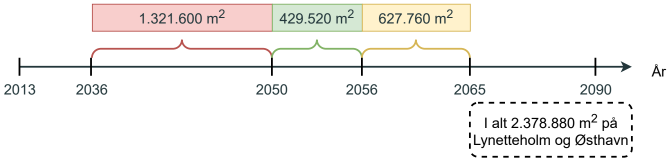

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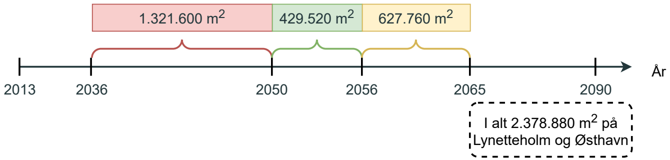

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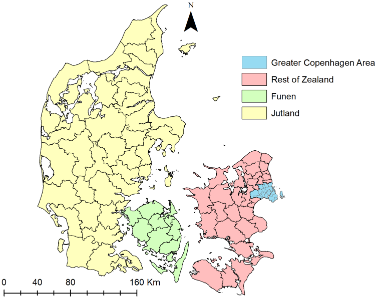
NB: may build in areas with high space constraints $\rightarrow$ baselines "too generous" wrt m^2 in high-density areas $\rightarrow$ conservative estimates of welfare gains in Case II

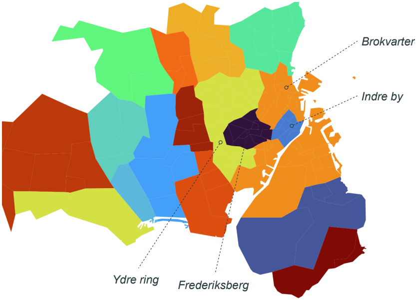
Regional definition

Figure 25: Definition of regions

(a) Entire Denmark



(b) Greater Copenhagen Area



Assumptions for out-of-sample simulations

1. Age-dependent pop growth: deaths and 26 y/o "newborns" acc. DST pop forecasts ▸ details

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4. Amenities kept at 2013 level

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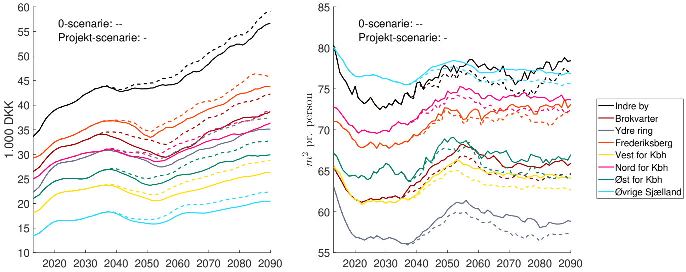
4. Amenities kept at 2013 level
5. Income growth: 0.9% p.a.

Case I: Effects on prices and m^2 demand

Figure 26: Price/m^2 (2021 prices) and m^2/person over time

(a) Price per m^2 **(b)** m^2 per person



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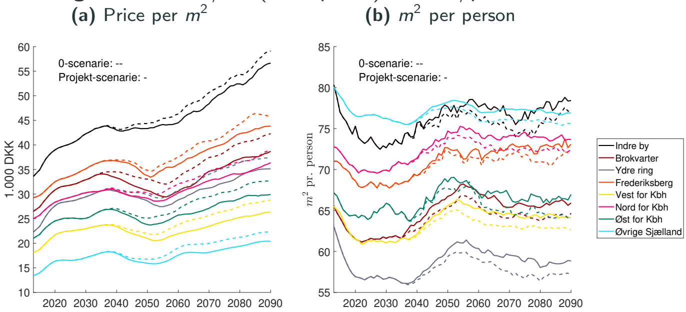

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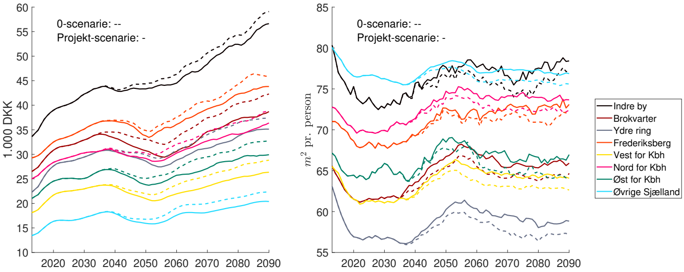

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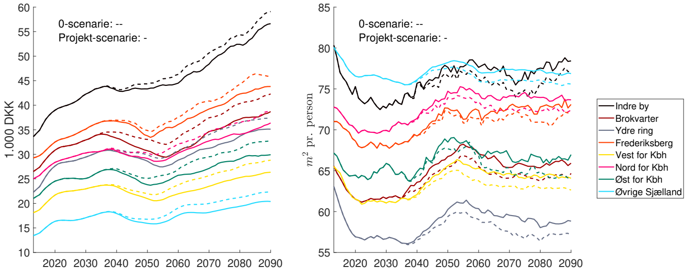

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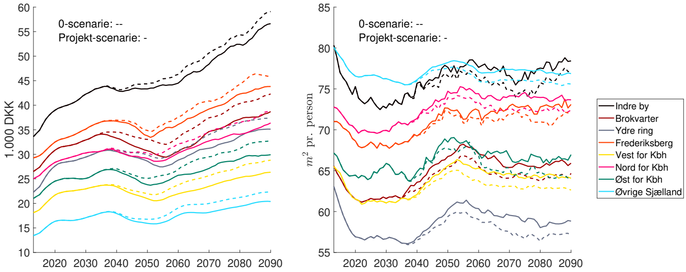

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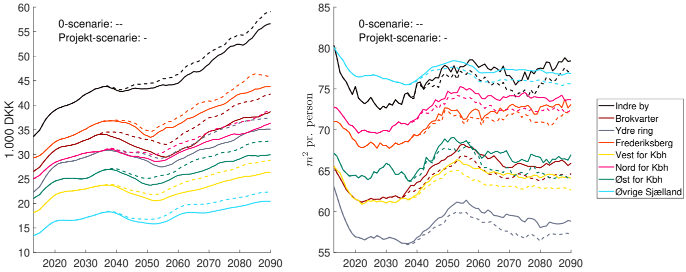

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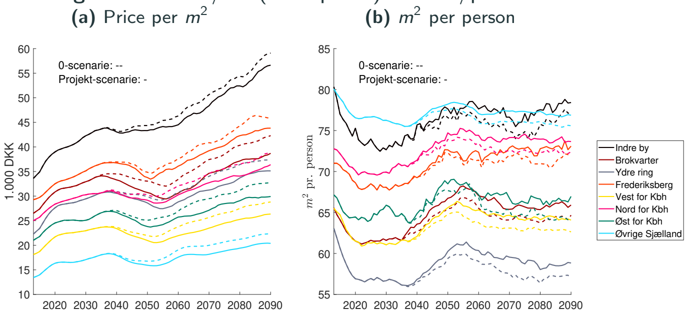

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- Indre By: $\uparrow$ share of young adults w. preference for city amenities
- Cph overall: $\uparrow$ concentration of jobs

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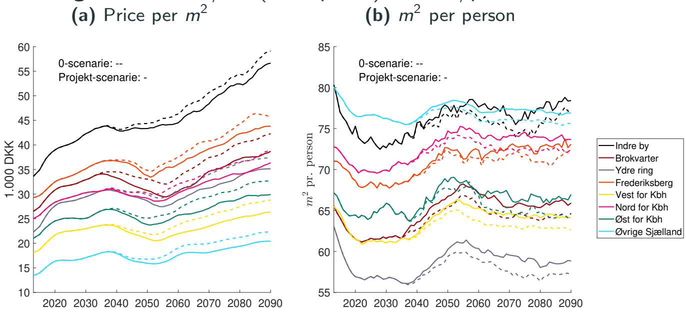

Counterfactual:

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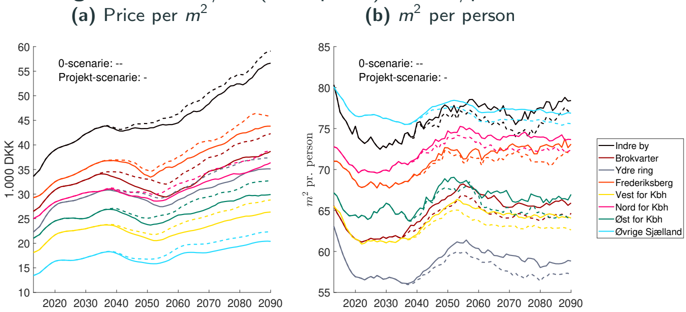

Counterfactual:

- Demographic composition, supply of jobs and unemployment rates similar to baseline

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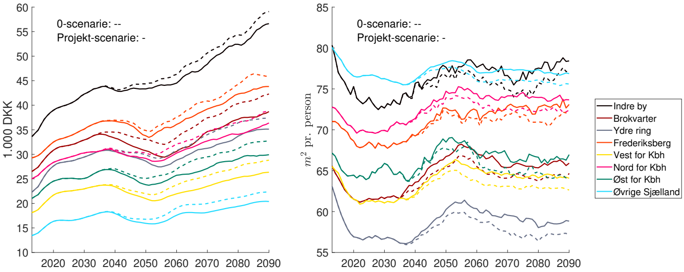

Counterfactual:

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- $\rightarrow$ increased supply $\Rightarrow$ prices drop

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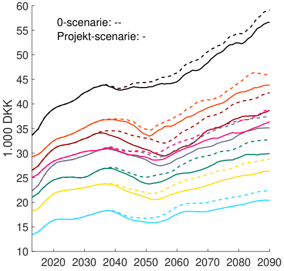

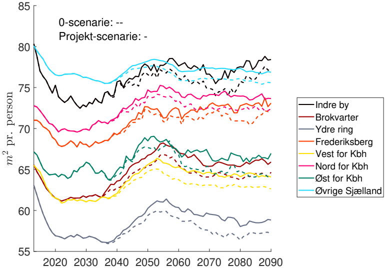

Counterfactual:

- Demographic composition, supply of jobs and unemployment rates similar to baseline
- $\rightarrow$ increased supply $\Rightarrow$ prices drop
- Price drop 2070: Brokvarterer (7.5%), Indre by (4.5%), Ydre ring (8.2%), remaining GCA (4.0 - 8.4%), rest of Zealand (9.1%)

Case I: Effects on residential locations

Table 11: Distribution of home locations in 2070

	Baseline shares (%)			CF minus base (#)			Δ pp in shares		
Schooling	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
Indre by	21,4	15,4	63,2	−147	−183	−213	−0,13	−0,42	0,55
Brokvarter	22,3	21,6	56,1	7.455	8.244	12.411	´0,52	0,94	−1,46
Ydre ring	30,5	28,8	40,7	−993	−888	−2.040	0,18	0,22	−0,40
Frederiksberg	18,3	18,8	63,0	−150	−24	−606	−0,01	0,20	−0,19
Vest for Kbh	33,5	36,1	30,4	−1.851	−2.043	−1.350	−0,04	−0,07	0,12
Nord for Kbh	23,3	23,9	52,9	−1.269	−1.017	−129	−0,65	−0,41	1,06
Øst for Kbh	29,2	34,9	36,0	−177	36	−777	0,22	0,86	−1,07
Øvrige Sjælland	28,7	44,0	27,3	−2.484	−6.222	−5.583	0,19	0,01	−0,20

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- Net increase in Brokvarter: 28.000 (26-76 y/o). Composition unchanged.

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- Movers *to* Brokvarterer in counterfactual come from: Ydre ring (57.5%), Frederiksberg (9.5%), RoZ (7.4%) in baseline

Case I: Effects on residential locations

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- Movers *to* Brokvarterer in counterfactual come from: Ydre ring (57.5%), Frederiksberg (9.5%), RoZ (7.4%) in baseline
- Highly- and low-skilled individuals more likely to move (11.6% and 11.1% move prob vs 9.0% for med-skilled)
- They have higher job density in center of Cph than med-skilled. Low-skilled: 2.5% involuntary unemployment ⇒ high utility of residing close to dense labor market

Case I: Effects on work locations

Table 12: Distribution of work locations in 2070

	Baseline shares (%)			CF minus base (#)			Δ pp in shares		
Schooling	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
Indre by	24,1	29,4	46,5	1.308	1.572	2.913	−0,08	−0,12	0,20
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Vest for Kbh	27,8	43,8	28,4	−1.755	−4.260	−2.184	0,17	−0,22	0,05
Nord for Kbh	25,5	38,3	36,2	−1.026	−1.509	−1.596	0,02	0,06	−0,08
Øst for Kbh	34,1	41,1	24,8	−126	−594	456	−0,07	−0,91	0,97
Øvrige Sjælland	28,3	46,3	25,4	−228	−576	−87	0,08	−0,53	0,45
Non-employment	28,6	32,0	39,3	612	1.620	1.548	−0,07	0,06	0,01

Case I: Effects on work locations

Table 12: Distribution of work locations in 2070

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- Non-employment ↑ ∼ 3.800 pers. (0.23 pp ↑ in share)
  - Not due to more involuntary unemployment: closer by dense labor market
  - Wealth effect: lower house prices → easier to afford housing on unemployment benefits → increased demand for leisure (no intensive margin adjustments)
  - Wealth effect lower for LS workers due to lower savings

Case I: Effects on welfare

Welfare gain in DKK, W: CV in terms of experienced utilities

$$W = \Gamma \sum_{t=2025}^{2090} \delta(t) \sum_{i \in \mathcal{N}(t)} \left\{ \frac{u_{it}^{proj}}{\kappa_{it}^{proj}} - \frac{u_{it}^{0}}{\kappa_{it}^{0}} \right\} \tag{16}$$

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- Adding welfare for 20-25 y/o by duplicating welfare for 26 y/o according to distribution on states (lower bound for 20-25 y/o due to higher marginal utility of income)

Case I: Effects on welfare

Table 13: Welfare gain from Case I (2021 DKK prices)

Schooling	*Low*	*Medium*	*High*	*Total*
Total (bn DKK)	38.4	44.2	53.4	136.0
Avg. pr. pers. (1,000 DKK)	72.1	64.0	79.4	-

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- Foregone capital gains (back-of-the-envelope): $(P_t^{cf} - P_t^{base}) - (P_{t-1}^{cf} - P_{t-1}^{base}) \cdot m^2(t) = 115.41$ bn DKK (16.5 bn USD)

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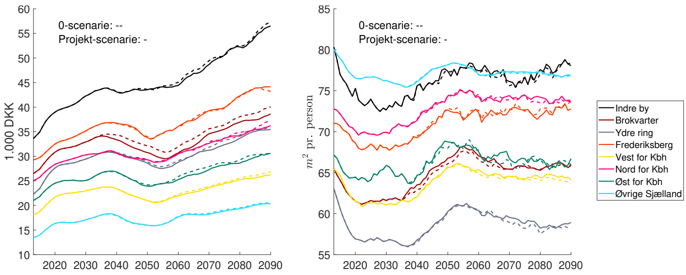
- Welfare gain including foregone capital gain: 20.59 bn DKK (2.9 bn USD)

Case II: Effects on prices and m^2 demand

Figure 27: Price/m^2 (2021 prices) and m^2/person over time

(a) Price per m^2 **(b)** m^2 per person



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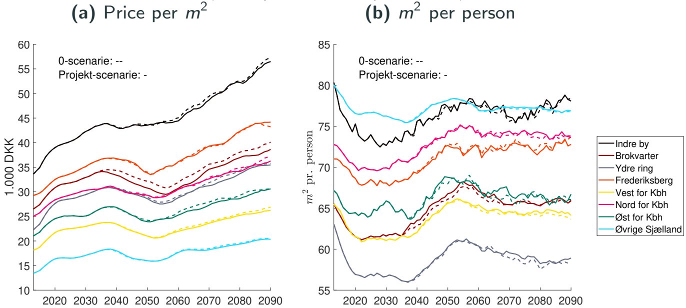

Counterfactual:

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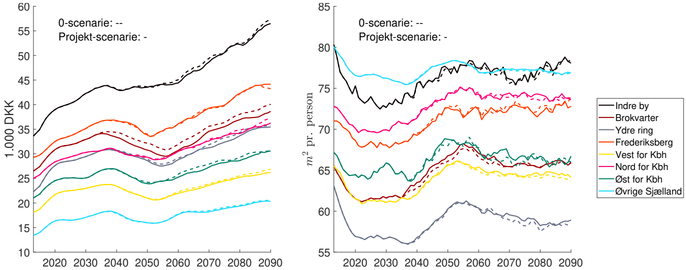

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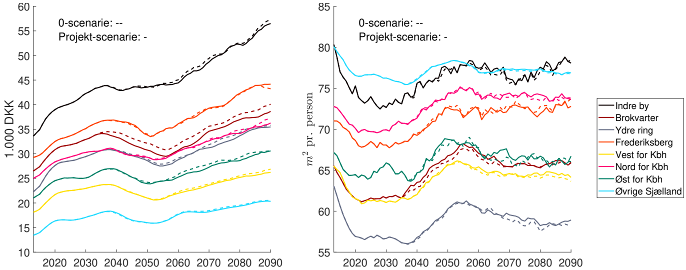

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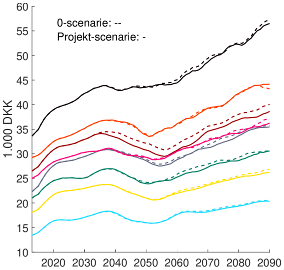

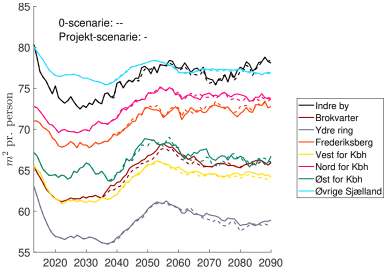

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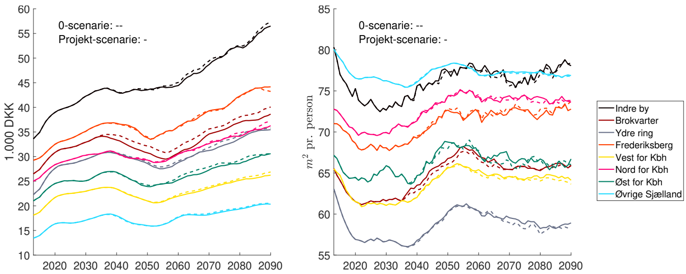

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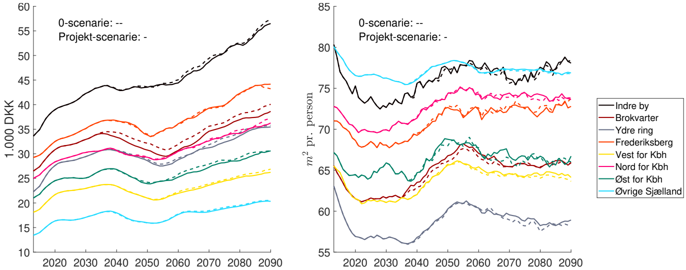
  2. Keeping m^2 from exogeneous pop growth in each reigon (P^{GCA} and $P^{RoZ} \downarrow$)
  3. Reallocation of newcomers from GCA and RoZ to Cph ($P^{bro} \uparrow$, P^{GCA} and $P^{RoZ} \downarrow$)
- GCA and RoZ: $-1) \approx 2) + 3)$.
- Price drop 2070 Brokvarterer (2.9%)
  Case I: Brokvarterer (7.5%), Indre by (4.5%), Ydre ring (8.2%), remaining GCA (4.0 - 8.4%), rest of Zealand (9.1%)

Case II: Effects on prices and m^2 demand

Figure 27: Price/m^2 (2021 prices) and m^2/person over time

(a) Price per m^2 **(b)** m^2 per person

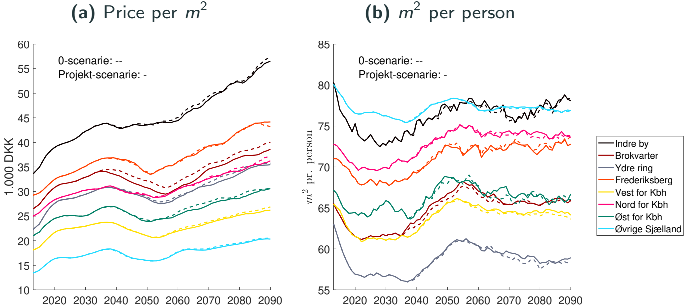


Counterfactual:

- m^2/pers almost unchanged: equilibrium ensures additional m^2 in Brokvarterer used but not trivial¡

Case II: Effects on prices and m^2 demand

Figure 27: Price/m^2 (2021 prices) and m^2/person over time



Counterfactual:

- m^2/pers almost unchanged: equilibrium ensures additional m^2 in Brokvarterer used but not trivial¡
- Demand for Cph residence so high that prices don't need to drop very much to ensure high enough demand
- Sorting of residents acc. demand for m^2 not very different from original sorting

Case II: Effects on residential locations

Table 14: Distribution of home locations, 2070

	Baseline shares (%)			CF minus base (#)			Δ pp in shares		
Schooling	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
Indre by	21,1	14,9	64,1	−3	9	−168	0,13	0,14	−0,27
Brokvarter	22,1	21,3	56,6	8.718	10.467	13.002	0,70	1,57	−2,27
Ydre ring	29,5	29,2	41,4	822	−795	−1.197	1,04	−0,40	−0,64
Frederiksberg	18,3	19,0	62,6	−105	−285	−828	0,19	−0,09	−0,11
Vest for Kbh	33,3	36,4	30,3	−1.812	−2.505	−483	−0,10	−0,36	0,46
Nord for Kbh	22,9	23,8	53,3	−1.014	−837	−1.263	−0,28	−0,09	0,37
Øst for Kbh	30,3	33,5	36,1	−624	642	−1.089	−0,72	2,39	−1,68
Øvrige Sjælland	28,8	44,0	27,2	−4.512	−10.170	−5.970	0,17	−0,13	−0,04

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- Net increase in Brokvarter: 32.000 (26-76 y/o). Composition almost unchanged.

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- Net increase in Brokvarter: 32.000 (26-76 y/o). Composition almost unchanged.
- Stronger reaction than Case I: baseline incentivises moving out of Cph, opposite in counterfactual

Case II: Effects on work locations

Table 15: Distribution of work locations in 2070

	Baseline shares (%)			CF minus base (#)			Δ pp in shares		
Schooling	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
Indre by	23,5	29,6	46,9	2.241	1.671	2.961	0,56	−0,32	−0,23
Brokvarter	28,1	37,2	34,7	2.073	2.679	618	0,28	0,34	−0,62
Ydre ring	24,1	35,9	40,1	894	321	1.329	0,41	−0,85	0,45
Frederiksberg	27,1	31,8	41,1	−21	387	−924	0,31	1,36	−1,68
Vest for Kbh	27,8	44,2	28,0	−1.884	−5.601	−1.257	0,18	−0,57	0,39
Nord for Kbh	25,6	38,2	36,2	−1.200	−1.188	−1.545	−0,15	0,24	−0,09
Øst for Kbh	34,0	41,0	25,0	−726	−849	336	−0,57	−0,64	1,21
Øvrige Sjælland	27,9	46,7	25,4	222	−672	228	0,92	−1,84	0,92
Ikke-beskæftiget	28,6	32,1	39,3	−129	−222	258	−0,02	−0,03	0,04

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- Also slightly stronger reactions than Case I due to close link btw home and work choices

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- Also slightly stronger reactions than Case I due to close link btw home and work choices
- Slight drop in non-employment. Wealth effect weaker than in Case I due to lower prices in baseline → less room for wealth gains from price drop in counterfactual

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- Also slightly stronger reactions than Case I due to close link btw home and work choices
- Slight drop in non-employment. Wealth effect weaker than in Case I due to lower prices in baseline → less room for wealth gains from price drop in counterfactual
- Only for LS and MS workers: lower non-employment incomes → stronger incentive to choose work

Case II: Effects on welfare

Table 16: Welfare gain from Case II (2021 DKK prices)

Schooling	*Low*	*Medium*	*High*	*Total*
Total (bn DKK)	7.9	0.0	14.9	22.8
Avg. per pers. (1,000 DKK)	14.8	0.1	22.2	-

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- No large price drop reason for $WTP(HS) > WTP(LS)$ as price reductions contributes more significantly to their WTP
- Foregone capital gains: 18.64 bn DKK (2.7 bn USD) $\rightarrow$ Welfare gain incl capital gains: 4.16 bn DKK (0.6 bn USD)

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Lynetteholm in the harbour of Copenhagen

Figure 28: Map of Lynetteholm

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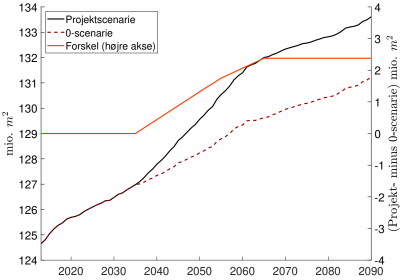
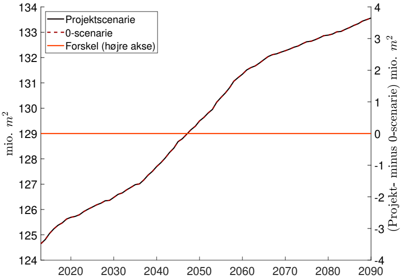
Evolution of housing stock in each case

Figure 29: Total m^2 over time





Note: Total housing stock over time in each scenario for entire Zealand region.

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Assumptions: population growth

Newborns share the m^2 left by the dead and are allocated to states acc.:

- Home region: pdf of *rl* for 26-30 y/o in year
- Schooling: pdf of *edu* for 35 y/o in 2013 (avoid declining schooling lvls) cond allocated *rl*
- $wl = \emptyset$ (new graduates)
- Remaining states: pdf of these for 26 y/o in the year

For exogenous growth to region: states acc. pdf of existing population in year.

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