Winners and Losers from the Work-from-Home Technology Boon

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Motivation

Improvement in WFH productivity during the pandemic

Workers really value the option to do some WFH

But

- only some workers get a utility benefit from WFH
- increase in WFH productivity implies heterogeneous impacts on TFP
- substantially increased housing demand

This paper: How does the technology improvement affect welfare of different worker types?

What we Do

Specify model where

- workers differ in occupation and skill level
  - Some workers can work either fully on-site or a hybrid schedule
  - Some workers can choose to be fully remote (hereafter 'remote')
- All workers choose in which city to live
- Housing is an input in production of WFH
- **All workers must consume housing**
- **Housing is supplied inelastically**

Calibrate the model to prepandemic data on 30 largest US cities

Use the model to study effects of large increase in TFP of WFH

Findings

Improvement in WFH technology leads to

- 16% increase in residential rents in the model long run vs. 14% in the data
- 12% decrease in office rents in the model long run vs. 11-13% in the data after controlling for lease characteristics
- Increase in measured income for all worker types
- Biggest increase in welfare for remote-capable workers
  - Increase in WFH TFP allows them to shift to remote work and they get a big utility benefit from being remote

Findings

- Welfare **loss** for workers in non-telecommutable occupations
  - Face higher housing costs and they must consume housing
- Biggest loss in welfare for college educated workers in non-telecommutable occupations
  - Face higher housing prices *and* loss in TFP from lower agglomeration economies
- Welfare loss comes despite measured income increasing slightly
  - Cheaper office rents mean labor productivity increases slightly
  - Slightly higher labor supply from shorter commutes

Relation to Existing Literature

We build on spatial models of WFH (Davis et al., forthcoming; Delventhal and Parkhomenko, 2022) and models of the productivity of WFH (Davis et al., forthcoming; Behrens et al., 2024)

What is new: improvement in WFH TFP increases not just inequality (Davis et al., forthcoming; Behrens et al., 2024) but can actually lower welfare

Modeling contribution: model remote, hybrid, and on-site workers

- Remote vs. hybrid worker important for urban because remote workers can live in a different city from their employer,

Urban Model with WFH

- All office work occurs in the Central Business District (CBD) and requires a commute
- WFH does not require a commute
- Five types of workers (exogenous shares):
  1. High-skill workers in telecommutable occupations (type 1)
  2. Low-skill workers in telecommutable occupations (type 2)
  3. High-skill workers in non-telecommutable occupations (type 3)
  4. Low-skill workers in non-telecommutable occupations (type 4)
  5. Tech workers - have the option to work remote (type 5)
- Housing supply is exogenous and inelastic

Households: Sequencing of Decisions

- Type 5 HHs first choose whether to be remote
  - If choose not to be remote, they become ilk 5
  - If choose to be remote, they are ilk 6

- ilk indexed by ι, $\iota \in (1, 2, 3, 4, 5, 6)$
  - ilk 1 = type 1 (skilled, telecommutable)
  - ilk 2 = type 2 (unskilled, nontelecommutable)
  - ilk 3 = type 3 (skilled, nontelecommutable)
  - ilk 4 = type 4 (unskilled, nontelecommutable)
  - ilk 5 = type 5 (tech worker) not remote
  - ilk 6 = type 5 (tech worker) remote

- Then, all ilks choose which of c cities to live in

Households: Sequencing of Decisions

- Next, all ilks choose which of n zones to live in
- Then, ilk $\iota = 1, 2, 5$ choose whether to work for a firm that allows hybrid work (hybrid firm)
  - $\kappa = 0$ denotes a non-WFH firm, $\kappa = 1$ denotes a hybrid firm
- Finally, all ilks choose non-housing consumption and housing
- HHs that choose hybrid firms also choose
  - number of days to WFH in the year
  - size of home office
  - amount of business equipment for home office

Type 5 Remote Decision

- V_6 is the expected value of choosing to be remote
- V_5 is the expected value of choosing not to be remote

A given HH j that is type 5 decides whether or not to be remote by choosing the max of the following:

$$\max\left\{\nu_r\left(\hat{a}+V_6\right)+\hat{e}_{6,j},\quad \nu_r V_5+\hat{e}_{5,j}\right\}$$

where

- $\hat{e}_{6,j}$ and $\hat{e}_{5,j}$ are iid Type 1 Extreme Value shocks specific to HH j,
- $\hat{a}$ is a preference shifter that pins down the avg fraction of type 5 workers that choose remote work
- ν_r determines the elasticity of this choice with respect to changes in $[V_6 - V_5]$

City Choice

$V_{\iota c}$= expected value of ilk ι living in city c

Household j of ilk ι chooses a city $c \in \{1, \ldots, C\}$ according to

$$\max_{c \in \{1,\ldots,C\}} \left\{ \nu_c \left(\tilde{a}_{\iota,c} + V_{\iota c} \right) + \tilde{e}_{\iota,c,j} \right\}$$

where

- $\tilde{e}_{\iota,j,c}$ is an iid Type 1 Extreme Value shock specific to HH j living in city c
- $\tilde{a}_{\iota,c}$ pins down the avg population, by type, in each metro area
- ν_c pins down the elasticity of city choice in response to changes in the differential of economic fundamentals across cities

For each ilk, we denote the expected value of this decision before the $\tilde{e}_{\iota,c,j}$ are drawn as V_ι

Within City Location Decision

At the time household j makes its location decision, the household receives utility equal to

$$V_{n\iota cj} = \underbrace{\nu\left[a_{n,\iota,c} + X_{n\iota c}\right]}_{\equiv V_{n\iota c}.} + e_{n,\iota,c,j}$$

- $a_{n,\iota,c}$ are amenities in location n of city c
- Be patient on definition of $X_{n\iota c}$ please
- $e_{n,\iota,c,j}$ is idiosyncratic preference for location n
- ν determines importance of idiosyncratic location preferences
- $e_{n,\iota,c,j}$ drawn IID Type I Extreme Value Distribution

Ilk 1, 2, and 5 Choice of Firm Type

A household j of ilk ι ($\iota = 1$, 2, or 5) living in city c in location n and working for a firm of type $\kappa \in 0, 1$ receives the following utility

$$X^{\kappa}_{n\iota cj} \quad = \quad X^{\kappa}_{n\iota c} \; + \; (1/\zeta)\, \epsilon^{\kappa}_{n,\iota,c,j}$$

- $\kappa = 0$ firm type does not allow WFH
- $\kappa = 1$ firm type allows WFH
- $\epsilon^{\kappa}_{n,\iota,c,j}$ is drawn iid Type 1 Extreme Value
- $\frac{1}{\zeta}$ determines the importance of firm type preference
- Be just a little more patient on definition of $X^{\kappa}_{n\iota c}$ please

Ilk 1, 2, and 5 Utility if Choose Non-WFH Firm

Choose consumption ($c^0_{n\iota c}$), housing ($h^0_{n\iota c}$), leisure ($\ell^0_{n\iota c}$) and the fraction of time to spend working ($b^0_{n\iota c}$) to maximize

$$X^0_{n\iota c} = (1-\alpha_\iota)\ln c^0_{n\iota c} + \alpha_\iota \ln h^0_{n\iota c} + \psi_\iota \ln \ell^0_{n\iota c}$$

subject to the budget and time constraints of

$$\begin{aligned} 0 &= \left(w^0_{\iota,c} - \tau_n\right) b^0_{n\iota c} - c^0_{n\iota c} - r_n h^0_{n\iota} \\ 0 &= 1 - (1+t_{n,c})\, b^0_{n\iota c} - \ell^0_{n\iota}. \end{aligned}$$

- 0 superscripts to denote firm type is non-WFH
- $w^0_{\iota,c}$ denotes wage at non-WFH firm
- τ_n is a pecuniary cost of commuting from location n
- $t_{n,c}$ is a time cost of commuting

Ilk 1, 2, 5 Utility if Choose Hybrid Firm ($\kappa = 1$)

Make choices to maximize

$$X^1_{n\imath c} = \chi_\imath + (1-\alpha_\imath)\ln c^1_{n\imath c} + \alpha_\imath \ln h^1_{n\imath c} + \psi_\imath \ln \ell^1_{n\imath c}$$

subject to

$$\begin{aligned} 0 &= \omega\left(l^b_{n\imath c}, l^h_{n\imath c}, s^h_{n\imath c}, k^h_{n\imath c}\right) - \tau_n l^b_{n\imath c} - c^1_{n\imath c} - \\ &\quad r_{n,c}\left(h^1_{n\imath c} + s^h_{n\imath c}\right) - r^k k^h_{n\imath c} \\ 0 &= 1 - (1+t_{n,c})\, l^b_{n\imath c} - l^h_{n\imath c} - \ell^1_{n\imath c} \end{aligned}$$

- 1 superscripts to denote firm type is WFH
- $\chi_\imath$ is a fixed, common preference for being at a WFH firm
- $\omega\left(l^b_{n\imath c}, l^h_{n\imath c}, s^h_{n\imath c}, k^h_{n\imath c}\right)$ is the wage
- $l^b_{n\imath c}$ and $l^h_{n\imath c}$ are days worked at the office and at home
- $s^h_{n\imath c}$ an $k^h_{n\imath c}$ are home office space and home business equipment

Utility if Remote Worker

Fully remote households own their own firms and produce output

$$y_{n6c} = Z_{6,c} \left(l_{n6c}\right)^{\theta_b} \left(k_{n6c}\right)^{\theta_k} \left(s_{n6c}\right)^{\theta_s}$$

HHs make choices according to

$$\max_{c_{n6c}, h_{n6c}, \ell_{n6c}, y_{n6c}, l_{n6c}, s_{n6c}, k_{n6c}} \left\{ (1-\alpha) \ln c_{n6c} + \alpha \ln h_{n6c} + \psi \ln \ell_{n6c} \right\}$$

subject to

$$\begin{aligned} 0 &= \mu_c \left[y_{n6c} - c_{n6c} - r_{n,c} \left(h_{n6c} + s^h_{n6c} \right) - r^k k^h_{n6c} \right] \\ 0 &= \mu_l \left[1 - l_{n6c} - \ell_{n6c} \right] \\ 0 &= \mu_h \left[Z_{6,c} \left(l_{n6c}\right)^{\theta_b} \left(k_{n6c}\right)^{\theta_k} \left(s_{n6c}\right)^{\theta_s} - y_{n6c} \right]. \end{aligned}$$

Non-WFH Firms

Chooses its quantities of labor $b_{n\iota c}$ and capital, in the form of both equipment and software $k_{n\iota c}$ and office space $s_{n\iota c}$, to maximize

$$y_{n\iota c} - w_{\iota,c} b_{n\iota c} - r^k k_{n\iota c} - r^o_c s_{n\iota c}$$

where $\quad y_{n\iota c} = Z_{\iota,c} b_{n\iota c}^{\theta_b} k_{n\iota c}^{\theta_k} s_{n\iota c}^{\theta_s}.$

Hybrid Firms

A firm that hires a household living in location n of type $\iota = 1$, 2, or 5 produces output of

$$y_{n\iota c} = \left[\left(y^b_{n\iota c}\right)^{\rho} + \left(y^h_{n\iota c}\right)^{\rho}\right]^{1/\rho}$$

where $y^b_{n\iota c}$ is output produced while working at the firm and $y^h_{n\iota c}$ is output produced while WFH

- $\frac{1}{1-\rho}$ is the elasticity of substitution between output at office and output from WFH
- $\rho < 1$ indicates not perfect substitutes
- Davis et al. (forthcoming) discuss at length why data indicates $\rho < 1$ and estimate $\rho \approx 0.72$

Hybrid Firms

$$y_{n\iota c} = \left[\left(y^b_{n\iota c}\right)^{\rho} + \left(y^h_{n\iota c}\right)^{\rho}\right]^{1/\rho}$$

Cobb-Douglas production functions for output from WFH and work at the office:

$$\begin{aligned} y^b_{n\iota c} &= A^b_{\iota,c}\left(l^b_{n\iota c}\right)^{\theta_b}\left(k^b_{n\iota c}\right)^{\theta_k}\left(s^b_{n\iota}\right)^{\theta_s} \\ y^h_{n\iota} &= A^h_{\iota,c}\left(l^h_{n\iota c}\right)^{\theta_b}\left(k^h_{n\iota c}\right)^{\theta_k}\left(s^h_{n\iota c}\right)^{\theta_s} \end{aligned}$$

Firm chooses office space, $s_{n\iota c}$, and business equipment $k_{n\iota c}$ to maximize $y_{n\iota c} - r^k k^b_{n\iota c} - r^o_c s^b_{n\iota c}$

Households choose home office space and business equipment to use at home taking into account the impact on their wages that comes from productivity assuming firms are competitive and HH owns the firm

TFP at Home

Recall, output from WFH given by

$$y^h_{n\iota c} = A^h_{\iota,c} \left(l^h_{n\iota c}\right)^{\theta_b} \left(k^h_{n\iota}\right)^{\theta_k} \left(s^h_{n\iota c}\right)^{\theta_s}$$

Productivity of WFH evolves according to

$$A^h_{\iota,c} = \bar{A}^h_{\iota,c} \left(L^{max}_h\right)^{\delta_{\iota,h}}$$

- L^{max}_h is the maximum amount of time that households in aggregate spent working at home in any previous yea
- $\delta_{\iota,h}$ is the extent of the adoption externality

TFP at the Office

Agglomeration economies in production only for high-skill workers:

- Gould (2007), Rosenthal and Strange (2008), Bacolod, Blum, and Strange (2009), Roca and Puga (2016), and Rossi-Hansberg, Sarte, and Schwartzman (2019)

Non-WFH firm TFP, $\iota = 1, 3, 5$ $\quad Z_{\iota,c} = \bar{Z}_{\iota,c} \, \mathcal{H}_c^{\delta_b}$

Hybrid firm TFP while at the office, $\iota = 1, 5$ $\quad A^b_{\iota,c} = \bar{A}^b_{\iota,c} \mathcal{H}_c^{\delta_b}$

- $\mathcal{H}_c$ is total high-skill household time working at the office in city c during the period

TFP of Remote Workers

$$Z_{6,c} = \phi(\lambda Z_{1,c} + (1 - \lambda) Z_1)$$

where

- Z_1 is the national average productivity of onsite type 1 workers.
  - some TFP inherited from city, some from nation as a whole
- $\phi < 1$ is a discount factor representing the extent to which remote workers are less productive than their hybrid counterparts

Commuting Speed

Denote $\mathcal{L}_{nc}$ as the aggregate number of days households living in zone n of city c worked at the office and define $d_{n,c}$ as the distance from location n to the CBD in city c. Aggregate distance spent commuting, $\mathcal{V}_c$, is equal to

$$\sum_{n=1}^{N} d_{n,c}\mathcal{L}_{nc}$$

Following Couture, Duranton, and Turner (2018), travel speed of any commuter, $\mathcal{S}_c$, is subject to a negative congestion externality in the aggregate distance spent commuting, determined as

$$\mathcal{S}_c = \bar{\mathcal{S}}_c \mathcal{V}_c^{\gamma}$$

such that time spent commuting from location n is $d_{n,c}/\mathcal{S}_c$.

Equilibrium

An equilibrium is a set of rents $(r^k,\, r_c^o,\, r_{n,c})$; a wage rate for each ilk of worker $\iota = 1, \ldots, 5$ working at a non-WFH firm in each city, $w_{\iota,c}^0$; a wage function $\omega_{\iota,c}\left(l_{n\iota c}^b, l_{n\iota}^h, s_{n\iota c}^h, k_{n\iota c}^h\right)$ for each ilk of worker $\iota = 1, 2, 5$ choosing to work at a hybrid firm; and commute times $t_{n,c}$ for locations $1, \ldots N$ in each city c such that

- all households optimize,
- all firms optimize,
- the total demand for housing inclusive of home office space in each location is equal to the supply of housing in each location
- total demand for office space is equal to the supply of office space, and
- quantities in each city are consistent with the externalities affecting all wages and commute times in that city.

Matching Model Concepts to Data

- Parameterize the model as close as possible to immediately before COVID
- High-skill workers = workers with four-year degree
- In model, all workers are full-time workers so restrict to full-time workers
- Telecommutable occupations: Those that Dingel and Neiman (2020) determined are telecommutable
- Type 5 = IT workers
- Two residential zones: Zone 1 is same county as CBD, Zone 2 is all other counties in the metro area
- Estimate the model using data on 30 largest US cities
  - exclude Denver because missing county information in 2015-2019 5-year ACS for Denver

Parameter Strategy

- For some parameters, use values from other studies
- For other parameters, match with data counterpart or estimate from single moment in the data
- Main dataset is 2015-2019 5-year American Community Survey (ACS) due to large sample size and ability to observe county
- Supplement with LJF and GSS where there is more detail on WFH to estimate ρ

Pre-pandemic Productivity Parameters

City-specific $Z_{\iota,c}$ inferred from pre-pandemic ACS wages stripped of demographics

Relative TFP of WFH and work in the office for hybrid workers: Match share of workers choosing to be hybrid and WFH intensity with wage discounts Mas and Pallais (2017) report workers willing to accept to be hybrid workers

Pre-pandemic Productivity of Remote Workers

He et al. (2021) find that workers were willing to accept a 36% wage discount to be remote relative to fully in-person $\rightarrow$ use this to calibrate ϕ in

$$Z_{6,c} = \phi(\lambda Z_{1,c} + (1-\lambda)Z_1)$$

Have to guess λ, no evidence on this right now

We set $\lambda = 0.5$ and then calibrate ϕ such that the wages of remote are 64% of those of type 1

Fixed Parameters

- $\alpha_1 = 0.22$, $\alpha_2 = 0.27$, $\alpha_3 = 0.23$, $\alpha_4 = 0.29$, $\alpha_5 = \alpha_6 = 0.19$: housing expenditure shares based on median ratio of gross rent to famiily income of renters of that type in the ACS
- $\nu_c = \nu = 3.3$: importance of city-specific and within city location-specific draws to utility
- $\theta_s = 0.18$: structures share in production
- $\theta_k = 0.12$: business equipment share in production
- $\pi_{\iota,c}$: share of each worker type, measured from ACS
- $t_{1,c}$, and $t_{2,c}$: one-way commute times from Zone 1 and Zone 2 for workers commuting into Zone 1 (ACS)
- τ_1, τ_2 from American Housing Survey
- Rents: Office effective rents psf from Compstak, residential rents psf imputed from Realtor.com county-level prices psf
  - Rents are normalized to NYC office psf (NYC = 1)

City by Type Amenity Parameters
Selected Cities

	Type 1	Type 2	Type 3	Type 4	Type 5	Avg
Boston	1.99	2.54	2.29	2.53	1.99	2.24
San Diego	1.67	1.91	1.75	2.04	1.70	1.85
NYC	1.44	1.98	1.85	2.21	1.11	1.81
Miami	1.59	1.74	1.78	1.86	1.54	1.75
Phoenix	1.63	1.65	1.39	1.60	1.74	1.60
Nashville	-0.89	-1.47	-1.03	-1.93	-0.72	-1.38
Baltimore	-1.27	-1.42	-1.35	-1.51	-1.53	-1.39
Pittsburgh	-1.53	-1.36	-1.58	-1.34	-1.36	-1.43
St. Louis	-1.58	-1.85	-1.49	-1.96	-1.76	-1.76
Dallas	-3.56	-3.12	-3.31	-2.68	-3.85	-3.14

This is how you got David and Stefania!!

Post-Pandemic Counterfactuals

1. SR: Supply of space fixed to baseline in CBD, Zone 1, Zone 2; prices adjust
   - Calibrate technological improvement over pandemic for hybrid workers to values in Davis et al. (forthcoming)
     - generates fourfold increase in days of WFH for types 1 and 2
   - Calibrate increase in TFP (ϕ) of remote work for tech workers such that the share choosing remote work goes from 11.7% in 2019 to 50.6% in 2022
   - Allow city-specific amenity values to change to match population changes by ilk between 2019 and 2022 1-year ACS
2. LR:
   - Supply elasticity of office space set to 0.1 and price adjusts
   - Supply elasticity of residential space in zones 1 and 2 given by Baum-Snow and Han (forthcoming)

Technological Improvement over Pandemic

	Pre-COVID Baseline	Post-COVID SR
$\frac{A^h_{1,c}}{A^b_{1,c}}$	0.365	0.665
$\frac{A^h_{2,c}}{A^b_{2,c}}$	0.348	0.515

- 82% increase in relative TFP for high-skill workers
- 48% increase in relative TFP for low-skill workers
- ϕ (relative TFP of remote work) increases by 20% relative to prepandemic value

Real Change in Office Rents

Unlike residential real estate, far fewer transactions and more heterogeneity in office than residential

Measure change in real office rents using hedonic regression:

$$r_{i,t} = \beta_{post} postwfhboon_{i,t} + \beta_x X_{i,t} + \epsilon_{i,t} \quad (1)$$

where $r_{i,t}$ is the log of effective rents psf

$X_{i,t}$ contains controls for

- expense sharing between landlord and tenant
- location FEs
- lease term
- total transaction square footage

Real Change in Office Rents 2019-2022

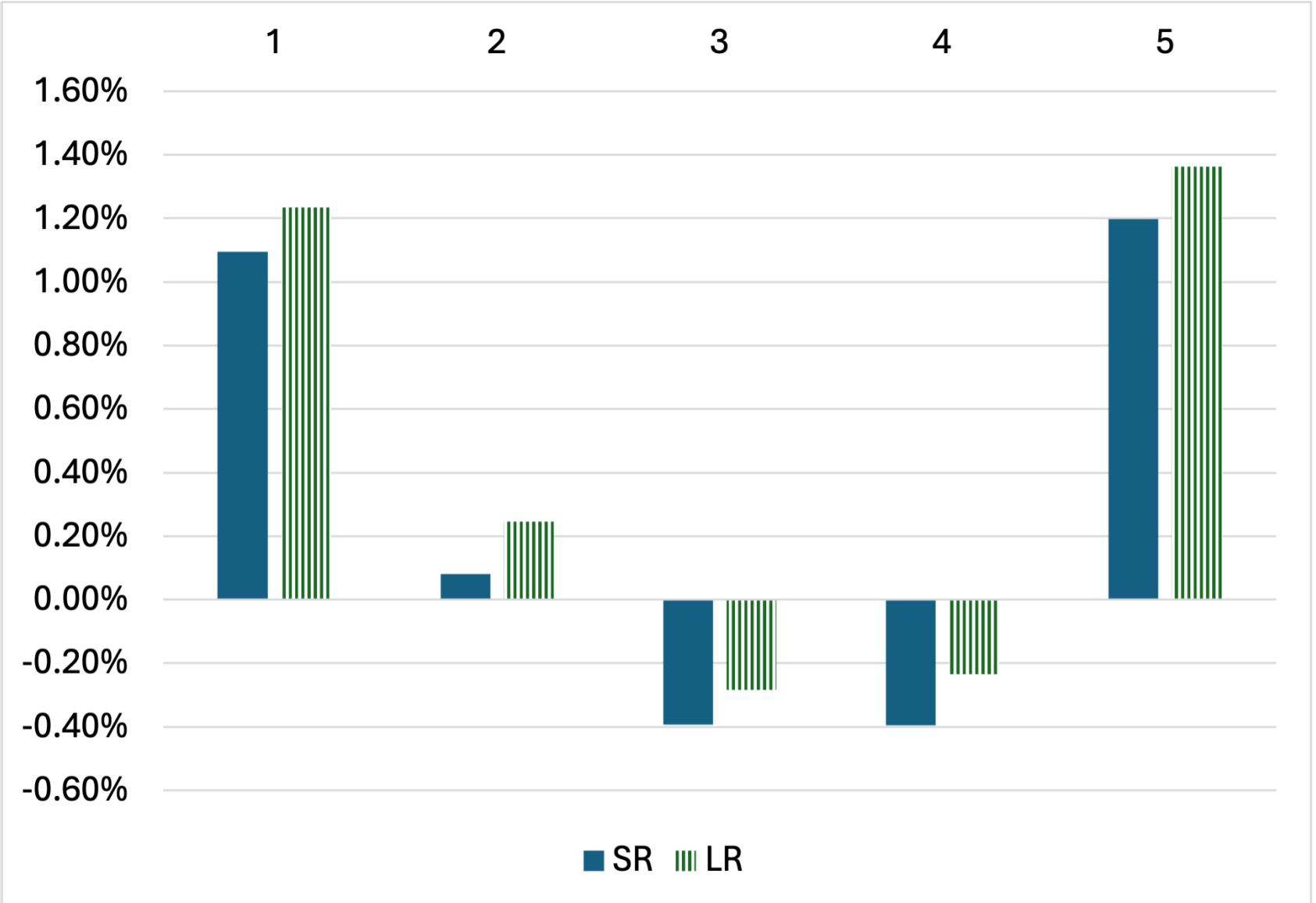
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
postwfhboon	-0.12***	-0.13***	-0.12***	-0.13***	-0.11***	-0.13***	-0.14***
	-0.0073	-0.0069	-0.0079	-0.0087	-0.018	-0.0085	-0.012
transactionsqft	2.6e-07***	2.2e-07***	2.5e-07***	3.9e-07**	0.00000021	2.8e-07***	0.00000008
	-0.0000001	-0.0000001	-0.0000001	-0.000002	-0.0000002	-0.0000001	-0.0000001
termdum1	-0.15***	-0.14***	-0.15***	-0.15***	-0.034	-0.19***	-0.057***
	-0.012	-0.011	-0.013	-0.014	-0.03	-0.014	-0.019
termdum2	-0.13***	-0.12***	-0.14***	-0.12***	-0.086***	-0.14***	-0.068***
	-0.011	-0.01	-0.012	-0.014	-0.026	-0.012	-0.02
termdum3	-0.088***	-0.083***	-0.092***	-0.061***	-0.078***	-0.091***	-0.048***
	-0.0093	-0.0087	-0.0097	-0.012	-0.021	-0.01	-0.018
Constant	3.60***	3.61***	3.63***	3.61***	3.12***	3.65***	3.51***
	-0.0084	-0.0079	-0.0088	-0.012	-0.019	-0.009	-0.017
Observations	8475	8381	6684	4242	1726	5870	2438
R^2	0.736	0.787	0.762	0.811	0.647	0.782	0.824
Building Class FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Renewal/New FEs	Yes	Yes	Yes	Yes	Yes	New	Renewals
Gross/Net FEs	Yes	Yes	Yes	Gross	Net	Yes	Yes
Cal Qtr FEs	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CBSA FEs	Yes	No	Yes	No	No	No	No
Zip Code FEs	No	Yes	No	Yes	Yes	Yes	Yes
Tenant Industry FEs	No	No	Yes	No	No	No	No

Tightly estimated decline of 12-14% in real office rents

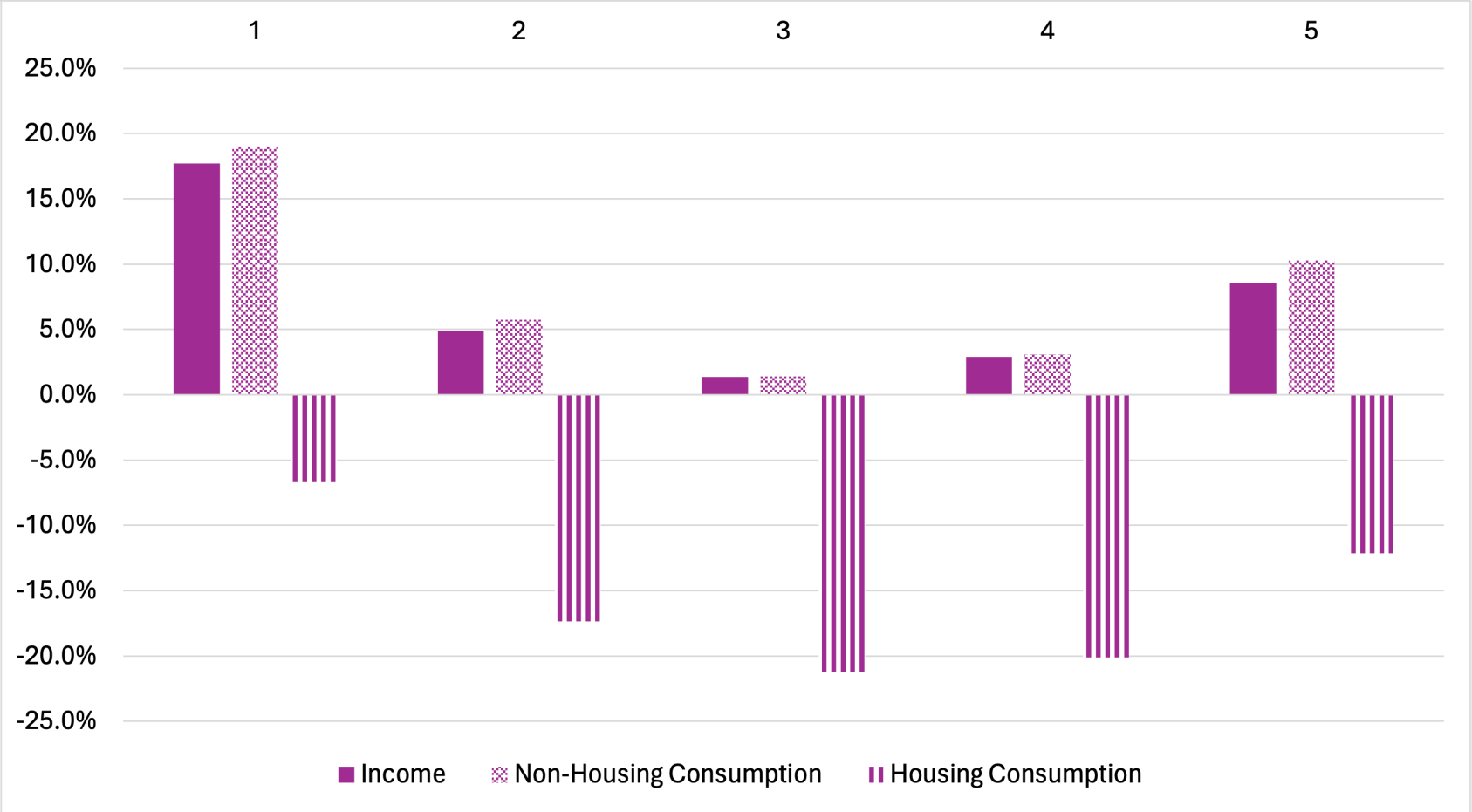
Rent Changes in the Model and the Data

1) Residential rent change is calculated as the real change in residential listing prices between 2023 and 2019. 2) Office rent change is calculated as the real change in office rents between 2022 and 2019 after adjusting for lease characteristics.

Welfare Changes in the Model by Worker Type

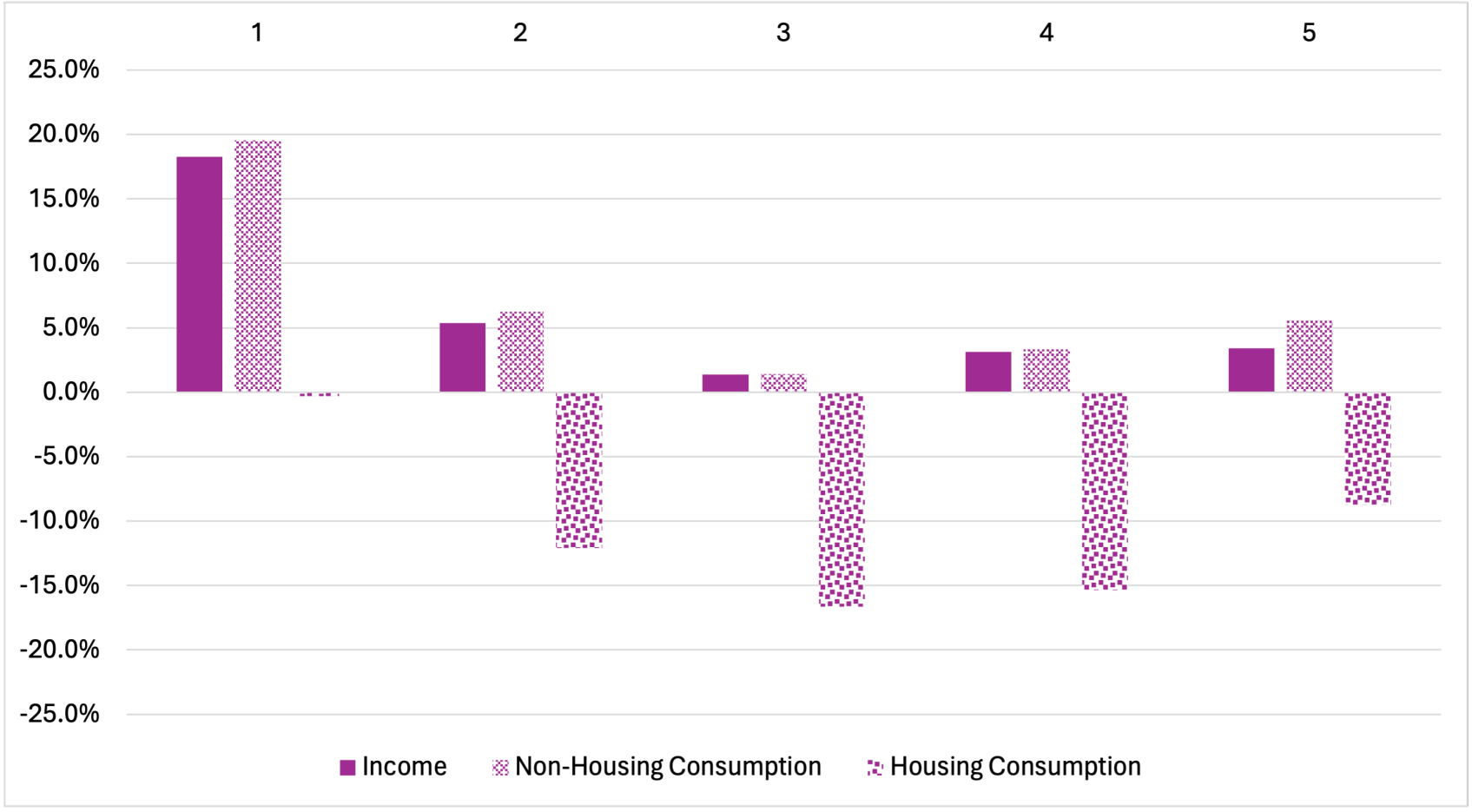


Model SR Income and Consumption Changes

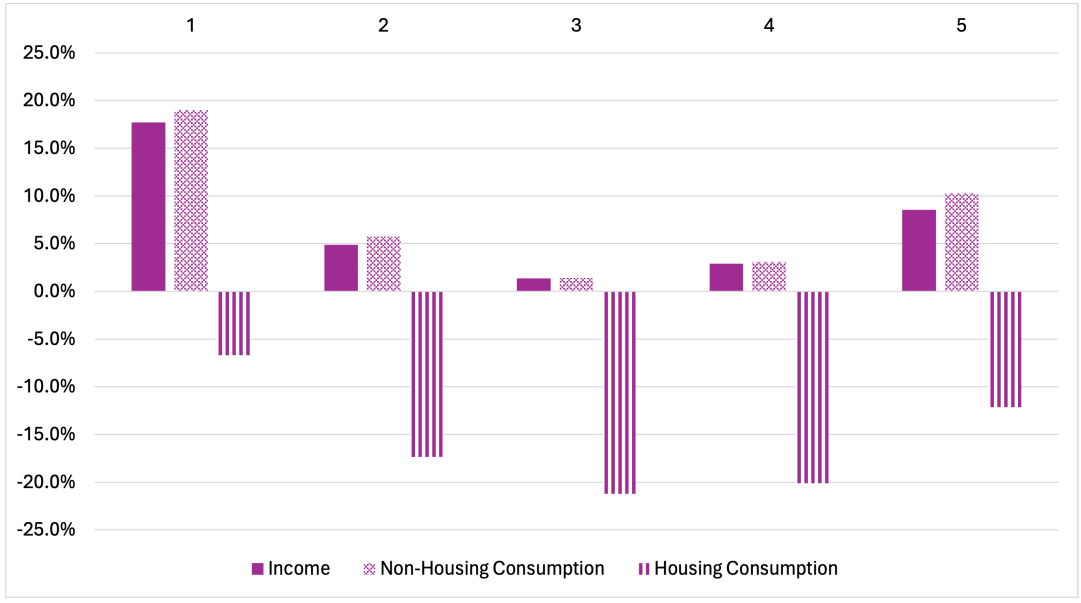


Notes: 1) A type 5 worker is a worker in an IT occupation. 2) Types 1 and 2 are in telecommutable occupations other than IT occupations. 3) Types 3 and 4 are in non-telecommutable occupations. 4) Types 1 and 3 have educational attainment of a four-year degree or greater.

Model LR Income and Consumption Changes



SR vs. LR


1
2
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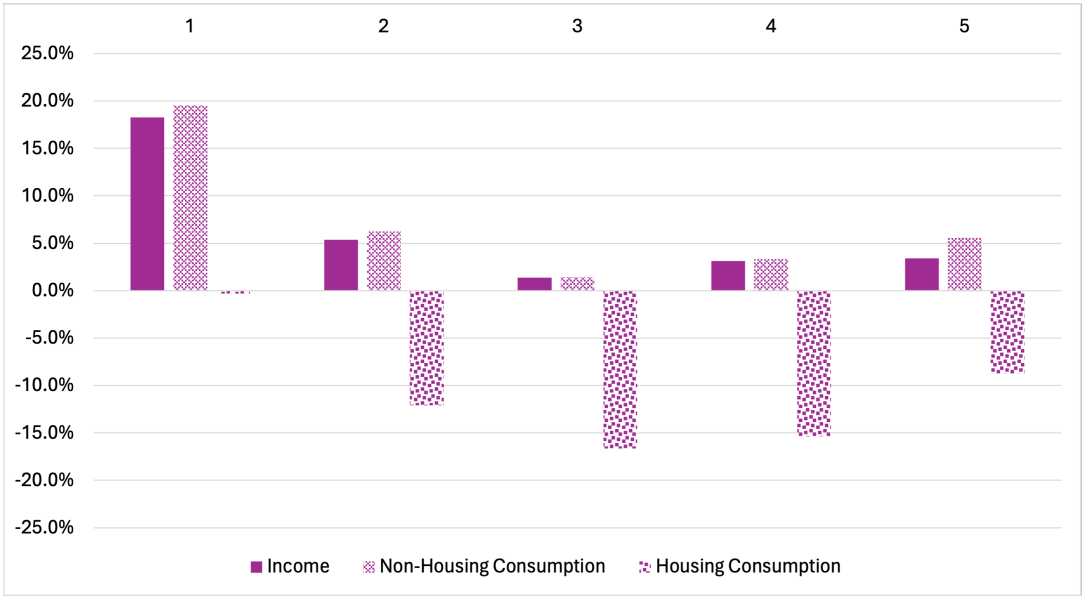
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
-5.0%
-10.0%
-15.0%
-20.0%
-25.0%
Income
Non-Housing Consumption
Housing Consumption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25.0%
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0.0%
-5.0%
-10.0%
-15.0%
-20.0%
-25.0%
Income
Non-Housing Consumption
Housing Consumption

Changes in Income

- All workers see incomes rise
  - TFP rises for telecommutable types
  - Slight rise in labor supply because of decline in commuting costs (all types) since leisure is a constant
  - Non-telcommutable types have more office equipment to work with so a bit higher wages
- Part of rise in income for telecommutable types is accounting - workers now rent home office space and business equipment out of their salaries
- Biggest rise in income is for type 1 workers
- Type 5 income actually decreases between SR and LR
  - More switch to being remote which earn lower incomes

Changes in Income

Bigger increase in income for type 4 than for type 3

- Slight fall in TFP for type 3 because of lower agglomeration economies with less in-person work

Change in TFP of In-person Work Relative to Pre-pandemic Baseline

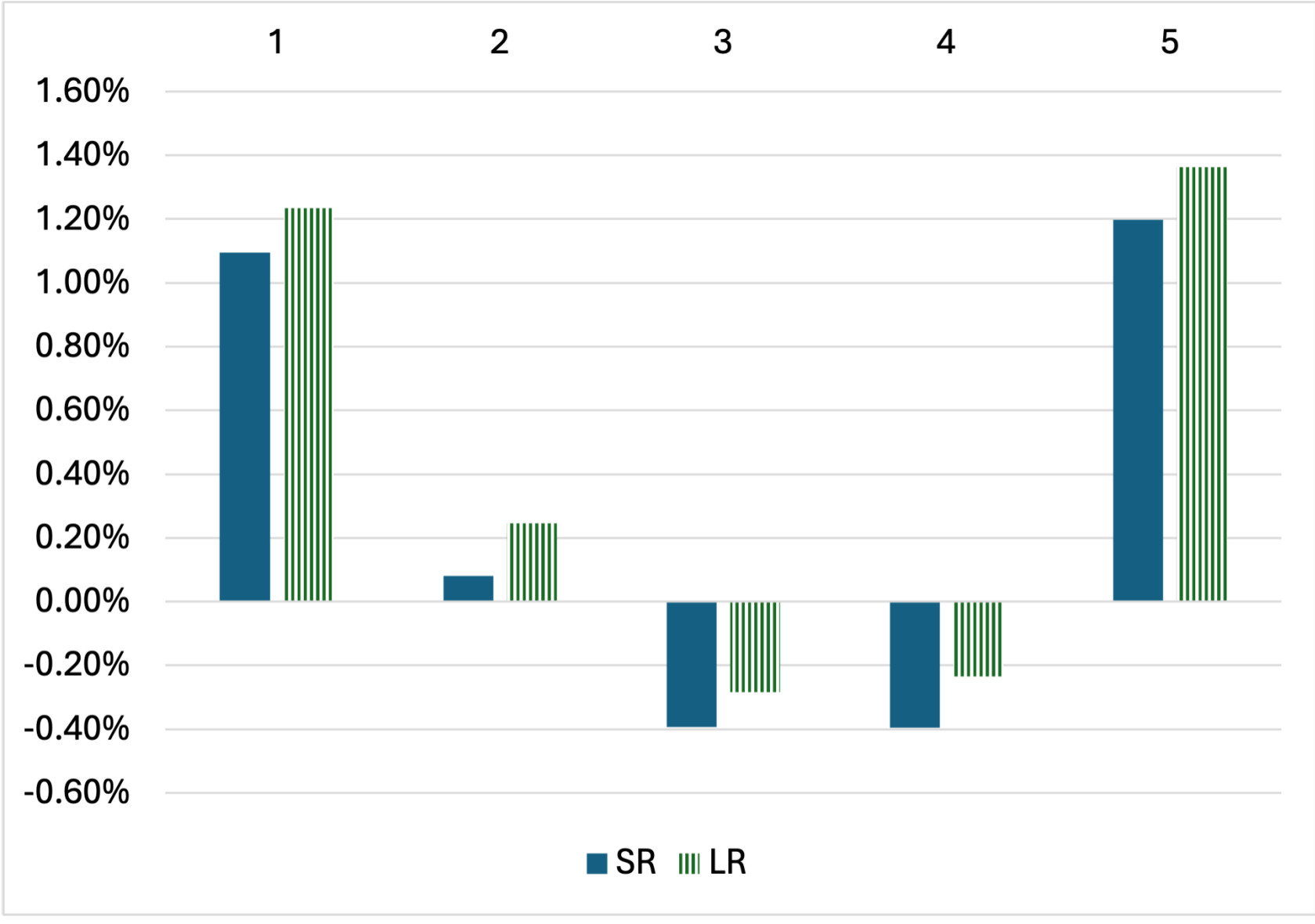
	Actual Pop. Dist.		2019 Pop. Dist. In SR and LR	
Worker Type	SR	LR	SR	LR
1	-1.43%	-1.64%	-1.12%	-1.27%
3	-1.53%	-1.71%	-1.10%	-1.25%

Most of the decline in the TFP of in-person work is due to decrease in agglomeration economies, not reallocation to less productive cities

Changes in Housing and Non-housing Consumption

- All workers consume less housing
  - In SR, more housing used for WFH so consumption housing falls
- Decline in housing consumption more modest in LR after housing supply has a chance to increase
- Non-housing consumption rises because it's relatively cheaper and incomes rise

Welfare Changes in the Model



Conclusions

Pandemic induced a large increase in the demand for residential space

Pandemic also increased the TFP of WFH

Because housing is supplied inelastically AND all households must consume housing, technological progress may have negative welfare consequences for some households

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