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

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What we Do

Study welfare effects of increase in WFH productivity on different types of workers

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**

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
- **Welfare loss (absolute!) for workers in non-telecommutable occupations**
  - Face higher housing costs and they must consume housing
  - Despite increase in measured income
  - Decrease in welfare equivalent to 1 to 9% of consumption
  - Magnitude of welfare loss depends critically on Elasticity of Substitution (EOS) between WFH and work at the office

Findings

Biggest welfare gains 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
- Welfare gain equivalent to 10-50% of measured consumption depending on EOS
- Despite only small gain in measured income

Welfare changes depend on EOS because **magnitude of $\uparrow$ in TFP of WFH necessary to get 4X$\uparrow$ in TFP depends on substitutability**

- When WFH is more substitutable with work at the office, only need small increase in TFP of WFH to get a big increase in WFH

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 $[V_6 - V_5]$

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

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

subject to the budget and time constraints of

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

- 0 superscripts to denote firm type is non-WFH
- $w^0_{\imath,c}$ 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 $$y_{n\iota c} = Z_{\iota,c} b_{n\iota c}^{\theta_b} k_{n\iota c}^{\theta_k} s_{n\iota c}^{\theta_s}.$$

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. (2024) 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:

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

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

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

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 year
- $\delta_{\iota,h}$ 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

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. (2024)
     - 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 (2024)

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

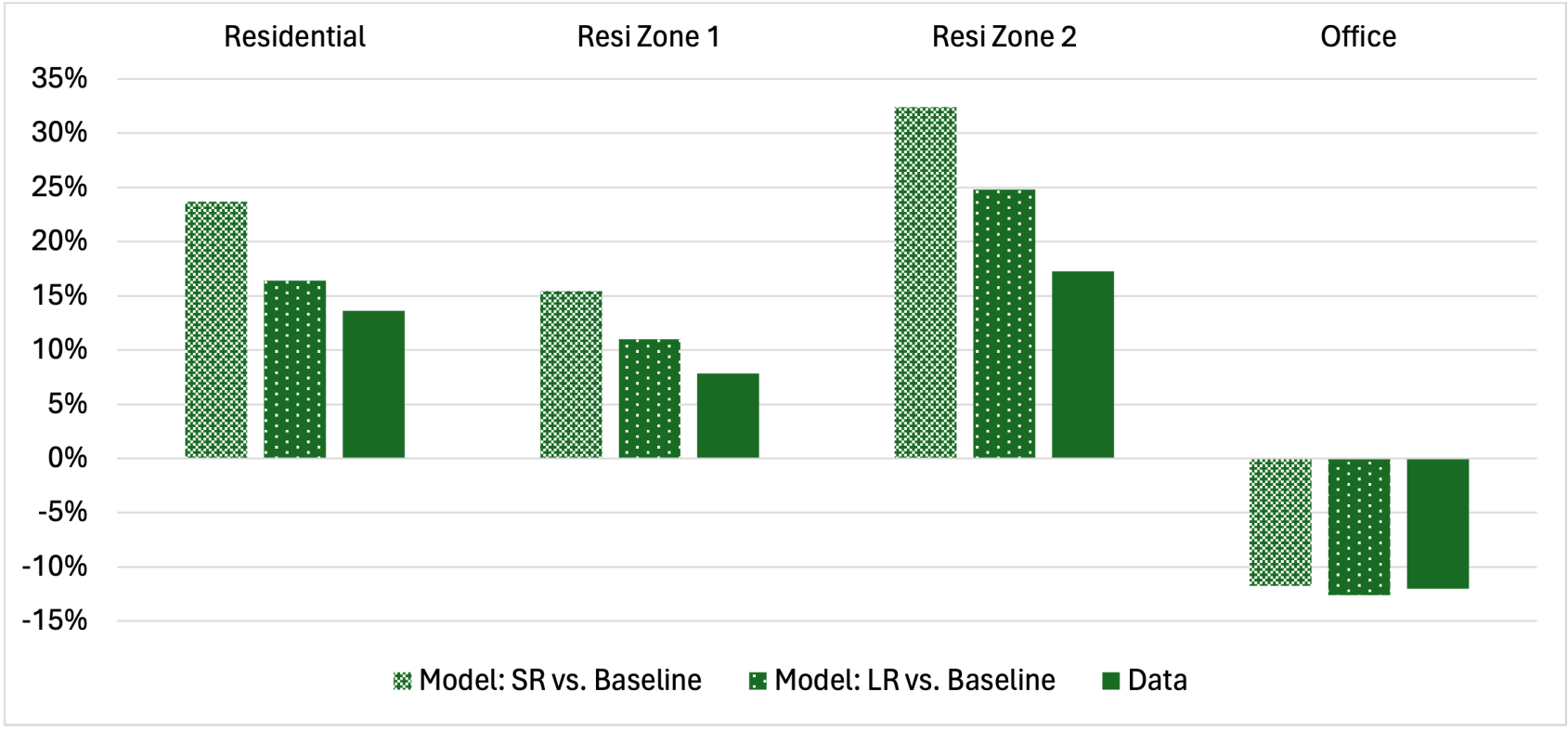
- expense sharing between landlord and tenant
- location FEs
- lease term
- total transaction square footage

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

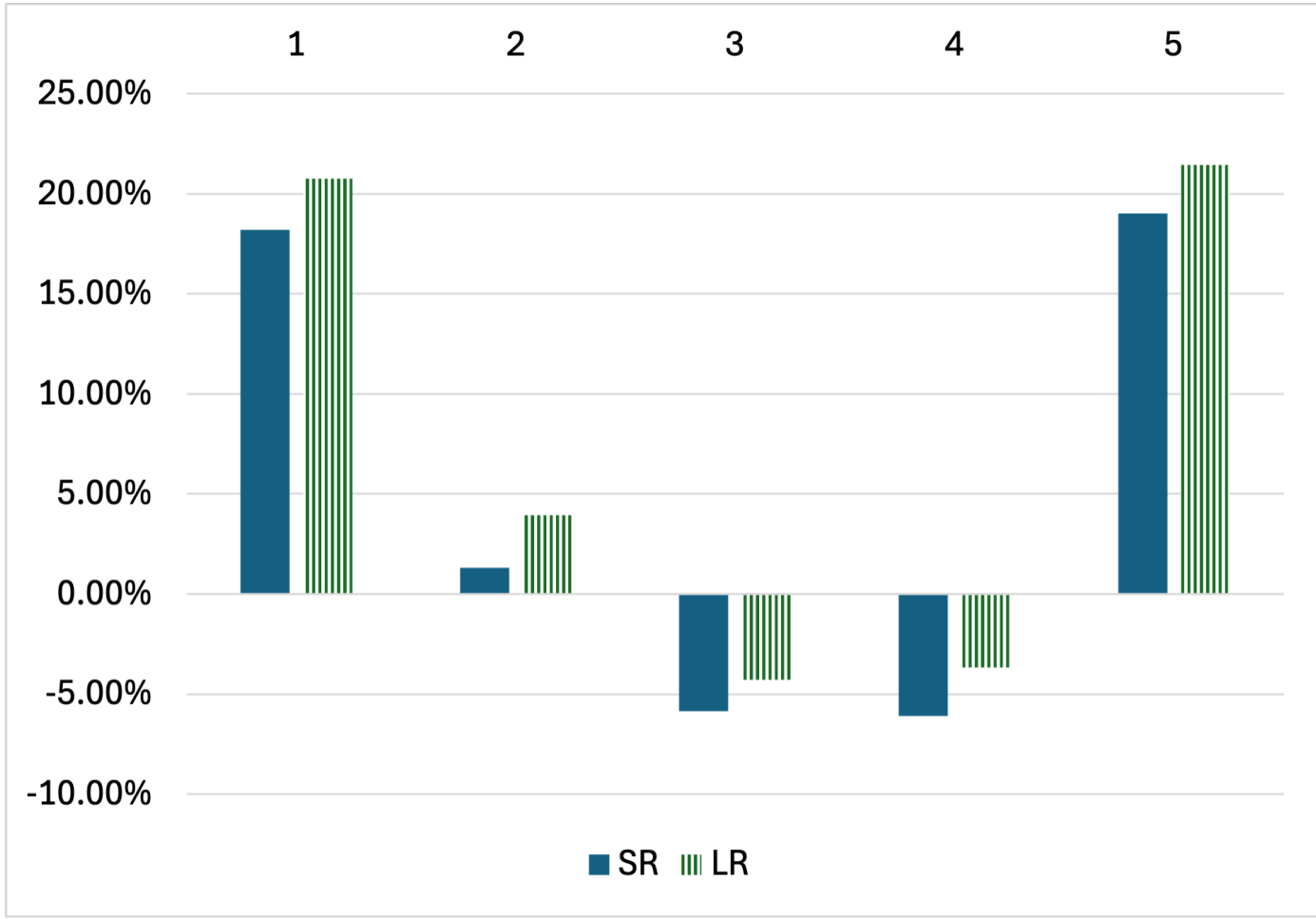
Tightly estimated decline of 12-14% in real office rents

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 (% of Consumption) by Type



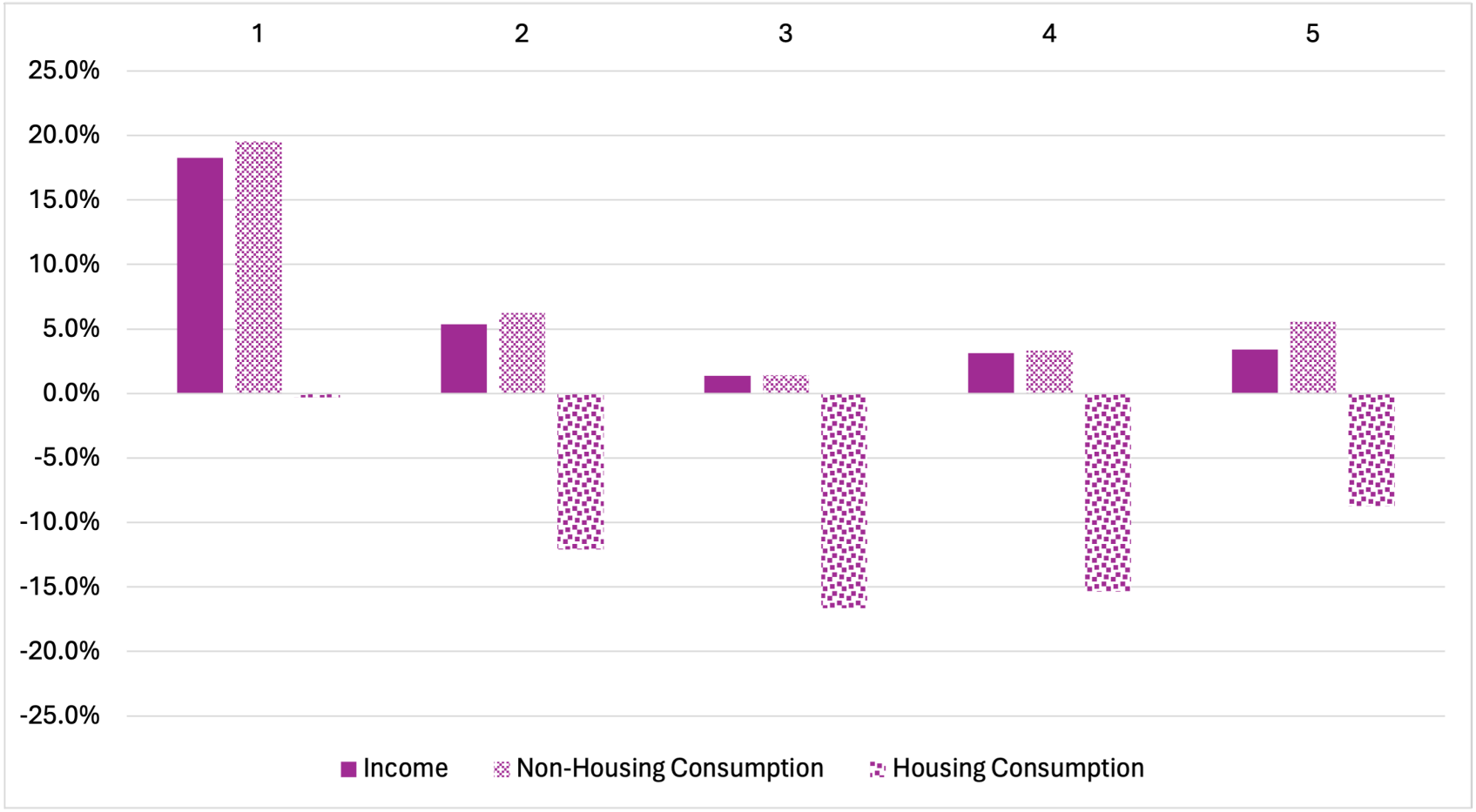
Notes: 1) A type 5 worker is a worker in an IT occupation. 2) Types 1 and 2 are in telecommutable occupations other than IT occupations. 3) Types 3 and 4 are in non-telecommutable occupations. 4) Types 1 and 3 have educational attainment of a four-year degree or greater.

Welfare Losses for Workers in Non-telecommutable Occuaptions

- Have to consume housing and housing has gotten much more expensive
  - Loss comes despite them being able to relocate to cities and areas within cities with cheaper housing

- Benchmark LR welfare losses:
  - Type 3 (college-educated): equivalent to 4.3% of consumption
  - Type 4: equivalent to 3.7% of consumption
  - Bigger loss for Type 3 than for Type 4 because of $\downarrow$ in agglomeration economies in production for work at the office for them because of large $\uparrow$ in WFH

Model LR Income and Consumption Changes

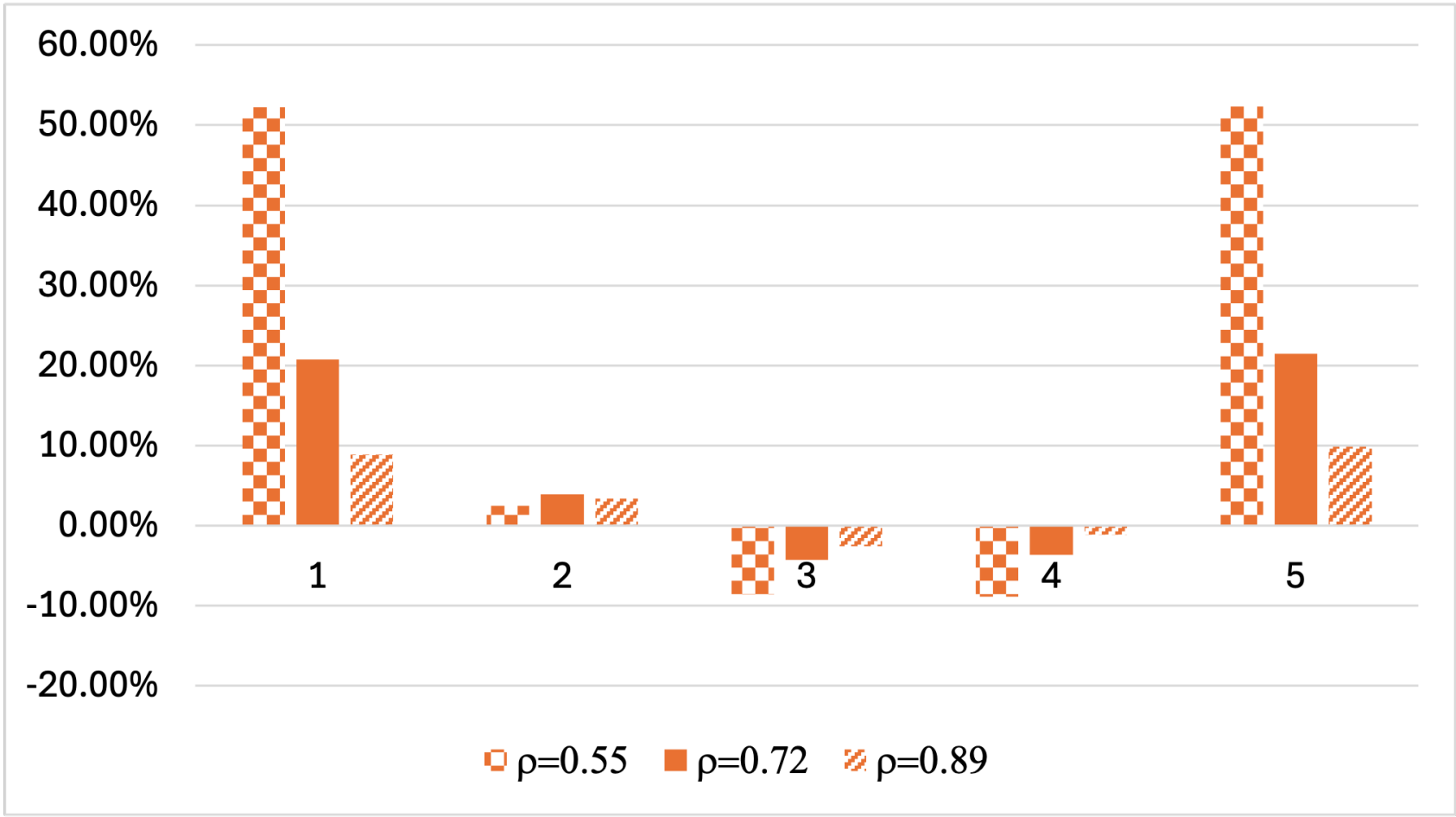


Everyone substitutes away from housing because some housing now used in production

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

Effect of Substitutability of WFH with Work at the Office



Higher $\rho \implies$ WFH more substitutable with work at the office so smaller increase in TFP (and therefore income) to increase WFH

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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