The Work-from-Home Technology Boon and Its Consequences

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What We Do

- Pre-COVD:

  Full time, college-educated workers spent 8.7% of days WFH (standard error of 20.9)%

- Post-COVID:

  Surveys indicate an expected tripling or quadrupling

- We use a calibrated/estimated model to:
  - Explain pre- and post-COVID change in time allocation
  - Predict post-COVID changes to wages, prices, urban form

Some Findings

- EOS ≈ 5 of WFH and working at the office in production
- Productivity of WFH rose $\approx 46\%$ during COVID
- CBD office rents to fall by 15%
- Long-term increase in WFH greater than immediate post-pandemic change
- Increased demand for housing in suburbs by 10 - 20 percent
- 8% increase in measured income inequality (3% increase in consumption inequality) between low- and high-skill labor

Urban Model with WFH

- Two residential locations ($n = 1, 2$) and a CBD
- Two types of workers, low- and high-skill
- Workers are identical except along one dimension:
  - Low-skill workers work at the office and commute to CBD
  - High-skill workers choose how to allocate time between working at office and WFH; they also choose office space at home and at CBD

Low-Skill Workers (type 0)

- Utility for low-skill agent i at residential location n:

$$\nu\Big[\underbrace{\log\chi_n^0}_{\text{amens}} + \underbrace{(1-\alpha)\log c_n^0}_{\text{consum}} + \underbrace{\alpha\log h_n^0}_{\text{hous}} + \underbrace{\phi\log\ell_n^0}_{\text{leisure}}\Big] + \underbrace{e_{ni}}_{\text{shks}}$$

- Budget and time constraints:

$$\begin{aligned} w^0 b_n &= c_n^0 + r_n h_n^0 \\ 1 &= \ell_n^0 + (1+t_n)\, b_n \end{aligned}$$

  - r_n is rental price per unit of housing
  - w^0 is wage rate
  - b_n is days spent working at CBD
  - t_n is commute time per day

- e_{ni} drawn IID extreme value; ν scales shocks

High-Skill Workers (type 1)

- Utility for high-skill agent j at residential location n:
  (same as low skill)

$$\nu\Big[\underbrace{\log\chi_n^1}_{\text{amens}} + \underbrace{(1-\alpha)\log c_n^1}_{\text{consum}} + \underbrace{\alpha\log h_n^1}_{\text{hous}} + \underbrace{\phi\log\ell_n^1}_{\text{leisure}}\Big] + \underbrace{e_{nj}}_{\text{shks}}$$

- Budget and time constraints:
  (must choose allocation of time and space for office at home and firm)

$$\begin{array}{rcccccc} w^1 y_n & = & c_n^1 & + & r_n h_n^1 & + & \left(r_n s^h + r^b s^b\right) \\ 1 & = & \ell_n^1 & + & (1+t_n)\, l_n^b & + & l_n^h \end{array}$$

- l_n^b and l_n^h are days worked at the office and at home
- s^b and s^h are office space and home-office space
- What is y_n (y earned in location n).... ?

High-Skill Worker Income (type 1)

- Each unit of y is paid w^1
- y is a CES aggregate of home and firm effective hours

$$y_n = \left[\left(y_n^b\right)^\rho + \left(y_n^h\right)^\rho\right]^{1/\rho}$$

- Effective hours are produced using space and time

$$\text{Effective firm hours:} \quad y_n^b = A^b \left(s_n^b\right)^\theta \left(l_n^b\right)^{1-\theta}$$

$$\text{Effective home hours:} \quad y_n^h = A^h \left(s_n^h\right)^\theta \left(l_n^h\right)^{1-\theta}$$

TFP Space Time

Closing the Model

1. Aggregate low-skill hours and high-skill output are complements in production.

2. We allow for (a) agglomeration in TFP at the office and (b) adoption-effects on TFP at home

3 We allow a congestion externality: commute time depends on number of workers commuting

Equilibrium

- An equilibrium is a vector of wages and rents:
  - Low- and high-skill wages: w^0 and w^1
  - Office rent per sf (CBD): r^b
  - Housing rent per sf (Zones 1 and 2): r_1 and r_2
- such that
  - Low- and high-skill workers optimally choose where to live, hours, space, non-housing consumption, and housing services
  - The markets for space and labor clear

Calibration and Estimation Strategy

- High-skill workers = workers with four-year degree
- Two residential zones: inner suburbs and outer suburbs
- Parameter strategy:
  - Use model FOC to estimate ρ using micro data
  - For some other parameters, use estimates from other studies
  - For remaining parameters, use Method of Moments

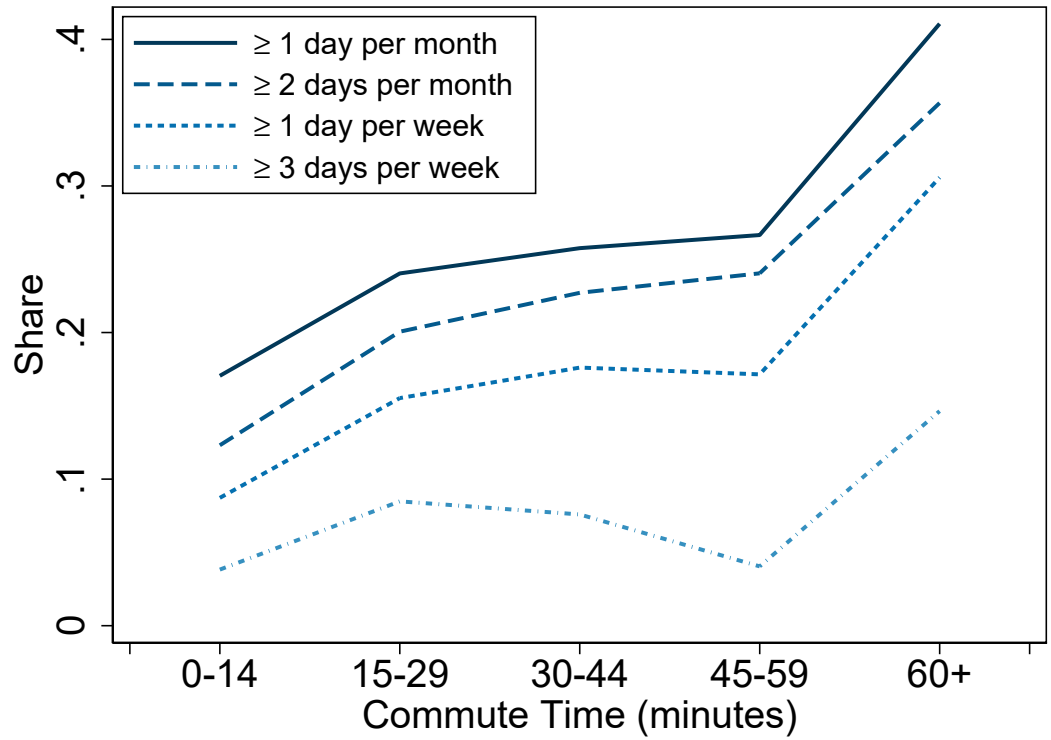
Estimating ρ

Model FOC: at any given location

$$\log\left(l^b/l^h\right) = \frac{\rho}{1-\rho}\log\left(A^b/A^h\right) - \frac{\rho\theta}{1-\rho}\log\left(r^b/r\right) - \frac{(1-\rho\theta)}{1-\rho}\log\left(1+t_n\right)$$

- Estimate this equation using data from Current Population Survey (CPS), American Time Use Survey (ATUS), and 2017-2018 module Leave and Job Flexibility (LJF)
  - LJF module: fraction of days respondents commute to work
  - ATUS: commute times
  - CPS: demographics and occupation
- Denote Ψ as the coefficient on $\log\left(1+t_n\right)$. Estimate Ψ using GMM, correcting for measurement error in commute times

Work at Home Frequency and Commute Times



Work at Home increases with Commute Times

GMM Estimates of the Elasticity of Substitution

Columns (6)-(9) correct for measurement error

			with Analytic Bias Correction			
			$\rho_e = 0$	$\rho_e = 0.1$	$\rho_e = 0.25$	$\rho_e = 0.50$
	(1)	(2)	(6)	(7)	(8)	(9)
log(1+t)	-2.63**	-2.78**	-3.85**	-4.02**	-4.41**	-6.22**
	(1.21)	(1.20)	(1.66)	(1.74)	(1.91)	(2.69)
Implied ρ	0.67	0.69	0.78	0.79	0.81	0.86
EOS	2.99	3.18	4.47	4.68	5.16	7.37
Demographics	no	yes	yes	yes	yes	yes
Ind. FEs	no	yes	yes	yes	yes	yes
Occ. FEs	no	yes	yes	yes	yes	yes
N	1,771	1,771	1,771	1,771	1,771	1,771

ρ_e is the assumed value of the correlation between the measurement error in the two commute times

Parameters from Other Studies

- $\alpha^0 = 0.33$, $\alpha^1 = 0.2$: housing expenditure shares
- $\nu^0 = \nu^1 = 3.3$: importance of location-specific draws to utility
- $\theta = 0.18$: structures share in production
- $\omega = 0.33$: EOS between low- and high-skill labor is 1.5
- $\delta_b = 0.04$: strength of agglomeration economies in CBD
- $\gamma = -0.15$: elasticity of driving speed wrt aggregate commuting miles

Targeted Moments given Zone Definitions

1. Commute time from Zone 1: 30 min each way (t_1)
2. Commute time from Zone 2: 50 min each way (t_2)
3. Share of low-skill workers living in Zone 2 (χ_2^0)
4. Share of high-skill workers living in Zone 2 (χ_2^1)
5. Age-adjusted income of high-skill relative to low-skill: 1.8 (λ)
6. Share of work-at-home for high-skilled: 10% (A_h)

Rents

Matched to relative values for NYC Core-Based Statistical Area (CBSA) given availability of prices per square foot at the county-level

- r^b rent per sf on Manhattan office space: set to 1
- r_1 residential rent per sf in counties next to Manhattan: 0.35
- r_2 residential rent per sf in NYC counties not adjacent: 0.24

Pre-pandemic – find quantities of structures in zone 1, zone 2, CBD such that market for space clears in each zone at r^b, r_1, r_2.

Post-Pandemic Counterfactuals

1. SR: Supply of space fixed to baseline in CBD, Zone 1, Zone 2; prices adjust

2. LR: Price of space fixed to baseline in CBD, Zone 1, Zone 2; quantities adjust

3. LR Putty-Clay:

    - Supply of space fixed in CBD to baseline and price adjusts
    - Rents fixed to baseline in zones 1 and 2 and quantities adjust

Productivity and Hours Worked

	Base	SR	LR	LR Putty-Clay
Productivity:				
A^b	0.94	0.93	0.93	0.93
A^h	0.37	0.54	0.54	0.54
Share high-skill hours worked at home:				
$\frac{l^h}{l^h+l^b}$	0.10	0.30	0.35	0.32

- If hours worked at home triples from 0.10 to 0.30, given $\rho = 5$ this implies increase in A^h of 46% (0.37 to 0.54) during pandemic.
- Hours worked at home has further endogenous increase as supply of space in residential zones increases

Relative Rents and Demand for Space Post-COVID

	Pre-COVID	SR	LR	LR Putty-Clay
Rents:				
CBD	1.00	0.85	1.00	0.84
Zone 1	0.35	0.38	0.35	0.35
Zone 2	0.24	0.28	0.24	0.24
Demand for Space:				
Office Space in CBD	0.36	0.36	0.29	0.36
Aggregate Space in Z1	1.95	1.95	2.10	2.11
Home Office per High-Skill in Z1	0.25	0.77	0.96	0.89
Other Housing per High-Skill in Z1	3.17	3.03	3.28	3.34
Housing per Low-Skill in Z1	2.97	2.79	3.04	3.07
Aggregate Space in Z2	1.63	1.63	1.95	1.94
Home Office per High-Skill in Z2	0.54	1.47	1.93	1.80
Other Housing per High-Skill in Z2	4.36	4.11	4.68	4.75
Housing per Low-Skill in Z2	4.03	3.63	4.13	4.17

- CBD rents fall by 15% in SR and 16% in LR Putty-Clay
- Residential rents rise 9% in Zone 1 and 17% in Zone 2 in SR due to increased demand for home office space

Incomes and Residential Sorting Post-COVID

	Pre-COVID	SR	LR	LR Putty-Clay
Incomes:				
High- / Low-Skill Income	1.80	1.92	1.93	1.94
High-Skill Income	5.52	6.10	6.07	6.15
Low-Skill Income	3.07	3.17	3.15	3.18
Residential Sorting:				
% High-Skill in Z1	59%	58%	56%	57%
% High-Skill in Z2	41%	42%	44%	43%

- Income rises for all workers but income inequality widens:
  - Fundamental: Increase in A^h only for high-skill workers
  - Accounting: Shift in payments from CBD office space, not measured as wages, to home-office space, measured as wages
- Decrease in high-skill workers living near CBD

Identifying Adoption Effects

- We find that A_h increases by 46% during the pandemic
- Estimates are that home hours of high-skill were as high as 80% during the pandemic
- We specify $A_h = \bar{A}^h \left(L_h^{max}\right)^{\delta_h}$
- Under the assumption that technology did not change much in $\approx$ one year, i.e. $\bar{A}^h$ is fixed, this identifies adoption effects (δ_h)

$$\begin{aligned} A_h^{new} &= 0.543 = \bar{A}^h \left(0.59\right)^{\delta_h} \\ A_h^{old} &= 0.371 = \bar{A}^h \left(0.07\right)^{\delta_h} \end{aligned}$$

$$\rightarrow \delta_h = 0.18$$

- 10% increase in total number of hours worked from home raises TFP at home by 1.8%

Conclusions

- Pandemic accelerated growth in A^h, working from home
- Model offers a framework to study effects of this increase
- With higher productivity of work-at-home, expect
  - CBD office rents to fall
  - Increased demand for housing in suburbs, especially for home office space
  - Large increase in measured income inequality