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Working from home: Too much of a good thing?[☆]

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ABSTRACT

We develop a general equilibrium model with skilled workers who can and unskilled workers who cannot work from home (WFH). Firms choose the amount of time they require workers in the office, whereas workers choose to either work on-site or hybrid, splitting working time between office and home. The endogenous work arrangements determine productivity, wages, and demand for residential and commercial real estate. We find that firms 'outsource' workers to their homes to save on real estate costs, and in doing so push beyond the WFH share that maximizes skilled workers' productivity. This effect is more pronounced if land-use regulations are strict, thus showing another channel through which the latter may reduce productivity. More efficient information and telecommunication technologies allow firms to shift office expenditures toward skilled workers who invest more in home working space. In a nutshell, WFH may well be the 'new margin of offshoring' for firms.

1. Introduction

Since widespread teleworking is becoming a permanent feature of the economic landscape, our societies might experience a systemic shock whose consequences are still unclear (Aksoy et al., 2023; Bick et al., 2023; Criscuolo et al., 2023; Smite et al., 2023). For example, studying data from January 2019 to November 2022 for 62 cities of at least 350,000 people across the United States and Canada, Chapple et al. (2023) calculated a Recovery Quotient (RQ) for the corresponding downtowns and found that the RQ is below 75 percent for most large cities in December 2022. In New York, office vacancies hit a record high of 22.7 percent in May 2023 amid remote work.[1]

While a growing number of empirical contributions study the effects of teleworking, theoretical papers are few and far between. This is partly due to the fact that working-from-home (WFH, hereafter) has multiple facets and is thus hard to model. Our paper aims to partly fill this gap by providing a full-fledged general equilibrium model in which we can trace out the possible aggregate long-run effects of WFH. More specifically, the core goal is to study how firms and workers choose their WFH shares and how these choices affect the efficiency of firms, as well as workers' well-being and the economy as a whole.

What are the main features theory needs to take into consideration? First, it is a robust empirical fact that WFH affects the skilled and the unskilled differently. Although there are exceptions (think of call centers), telework characterizes predominantly skilled workers (Dingel and Neiman, 2020; Adams-Prassl et al., 2022; Kawaguchi and Motegi, 2021). This point has been amply scrutinized during the recent COVID pandemic. Hence, to trace out the productivity and distributional effects of WFH, we need a model with skilled workers who can and less-skilled workers who cannot work remotely.

Second, by its very nature, teleworking is bound to have profound effects on labor markets, changing the distribution of both labor supply and demand, as well as workers' productivity. Starting with individual productivity, whether WFH makes workers more or less productive remains an open question. While Bloom et al. (2015) document that the productivity of some workers increased due to telework in China, Morikawa (2022, p.508) finds for Japan that "*the mean WFH productivity relative to working at the usual workplace was about 60%–70%, and it*

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was lower for employees and firms that started WFH practice only after the spread of the COVID-19 pandemic."[2] Likewise, studying a large Asian IT services company, Gibbs et al. (2023) find that the average effect of WFH on productivity was negative and substantial. We thus require a model in which the work arrangements between firms and workers affect worker productivity, and where that productivity could be higher or lower at home than in the office.

Third, teleworking is also bound to have profound effects on real estate markets. Stanton and Tiwari (2021) show that prior to the pandemic, wired workers spent 7 percent more on housing than similar on-site workers living in the same commuting zone. The very recent trend toward more suburbanization in several US metropolitan areas and in Greater London suggests that the additional demand for space is key in the residential choices made by a growing number of households (Liu and Su, 2021; Gokan et al., 2022; Brueckner et al., 2023; Van Nieuwerburgh, 2023). Likewise, firms' space requirements are strongly reduced (Gupta et al., 2022). Studying the impact of teleworking on corporate real estate in France, Bergeaud et al. (2023) find that a one standard deviation increase in teleworking would translate into a price decline of 1.35 percent. As a result, the markets for land and buildings must occupy center stage in a work that aims to assess the economy-wide effects of teleworking.[3] Given the central role of land and building markets, we also need to understand of how locales with different land supply elasticities are affected.

Studying how the above effects interact to shape the economy requires a *general equilibrium* setting. To achieve our goal, we develop a model with three primary production factors – land, skilled, and unskilled labor – and two sectors – the construction sector that supplies buildings to firms and workers, and the consumption sector that supplies a range of differentiated varieties to consumers. Hence, there is competition for land between different types of agents through the construction sector. Skilled workers can work in the office full time or at home a variable share of time that is endogenously determined. These hybrid workers face the following trade-off: when they work home, they save on their commuting expenditure but spend more on housing because they need addition space for professional tasks.

We do not know yet who will choose the actual value of the WFH share and how it will be chosen. It is likely to differ across countries, due to different institutional contexts (e.g., labor laws and trade unions), and sectors, due to their skill intensity and the types of jobs they offer. Even though hybrid solutions seem to emerge, it remains unclear how the labor arrangements will be settled down.

In this paper, we distinguish between firms' WFH share and workers' WFH share, and model the choices of those shares as a two-stage game. In the first stage, firms choose non-cooperatively the amount of time they need their workers in the office and thus the amount of time they want their skilled workers as a whole to work home. In the second stage, workers choose non-cooperatively either to work on-site or a hybrid solution in which they freely split their working time between office and home. In equilibrium, the desiderata of firms and workers must match. We show that there are two types of equilibria. In the first one, some skilled workers choose to work on-site while the others choose a hybrid solution. By arbitrage, the number of hybrid workers is such that on-site and hybrid workers are equally well-off. The second equilibrium arises when all skilled workers choose a hybrid labor arrangement such that the time share they spend home is equal to the time share chosen by firms.

Our key results can be summarized as follows. First, we show that *firms always choose a WFH share that exceeds the share which maximizes skilled workers' productivity because this allows firms to reduce their expenditure on floor space*. Stated differently, firms are willing to 'outsource' workers to their home offices to save on costly real estate, and in doing so push beyond the WFH share that maximizes skilled workers' productivity. This suggests that WFH may reduce productivity, a result that echoes empirical findings by Morikawa (2022) and Liu and Su (2023). Second, a more elastic land supply reduces the cost of office space relative to the skilled wage. As a result, firms have less incentives to outsource workers to their homes because savings in land rents are lower compared to productivity losses. Firms thus mandate a lower WFH share. This, in turn, implies that some hybrid workers must switch to a full-time office regime to meet the constraint set by firms, so that *there are fewer hybrid workers when the land supply is more elastic*. Furthermore, a lower WFH share for firms increases the productivity of skilled workers, thus reducing the inefficiency of too much WFH. This finding highlights another, hitherto unnoticed, channel through which land use regulations may be damaging to the economy by reducing productivity (Hilber and Vermeulen, 2014; Hsieh and Moretti, 2019).

Third, when information and communication technologies (ICT, henceforth) are not very efficient, firms choose a small WFH share and workers are better off when the WFH share remains relatively small. This may explain why WFH has not yet been implemented on a large scale. Furthermore, ICT improvements – a likely scenario – lead firms to choose a WFH share that diverges more and more from the efficiency-maximizing one. This in turn leads more workers to choose to be hybrid. In other words, a growing efficiency in ICT incentivizes firms to outsource more work time to workers' homes because skilled labor becomes cheaper relative to the value of office space. As a result, skilled workers must spend more on housing. In a nutshell, *WFH and efficient ICT allow firms to transfer some of their office expenditures toward skilled workers who must invest more in home working space, thus making all workers worse-off*.

Fourth, the impact of commuting costs is different because commuting costs are a mere loss for skilled workers whereas ICT affects not only the skilled workers' income but also their productivity. Higher commuting costs make office space cheaper relative to skilled labor. As a result, firms raise their share of on-site working hours, which increases skilled workers' productivity. Thus, higher commuting costs act as an efficiency-improving device. Finally, fewer workers choose to be hybrid in response to higher commuting costs.

Developing a full welfare analysis in an economy with workers who differ in their marginal utility of income is a challenging task (Charlot et al., 2006). Our analysis shows that WFH may be desirable for one group of workers but not for the other. Furthermore, how skilled and unskilled workers are affected depends on several parameters such as the elasticity of the land supply, the efficiency of ICT, and the level of commuting costs. Assessing the impact of WFH on each group of workers is, therefore, problematic. We may at least conclude by saying that small WFH shares are desirable ("a good thing"), whereas high shares are detrimental to the economy by reducing its overall productivity and welfare ("too much of a good think").

Related literature. While the management and psychology literature on telecommuting is mounting – the survey by Allen et al. (2015) includes about 200 references – the economic theory literature on teleworking and cities was meager prior to the COVID-19 pandemic. Safirova (2002) extends the monocentric city model to account for telecommuting but provides only numerical solutions. Rhee (2008) studies the trade-off between working time and leisure and shows that most of the commute time saved by WFH is allocated to work rather than leisure. Closer to us, both temporally and topic-wise, a handful of theoretical papers, which

[2] At a more aggregate level, WFH might also reduce productivity through foregone agglomeration economies due to less face-to-face interactions in the workplace. In a recent study, Liu and Su (2023) find that increased WFH triggered by the COVID-19 pandemic has persistent wage effects as measured using advertized wages. These effects are especially pronounced in industries and jobs that can be done remotely, and affect particularly skill-intensive jobs that require more face-to-face interactions. These findings are consistent with a weakening of agglomeration economies.

[3] Like Brueckner et al. (2023), we model a dimensionless economy (city). However, we account for commuting costs when workers have to go to the office.

include Gokan et al. (2022), Kyriakopoulou and Picard (2023) and Monte et al. (2023), and study how WFH may affect the city structure. In our paper, we consider a macrospatial setting and focus more on the interactions between different industrial sectors and labor markets. Brueckner et al. (2023) and Brueckner and Sayantani (2023) consider two cities and study how WFH affects the relative size of the cities. They allow for mobility between cities but not for commuting within cities. Delventhal et al. (2022) calibrate a quantitative model of city structure to study what would happen in Los Angeles if teleworking becomes popular over the long run. They find that WFH fosters the spatial concentration of jobs, which agrees with Kyriakopoulou and Picard (2023) who show that a wide adoption of WFH leads to the emergence of a monocentric city. Monte et al. (2023) develop a dynamic model of a city in which workers can choose to work in the central business district or partly at home. They show the existence of two stationary equilibria in which most workers commute or most of them work partially from home. By contrast, we prove uniqueness of the equilibrium outcome. Most of the recent literature is empirical. Several papers will be cited in the main text as illustrations of our main assumptions or results.

The remainder of the paper is organized as follows. Section 2 lays out the model. Section 3 derives the equilibrium system and analyzes the equilibrium work arrangements. Section 4 establishes comparative static results with respect to the land supply elasticity, the efficiency of ICT, and commuting costs. Section 5 discusses how the equilibrium is affected by institutional constraints on the equilibrium work arrangements. Last, Section 6 concludes. We relegate most proofs and additional material to a set of (online) appendices.

2. The model

We consider a macrospatial setting with a single location. The population consists of unskilled and skilled workers and landlords. There are three primary production factors—land $\mathcal{L}$, skilled labor s (e.g., management, professional, R&D, and other non-production occupations) and unskilled labor ℓ (e.g., construction and assembly-line workers). The economy produces two goods: (i) a differentiated consumption good, made available as a continuum of varieties $x(i)$; and (ii) buildings B. The consumption sector operates under monopolistic competition and increasing returns, while the construction sector produces a homogenous good under perfect competition and constant returns.

Land is used as an input by the construction sector only, while buildings are used by workers as housing and by the final sector as an intermediate input—plants and offices. Although housing, plants, and offices are different types of buildings, we assume for simplicity that they are perfectly substitutable across uses. Land is supplied inelastically with elasticity $\mu \in [0,1]$ and is owned by landlords. The latter have only rental incomes. Since there is only one location and buildings are perfectly substitutable across uses, there is a single price for land and a single price for buildings.

2.1. Consumption

The mass of workers of type $k = \ell, s$ is given by L_k. We assume that $L_\ell > L_s$. Skilled workers are involved in creative or administrative activities, while the unskilled are employed in the production of goods. Each worker supplies inelastically one unit of her type of labor and consumes h_k units of housing and $x_k(i)$ units of variety i of the consumption good.

Preferences are Cobb–Douglas and given by

$$U_k = \gamma^{-\gamma}(1-\gamma)^{-(1-\gamma)} h_k^{\gamma} \mathbf{X}_k^{1-\gamma}, \tag{1}$$

where $\gamma \in (0,1)$ is the share of income spent on housing; h_k stands for the housing consumption; and $\mathbf{X}_k = \left[\int_0^M x_k(i)^{\frac{\sigma-1}{\sigma}} \mathrm{d}i\right]^{\frac{\sigma}{\sigma-1}}$ is a CES aggregator over the demands $x_k(i)$ for the M varieties of the consumption good, with $\sigma > 1$ the elasticity of substitution across varieties.

2.1.1. Skilled workers

Skilled workers can work from home (telecommuting) or go to the office (commuting). We thus distinguish between on-site office and remote home working. We assume that the former generates a utility loss, which we capture for simplicity in a monetary way through an iceberg commuting cost. Given the wide variety of alternative work arrangements we observe, we assume that *skilled workers are free to choose between two options: a hybrid solution* (combining part-time office and home work) *and full-time office work*.[4] In what follows, we use subscripts $s = \{r, o\}$ for remote hybrid and for full-time office workers, respectively.

When a skilled works full time in the office, her budget constraint is given by

$$p_b h_o + \int_0^M x_o(i) p(i) \mathrm{d}i = \frac{w_s}{\tau}, \tag{2}$$

where p_b is the unit price of housing; $x_o(i)$ and $p(i)$ are the demand and price for variety i of the consumption good; w_s is the endogenously determined skilled wage or an efficiency unit of labor that varies with the work arrangement in equilibrium; and $\tau > 1$ is the iceberg commuting cost that the worker incurs when commuting to the office.

Maximizing (1) subject to (2) yields the following demand functions for the housing and the consumption good of an office worker:

$$h_o = \gamma \frac{w_s}{\tau p_b} \quad \text{and} \quad x_o(i) = (1-\gamma)\frac{w_s}{\tau} \mathbf{P}^{\sigma-1} p(i)^{-\sigma}, \tag{3}$$

where $\mathbf{P} = \left[\int_0^M p(i)^{1-\sigma} di\right]^{\frac{1}{1-\sigma}}$ is a CES price index.

We assume that the efficiency of WFH depends on the available ICT. Let $\phi \geq 0$ denote the level of ICT development, which here captures the efficiency of WFH relative to working in the office. A larger ϕ corresponds to a more efficient ICT and, therefore, more efficient home working. In what follows, we normalize productivity in the office to one, so that $\phi < 1$ (resp., $\phi > 1$) denotes relatively less (resp., more) efficient WFH compared to the efficiency of face-to-face communication. The results obtained by Battiston et al. (2021) and Davis et al. (2021) suggest that face-to-face communication remains more efficient than communicating through ICT. Using a sample of 2718 Japanese employees who have different occupations and training, Morikawa (2022) observes that these workers were on average 30 percent less productive in June 2020 than before the pandemic, which could explain why Japanese employees work on average only 0.5 day per week from home (Aksoy et al., 2023). These results suggest that $\phi < 1$.

As discussed in the introduction, WFH requires additional space to perform professional tasks. As a result, a skilled worker must acquire more housing space than what she uses for personal consumption, the difference being used as a home office. Let h be the size of her home office. When a hybrid worker uses h_r units of housing for personal consumption, she must acquire $h_r + h > 0$ units of housing overall.

A hybrid worker chooses to work home a share $\theta \in (0,1]$ of her working time. Since the skilled are homogeneous, we focus on equilibria where hybrid workers choose the same share θ of home work. Given a share $1-\theta$ in the office and θ at home, and relative productivity ϕ at home, a hybrid worker gets a wage $\phi\theta w_s$ for home working and a

[4] In 2018, only 5.1 percent of the EU labor force worked home on a consistent basis (Eurostat, 2020), while full-time telecommuters in the US accounted for 3 to 8 percent of total employment (Bick et al., 2023). Even during the pandemic lock-downs we did not observe full WFH because some essential activities are required on site to organize the production processes. After the pandemic, the first best of a large share of skilled workers seems to be a hybrid solution that combines both office and home working (e.g., Barrero et al., 2021; Bergeaud et al., 2023; Smite et al., 2023). Yet, in some countries and industries, workers are back full-time in the office.

wage $(1-\theta)w_s/\tau$, net of commuting costs, when working in the office. Her budget constraint is then given by

$$p_b h_r + \int_0^M x_r(i)p(i)di = \left(\frac{1-\theta}{\tau} + \phi\theta\right) w_s - p_b h. \tag{4}$$

Note the difference between the disposable income of an office worker, $\omega_o = w_s/\tau$, and that of a hybrid worker, $\omega_r = \left[(1-\theta)/\tau + \phi\theta\right] w_s - p_b h$. This shows that a skilled worker faces the following trade-off: *when she opts for a hybrid solution, she bears the additional housing cost $p_b h$ and productivity losses $\phi < 1$, but saves $\theta(1-1/\tau)w_s$ on her commuting expenditure*.

Maximizing (1) subject to (4) then yields the following demand functions for housing and consumption goods for the hybrid workers:

$$h_r = \frac{\gamma}{p_b}\left[\left(\frac{1-\theta}{\tau} + \phi\theta\right) w_s - p_b h\right] \quad \text{and}$$
$$x_r(i) = \frac{(1-\gamma)}{p(i)^\sigma}\left[\left(\frac{1-\theta}{\tau} + \phi\theta\right) w_s - p_b h\right]\mathbf{P}^{\sigma-1}. \tag{5}$$

How do hybrid workers determine the size h of their home office? In our setup,workers do not derive utility from their home-office space h. In what follows, we assume that the additional space used for work purposes is given by a share $\kappa > 0$ of a hybrid worker's housing space, that is, $h = \kappa h_r$, where $\kappa \in (0,1)$ is a scale parameter such that $h \ll h_r$.[5]

Substituting $h = \kappa h_r$ into (5) and solving for h_r and $x_r(i)$ yields the following demand functions:

$$h_r = \frac{\gamma}{(1+\gamma\kappa)p_b}\left(\frac{1-\theta}{\tau} + \phi\theta\right) w_s \quad \text{and}$$
$$x_r(i) = \frac{1-\gamma}{1+\gamma\kappa}\left(\frac{1-\theta}{\tau} + \phi\theta\right) w_s \mathbf{P}^{\sigma-1} p(i)^{-\sigma}. \tag{6}$$

Plugging (3) and (6) into (1) we finally obtain the indirect utilities of office and hybrid workers:

$$V_o = \frac{w_s}{\tau p_b^\gamma \mathbf{P}^{1-\gamma}} \quad \text{and} \quad V_r = \frac{1}{1+\gamma\kappa}\frac{[1+\theta(\phi\tau-1)]\, w_s}{\tau p_b^\gamma \mathbf{P}^{1-\gamma}}. \tag{7}$$

Since V_r increases with θ when $\phi\tau > 1$, the latter must hold for skilled workers to find home working desirable. In other words, losses associated with office work, $1/\tau$, must be lower than the WFH efficiency relative to office work ϕ. If ICT are inefficient and/or commuting inexpensive, the skilled workers prefer to work full-time in the office. We thus assume that $\phi\tau > 1$ always holds, that is, the efficiency gains associated with the use of ICT overcome the commuting effect. Hence, *the hybrid workers want to raise their WFH share to reduce their commuting*.

Last, using (7), the relative utility of a hybrid vs a full-time office worker is given by

$$\frac{V_r}{V_o} = \frac{1+\theta(\phi\tau-1)}{1+\gamma\kappa}. \tag{8}$$

2.1.2. Unskilled workers

Unskilled workers are assumed to work full time on-site. Hence, their budget constraint is

$$p_b h_\ell + \int_0^M x_\ell(i)p(i)\mathrm{d}i = \frac{w_\ell}{\tau_\ell},$$

where w_ℓ/τ_ℓ is their wage net of commuting cost τ_ℓ. We assume that $\tau > \tau_\ell \geq 1$, i.e., the unskilled spend a larger share of their income for commuting.[6] Without loss of generality, we normalize $\tau_\ell \equiv 1$ in what follows.

The demand functions of an unskilled worker are given by

$$h_\ell = \gamma\frac{w_\ell}{p_b} \quad \text{and} \quad x_\ell(i) = (1-\gamma)w_\ell \mathbf{P}^{\sigma-1}p(i)^{-\sigma}. \tag{9}$$

Plugging (9) into (1) then yields the following indirect utility:

$$V_\ell = \frac{w_\ell}{p_b^\gamma \mathbf{P}^{1-\gamma}}. \tag{10}$$

As (9) and (10) show, there is no direct effect of teleworking on the unskilled since neither of these two expressions depends on the work arrangements θ. However, through general equilibrium effects, the unskilled welfare will vary with θ as the prices of goods and housing, as well as the unskilled wage, adjust to clear markets.

2.1.3. Landowners

The last type of agent are the landowners, who do not work and derive rental income from their land endowments. They sell (or rent) land to the construction sector so that their income is given by the total rent they collect from that sector. Let R denote the price (land rent) of one unit of land. Then, the aggregate income of landowners is equal to the aggregate land rent $ALR = R\mathcal{L}$, where $\mathcal{L}$ is the quantity of developed land used by the construction sector. To keep the analysis tractable, we assume that landlords have the same preferences as the other types of workers. In other words, they spend a share γ of their aggregate income on housing and a share $1-\gamma$ of their aggregate income on the consumption good.

2.2. Production

We now turn to the production side of the economy.

2.2.1. Buildings

We assume that the supply of land is given by

$$\mathcal{L} = B^\mu, \tag{11}$$

where $\mu \in [0,1]$ is the land supply elasticity in the economy. This means that the amount of land available for development, $\mathcal{L}$, increases with the output of the construction sector, B, i.e., a higher demand for buildings increases the amount of land used for development. A low value of μ implies an inelastic land supply like in areas characterized by either strong land-use regulations (Glaeser et al., 2005), or difficult topography (Saiz, 2010), or both. A high value of μ means that the land supply is more elastic, perhaps because there is still a large amount of undeveloped land or because land-use regulations are lax.

The demand for buildings stems from two types of buyers, consumers (who buy houses, B_h) and firms (which buy offices and plants, B_f). For simplicity, we assume that buildings are perfectly fungible. Therefore, the output of the construction sector is given by $B \equiv B_h + B_f$, where $B_h = L_\ell h_\ell + L_s h_s + \gamma ALR/p_b$ is the total residential housing demand, while B_f is the total commercial demand for buildings.

Following Glaeser et al. (2005), the construction sector is assumed to be perfectly competitive. As in Combes et al. (2021), we consider a Cobb–Douglas production function $B = \delta^{-\delta}(1-\delta)^{-(1-\delta)}\mathcal{L}^\delta L_b^{1-\delta}$, where δ denotes the cost share of land and L_b is the quantity of unskilled

[5] Usually, a home office is an additional room the worker reserves for work at home. Since rooms are arguably larger in larger houses and apartments, the assumption that h increases with h_r seems plausible to us. An increasing size of home office with respect to h_r, which is itself increasing in income, would also obtain if we would model a consumption value of a larger home office or a productivity benefit. It is more comfortable and efficient to work in a larger room than in a small room or a room not devoted to home office (such as a bedroom).

[6] It is known that commuting is more costly for the more skilled because the opportunity cost of time increases with income, which is in line with empirical evidence (Small, 2012). Furthermore, skilled workers are likely to opt for high fixed cost modes of transportation – e.g., the car – which can make their commuting even more costly.

labor used in the construction sector.[7] The marginal cost thus equals $c_b = R^{\delta} w_{\ell}^{1-\delta}$.

The land rent is determined by the land market clearing condition:

$$B\frac{\partial c_b}{\partial R} = \mathcal{L}, \tag{12}$$

where $\partial c_b/\partial R$ is the amount of land required to produce one unit of building. Equalizing (11) and (12) yields $\delta\left(w_{\ell}/R\right)^{1-\delta} B = B^{\mu}$, which can be solved for the equilibrium land rent as a function of the construction sector's output:

$$R = \delta^{\frac{1}{1-\delta}} w_{\ell} B^{\frac{1-\mu}{1-\delta}}. \tag{13}$$

Combining (11) and (13) yields the land supply function $\mathcal{L}(R) = [(1/\delta)\left(R/w_{\ell}\right)^{1-\delta}]^{\mu/(1-\mu)}$, which increases with the land rent when $\mu \in (0,1)$. The elasticity of the land supply function also increases with μ.

Perfect competition in the construction sector implies marginal cost pricing, i.e.,

$$p_b = w_{\ell}^{1-\delta} R^{\delta} = \delta^{\frac{\delta}{1-\delta}} w_{\ell} B^{\frac{(1-\mu)\delta}{1-\delta}}. \tag{14}$$

Using expression (14), the aggregate land rent is then given by

$$ALR = R\mathcal{L} = \delta B p_b. \tag{15}$$

To sum up, both the price of buildings and the price of land increase with the output B when $\mu < 1$. By contrast, when the land supply is perfectly elastic ($\mu = 1$), p_b and R are independent of the output B because the demand for land is exactly matched by an increase in land supply.

2.2.2. Consumption good

The consumption sector produces a continuum of horizontally differentiated varieties under monopolistic competition and increasing returns, using skilled labor, unskilled labor, and buildings. As is standard in such a setting, each firm produces a single variety and each variety is produced by a single firm. In line with trade and endogenous growth models, we assume that a firm hires skilled workers to design a variety, which is then produced using unskilled labor and buildings. Hence, skilled workers' wages can be viewed as the firms' fixed costs.

Fixed costs. In conducting non-production activities, a firm i combines skilled home and office labor. Firm i hires L_s^i skilled workers and can mandate a share $1-\beta_i$ of work that the skilled have to perform in the office (for example, 'critical tasks' that require on-site presence). We assume that one unit of office work requires one unit of office space. Hence, for any given $\beta_i \in [0,1]$ and mass of skilled workers L_s^i, firm i must provide $(1-\beta_i)L_s^i$ units of office space to accommodate its office workers. An increase in β_i thus allows the firm to reduce its space usage by 'outsourcing' skilled workers to their homes. Since firms are homogeneous, we focus on equilibria where firms choose the same share β of home work. For notational simplicity, we thus omit subscript i.

If office cost savings were the only consequence of WFH, firms would minimize their costs by mandating full-time WFH. Yet, WFH also induces changes in productivity as workers learn from more skilled co-workers through face-to-face contacts (Battiston et al., 2021; Jarosch et al., 2021). In what follows, we capture these aspects by assuming that skilled home and office labor are imperfect substitutes, which are aggregated at the firm level via a homothetic transformation function T. Let ρ be the share of hybrid workers who work home a share θ of their working time, so that $1-\rho$ is the share of workers who work full time in the office. We assume that for a WFH share θ of hybrid workers and ICT technology ϕ, the number of efficiency units of labor supplied by skilled workers is given by

$$\begin{aligned} T(\theta,\phi,L_s) &\equiv f[\phi\theta\rho L_s, (1-\rho)L_s + (1-\theta)\rho L_s] \\ &= f[\phi\theta\rho, (1-\rho)+(1-\theta)\rho]L_s. \end{aligned} \tag{16}$$

Since ϕ is the productivity of a hybrid worker at home, $\phi\theta\rho L_s$ stands for the total number of efficiency units of skilled labor provided at home. As for $(1-\rho)L_s$ and $(1-\theta)\rho L_s$, they denote the number of efficiency units provided by full-time office workers and hybrid workers when they work on-site.

In equilibrium, the share ρ of hybrid workers, their share θ of hours worked at home, and the share $1-\beta$ of office work mandated by firms are related as follows: the total supply of hours in the office, i.e., $\rho(1-\theta)L_s + (1-\rho)L_s$, must equal the target $(1-\beta)L_s$ mandated by firms. As a result, the three shares must satisfy the following global constraint: $\rho\times\theta = \beta$, where the left-hand is the supply of home-working hours while the right-hand side is the demand for home-working hours. Plugging $\rho = \beta/\theta$ into (16) yields

$$T(\phi,\beta,L_s) = A(\beta)L_s = f\left(\phi\beta, 1-\beta\right)L_s,$$

which shows that A has the nature of a TFP shifter, i.e., A determines the productivity of the skilled workers as a function of the work arrangement (β) and the efficiency of ICT (ϕ). In what follows, we assume that $f(\phi\beta, 1-\beta)$ is a positive and twice continuously differentiable function of β. We further assume that $f(\phi\beta, 1-\beta)$ is strictly concave in β.[8]

It is then straightforward to prove that, since f is strictly concave, $A(\beta)$ is single-peaked with a maximum at β^A. However, this result does not tell us whether the maximizer is an interior or a corner solution. Since the number of teleworkers was positive before the pandemic and since most firms reject full-time home working, we find it reasonable to assume that $A'(0) > 0$ and $A'(1) < 0$. Therefore, $A(\beta)$ is maximized at a unique interior WFH share $\beta^A \in (0,1)$.[9]

As said above, to develop a variety, each firm requires a fixed amount $F > 0$ of efficiency units of skilled labor. Without loss of generality, we choose units such that F is normalized to 1. Then, for a work arrangement β, each firm hires a mass of skilled workers given by

$$L(\beta) = \frac{1}{A(\beta)}. \tag{17}$$

Given the office space the firm has to provide to its office workers, the full price paid by the firm for one skilled worker equals $(1-\beta)p_b + w_s$. Therefore, using (17), the fixed cost borne by a firm under the work arrangement β is given by

$$FC = \left[(1-\beta)p_b + w_s\right]/A(\beta). \tag{18}$$

[7] Even when the total amount of available land, $\mathcal{L}$, is fixed, the total amount of buildings is endogenous because land and unskilled labor are substitutes. Observe further that we could add capital to the model and assume that its supply is perfectly elastic at a given price determined in the international market. Doing so amounts to adding constant terms to the model and leaves our insights unchanged.

[8] The estimations undertaken by Davis et al. (2021) suggest that home labor and office labor are complements, that is, $f_{12} > 0$. Two cases may then arise. First, if the marginal productivity of each type of labor decreases, $f_{11} < 0$ and $f_{22} < 0$, then $f(\phi\beta, 1-\beta)$ is strictly concave in β when its second derivative $\phi^2 f_{11} - 2\phi f_{12} + f_{22}$ is negative. In the opposite case, we have $f_{11} > 0$ and $f_{22} > 0$. Then, $f(\phi\beta, 1-\beta)$ is strictly concave in β when the following two conditions hold: $\phi f_{11} < f_{12}$ and $f_{22}/\phi < f_{12}$. In other words, when the marginal productivity of each type of labor increases, $f(\phi\beta, 1-\beta)$ is strictly concave when the complementarity effect, $f_{12} > 0$, dominates the degree of increasing returns associated with each type of labor. Furthermore, ϕ can neither be too large nor too small, for otherwise the complementarity effect should be very strong for the inequalities $\phi f_{11} < f_{12}$ and $f_{22}/\phi < f_{12}$ to hold.

[9] Accounting for agglomeration economies among office-workers shifts the function $A(\beta)$, hence the maximizer β^A, left-ward. That said, our results hold true.

Production costs and profits. Once variety i has been developed using skilled labor and office space, producing that variety requires unskilled labor and buildings according to a Cobb–Douglas production function.[10] Let q denote a firm's output. Its total production cost is then given by

$$C(q) \equiv VC(q) + FC = w_\ell^{1-\alpha} p_b^\alpha q + \left[(1-\beta)p_b + w_s\right] L(\beta). \tag{19}$$

Using (3), (9), and (15), the aggregate demand $q(i)$ for variety i is given by

$$q = Y\mathbf{P}^{\sigma-1} p^{-\sigma}, \tag{20}$$

where

$$Y \equiv (1-\gamma)\left\{\frac{w_s}{\tau}\left[\frac{\beta}{\theta}\frac{1+\theta(\phi\tau-1)}{1+\gamma\kappa} + 1 - \frac{\beta}{\theta}\right] L_s + w_\ell L_\ell + \delta B p_b\right\} \tag{21}$$

is the total expenditure on the consumption good. Consequently, the profit function of firm i can be expressed as follows:

$$\pi = \left(p - w_\ell^{1-\alpha} p_b^\alpha\right) Y\mathbf{P}^{\sigma-1} p^{-\sigma} - \left[(1-\beta)p_b + w_s\right] L(\beta), \tag{22}$$

where we have used (20). Note that a firm treats total income Y and the price aggregate $\mathbf{P}$ parametrically because it is negligible to the market. The second term on the right-hand side of (22) highlights the fact that *firms are incentivized to increase their WFH share to reduce their expenditure on floor space*.

Equilibrium price and firm size. Maximizing profits with respect to prices yields:

$$p = \frac{\sigma}{\sigma-1} w_\ell^{1-\alpha} p_b^\alpha. \tag{23}$$

Since all firms set the same price p, we may choose the CES bundle of the consumption good as the numeraire, that is, $\mathbf{P} \equiv 1$. As a result, with M active firms, the price index of the consumption sector must satisfy

$$1 = M^{\frac{1}{1-\sigma}} p = \frac{\sigma}{\sigma-1} M^{\frac{1}{1-\sigma}} w_\ell^{1-\alpha} p_b^\alpha. \tag{24}$$

Plugging (23) and (24) into firm i's operating profit, given by $\Pi \equiv \left(p - w_\ell^{1-\alpha} p_b^\alpha\right) Y p^{-\sigma}$ at the symmetric equilibrium with $\mathbf{P} = 1$, yields $\Pi = Y/\sigma M$.

In line with models of monopolistic competition used in growth and trade theories, we assume that the skilled are the residual claimants to profits. In other words, a firm's residual profit, $\Pi - (1-\beta)L(\beta)p_b$, is used to pay its skilled employees. Since there is free entry in the final sector the equilibrium wage w_s thus solves the zero-profit condition:

$$w_s = \frac{Y}{\sigma M L(\beta)} - (1-\beta)p_b = \frac{Y A(\beta)}{\sigma M} - (1-\beta)p_b. \tag{25}$$

Furthermore, plugging (23) and $\mathbf{P} = 1$ into (20) and using the market clearing condition for variety i imply that every firm's equilibrium output is given by

$$q = Y M^{-\frac{\sigma}{\sigma-1}}, \tag{26}$$

which does not directly depend on β. Yet, firm size will depend on the work arrangements β via the aggregate income Y and the mass of firms M.

Two comments are in order. First, perfect competition in the labor market implies that there is a unique wage w_s per efficiency unit of skilled labor for all firms. This is possible if and only if the WFH share is the same across firms.[11] Second, as can be seen from (25), the direct effect of WFH is to raise the skilled wage. Yet, WFH has also general equilibrium effects, notably through the housing market. We will see below what happens when we account for the endogeneity of the price p_b of buildings and of the total expenditure Y on the consumption good.

[10] As our model omits capital, we consolidate buildings and capital within a single input.

[11] The only alternative would be that $A(\beta,\phi) = -(\sigma M p_b/Y)\beta$, which violates the concavity of A and which would imply that $w_s = -p_b$, which is impossible.

3. Equilibrium

Observe that firms' profits depend on their WFH share β, but not on workers' WFH share θ. Conversely, the indirect utilities of hybrid and office workers reveal that they care about their own share, but not about firms' share. We thus find it natural to model the interactions between workers' and firms' choices as a non-cooperative two-stage game. More specifically, in the first stage, firms enter the market, choose their WFH share β, and determine their output. In the second stage, the skilled workers choose between full-time office and hybrid solutions and their consumption bundle, while hybrid workers also choose their WFH share θ. The unskilled choose their utility-maximizing consumption bundle. As usual, the market outcome is given by a subgame perfect Nash equilibrium. Note that total profits in the economy equal zero because the equilibrium profits in the construction sector equal zero – due to perfect competition and constant returns – while free entry drives profits to zero in the consumption sector.

3.1. Market clearing conditions

Unskilled labor. Recall that unskilled labor is used by the construction and consumption sectors. Hence, the unskilled labor market clearing condition is given by

$$L_\ell = B\frac{\partial c_b}{\partial w_\ell} + M\frac{\partial C(q)}{\partial w_\ell}.$$

Using the cost functions $C(q)$ and c_b defined above then yields

$$L_\ell = (1-\delta)R^\delta w_\ell^{-\delta} B + (1-\alpha)p_b^\alpha w_\ell^{-\alpha} M q.$$

By implication of (24) and (26), the market clearing condition for the unskilled can then be rewritten as follows:

$$w_\ell L_\ell = (1-\delta)B p_b + (1-\alpha)\frac{\sigma-1}{\sigma} Y. \tag{27}$$

The supply of buildings. Using (19), we obtain the demand for buildings stemming from the firms in the consumption sector as follows:

$$B_f = M\frac{\partial C(q)}{\partial p_b} = \alpha M q \left(w_\ell/p_b\right)^{1-\alpha} + M(1-\beta)L(\beta).$$

Using (26) and the aggregate demand for skilled labor $L_s = ML(\beta)$, this expression becomes:

$$B_f = (1-\beta)L_s + \alpha\frac{\sigma-1}{\sigma}\frac{Y}{p_b}. \tag{28}$$

Total demand for housing can be obtained by using (3), (5), (9) and (15):

$$B_h = \frac{\gamma}{\tau}\left[\frac{\beta}{\theta}\frac{(1+\kappa)(1+\theta(\phi\tau-1))}{1+\gamma\kappa} + 1 - \frac{\beta}{\theta}\right]\frac{w_s}{p_b} L_s + \gamma\frac{w_\ell L_\ell}{p_b} + \gamma\delta B. \tag{29}$$

Market clearing in the construction sector implies $B = B_h + B_f$. It then follows from (28) and (29) that the total output of the construction sector satisfies the condition:

$$(1-\gamma\delta)B = \frac{\gamma}{\tau}\left\{\frac{\beta}{\theta}\frac{(1+\kappa)[1+\theta(\phi\tau-1)]}{1+\gamma\kappa} + 1 - \frac{\beta}{\theta}\right\}\frac{w_s}{p_b} L_s + \gamma\frac{w_\ell L_\ell}{p_b} + (1-\beta)L_s + \alpha\frac{\sigma-1}{\sigma}\frac{Y}{p_b}. \tag{30}$$

Mass of firms. Since each firm requires $L(\beta)$ units of skilled labor, market clearing implies $ML(\beta) = L_s$, where L_s is the total mass of skilled workers in the economy and $L(\beta)$ is the symmetric per-firm demand for skilled workers. Using (17), and recalling that F is normalized to 1, the mass of firms at a symmetric equilibrium, therefore, satisfies

$$M = A(\beta)L_s. \tag{31}$$

3.2. Equilibrium equations

For given β and θ, the system of Eqs. (14), (21), (27), and (30) can be reduced to the following system whose unknowns are B, w_ℓ/p_b, and w_s/p_b:

$$\frac{C_1}{L_s}B = (C_1+C_2)(1-\beta) + \left[C_2\left(\frac{\beta}{\theta}\frac{\theta(\phi\tau-1)-\gamma\kappa}{1+\gamma\kappa}+1\right) + (C_1+C_2)(\phi\tau-1)\beta\right]\frac{1}{\tau}\frac{w_s}{p_b}, \tag{32}$$

$$C_2\frac{w_\ell L_\ell}{p_b L_s} = (1-C_1-\delta C_2)\frac{B}{L_s} - (1-C_1-C_2)\left(1-\beta-(\phi\tau-1)\beta\frac{1}{\tau}\frac{w_s}{p_b}\right), \tag{33}$$

$$\frac{w_\ell}{p_b} = \delta^{-\frac{\delta}{1-\delta}}B^{-\frac{(1-\mu)\delta}{1-\delta}}, \tag{34}$$

where $C_1 \equiv (1-\gamma)/\sigma > 0$ and $C_2 \equiv \gamma + \alpha(1-\gamma)(\sigma-1)/\sigma > 0$ are bundles of parameters independent of β, θ, μ, ϕ, and τ. Furthermore, we can show that $1-C_1-\delta C_2 > 0$, so that $1-\delta(C_1+C_2) > 0$ since $\delta < 1$. In other words, all bundles of parameters in (32) and (33) are strictly positive.

Observe that we can solve (34) for w_ℓ/p_b and (32) for w_s/p_b and substitute both expressions into (33). Hence, we have a single equation in the single unknown B. Using the solution to this equation, we can then reconstruct all equilibrium values of the market variables.

3.3. Firms' WFH share

Operating profits and variable production costs do not directly dependent on the work arrangement θ chosen by the skilled workers. Furthermore, operating profits and variable production costs do not directly depend on firms' WFH share β because each firm is negligible to the market. However, as shown by (22), a firm's fixed cost varies with β. Therefore, a firm's profit-maximizing WFH share minimizes its fixed costs. Since Y, p_b, w_s, and M do not depend on the choice made by a firm, we have

$$\frac{\partial FC}{\partial\beta} = -\left[\beta p_b + \left((1-\beta)p_b + w_s\right)\varepsilon_\beta(A)\right]\frac{1}{\beta A(\beta,\phi)}, \tag{35}$$

where $\varepsilon_\beta(A) \equiv -\beta A'(\beta,\phi)/A(\beta,\phi)$ denotes the elasticity of A with respect to β. Since firms face the same prices for skilled labor w_s and buildings p_b, they make the same choice of β.

Expression (35) describes the optimal choice of β^* that minimizes firms' fixed costs. Recall that $A(\beta,\phi)$ is a concave function that is maximized at $\beta^A \in (0,1)$. Then, (35) implies that fixed costs decrease at $\beta = \beta^A$ because $\varepsilon_\beta(A)$ is zero. Therefore, firms choose β^* that is larger than β^A that maximizes skilled productivity. The reason is the presence of office space in firms' production. Indeed, if office workers did not require office space or, equivalently, if office space was costless, fixed costs would reduce to $FC = w_s/A(\beta)$. Firms' fixed costs would be minimized at $\beta = \beta^A$, i.e., they would choose $\beta^* = \beta^A$. However, since costly office space is required, firms are willing to trade-off some labor productivity to save on their costs associated with buying (or renting) office space. Furthermore, (35) uncovers the drivers underlying firms' WFH policy: as office space becomes relatively more expensive compared to skilled labor, firms want to increase their WFH share to outsource labor to workers' homes.

To sum up, we have:

Proposition 1. *Firms choose a WFH share that exceeds the share that maximizes the productivity of skilled workers.*

Proof. In the text. □

To obtain clear-cut results in what follows, we assume that $A(\beta) = (\phi\beta)^\varepsilon(1-\beta)^{1-\varepsilon}$ is of the Cobb–Douglas form, with $\varepsilon \in (0,1)$. Clearly, $A(\beta)$ is maximized at $\beta^A = \varepsilon$. It is then readily verified that

$$\beta^* = \frac{\varepsilon\left(1+\frac{w_s}{p_b}\right)}{\varepsilon+\frac{w_s}{p_b}} \in (\varepsilon,1). \tag{36}$$

Furthermore, fixed costs are minimized at $\beta^* > \beta^A = \varepsilon$ as implied by Proposition 1. Inverting the relationship (36) yields:

$$\frac{w_s}{p_b} = \frac{\varepsilon(1-\beta^*)}{\beta^*-\varepsilon}, \tag{37}$$

which will be useful in the following discussion.

3.4. Skilled workers' WFH share

Each firm mandates the share $1-\beta$ of total working hours that have to be provided on-site, which constrains the skilled workers in their own choices. Conditional on meeting the required office labor supply $(1-\beta^*)L_s$, workers are free: (i) to choose between hybrid work and full-time office work; and (ii) to determine their hybrid work arrangements, θ.

Since $\beta^* > \varepsilon$, an equilibrium is such that there are either both full-time office and hybrid workers or that all skilled workers choose a hybrid labor arrangement. We henceforth refer to the former case as an *interior equilibrium* and to the latter case as a *corner equilibrium*. In an interior equilibrium, the share ρ of hybrid workers satisfies the condition $0 < \rho < 1$. At such an outcome, skilled workers must be indifferent between the hybrid and full-time office options. Using (7), we equalize the indirect utilities of the full-time office and hybrid solutions to obtain the share θ^* of workers who wish to work hybrid:

$$\frac{V_r}{V_o} = \frac{1+\theta(\phi\tau-1)}{1+\gamma\kappa} = 1 \quad\Leftrightarrow\quad \theta^* = \min\left(1, \frac{\gamma\kappa}{\phi\tau-1}\right) > 0. \tag{38}$$

Observe that (38) is independent of β. As a result, θ^* is a dominant strategy for the skilled workers. Observe further that, as expected, hybrid workers choose to spend more time working home when ICT are more efficient (a larger ϕ) and commuting costs are higher (a larger τ).

Since we assume that $\phi\tau > 1$, the indirect utility of hybrid workers increases in θ.[12] As a result, if the skilled workers were not constrained by the office hours mandated by firms, all these workers would choose to raise their share θ as much as they can. Then, if $\beta^* > \theta^*$ given by (38), all skilled workers would choose the labor arrangement $\theta = \beta^*$. In this case, there are no full-time skilled office workers.

To sum up, two cases may arise. In the first one, $\gamma\kappa/(\phi\tau-1) > \beta^*$ and θ^* is given by (38). We thus have an interior equilibrium with both hybrid and full-time office workers ($0 < \rho^* < 1$). In the second case, $\theta^* = \beta^*$ when $\gamma\kappa/(\phi\tau-1) < \beta^*$, and the equilibrium is such that all skilled workers are hybrid ($\rho^* = 1$).

In what follows, we study the empirically relevant case of an interior equilibrium ($0 < \rho^* < 1$) and relegate the discussion of the corner equilibrium ($\rho^* = 1$) to the supplementary material. We can show the following result:[13]

Proposition 2. *There exists a unique interior equilibrium.*

Proof. See Appendix A. □

[12] When $\phi\tau < 1$, the indirect utility of the skilled workers is decreasing in θ. Hence, the skilled want to work full time in the office. Since firms mandate a share β^*, the condition $\theta = \beta^*$ must hold. In this case, we have $\rho^* = \beta^*/\theta^* = 1$ and all workers are hybrid. In other words, we have a corner equilibrium.

[13] For the uniqueness of the corner equilibrium, see the supplementary material.

4. Comparative static analysis

We now discuss the effects of changes in our model's key parameters. More precisely, we investigate the effects of: (i) the land supply elasticity μ; (ii) the ICT efficiency ϕ; and (iii) commuting costs τ, on the equilibrium labor arrangement, β^*, as well as on various outcomes such as prices, productivity, building supply, and welfare.

4.1. Changes in firms' WFH share

We show in Appendix A that Eqs. (32) and (33) can be rewritten as follows at an interior equilibrium:

$$B = f_1(\beta, \phi, \tau) \quad \text{and} \quad \frac{w_\ell}{p_b} = f_2(\beta, \phi, \tau), \tag{39}$$

where f_1 and f_2 are functions of β and our key parameters $\{\phi, \tau\}$ but do not directly depend on μ. The effect of the latter is captured by (34). We suppress all other parameters (which are held fixed) to alleviate notation. Then, for $x \in \{\phi, \tau\}$, we have

$$\mathrm{d}B = \underbrace{\frac{\partial f_1(\beta, \phi, \tau)}{\partial \beta}}_{<0} \mathrm{d}\beta + \frac{\partial f_1(\beta, \phi, \tau)}{\partial x} \mathrm{d}x \tag{40}$$

$$\mathrm{d}\left(\frac{w_\ell}{p_b}\right) = \underbrace{\frac{\partial f_2(\beta, \phi, \tau)}{\partial \beta}}_{<0} \mathrm{d}\beta + \frac{\partial f_2(\beta, \phi, \tau)}{\partial x} \mathrm{d}x. \tag{41}$$

Eqs. (40) and (41) show that the direct effect of a change in β (i.e., for $\mathrm{d}x = 0$) is to decrease B and $\frac{w_\ell}{p_b}$. Combining Eqs. (40) and (41) with the final equilibrium condition (34) then allows for a simple comparative static analysis.

Land supply elasticity. Let us start with the effects of changes in μ. We see from (39) that B and w_ℓ/p_b are independent of μ, while the right-hand side of (34) shifts upwards with μ.[14] It thus follows that β^* decreases with μ, so that B and w_ℓ/p_b increase with μ from (40) and (41).

ICT improvements. Let us now turn to the effects of changes in ϕ. Since $\partial f_1/\partial\phi > 0$ and $\partial f_2/\partial\phi > 0$ from Appendix A, for a given β the left-hand side of (34) shifts up and the right-hand size shifts down. This implies that β^* increases with ϕ in equilibrium.

Commuting costs. Last, we consider the effects of changes in τ. This effect is more complex as the right-hand sides of (40) and (41) are non-monotonic in τ. However, we show in Appendix B that for WFH shares $\beta^* < 0.8$, the right-hand sides of (40) and (41) decrease with τ. This implies that the left-hand side of (34) shifts downwards whereas the right-hand side shifts upwards. As a result, an increase in commuting costs τ leads to a lower firm WFH share β^*.

We can summarize the foregoing results as follows:

Proposition 3. *A more elastic land supply (a larger μ) or higher commuting costs (a larger τ) reduce β^*, whereas more efficient ICT (a larger ϕ) increase β^*.*

Proof. In the text above. □

Using the equilibrium response of β^* to changes in our key parameters, we can assess the equilibrium changes in prices, productivity, building supply, and welfare.

4.2. Changes in prices and productivity

As in the foregoing subsection, we discuss in turn the results for the land supply elasticity μ, ICT ϕ, and commuting costs τ.

Land supply elasticity. As β^* decreases with μ, w_s/p_b increases from (37). Since $A'(\beta^*) < 0$, an increase in μ leads to an increase in $A(\beta^*)$ through a smaller share β^*. A more elastic land supply, thus increases the productivity of skilled workers, which reduces the inefficiency of a too high WFH share. The intuition is easy to grasp. As office rent relative to skilled wages, p_b/w_s, decreases, firms use more office space, thus implying that more skilled workers return to the office.

Eq. (38) shows that the share of time spent working home is independent of μ. Therefore, the share of hybrid workers $\rho^* = \beta^*/\theta^*$ decreases with μ. Stated differently, *there are fewer hybrid workers when the land supply is more elastic*. The reason is that a more elastic land supply (i.e., a higher μ) reduces office rent p_b relative to the skilled wage w_s. Consequently, firms have less incentives to outsource workers to their homes because savings in office rents are lower. They thus mandate a lower WFH share. This, in turn, implies that some hybrid workers must switch to a full-time office regime to meet the constraint $1 - \beta^*$ set by the firms.

We summarize our findings in the following proposition.

Proposition 4. *A more elastic land supply reduces the inefficiency from too much WFH, whereas a less elastic land supply exacerbates that inefficiency. A more elastic land supply also leads to a lower share of hybrid workers.*

Proof. In the text above. □

Proposition 4 shows that a policy instrument such as land-use regulation – which is a priori unrelated to home working – may have a significant impact on the equilibrium labor arrangements and productivity when general equilibrium effects are accounted for. It also shows that commercial and residential real estate markets play a central role in understanding the long-run effects of labor arrangements that differ by their WFH share.

ICT improvements. Improvements in ICT leads to an increase in the productivity of remote workers via a higher value of ϕ. As a result, firms naturally increases their WFH share β^* as shown in Proposition 3. The intuition for this result is as before: firms trade off productivity losses for real estate savings. A higher productivity at home makes rents relatively more costly as compared to labor, which leads firms to mandate a larger WFH share.

Eq. (37) shows that w_s/p_b decreases with ϕ through an increase in β^*. We show in Appendix C that w_ℓ/p_b also decreases with ϕ. Furthermore, since $A'(\beta^*) < 0$, the productivity of skilled workers decreases with ϕ. The intuition underlying this result goes as follows. As w_s/p_b decreases with ϕ, firms have incentives to raise their WFH share even more because rents become more expensive relative to skilled labor. Expensive office space incentivizes firms to decentralize their skilled jobs, so that the corresponding higher WFH share leads to an additional efficiency loss. As a result, firms pay a (much) lower wage to the skilled workers who react by spending less on housing, which becomes relatively more expensive. In sum, *more efficient ICT exacerbate the efficiency loss due to firms choosing too high a WFH share*.

[14] Formally, the latter holds only if $B > 1$. Recall that $\beta^* > \epsilon$. When β^* increases starting from ϵ, B decreases from infinity and may potentially become smaller than 1. Using empirically relevant parameter values, we now show from a simple back-of-the-envelope calculation that this case is not very plausible. First, since our model omits capital, we consolidate the land and capital share to be $\alpha = 0.4$, which amounts to a labor share equal to 0.6. We take $\gamma = 0.3$ for the housing share of income and $\delta = 0.25$ for the land share in construction (Davis and Ortalo-Magné, 2011). From Redding and Turner (2015), $\tau = 1.08$, i.e., commuting costs are 8 percent of workers' wages. Finally, $\sigma = 6$ for the elasticity of substitution among varieties (Bergstrand et al., 2013). Using those values and a WFH share in production of $\epsilon = 0.25$, B falls below 1 only when β exceeds 0.85. For larger values of ϵ, β needs to be even larger. Since WFH shares are clearly much below 85%, in what follows we hence focus on the empirically plausible case where $B > 1$.

In our setting, improvements in ICT are detrimental to workers since firms offshore too many jobs to workers' homes at the expenses of their productivity. These effects are likely to be especially important in locations commanding high rents, e.g., the downtowns of large cities or technology clusters.

Eq. (38) implies that θ^* decreases with ϕ. Therefore, $\rho^* = \beta^*/\theta^*$ increases. In other words, improvements in ICT lead to more hybrid workers but each of them works a smaller share of their work time remotely. The intuition behind this result is relatively straightforward. ICT improvements lead to an increase in the productivity of hybrid workers when they work home, which fosters a higher income. Further, higher productivity of remote work also entices firms to increase their WFH share β^*. Hence, some office workers switch to a hybrid solution. However, welfare equalization between hybrid and full-time office workers implies that hybrid workers must reduce their share of remote work.

Proposition 5. *ICT improvements lead firms to choose a higher WFH share and reduce the productivity of skilled workers. While more workers choose to be hybrid, they reduce their home-working time.*

Proof. In the text above. □

Commuting costs. Since firms' WFH share β^* decreases with commuting costs τ, it then follows from (37) that w_s/p_b increases with τ. Firms choose their WFH share based on the ratio of skilled wage to office rent, which decreases with τ. As office space gets cheaper relative to skilled labor, firms want to raise their share of on-site working hours.

Hybrid workers, however, choose their individual WFH share based on other considerations. Indeed, Eq. (38) shows that θ^* also decreases with τ. Intuitively, one would expect higher commuting costs to reduce skilled workers' income and, therefore, to increase their share of home work. Yet, an increase in commuting costs leads to a decrease in net income from office work relative to home work, which strongly affects full-time office workers because they earn their entire wage on-site. Therefore, their welfare falls relative to that of hybrid workers. Since welfare of hybrid and full-time office workers must be equalized at an interior equilibrium, hybrid workers reduce their share of work from home. To summarize:

Proposition 6. *When commuting costs increase, firms choose a lower WFH share and the productivity of skilled workers increases. Hybrid workers reduce their time working at home.*

Proof. In the text above. □

There is a substantial difference between the impacts of commuting costs and ICT. Although, an increase in both τ and ϕ incentivizes hybrid workers to raise their WFH share θ^*, firms' WFH share β^* moves in opposite directions. The reason is that commuting costs are mere losses for skilled workers, whereas ICT affects not only skilled income but also their productivity. Only the latter matters for firms' decisions.

4.3. Changes in building supply and welfare

We again discuss in turn the results for μ, ϕ, and τ.

Land supply elasticity. Since β^* decreases with μ, Eq. (40) shows that the output of the construction sector B naturally expands when the land supply is more elastic. There are at least two reasons for that. First, the increase in wages relative to housing price, w_s/p_b and w_ℓ/p_b, implies that both unskilled and skilled workers consume more housing, which increases the equilibrium supply of the construction sector. Second, firms also consume more office space (β^* is lower) because office rents decrease relative to the skilled wage, thus leading to less WHF and more office work (and hence demand for commercial real estate).

Lax land use regulations naturally lead to a larger supply of buildings. The foregoing discussion shows that, due to a relatively lower building price, both types of workers can afford larger houses while firms use more office space. By contrast, strict land use regulations entice firms to reduce office space and to 'outsource' the work so that more skilled workers choose the hybrid option. Large-scale working from home thus provides a new margin by which firms can adjust costs and this may lead to substantial 'domestic off-shoring' of skilled jobs.

Eq. (A.3) in Appendix A implies that the wage ratio w_ℓ/w_s falls when μ increases, which means that the gap between skilled and unskilled wages expands. As a result, a more elastic land supply leads to more inequality between the two groups of workers.

Since β^* increases in μ, this raises the equilibrium mass of varieties as implied by (31). Then, Eq. (24) can be rewritten as follows:

$$w_\ell = \frac{\sigma-1}{\sigma}\left(\frac{w_\ell}{p_b}\right)^{\alpha} M^{\frac{1}{\sigma-1}}. \tag{42}$$

Since both M^* and w_ℓ/p_b increase with μ, the same holds for w_ℓ. Since w_s/w_ℓ increases with μ, the skilled wage then must also increase. In sum, even though the skilled–unskilled wage gap expands, both unskilled and skilled wages rise with a higher land supply elasticity.

The full impact of a higher μ on individual welfare can be assessed using the indirect utilities. Since both wages w_s and w_ℓ, as well as w_s/p_b and w_ℓ/p_b, increase with μ, (7) and (10) imply that *all workers are better-off when land supply is more elastic*. However, the welfare gap is given by

$$\frac{V_o}{V_\ell} = \frac{w_s}{\tau w_\ell}, \tag{43}$$

so that skilled gains are larger because the skilled–unskilled wage gap expands.[15] We can summarize our results as follows:

Proposition 7. *A more elastic land supply leads to a larger supply of buildings. It increases welfare of both skilled and unskilled workers, yet widens the skilled–unskilled wage and welfare gaps.*

Proof. In the text above. □

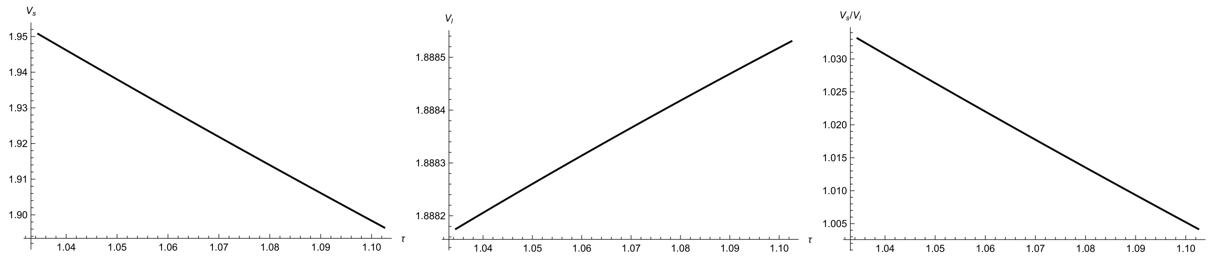
ICT improvements. Since w_ℓ/p_b decreases with ϕ, B increases by (34). ICT improvements naturally lead to a larger supply of buildings. Although firms reduce their office space usage, there is higher demand for housing compensating for this reduction. Indeed, an increasing number of hybrid workers induces higher demand for housing as they require more space for their home office. Note that the increase in the number of hybrid workers is strong for two reasons. First, firms mandate more WFH, which directly increases the number of hybrid workers. Second, since the existing hybrid workers reduce their WFH share, this further increases the number of workers who need to use a hybrid work arrangement. As a result, the larger demand for housing more than offsets the decrease in demand for office space.

Plugging (14) into (24), we get

$$\frac{\sigma}{\sigma-1} w_\ell \delta^{\frac{\alpha\delta}{1-\delta}} B^{\frac{\alpha(1-\mu)\delta}{1-\delta}} = M^{\frac{1}{\sigma-1}}.$$

Since B increases whereas M decreases with ϕ as implied by (31), unskilled wages w_ℓ decrease. Moreover, by (A.3) in Appendix A the wage gap w_s/w_ℓ also decreases, which shows that skilled wages also decrease. Finally, as both w_s/p_b and w_ℓ/p_b decrease with ϕ, by the same argument as in Section 4.2, the welfare of both skilled and unskilled hence falls. The welfare gap (43) shrinks because w_s/w_ℓ shrinks.

[15] Recall that $V_o = V_h$ in an interior equilibrium by arbitrage between the full time office and hybrid options. Hence, the result holds for both types of skilled workers.



(a) Changes in V_s (b) Changes in V_ℓ (c) Changes in V_s/V_ℓ

Fig. 1. Changes in absolute and relative welfare with skilled commuting costs τ.
Notes: The parameter values are set as described in footnote 14. We also let $\kappa = 0.121$, $\varepsilon = 0.25$, $\phi = 1$, $\mu = 0.95$, $L_s = 100$ and $L_\ell = 1000$.

Proposition 8. *ICT improvements lead to a larger supply of buildings and to a reduction in both skilled and unskilled wages. Furthermore, both skilled and unskilled workers are worse off while the skilled–unskilled wage and welfare gaps shrink.*

Proof. In the text above. □

Commuting costs. We show in Appendix B that the skilled–unskilled wage gap w_s/w_ℓ increases. The intuition is that the unskilled cannot make arbitrage between home and office work, whereas the skilled can use that margin of adjustment to mitigate the effects of changes in commuting costs. We also show in the same appendix that building supply increases. This is accompanied by an increase in the equilibrium building prices (recall that incomes change, so that the demand curves shift up in equilibrium).

Since β^* decreases with τ, the mass of firms M increases. Indeed, as higher commuting costs reduce β^*, they allow the industry to operate at a higher level of aggregate productivity A, which increases the range of available varieties.

Panel (a) of Fig. 1 shows that the effect on welfare of an increase in τ is still negative for the skilled since it directly reduces their net income. Hence, skilled welfare falls with commuting costs: the direct effect of higher commuting costs the skilled have to incur is not compensated by the combination of higher wages – due to productivity increases in the office – and the corresponding increase in the mass of available varieties.

We show in Appendix B that w_ℓ/p_b decreases with τ. Despite that decrease, panel (b) of Fig. 1 shows that unskilled welfare increases with τ. The reason is that only a share $\gamma < 1$ of income is spent on housing, thus mitigating the effect of higher housing price and increasing unskilled real wages. Therefore, as panel (c) of Fig. 1 shows, the welfare gap between the skilled and the unskilled shrinks. To summarize:

Proposition 9. *Higher commuting costs for skilled workers reduce skilled welfare and increase unskilled welfare. Although the skilled–unskilled wage gap widens, the welfare gap shrinks because higher commuting costs reduce skilled net wages. The building supply expands with higher commuting costs.*

Proof. In the text above. □

5. Exogenous shocks to the WFH shares

We finally study the effects of ceilings on the equilibrium work arrangements as summarized by $\bar{\beta} < \beta^*$ and $\bar{\theta} < \theta^*$. We view this exercise as one where various decision makers – governments, legislative bodies, or other institutions – restrict the choices of work arrangements by imposing ceilings. Even in the presence of mandated ceilings, agents make optimal decisions conditional on the constraints they face. What are the likely outcomes when governments or other institutions impose upper bounds on β or θ?

The case of firms' share β. Assume that firms are constrained in their choice in that β must be smaller than or equal to $\bar{\beta} < \beta^*$. We can show the following result.

Proposition 10. *Imposing a binding ceiling on firms' WFH share improves skilled worker productivity but increases housing prices relative to wages, thus making both skilled and unskilled workers worse off. Furthermore, both the skilled–unskilled wage and welfare gaps shrink.*

Proof. See Appendix D. □

Given that firms operate in the decreasing portion of productivity, public policy that restricts WFH arrangements improves skilled productivity which was harmed by excessive 'offshoring' of work to workers' homes. However, it increases fixed costs of firms which increases the social cost of creating variety. So, there is a trade-off between lower fixed costs and higher skilled productivity. Furthermore, although, productivity improves, a lower WFH share reduces both skilled and unskilled wages relative to housing price. This has two implications. First, both skilled and unskilled are worse off. Second, as w_s/p_b decreases, firms are willing to increase their WFH share as implied by (37). In other words, fixed costs increase even more, which amplifies the losses from variety creation. This discussion shows that the trade-off between lower fixed costs and higher skilled productivity does not have a simple and universal solution.

The case of hybrid workers' share θ. We now consider the impact of a restriction on the skilled workers' share such that θ must be smaller than θ^*. Since firms are aware of this constraint, they adjust their WFH share accordingly (recall that firms are the first movers in the two-stage game). Furthermore, equalization of welfare between office and hybrid workers no longer needs to hold in that case. We can show the following result.

Proposition 11. *Imposing a binding ceiling on hybrid workers' WFH share reduces office rents relative to skilled wages, entices firms to reduce their WFH share, and improves skilled productivity. It increases the welfare of office workers and makes them better off compared to hybrid workers.*

Proof. See Appendix E. □

Imposing a ceiling on hybrid workers' WFH share has the same effect on skilled productivity. Indeed, a lower θ increases w_s/p_b, i.e., makes office space relatively cheaper than skilled labor. As a result, firms reduce their WFH share, which, in turn, improves productivity of skilled workers. Note the major difference with the ceiling on firms' WFH share: here, the productivity of skilled workers increases keeping fixed costs at a minimum level for prevailing prices. In other words, there is no trade-off between productivity improvements and the cost of variety creation. Instead, a decrease in θ reduces the inefficiency associated with "too much WFH" keeping those costs at the minimum. This discussion shows that public policy that restricts hybrid workers'

WFH share may be a more efficient tool than one that restricts firms' WFH share.

Furthermore, despite the absence of agglomeration economies among office workers, this proposition suggests that the equilibrium outcome may be detrimental to the office workers. The reason is that there is too much WFH, i.e., productivity losses due to WFH. Since hybrid workers drag down skilled wages, and since there is welfare equalization between office and remote workers at an interior equilibrium, office workers are worse off at an interior equilibrium compared to the case where there is a ceiling on θ.

6. Conclusion

Telecommuting triggers a variety of effects that go far beyond its impact on individual workers' productivity. To study the interplay between these effects, we have developed a general equilibrium model with land, two sectors, and two types of labor that allows us to shed new light on the main trade-offs arising in an economy where WFH is used on a relatively large scale. Our analysis shows that it is profit-maximizing for firms to split the working time between home and office. This choice is driven by the savings made by firms on their real estate expenditure when they outsource their work. However, this comes at the cost of a lower productivity of skilled labor, which negatively affects the efficiency of the economy, especially in dense urban areas where real estate is expensive. Importantly, these effects are strengthened by the development of increasingly efficient ICT.

Furthermore, the choice of WFH shares has distributional consequences that have so far been put aside. More specifically, how skilled and unskilled workers are affected depends on several parameters such as the elasticity of the land supply, the efficiency of ICT, and the level of commuting costs. Thus, looking only at the short-run performance of teleworking firms to predict the global impact of WFH will provide a very incomplete picture of how the economy will be transformed. Nevertheless, we may already conclude that WFH is not the universal panacea embraced by some of its proponents. This is increasingly recognized by firms and reflected in their moves to bring their workers back to the office.[16]

In this paper, we have used a setting which is too stylized to work out all the effects of WFH. In particular, our one-location framework should be extended to a multi-location space in order to understand how the structure and composition of cities will be affected by teleworking. After decades of flight to the suburbs, city centers have again become desirable places where to live. This trend is partly rooted in the shift toward a knowledge-based economy and is embodied in an expanding class of highly-educated and young professionals who work for high-tech, multinational firms, or finance, insurance, and real estate. These workers spend a large number of hours at their jobs, which explains their distaste for commuting to the workplace and stronger preferences for amenities provided nearby. This has fostered the emergence of a wide range of business-to-consumer activities supplied in city centers and produced by low-pay workers (Couture and Handbury, 2023). WFH should reduce the willingness to pay for residential proximity to the city center, and thus induce skilled workers to move to suburbs. In particular, the magnitude of the change in city structure, and its effect on labor markets and skilled/unskilled wage inequality, will depend on the supply and demand for local services, as well as on the development of e-commerce (De Fraja et al., 2022; Gokan et al., 2022).

[16] "In August, ResumeBuilder surveyed 1000 corporate decision-makers about their return-to-office (RTO) plans. Here are the main results: (i) 90% of companies will return to the office by 2024; (ii) only 2% say their company never plans to require employees to return to work in person; (iii) 72% say RTO has improved revenue; (iv) 28% will threaten to fire employees who do not comply with RTO policies". (Forbes, Sept 24, 2023, https://www.forbes.com/sites/shephyken/2023/09/24/nine-out-of-10-companies-will-require-employees-to-return-to-the-office/?sh=1cea60732baf).

Declaration of competing interest

The authors declares that they have no relevant or material financial interests that relate to the research described in the paper: "Working from home: Too much of a good thing?"

Data availability

No data was used for the research described in the article.

Appendix A. Uniqueness of the interior equilibrium

Plugging (37) and (38) into (32) and (33), the two equilibrium conditions can be expressed as follows:

$$B = (1-\beta)\left\{(C_1+C_2) + \left[(C_1+C_2)(\phi\tau-1)\beta + C_2\right]\frac{1}{\tau}\frac{\varepsilon}{\beta-\varepsilon}\right\}\frac{L_s}{C_1}, \tag{A.1}$$

$$\frac{w_\ell}{p_b} = (1-\beta)\left[1-\delta(C_1+C_2) + \left[\left(1-\delta(C_1+C_2)\right)(\phi\tau-1)\beta + 1 - C_1 - \delta C_2\right]\frac{1}{\tau}\frac{\varepsilon}{\beta-\varepsilon}\right]\frac{L_s}{C_1 L_\ell}. \tag{A.2}$$

The right-hand sides of these two equations decrease with β. Therefore, the left-hand side of the equilibrium condition (34) decreases with β, whereas its right-hand side increases with β. Eq. (36) shows that $\varepsilon < \beta^* < 1$. For those values, the left-hand side of (34) decreases from infinity to zero, while the right-hand side increases from 0 to infinity. Consequently, since all functions are continuous, (34) has a unique positive solution β^* satisfying $\varepsilon < \beta^* < 1$.

Combining (37) and (A.2), we obtain the following expression for the wage ratio:

$$C_1\frac{w_\ell}{w_s}\frac{L_\ell}{L_s} = \left(1-\delta(C_1+C_2)\right)\frac{\beta^*-\varepsilon}{\varepsilon} + \frac{1}{\tau}\left[\left(1-\delta(C_1+C_2)\right)(\phi\tau-1)\beta^* + 1 - C_1 - \delta C_2\right]. \tag{A.3}$$

Substituting the equilibrium value β^* into (A.1) and (A.3) yields the equilibrium values for the building output B and the wage ratio w_ℓ/w_s, while plugging β^* into (31) yields the equilibrium mass of firms. In sum, for any value of β^* we can uniquely determine the equilibrium values of all the market variables. □

Appendix B. Commuting costs

Observe that the right-hand side of (A.1) is decreasing with τ if and only if $\beta^* < \beta_1 \equiv \frac{C_2}{C_1+C_2}$, whereas the right-hand side of (A.2) is also decreasing with τ when

$$\beta^* < \beta_2 \equiv \frac{1-C_1-\delta C_2}{1-\delta(C_1+C_2)},$$

where $\beta_2 > \beta_1$. Thus, we generally cannot unambiguously sign the expressions. However, computing back-of-the-envelope values for β_1 and β_2 based on the same parameter estimates as for land elasticity (see footnote 14 for details), we find that β^* would need to be very larger (more than 0.8) for at least one of the above conditions to be violated. Since WFH shares are clearly much below 80%, in what follows we focus on the empirically plausible case where $\beta^* < \beta_1$. Then, the right-hand sides of (40) and (41) decrease with τ.

Eq. (34) shows that B and w_ℓ/p_b move in opposite directions with τ. We then rewrite (A.1) and (A.2) as follows

$$B\frac{C_1}{(C_1+C_2)L_s} = (1-\beta) + \left[(\phi\tau-1)\beta + \frac{C_2}{(C_1+C_2)}\right]\frac{1}{\tau}\frac{\varepsilon(1-\beta)}{\beta-\varepsilon}, \tag{B.1}$$

$$\frac{w_\ell}{p_b}\frac{C_1 L_\ell}{(1-\delta(C_1+C_2))L_s} = (1-\beta) + \left[(\phi\tau-1)\beta + \frac{1-C_1-\delta C_2}{(1-\delta(C_1+C_2))}\right]\frac{1}{\tau}\frac{\varepsilon(1-\beta)}{\beta-\varepsilon}. \tag{B.2}$$

The first term on the right-hand sides of both equations is $1-\beta$, which increases with τ. Therefore, the second terms on the right-hand sides increase with τ. Then, $1-C_1-C_2>0$ implies

$$\frac{C_2}{(C_1+C_2)} < \frac{1-C_1-\delta C_2}{(1-\delta(C_1+C_2))},$$

which shows that the second term on the right-hand side of (B.1) decreases faster than the second term on the right-hand side of (B.2). Therefore, it must be that B increases whereas w_ℓ/p_b decreases with τ. Finally, since w_ℓ/p_b decreases with τ and w_s/p_b increases with τ, the wage gap w_s/w_ℓ increases.

Appendix C. ICT improvements

Combining (25) and (31) yields $\frac{Y}{\sigma p_b} - \frac{w_s}{p_b}L_s = L_s(1-\beta^*)$. Since β^* increases with ϕ, the left-hand side of the above equation is a decreasing function of ϕ. Plugging (38) in (21) results in

$$\frac{Y}{\sigma p_b} = \frac{1-\gamma}{\sigma}\left[\frac{1}{\tau}\frac{w_s}{p_b}L_s + \frac{w_\ell}{p_b}L_\ell + \delta B\right],$$

which can be rewritten as follows:

$$\frac{Y}{\sigma p_b} - \frac{w_s}{p_b}L_s + \left(1-\frac{1-\gamma}{\tau\sigma}\right)\frac{w_s}{p_b}L_s = \frac{1-\gamma}{\sigma}\left[\frac{w_\ell}{p_b}L_\ell + \delta B\right].$$

The left-hand side of this equation decreases with ϕ because $1-(1-\gamma)/\tau\sigma > 0$. Therefore, the same does the right-hand side. Combining (A.1) and (A.2) and using (37) yield:

$$\left(\frac{w_\ell}{p_b}L_\ell + \delta B\right)\frac{C_1}{L_s} = (1-\beta) + \left((\phi\tau-1)\beta + 1 - C_1\right)\frac{1}{\tau}\frac{w_s}{p_b},$$

while Eq. (A.2) could be written as follows:

$$C_1\frac{w_\ell}{p_b}\frac{L_\ell}{L_s} = \left[(1-\beta) + \left((\phi\tau-1)\beta+1-C_1\right)\frac{1}{\tau}\frac{w_s}{p_b}\right](1-\delta(C_1+C_2)) + \delta C_1(1-C_1-C_2)\frac{1}{\tau}\frac{w_s}{p_b}.$$

Combining two last equations yields:

$$\frac{w_\ell}{p_b}\frac{L_\ell}{L_s} = \left(\frac{w_\ell}{p_b}L_\ell + \delta B\right)\frac{1}{L_s}(1-\delta(C_1+C_2)) + \delta(1-C_1-C_2)\frac{1}{\tau}\frac{w_s}{p_b}.$$

Since both first and second terms in the right-hand side of the above equation decreases with ϕ, the ratio w_ℓ/p_b decreases with ϕ. □

Appendix D. Proof of Proposition 10

Plugging (38) into (32) and (33) and combining the resulting expressions with (34) yield:

$$\left(1-C_1-\delta C_2\right)\frac{C_1}{L_s}B - C_1C_2\delta^{-\frac{\delta}{1-\delta}}B^{-\frac{(1-\mu)\delta}{1-\delta}}L_\ell = C_1(1-C_1-C_2)(1-\beta), \quad \text{(D.1)}$$

and

$$C_1L_\ell\frac{w_\ell}{p_b} = (1-\delta(C_1+C_2))(1-\beta) + \left(1-C_1-\delta C_2\right)\frac{1}{\tau}\frac{w_s}{p_b}. \quad \text{(D.2)}$$

The first equation pins down B as a function of β, while the second equation provides the relationship between w_s/p_b and w_ℓ/p_b. The left-hand side of (D.1) increases with B, while the right-hand side is independent of B. Therefore, a decrease in β from β^* to $\bar{\beta}$ increases the provision of buildings. Indeed, firms increase their office consumption whereas a smaller number of skilled workers choose the hybrid solution, which decreases housing consumption. As the former effect dominates the latter, B increases.

Since (34) implies that w_ℓ/p_b is a decreasing function of B, w_ℓ/p_b decreases when β decreases. It then follows from (D.2) that w_s/p_b also decreases. This in turn implies that both the skilled and the unskilled workers are worse off because the indirect utilities (7) and (10) decrease.

Furthermore, we may rewrite (D.2) as follows:

$$C_1L_\ell\frac{w_\ell}{w_s} = (1-\delta(C_1+C_2))(1-\beta)\frac{p_b}{w_s} + \left(1-C_1-\delta C_2\right)\frac{1}{\tau}.$$

Since p_b/w_s increases when β decreases, w_ℓ/w_s also increases, that is, the wage gap between skilled and unskilled shrinks. Taking the ratio of indirect utilities (7) and (10) yields

$$\frac{V_s}{V_\ell} = \frac{w_s}{\tau w_\ell},$$

which implies that the welfare gap between skilled and unskilled workers also shrinks. Thus, mandating a WFH share that is below the firms' equilibrium choice leads to decreasing welfare differences between the unskilled and the skilled.

Last, a ceiling on β lower than its equilibrium value β^* increases the value of A since $A'(\beta^*)<0$ and, therefore, leads to a wider range of varieties. □

Appendix E. Proof of Proposition 11

As shown by (36), firms' choice of a WFH share is affected by the workers' WFH share only through w_s/p_b. Then, plugging (37) into (32) and (33) yields:

$$\frac{C_1}{L_s}B = (C_1+C_2)(1-\beta) + C_2\left[\frac{\beta}{\theta}\frac{\theta(\phi\tau-1)-\gamma\kappa}{1+\gamma\kappa}+1\right]\frac{1}{\tau}\frac{\varepsilon(1-\beta)}{\beta-\varepsilon}, \quad \text{(E.1)}$$

and

$$C_1L_\ell\frac{w_\ell}{p_b} = (1-\delta(C_1+C_2))(1-\beta) + \left(1-C_1-\delta C_2\right)\left[\frac{\beta}{\theta}\frac{\theta(\phi\tau-1)-\gamma\kappa}{1+\gamma\kappa}+1\right]\frac{1}{\tau}\frac{\varepsilon(1-\beta)}{\beta-\varepsilon}. \quad \text{(E.2)}$$

As θ takes on a value below θ^*, we have $\theta(\phi\tau-1)<\gamma\kappa$, so that the right-hand sides of both equations decreases with β. Therefore, the left-hand side of (34) decreases with β while the right-hand side increases with β. As a result, (34) pins down the new equilibrium value β^*.

Similarly, a decrease in θ shifts downwards the right-hand sides of both (E.1) and (E.2). As the left-hand side of (34) is shifted downwards while the right-hand side of (34) is shifted upwards, β^* decreases when θ decreases. Hence, (37) implies that w_s/p_b increases, so that the welfare of office workers increases.

Furthermore, as θ is now exogenous, there is no welfare equalization between hybrid workers and office workers. The change in hybrid workers' welfare is ambiguous because a lower θ negatively affects their welfare, whereas a higher w_s/p_b positively affects it. However, the relative welfare of a hybrid versus an office worker (8) unambiguously decreases, which makes full-time office work a preferable option for the skilled workers. □

Appendix F. Supplementary material

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.regsciurbeco.2024.103990.

References

Adams-Prassl, A., Boneva, T., Golin, M., Rauh, C., 2022. Work that can be done from home: Evidence on variation within and across occupations and industries. Labour Econ. 74, 102083.

Aksoy, C.G., Barrero, J.M., Bloom, N., Davis, S.J., Dolls, M., Zarate, P., 2023. Working from home around the globe: 2023 report. NBER Working Paper #30866.

Allen, T.D., Golden, Shockley, K.M., 2015. How effective is telecommuting? Assessing the status of our scientific findings. Psychol. Sci. Publ. Interest 16, 40–68.

Barrero, J.M., Bloom, N., Davis, S.J., 2021. Why working from home will stick. NBER WP 28731.

Battiston, D., Blanes i Vidal, J., Kirchmaier, T., 2021. Face-to-face communication in organizations. Rev. Econom. Stud. 88, 574–609.

Bergeaud, A., Eyméoud, J.-B., Garcia, T., Henricot, D., 2023. Working from home and corporate real estate. Reg. Sci. Urban Econ. 99, 103878.

Bergstrand, J.H., Egger, P., Larch, M., 2013. Gravity redux: Estimation of gravity-equation coefficients, elasticities of substitution, and general equilibrium comparative statics under asymmetric bilateral trade costs. J. Int. Econ. 89, 110–121.
Bick, A., Blandin, A., Mertens, K., 2023. Work from home before and after the COVID-19 outbreak. Am. Econ. J.: Macroecon. 15, 1–39.
Bloom, N., Liang, J., Roberts, J., Ying, Z.J., 2015. Does working from home work? Evidence from a Chinese experiment. Q. J. Econ. 130, 165–218.
Brueckner, J., Kahn, M., Lin, G., 2023. A new spatial hedonic equilibrium in the emerging work-from-home economy? Amer. Econ. J.: Appl. Econ. 15, 285–319.
Brueckner, J.K., Sayantani, S., 2023. Intercity impacts of work-from-home with both remote and non-remote workers. J. Hous. Econ. 59, 101910.
Chapple, K., Leong, M., Huang, D., Moore, H., Schmahmann, L., Wang, J., 2023. The death of downtown? Pandemic recovery trajectories across 62 North American Cities.
Charlot, S., Gaigné, C., Robert-Nicoud, F., Thisse, J.F., 2006. Agglomeration and welfare: the core–periphery model in the light of Bentham, Kaldor, and Rawls. J. Publ. Econ. 90 (1–2), 325–347.
Combes, P.-P., Duranton, G., Gobillon, L., 2021. The production function for housing: Evidence from France. J. Polit. Econ. 129, 2766–2816.
Couture, V., Handbury, J., 2023. Neighborhood change, gentrification, and the urbanization of college graduates. J. Econ. Perspect. 37, 29–52.
Criscuolo, C., Gal, P., Leidecker, T., Losma, F., Nicoletti, G., 2023. The role of telework for productivity during and post COVID-19. Econ. et Stat./Econ. Stat. 539, 51–72.
Davis, M.A., Ghent, A.C., Gregory, J.M., 2021. The work-from-home technology boon and its consequences. NBER Working Paper #28461.
Davis, M.A., Ortalo-Magné, F., 2011. Household expenditures, wages, rents. Rev. Econ. Dyn. 14, 248–261.
De Fraja, G., Matheson, J., Mizen, P.D., Rockey, J., Taneja, S., 2022. Remote working and the new geography of local service spending. CEPR Discussion Paper DP 17431.
Delventhal, M., Kwon, E., Parkhomenko, A., 2022. How do cities change when we work from home? J. Urban Econ. 127, 103331.
Dingel, J., Neiman, B., 2020. How many jobs can be done at home? J. Publ. Econ. 189, 104235.
Eurostat, 2020. How usual is it to work from home? Available online at: https://ec.europa.eu/eurostat/fr/web/products-eurostat-news/-/DDN-20200206-1.
Gibbs, M., Mengel, F., Siemroth, C., 2023. Work from home and productivity: Evidence from personnel and analytics data on information technology professionals. J. Polit. Econ. Microecon. 1, 7–41.
Glaeser, E., Gyourko, J., Saks, R., 2005. Why is Manhattan so expensive? Regulation and the rise in housing prices. J. Law Econ. XLVIII 331–369.
Gokan, T., Kichko, S., Matheson, J., Thisse, J.-F., 2022. How the rise of teleworking will reshape labor markets and cities. CEPR DP17672.
Gupta, A., V. Mittal, Jonas Peeters, Van Nieuwerburgh, S., 2022. Flattening the curve: Pandemic-induced revaluation of urban real estate. J. Financ. Econ. 146, 594–636.
Hilber, C.A.L., Vermeulen, W., 2014. The impact of supply constraints on house prices in England. Econom. J. 126, 358–405.
Hsieh, C.-T., Moretti, E., 2019. Housing constraints and spatial misallocation. Am. Econ. J.: Macroecon. 11, 1–39.
Jarosch, G., Oberfield, E., Rossi-Hansberg, E., 2021. Learning from coworkers. Econometrica 89, 647–676.
Kawaguchi, D., Motegi, H., 2021. Who can work from home? The roles of job tasks and HRM practices. J. Jpn. Int. Econ. 62, 101162.
Kyriakopoulou, E., Picard, P.M., 2023. The Zoom city: working from home, urban productivity and land use. J. Econ. Geogr. 23(6), 1397–1437.
Liu, S., Su, Y., 2021. The impact of the COVID-19 pandemic on the demand for density: Evidence from the U.S. housing market. Econom. Lett. 207, 110010.
Liu, S., Su, Y., 2023. The effect of working from home on the agglomeration economies of cities: evidence from advertised wages. Available at SSRN 4109630.
Monte, M., Porcher, C., Rossi-Hansberg, E., 2023. Remote work and city structure. CEPR Discussion Paper DP18311.
Morikawa, M., 2022. Work-from-home productivity during the COVID-19 pandemic: Evidence from Japan. Econ. Inq. 60, 508–527.
Redding, S.J., Turner, M.A., 2015. Transportation costs and the spatial organization of economic activity. In: Duranton, G., Henderson, J.V., Strange, W.C. (Eds.), In: Handbook of Urban and Regional Economics, vol. 5, Elsevier, Amsterdam, pp. 1339–1398.
Rhee, H.-J., 2008. Home-based telecommuting and commuting behavior. J. Urban Econ. 63, 198–216.
Safirova, E., 2002. Telecommuting, traffic congestion, and agglomeration: A general equilibrium model. J. Urban Econ. 52, 26–52.
Saiz, A., 2010. The geographic determinants of housing supply. Q. J. Econ. 125 (1), 1253–1296.
Small, K.A., 2012. Valuation of travel time. Econ. Transp. 1, 2–14.
Smite, D., Moe, N.B., Hildrum, J., Gonzalez-Huerta, J., Mendez, D., 2023. Work-from-home is here to stay: Call for flexibility in post-pandemic work policies. J. Syst. Softw. 195, 111552.
Stanton, C., Tiwari, P., 2021. Housing consumption and the cost of remote work. NBER Working Paper #28483.
Van Nieuwerburgh, S., 2023. The remote work revolution: Impact on real estate values and the urban environment. Real Estate Econ. 51, 7–48.