Covid and Cities, Thus Far

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OVERVIEW

- A key story of the COVID-19 pandemic was the shift to working from home, an arrangement that was once unusual, by necessity became widespread, and persists for many even as the health crisis subsides.
- This study considers the effects of this shift on property prices and the spatial and functional differentiation of cities as those able to work remotely reassess their housing choices and push outward from city centers.
- Adapting a textbook "monocentric" model of resource allocation within a city, the authors provide a framework for quantifying the effects of the work-from-home shock.
- They extend the analysis to consider how these effects might be magnified by changes in the mix of urban amenities that cities can offer, while also addressing the implications of the work-from-home shift for wages, worker productivity, and the strength of agglomeration forces.

The use of cities has changed during the COVID-19 pandemic. But how will cities develop as the immediate health risks associated with the virus subside? To provide insights on this issue, we consider the impact of the pandemic on how people want to use space in cities and how these changes in the use of cities, in turn, shape the opportunities these cities offer, both as places to work and places to live.

We first summarize recent evidence about the evolution of housing prices, commercial property prices, and population in cities from the onset of the pandemic to early 2022. We observe that residential prices increased, on average, while commercial property prices decreased. Beneath these averages, we find important differences in price changes within cities: residential prices increased in the suburbs relative to neighborhoods closer to city centers, where prices, in some cases, declined. This flattening of the property price gradient is associated with a significant relocation of residents and businesses away from downtowns. Across cities, we have, so far, only observed minimal changes with small and temporary population outflows away from the largest cities.

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Nonetheless, there are hints of more persistent population changes as the housing supply begins to adjust.

We argue that the COVID-era price changes and within-city migration patterns result from work-from-home (WFH) arrangements. Working from home changes the household location decision in two ways: the first is a reduction in commuting costs and the second is a reduction in, or tax on, the space one can consume at home to make room for an office. We refer to these as a "commuting dividend" and a "home-office tax." Taken together, these two forces imply an increase in the aggregate demand for housing, since households want to counterbalance the home-office they had to set up, and they find more remote locations relatively more attractive. As long as WFH stays, these forces will remain at play.

The COVID-era shifts we observe in the price gradient are, to a large extent, textbook illustrations of what the simplest urban models would predict following the twin WFH shocks of the commuting dividend and the home-office tax. They also reflect what more recent models would predict from a reduction in the amenity value of downtowns, induced by the health risks associated with the indoor activities that characterize downtowns. Many of these changes are ongoing. We use the textbook model to interpret the current situation, but it also provides us with a framework with which to form ideas about how future changes may look.

We find that a simple urban model where residential choices depend only on housing and commuting costs matches the short-run response to the twin COVID shocks that we observe: When most of the workforce is working from home, prices increase in the suburbs and decline near city centers. We then adjust the model to allow for the medium-run scenario where only some workers, typically college-educated, continue to WFH, but everyone else resumes commuting full-time. In this specification, we match the medium-run response of prices to increases citywide: prices increase everywhere because the skew in the commuting dividend toward the higher-paid college graduates results in a larger increase in aggregate housing demand.

Changes in urban amenities amplify all of these effects. We expect household demand for restaurants, bars, gyms, salons, and other nontradable services to rebound as the health risks of engaging in these indoor activities subside. However, these amenities may spread out more post-pandemic so that they locate closer to where their customers are. The advantage of urban centers in providing a wide variety of these establishments relies crucially on the daytime workforce. So, if downtowns cease to be great places to work, they may also stop being such great places to live.

We also consider the effect that WFH has on the strength of agglomeration forces in cities. To a large extent, the agglomeration economies associated with the physical proximity of workers who learn from each other behave like local amenities. At the same time, these direct interactions are only one channel for agglomeration effects. Other channels, such as those that rely on the thickness of local labor markets or a dense network of input-output transactions, are less susceptible to change from WFH.

Finally, we return to the same model and allow for the long-run margins to operate. While obviously speculative, we expect that the twin shocks of the commuting dividend and the home-office tax will amplify the current trends in the longer run. More attractive downtowns are likely to enjoy a renaissance. We expect that the recovering downtowns will host more creative workers who go to work to benefit from exchanging with others. Because of their outward orientation and their spending power, these workers will energize downtowns and other concentrations of economic activity much more than the many workers who previously showed up at work just because everyone thought they should. These centers of economic activity may turn out to be even more vibrant than they were pre-COVID. Since there are only so many of these creative workers whose jobs depend on human interactions, and since these workers can move to cluster in certain cities, perhaps not all downtowns will recover.

Meanwhile, housing supply will adjust to accommodate the increasing demand for housing by support workers who work from home the majority of the time and may demand a home office. Cities will likely expand physically to allow new residential construction. As the response of housing supply is likely to differ greatly across cities, "housing hungry" residents will relocate to cities willing to accommodate urban expansion.

1. COVID's Initial Impact on Cities

In the midst of the pandemic, economists have used (close to) real-time data to document how real estate prices and demand adjusted within and across U.S. cities in response to COVID-19.[1] We report findings up to early 2022 before changes in the macroeconomic situation started interfering with some of the features we document here.[2]

1.1 Suburban Migration

The U. S. Postal Service National Change of Address database shows households moving from downtown toward the suburbs in large U.S. cities at the onset of the pandemic. Ramani and Bloom (2021) use these data to show that the densest zip codes lost about 15 percent of their populations, while the least dense gained about 2 percent between February 2020 and January 2021. Gupta et al. (2022) document a similar shift in residential population toward the suburbs over 2020 in the thirty largest metropolitan areas. These changes are often referred to as a "donut effect," with renewed suburbanization and a partial hollowing out cities of their downtown residents. Liu and Su (2021) find evidence of adjustments consistent with such flows, including increased home searches and declining housing inventories in suburbs.

To put these figures in perspective, we note that the 2 percent population growth for less dense locations corresponds to the annual population growth between 2010 and 2019 of Dallas, Texas, the fastest growing large metropolitan area in the United States during this period. More striking, the 15 percent population decline for the densest locations exceeds the population loss of Pine Bluff, Arkansas, between 2010 and 2019. No other metropolitan area did worse than Pine Bluff, a struggling mid-sized city, during this period.

1.2 Migration across Cities

Across cities, the migration toward less dense cities has been less pronounced so far. Despite a much talked about exodus from the largest and densest cities early on in the COVID crisis, Haslag and Weagley (2021) find that only about 10 percent of long-distance moves are

COVID-related. This is perhaps because only a small minority of workers expect to remain fully remote.

However, more recent evidence is starting to emerge that between a quarter and one-third of moves are beyond commutable distance, four or more hours away from the workplace (Ozimek 2022). Brueckner, Kahn, and Lin (2023) also document a movement away from more productive counties where the mix of occupations is more amenable to WFH. With more workers planning to move away from relatively expensive cities with a strong WFH potential, this may be just the beginning of a significant trend. Eventually, both residents and jobs may move to cities where elastic housing supply makes living there more affordable. We return to these issues below as we seek to provide a framework within which these trends can be interpreted.

1.3 Rising House Prices and Flattening Urban Gradients

Mondragon and Wieland (2022) report that house prices grew by 23.8 percent between November 2019 just before the pandemic and November 2021. The same authors also argue that the increased demand for housing caused by the rise of WFH explains more than half of that growth. In related evidence, Gamber, Graham, and Yadav (2023) show that house price growth is stronger in counties where residents have spent more time at home owing to a more severe incidence of the pandemic.

This increase in housing prices is not homogeneous over space. The donut effect of residents moving from downtown to the suburbs is reflected in a drop in downtown rents and house prices relative to those in the suburbs. Between February 2020 and January 2021, Zillow's Observed Rental Index dropped by 20 percent in the top twelve central business districts relative to below-median-density zip codes (Ramani and Bloom 2021). See Chart 1 for an illustration. The corresponding relative drop in Zillow's Home Value Index was 15 percent. Gupta et al. (2022) show that the rent gradient flattened over 2020 by 0.032, with rents increasing by 12 percent and house prices increasing by 6.5 percent in suburban locations 50 kilometers from city centers.[3]

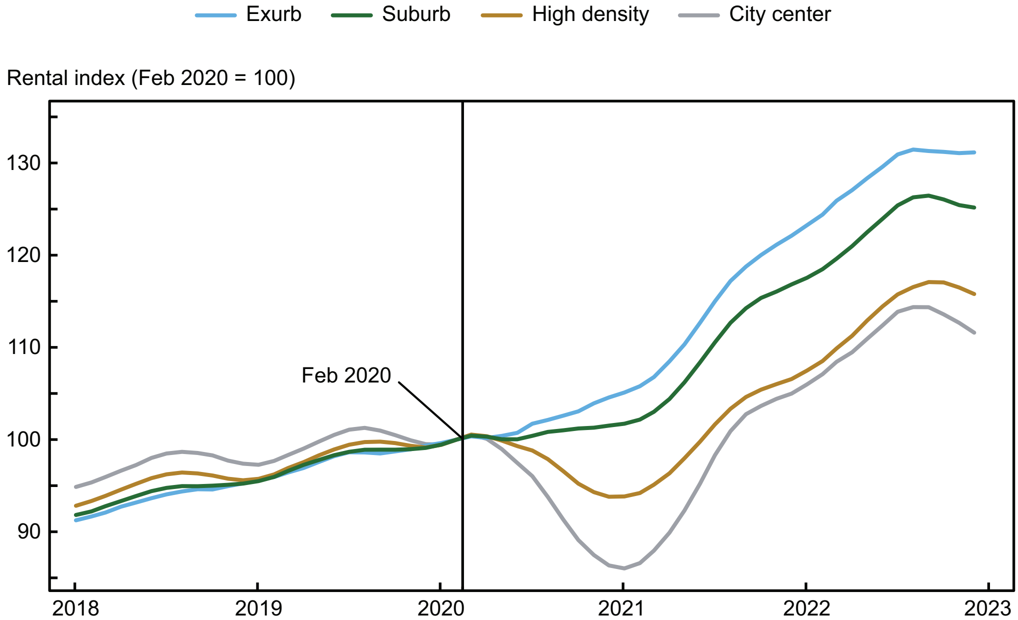
This flattening of house price gradients is also evidenced by Brueckner, Kahn, and Lin (2023). Consistent with these findings, D'Lima, Lopez, and Pradhan (2022) document declines in housing rents in denser locations and increases in less dense locations with stronger effects for smaller properties.

Importantly, Chart 1 shows that housing rents strongly recovered everywhere in the second quarter of 2021 until the summer of 2022 as the U.S. economy slowly reopened. Nonetheless, there is still a large differential between rents in the outer parts of cities which have increased by 15 to 20 percentage points more than in urban centers.

1.4 Flattening Commercial Rents

Rosenthal, Strange, and Urrego (2022) document a qualitatively similar, but smaller, decline in the commercial rent gradient during the summer of 2020. In transit-oriented cities, rents on new office and retail leases fell by over 30 percent within 10 miles of the city center but less in

Chart 1
Housing Rents in the Twelve Largest U.S. Cities



Source: Ramani and Bloom (2021, Figure 1), version updated by authors. Used by permission.

Note: Calculations are based on Zillow data for New York, Los Angeles, San Francisco, Chicago, Dallas, Houston, Miami, Philadelphia, Washington, D.C., Atlanta, Boston, and Phoenix by zip code population density.

outlying areas. This decline is concentrated within 0.5 miles of transit stations and is not observed to the same extent in car-oriented cities. These results are based on new leases signed, but the volume of leasing activity in this period was also depressed to around 50 percent of its pre-pandemic level.

To get a longer-run view of the market, Ling, Wang, and Zhou (2020) study how the value of commercial real estate adjusted in response to COVID. They show that the pandemic led to a decrease in the stock prices of public real estate companies with heavily exposed portfolios that persisted even after re-openings from local shutdowns. These adjustments to valuations indicate market expectations for further rent decreases and/or increased cash flow volatility.

These early responses of public markets have since been observed in the market for office space, which are seeing rising vacancies and now flat or declining rents. Gupta, Mittal, and Van Nieuwerburgh (2022) document an 8 percent decline in revenue for the entire office sector in the United States between early 2020 and late 2021. This decline can be entirely accounted for by fewer leases rather than by lower rents on existing leases. Although average rents on new leases decreased sharply, rents on in-place leases increased in accordance with built-in rent escalation clauses.

Looking forward, the large increase in vacancies that resulted from difficulties in finding new tenants, fewer renewals, and partial renewals will likely put further downward pressure on commercial rents. Vacancies may also worsen if many firms decide not to renew their leases, putting further downward pressure on rents and slowing price discovery.[4]

The lower demand for office space is foreshadowed by sharp declines in occupancy rates of office buildings, a natural consequence of increased WFH. As of May 2022, Gupta, Mittal and Van Nieuwerburgh (2022) report an occupancy rate of only about 50 percent for the ten largest office markets in the United States and find a strong negative correlation between office demand and the share of remote jobs in new listings. Declining occupancy rates in downtown office buildings and WFH also correlate naturally with a sharp reduction in transit ridership (Qi et al. 2021) and a still sizeable reduction in car travel of more than 20 percent for commutes to downtowns in the United States in 2021 (Pishue 2021).

2. Will These Patterns Persist?

The patterns documented during the height of the pandemic could be attributable to the fact that households spent more time at home. This shift was not just about remote work, but it was also attributable to a move away from leisure activities at indoor commercial establishments due to health concerns. As these health concerns abate, we have seen these leisure patterns outside the home return to their pre-pandemic levels, while remote work appears to be persisting.

Kastle's "Back to Work Barometer," for example, shows that physical office occupancy remained below 45 percent of its pre-pandemic level across the largest ten U.S. cities as of May 2022, while dining activity and travel through airport checkpoints, as measured by OpenTable and the Transportation Security Administration, both returned to over 80 percent of pre-pandemic levels by that time.[5] These data support the predictions from survey-based evidence that WFH will stick (Barrero, Bloom, and Davis 2021a; Bick, Blandin, and Mertens 2022; Abel, Bram, and Deitz 2022). Further supportive evidence is also provided by Delventhal and Parkhomenko (2022).

2.1 An Interpretive Framework

To interpret the data, we consider the WFH shock in a model of housing in cities in the tradition of Alonso (1964), Mills (1967), and Muth (1969) as presented in Duranton and Puga (2015). We start with stark assumptions to highlight the main trade-offs. We consider one city that produces its consumption good downtown (often referred to as the central business district, or CBD) where all jobs are concentrated.[6] We normalize the price of this consumption good to 1. Residents also consume housing, which is supplied competitively along a segment between downtown, 0, and the urban fringe, $\bar{x}$. For now, we take the supply of housing and its distribution between the center and the urban fringe in the city as given.

Preferences can be represented by a utility function $u(h, z)$ where utility is obtained from consuming housing, h, and other goods, z, which we take as the numéraire. Utility is increasing in both arguments (and we assume strict quasi-concavity).

A resident living at distance x to downtown incurs a commuting cost τx. This leaves this resident with a disposable income of $w - \tau x$ for expenditure on housing and other goods. Letting $P(x)$ denote the rental price of housing at a distance x from the center, this resident's budget constraint is thus $w - \tau x = P(x)\, h + z$. Expressed in words, after paying a commuting cost τx, a resident at distance x from the center buys a quantity h of housing ("the size of the house") at a price $P(x)$ per unit and spends z on other goods.

So, at a given location, a resident is facing a consumption problem having to choose between housing and other goods. This appears very similar to the standard consumer problem studied in intermediate microeconomics after replacing the traditional "pizza" and "beer" by housing and other goods.

There are two differences, though. The first is that the price of housing at each location is endogenously determined (and to be solved for as well). The second difference is that residents also choose where to live. Assuming for now that all residents in the city are identical in income and preferences and that they are freely mobile within the city, they must achieve the same level of utility $\underline{u}$ everywhere. This is usually referred to as a "spatial equilibrium." In essence, nobody in the city can increase their utility by moving to another location. Housing prices adjust to that effect.[7]

Finally, let us assume that there is no movement into and out of the city; that is, the city is "closed." To a first approximation, this assumption is consistent with what we observed during the first two years of the pandemic: flows of migrants between cities were small. We understand that WFH does not in most cases allow residents to relocate anywhere they would wish. They still need to get to their jobs, at least some of the time.[8]

We solve for the consumption choice between housing and other goods in the usual way. That is, a resident will allocate her expenditure so as to equalize the bang-for-the-buck across the two goods:

$$\frac{u_h}{P} = u_z. \tag{1}$$

Equation (1) shows that the marginal utility per dollar for housing, u_h is equal to the marginal utility for other goods u_z (recall that we normalized the price of other goods to 1).[9]

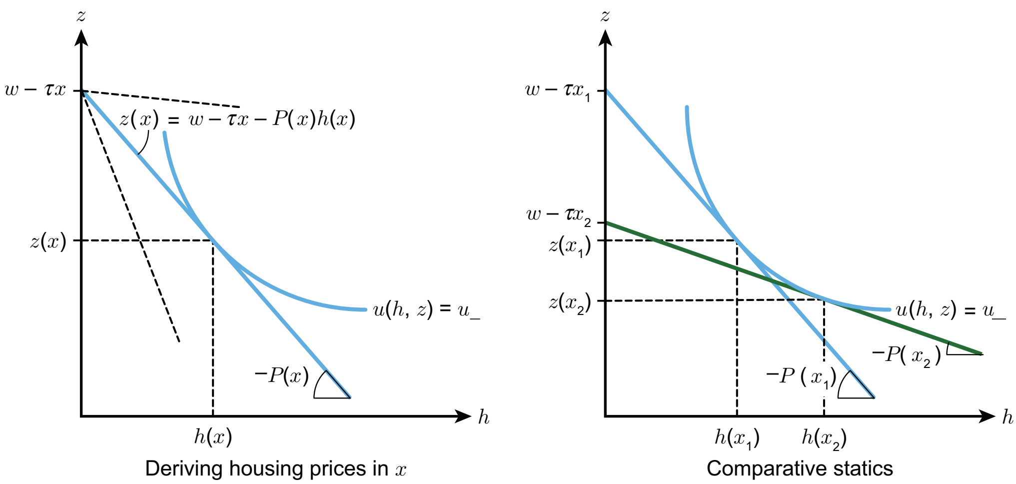
We assume residents will choose their residence optimally, knowing their consumption choice at each location. The key optimality condition here is that a resident who moves slightly farther away from downtown must still enjoy the same level of utility. To satisfy this condition, a small increase in distance to the center *d(x)*, which increases commuting costs by $\tau\, d(x)$, must be exactly offset by declining housing costs $dP(x) \times h(x)$, where $dP(x)$ is the change in the price of housing per unit.[10] We can thus write the following expression:

$$P'(x) = -\frac{\tau}{h(x)}. \tag{2}$$

This condition, known in the literature as the Alonso-Muth condition, indicates that there is a negative house-price gradient in cities as one considers dwellings farther away from the center. Importantly, this gradient is equal to the cost of commuting per unit distance divided by the consumption of housing.

The left panel of Exhibit 1 provides an illustration of the mechanics associated with equation (1) at the spatial equilibrium. The consumption of housing is represented on the horizontal axis and that of other goods on the vertical axis. The indifference curve $u(h, z) = \underline{u}$ represents all the combinations of housing and other goods that allow a resident to achieve

Exhibit 1
A Graphical Representation of the Monocentric Model



Note: These figures borrow from Duranton and Puga (2015) and were inspired by Brueckner's (1987) earlier work.

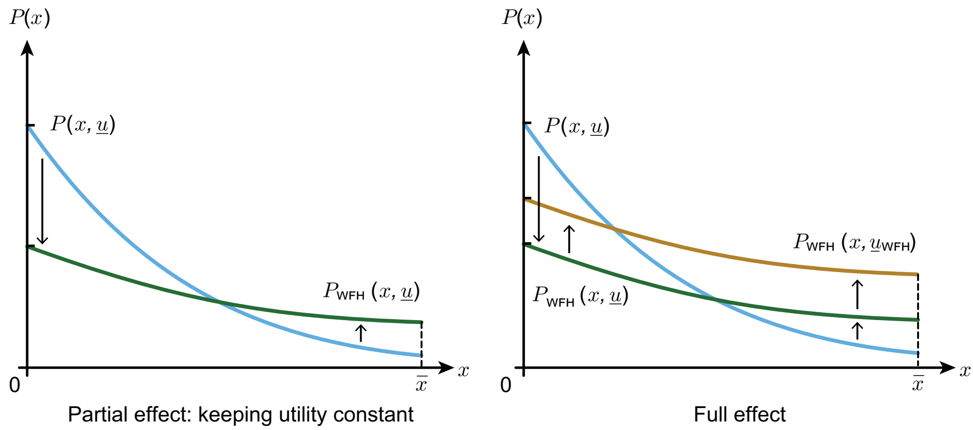
utility $\underline{u}$. Then, if we consider a resident living in x, the budget constraint of this resident is given by the line $z(x) = w - \tau x - P(x)h(x)$. The slope of this budget line is $-P(x)$. As the price of housing increases, the budget line rotates clockwise around its intercept $w - \tau x$. If the slope of the budget line is very flat as for the upper dashed line in the left panel, residents in x can attain a level of utility higher than $\underline{u}$. Then, residents from other locations in the city will bid up the price of housing until the budget constraint is just tangent to the indifference curve for $\underline{u}$. At the point of tangency, we can read, for the resident living at location x, the consumption of housing $h(x)$ on the horizontal axis and that of other goods $z(x)$ on the vertical axis.[11]

To illustrate the workings of equation (2), the right panel of Exhibit 1 considers two locations x_1, closer to the center, and $x_2 > x_1$, farther away. At x_1, the price of housing, $P(x_1)$, is reflected by the slope of the budget constraint with intercept $w - \tau x_1$ that is tangent to the indifference curve $u(h, z) = \underline{u}$. Again, the tangency point allows us to read the consumption of housing $h(x_1)$ and other goods $z(x_1)$ for this resident. We can repeat the same exercise for the other resident in x_2. For this second resident, the intercept of the budget line is lower because of the higher commuting cost in x_2. As a result, the budget constraint for x_2 must be flatter and must involve a lower housing price for the budget line to be tangent to the indifference curve. It is also the case that the consumption of housing is higher in x_2 relative to x_1, whereas the consumption of the numéraire is lower in x_2.

2.2 Introducing Work from Home

We can now use this model to assess the effects of an increase in WFH. We start with a situation where WFH affected most households and, for now, we ignore differences between skill groups. Not having to commute every day, unlike the norm prior to the pandemic, implies a reduction in commuting costs.[12] At the same time, moving the office inside the home implies devoting part of what was a resident's living space to a home office. When working from home,

Exhibit 2
Effects of Lower Commuting Costs on the Rent Gradient



Notes: The illustration reflects a 30 percent reduction in commuting costs, equivalent to working from home two days per week instead of none. See Appendix 1 for derivations and the main text for details about the quantification.

the place of work might be more convenient but it still takes space. It is as if housing space at home is taxed. This "tax" could be either a fixed amount, say 100 square feet, or proportional to the size of the house, say the home office h_o is 5 to 10 percent of h.

Let us explore these two changes in light of the model. We consider a short-run situation where people can move within the city and adjust their consumption of housing space. The urban fringe remains the same and housing supply inside the city is, for now, fixed. We also ignore any change in productivity or in amenities associated with work from home.

The "Commuting Dividend"

People who WFH do not need to commute to work as frequently and, therefore, face lower average commuting costs. The effect of lower commuting costs is most directly apparent in condition (2). A lower cost of commuting τ flattens the housing-price gradient through a direct effect on the numerator in equation (2). With lower commuting costs, housing closer to the urban fringe enjoys cheaper access to downtown and its price increases. Housing closer to downtown now offers a smaller accessibility advantage and its price goes down. What we called a flattening of the housing-price gradient in Section 2 is really a rotation counter-clockwise. We provide a visual representation of this rotation using the functional forms and parameter values we propose below. The left panel of Exhibit 2 represents the effect of lower commuting costs, keeping utility constant.

Because the city remains "closed" to new residents for now, a lower cost of commuting also implies an income effect whereby residents all enjoy a higher disposable income after spending less on commuting. In turn, a higher disposable income implies a greater demand for both housing and other goods. Because housing is in fixed supply at each location, its price increases. So after rotating the house-price gradient, housing prices also increase. This change is represented in right panel of Exhibit 2.

Despite this increase in housing prices, residents are collectively made better off by lower commuting costs. Downtown residents enjoy a higher level of utility just like everyone else in the city. To achieve this, the price of housing at the center must be lower than it was initially. In turn, households residing at the center each consume more housing than they did previously and the central city population density falls. By contrast, more expensive housing prices in the suburbs are synonymous with less consumption of housing per suburban resident and thus a higher suburban population density than before the WFH shock.

Lower commuting costs provide a parsimonious explanation for the changes we describe above. With a constant population and a constant stock of housing, the city-level average housing consumption is unchanged but the housing-price gradient shifts: housing costs decrease in the city center and increase in the suburbs. These patterns are consistent with the short-run price response to the WFH shock in the first year of the pandemic, when urban expansion was indeed limited.[13] Changes in housing prices also imply diverging outcomes for renters and (suburban) owners.[14]

The Home-Office "Tax"

Lower commuting costs are the sunny aspect of WFH but there is also a darker side. Part of what was "home" is now the office. Recall that we model this shift as if WFH is taxing away part of home, say, by a fraction t. A simple way to represent this tax is to argue that for a purchase of h^T units of housing, a resident only gets to enjoy $h = (1 - t)h^T$ with the rest, $h_o = th^T$, being devoted to a home-office from which no utility is derived. Let us call h^T total housing and h "effective housing." So utility is still $u\,(h,z)$ but the budget constraint is now such that $P\,(x)\,h^T\,(x) + z = w - \tau\,x$. Since $h = (1 - t)h^T$, we can rewrite the budget constraint as $\frac{P(x)}{1-t}h(x)+z = w-\tau x$. Hence, this tax is equivalent to an increase in the price of effective housing for which demand will decline. The first effect of the home-office tax is thus to reduce the amount of housing available for enjoyment by a factor of $1 - t$, which in turn reduces utility.

Turning to the demand for total housing, we note that if the price elasticity of the demand for *effective* housing is below 1 (that is, housing demand is relatively inelastic), demand for *total* housing will actually increase with the home-office tax. The main intuition behind this result is the following. When a good is inelastic, a price increase leads to a less than proportional reduction in the quantity consumed and thus an increase in the expenditure on this good. A 10 percent home-office tax may thus lead residents to reduce their consumption of effective housing by 5 percent; Yet, with a home office representing 10 percent of residents' consumption of total housing, this tax still implies a 5 percent increase in the consumption of total housing. In practice, with 10 percent of a dwelling now devoted to a home office, residents will want to increase their consumption of total housing, for instance, to regain a small guest bedroom after losing it to a home office.

Conversely, if the price elasticity of the demand for housing is above 1 (that is, housing demand is relatively elastic), the home-office tax will instead lead to a decline in housing expenditure and a lower consumption of total housing. In the particular case of a unit price elasticity of the demand for housing, housing expenditure remains constant and households keep demanding the same quantity of total housing, since the price increase associated with the tax will be met with a proportional reduction in the demand for effective housing, leaving the taxed part of total housing to accommodate the home office.

The literature is not definitive on the price elasticity of housing demand. For tractability in the analysis above, we impose a value of 1. If demand for housing is instead inelastic, as suggested in the still-preeminent Hanushek and Quigley (1980), and supply is fixed, then the effect of the WFH dividend will be amplified by higher prices.[15]

Discussion

To summarize, the commuting dividend implies a flattening of the bid-rent curve, the suburbanization of residents, and a further shift up in prices caused by a higher disposable income with reduced commuting costs. The WFH tax reduces utility as the home office is not valued as part of household consumption. As we discuss below, housing is perhaps modestly inelastic so that this tax may increase housing prices further, but only by a modest amount.

Before turning to the quantification of our model, let us briefly relate our work to other attempts at evaluating the effects of WFH on cities. Gokan et al. (2022) develop a model closely related to ours in spirit. We view their work as a complement to what we do. Their model does not allow for changes in the quantity of housing per household and they do not provide as detailed a quantification as we do. On the other hand, they close the link between local amenities and the employment and wages of the workers providing them. Kyirakopoulou and Picard (2021) provide a rich model of urban land use where downtown locations emerge endogenously from spillovers between different types of workers. While we discuss productivity issues separately below, we note that their framework shares many of the features and properties that we highlight here but its complexity makes it less amenable to a detailed quantification. Delventhal, Kwon, and Parkhomenko (2022) use a very different framework inspired by Ahlfeldt et al. (2015) with no predetermined downtown but where the city remains enclosed within a fixed urban fringe. Despite this very different setting, their model also generates features similar to those highlighted here and below, where we extend our approach to deal with urban sorting.[16] Brueckner, Kahn, and Lin (2023) explore the effects of a possible decoupling between a city of residence and a city of work. While these are important issues looking forward and we discuss them below, they are less relevant to explaining the evolution of the housing market over the last two years, our main concern here.

2.3 A Quantification

To provide a sense of the economic magnitudes of these effects, we consider an example with specific functional forms that we calibrate to reasonable estimates for its key parameters.[17]

Baseline Calibration

We consider the particular case where utility is Cobb-Douglas in housing and other goods $U(x) = h(x)^{\alpha} z(x)^{1-\alpha}$. We can take $\alpha = 1/3$ as a first approximation for the share of housing in utility. According to the U. S. Bureau of Labor Statistics (2021), American households devoted 32.8 percent of their income to housing (and 17.0 percent to transportation) in 2019.[18]

To set up a reference city, we note that after ranking U.S. metropolitan areas by their 2010 population, the median metropolitan resident lives in Tampa, Florida, with a population of 2.4 million and a distance $\bar{x}$ between its center and its urban fringe of close to 60 kilometers.[19]

Relative to the baseline model, we introduce a small change to the specification of commuting costs. Rather than assume that commuting costs increase linearly in distance, x, we make them proportional to x^{γ}. Empirically, households' distance to work and total vehicle-kilometers driven increase less than proportionately to distance to the center. Taking a value of γ much below 1 turns out to be an important adjustment.

Duranton and Puga (2022) estimate a value of γ of about 0.07 when exploiting annual driving distance for all trips in U.S. metropolitan areas. Interestingly, they estimate a similar gradient for housing rents as predicted by the analogous equation to expression (2) when commuting costs are proportional to x^{γ} rather than x. Given our focus on commuting and WFH, it is more appropriate to consider only distance driven to and from work. Replacing the total distance driven with commuting distance as dependent variable in the Duranton and Puga (2022) regression, we estimate a higher value of γ of about 0.21.

Then, we set total daily commuting distance to $x^{0.21} \times 2 \times 10$ kilometers where distance to the center x, elevated to the power 0.21, is multiplied by two commutes a day and by 10 kilometers, the commute of a resident living 1 kilometer away from the center. This specification matches the data well.[20]

To value these commutes, we first note that the cost of commutes sums an implicit value of travel time and the cost of operating a vehicle. Starting with the valuation of time, we first calculate daily commuting time for each resident in our model by dividing commuting distance by the U.S. average commuting speed of 43 kilometers per hour based on data from the National Household Travel Survey (NHTS). Then, to set a value of time, we note that there is a large literature on the subject given its importance of valuing time saved as a result of transportation improvements. Small (2012) provides an extensive review and supports the traditional consensus value of 50 percent of the wage. He also highlights the heterogeneity in these valuations, including results suggesting that perhaps commutes should be valued more highly than other trips. In recent work, Le Barbanchon, Rathelot, and Roulet (2021), Buchholz et al. (2020), and Kreindler (2023) obtain higher estimates. To remain conservative, we choose a value of time of about 60 percent of the wage, slightly above the traditional consensus but below some of the most recent estimates.

Then, for the cost of operating a vehicle, we rely on the Internal Revenue Service's mileage rate of 56 cents per mile or 35 cents per kilometer. At a speed of 43 kilometers per hour, this represents \$15.05 per hour. To sum these two quantities, we consider a worker making the median wage of about \$42,000 per year in 2019. This corresponds to \$21 per hour with 250 workdays per year and 8 hours of work per day. Hence, the cost of operating a vehicle during an hour represents about 72 percent of the median wage during this hour. Summing the value of time when commuting and the cost of operating a vehicle, we end up valuing the total cost of commuting time at 1.30 times the wage.

This quantification predicts that residents at the urban fringe 60 kilometers away from the center commute for about an hour and 6 minutes daily. Their total cost of commuting corresponds to close to 18 percent of income. For residents located 1 kilometer away from the center, the cost of commuting falls to about 7.5 percent of income.

Additionally, we need to take a stance about the distribution of the supply of housing and specify how it varies with distance to the center. We assume that housing supply is proportional to x^{σ}. Empirically, we choose a value of σ of 0.50 after estimating how the supply of housing increases with distance to the center using data from the American Community Survey as detailed in Appendix 3.

Next, we feed parameter values for our representative city, a hypothetical Tampa, into our model. As just discussed, we consider a distance to the urban fringe of 60 kilometers, 2.4 million residents, and a wage of $21 per hour, assuming a travel speed of 43 kilometers per hour, a total cost of travel of 1.3 times the wage, an elasticity of the supply of housing with respect to distance to the center of 0.5, an elasticity of commuting distance with respect to distance to the center of 0.21, and a share of housing of 0.33. This parameterization of our model allows us to generate a (counterfactual) price of housing for each location between the city center and the urban fringe. See Appendix 1 for a full set of derivations.

To have a sense of what our model predicts, we regress the log *predicted* housing price on the log distance to the center for a hypothetical pre-COVID situation where all residents commute to work every day. We estimate an elasticity of -0.096 (or -0.102 when we weight each level of distance to the center by its population).[21]

This elasticity of -0.096 predicted by the model is slightly larger (in absolute value) than the corresponding elasticity of -0.077 estimated by Duranton and Puga (2022) for *actual* housing values in all U.S. metropolitan areas. This differential is consistent with the tendency, in the data, for larger metropolitan areas to have larger elasticities. Our predicted elasticity fits well what is observed for cities with the population similar to our reference city, Tampa.[22]

For the entire city, the cost of commuting is predicted to be equivalent to 15.6 percent of income. If commuters are located following the distribution predicted by our model, the cost of commuting for someone located half way to the urban fringe, or 30 kilometers away from the center, is equivalent to 15.4 percent of income. This figure is slightly less than the mean commuting cost because more people live in the outer rings.

Quantitative Impact of the Twin COVID Shocks

To assess the COVID dividend, we compare the situation with no WFH we just described with one where workers commute only three and a half times a week instead of five, which corresponds to a decline in commuting costs of 30 percent. This figure is in line with the long-term prospects for WFH discussed above. This change in WFH implies a flattening of the land gradient. For the same baseline city, we now estimate an elasticity of predicted housing prices to distance to the center of -0.064, a decline of about one-third relative to the situation with no WFH. This flattening of the rent gradient by about 0.032 is exactly the same as the flattening of the price gradient for residential rents for the COVID shock estimated by Gupta et al. (2022) for the thirty largest U.S. metropolitan areas.[23]

Ignoring any residential change and any equilibrium effect, a 30 percent reduction in commuting is equivalent to a gain in real income of 5.4 percent for the resident at the urban fringe (60 kilometers away from the center), 2.3 percent for the resident living 1 kilometer away from the center, and, of course, no change for the resident living right at the center. With commuting costs being equivalent to 15.6 percent of city income, a 30 percent rate of WFH would bring the cost of commuting to an equivalent of 10.90 percent of city income and imply the equivalent of a 4.7 percent increase in real income for the city. When we allow for residents to adjust their location and their consumption of housing, commuting now represents 10.92 percent of city income instead of 10.90 percent in the absence of any change. These figures imply that the re-sorting of residents and their move toward the suburbs implies only a minimal change in commuting costs and does not undo the WFH commuting dividend, keeping in mind that we do not (yet) allow the city to expand. Because of the greater suburbanization of city residents, land rents also increase. This increase represents slightly less than 1 percent of city income. In turn, this result implies that most of the 4.7 percent increase in city (equivalent) income accrues to commuters.

We can also compute the change in housing prices at the center after the rise in WFH: a 10.3 percent decline. This figure is close to but slightly less than the 15 percent decline in central prices estimated empirically by Ramani and Bloom (2021) for early 2021 during the peak of the pandemic when the rate of WFH may have been higher than our assumed level. With the flattening of the land gradient, this 10.3 percent decline in downtown housing prices morphs into a predicted 8.5 percent increase in housing prices at the urban fringe. The two changes even out close to the center, about 7 kilometers away from it, consistent with the empirical findings of Ramani and Bloom (2021).

Turning to the home-office tax, Stanton and Tiwari (2021) compare households in the same housing market (defined as Public Use Microdata Areas, or PUMAs, each of which have a population of around 100,000). Prior to COVID, they find that for the average renting household with at least one adult who works remotely, expenditure on housing was between 6.5 and 7.4 percent higher than similar nonremote households in the same area. Among owners, mortgage payments and property taxes were between 8.4 and 9.8 percent greater for remote households.[24]

Overall, according to Stanton and Tiwari (2021), additional housing expenditure associated with remote work represents 3.8 percent of household income (and 2.4 percent when accounting for lower vehicular expenses). With housing representing about one-third of expenditure, it is reasonable to associate remote work with about a 10 percent tax on housing. This tax is almost surely highly regressive.[25]

In our model, because of our Cobb-Douglas assumption for the demand for housing, the demand for total housing is unchanged. This leaves the price of housing unchanged by residents enjoying less of it. The home-office tax is thus equivalent to scaling down the utility of residents by a factor of $(1 - t)^{\alpha}$, which corresponds to about a 3.5 percent reduction in income with a 10 percent home-office tax and $\alpha = 1/3$. This tax, however, does not affect the urban equilibrium in any other way. This loss from the home-office tax offsets a large part of the 4.7 percent increase in equivalent income in the city from the commuting dividend, keeping in mind that renters also pay higher rents corresponding to about 1 percent in city income. Overall, these changes are about zero for renters and a small positive for homeowners. These owners of course also enjoy an increase in their property values.

3. COVID and Spatial Sorting

Not all jobs can be done remotely and so not all people have the option to work from home. In particular, the increase in remote work has disproportionately affected college-educated workers who earn higher incomes (Mongey, Pilossoph, and Weinberg 2021). Accordingly, we might expect the growth in WFH to affect where households of different incomes choose to reside relative to the city center.

3.1 Extending the Interpretive Framework

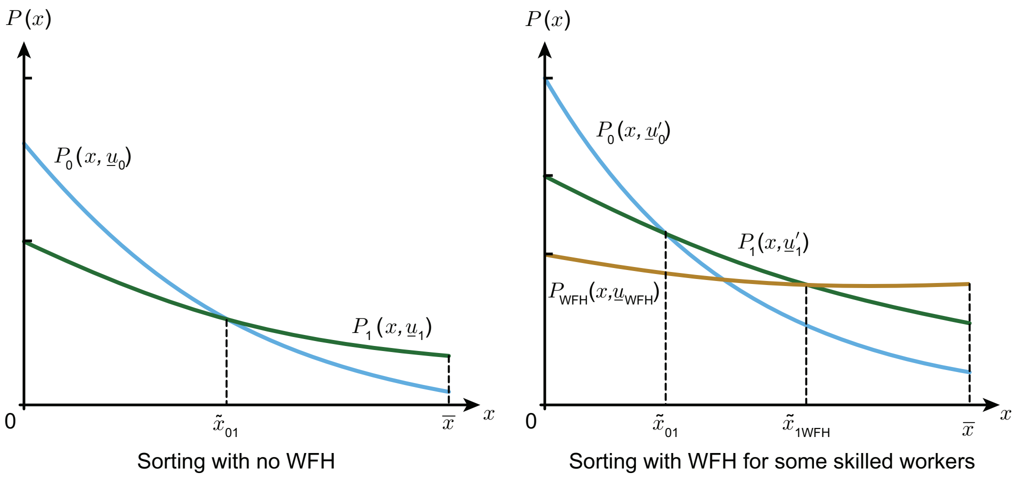
To think about the impact of WFH on spatial sorting, we extend the model above to allow for two groups of workers, unskilled and skilled, noted with subindexes 0 and 1. Earnings for the skilled are higher than for the unskilled, $w_1 > w_0$. Empirically, we identify the skilled in our model as the college-educated, so we use the terms skilled and college-educated interchangeably. We discuss how WFH may affect wages below, but for now we take them as exogenous. Commuting costs are also higher for the skilled, $\tau_1 > \tau_0$, to reflect that the value of their time is higher because of their higher wages.

For residents of each group, we first solve for how much a utility-maximizing resident is willing to pay for housing at each location while reaching the group-specific utility achieved at the spatial equilibrium $\underline{u}_0$ or $\underline{u}_1$, which is unknown at this stage. The solution to this problem is a bid-rent function that reflects the price that each group is willing to pay for housing at each location x. For a given level of utility $\underline{u}_0$ or $\underline{u}_1$, this bid-rent function is denoted $P_0(x, \underline{u}_0)$ for the unskilled and $P_1(x, \underline{u}_1)$ for the skilled.

In equilibrium, each group resides in the set of locations where it outbids the other groups and the utility that residents of each group obtains must coincide with the utility $\underline{u}_0$ or $\underline{u}_1$ they expected when bidding for housing. Finding this equilibrium is relatively straightforward when bid-rent functions cross a single time. To understand why, note that there must be some region in which $P_1(x) \geq P_0(x)$ and some region in which $P_0(x) \geq P_1(x)$ for both types of residents to live in the same city. In turn, this implies that bid-rents must cross at some interior point $\tilde{x}$.

Where they cross, the relative slopes of the bid-rent functions determine on which side each group outbids the other and, therefore, resides in equilibrium. If $P_1'(\tilde{x}) = -\frac{\tau_1}{h_1(\tilde{x})} > -\frac{\tau_0}{h_0(\tilde{x})} = P_0'(\tilde{x})$, the skilled reside in the suburbs while the unskilled reside closer to the center with perfect sorting.[26] This equilibrium is formally solved for in Appendix 2 and depicted in the left panel of Exhibit 3. The last equation simplifies into $\frac{h_1(\tilde{x})}{h_0(\tilde{x})} > \frac{\tau_1}{\tau_0}$. This is a comparison of how much more housing the skilled consume relative to the unskilled with their relative commuting costs. More generally, richer residents live farther away from the center if the income elasticity of the demand for housing exceeds the income elasticity of the cost of commuting (Glaeser, Kahn, and Rappaport 2008).

Exhibit 3
Effects of Work-from-Home (WFH) Shocks on Spatial Sorting



Notes: The distance at which skilled workers become more likely to live in the suburbs adjusts up or down in relation to vertical shifts in the bid-rent function. See Appendix 2 for derivations and the main text for details about the quantification.

We can now consider what happens to this equilibrium sorting behavior after an increase in WFH. To gain insight, we exaggerate the current situation and assume that only skilled workers can work from home. As noted previously, they benefit from the commuting dividend but they also need to incur the home-office tax. From above, we know that this change will rotate the bid-rent function of remote skilled workers $P_1(x)$ to $P_{\mathrm{WFH}}(x)$, lowering its slope. This adjustment is depicted in the shift in the right panel of Exhibit 3. Depending on how far the skilled bid-rent function shifts vertically because of the WFH housing tax, the distance at which the skilled become more likely to live in the suburbs $\tilde{x}$ will adjust either up or down.[27]

In a slightly more realistic scenario, only a subset of the skilled can work remotely. We model this scenario using three heterogeneous types: in-person skilled workers, remote skilled workers who mainly work from home, and in-person unskilled workers, as in Gokan et al. (2022). With three types, a share of the skilled stay at the same bid-rent function as prior to the WFH shift $P_1(x)$, while others move to the new bid-rent function, $P_1^{\mathrm{WFH}}(x)$. The sorting in this scenario is depicted in the right panel of Exhibit 3. The unskilled continue to reside in a first ring close to downtown, while the in-person skilled reside in a second ring between $\tilde{x}$ and $\tilde{x}^{\mathrm{WFH}}$ and the remote skilled reside in the outer suburbs, beyond $\tilde{x}^{\mathrm{WFH}}$.

3.2 Quantifying the Model with Spatial Sorting

We quantify this extension by adding heterogeneous wages and commuting costs to the baseline specification above. Households still choose to allocate their post-commute income between housing and other goods, but we now have two groups earning different wages.[28] We fix the unskilled wage at \$15 per hour, or \$30,000 per year, and the skilled wage at \$30 per hour, or \$60,000 per year.[29]

We maintain that the per-hour commuting cost is the sum of the value of time and the cost of operating a vehicle. We assume that the value of time is still 0.6 of the hourly wage for each group. The cost of operating a vehicle is the same (still $15.05 per hour) for both groups, but because vehicle costs make up a different fraction of each group's wage, the wage gap drives the difference in commuting costs between the two groups. Where the model with homogeneous agents had a total cost of travel per hour of commuting equal to 1.3 times the hourly wage, in the heterogeneous agent case, this value diverges to 1.1 times the skilled wage and 1.6 times the unskilled wage.

We assume that the WFH shock affects half of the skilled and causes a 90 percent reduction in commuting for those who work from home.[30] With two skill groups, the predicted elasticity of housing prices with respect to distance from the center in the pre-COVID situation with no WFH is 0.116, similar to the 0.102 found previously in the homogeneous case, also pre-COVID. When we add the WFH shock just described, however, the overall elasticity does not change nearly as much as when we assumed that all workers worked from home a moderate amount. With WFH only for a subset of skilled workers, the elasticity drops from 0.116 to 0.113, while in the homogeneous case it falls from 0.102 to 0.068. This smaller decline in the price gradient is illustrated in the right panel of Exhibit 3.[31]

The residents who still commute every day are not unaffected by the WFH shock, however. Remote skilled workers spend part of their commuting dividend on housing, which increases aggregate housing expenditure. With a fixed supply of housing, a higher housing expenditure from residents of the outer ring ends up pushing housing prices up everywhere in the city. Despite a lower share of WFH relative to our baseline calculation, we note that the commuting dividend is still large since it applies to residents of the outer ring who live the farthest away from downtown and whose value of time is highest. Interestingly, the housing-price gradient does not rotate in the heterogeneous agent case as much as with homogeneous residents because the commuting costs of unskilled workers and in-person skilled workers are unchanged. Hence, the slopes of their bid-rent curves, which determine the housing-price gradient in the inner rings where they reside, remain the same.

The difference between the house-price gradient in the homogeneous and heterogeneous cases might help to explain the difference in the short-run and longer-run price dynamics documented above. Early in the pandemic, when most workers were remote, the homogeneous counterfactual where all workers enjoy the commuting dividend may be closer to reality. In the subsequent years, we expect to see remote work persist among the skilled and, even in this group, be bimodal, with some workers working remotely part or most of the time while others instead opting (or needing, in the case of high-skilled service jobs) to work in-person most of the time. These shifts align with housing rents first decreasing in the city center and then rising thereafter, while they monotonically rise in the suburbs over the whole period, where the reaction of housing prices was more subdued.[32]

To get a sense of the magnitude of the spillovers both across space and between groups in the heterogeneous model, we turn to the quantitative model's predictions of price growth at different distances from the city center and consider how these price adjustments affect the utility of the different types of workers. With homogeneous residents, prices decrease by 5.3 percent in the city center and increase by 4.2 percent at the periphery. These relative price adjustments maintain the spatial equilibrium where all households receive the same utility at all locations, and the relative growth of house prices in the suburbs offsets the higher commuting dividend enjoyed by suburban residents. On net, all households see a slight gain in utility.

With heterogeneous residents, house prices increase by over 3.5 percent at all distances from the city center, with larger increases at the farthest distances from the city center, where the aggregate expenditure effect is compounded by the group-specific bid-rent increase for the remote skilled workers who live there. The share of income spent on commuting also changes for each of the groups. This happens for two reasons: first, half of the skilled workers reduce the number of times they commute, and second, spatial sorting causes the distances at which the groups reside to change. The aggregate amount spent on commuting therefore decreases by 0.05 percent for unskilled residents, who move slightly closer to the city center, and 46 percent for college-educated residents, who either live closer to the city center or work from home.

For in-person workers, the house-price increases outweigh the reductions in commuting costs. The utility of both skilled and unskilled workers who return to work in person declines by around 0.1 percent. The WFH dividend to the segment of college graduates that works from home results in a 14 percent increase in utility after accounting for changes in house prices and commuting costs. However, for people in this group, converting part of their homes into office space reduces utility. After accounting for both the commuting dividend and home-office tax, the result is a 5.5 percent increase in welfare inequality between the average skilled and unskilled workers.

Qualitatively, these predictions align with empirical evidence from Li and Su (2021) and are effectively the reverse of the pre-COVID trends studied in Su (2022), who identified the rising value of time among the high-skilled and the increasing attractiveness of a short commute as driving the sorting of these households downtown in recent decades (Baum-Snow and Hartley 2020; Couture and Handbury 2020). The increase in WFH stems from the relative benefit of the short commute offered by downtowns, so it is not surprising that this component of “urban revival” will reverse as a result.

4. Endogenous Amenities

The framework above assumed that location choice was a function of a simple trade-off between housing and commuting costs. Locations are not only characterized by proximity to workplaces and housing costs, but also by their amenities. Downtowns, in particular, offer far more density and variety of consumption amenities than the suburbs: businesses that provide nontradable services, such as restaurants, bars, and gyms, cluster in downtown areas attracted by the 24-hour foot traffic of workers during weekdays and residents on nights and weekends. Couture and Handbury (2020), for example, show that the density of restaurants was 20 percent higher at the center of the 100 largest cities in the United States than at their periphery. The relative density, variety, and quality of amenities in city centers also attract, and rely on, business from visitors (for example, tourists, business travelers, and suburban residents).

Policy restrictions closed service establishments across the United States during the early months of COVID. As cities emerged from the lockdowns of the early pandemic period some, but not all, of this business returned and many establishments in city centers remained closed. Sedov (2021) showed that downtown restaurants were more likely to close over the course of 2021. De Fraja, Matheson, and Rockey (2021) document similar patterns in U.K. cities.

The extent to which amenities will return to city centers is an open question. In the short run, it depends on whether customers return. Some tourists and suburban residents visit downtowns for these amenities, so their return will depend on the reopening of the amenities themselves. Some of these customers visit downtowns for other reasons, such as work, visiting hotels for business conferences, or visiting historical or cultural venues.

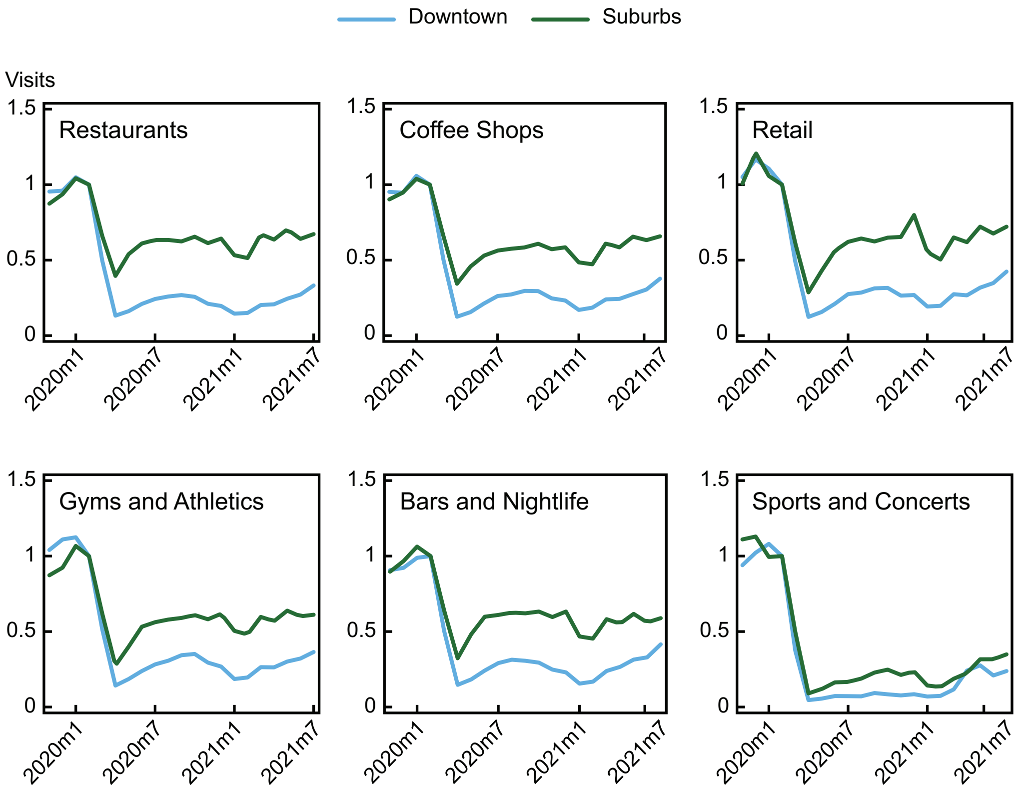
So their return will rely less crucially on service establishments taking the first step of reopening. By summer 2022, business travelers and tourists mostly returned after conferences resumed and capacity restrictions at public historical and cultural venues were relaxed.[33] Still largely absent at this point, however, was foot traffic from office workers. Althoff et al. (2022) showed that consumer service spending and employment fell the most in U.S. cities with large pre-pandemic shares of business service workers, whose jobs can more easily be done remotely, and in spite of repeated predictions of the "return to the office," office foot traffic remained depressed below 50 percent of its pre-pandemic levels.

This shift in office foot traffic is mimicked in foot traffic to downtown restaurants and retail establishments. Chart 2 shows the foot traffic to dining, entertainment, and retail establishments by distance to the central business district. Foot traffic downtown dropped precipitously in March 2020 both downtown and in the suburbs. The drop was sharper downtown, however, and the subsequent rebound less robust. Through 2021, the restaurant and retail foot traffic downtown was at best 40 percent of its level in February 2020, but above 60 percent of its February 2020 level in the suburbs. Interestingly, the recovery of foot traffic at downtown entertainment venues was approaching that of entertainment venues in the suburbs, potentially reflecting a shift in downtown amenities from venues that sustain regular office workers and residents toward venues that cater to tourists and visitors from the suburbs for special events.

With the persistent de-densification of downtown offices and the return of travelers, the mix of customers visiting city centers has changed. The right panel of Chart 2 shows that downtown entertainment venues are seeing a stronger rebound in foot traffic than restaurants and retail, for example. In the medium run, the mix of establishments offered downtown will reflect this shift (see Duguid et al. [2023] for early systematic evidence). Businesses that serve regular office workers—take-out food stores, bars, and gyms, for example—will get replaced, to some extent, by businesses that cater to one-off visits by tourists and business travelers such as higher-end restaurants and entertainment venues. To the degree that the businesses that serve regular office workers also attract residents, particularly young professionals looking to spend time and money on services like bars and gyms, instead of on retail products and at home, the exit of these amenities will amplify the medium-run shift in these residential populations to the suburbs, as discussed more below. In the longer run, as office space is converted to hotel and residential space, we may also see the entry of businesses that cater specifically to the urban residential population (for example, supermarkets) attracting some residents back downtown, but this transition will be slow.[34]

Chart 2

Restaurant and Retail Foot Traffic in the Twelve Largest U.S. Cities



Source: Precisely PlaceIQ. Used by permission.

Notes: The illustrations present data for New York, Los Angeles, Chicago, San Francisco, Dallas, Houston, Miami, Philadelphia, Washington, D.C., Atlanta, Boston, San Francisco, and Phoenix by distance to the center. Downtown establishments are those within 2 kilometers of the center; suburban establishments are those farther out but within the same core-based statistical area (CBSA). The y-axes indicate total visits to the establishment category as measured by Precisely PlaceIQ reemergence data set.

4.1 Amenitization of the Suburbs?

Amenities do not only exist in city centers. The suburbs also offer nontradable services, albeit at lower densities, and the suburban shift in work-hour activity and residents will bring business to the suburbs. Chart 2 already shows a bias in the return of in-person activity toward suburban venues. The extent to which this increase in business will induce entry is an empirical question, but whatever entries of establishments occur in the suburbs is unlikely to entirely offset the number of exits from city centers. Duguid et al. (2023), for example, show that the number of establishments open in the suburbs had recovered their early COVID losses by the end of 2021, with a net gain of approximately 0.5 percent between the end of 2019 and the end of 2021, but establishment counts in the downtown core still lagged, with net losses of more than 3 percent over the same period. The features that make the suburbs more attractive for remote workers are exactly those that make the suburbs less conducive for offering a rich density and variety of nontradable services. Suburban residents have access to more space for meal preparation at home than in the office, for example, so are likely to eat more of their daytime meals at home than the fast-casual options near work. Remote workers may substitute their daytime socializing for evening get-togethers but the extent to which this happens at home, at suburban establishments, or downtown will depend on the density and quality of options available to them in each location.

Dense suburban town centers that can leverage the increase in local demand with agglomeration benefits are likely to see the most gains from the remote work shift. These are also the most likely locations for entry of co-working spaces that some remote workers will seek out to take advantage of a shorter commute without having to create a home-office space.

On net, between the suburbs and downtown, the overall density of service establishments is likely to end up lower and, as a result, the average households will consume less of these services during their workdays, in particular. Net exit will induce people to eat more of their daytime meals and to socialize and work out more at home. Some substitution may happen to consumption on weekends or vacations, when consumption trips to city centers are more feasible. This substitution was seen in the summer of 2022, with the rebound of travel and tourism. To the extent that this trend persists, it points towards a shift in downtown amenities from the fast-casual chain restaurants and gyms that served workers, to restaurants, cafes, and more unique establishments that serve a group with more time on their hands and who are looking for a break from their day-to-day experience.

4.2 Urban Amenities in the Model

The response of local businesses to the suburbanization of work will amplify the predictions of the model presented above. To see this amplification, we can start by adding amenities to the model as in Brueckner, Thisse, and Zenou (1999). Utility is now obtained from consuming housing, h, other goods, z, and the amenities $a(x)$ afforded by the location of residence. The budget constraint is, as before, $w - \tau x = P(x)\, h + z$. The slope of the bid-rent function now has two terms to reflect that, and to maintain constant utility at all distances from the city center, housing prices must adjust to offset the differences in commuting costs and amenities across locations:

$$P'(x) = -\frac{\tau}{h(x)} + \frac{u_a}{u_z}\frac{a'(x)}{h(x)}$$

If households value amenities ($u_a > 0$) and amenities fall with distance from the city center (Couture and Handbury 2020), $a'(x) < 0$, the negative price gradient in the base case is explained by both commuting costs and the amenity gradient.

This simple setup assumes that amenities in each location x are exogenously determined and only consumed in the place of residence, so it abstracts from the forces that result in the suburbanization of amenities discussed above. To study the role that amenities will play in shaping how residential location choices and house prices respond to the increase in WFH, we consider how these factors respond to an exogenous shift in the amenity function, $a(x)$. We model the shift in the amenity function to reflect qualitative changes that we have observed in the data since the COVID pandemic and expect to continue in the medium term. There are two elements to this shift. First, the amenity gradient ($a'(x)$) has become less steep: the suburban shift in workday foot traffic has led to closures of downtown establishments lessening the amenity advantage of city center. Second, while some of this foot traffic will lead to establishments opening in the suburbs, these openings are unlikely to increase the amenity value of the suburbs by enough to maintain the mean level of amenities across all locations. The suburbs, in particular, do not have the same population and employment density that make city centers such breeding grounds for amenities. As a result, the amenity curve $a(x)$ will be at a lower level than before the WFH shift.

To a first order, the dampening of the amenity gradient will affect the housing rent gradient in the same manner as the reduction in commuting costs. So the shift in amenities would amplify the outward shift in residential population to the suburbs and the twist in the house-price gradient depicted in left panel of Exhibit 2.[35] The downward shift in the amenity curve will decrease $\underline{u}$, offsetting the increase in average utility from the "commuting dividend." This drop in amenities would mitigate the increase in the citywide average of house prices from the dual WFH shocks depicted in the right panel of Exhibit 2. These two effects will unambiguously cause the price of housing downtown to decrease by more than it did when ignoring amenities. The effect on the price of housing in the suburbs will be ambiguous: accounting for the amenity shift to the suburbs will tend to cause prices to rise by more there (reflecting the increase in the amenity value of the suburbs) but by less overall (since the mean amenity value citywide drops).

4.3 Distributional Implications and Secular Trends

The loss of downtown amenities may have significant distributional consequences, since the way in which people engage with these businesses varies with socioeconomic status. College graduates are more frequent consumers of nontradable services, while the non-college-educated are more likely to work for firms that provide these services. Non-college-educated workers in these nontradable service businesses experienced severe job losses and see further losses or increased reverse commutes, as these amenities shift to the suburbs or close for good.

Offsetting these declines have been recent job growth associated with the strong rebound of tourism and the longer-run secular trends driving increasing demand for nontradable services among college graduates. Couture and Handbury (2020) linked an increasing demand for "urban" amenities (nontradable services that are offered distinctly downtown) to top income growth (reflecting increasing returns to education) and delayed childbearing. Neither of these trends show any sign of abating, so preferences for nontradable services will likely increase among the college-educated.

The extent to which this continuing shift in preferences for these activities will continue to drive high-income households downtown will depend on the extent to which these "urban" amenities continue to be an "urban" phenomenon. This potential development hinges largely on the intensity of the scale economies in city centers relative to the suburbs. If the scale economies in suburban town centers are strong, then the increasing tastes for nontradable services may interact with the WFH shift in the college-educated population to the suburbs to result in the growth of "urban" clusters of amenities in these areas. We do have evidence of amenity locations shifting in response to changing commuting costs: Gorback (2020), for example, shows that the introduction of ride-sharing apps spurred entry of amenities away from public transit corridors and toward areas only accessible by car or foot. To the best of our knowledge, the elasticity of nontradable retail entry in response to demand growth has not been measured, so the degree of amenitization the suburbs will see in response to the WFH shocks remains an open empirical question, with the exception of the early signals reported above from Duguid et al. (2023).

5. Endogenous Productivity

In our model above, we make three important simplifying assumptions about productivity. First, there is no direct effect of WFH on wages, as if productivity when working from home was the same as in the workplace. Second, the choice of working from home is exogenous and, in the baseline model, is the same for everyone. Third, there is no indirect effect of WFH on wages. The choice made by others to work from home does not affect one's productivity at the workplace. Let us examine these issues in turn.

5.1 How Productive Is Work from Home?

Unfortunately, measuring the productivity differential between the workplace and home is difficult. Many of the skilled occupations that can be performed from home involve a variety of tasks and productivity for these tasks cannot be precisely measured, let alone compared between home and the workplace. For some insight, however, we can turn to pioneering research that measures the work-from-home productivity differential for call center workers, whose output is easily measurable and can also be performed remotely. In a field experiment, Bloom et al. (2015) found that Chinese call center worker output increases by about 13 percent when moving from the workplace to working from home. Most of this increase is because workers increase their hours, but one-third is attributable to an approximate 4 percent increase in productivity. Emanuel and Harrington (2023) find an even larger 7.5 percent productivity increase for U.S. call center workers who elected to work from home when given the option in a 2018 field experiment. Notably, the remaining workers who had not elected to work from home saw a similar increase in productivity when they had to work from home early in the COVID pandemic. The output gains in the Bloom et al. (2015) setting were in fact amplified to 22 percent when all workers became eligible to select to either work in the workplace or from home. Beyond output, Bloom et al. (2015) also found that workers reported greater work satisfaction when working from home.

More recent work suggests that WFH might help stem attrition but not enhance the productivity of the skilled workforce that is more likely to work from home post-pandemic. Bloom, Han, and Liang (2022) randomizes Chinese workers, including engineers and finance and marketing employees, into a hybrid work setup where they WFH two days a week. The treated hybrid workers were 35 percent less likely to leave the firm and reported higher work satisfaction but, overall, WFH had no impact on performance reviews or promotions. The news was more positive for IT engineers, whose productivity could be measured with the number of lines of code written: the productivity of treated IT engineers rose by 8 percent relative to similar employees in the control group.

Barrero, Bloom, and Davis (2021b), Etheridge, Wang, and Tang (2020), Bartik et al. (2020), and Morikawa (2020, 2021) also provide similarly varied estimates of the impact of remote work on productivity.[36] Part of this variation might be due to WFH and in-person work being imperfect substitutes, which Behrens, Kichko, and Thisse (2021) show implies a bell-shaped relationship between WFH and productivity. There is also considerable heterogeneity with large declines in productivity in occupations less suitable for WFH.[37] Further, many of these studies are conducted in the context of serious lockdowns that may lower productivity independent of work location. Many firms also reduced their activity during lockdowns so it is difficult to distinguish between the effects of a lower demand and actual productivity (output per unit of time). Relevant for our purpose here, results from less drastic WFH experiments with optional hybrid work arrangements are much more encouraging and suggest modest overall productivity improvements and sizeable increases in well-being.

5.2 How Many Workers Will Work from Home?

There is tremendous heterogeneity among occupations in their suitability for WFH; call center workers are perhaps at one extreme and hairdressers at the other. Among skilled workers, there is also tremendous heterogeneity among tasks within occupation. Some tasks require face-to-face interactions while others may be conducted more productively at home.[38] There are also large differences in workers' individual desire and ability to work from home (Bloom et al. 2015; Emanuel and Harrington 2023). Personality traits and family situations are likely to loom large here.

With massive differences in the possibility to work from home on the supply side and equally large differences in workers' desire for such an arrangement on the demand side, WFH must be a preferable option, at least some of the time for some workers. Some workers will need to commute to work every day, others will work from home part of the time, and some may perhaps work from home all the time. More generally, we expect the demand for WFH by workers to be governed by how amenable to WFH their job is and their relative like or dislike of WFH weighted against (commuting) gains and (home-office) losses when working from home.

Davis, Ghent, and Gregory (2021) model the choice between WFH and work at the office jointly with the choice of residential location. Like for Behrens, Kichko and Thisse (2021), key to the model is the elasticity of substitution between WFH and work from the office. They estimate this parameter using the pre-COVID relationship between commuting times and the propensity to work from home. Their preferred estimate for the elasticity of substitution between WFH and work from the office is about 5.[39] Assuming this elasticity, it takes a near 50 percent increase in the productivity of WFH to explain the trebling in the propensity to WFH (from about 10 percent of the time to 30 percent) observed between 2019 and 2021.[40]

Stepping back from the specifics of the model, both a large increase in the efficiency of WFH and a fairly high elasticity of substitution between WFH and work from the office are needed to explain such a large shift towards WFH from "almost never" before COVID to "some of the time" two years later.[41] Looking forward, the same high elasticity of substitution implies that the WFH productivity gain to reach "a lot" of WFH (say, four days a week) may not be that high.[42] But, by the same token, a more productive workplace could easily swing the WFH pendulum back to, say, only one day a week on average. We are in a region where the share of WFH can move easily.[43] Pushing the argument further, reaching a state of WFH "most of the time" is a much more distant prospect as it would require massive further improvements in the WFH technology.

This said, workers may not care so much about their productivity as they care for their wage and career prospects. Productivity, wages, and career progression do not map one-for-one into each other. In particular, there is a well-known stigma associated with WFH. Bloom et al. (2015) and Emanuel and Harrington (2023) document that workers working from home are, all else equal, less likely to be promoted.[44] The key question here is, of course, whether this stigma will fade as firms get better in their assessment of remote work and workers.[45] If not, it is easy to imagine situation where future selection into WFH, likely driven by non-labor-market considerations, could worsen outcomes for certain groups of workers.[46]

5.3 Agglomeration Effects

Although we cannot say for certain how much work will be done remotely in the long run, many workers appear to have decided they want to work remotely, at least some of the time, (Barrero, Bloom, and Davis 2021a) and firms will bow to these demands, to some extent. This shift has already left many downtown firms with vast amounts of surplus office space. As argued above, key to the revival of downtown retail is the return of daytime workers. A second concern is how productive city centers will be with half (or fewer) as many workers on-site. daily. That is, will the productivity advantage of cities remain when fewer workers are concentrated there to generate agglomeration effects?[47]

Following Marshall (1890), we traditionally distinguish between agglomeration effects happening through input-output linkages, thick local labor markets, and direct interactions (spillovers). For input-output linkages, the relevant spatial scale is the metropolitan area and perhaps the region around it. Even in a world of just-in-time production, there is no real need for trading firms to cluster closely because an extra hour's drive for a delivery may not be crucial. Hence, when agglomeration effects find their source in metropolitan or regional trade between firms, WFH is unlikely to play a major role, provided remote workers remain in the same region.

For direct interactions and knowledge spillovers, distances are arguably much shorter. As stated by Glaeser et al. (1992): "After all, intellectual breakthroughs must cross hallways and streets more easily than oceans and continents." If agglomeration effects are all about knowledge spillovers, a lower downtown density could really reduce a downtown's productive advantage, relative to both other downtowns and other locations in the same city.

Unfortunately, the literature has not successfully disentangled the channels of agglomeration, an extremely challenging exercise.[48] Studies that organize a horse race between channels often conclude with a fairly even split (see, for example, Ellison, Glaeser, and Kerr [2010]). If these results hold true, the rise of WFH could amount to a wash in terms of urban productivity. Falling downtown employment because of WFH implies fewer direct spillovers, but, with the reduced need for commutes, these cities will also be able to benefit from a thicker labor market as they expand their reach.

While the productivity effects of WFH via agglomeration might wash out given the various agglomeration externalities operating at different spatial scales, their impact might vary within and across cities given the variation in the extent of WFH across these locations. Rosenthal and Strange (2020), for example, report that there is strong spatial decay in local agglomeration effects, with spillovers fully disappearing within 10 minutes of travel time. If true, this finding is both bad news and good news. Downtowns may end up suffering greatly because of WFH but the damage will be contained within a short radius.[49] Then, the metropolitan area outside of this center may be mostly unaffected.[50]

Even if we take agglomeration effects at face value and assume that they are a direct function of local employment density as estimated by much of the literature, we note that the same literature has consistently found relatively modest agglomeration effects. This near-consensus retains an agglomeration elasticity between 0.02 and 0.08. That is, a 10-percent increase in the scale of a city translates into 0.2 to 0.8 percent higher wages. Naively applying the upper bound of this estimate to the WFH shock implies that the reduction in worker density downtown of 40 percent would yield a drop in wages of 4 percent. Although not trivial, this maximum effect corresponds to about two years of income growth.[51] This benign effect would offset some of the increase in demand for cities coming from the WFH commuting dividend and the home-office tax.[52]

6. Long Run

Using the framework we have developed and the evolution we described in Section 2, we can now extrapolate and consider a longer time horizon where the stock of both housing and commercial real estate adjust. The considerations that follow are obviously highly speculative and should thus be taken with caution.

6.1 The Consumer City for the Creative Class?

In the longer run, as office space is converted to alternative uses, downtowns could become more consumer-centric destinations. As the growth in WFH reduces the density of workers downtown, commercial office rents are likely to drop in real terms inducing some re-sorting of commercial tenants in the medium run and redevelopments and adjustments in land use in the long run. Firms whose activities can only be done (or are done best) in person, such as entertainment, medical services and research, and education, but were previously outbid for downtown space, might move or expand closer to city centers as rents decline.

Though possible, this transition is likely to be slow. For the "creative class" of tenants to move into downtown office space, the prevailing rent level first needs to drop. The multiples at which the stocks of public companies that own office buildings were being traded dropped in 2020, indicating that the market expects rent declines, or at least elevated rent uncertainty, but these shifts might take time to be realized as since commercial rents are notoriously sticky. For one, many tenants will be paying rents contracted pre-COVID on 10-year leases that will run through at least 2025. Considerable uncertainty also remains regarding when WFH will shift to purely optional and not be driven by health concerns as it was as recently as January 2022. So, tenants with leases maturing might be considering short-term extensions based on existing lease terms and delaying making long-run real estate decisions until more uncertainty is resolved. Finally, landlords uncertain of the impact of WFH on market rents will sustain high vacancies in the medium term while they test the elasticity of demand for their product.

Further, accommodating new tenants can require significant refurbishments and, sometimes, redevelopments of the commercial space. These redevelopments cannot begin until these properties are being sold at a basis low enough for buyers to make these expensive investments profitably. Prices will be sticky in the asset market as well, and with sizeable amounts of capital-seeking yield, the type of distress—forced and foreclosure sales—that often pushes property prices down has not yet been widely observed since the pandemic. Once prices do drop, however, there will be scope for redevelopment, though it too will take time given zoning and construction lags.[53]

6.2 Sprawl and Cross-City Migration

Other longer-run adjustments will occur in the residential market. One possibility of the redevelopment of downtowns might be an increase in multifamily apartment housing. In other cities, the more likely scenario is an outward expansion with new development of housing in far-reaching suburbs.

We can use the model from Section 2 to gauge the potential scope of this sprawl. Consider the following thought experiment. Assume that pre-COVID, the cost of housing at the urban fringe is equal to its replacement cost and any extra amount needed to convert land into a residential use. Put differently, we now assume that the baseline city we consider was, pre-COVID, at its long-term equilibrium where we allow for workers to move across cities and construction to expand the urban fringe. With WFH, it is easy to show that the urban fringe needs to expand considerably to reach again the same price as at the pre-COVID fringe. With our values and a 30 percent rate of WFH, the urban fringe, initially 60 kilometers from the center, nearly doubles to about 114 kilometers (ignoring any increase in population).[54] Put slightly differently, the increase in housing prices at the urban fringe will put considerable pressure for cities to expand.

Glaeser (2022) provides early evidence of a boom in new permits in 2021 relative to 2019. While this boom may be short-lived in a period of higher interest rates and much lower growth, it reflects some underlying long-term trends and a high unmet demand for housing. Crucially, this boom in new permits is spatially uneven. Among the largest metropolitan areas in the country, San Francisco, San Jose, Portland, and New York all experienced a decline in new permits despite house prices going up by 12 to 20 percent between 2019 and 2021. Sunbelt metropolitan areas have been much more willing to accommodate this increased demand for housing. The likes of Austin, Phoenix, Raleigh, Nashville, Memphis, and San Antonio all experienced a growth in new permits of 30 percent or more. Linking back to our model above, only some cities will experience the type of expansion we just described while others will remain stuck within their fixed boundaries without allowing for much more densification either. With a near-fixed stock of housing and a higher demand for residential space by households working from home, more restrictive cities are likely to experience a continuous slow decline in population. Many of their residents will migrate to Sunbelt cities. This is of course not a new phenomenon. The novelty is that these growing cities will likely accommodate these new residents at their urban fringe made appealing by reduced commuting requirements.

7. Conclusions

For cities in the United States, the first two years of the pandemic led to an initial plunge in downtown residential property prices followed by a rebound while suburban residential prices kept increasing. We relate this evolution to a sharp rise in working from home, a trend that shows no sign of abating. Our analysis interprets these changes using a simple urban monocentric model. We first consider a pandemic period with WFH for all workers. We then model a post-pandemic situation where WFH is disproportionately performed by a subset of more skilled workers. A calibrated version of our model is able to replicate the magnitude of the observed changes in housing prices as WFH increases housing demand owing to a commuting dividend and a home-office tax. Overall, our modeling suggests small net gains associated with WFH. However, the distributional implications of WFH are stark with significant gains for remote workers and losses for in-person workers caused by higher housing prices.

To gain insight on the broader effects of COVID on cities, we further highlight the importance of urban amenities which follow workers and reinforce the downtowns' losses relative to their suburbs. Reviving a daytime economy is a major challenge for downtown if cities want to keep a vibrant nighttime economy. We also consider the effects of these changes on the agglomeration benefits of cities and conclude that they are unlikely to affect our conclusions in a major way.

Finally, we provide some speculation as we consider a longer-run situation with adjustments to the stock of housing, perhaps only in some cities. Rising work from home will likely result in considerable pressure for urban expansion. Some downtowns may also enjoy a strong revival as they attract more creative workers who still want to work in person.

Appendix 1: The Monocentric Model with Cobb-Douglas Preferences

Assume that utility is Cobb-Douglas in housing and other goods: $u(h, z) = h^{\alpha} z^{1-\alpha}$. Relative to the assumptions made in the main text, we also assume that the cost of commuting is no longer linear in distance and follows instead τx^{γ} with $\gamma < 1$. This reflects the fact that in the data, the vehicles miles traveled by residents are less than proportional to the distance between their residence and the city center. Finally, we also assume that one unit of housing is supplied at every location between the center 0 and the urban fringe $\bar{x}$.

To solve this model, we follow the Marshallian approach, as used by Duranton and Puga (2015). For a resident in x, maximizing $u(h,z) = h^{\alpha} z^{1-\alpha}$ with respect to h and z subject to $w - \tau x^{\gamma} = P(x)\, h + z$ implies:

$$P(x) = \frac{\frac{\partial u(h,z)}{\partial h}}{\frac{\partial u(h,z)}{\partial z}} = \frac{\alpha z}{(1-\alpha)h} = \frac{\alpha\left(w - \tau x^{\gamma}\right)}{h}, \tag{a1}$$

where the first equality results from equating marginal utility per unit of income across housing and other goods, the second one is obtained using the functional form we chose for utility, and the third one follows from the substitution of z using the budget constraint.

In equilibrium, free mobility among similar residents implies a common, but yet to be determined, level of utility $\underline{u}$:

$$u(h(x), z(x)) = \underline{u}\,. \tag{a2}$$

To find the optimal location of a resident, we can substitute $z(x)$ into equation (a2) using the budget constraint $z(x) = w - \tau\, x^{\gamma} - P\,(x)\; h(x)$ before totally differentiating equation (a2) with respect to x to obtain:

$$\frac{\partial u(h,z)}{\partial h}\frac{\partial h(x)}{\partial x} - \frac{\partial u(h,z)}{\partial z} P(x) \frac{\partial h(x)}{\partial z} - \frac{\partial u(h,z)}{\partial z}\left(\tau\gamma x^{\gamma-1} + h(x)\frac{\mathrm{d}P(x)}{\mathrm{d}x}\right) = 0. \tag{a3}$$

From the first order condition (a1), the first two terms in equation (a3) cancel out, which implies

$$\frac{\mathrm{d}P(x)}{\mathrm{d}x} = -\frac{\tau\gamma x^{\gamma-1}}{h(x)}. \tag{a4}$$

This last expression is analogous to equation (2) in the main text for the more complicated case of nonlinear commuting costs.

Appendix 1 (Continued)

Substituting $h(x)$ from this last equation using equation (a1) yields the following ordinary differential equation:

$$\frac{\frac{\mathrm{d}P(x)}{\mathrm{d}x}}{P(x)} = -\frac{-\tau\gamma}{\alpha x^{1-\gamma}\left(w-\tau x^{\gamma}\right)}. \tag{a5}$$

It can be verified that the solution of this ordinary differential equation is of the form:

$$P(x)=C_1\left(w-\tau x^{\gamma}\right)^{\frac{1}{\alpha}}, \tag{a6}$$

where C_1 is a constant to be solved for. Fitting equation (a1) into this last expression, we can write housing demand as

$$h(x)=\frac{\alpha}{C_1}\left(w-\tau x^{\gamma}\right)^{1-\frac{1}{\alpha}}. \tag{a7}$$

To solve for $C_{1,}$ we use the population constraint which states that the supply of housing in the city must equal demand:

$$\int_0^{\bar{x}} \frac{s(x)}{h(x)}\mathrm{d}x = \int_0^{\bar{x}} n(x)\mathrm{d}x = N, \tag{a8}$$

where $s(x)$ is the supply of land at location x, which divided by the individual consumption of land, $h(x)$ is also the density of population at the same location. Then, integrating population density over the whole extent of the city from 0 to the urban fringe $\bar{x}$ yields city population, N.

Assuming $s(x) = x^{\sigma}$ and substituting $h(x)$ using equation (a7), equation (a8) can be rewritten as

$$N=\int_0^{\bar{x}} \frac{C_1}{\alpha} x^{\sigma}\left(w-\tau x^{\gamma}\right)^{\frac{1}{\alpha}-1}\mathrm{d}x. \tag{a9}$$

When $\alpha = 1/3$, as we assume, this expression easily integrates and we can solve for C_1:

$$C_1=\frac{N}{3\bar{x}^{\sigma+1}\left[\frac{\tau^2\bar{x}^{2\gamma}}{\sigma+2\gamma+1}-\frac{2\tau w\bar{x}^{\gamma}}{\sigma+\gamma+1}+\frac{w^2}{\sigma+1}\right]}. \tag{a10}$$

Appendix 1 (Continued)

Importantly, we also note that at the spatial equilibrium

$$\bar{u}=u(0)=\alpha^{\alpha}(1-\alpha)^{1-\alpha}\frac{w}{P(0)^{\alpha}}=\alpha^{\alpha}(1-\alpha)^{1-\alpha}C_1^{-\alpha}, \qquad \text{(a11)}$$

where the second equality arises directly from the first-order conditions for profit maximization and the last one uses expression (a6) valued at $x = 0$. Keeping in mind that the disposable wage $w - \tau\,\bar{x}^{\gamma}$ is positive, it is easy to show that $\mathrm{d}\bar{u}/\mathrm{d}\tau < 0$ and $\mathrm{d}\bar{u}/\mathrm{d}N < 0$.

Appendix 2: An Extension with Heterogeneous Residents

In an extension of the model, utility is still Cobb-Douglas in housing and other goods: $u(h,z) = h^{\alpha}z^{1-\alpha}$. We consider three groups of workers: unskilled, skilled, and skilled who work from home. The earnings of "in-person" and "remote" skilled workers are equal and higher than earnings of the unskilled: $w_1 = w_{\text{WFH}} > w_0$. Commuting costs also differ across groups with $\tau_1 > \tau_{\text{WFH}}$ and $\tau_1 > \tau_0$. We further restrict commuting costs to be such that the unskilled reside closer to downtown in equilibrium.

For residents of each group k in {0, 1, WFH}, the bid-rent functions

$$P_k(x) = C_k\left(w_k - \tau_k x^{\gamma}\right)^{\frac{1}{\alpha}} \quad \text{(b1)}$$

match equation (a6), and the housing demand functions

$$h_k(x) = \frac{\alpha}{C_k}\left(w_k - \tau_k x^{\gamma}\right)^{1-\frac{1}{\alpha}} \quad \text{(b2)}$$

match equation (a7) as the consumer problem for residents of each group is solved in the same manner as above.

There are five remaining unknowns: the three bid-rent intercepts C_0, C_1, and C_{WFH}, as well as the boundaries $\tilde{x}_{01}$ between unskilled and in-person skilled and $\tilde{x}_{1\text{WFH}}$ between in person and remote skilled. First, it must be the case that the bid-rent curves are equal between two groups at the boundaries where they intersect:

$$P_0(\tilde{x}_{01}) = P_1(\tilde{x}_{01}) \quad \text{(b3)}$$

$$P_1(\tilde{x}_{1\text{WFH}}) = P_{\text{WFH}}(\tilde{x}_{1\text{WFH}}) \quad \text{(b4)}$$

Second, the group-specific market clearing conditions resembling equation (a8) imply the following three equations

$$\int_0^{\tilde{x}_{01}} \frac{s(x)}{h_0(x)}\,\mathrm{d}x = N_0, \quad \text{(b5)}$$

$$\int_{\tilde{x}01}^{\tilde{x}_{1\text{WFH}}} \frac{s(x)}{h_1(x)}\,\mathrm{d}x = N_1, \quad \text{(b6)}$$

$$\int_{\tilde{x}_{1\text{WFH}}}^{\tilde{x}} \frac{s(x)}{h_{\text{WFH}}(x)}\,\mathrm{d}x = N_{\text{WFH}}, \quad \text{(b7)}$$

where N_k denotes the population of group k, $s(x)$ denotes the supply of land at location x, and $\bar{x}$ is the distance to the urban fringe. After finding an analytical form of the integral analogous to equation (a10), we solve the system of nonlinear equations (b3) through (b7) numerically.

Appendix 2 (Continued)

Finally, we are able to calculate equilibrium welfare for each group using the computed values of C_k, as in equation (a11):

$$\bar{u}_k = \alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha} C_k^{-\alpha}. \quad \text{(b8)}$$

Appendix 3: Data Sources and Treatments

To discipline our quantification, we use data similar to those of Duranton and Puga (2022) and treat them in the same way, unless our model requires a different approach to accommodate variable housing consumption, which is constrained exogenously in Duranton and Puga (2022). The appendix of Duranton and Puga (2022) provides further details not reported here.

Cities

To define cities, we use Metropolitan Statistical Area and Consolidated Metropolitan Statistical Area (MSA) definitions outside of New England and New England County Metropolitan Area (NECMA) definitions, as set by the Office of Management and Budget on June 30, 1999. This defines 275 metropolitan areas in the conterminous United States. We define the city center as the location indicated by Google Maps for the core city of the metropolitan area. We measure the distance to the center as the haversine distance between the centroid of each block-group and the center of each metropolitan area. For city population, we use county-level population from the U.S. Bureau of the Census (2012) for 2010.

National Household Travel Survey

Data on household travel behavior come from the 2008–09 U.S. National Household Travel Survey (NHTS) produced by the U.S. Department of Transportation. We measure commuting trips from trip-level data using information about trip purpose.

The elasticity of commuting distance with respect to distance to the center

For consistency with Duranton and Puga (2022), we estimate the elasticity of commute trip length with respect to distance to the center by duplicating their estimation of a similar elasticity for total vehicle distance traveled. That is, we use the natural log of trip length for commuting trips as a dependent variable instead of an estimate of annual vehicle kilometers traveled. Then, we use the same controls for household and block-group characteristics, and metropolitan area fixed effects. The controls are socioeconomic characteristics of drivers and their households as well as socioeconomic and geographic characteristics of their block-group of residence. For comparability with Duranton and Puga (2022), we use the same approach to data cleaning and excluding observations.

American Community Survey

All our estimations regarding population and the number of housing units are at the block-group level using 5-year (2008–12) data from the 2012 American Community Survey (ACS), obtained from the IPUMS-NHGIS project (Manson et al. 2021).

The elasticity of housing supply with respect to distance to the center

We use data from the American Community Survey for 2008-12 at the block-group level as in Duranton and Puga (2022). We first multiply the number of housing units in each block-group by the average number of rooms to obtain the total number of rooms in each block-group. Because we are interested in measuring total housing supply for each distance, we must account for the fact

Appendix 3 (Continued)

that block-groups tend to be slightly larger and more numerous as distance to the center increases. These characteristics are obviously because cities expand over two dimensions.

To obtain total housing supply, we thus multiply the number of rooms in each block-group by a weight factor. This weight factor is computed using a nonparameteric estimate (kdensity) of the density of block-groups by log distance to the center for each of 275 U.S. MSAs.

We finally regress the natural log of housing supply on log distance to the center and MSA fixed effects. We only consider block-groups more than 5 kilometers away from the center as to avoid non-residential areas. We also consider only block-groups closer than the 90th percentile of block-group distance in its MSA. This selection avoids scarce block-groups close to the urban fringe of metropolitan areas which is often highly jagged. Finally, we weight block-groups in the regression by their inverse density weight to avoid double counting.

For 114,876 block-groups in 275 MSAs, we estimate an elasticity of 0.490 with an R-squared of 0.34. We retain a rounded-up value of 0.5 for our quantification. For 87,026 block-groups in the fifty largest MSAs, we estimate an elasticity of 0.561 with an R-squared of 0.38. We acknowledge that this regression may slightly underestimate the true elasticity of housing supply with respect to distance since we do not account for the fact that room size is likely to vary with distance to the center.

Notes

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[1] A related literature has studied the role of cities in the spread of infections (for example, Glaeser, Gorback, and Redding [2022]; Almagro and Orane-Hutchinson [2022], Almagro et al. [2022]; and Glaeser and Cutler [2021]). We set aside issues of the role of cities in driving infections for two reasons. First, we take a longer view. Second, the literature so far has concluded that while cities get infected first, they do not get hit harder than nonurban regions (Carozzi, Provenzano, and Roth [2020]).

[2] See Van Nieuwerburgh (2023) for another review.

[3] The differences between rents and prices are difficult to interpret. The lesser price appreciation in the suburbs could reflect expectations of a tapering of rents or a change in risk perception. We also keep in mind that Mondragon and Wieland (2022) find statistically indistinguishable effects on rents and prices.

[4] Rent adjustments can be extremely slow following a crisis. Because leases are signed for many years in the office sector, building owners often prefer to wait for rents to recover rather than be stuck with a tenant paying a much lower rent for many years. Interestingly, Gupta, Mittal, and Van Nieuwerburgh (2022) also document large differences between class A offices and the rest of the market, suggesting the emergence of a marked "flight to quality" effect.

[5] See https://www.kastle.com/safety-wellness/getting-america-back-to-work/.

[6] Of course, not all jobs are literally located downtown. We take this into account in our quantification. We also discuss the difference between (often) highly skilled office jobs and the provision of local services, which are located where people work and live. However, for now, we abstract from these complications to focus on the key trade-offs.

[7] Obviously, there is a lot of heterogeneity among residents in any city. As in our analysis, the literature deals with this heterogeneity by assuming that it can be modeled though the existence of different groups, based on income or race. These groups differ by income or taste but group members are identical.

[8] Barrero, Bloom, and Davis (2021a), for example, report survey evidence that employers expect that approximately half of their employees will be able to work from home post-pandemic, but for only two days a week. The requirement that employees work on site three or more days a week will keep most in the same commuting zone in which they work.

[9] We consider for simplicity that households can choose exactly how much housing to consume. In reality, this choice is constrained by the discreteness of housing units. Hence, it is not only the aggregate quantity of housing but also the nature of that housing that is fixed in the near term. When housing is discrete and differentiated, the equilibrium must be solved as an assignment problem (Wang 2022). This assignment is subject to frictions such as the cost of brokerage and imperfect information. These assignment frictions were possibly exacerbated during the COVID-19 crisis, resulting in fewer quantity adjustments and stronger price effects than we have here.

[10] Formally, this condition appears after fully deriving the spatial equilibrium condition $u(h(x), w - \tau x - P(x) h(x)) = \underline{u}$ with respect to x. Small changes in the consumption of housing, $\mathrm{d}h(x)$, do not appear in this expression because they cancel out with small changes in the consumption of other goods after making use of condition (1). See Appendix 1 or Duranton and Puga (2015) for a full proof.

[11] As noted above, this consumption problem differs from the standard consumer problem, which takes prices as given and thus keeps the slope of the budget constraint fixed. We instead keep the intercept fixed and rotate the budget constraint to reach the tangency point between the budget constraint and the indifference curve. In turn, the slope of the budget line in equilibrium gives us the price of housing at this location. In the full model, we then solve for the common utility by equating the demand and supply of housing at every location. See Appendix 1 for an example with a specific utility function.

Notes (Continued)

[12] To keep matters simple, we consider that the change in the number of commuting days is exogenous. It would be easy to endogenize this fact and consider working from home a choice made easier after COVID. See Bond-Smith and McCann (2022). The main additional result we would expect in this setting is a greater propensity to work from home for residents located farther from downtown. We discuss residential sorting in Section 3 on “COVID and Spatial Sorting.”

[13] In Section 3, we discuss the opening of two important margins: building new housing and moving across cities.

[14] There are further differences among owners. Owners who are earlier in their life cycles seek to increase their housing consumption, while older owners seek to reduce housing consumption after the departure of their children. All else equal, the increase in house prices therefore hurts the first group but benefits the second.

[15] The effect of the WFH tax on the slope of the bid-rent curve is ambiguous and depends in complex ways on how the price elasticity of the demand for housing varies with the price level. It also depends on the income elasticity of the demand for housing.

[16] We discuss recent work that centers on the sorting implications of WFH in Section 3.

[17] See also Rappaport (2014, 2016) and Duranton and Puga (2022) for related quantifications of the monocentric model.

[18] While this Cobb-Douglas specification is commonly used in the literature, preferences for housing vs. other goods would perhaps be more appropriately modeled using an elasticity of substitution of less than 1 since residents of cities where housing is more expensive spend a higher share of their income on this item. The share of housing in expenditure also declines with income, a fact that would call for further modeling complications such as a minimum level of housing consumption. See Combes, Duranton, and Gobillon (2019) for evidence and discussion. We note a small increase in the share of housing in U.S. household expenditure to 34.9 percent in 2020 from 32.8 percent in 2019.

[19] Following Duranton and Puga (2022), for each metropolitan area, we measure the urban fringe using the 95th percentile of distance to the center for the entire population of this metropolitan area, which we locate at the block-group level. The average distance to the fringe for the three cities just below Tampa in the population ranking and the three just above is 66 kilometers, slightly above Tampa’s 58 kilometers.

[20] The average distance to work for commuters who live within 3 kilometers of their city center is 10.02 kilometers in the 2008 NHTS. For commuters who live between 3 and 7 kilometers from their city center, average distance to work is 11.85 kilometers. For commuters residing at the “urban fringe” (between 50 and 70 kilometers from the center), their one-way commuting distance is about 23 kilometers. For the much smaller sample of only Tampa drivers, distance to work for commuters at the urban fringe is slightly lower at 21 kilometers.

[21] Note that our functional forms imply that the price gradient is not exactly a power function of the distance to the center, x. The R^2 of the regression is 0.99, however, so our log-log form is a reasonable approximation. More generally, we know from Appendix 1 that housing prices in the model with our assumptions are proportional to $(w - \tau x^{\gamma})^{1/\alpha}$. Since commuting costs are modest relative to the wage, when taking logs, the slope of log $P(x)$ when measured against log(x) is roughly proportional to τ and thus to the cost of commuting time. By the same token and to preview an important result discussed later in this analysis, we note that this gradient elasticity is also close to proportional to the share of workdays at the workplace, that is, 1 minus the share of WFH.

[22] Our predicted elasticity is also larger in magnitude than the possibly underestimated elasticity of about -0.03 estimated by Gupta et al. (2022) for rents in the thirty largest U.S. metropolitan areas. The difference with the results of Duranton and Puga (2022) is likely due to the fact that Gupta et al. (2022) do not control as extensively for local and house characteristics, which on average improve with distance to the center for U.S. cities. Gupta et al. (2022) also estimate an elasticity of about -0.10 for house prices in the largest metropolitan areas.

[23] We keep in mind that Gupta et al. (2022) estimate a smaller decline for the elasticity of house prices.

Notes (Continued)

[24] When decomposing the differences between remote and nonremote households, Stanton and Tiwari (2021) first find that remote households own fewer cars but this difference, which translates into a lower transportation expenditure, only partly offsets higher housing expenditure. They also find that remote households tended to live on average in neighborhoods with more expensive housing. Most importantly, remote households consumed 0.3 to 0.4 more rooms per dwelling. This corresponds to a 5 to 7 percent increase in the number of rooms relative to nonremote households. Remote households also spent more per room, perhaps because these rooms were larger. Overall, remote households were thus consuming more space and were possibly consuming higher quality space.

[25] Stanton and Tiwari (2021) compute that households in the bottom decile require an earnings premium of between a 10 and 15 percent to offset additional housing expenses associated with remoted work, while households in the top decile require no discernible additional compensation. An alternative is, of course, to think of the home-office tax as a lump sum, which would be an exaggeration in the opposite direction.

[26] In reality, sorting is not perfect. This model provides the intuition only for the general conditions under which the skilled will have a tendency to reside downtown or in the suburbs. In reality, residents will also have idiosyncratic preferences for locations, and the supply of housing is discrete and heterogeneous. See Duranton and Puga (2015) for further discussion.

[27] If skilled workers gain from WFH, part of that gain must imply an increase in their bid-rent and thus a reduction in $\tilde{x}$, the boundary between the region occupied by the unskilled closer to downtown and the region occupied by the skilled farther away.

[28] We assume that two-thirds of the residents are unskilled (group 0) and one-third of the residents are skilled (group 1). This split aligns with the national share of the population 25 years and over who have a bachelor's degree or higher, reported in the 2015-19 American Community Survey.

[29] These approximations are based on data from the 2015-19 American Community Survey about the median annual earnings for the U.S. population aged 25 years and older, broken up by education level. The median earnings are approximately $24,000 for less than high school graduates, $31,000 for high school graduates, $54,000 for bachelor's degree recipients, and $74,000 for graduate or professional degree recipients.

[30] Overall, this implies only a 15 percent reduction in the number of commutes, less than the 30 percent we considered in the analysis previously. We retain this lower number to keep the exercise transparent. Reaching a perhaps more realistic share of 30 percent as previously would require some WFH for the other groups of residents and a less transparent thought experiment.

[31] In part, this milder flattening of the bid-rent curve reflects a smaller aggregrate share of WFH, 15 percent instead of 30 percent previously. With homogeneous residents, a share of 14 percent of WFH lowers the elasticity of housing prices with respect to distance to 0.0796 instead of 0.106 with heterogeneous residents.

[32] We do not claim that our simple model explains all of these price dynamics. There are, of course, many other macroeconomic factors that led to the aggregate price level dropping early in the pandemic and then rising shortly thereafter.

[33] Total seats on domestic U.S. routes in summer 2022 reached over 90 percent of their summer 2019 level (OAG 2022) and hotel occupancy was above 85 percent of its 2019 level (STR 2022). Survey evidence indicates that domestic travel was back to 63 percent of pre-pandemic levels by October 2022 (Global Business Travel Association 2022).

[34] One factor that has been rumored to be keeping all of these groups from visiting city centers is an increase in crime and homelessness. Some of this is attributed to the de-densification of city centers, which made the homeless population more visible. The increase in crime is also attributed to exogenous factors such as reduced police presence after the Black Lives Matter protests in the summer of 2020 that questioned policing practices. While policing decisions are mostly exogenous, we expect that these deterrents will abate as downtowns re-densify with office workers and tourists. In a process to that of the return of service amenities, the re-densificiation of downtowns will reduce crime in a virtuous cycle that will attract more visitors.

Notes (Continued)

[35] If we were to endogenize amenities, the suburban shift in amenities would be amplified by the residential response of households moving to the suburbs, particularly if these households are the more affluent households with greater disposable income to spend on consumer services.

[36] Positive effects of WFH are also reported by Barrero, Bloom, and Davis (2021b) for workers' self-assessed productivity. Etheridge, Wong, and Tang (2020) use a similar source of information for U.K. workers and report on average no difference in self-assessed productivity between home and the workplace. On the other hand, Bartik et al. (2020) report sizeable negative productivity effects associated with WFH of about -20 percent. The employee surveys conducted by Morikawa (2020, 2021) in Japan suggest an even stronger decline in productivity of about 30 percent mid-2020, early in the pandemic. This drop in productivity was still about 20 percent a year later.

[37] Dingel and Neiman (2020) flag that less than 40 percent of occupations are good candidates for WFH.

[38] We note that in the field experiment of Bloom et al. (2015), workers selected for WFH were still coming to the workplace one day a week.

[39] Past literature has emphasized complementarities between different modes of communication (Gaspar and Glaeser 1998; Storper and Venables 2004) and provided suggestive evidence for these complementarities (Charlot and Duranton 2006; Battiston, Blanes i Vidal, and Kirchmaier 2021). A fairly high elasticity of substitution between WFH and work from the office is not inconsistent with these findings, but quite the opposite. Face-to-face and other forms of communication were previously all taking place in the workplace. With a greater prevalence of WFH, much remote communication can now take place from home while important face-to-face communication may still take place overwhelmingly in the office.

[40] Delventhal and Parkhomenko (2022) raise the possibility that the shock was more of a preference shock than a technology shock.

[41] While the estimate of the substitutability between remote and in-person work seems large, assuming a lower elasticity would imply a larger productivity gain for WFH.

[42] Although these productivity gains need not be as high as those we have experienced in the last ten years with easy and fairly high-quality "face-to-screen" communication and ubiquitous file, information, and data sharing, they may be hard to achieve as many tasks remain difficult to conduct well remotely.

[43] The same argument implies a lot of heterogeneity across workers in their WFH decision.

[44] Emanuel and Harrington (2023) also find that less productive workers elect to work from home, perhaps a strong reason behind the WFH stigma.

[45] Negative selection into WFH, for example, could decline in a post-COVID environment.

[46] Mothers of young children are only one such group.

[47] Urban economists usually justify the existence of cities by highlighting the productivity advantages associated with a greater concentration of workers into larger and denser cities. For an introduction and a discussion of the latest developments, see Duranton and Puga (2020). Duranton and Puga (2004) and Behrens and Robert-Nicoud (2015) provide in-depth discussions of the theoretical foundations of agglomeration mechanisms while Combes and Gobillon (2015) propose an extensive review of the empirical literature. Most of what follows in this section builds on the content of these papers.

Notes (Continued)

[48] The first reason is that measuring specific agglomeration channels is difficult. A "thick" local labor market is easy to conceptualize but much harder to measure. These channels may also intermix in practice. Input-output linkages that are potentially more regional in scope may find their ultimate cause in direct interactions between executives of different firms located in close proximity. Second, the importance of these specific channels in explaining outcomes such as workers' wages or firms' productivity must be causally measured against all other possible confounding channels. Third, we must also establish how agglomeration measured by, say, city population or density, fosters these different channels. Estimating this type of relationship is also fraught with simultaneity concerns. Results from studies that look at a single channel for agglomeration effects tend to grossly over-account for agglomeration effects. When summing the shares of agglomeration effects that various studies claim to explain, the total vastly exceeds 100 percent because of confounding factors.

[49] We also conjecture some complementarities between local amenities and agglomeration effects. The main reason behind this conjecture is that the same highly skilled workers at the origin of local amenities that emerge to serve them are also the main emitters and benefactors of agglomeration benefits through face-to-face interactions. In that case, the loss of amenities and agglomeration effects may reinforce each other, but perhaps only within a limited radius.

[50] These statements are not meant to be interpreted normatively. The choice of working from home when in-person work generates positive agglomeration benefits implies that workers will work from home too much relative to what is socially desirable. However, since we expect the effects of WFH on agglomeration benefits to be modest, the inefficiencies at play are also likely to be modest.

[51] Growth in income per person for the United States was 2.1 percent per year on average over the period 1950–2010 (U.S. Bureau of Economic Analysis 2019).

[52] To affect the urban landscape more profoundly, we would need this effect to differ across cities. It is true that the share of jobs that can be conducted remotely varies across metropolitan areas and increases with their density. Althoff et al. (2022) report a perhaps 20 percentage point difference in WFH between the densest and least dense commuting zones in the United States. But this difference only implies a 2 percent difference in productivity loss between a city with 20 percent of workers working from home and one with 40 percent. This will hardly make a dent in the productivity advantage enjoyed by the likes of New York or San Francisco.

[53] Ellen and Kazis (2022) study the issue in New York City. They conclude that only a small fraction of office buildings can be converted into housing. Both hard physical constraints and regulatory and legal obstacles explain this result. At the same time, the stock of possibly permanently vacant office space is so large that conversions could lead to a flow of new housing in New York City comparable to what has been added through new construction in the recent past.

[54] Considering the case with multiple income groups for which the increase in housing price is stronger will put even more pressure on urban expansion.

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