Casting shadows: How work from home rescales cities across the urban system

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Extended Abstract

We develop a tractable general-equilibrium framework to analyze how work from home (WFH) reshapes the structure and population distribution of cities across an interconnected urban system. While a growing literature documents the intra-urban consequences of remote and hybrid work—flattening density gradients, reducing central rents, and altering commuting behavior—there is currently no unified analytical model that links these within-city adjustments to system-wide population reallocation and urban scaling. We fill this gap by embedding endogenous commuting frequency (Bond-Smith and McCann, 2025) into a system-of-cities extension of the classic Alonso–Muth–Mills (AMM) model and characterizing the resulting equilibrium with adjusted urban scaling laws.

The starting point is a system of monocentric cities linked by a common reservation utility determined through national market clearing. Households choose both their city of employment and their residential location within that city. In addition, unlike the standard AMM framework, we follow Bond-Smith and McCann (2025) in which households choose commuting frequency. This choice reflects a trade-off between distance-based commuting costs and productivity losses associated with working remotely. Productivity depends on both individual commuting frequency and on aggregate in-person attendance in the city, allowing for complementarities in face-to-face interaction. This assumption also endogenizes the system-wide split and extent of hybrid and fully remote work while preserving tractability.

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Within each city, optimal commuting frequency becomes part of the transport technology, with a nonlinear impact on the effective cost of distance. Households that commute fewer days per week are willing to reside farther from the central business district (CBD), thereby flattening bid–rent gradients and expanding the urban boundary. This generates an internal "donut" mechanism: population decentralizes and average commuting distance rises as commuting frequency falls. However, the key contribution of the paper lies in showing how these internal adjustments interact with the inter-city equilibrium to reshape, *and rescale*, the entire urban system.

In the standard AMM model, the equilibrium open-city population is pinned down by CBD income and the reservation utility. As a result, any urban quantity that is a power function of CBD income can also be written as a power function of city population. Bond-Smith et al. (2026) show that this mapping is consistent with the science of urban scaling, yielding relationships of the form $Y \propto N^{\gamma}$. In the AMM foundation, the scaling exponent γ is determined by structural parameters governing preferences and commuting technology. We extend this result from the single open city to our system of open cities with endogenous commuting frequency. This extension allows us to characterize how work from home reshapes both within-city structure and the cross-city scaling relationships that govern the distribution of city sizes across the urban system.

In the baseline model, commuting costs take the form $T(d) = \tau d^{\delta}$, where δ governs the curvature of distance costs. Urban scaling exponents depend on this curvature parameter. When households optimize commuting frequency, the commuting wedge becomes frequency-adjusted, $T(d) = f^{*}(d)\tau d^{\delta}$, where $f^{*}(d)$ is determined by the household's first-order condition balancing the marginal productivity benefit of commuting against the marginal commuting cost, $y\, m_f(f^{*}(d)) = \tau d^{\delta}$. The resulting reduced-form commuting technology is no longer proportional to a simple power of distance because it alters the effective curvature of commuting costs, thereby changing the scaling exponent governing the income–population relationship. Work from home, therefore, changes the geometry of the urban system spatial equilibrium itself.

Urban scaling delivers a system-wide mapping from city fundamentals to equilibrium size. But the WFH-adjusted scaling law, with optimal commuting frequencies, flattens the income–population relationship. As a result, city populations adjust according to this new scaling schedule, with more productive cities expanding and less productive cities contracting. More intuitively, utility rises everywhere, but the gains are uneven across the urban hierarchy. To restore spatial equilibrium, population flows toward cities with higher utility, leading them to expand, while cities with lower utility contract. In this sense, large cities "cast shadows" over smaller cities both by extending their reach and by weakening the relative position of smaller urban centres that lie outside the expanded hinterlands. The shadow effect is therefore not a literal reordering of cities, but a systematic divergence driven by commuting thresholds and relative scale.

The model yields three core results. First, WFH alters internal city form by flattening density gradients and expanding urban footprints. Second, through national market clearing, these local adjustments reallocate population across cities. Third, by modifying the effective commuting curvature, WFH changes the urban scaling exponent itself. Cities continue to obey power-law relationships between population and urban quantities, but the slope of these relationships shifts in response to commuting frequency optimization. Urban rescaling is therefore an equilibrium outcome of frequency-optimized commuting. Optimal frequency is the only commuting technology that produces this rescaling outcome because it endogenously alters the effective curvature of commuting costs, whereas other commuting technologies change the level of commuting costs, leaving the scaling exponent unchanged.

The presence of fully remote workers adds an additional layer of system-wide adjustment. Fully remote households reside outside cities at the housing cost floor but remain tied to city-level labour markets. Their location choices depend on effective productivity, which we assume depends on aggregate in-person attendance. As remote work expands, some cities experience a weakening of in-person externalities, limiting their ability to sustain large resident populations. Thus, WFH simultaneously expands urban footprints through reduced commuting frequency and constrains them through the decoupling of jobs from physical land markets.

More realistic urban systems also experience urban consolidation. As the burden of commuting falls, commuting distances increase, expanding effective commuting hinterlands. This expansion can draw in nearby smaller cities and towns, turning them into hybrid commuter — Zoom towns within a larger labour market area, in addition to redistributing labour across the urban system.

To illustrate these mechanisms, we apply the framework to the UK urban system using data from the National Travel Survey. We calibrate commuting frequency responses and productivity parameters to observed changes in hybrid work and commuting patterns. In the model, modest reductions in commuting frequency translate into measurable shifts in urban attractiveness and population allocation. The UK application also highlights an important departure from the standard theory since commuting technologies differ across cities. In particular, congestion implies that some cities experience larger effective reductions in commuting burdens than others. This heterogeneity can amplify shadow effects in places that were previously less constrained by congestion, while making previously congested cities relatively more attractive after the WFH shock. Accounting for this realistic heterogeneity, the model's predictions are consistent with early post-pandemic commuting patterns in the UK.

The analysis has implications for infrastructure planning, land-use policy, and regional development. Because WFH changes commuting behaviour and the effective commuting technology, it also changes the cost–benefit calculus of transport investments, especially the relative returns to projects that reduce long-distance versus short-distance commuting costs. Investments that improve access to large centres can magnify the expansion of large-city hinterlands by drawing more workers from smaller places. By contrast, policies that raise the productivity of smaller towns and secondary centres can increase their attractiveness and mitigate shadow effects. The framework also implies that the payoff from prior transport investments can shift after the WFH shock: smaller cities that previously reduced congestion see a smaller gain from reduced commuting frequency, implying a stronger shadow effect, whereas even small places that were already congested can experience larger relative gains from commuting less often, improving their relative post-shock attractiveness, mitigating the shadow effect.

The results also contribute to the urban scaling literature by providing a spatial-equilibrium microfoundation for why scaling exponents need not be universal constants. In the standard AMM framework, scaling relationships arise from the equilibrium mapping between CBD income and population implied by commuting costs and residential location choice. When work from home makes commuting frequency endogenous, commuting behaviour becomes part of the commuting technology and changes the effective curvature of commuting costs, in contrast to commuting innovations that only shift commuting costs proportionally. This reshapes the income–population mapping and therefore shifts the scaling exponent linking population to core urban quantities. In this view, scaling exponents reflect the underlying spatial equilibrium, including optimal commuting behaviour, which has not been previously incorporated into the urban scaling literature.

In sum, work from home does not merely decentralize activity within cities. By altering commuting technology and effective spatial reach, it reshapes the distribution of population across the entire urban system. Large cities expand their shadows, smaller cities face contraction pressures, and the scaling laws that govern urban structure adjust accordingly. The transformation of commuting behavior thus operates simultaneously within cities and across the urban hierarchy, redefining the geometry of the urban system itself.

References

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