Work-From-Home, Relocation, and Shadow Effects:

Evidence from Sweden

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Abstract

In this paper, we explore new and significant economic geography features of the work-from-home (WFH) revolution. The increased practice of WFH has prompted a potential redistribution of working populations between urban and rural locations, and between large cities and smaller towns. We build directly on the theoretical arguments developed in Shadows and Donuts: The Work-From-Home Revolution and the Performance of Cities, by Steven Bond-Smith and Philip McCann, TPI Working Paper 026, updated November 2024, which posits that larger cities are the major winners from the WFH revolution. At the level of an individual city, WFH revolution gives rise to a well-known centrifugal 'donut' effect whereby the city peripheries and edges are the major winners of these working pattern changes at the expense of the downtown areas. However, the theoretical framework also uncovers for the first time a centripetal hinterland 'shadow effect' whereby the larger cities gain at the expense of smaller cities and towns.

In this paper, we test the theoretical predictions by using a uniquely detailed and comprehensive individual-level nationwide Swedish micro-dataset. These data allow us to analyse shifts in commuting distances pre- and post-pandemic and explore their association with teleworkability. Sweden provides an ideal setting to test the theoretical 'donut' and 'shadow' predictions, because as well as having uniquely-detailed individual-level data, the major urban centres in Sweden are also sufficiently far apart that their hinterlands do not overlap, thereby allowing for a clearer set of empirical insights. Beyond the well-documented centrifugal 'donut'-type effects within, our study does indeed find a significant centripetal 'shadow' effect on smaller cities. This phenomenon draws workers relocating from outside metropolitan regions closer to major urban areas, reinforcing urbanisation trends, contrary to the expectations of geographic decentralisation enabled by remote work. These nuanced dynamics – highlighting simultaneous 'donut' dispersion effects at the local level and 'shadow' concentration effects within the overall urban system – provide new insights into the complex interplay between remote work, urbanisation, and regional development.

1 Introduction

In this paper, we explore some new and significant, economic geography features of the work-from-home (WFH) revolution. In particular, our empirical work using uniquely-detailed population-wide data demonstrates that the WFH revolution engenders a significant centripetal spatial 'pull' effect *towards* large cities, as the benefits of locating near a large city are magnified by the WFH revolution, also resulting in *shadow* effects in regions beyond their hinterlands. This large city pull effect occurs at the urban system level and contrasts with the widely-documented centrifugal 'donut'-type spread effects localised within cities (Aksoy et al. 2022), that we also observe. The donut effect and the pull effect of larger cities as well as the associated shadow effects from both of these are explained by forces that return the urban system to a spatial equilibrium following the WFH revolution. But this large city pull effect and associated rural shadow effects have not previously been observed.

It is widely-documented that the adoption of new communication technologies such as Zoom, Microsoft Teams, Cisco Webex, GoogleMeet and other similar technologies, has provided for greater degrees of remote or hybrid work patterns, and the commercial adoption of these technologies in turn offer greater possibilities for greater residential spread effects and a reduced association between the locations of work and living. Indeed, as well as localised city 'donut' effects, there are also widespread narratives about the potential for WFH to encourage economic and employment activities in more peripheral and remote regions. However, our uniquely-detailed and comprehensive nationwide empirical analysis demonstrates that the purported latter spread effect is largely a mirage, with centripetal shadow effects pulling workers closer to the cities being the dominant hinterland response to hybrid work practices.

Prior to the COVID-19 pandemic, WFH was not an alternative to work at work in the daily routines of most employees. Some work may occur at home, such as responding to emails or completing unfinished tasks, which extends the workday beyond office hours (de Graaff & Rietveld, 2007; Vilhelmsson & Thulin, 2016), but most jobs required daily commuting to a workplace. The COVID-19 pandemic upended this norm permanently, so many employees can now spend at least some days per week working from home and avoiding commuting to work. As workers began to return to workplaces, the dominant form of WFH that has emerged is hybrid, where commuting occurs regularly, though not every day. This significant shift changes the appeal of different locations and prompts workers to relocate to places with lower costs of living or higher amenities as the importance of commuting distances diminishes, which prompts questions about the future of the urban system. While initial empirical research has focussed on measuring the so-called 'donut effect'—characterized by the expansion of residential areas surrounding urban centres (Ahrend et al., 2023; Ramani & Bloom, 2021; Vogiazides & Kawalerowicz, 2023; Howard et al., 2023; Delventhal et al., 2023)—there has been very little research on population changes between centres. This article examines how working from home is already associated with changes in population locations across the urban system in Sweden after the pandemic, showing both the donut effect of people shifting *away* from local centres to more distant suburban and exurban locations, and a concentration effect of people shifting *towards* larger cities, that also suggests a shadow effect in smaller centres.

Prior to the pandemic, the proportion of workers primarily operating from home was minimal. The COVID-19 pandemic triggered a significant transformation in work dynamics, moving WFH to a central role for millions of employees globally. These shifts have prompted a re-evaluation of roles for individuals and organizations, giving rise to hybrid working models that integrate both WFH and in-person work (Bloom, 2022; Vij et al., 2023), also affecting *how* people work (Divle et al., 2024).[1] Today, WFH in Sweden has soared from 1.3 per cent before the pandemic to 9.8 per cent presently (Adrjan et al., 2023). In the UK, WFH has increased from less than 5 per cent to 14.5 per cent, now even surpassing peak pandemic levels. This rapid embrace of virtual meeting technology and the labour market's newfound acceptance of working from home has notably diminished the necessity for commuting daily between residential and workplace locations.

While remote work offers various benefits, including reduced total commuting time and enhanced personal well-being (Haldane, 2020; JLL, 2020), it potentially also presents challenges such as impeding innovation and lowering productivity, particularly among higher-skilled employees (Brucks & Levav, 2022; Gibbs et al., 2023).During the pandemic, WFH arrangements were predominantly adopted by higher-skilled and higher-income workers, especially in knowledge-intensive service sectors and managerial or professional occupations (Dingel & Neiman, 2020; Bloom, 2020; Sostero et al., 2020). The degree of work occurring at home is expected to remain elevated compared to pre-pandemic levels, particularly among white-collar workers (Barrero et al., 2020; Aksoy et al., 2022), although variations are anticipated across countries and industries.

The spatial implications of hybrid and WFH practices remain uncertain. Some US cities exhibit a 'donut' effect, with downtown areas resilient compared to suburbs, but this trend varies in economically weaker cities (Chun et al., 2022; Lee & Huang, 2022). There has been a surge in long-distance commuting in the largest US cities (Bloom & Finan, 2024). There is some evidence suggesting population shifts towards smaller centres, although there are limited employment dispersion effects around these secondary cities (Frey, 2022; Muro & You, 2021). It remains unclear whether similar patterns are observed globally. City-centre retail has struggled in the UK, while some prosperous city centres are experiencing rapid office employment growth, suggesting varied responses to remote work dynamics (Hammond, 2022a,b). In France, real estate markets are adjusting to the potential for telework, with city-centre landlords facing challenges (Bergeaud et al., 2023; The Economist, 2022a,b). The impact of WFH and hybrid practices on city productivity and the wider economy hinges on the balance between

[1] Throughout the remainder of this article, the terms work-from-home and remote work refer to both hybrid and fully-remote jobs.

technological advancements, shifts in work behaviours, and their influence on agglomeration processes, with the overall outcomes still to be fully understood (Behrens et al., 2024; Mischke et al., 2021).

The rise in WFH practices could potentially flatten city land markets, which might, in turn, affect city productivity. Urban centres, traditionally dependent on face-to-face knowledge sharing, may encounter productivity hurdles as hybrid working models become more prevalent (Althoff et al., 2022; Gupta et al., 2022). Excessive WFH may also hinder inter-firm agglomeration spillovers, reducing productivity (Behrens et al., 2021; Nathan & Overman, 2020). Both factors may reduce the productivity benefits of locating in larger cities. Additionally, increased residential space requirements for WFH might affect firm profitability (Stanton & Tiwari, 2021). Nonetheless, the productivity gains of avoiding costly commuting trips could offset such setbacks (Nathan & Overman, 2020). For instance, firms may optimize in-person interactions while streamlining routine office tasks, thereby boosting productivity (Mackenzie, 2021). In spatial equilibrium, firms and workers balance these effects on productivity with commuting costs and other hedonic factors. But the change to WFH implies that the current urban system is no longer in a spatial equilibrium. Recent changes to population settlement patterns and relative work and home location decisions point towards how the urban system is changing in its return to a spatial equilibrium.

The overall share of WFH in many professions is expected to be hybrid—somewhere between full in-person presence and complete WFH (Behrens et al., 2021). The long-term impact of hybrid and remote work on the urban and rural population landscape remains unclear. Remote work has the potential to create growth opportunities for peripheral regions, yet questions arise regarding the definition of "peripheral" and how WFH affects different types of communities that could lead to a reshaping of urban hierarchies. The ability to work remotely may level the playing field in terms of development opportunities across regions, potentially reducing inter-regional disparities. On the other hand, the impact of WFH might be more pronounced in peripheral areas, particularly those on the outskirts of large urban centres with a possibility for regular, though less frequent commuting. Moreover, certain types of cities may benefit more from the WFH trend, exacerbating interregional inequalities, while novel hinterland effects could potentially disrupt the existing urban hierarchy.

To examine these issues in the greatest detail possible, this study uses uniquely detailed and extensive data to analyse population-wide commuting distances in relation to the ability to telework, focusing on commuting distance changes between 2015 and 2022, spanning both the pre-and post-pandemic periods. Additionally, we study the correlation between these commuting distances and the proximity of individuals' residences and workplaces to major cities and examine how these relationships changed in response to the WFH revolution. We explore potential variations in these trends based on regional attributes and levels of urbanization. For this purpose, we employ geo-coded individual-level microdata from Sweden, covering the full nationwide workforce. This dataset facilitates the examination of the locations of people's homes and their employers for all Swedish workers, enabling the identification of relocation choices across the urban system, in response to the WFH revolution. As expected, the centrifugal 'donut' effect holds within the major cities in which workers tend to shift further from city centres and workplaces. But in contrast to this effect, larger cities experience a centripetal effect that pulls workers *towards* the major cities from areas surrounding the major city hinterlands; implying economic *shadows* cast over smaller communities. The strength of both the donut (push) effect and large city pull effect are positively associated with the size of the city. The combination of shadows and donuts implies ambiguous effects for smaller centres that depend on both their scale and proximity to large cities. Importantly, this is the first study to observe and document the regional shadow effects that result from the WFH revolution.

The rest of the paper proceeds as follows. Section 2 explains predictions from urban economic theory for both relocation decisions within cities and relocation decisions between centres across the urban system. Section 3 explains the nature of our data, the geography of the urban system in Sweden, and our empirical approach. Section 4 presents the empirical results, finding that teleworkability is predictive of changes in commuting distances that reflect both the donut effect and pull effects towards the three largest cities in Sweden—Stockholm, Gothenburg, and Malmö, that respectively imply shadow effects cast over both city centres and smaller communities beyond the urban hinterland. The final section of the paper provides concluding remarks.

2 A theoretical basis for changes in population locations

In this section, we derive testable hypotheses from economic theory about how the rise of WFH motivates relocation decisions and changes to commuting distances. The standard Alonso-Muth-Mills (AMM) city structure describes how workers face trade-offs between costly rent for homes close to the city centre and commuting costs in more distant locations. To add WFH to the AMM model, Bond-Smith and McCann (2024) optimise *commuting frequency* in an urban model that includes both home and office location decisions relative to commuting trips via the city centre. The critical equation is the *total cost of commuting*, including *both commuting travel costs and the opportunity cost of working at home* rather than at the workplace. The AMM model makes several unrealistic assumptions about workplaces in the city centre (or commuting trips via the city centre in Bond-Smith and McCann (2024)). The foundation for these assumptions is the clustered nature of workplaces around city centres to access city-wide benefits like labour market pooling and city-wide transport networks, leading to realistic inferences about the nature of cities and the urban system, both before and after the WFH revolution. .

The model

The theoretical predictions in this article are based on a slightly modified commuting cost function from a standard AMM model in which workers choose the frequency that they commute a distance d from their homes to their workplace. The *total cost of commuting* to the workplace for work at work and otherwise working from home is captured by the function:

$$C = \phi d^{\rho} f^{n} + a\theta f^{-m} \quad (1)$$

where d is the distance between a worker's home and their workplace, f is the frequency a worker commutes to their workplace for work at work, ϕ is a distance-based commuting cost, a is the productivity level of an employee working at the workplace and θ is the proportional decrease in productivity when working at home relative to working at work. The remaining letters are parameters for calibration. The total cost of commuting, whether work occurs only at home, only at the workplace, or some combination of both, includes the *travel* costs of commuting to the workplace ($\phi d^{\rho} f^{n}$) and the *opportunity cost* of working at home at a different productivity level than when working at work ($a \ \ \theta f^{-m}$). Notably, this specification is flexible enough to enable working from home to be more productive than working at work (in which case the proportional decrease in productivity θ is a negative "cost"), or is less productive at home than at work. [2]

The rise of WFH implies that the frequency of commuting, f, has reduced from a requirement that workers commute to the workplace every day, as is standard and often implicitly assumed in urban models, but denoted f_{max} in this article. Instead, WFH implies that workers can commute at an optimal frequency, denoted f^{*}, that allows regular WFH. To maximise utility, workers optimise commuting frequency to minimise the overall cost of commuting, including opportunity costs when working from home. Differentiating the total cost of commuting in Equation 1 with respect to f, setting to zero, and rearranging gives the first-order condition that optimizes commuting behaviour over any distance by minimising the joint commuting and opportunity costs of WFH relative to working at work:

$$\frac{\partial C}{\partial f} = n\phi d^{\rho} f^{n-1} - ma\theta_{o} f^{-m-1} = 0 \quad (2)$$

Rearranging such that f is the dependent variable, the optimal commuting frequency for any commuting distance is:

$$f^{*} = \left(\frac{ma\theta_{o}}{n\phi d^{\rho}}\right)^{\frac{1}{m+n}} \quad (3)$$

Where f^{*} is between zero and f_{max}. Rearranging such that commuting distance (d) is the dependent variable.

[2] While the proportional change in productivity θ is specified as a calibrated constant it could also be thought of as the result of an optimisation problem based on the relative marginal productivities of work at work compared to WFH. If workers (or employers) choose any share of tasks to occur in-person, then it implies that the marginal productivity of WFH is lower than work at work because the worker (and employer) is willing to pay commuting travel costs in order to access higher productivity at the workplace. This means that a calibration where θ is positive simply reflects the observation that the dominant form of work from home requires at least some tasks to occur in-person.

$$d = \left(\frac{ma\theta_O}{n\phi f^{*n+m}}\right)^{\frac{1}{\rho}}, \tag{4}$$

where the optimal commuting frequency f^* can now be thought of in terms of the job- or profession-specific requirements for work to occur at work and its flexibility to WFH. Interpreted this way, equation (4) implies that workers in jobs that allow regular WFH—and so require less frequent commuting—will live further from their workplaces. This is the so-called "donut effect" (Ramani and Bloom, 2021).

Taking the logs of each side provides an equation suitable for empirical analysis:

$$\log d = \varepsilon - \frac{n+m}{\rho}\log(f) \tag{5}$$

where $\varepsilon = \frac{1}{\rho}(\log(m) + \log(a_i) + \log(\theta_o) - \log(n) - \log(\phi))$ is a constant that includes all the calibrating parameters of the model. To examine the likely effects of WFH on the locations of workers, this equation is examined based on regressing various measures of distance between homes and workplaces and between homes and city centres against a measure of teleworkability specific to each profession, which we substitute for $\log(f)$. The expected positive coefficient on teleworkability (negative coefficient on $\log(f)$), implies that commuting distances increase for jobs that are more amenable to WFH and therefore require less frequent commuting.

Deriving hypotheses

This hypothesis that workers in teleworkable jobs will relocate further from their workplace, as in the so-called 'donut effect' (Ramani and Bloom, 2021, Bond-Smith and McCann, 2024), is not the only effect of increased work from home. Workers who regularly WFH can now also make decisions to live (work) in a different city than where they work (live) or to relocate both their home and work to a different city than where they previously lived. In the context of the AMM modelling framework, such decisions change the reference point from which the corresponding bid-rent curve and distance d is measured.

To examine the incentives to relocate, consider how utility changes in different locations with the rise of WFH. Assume that the initial conditions, when most workers had to commute every day, were a spatial equilibrium, in which workers cannot be made better off by relocating or shifting employer, and that a worker's utility in their present location is represented by U. Initial utility is $U = y - C$ where y is the worker's income before commuting costs and C is the total cost of commuting every day. In making their original location decisions, workers also considered the utility attainable by living and working in other cities. The hypothetical utility in an alternate city is $U' = y' - C'$, where the prime (′) indicates that the reference point is an alternate city. In the spatial equilibrium that existed prior to the rise of WFH, $U = U'$ and U and U' are constant across all locations in the urban system, both within cities and between alternate cities. Commuting costs vary by location but equilibrium rents adjust such that U is the same everywhere in spatial equilibrium.

The rise of WFH means that commuting costs have changed as workers can now regularly avoid commuting. Prior to any relocation decisions, the rise of WFH means that utility with optimal commuting frequency increases to $U^* = y - C^*$ where the star indicates that the parameter is determined by optimal frequency. The change in utility due to the rise of WFH is $\Delta U = U^* - U = C - C^* = \Delta C$, implying that utility increases by the amount workers save on overall commuting costs. This is also true in alternate cities. As f^* varies with distance between homes and workplaces in city centres, the change in commuting costs and utility is uneven. While the WFH revolution increases utility in all locations, the increase in utility is greater in places that offer a greater reduction in commuting frequency and commuting costs. So, the former population distribution is no longer a spatial equilibrium and the rise of WFH incentivises relocation decisions. Relocating allows those who WFH to take greater advantage of the opportunity to do so, but since the increase in utility occurs everywhere, workers are incentivised to relocate from locations with a smaller increase in utility to locations with larger increases in utility.

The change in overall commuting costs:

$$\Delta C = \phi(d)^{\rho} f^{*n} + a_i \theta f^{*-m} - \phi(d)^{\rho} f_{max}{}^{n} - a_i \theta f_{max}{}^{-m}, \quad (6)$$

describes the increase in utility that occurs with the rise of WFH. While utility increases everywhere that people live, the change in commuting costs is positively related to the length of a commuting trip. So, in the donut effect, welfare increases if people relocate further from their workplace where they can take advantage of lower rents and a reduced commuting frequency. The *average* change in commuting costs defines the welfare gain achieved everywhere in that city in the new spatial equilibrium, prior to any relocation decisions between cities. Setting Equation (6) to the *city-wide* average change in overall commuting costs, $\overline{\Delta C}$, substituting optimal commuting behaviour as a function of distance, and rearranging to solve for distance defines a city-specific threshold distance, denoted d_t, where population density does not change

$$d_t = \left(\frac{\overline{\Delta C} - a_i \theta \left(f^{*-m} - f_{max}{}^{-m}\right)}{\phi\left(f^{*n} - f_{max}{}^{n}\right)}\right)^{\frac{1}{\rho}} \quad (7)$$

The model predicts that the area closer to the city centre than this threshold will experience a population decline, in the centre of the donut, as people move further away from the city centre. The area beyond this threshold distance will increase in population density. The average change in frequency is greater in larger cities where workers already commute longer distances, which means that commuting distances are expected to increase more in larger cities or that *there is a stronger donut effect in larger cities, meaning a larger area affected and stronger incentives to relocate within the city*.

However, the predicted donut effect is entirely an intra-city effect that is predicted by the closed-city AMM model. In the closed city model, the city's population remains constant and market clearing for housing in spatial equilibrium determines the level of utility attained by residents in the city. The uneven increase in utility across the city due to the increase in working from home initiates the donut-shaped redistribution of workers *within* the city. But it does not account for any redistribution of people between cities—Workers who regularly WFH can make decisions to work in a different city than where they live, live in a rural area, live in a different city than where they work, or migrate both home and work to a new city altogether.I Such inter-city relocations are based on the *system-wide* average utility level which also equalises in spatial equilibrium. That is, the system-wide average change in utility defines the new system-wide spatial equilibrium and people will shift from locations with a smaller-than-average welfare gain to locations with a larger-than-average welfare gain.

In the context of the AMM modelling framework, solving equation 6 for distance using the *system-wide average* change in overall commuting costs, also implies a shadow effect on the central regions of cities that concurs with the donut effect. But the inter-city shadow region does not differ in area in cities of different sizes. As a result, some smaller cities may fall entirely within the shadow region while larger cities will have an inter-city shadow region that is smaller than the central shadow of its own donut effect, thereby mitigating the donut effect. The exact way cities are affected depends on the population distribution between cities and where each city ranks in that distribution. Taken together, the intra-city donut effect and the inter-city shadow effect mean that *the shift in the forces driving the spatial equilibrium favours relocations to larger cities over smaller cities*.

For workers living and working in small towns, the utility gain of working from home is relatively small since the commuting distance is relatively small. And much like the donut effect, larger cities with longer potential commuting distances have a greater increase in utility due to a greater reduction in commuting frequency and longer commuting distances. Similar to moving to the outskirts of a large city, workers residing in smaller towns may be able to take greater advantage of WFH by either transitioning to job in a nearby major city that is now within commuting reach or relocating to a proximity that allows for manageable commutes, provided they aren't required to travel daily. That is, there can be a greater increase in utility by switching employment to a larger city due to a lower optimal commuting frequency. Furthermore, they could also choose to relocate their home location to the hinterland of a larger city to take the opportunity. Such workers would currently live beyond a commutable distance from the larger city and previously commuted to a local town but may now be sufficiently incentivised to take employment in the larger city by sometimes working from home. In other words, regularly working from home means the commuting travel costs to the larger city are now less of a deterrent than when workers had to commute every day. Based on this premise, the model suggests that individuals residing in smaller cities are prompted to relocate work and home locations, or both, closer to a larger city, counter to the donut effect experienced by workers already living a shorter distance to the larger city.

To adapt the model for empirical analysis, consider the change in the log of distance metric shown in equation (5):

$$\Delta \log dist. = \frac{n+m}{\rho}(\log(f_{max}) - \log(f^*)). \qquad (8)$$

Since we do not observe how frequently workers commute to work, the empirical analysis is instead based on an index of *teleworkability*, denoted T, which is between zero and one, that we expect to be an inverse proxy for equilibrium commuting frequencies. That is, the relevant equation is now:

$$\Delta \log dist. = \frac{n+m}{\rho}\big(\alpha \log(1) + \beta \log(T)\big). \qquad (9)$$

Where $\frac{n+m}{\rho}\beta$ is the coefficient on teleworkability. For people in jobs amenable to regularly working from home, the model predicts that they will relocate further from their workplaces so that the coefficient will be positive. But, countering to the donut effect, the model predicts that workers outside of major cities will tend to relocate closer to those major cities to take advantage of WFH opportunities. So, for this distance measure relative to larger city centres, the coefficient would be negative.

In summary, the model predicts the following. The increase in work from home means that:

(1) workers in professions that allow them to WFH will relocate further from their workplaces;

(2) workers in professions amenable to WFH will live further from the city centre where they live; and

(3) firms hosting professions amenable to WFH will locate further from the city centres where they are located.

These first three hypotheses are all predictions of the donut effect. The model also predicts the following inter-city effects that analysing distances to the largest cities can detect. The increase in work from home means:

(4) workers in professions amenable to WFH, living outside of larger cities, are likely to relocate closer to a nearby larger city; and

(5) firms hosting professions amenable to WFH, but located outside larger cities, are likely to relocate closer to a nearby larger city.

These latter two predictions are not derived in any other analytical frameworks and are uniquely associated with this particular model approach, because the frequency of commuting is not incorporated in any other modelling framework as the explicit decision-making parameter which influences the relationships between all other spatial and non-spatial variables associated with the WFH revolution.

This is critical, because it is the uneven changes in commuting frequencies that generate the uneven change in commuting cost savings between cities of different sizes. These latter two hypotheses are central to the insights uncovered by this article.

3 Data, variables, and descriptives

Following this framework, we empirically analyse individuals with teleworkable jobs, focusing on the geographical distances between their homes and workplaces and the distances to higher-density places, such as the central municipality of their regions, and the three metropolitan areas. Using data from 2015 to 2022, we aim to control for the post-pandemic years (2020-2022) and examine the interaction between the post-pandemic period and the degree that an individual's profession is teleworkable. For this, we use data from Statistics Sweden, covering the entire working-age population (20-64 years), and since it is geocoded, we can track individuals geographically. In total, this leaves us with 37,805,373 observations across 5,659,775 individuals.

Geography of Sweden

Sweden is an especially apt case study for this exercise due to its geographical layout. Characterised by a dispersed geography, the nation features three major metropolitan areas—Stockholm, Gothenburg, and Malmö—all situated in the south but maintaining significant distances between them. This spatial arrangement prevents direct integration and overlap of their respective labour markets, giving rise to distinct, non-contiguous and non-overlapping regions surrounding these metropolitan hubs. The large distances between these major Swedish cities provide clear reference points for our analysis to detect evidence of the anticipated inter-city shadow effect. While shadow effects are also likely to occur in other urban systems, they could be more complicated to discern amidst donut effects and overlapping labour market areas typical in densely populated countries, potentially diminishing the visibility of both phenomena.

Sweden can be divided into 60 Labour Market Regions (*LM*), and 290 municipalities. The map to the left in Figure 1 below shows the functional regions, highlighting the functional regions of Stockholm, Gothenburg, and Malmö (*SGM*). The map to the right displays the municipalities, picking out the central business districts of these metropolitan areas (*Central SGM*). The distances between these city centres are approximately 500 km between Stockholm and Gothenburg (5 hours driving time), 600 km between Stockholm and Malmö (6.5 hours driving time), and 270 km between Gothenburg and Malmö (3 hours driving time).

The map below (Figure 1) marks where we draw the border for 'southern Sweden,' encompassing the regions where most people live, a definition we use in the analysis below. These southern regions account for 91 per cent of the Swedish population. The Stockholm labour market region accounts for

28%, and the Gothenburg and Malmö labour market regions account for some 12% and 8%, respectively.[3] Based on the apparent tilt to the south of Sweden regarding people being able to commute to larger labour markets, we focus our analysis on this part of the country only, shown in Figure 2.

(Figure 1 and 2 about here)

Figure 1 Labour market regions (LM), highlighting the functional regions of Stockholm, Gothenburg and Malm (SGM)

[3] This geographically skewed population distribution is shown in Figure 3 in the appendix.

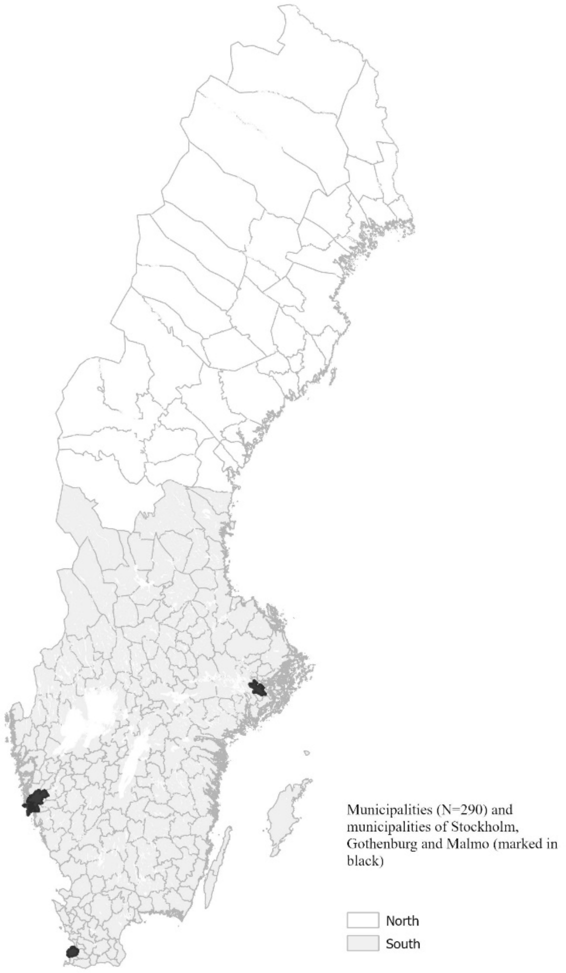

Figure 2 Municipalities in Sweden, divided into southern and northern, also highlighting the municipalities of Stockholm, Gothenburg and Malmö (Central SGM)

To discern potential correlations between remote work and migration patterns following the pandemic, we leverage geo-coded data from Statistics Sweden from 2015 to 2022. This dataset enables us to pinpoint our individuals' municipal places of residence and workplace locations. Based on a time/distance matrix for all 290 municipalities across the 60 labour markets, we examine the commute duration between an individual's residence and their workplace, an individual's residence and the primary, central municipality (*CM*) within their respective labour market, an individual's workplace and the CM, as well as their distances to the three metropolitan areas. From a labour market standpoint, the CMs serve as the region's local central business district, embodying economic and population density while housing principal public offices. For the LMs of Stockholm, Gothenburg and Malmö we name the CMs *Central SGM*, as stated above.

Commuting duration and change in the geographical distribution of individuals

Our analysis focuses on whether individuals with an opportunity for remote work have experienced extended commuting times over time and whether their situations significantly changed in the post-pandemic period. And primarily, what are the geographical patterns of these shifts? We do not only focus on the residents' locations but also evaluate whether their workplaces have shifted to more remote locations away from the central municipality within their labour market.

Our variable(s) of interest is the commuting duration between point A (residence *or* work) and point B (SGM *or* the CMs). We compute the travel time in minutes for individuals with these points of references. Drawing from our theoretical model, we refine our dataset by segmenting it according to individuals' residential labour market each year and distinguish between residing in the LMs of Stockholm, Gothenburg, and/or Malmö or elsewhere in southern Sweden. This allows us to exhibit whether there are more significant changes in the location patterns in SGM compared to those in smaller regions and to what extent this relates to their ability to WFH. Overall, the relevant distances are illustrated in Figure 3 below:

(Figure 3 about here)

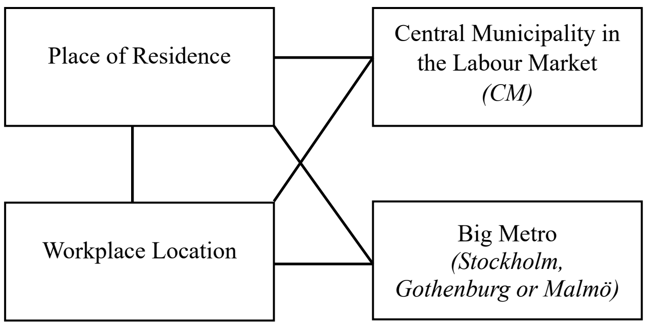

Figure 3 Possible commuting distances.

Embedded within these commuting directions and the temporal scope of our study, we also account for the likelihood of individuals changing their residential and/or work locations. In the analysis, we separately analyse individuals in southern Sweden *not* living or working in SGM and those living or working *within* SGM. For individuals outside SGM, the analysis is conducted in two steps. First, we examine the likelihood of changing their residential or work location. Second, conditional on such a change, we examine the likelihood of moving closer to SGM. For individuals residing or working *within* SGM, we analyse whether they change their municipality of residence or work, and if so, whether the shift brings them closer to or farther from Central SGM.

Descriptive analysis

In the analysis, we focus on the southern parts of the country (see Figure 3), which accounts for more than 90 percent of the population. In contrast, the northern regions represent a smaller share of the population and are characterized by significantly more sparsely populated areas with longer average commutes. Given these differences in population density and commuting patterns, the inclusion of northern areas would introduce substantial heterogeneity, potentially complicating the interpretation of results. By concentrating on the southern regions, we ensure a more representative and consistent analysis of the majority population's residential and commuting behaviours. Table 1 shows average commuting distances (in minutes) between home and work locations, and relative to the nearest centre of the three metro LMs, Stockholm, Gothenburg, and/or Malmö. On the left side of the panel, we examine those residing in the southern parts but *not* in any of the three metro LMs.[4] In the panel to the right, we focus on those living in these three metro LMs. The commuting time between home and work is generally slightly higher outside SGM and travel times increase steadily over time for both groups, with a change in this trend in 2022 when they begin to drop.

(Table 1 about here)

Table 1 Average distance (in minutes) yearly for individuals, living in the south of Sweden not in SGM (left) and within SGM (right)

	Living in the south of Sweden, not in SGM *(average minutes)* $N_{2014\text{-}2022}$=12,445,223			Living in SGM *(average minutes)* $N_{2014\text{-}2022}$=22,393,257		
	Home and Work	Home and Central SGM	Work and Central SGM	Home and Work	Home and Central SGM	Work and Central SGM
2014	22.63	116.74	113.49	20.34	21.51	21.55
2015	23.22	116.90	113.59	20.80	21.53	21.81
2016	23.88	116.89	113.41	21.47	21.42	21.92
2017	23.99	116.76	113.22	21.67	21.37	21.90
2018	23.91	116.64	113.19	21.42	21.35	21.88
2019	24.05	116.57	113.10	21.80	21.37	21.94
2020	24.40	116.59	112.97	22.44	21.34	22.09
2021	25.01	116.59	112.76	23.24	21.41	22.28
2022	24.75	116.49	112.69	22.85	21.40	22.01

Table 2 describes average distances for a subset of the workforce in southern Sweden, not residing or working in SGM, as in the left panel in Table 1, but including only those who *change* their LM of residence (left-hand panel of Table 2) between each year and those who change their LM of work (right-hand panel of Table 2). Between 2015 and 2022, 328,050 individuals outside SGM transitioned to a different LM of residence, while 710,419 changed their LM of work (across all years). Naturally, these two groups overlap for those who change both their LMs of residence *and* work. Looking at commuting time between home and work for those who change residence, we see stagnation during the pandemic years and a rather sharp drop in 2022. Also, it these workers move slightly closer to SGM, consistent

[4] Tables 6 in the appendix presents the average distance in minutes for individuals in the South of Sweden and all individuals in all of Sweden, respectively.

with the theoretical arguments above. Similar patterns are revealed in the right-hand panel, focusing on those who change their work LM.

(Table 2 about here)

Table 2 Average distance (in minutes) yearly for individuals living in the south of Sweden, not in SGM and changed location of residence (left) or location of work (right)

	Living in the south of Sweden, not in SGM- changed residence location *(average minutes)* $N_{2014\text{-}2022}$=328,050			Living in the south of Sweden, not in SGM- changed work location *(average minutes)* $N_{2014\text{-}2022}$=710,419		
	Home and Work	Home and SGM	Work and SGM	Home and Work	Home and SGM	Work and SGM
2015	71.70	69.82	91.63	58.19	87.32	76.69
2016	69.60	70.89	90.96	58.11	88.80	77.84
2017	68.64	71.33	90.99	57.34	88.21	78.23
2018	68.88	70.95	90.91	55.82	88.32	78.60
2019	70.51	70.30	91.22	58.35	88.00	77.71
2020	72.22	71.64	93.14	60.90	88.12	78.30
2021	72.66	71.50	93.04	61.40	88.52	78.10
2022	65.76	70.34	88.82	56.74	86.36	75.66

Table 3 is a similar subset of the workforce, but includes those residing or working in SGM, as in the right-hand panel of Table 1, who change their municipality of residence (left-hand panel of Table 3) between each year and those who change their municipality of work (right-hand panel of Table 3). The average distance between home and work follows the same patterns as those residing and working outside SGM. What differs, however, is the relation between residence location and central SGM, which, on average, appears to *increase* even after the pandemic, also consistent with the theoretical arguments above.

(Table 3 about here)

Table 3 Average distance (in minutes) yearly for individuals living in SGM and changed municipality of residence or work

	Living in SGM- changed residence municipality *(average minutes)* $N_{2015\text{-}2022}$=932,334			Working in SGM- changed work municipality *(average minutes)* $N_{2015\text{-}2022}$=1,959,900		
	Home and Work	Home and Central SGM	Work and Central SGM	Home and Work	Home and Central SGM	Work and Central SGM
2015	43.23	42.93	31.36	37.33	27.24	30.52
2016	44.50	45.26	33.42	37.75	.27.21	30.39
2017	43.86	45.17	33.13	37.07	27.35	30.41
2018	42.95	44.86	33.14	35.71	27.36	30.38
2019	43.51	44.13	32.67	38.35	.27.41	30.64
2020	45.01	44.47	32.65	40.60	27.58	31.56
2021	46.57	45.61	33.23	42.59	27.88	32.24
2022	45.13	46.40	34.57	39.47	27.45	30.25

Estimation Strategy

The descriptive tables above provide an overview of how travel times have evolved since 2015, highlighting significant changes in the post-pandemic period that are consistent with the combination of the intra-city donut effect and the inter-city shadow effect. However, our key questions remain: To what extent can these changes in commute durations be attributed to increased opportunities for remote work? And does the teleworkability of jobs retain its importance after accounting for individual characteristics and the industry in which a person works? We begin our analysis with a panel estimation for all individuals in the southern parts of the country to examine how commuting time distances in general changed between 2015 and 2022. Particular attention is given to the role of the ability to work remotely (teleworkability) and if the role of teleworkability in location decisions (measured by travel time) was significantly influenced by the pandemic. Following this (below), we conduct an analysis where we distinguish between individuals living outside a metropolitan region (outside SGM) and those residing within one of the three metropolitan regions (within SGM). In this part of the analysis, we also consider the likelihood of changing place of residence and/or workplace and, conditional on such a change, whether individuals relocate closer to or farther away from the metropolitan regions in a Heckman estimation. We thereby assume that this subset (those who change place of residence and/or workplace) is not random but systematically related to the outcome: the change in travel time.

In our analysis, our dependent variable is the log of the travel distance, in minutes, between individuals' municipality of residence (H), municipality of work (W), the largest city in the labour market region (CM), or Stockholm/Gothenburg and Malmö (SGM). Additionally, we conduct a similar selection-based analysis for individuals residing in SGM, examining how their movements relate to the central metropolitan areas within SGM.

The teleworkability variable is continuous (ranging from 0 and 1) and comes from the methodology developed by Sostero et al. (2020), aimed to capture the ability of different occupations to be performed remotely. In their work, they introduced a teleworkability index that ranges from 0 (no capability for remote work) to 1 (full capability for remote work). This index considers the technical feasibility of conducting tasks remotely within a specific occupation. Factors such as information processing, social interaction tasks, and physical activities are key in determining an occupation's teleworkability score. This score has been manually adapted to match the Swedish occupational code.

We also consider various personal characteristics such as age, gender, family status, income, ethnicity, and the 2-digit industry of employment.[5] Using this unbalanced panel from 2015 to 2022, our baseline empirical model for the individual's travel distance between home and work is as follows:

$$lnd_{it}^{HW} = \alpha_i + \beta_1 TW_{it} + \beta_2 Post_{it} + \beta_2 (TW_{it} \times Post_{it}) + \boldsymbol{\theta}'\mathbf{X}_{it} + \epsilon_{it}^{HW}$$

[5] Swedish industry codes SNI are comparable to EU-standard NACE rev.2

where d_{it}^{HW} is the distance between the individual's location of home (H) and the location of work (W). The coefficient β_1 represents the effect of teleworkability, TW_{it}. The coefficient β_2 gives us the baseline effect of the years after the start of the COVID-19 pandemic, i.e., 2020, 2021, and 2022, holding the other explanatory variables, including teleworkability, constant. β_2 is the interaction effect, distinguishing the additional effect of teleworkable professions post-COVID. $\boldsymbol{\theta}'\mathbf{X}_{it}$ is the vector of individual controls. To account for unobserved individual heterogeneity, we include individual fixed effects α_i.

Panel Estimation Results

Table 4 presents the results of the first estimations, for individuals in southern Sweden within a panel framework with individual fixed effects and consider our three versions of the dependent variable; the time distance between home and work, between home and the largest municipality in the labour market region, and between work and the largest municipality in the labour market region.[6] The primary variable of interest is teleworkability, examined in both pre- and post-COVID periods. In the pre-pandemic period, the first column (distance between home and work) shows no significant relationship between teleworkability and distance. However, we observe positive associations between teleworkability and the distance from home or work to the largest city (CM). This indicates that individuals with more teleworkable jobs, or those transitioning to such roles, are more likely to live farther from the regional centre than they would if opportunities for remote work were fewer.

Turning to the post-COVID effects, we find an overall increase in distances across our nodes of interest from 2020 onward, indicating a regional enlargement after the COVID-19 pandemic—a trend consistent with but additional to long-term patterns. However, examining the interaction term, teleworkability also emerges as having an additional effect on increasing distances after COVID, particularly for the distances between home and work, as well as between home and the largest city in the region. In contrast, for the distance between work and the CM, teleworkability is associated with *shorter* distances in the post-COVID period, counteracting the long-term trend and the post-COVID increase experienced by all workers.[7]

(Table 4 about here)

Table 4 Southern Sweden- panel FE, Dependent variable: time distance

	Home – Work	Home – CM	Work – CM
Teleworkability	$4.59e^{-6}$***	$2.28e^{-7}$***	$8.67e^{-7}$***
	$(4.14e^{-8})$	$(1.64e^{-8})$	$(2.34e^{-8})$

[6] The panel estimation for all of Sweden, including the detailed information on control variables, is presented in Table 7 in the appendix.
[7] The detailed information of the estimation is presented in Table 8 in the appendix.

Post	0.00462***	0.000843***	0.00296***
	(0.000339)	(0.000134)	(0.000191)
TW x Post	0.00771***	0.00160***	-0.00588***
	(0.000397)	(0.000157)	(0.000224)
Industry controls	YES	YES	YES
Observations	34,400,282	34,434,981	34,434,981
Individuals	5,193,310	5,195,880	5,195,880
R-squared	0.022	0.072	0.022
Robust standard errors *(in parenthesis)* *** p<0.01, ** p<0.05, * p<0.1			

Relocate home or workplace- a selection process

Next, we distinguish between larger and smaller regions and examine the potential shifts in people's relationships between their home and work locations. Specifically, we aim to analye the relationship between metropolitan areas (SGM) and all other regions in the southern parts of the country. In other words, we now make an important distinction between individuals who live or work within any of the three metropolitan areas and those who do not. Additionally, we now account for the likelihood of changing either the place of residence or work – a distinction not made in the panel estimations above. By doing so, we now address a possible selection bias in the decision to relocate either one's residence or workplace.

We use a Heckman selection model across the same years as our panel set-up (2015 to 2022), where the first step is to model the decision to relocate. Thus, the dependent variable in the selection equation is our binary indicator of whether an individual decides to relocate either their home or work:

$$Z_i^* = \gamma'\mathbf{X}_i + v_i$$

where Z_i^* represents the latent binary variable representing the propensity to relocate. $\mathbf{X}_i$ is the vector of explanatory variables affecting the decision to move. We do not include TW, post-COVID, and the interaction between these variables. Besides that, the same controls are used as in the fixed effect model. γ is the coefficient for the selction equation and v_i is the error term. Following this step, the observed decision to move is given by:

$$Z_i = \begin{cases} 1\, if\ Z_i^* > 0 \\ 0\ otherwise \end{cases}$$

In the second step for the individuals who decide to relocate, we study their geographical travel distances. Thus, our outcome equation has a dependent variable being the logged change of distance:

$$\Delta d_{it}^{HW} = d_{it} - d_{i,t-1} = \sigma_i + \mu_1 TW_{it} + \mu_2 Post_{it} + \mu_3(TW_{it} \times Post_{it}) + \gamma'\mathbf{X}_i + \epsilon_i$$

where Δd_{it}^{HW} is the first-order difference, providing us with the first-order condition that optimizes individuals' commuting behaviour. Our dependent variable appears in our estimations in two versions:

the distance between home and SGM, and between work and SGM. As we focus on them separately, it is also important to note that the two groups overlap for individuals that change both home and work locations. $\mathbf{X}_i$ is the vector of explanatory variables at t_1 affecting the decision to move and the geographical moving pattern.[8] Again, our focus variables are the ability to telework and the post-COVID interaction effect.

Closer to, or further away from metropolitan areas

In Table 5, we present the results from our Heckman estimations.[9] The left-hand panel focuses on individuals residing in any labour market region in southern Sweden, excluding the labour markets of Stockholm, Gothenburg, and Malmö (SGM), who relocate to another labour market region. The changes in distance are measured between their home region and the central SGM, and between their work region and the central SGM, respectively.

For the pre-pandemic period, we find no significant relationship between teleworkability and the change in distance between home and the central SGM. However, the results show a negative correlation for the distance between work and the central SGM, indicating that teleworkable jobs were historically associated with smaller increases—or even decreases—in the distance to Sweden's densest urban areas. This suggests that individuals in teleworkable roles were either relocating closer to the SGM or staying closer to these areas when moving for work.

Turning to coefficient of the post-COVID dummy variable, we observe that, on average, individuals who relocated tended to move *closer* to the central SGM. Furthermore, the interaction between teleworkability and the post-COVID period shows an even more pronounced negative effect, suggesting that teleworkability is associated with relocations that *reduce* travel distances to SGM in the post-pandemic context confirming our theoretical predictions about the inter-city shadow effects of increased WFH.

In the right-hand panel, we examine individuals residing within the labour markets of Stockholm, Gothenburg, or Malmö who relocate to another municipality. For the pre-pandemic period, we find that individuals with greater telework feasibility tended to relocate to locations with greater distances between their home and the central SGM. This indicates that teleworkability was associated with moves further away from the core metropolitan areas. However, this trend appeared to persist regardless of teleworkability. Post-COVID, the interaction between teleworkability and the post-COVID dummy reveals that the effect of teleworkability on the percentage change in home-to-SGM distances grew stronger, with relocators moving farther away from the metropolitan centres. This suggests that

[8] The explanatory variables are measured in t_1 with the logic that significance imlies they are "pull" factors affecting a moving decision. Alternatively, one could have measured them at t_0, considering them as "push" factors, but pull factors are more consistent with our modelling framework, especially the teleworkability of people's professions following a relocation decision.

[9] Detailed information on the estimations is provided in Table 8 in the appendix.

teleworkability increasingly enabled longer relocations in the post-pandemic years compared to the pre-pandemic period.

Finally, the last column of Table 5 examines the distance between work and the central SGM for individuals relocating to a new work municipality. Unlike the home-location pattern, this distance was decreasing for individuals with higher teleworkability, even before COVID. However, the post-COVID dummy shows that relocators experienced larger increases in work-to-SGM distances, even when teleworkability was not considered. When factoring in teleworkability, the interaction term reveals that this effect is more pronounced, suggesting that teleworkability had a stronger influence on longer-distance relocations of work post-COVID.

(Table 5 about here)

Table 5 Heckman selection model (pooled 2015-2022), either living outside the functional regions of Stockholm, Gothenburg and Malmö or in these functional regions. Differences in distances between home or work to the municipalities of Stockholm, Gothenburg and Malmö when either changing location of residence or changing workplace.

	Southern Sweden not living in functional region of SGM		Living in functional region of SGM	
	(ln)ΔDistance Home-Central SGM	(ln)ΔDistance Work-Central SGM	(ln)ΔDistance Home-Central SGM	(ln)ΔDistance Work-Central SGM
Teleworkability	$-6.53e^{-7}$	-2.61e-06***	$8.04e^{-7}$***	$-3.57e^{-6}$****
	($2.58e^{-7}$)	(2.33e-07)	($1.91e^{-7}$)	($1.63e^{-7}$)
Post	-0.104***	-0.329***	0.458***	0.878***
	(0.0110)	(0.00754)	(0.00474)	(0.00388)
TW x Post	-0.0252***	-0.0462***	0.0278***	0.0401***
	(0.00666)	(0.00404)	(0.00426)	(0.00267)
Selection Equation	*Change of functional region of residence.*	*Change of functional region of work.*	*Change of municipality of residence.*	*Change of municipality of work.*
Athrho	-2.344***	-2.494***	-0.113***	1.740***
	(0.00839)	(0.00355)	(0.0160)	(0.00194)
lnsigma	1.047***	1.021***	0.0905***	0.746***
	(0.00284)	(0.00142)	(0.00169)	(0.000999)
Individual controls	YES	YES	YES	YES
Industry controls	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES
Observations	11,358,798	11,211,740	20,775,541	20,966,410
Standard errors (in parenthesis) *** p<0.01, ** p<0.05, * p<0.1				

Taken together, the findings suggest heterogeneous responses to the ability to WFH among different types of individuals, which also vary based on their location, aligning with predictions from the theoretical model. A notable disparity emerges between individuals residing in metropolitan regions and those outside such areas. Importantly, however, in addition to observing the well-known centrifugal 'donut' effect at the local scale, we also observe for the large metropolitan areas a centripetal shadow effect at the broader regional hinterland scale across the south of Sweden which encourages work and home relocations towards the very largest cities. In other words, the results show standard donut effects in SGM and smaller LMs in the urban system but inter-city shadow effects on CMs outside of SGM. This latter effect has not been observed before. It suggests that, partly contrary to the expectation that teleworkability would lead to widespread decentralization, the gravitational pull of large metropolitan areas persists and is amplified by the WFH revolution. Such a trend could exacerbate challenges for smaller towns and rural areas, which struggle with population loss, potentially reinforcing existing spatial inequalities.

5 Conclusions

This study represents an important step in deepening our understanding of the potential social and economic impacts of the growing prevalence of remote work and digitalization. Building on a body of recent literature (Adrjan et al., 2023; Ahrend et al., 2023; Ramani & Bloom, 2021; Vogiazides & Kawalerowicz, 2023; Howard et al., 2023; Delventhal et al., 2023), our analysis focuses on the urban system implications of the rise of WFH practices. Using a uniquely detailed and comprehensive population-scale dataset, we describe shifts in commuting time during the pre- and post-pandemic periods for individuals living in the southern parts of Sweden. This period marked a significant shift in attitudes toward remote work, which may have resulted in notable changes in the geography of home and work. Additionally, we examine these changed time distances and their relationship with individuals' ability to WFH, based on their occupations (teleworkability).

We find that the distance between home and work has increased for those with greater opportunities to WFH. From the descriptive data, we observed such a trend already since 2015, our starting year. However, the years since the COVID-19 pancemic appear to have amplified this trend, particularly for individuals with occupations that enable remote work. Notably, we also see that individuals with the flexibility to work remotely tend to reside farther from the city centres in their regions. However, in the post-COVID setting, it appears that work location has moved closer to the city centres.

It is important to note that these shifts in the distance between home municipality and work municipality can occur in three ways: the individual has moved; the workplace has relocated; or both. To better understand these dynamics, we specifically focus on individuals who choose to move, analyzing their home or work location changes. We refine this analysis further by distinguishing between individuals living in the south outside the three metropolitan regions and those residing within them. The results support the hypothesis that residents outside these metropolitan areas who decide to move tend to relocate closer to them, especially when they have the remote work opportunities that facilitate such moves. This type of economic 'shadow effect' exerted by larger cities on peripheral regions points to significant socio-economic and possible policy implications for urbanisation and regional dynamics. Contrary to widespread predictions suggesting that remote work would reduce geographical disparities by eliminating much of the friction of distance and peripherality, it intensifies urbanisation trends towards the largest cities.

Another aspect is the change of workplace location of the non-SGM residents after COVID. They also appear to be shifting their jobs closer to these metropolitan hubs. So, for those in jobs offering remote work flexibility, there is a trend of moving employment closer to the largest central business districts. Therefore, when synthesizing these findings, it can be argued that firms hosting jobs conducive to remote work but situated outside a larger city are relocating closer to the nearby larger city as initially anticipated.

A closer examination reveals an even more detailed picture. In Sweden's three largest regions, residents are moving to homes farther from the regional centres, as are workplaces for those with teleworkable jobs. Interestingly, both individuals and workplaces seem to move in opposite directions relative to the centres of these largest cities, depending on their initial locations: those outside metropolitan areas tend to relocate closer to the largest cities, while those already within these large cities move farther from their centre.

Focusing on distances related to the municipality of residence, we find that the results vary depending on the type of distance and geographic context. We uncover heterogeneity in the results by segmenting our data to examine relocation patterns. Our findings provide new knowledge of changes in the urban system following the WFH revolution. Using a highly detailed and comprehensive population-wide individual-level dataset, we demonstrate not only the well-known local centrifugal 'donut' effect, but also a wider centripetal inter-city shadow effect, which encourages relocation *towards* major urban centres. This latter hinterland shadow effect has not been observed before. However, it is consistent with a model framework in which the frequency of commuting becomes the central choice variable influencing all the other spatial and non-spatial factors associated with WFH options.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the two fluent but non-native English-speaking co-authors used Grammarly and ChatGPT in order to improve grammar and readability. After using this tool/service, the two native English-speaking co-authors reviewed and edited the content as needed and collectively all four co-authors take full responsibility for the content of the publication.

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Appendix

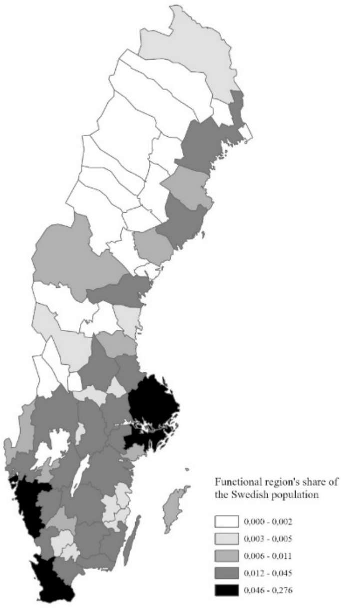

Figure 4 Distribution of population across Functional Regions

Table 6 Average distance (in minutes) yearly for individuals living in the south of Sweden, and all individuals in Sweden

	South			All		
	Home and Work	Home and CM	Work and CM	Home and Work	Home and CM	Work and CM
2014	21.38	21.19	19.75	23.01	21.89	20.49
2015	21.87	21.25	19.86	23.61	21.94	20.59
2016	22.53	21.18	19.83	24.36	21.87	20.56
2017	22.68	21.14	19.77	24.54	21.81	20.49
2018	22.50	21.09	19.72	24.29	21.75	20.42
2019	22.78	21.08	19.67	24.60	21.73	20.37
2020	23.28	21.06	19.64	25.19	21.71	20.34
2021	24.00	21.09	19.61	25.94	21.73	20.30
2022	23.66	21.07	19.53	25.52	21.69	20.21

Table 7 All individuals- panel FE including all explanatory variables

Variables	Home – Work		Home – LC		Work – LC	
Teleworkability	4.39e^{-6}	*(3.95e^{-8})*	2.48e-07***	(1.57e^{-8})	8.61e-07***	(2.19e^{-8})
Post	0.00480***	*(0.000329)*	0.000846***	(0.000131)	0.00292***	(0.000182)
TW x Post	0.00884***	(0.000387)	0.00246***	(0.000154)	-0.00546***	(0.000215)
Age	-0.00130***	(0.000155)	-0.00375***	(6.16e^{-5})	-0.00673***	(8.59e^{-5})
Age^2	2.70e-05***	(1.63e^{-6})	5.45e-05***	(6.50e^{-7})	8.02e-05***	(9.06e^{-7})
Gender (man=1)	-0.0151	(0.0177)	0.0156**	(0.00705)	0.00988	(0.00982)
Disposable income (ln)	0.00482***	(0.000203)	-0.00130***	(8.10e^{-5})	-0.00649***	(0.000113)
Base: Rental						
Tenant owned	-0.0314***	(0.000456)	-0.0293***	(0.000182)	-0.0114***	(0.000253)
Owner occupied	0.104***	(0.000445)	0.167***	(0.000177)	0.0389***	(0.000247)
Base: Elementary school						
High school	0.0236***	(0.00179)	-0.00390***	(0.000713)	-0.00169*	(0.000994)
Shorter higher education	0.0707***	(0.00191)	-0.0296***	(0.000761)	-0.0329***	(0.00106)
Longer higher education	-0.0386***	(0.00206)	-0.0460***	(0.000821)	-0.0601***	(0.00114)
Base: Single						
Single with children	-0.0244***	(0.000640)	0.0236***	(0.000255)	0.0106***	(0.000355)
Married	-0.0129***	(0.000467)	0.0117***	(0.000186)	0.000971***	(0.000259)
Married with children	-0.0341***	(0.000413)	0.0130***	(0.000164)	0.00465***	(0.000229)
Base: Other						
Stockholm	-0.614***	(0.000927)	0.0140***	(0.000369)	-0.0815***	(0.000514)
Gothenburg	-0.283***	(0.00122)	0.0405***	(0.000484)	-0.0536***	(0.000675)
Malmö	0.0413***	(0.00140)	0.439***	(0.000556)	0.208***	(0.000776)
Industry control	YES		YES		YES	
Constant	2.708***	(0.00982)	2.790***	(0.00390)	3.024***	(0.00544)
Observations	37,770,517		37,805,373		37,805,373	
Individuals	5,657,241		5,659,775		5,659,775	
R-squared	0.025		0.069		0.022	

Robust standard errors *(in parenthesis)* *** p<0.01, ** p<0.05, * p<0.1

Table 8 Heckman selection model (pooled 2015-2022), either living outside the functional regions of Stockholm, Gothenburg and Malmö or in these functional regions. Differences in distances between home or work to the municipalities of Stockholm, Gothenburg and Malmö when either changing location of residence or changing workplace. Detailed information on control variables.

	Southern Sweden not living in functional region of SGM		Living in functional region of SGM	
	(ln)ΔDistance Home-Central SGM	(ln)ΔDistance Work-Central SGM	(ln)ΔDistance Home-Central SGM	(ln)ΔDistance Work-Central SGM
Teleworkability	-6.53e^{-7}	-2.61e-06***	8.04e^{-7}***	-3.57e^{-6}***
	(2.58e^{-7})	(2.33e-07)	(1.91e^{-7})	(1.63e^{-7})
Post	-0.104***	-0.329***	0.458***	0.878***
	(0.0110)	(0.00754)	(0.00474)	(0.00388)
TW x Post	-0.0252***	-0.0462***	0.0278***	0.0401***
	(0.00666)	(0.00404)	(0.00426)	(0.00267)
Age	0.198***	0.121***	-0.00611***	0.0125***
	(0.00203)	(0.00136)	(0.000861)	(0.000679)
Age^2	-0.00154***	-0.000888***	0.000107***	-0.000400***
	(2.43e-05)	(1.64e-05)	(1.03e-05)	(8.27e-06)
Gender (man=1)	-0.0688***	-0.199***	0.0347***	0.0590***
	(0.00620)	(0.00444)	(0.00245)	(0.00214)
Foreign born	-0.601***	-0.297***	-0.103***	-0.0821***
	(0.00752)	(0.00550)	(0.00314)	(0.00249)
Disposable income (ln)	0.133***	0.0954***	-0.0390***	-0.0409***
	(0.00457)	(0.00333)	(0.00300)	(0.00151)
Rental-owned[χ]	-0.679***	-0.332***	-0.300***	-0.141***
	(0.00738)	(0.00588)	(0.00282)	(0.00258)
Owner-occupied	0.808***	0.299***	0.373***	0.0960***
	(0.00715)	(0.00506)	(0.00302)	(0.00261)
Unknown	-0.438***	-0.194***	0.113***	0.163***
	(0.0160)	(0.0130)	(0.00798)	(0.00623)
High school [ε]	0.0304***	0.0599***	0.0220***	0.0284***
	(0.0113)	(0.00767)	(0.00467)	(0.00386)
Shorter higher education	-0.576***	-0.534***	0.0313***	0.255***
	(0.0125)	(0.00859)	(0.00528)	(0.00427)
Longer higher education	-1.060***	-0.836***	0.0243***	0.211***
	(0.0126)	(0.00860)	(0.00519)	(0.00419)
Single with children [ω]	0.833***	0.268***	0.0492***	-0.129***
	(0.0144)	(0.00936)	(0.00759)	(0.00446)
Married	0.661***	0.232***	0.134***	-0.156***
	(0.00926)	(0.00594)	(0.00596)	(0.00296)
Married with children	1.446***	0.583***	0.188***	-0.249***
	(0.00914)	(0.00529)	(0.00729)	(0.00255)
Selection Equation	*Change of functional region of residence.*	*Change of functional region of work.*	*Change of municipality of residence.*	*Change of municipality of work.*
Age	-0.0788***	-0.0474***	-0.0182***	0.00455***
	(0.000581)	(0.000439)	(0.000347)	(0.000261)
Age^2	0.000639***	0.000356***	-7.12e-05***	-0.000207***

	(7.13e-06)	(5.30e-06)	(4.29e-06)	(3.17e-06)
Gender (man=1)	0.0239***	0.0826***	-0.0200***	0.0150***
	(0.00191)	(0.00145)	(0.00110)	(0.000845)
Foreign born	0.172***	0.0801***	0.0920***	-0.0159***
	(0.00227)	(0.00179)	(0.00126)	(0.000983)
Disposable income (ln)	-0.0485***	-0.0468***	0.167***	-0.0170***
	(0.00142)	(0.00107)	(0.000932)	(0.000595)
Rental-owned[χ]	0.0981***	0.0625***	-0.0183***	-0.0368***
	(0.00227)	(0.00193)	(0.00130)	(0.00103)
Owner-occupied	-0.228***	-0.0770***	0.0291***	0.0215***
	(0.00217)	(0.00166)	(0.00137)	(0.00103)
Unknown	0.207***	0.0966***	0.397***	0.0776***
	(0.00495)	(0.00428)	(0.00273)	(0.00250)
High school [є]	-0.00738**	-0.0230***	-0.00274	0.0106***
	(0.00342)	(0.00248)	(0.00204)	(0.00151)
Shorter higher education	0.190***	0.195***	0.0968***	0.139***
	(0.00378)	(0.00278)	(0.00224)	(0.00168)
Longer higher education	0.331***	0.283***	0.0930***	0.126***
	(0.00378)	(0.00277)	(0.00220)	(0.00164)
Single with children [ω]	-0.302***	-0.0907***	-0.332***	-0.0691***
	(0.00423)	(0.00304)	(0.00242)	(0.00176)
Married	-0.262***	-0.0921***	-0.309***	-0.0790***
	(0.00270)	(0.00193)	(0.00161)	(0.00116)
Married with children	-0.526***	-0.220***	-0.443***	-0.143***
	(0.00243)	(0.00171)	(0.00133)	(0.00100)
Athrho	-2.344***	-2.494***	-0.113***	1.740***
	(0.00839)	(0.00355)	(0.0160)	(0.00194)
lnsigma	1.047***	1.021***	0.0905***	0.746***
	(0.00284)	(0.00142)	(0.00169)	(0.000999)
Individual controls	YES	YES	YES	YES
Industry controls	YES	YES	YES	YES
Year dummies	YES	YES	YES	YES
Observations	11,358,798	11,211,740	20,775,541	20,966,410

Standard errors (in parenthesis) *** p<0.01, ** p<0.05, * p<0.1
[χ] Base: rental
[є] Base: elementary school
[ω] Base: single