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Work-from-home, relocation, and shadow effects: Evidence from Sweden

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ABSTRACT

In this paper, we explore some little-known, but significant, economic geography features of the work-from-home (WFH) revolution. The increased practice of work from home following the pandemic has prompted a redistribution of working populations between urban and rural locations. Using a uniquely detailed and comprehensive individual-level nationwide Swedish micro-dataset, we analyse shifts in commuting distances pre- and post-pandemic and explore the association between teleworkability and changes in these distances. Teleworkability alone does not significantly influence the distance between home and work municipalities, yet we observe heterogeneity in the responses. As well as the widely-documented centrifugal 'donut'-type spread effects localised within cities, our empirical work demonstrates that the work-from-home revolution also engenders a significant centripetal spatial 'pull' effect of large cities, as their hinterland shadow effects are magnified by the work-from-home revolution. This latter effect, which encourages workers to locate closer to the metropolitan areas, has not previously been seen or understood.

JEL classification: R12, R23

Key words: Working from home, agglomeration economies, regional distribution.

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1 Introduction

In this paper, we explore some little-known, but significant, economic geography features of the work-from-home (WFH) revolution. In particular, as well as the widely-documented centrifugal 'donut'-type spread effects localised within cities (Aksoy et al. 2022), our empirical work using uniquely-detailed population-wide data demonstrates that the work-from-home revolution also engenders a significant centripetal spatial 'pull' effect of large cities, as their hinterland shadow effects are magnified by the work-from-home revolution. This latter effect has not previously been seen or understood.

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 intra-urban 'donut' effects, there are also widespread narratives about the potential for work-from-home 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, work from home (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 require 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 work from home 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 and a shift towards larger cities.

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 work from home 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 work-from-home and in-person work (Bloom, 2022).[1] Today, work from home 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, work from home 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, work from home 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 work-from-home 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

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

and the wider economy hinges on the balance between 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 work-from-home practices could potentially flatten intra-urban 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 work from home 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 work from home 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 2019 and 2021, 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 by the work-from-home 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 distances between employers and employees for all Swedish workers, enabling the identification of the residential and workplace locales alongside their commuting behaviours. Our results demonstrate that while, as expected, the centrifugal 'donut' effect holds within the major cities, the regional hinterland centripetal shadow effects which pull workers towards the major cities are also evident for all of the major city hinterlands; the strength of both the donut and shadow effects are positively associated with the size of the city. Importantly, the observation of the regional hinterland shadow effects is new and has not previously been documented anywhere.

The rest of the paper proceeds as follows. Section 2 explains predictions from economic theory for both relocation decisions within cities and relocation decisions between regional centres. 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 and relocation decisions towards the three largest cities in Sweden—Stockholm, Gothenburg, and Malmö. The final section of the paper provides the reader with a conclusion and policy implications.

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 rents 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 (2022) 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 (2022)). While unrealistic, 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. The predictions of the AMM model can, therefore, be interpreted in terms of commuting distances between home and work locations and the distance between home locations and the city centre.

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 WAW and otherwise workers WFH is captured by the function:

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

where d is the distance between a worker's home and their workplace, f is the frequency a worker commutes to their workplace, ϕ is a distance-based commuting cost, a_i is the firm-specific 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 and symbols are parameters for calibration. The total cost of commuting for WAW and WFH includes both 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 ($a_i \theta f^{-m}$). 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 work-from-home implies that the frequency of commuting, f, has reduced from a requirement that workers commute to offices every day as is standard in urban models, denoted f_{max} in this article, to an optimal frequency that allows regular work from home, denoted f^*. To maximise utility, workers optimise commuting frequency to minimise the overall cost of commuting, including opportunity costs when working from home. Differentiating 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 WAW:

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

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

[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 WAW compared to WFH. If workers choose a hybrid combination of WAW and WFH in equilibrium, then it implies that the marginal productivity of WFH is lower than WAW because the worker 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 is hybrid.

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

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

$$d = \left(\frac{ma_i\theta_o}{n\phi f^{*n+m}}\right)^{\frac{1}{\rho}}, \quad (4)$$

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 work from home. Interpreted this way, equation (4) implies that workers in jobs that allow regular work from home—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:

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

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 work from home 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.

Deriving hypotheses

However, this is not the only effect, as workers who regularly work from home can now also make decisions to live in a different city than where they work or to work for a firm in a different city than where they live. In the context of the AMM modelling framework, such decisions change the reference point and corresponding bid-rent curve on which d is measured.

To examine this, consider how utility changes in different locations with the rise of work-from-home. 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 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 both the home city and alternate cities. However, commuting costs vary by location but equilibrium rents adjust such that U is constant.

The rise of work from home means that commuting costs have changed as workers can now regularly work from home. 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^* is specific to the distance between homes and workplaces in city centres, the former population distribution is no longer in a spatial equilibrium and the rise of work from home incentivises relocation decisions. Relocating allows those who work from home 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:

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

describes the increase in utility that occurs with the rise of WFH. While utility increases everywhere that people live, people will relocate from locations where the decline in overall commuting costs is less than the *average decline in overall commuting costs from all potential home locations*[3] to locations where the decline in overall commuting costs is greater than average. Rearranging (6) to make distance the dependent variable:

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

Setting Equation (7) to the average change in overall commuting costs, $\overline{\Delta C}$, and rearranging to solve for distance implicitly defines two specific threshold distances where the worker would not relocate as they are already in their optimal location. If the worker lives at any other distance, then they have an incentive to relocate.

The model predicts that workers living closer to the city centre than the inner distance threshold will relocate further from the city centre, as in the donut effect. The average change in frequency

[3] All subsequent references to averages in the AMM model refer to the average decline in overall commuting costs from all potential home locations.

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*. For residents living beyond the outer distance threshold, the model predicts that they would relocate closer to the city centre. Realistically, this outer distance is further than most workers, if any, would have been willing to commute if they had to commute every day. That is, these were rural locations beyond the city boundaries of the reference city centre.

Intuitively, this implies that all cities would experience only the donut effect of that inner boundary and that the donut effect is stronger in larger cities. However, the predicted donut effect is entirely an intra-city effect that does not account for changes between cities—Workers who regularly work from home can now make decisions to work in a different city than where they live, live in a rural area, or live in a different city than where they work. While such decisions are not directly considered in the AMM model, the micro-foundations of the overall commuting cost function still allow for predictions about such location decisions. In the context of the AMM modelling framework, where workplaces are only in the city centre, such relocation decisions imply changes in the reference point on which d is measured.

The applicable reference point for measuring distance and a worker's bid-rent curve is the city where their workplace is located as this is the relevant commuting trip. Again, initial utility is $U = y - C$. As noted above, if the worker were to move to another city utility would be $U' = y' - C'$, and in the spatial equilibrium that existed prior to the rise of WFH, $U = U'$ and U and U' are constant across all locations in both the home city and alternate cities. With the rise of WFH, U' increases to ${U'}^{*} = \Delta C'^{*}$. If the alternate city has longer commuting distances because it is a larger city, then $\Delta C'^{*} > \Delta C'$, which means that *the shift in the forces driving the spatial equilibrium favours relocations to larger cities over smaller cities*.

Similarly, if the worker were to change job to an employer located in a different city than the worker's home, without relocating their home, then their utility is $U' = y' - C'$ even if the home location has not yet changed because the reference point has changed. Prior to the rise of WFH, $U \geq U'$, since this comparison is for job changes without changing the home location and the worker chose to work in their own city. Again, with the rise of WFH, both U and U' increase but since C' occurs over a longer distance, which implies a greater decrease in the frequency of commuting according to equation 3, $\Delta C' > \Delta C$. If the change in commuting costs by switching employment to another city is greater than the initial utility difference that formerly prevented employment in another city (i.e. $\Delta C' - \Delta C > U - U'$), then workers will change employer to another city, even without relocating their homes. This is only likely to occur in much larger cities where the wage offered is sufficiently attractive. Essentially, these are the locations beyond the outer threshold implicitly defined by equation 7 which now fall under the bid-rent curve of the larger city due to the rise of WFH, and as a consequence, workers move towards those larger cities, into the donut region between the two thresholds where there is a greater increase in utility than in their former communities.

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 their workplace to 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 currently live beyond the outer threshold of the larger city and previously commuted to a local town but may now be sufficiently incentivised to take employment in the larger city to decrease commuting costs 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. This allows them to take jobs in those larger cities and potentially move to the hinterlands of larger cities. Based on this premise, the model suggests that individuals residing in smaller cities are prompted to relocate closer to a larger city, counter to the donut effect experienced by workers 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):

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

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

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

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, counterintuitive 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 work from home opportunities. So, for this distance measure relative to larger city centres, the coefficient would be negative.

In summary, the model predicts the following:

(1) workers in professions that allow them to work from home will live further from their workplaces than workers in jobs that require them to attend a workplace;

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

(3) firms hosting professions amenable to work from home will locate further from the city centre where they are located.

These are both predictions of the donut effect. The model also predicts the following intercity effects that analysing distances to the largest cities can detect:

(4) workers in professions amenable to work from home, living outside of a larger city, are likely to relocate closer to the nearby larger city

(5) firms hosting professions amenable to work from home, but located outside a larger city, are likely to relocate closer to the nearby larger city.

These latter two predictions are not derived in any other analytical frameworks and are uniquely associated with this particular model approach, due to the fact that the frequency of commuting is not incorporated in any other models as the explicit decision-making parameter which influences the relationships between all other spatial and non-spatial variables associated with the WFH revolution. These latter two hypotheses are central to the insights uncovered by this article.

3 Data and methodology

Following this model framework, we empirically examine potential post-pandemic shifts in individuals' geographical distances, along with their correlation to the rise of remote work possibilities. Our analysis focuses on the dimensions of the labour market and its interplay with these prospective changes. We use data from Statistics Sweden, which is advantageous due to its coverage of the entire working-age population (20-64 years). Further, since it is geocoded, it allows us to track individuals' mobility for the whole national working population.

Sweden also serves as an especially apt case study for this type of exercise due to its unique geographical layout. Characterized by a dispersed geography, the nation features three major metropolitan areas—Stockholm, Gothenburg, and Malmö—all situated in the southern region but maintaining significant distances between them. This spatial arrangement prevents direct integration and overlap of their respective labour markets, giving rise to very distinct noncontiguous and non-overlapping labour market regions surrounding these metropolitan hubs. Consequently, the substantial distances between the city centres of these major Swedish cities provide clear reference points for our empirical analysis to detect evidence of the anticipated shadow effect. While shadow effects may also occur in other geographies, they could be much harder to discern amidst donut effects and overlapping market areas typical in densely-populated countries, potentially diminishing the visibility of both phenomena.

The map below (Figure 1) illustrates the distribution of the Swedish population (left) across Functional regions, and the location of the three biggest metropolitan labour markets (right). The distances between the city centres of the Stockholm, Gothenburg and Malmö labour markets 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 on the right also marks where we draw the border for 'southern Sweden' encompassing the regions where the vast majority of the Swedish population live, a definition we use in the analysis further below. As per our definition, the southern regions account for 91 percent of the Swedish population. Out of this, the Stockholm labour market region accounts for 28%, and the Gothenburg and Malmö labour market region account for some 12% and 8%, respectively, of the overall southern Sweden population.

(Figure 1 about here)

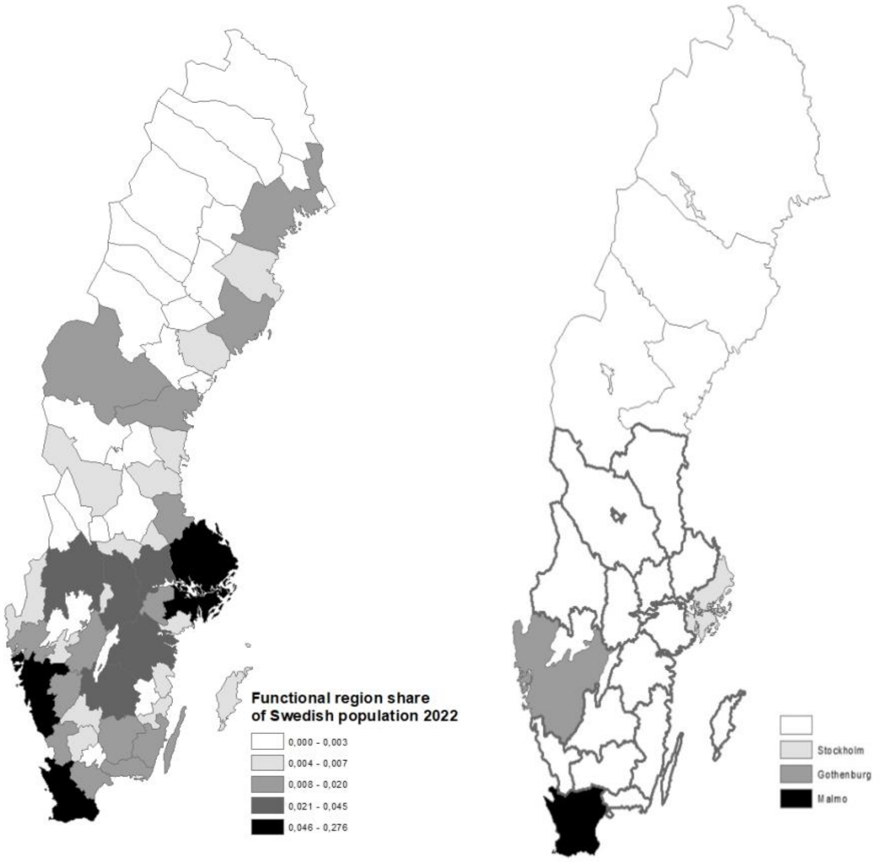

Figure 1 Labour market (Functional Region- FA60) population share (left) and the location of the metropolitan markets as well as the definition of Southern Sweden (right)

To discern potential correlations between remote work and migration patterns following the pandemic, we leverage geo-coded data from Statistics Sweden from 2019 to 2021. This dataset enables us to pinpoint the municipal places of residence and workplace locations for all individuals aged 20 to 64 (N=3,734,920). Based on a time/distance matrix for all 290 municipalities in Sweden across 60 different labour markets, we can examine the commute duration between (1) an individual's residence and their workplace, (2) an individual's residence and the primary, central municipality within their respective labour market, and (3) an individual's workplace and the primary, central municipality within their respective labour market. These central municipalities, from a labour market standpoint, serve as the region's CBD, embodying economic and population density while housing major public offices.

Commuting duration

In essence, our analysis delves into whether individuals with a greater capacity for remote work have experienced extended commuting times compared to their situation in the pre-pandemic period. Furthermore, we 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 (work *or* the largest city in the region). We compute the mean travel time in minutes for individuals during the pre-pandemic year of 2019 and juxtapose it against the circumstances in the post-pandemic year of 2021.

Drawing from our theoretical model, we refine our dataset by segmenting it according to individuals' residential labour market locations in 2019. This segmentation allows us to investigate whether individuals residing in Stockholm, Gothenburg, and/or Malmö exhibit more significant changes in their commuting patterns compared to those in smaller regions and to what extent this relates to their ability to work from home. We also divide our data to isolate those living in southern Sweden. Taken together, the possible commutes are illustrated in Figure 2 below:

(Figure 2 about here)

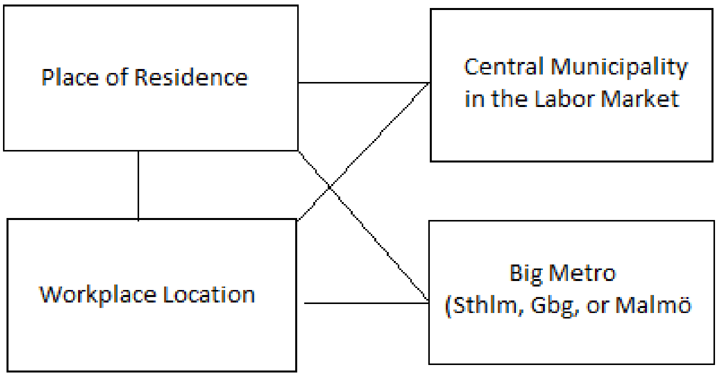

Figure 2 Possible commuting distances.

Embedded within these commuting directions and the temporal scope of our study, we also account for the opportunity for individuals to change their residential region, work region, or both. Between 2019 and 2020, approximately 66,000 individuals transitioned to a different labour market region of residence, while roughly 128,000 changed their place of work. Moreover, just over 27,000 individuals changed their home and work regions, most transitioning to the same areas.

Descriptive analysis

First, we analyse the change in commute duration (expressed in average minutes) for individuals in all of Sweden (see Table 1).[4]

[4] The change is recalculated from the average sum of minutes 2019 and 2021 respectively to percentage change in minutes.

(Table 1 about here)

Table 1 Change of commute duration (expressed in average minutes) for all individuals in all of Sweden aged 20-64

All			
	2019	**2021**	**Δ %**
Place of Residence - Workplace	23.18	24.39	5.79
Place of Residence – Central Municipality	21.29	21.37	0.61
Workplace - Central Municipality	20.01	20.04	0.30
Place of Residence – Stockholm/Gothenburg or Malmö	93.13	93.28	0.28
Workplace – Stockholm/Gothenburg or Malmö	91.01	91.11	0.20

Looking at these numbers, significant changes have occurred in the time distance, with a notable increase of approximately 5.79 per cent or close to 1½ minutes on average, in the commute between one's residence and workplace. In contrast, we see no significant alterations in the other scenarios, suggesting that workplace locations overall remain relatively unchanged. Likewise, there have been no substantial shifts in the distance between one's residence and the central municipality within the labour market region. Instead, individuals seem to extend their job search efforts over greater distances. Appendix 1 presents scatterplots of changes in these various relationships associated with urban scale, and in Appendix 2, we present the percentage changes observed in the two years leading up to 2019. Upon comparing these changes with the data in Table 1, a noteworthy shift in patterns becomes evident for most distances going from the pre- to the post-pandemic situation.[5]

With our theoretical model as the basis, we would assume that workers residing in larger cities will relocate further from the city centre. The patterns may be different in these metropolitan regions, where commute times, in general, are longer, which is why they are excluded in Table 2 below. So, the top panel of the table presents the re-estimations of commute duration in all regions except Stockholm, Gothenburg, and Malmö. The time distance between the place of residence and workplace seems to have expanded, but this increase is smaller than the one we noted for all of Sweden. Specifically, the increase now stands at 3.16 per cent, equivalent to less than a minute on average.

In the case of most other commute distances, we observe slight negative changes. The exception is the distance between the place of residence and Stockholm, Gothenburg, or Malmö, which seem to have experienced a larger change. On average, this distance has shortened by approximately 2 minutes, or -1.22 per cent.

The lower panel of Table 2 narrows the focus even further. Since most of the Swedish population lives in the south of Sweden, we select only the southern parts of the country, but still exclude

[5] All tables in this section are available in Appendix 3, but with numbers not recalculated as minutes but mean values of time.

Stockholm, Gothenburg, and Malmö, to better understand to what extent northern, sparsely populated regions drive the changes in the table above.

Once again, looking at these numbers, the most significant increase in commute duration is observed in the distance between the place of residence and workplace, with a rise of +2.59 per cent, approximately equivalent to 36 seconds. In contrast, all other commute durations remain relatively stable. It's worth noting that the 2.59 per cent increase is still lower than the numbers we identified for the entire country or the southern regions, particularly when excluding the largest metropolitan areas.

(Table 2 about here)

Table 2 (Upper) Individuals in all regions ***but*** *Stockholm, Gothenburg, and Malmö- change in commuting duration (expressed in average minutes). (Lower) All regions in* ***southern parts*** *of Sweden,* ***but*** *Stockholm, Gothenburg, and Malmö- change in commute duration (expressed in average minutes)*

All regions but Stockholm, Gothenburg and Malmö			
	2019	**2021**	**Δ %**
Place of Residence - Workplace	26.37	27.27	3.16
Place of Residence – Central Municipality	25.43	25.36	-0.47
Workplace - Central Municipality	24.17	24.13	-0.25
Place of Residence – Stockholm/Gothenburg or Malmö	173.30	171.24	-1.22
Workplace – Stockholm/Gothenburg or Malmö	168.54	167.36	-0.78
All southern regions but Stockholm, Gothenburg and Malmö			
	2019	**2021**	**Δ %**
Place of Residence - Workplace	23.35	24.12	2.59
Place of Residence – Central Municipality	25.08	25.00	-0.52
Workplace - Central Municipality	23.35	23.31	-0.25
Place of Residence – Stockholm/Gothenburg or Malmö	114.12	113.30	-0.62
Workplace – Stockholm/Gothenburg or Malmö	110.36	110.24	-0.24

Since the average commute duration increased for all of Sweden, but less so when we exclude the biggest metropolitan regions, it indicates that here is where we would find the biggest change. We therefore examine the change in commute duration for the three biggest metropolitan regions separately. Their commute durations are all presented in Table 3, starting with Stockholm, a labour market that accounts for 28 percent of the Swedish population. Here, the increase in commute duration becomes apparent when considering the distance between the place of residence and workplace. This increase averages over 2 minutes, translating to a 12.04 percent rise.

Additionally, we observe somewhat smaller increases in commute duration between the place of residence and the central core municipality (+1.14 percent), as well as between the workplace and the central core municipality (+1.04 percent). However, these changes are considerably less substantial. Overall, this indicates that it is neither a question of an out-migration of individuals nor workplaces in the Stockholm labour market, but rather that individuals here have been looking for jobs over larger geographical areas than before.

Moving forward, we shift our focus to Gothenburg, the second-largest labour market in Sweden. Accounting for approximately 12 percent of the Swedish population, its significance parallels that of Malmö-Lund, now recognized as a large integrated labour market region in the southern part of the country. In Gothenburg, there is a similar pattern as in Stockholm. The most significant change in commute duration is for the journey between the place of residence and workplace, with an increase of 8.37 percent (equivalent to approximately 1 minute and 45 seconds). While this increase is less than what was observed in Stockholm, it remains higher than in other regions of the country. Again, this doesn't appear to be primarily driven by individuals or firms relocating elsewhere. Instead, it appears to be a result of individuals seeking employment across larger geographic areas.

Moving on to the Malmö region, we once more observe a pattern in which individuals have extended their commute duration between their residence and workplace (+3.53 percent). However, this increase is smaller than that in Stockholm and Gothenburg.

(Table 3 about here)

Table 3 Change in commute duration (expressed in average minutes) for Stockholm, Gothenburg and Malmö respectively

	Stockholm			**Gothenburg**			**Malmö**		
	2019	**2021**	**Δ %**	**2019**	**2021**	**Δ %**	**2019**	**2021**	**Δ %**
Place of Residence - Workplace	18.57	21.14	12.04	21.19	23.07	8.37	25.08	26.01	3.53
Place of Residence - Central Municipality	19.47	20.01	1.14	19.05	19.17	1.07	27.04	27.00	-0.24
Workplace - Central Municipality	16.53	17.04	1.04	17.00	17.09	0.86	24.56	24.56	0.01

Collectively, these findings suggest that larger labour markets have witnessed a more pronounced rise in commute durations compared to smaller labour markets following the pandemic. To delve deeper, we conduct a correlation analysis between population size in the labour market and commute distances for 60 urban centres and for three scenarios: (1) between place of residence and workplace, (2) between place of residence and the central municipality, and (3) between workplace and the central municipality. The results are depicted in Table 4.

(Table 4 about here)

Table 4 Correlation between change in commute duration and labour market population (N=60)

	Correlation
Place of Residence - Workplace	0.474**
Place of Residence – Central Municipality	0.411**
Workplace - Central Municipality	0.501**
**indicates significance at the 1 percent level	

In all three cases, there is a positive and significant relationship between commute duration and population size. However, in terms of absolute numbers, the most substantial increase/least significant decrease is observed between one's place of residence and workplace.

Econometric analysis

All in all, our descriptive data indicate that specific changes in commuting patterns have taken place, and they seem to mainly concern the distance between residential locations and workplaces when we compare the periods before and after the pandemic (2019-2021). However, to what extent can changes in commute duration be explained by an increased opportunity to work remotely? And does teleworkability matter after controlling for individual characteristics and the type of industry they work within? To answer these questions, we next run a series of regressions to investigate whether teleworkability can be linked to increased commuting time. We start by examining all individuals across all of Sweden. Then, we narrow our focus to Southern Sweden, with and without including Stockholm, Gothenburg, and Malmö. Additionally, we analyse these three metropolitan regions individually.

Dependent variables

The dependent variable is the change in commuting duration between 2019 and 2021. Following our modelling framework, we calculate the first-order difference to provide us with the first-order condition that optimizes each individual's commuting behaviour. Subsequently, our dependent variable is divided into three versions, measured as changes in time between the place of residence (Home), the place of the workplace (Work), and the largest city in the local labour market region (LC).

$$\log(time\ 2021_{Home-Work}) - \log(time\ 2019_{Home-work}) \quad (11)$$

$$\log(time\ 2021_{Home-LC}) - \log(time\ 2019_{Home-LC}) \quad (12)$$

$$\log(time\ 2021_{Work-LC}) - \log(time\ 2019_{Work-LC}) \quad (13)$$

As we narrow our focus to southern Sweden, we make slight adjustments in the sample by singling out those who do not reside in any of the three metropolitan regions (Stockholm, Gothenburg, Malmo) and have changed their residential labour region or labour region of work. It is worth noting that, as mentioned earlier, approximately 22 per cent of those who change their work region also concurrently change their residential region, leading to overlap between these groups. Since we have been studying individuals for over two years, the number of region-shifters is higher than we would have observed for a year.

Within this refined framework, our dependent variable is adjusted to examine whether these individuals move closer to the metropolitan region or in the opposite direction. Here, 'SGM' denotes the particular metropolitan region (Stockholm, Gothenburg, Malmo) that is geographically closest to the individual's residential region in 2019.

$$\log(time\ 2021_{Home-SGM}) - \log(time\ 2019_{Home-SGM}) \quad (14)$$

$$\log(time\ 2021_{Work-SGM}) - \log(time\ 2019_{Work-SGM}) \quad (15)$$

Teleworkability

This variable in focus is continuous and based on the methodology by Sostero et al. (2020) to capture the ability of different occupations to be conducted remotely. In their work, they introduced a teleworkability index that ranges from 0 to 1, signifying the absence (=0) to the full presence (=1) of remote work capability. This index factors in the technical feasibility of contributing labour remotely to a specific process. Determinants such as information processing, social interaction tasks, and physical activities play a role in establishing an occupation's teleworkability score. This score has been manually translated into the Swedish occupational code.

Controls

In addition to accounting for the teleworkability variable, we also consider various personal characteristics such as age, gender, family status, income, and ethnicity. Our dataset encompasses approximately 5.7 million individuals within the working age range of 20 to 64 years, effectively representing the entire Swedish workforce. It is important to note that our observations may be limited due to missing data regarding individuals' occupations and the geographical location of their homes or workplaces. Consequently, there are cases where we may not have complete data for these individuals at two different points in time. This unbalanced panel is attributed to a variety of factors, including changes in age groups as individuals transition from 2019 to 2021, as well as fluctuations resulting from immigration and emigration to and from Sweden. Moreover, we also consider the specific 2-digit industry in which everyone is employed.[6]

[6] Swedish industry codes SNI, is comparable to EU-standard NACE rev.2

4 Results from the regression analysis

We apply an ordinary least square estimation and begin by examining all individuals across Sweden in a multivariate context. Table 5 presents the results of these overall estimations, considering our three versions of the dependent variable.[7]

(Table 5 about here)

Table 5 OLS regression results- all individuals, dependent variable ln(time2021)-ln(time2019)

Variables	Change in distance Home - Work		Change in distance Home - LC		Change in distance Work - LC	
Teleworkability	0.001	*(0.001)*	$-9.35e^{-5}$	*($3.72e^{-4}$)*	-0.008***	*(0.001)*
Age	-0.004***	*($2.71e^{4}$)*	0.04***	*($1.14e^{-4}$)*	0.001***	*($1.40e^{-4}$)*
Age^2	*$3.88e^{-5}$******	*($3.15e^{-6}$)*	$-4.35e^{-5}$***	*($1.31e^{-4}$)*	*$-1.26e^{-4}$******	*($1.63e^{-6}$)*
Gender (man=1)	0.003***	*(0.001)*	-0.003***	*($3.07e^{-4}$)*	-0.003***	*($3.78e^{-4}$)*
Foreign born	-0.013***	*(0.001)*	-0.011***	*($3.71e^{-4}$)*	-0.002***	*($4.73e^{-4}$)*
Disposable income (ln)	-0.022***	*(0.001)*	0.011***	*($2.66e^{-4}$)*	-0.001***	*($3.61e^{-4}$)*
Base: Rental						
Tenant owned	0.007***	*(0.081)*	0.006***	*($4.47e^{-4}$)*	$-6.42e^{-4}$	*($5.27e^{-4}$)*
Owner occupied	-0.028***	*(0.072)*	-0.029***	*($3.83e^{-4}$)*	$-8.21e^{-5}$	*(0.011)*
Base: Elementary school						
High school	0.008***	*(0.001)*	$-4.56e^{-4}$	*($4.92e^{-4}$)*	$-3.75e^{-4}$	*($6.74e^{-4}$)*
Shorter higher education	0.005***	*(0.001)*	0.002***	*($5.90e^{-4}$)*	$-4.58e^{-4}$	*(0.001)*
Longer higher education	0.005***	*(0.001)*	0.007***	*(0.002)*	-0.001	*(0.002)*
Base: Single						
Single with children	*$8.88e^{-5}$*	*(0.001)*	-0.007***	*(0.001)*	$3.48e^{-5}$	*($8.07e^{-4}$)*
Married	-0.002***	*(0.001)*	0.002***	*($4.01e^{-4}$)*	0.001***	*($4.97e^{-4}$)*
Married with children	0.004***	*(0.002)*	0.013***	*(0.011)*	0.002***	*($4.61e^{-4}$)*
Base: Other						
Stockholm	0.031***	*(0.001)*	0.026***	*($3.84e^{-4}$)*	0.018***	*($4.98e^{-4}$)*
Gothenburg	0.015***	*(0.001)*	0.015***	*($3.40e^{-4}$)*	0.007***	*($4.46e^{-4}$)*
Malmö	0.001	*(0.001)*	0.001***	*($3.45e^{-4}$)*	0.001***	*($5.06e^{-4}$)*
Industry control	YES		YES		YES	
Constant	0.17***	*(0.014)*	-0.078***	*(0.005)*	-0.047***	*(0.007)*
Observations	3,732,814		3,737,006		3,737,006	
R-squared	0.002		0.007		0.004	
Robust standard errors *(in parenthesis)* *** p<0.01, ** p<0.05, * p<0.1						

Our variable of focus is teleworkability, and the first column (change in distance between home and work) shows no significant effect on the change in distance (in time) between 2021 compared to 2019. This finding is slightly surprising because the previously presented descriptive analysis of

[7] As a further robustness check on our analysis, in Appendix 4, we also present the results from the Multinomial logit estimations and marginal effects of teleworkability. The MNL results are broadly consistent with the OLS results reported here.

absolute and percentage changes indicates a strong impact on this distance in particular. The significant result of any effect of teleworkability only emerges when examining the change in distance between work and the largest city (municipality) in the labour market region (column 3). More teleworkability exhibits a negative correlation with changes in distance, suggesting that the proximity between the workplace and the largest city increased from the pre-pandemic year to the post-pandemic year, with the average distance between the falling between these two locations.

Generally, the control variables are highly significant and robust across estimations, irrespective of the sample. The distance between home and work is negatively related to age, suggesting that as individuals age, the distance between home and work decreases. However, this relationship is also non-linear. When we shift our focus to the distances to the largest cities, whether from home or work, the distances increase as individuals age, but this relationship gradually levels off. The gender and foreign background variables both have negative coefficients in relation to distances concerning the largest cities, indicating that these attributes are associated with a reduced distance between the years we are comparing. In contrast, gender (men) is significant but positively related to the change in distance between home and work.

A higher disposable income is associated with a decrease in the distance between home and work when comparing our two years. This relationship follows a consistent trend for the change in distance between the workplace and the region's largest city. However, it appears to exhibit the opposite pattern for the change in distance between home and the largest city. Increased income levels are linked to homes being situated at greater distances from the largest city during the post-pandemic period compared to the preceding year. As for education, all higher levels of education are associated with increased distance, regardless of the type of dependent variable (elementary school degree is the baseline).

Housing tends to play a role as well. Tenant-owned housing is associated with a greater distance between home and work (with rental homes as the baseline). In contrast, owner-occupied housing shows the opposite effect. These same patterns apply to the change in distance between home and the nearest major city.

Regarding civil status, distances tend to increase for groups that are not the baseline (single without children). However, there are two exceptions: the category 'married with children' shows a decrease in the home-work distance change, and 'single with children' exhibits a decrease in the change in distance between home and the largest city in the region.

Living in one of the metropolitan regions consistently results in positive and significant coefficients, suggesting that individuals residing in these areas experience longer commute times compared to those who live in the rest of the country.

From this point forward, our primary focus is on teleworkability. Subsequently, we will narrow our focus and dissect our dataset into samples to untangle the connection between teleworkability and its correlation with changes in distances. This exercise entails three additional analyses. The following subset of data, presented in Table 6, includes only southern Sweden. This segmentation is justified by the fact that the majority of the population resides in these regions, and commuting dynamics significantly differ from those in the northern parts of the country.

(Table 6 about here)

Table 6 OLS regressions results- Southern Sweden, dependent variable ln(time2021)-ln(time2019)

	Change in distance Home - Work	Change in distance Home - LC	Change in distance Work - LC
Teleworkability	0.002***	$3.07e^{-4}$	-0.007***
	(0.001)	*($3.89e^{-4}$)*	*(0.001)*
Observations	3,412,482	3,416,655	3,416,655
Individual controls	YES	YES	YES
Industry controls	YES	YES	YES
R-squared	0.002	0.008	0.004
Robust standard errors *(in parenthesis)* *** p<0.01, ** p<0.05, * p<0.1			

The relationship between teleworkability and the change in distance between the place of residence and the place of work is positive, suggesting that this distance has increased in the post-pandemic situation compared to the situation before Covid-19. People for whom teleworking is feasible have either moved further away from work, have a job further away from home, or both. Given the insignificant result for the distance between home and the largest local city, our findings are confined to the distance between work and the corresponding city, which displays a negative correlation. In simpler terms, the feasibility of telecommuting appears to be linked to a decreased distance between the workplace and the largest city, essentially indicating that work locations are shifting closer to these regional hubs.

Next, we focus on individuals who live in one of the three metropolitan regions Stockholm, Gothenburg, or Malmö in 2019 (Table 7).

(Table 7 about here)

Table 7 Regressions results- Stockholm, Gothenburg, Malmö, dependent variable ln(time2021)-ln(time2019)

	Distance Home - Work	Distance Home - LC	Distance Work - LC
Teleworkability	0.003	0.003***	-0.006***
	(0.002)	*(0.001)*	*(0.001)*
Individual controls	YES	YES	YES
Industry controls	YES	YES	YES

Observations	919,795	921,467	921,467
R-squared	0.004	0.010	0.008
Robust standard errors *(in parenthesis)* *** p<0.01, ** p<0.05, * p<0.1			

Notably, when we now narrow our analysis to only Stockholm, Gothenburg, and Malmö, it becomes apparent that individuals with better teleworkability opportunities have expanded the commuting distance between their place of residence and the labour market centre (LC). The relationship between our focus variable and the change in distance between home and work is insignificant in these metropolitan regions. However, as is also shown in Table 7, the relationship between teleworkability and distance between workplaces and the largest city in these regions, is negative. This indicates that the distance between workplaces and the largest cities has diminished for individuals with greater telecommuting capabilities. So, for them, work seems to have moved closer to the centres of the three metropolitan areas.

In the final part of our analysis, we focus on individuals who have relocated to another labour market region during the time period. More specifically, we want to examine those whose 2019 location was in southern Sweden but not in Stockholm, Gothenburg, or Malmö. This allows us to see if individuals with the ability to work remotely tend to move closer to or further away from the largest metropolitan regions (Table 8). Changing one's labour market region can encompass a relocation in their residential area, their workplace location, or potentially both (resulting in overlaps between observations in these two groups).

(Table 8 about here)

Table 8 Regressions results- Individuals residing in southern Sweden year 2019 (except Stockholm, Gothenburg, Malmö) who have changed labour market region ***of residence and work respectively****- dependent variable ln(time2021)-ln(time2019)*

	Individuals who have changed ***home*** region: Dep: Change in distance Home – SGM (nearest)	Individuals who have changed ***work*** region: Dep: Change in distance Work – SGM (nearest)
Teleworkability	-0.081***	-0.057***
	(0.015)	*(0.010)*
Individual controls	YES	YES
Industry controls	YES	YES
Observations	85 800	167 088
R-squared	0.040	0.013
Robust standard errors *(in parenthesis)* *** p<0.01, ** p<0.05, * p<0.1		

The first column in the table displays the results for individuals who altered their place of residence to another labour market, and the second column shows the results for those who changed their workplace location. The starting point was always outside of the Stockholm, Gothenburg, or

Malmö labour market. It is important to note that the observations in both columns encompass individuals who made such transitions over a two-year span, which enhances the sample size.

The dependent variable has now been modified to measure the change in proximity to the nearest of Stockholm, Gothenburg, or Malmö. In simpler terms, it assesses how the distance to one of these metropolitan regions has changed when individuals change their location. For both 2019 and 2021, we calculate the distance to the nearest of these three cities, which means the metropolitan region of reference could have shifted between the years.

We find that both distances have a negative correlation with increased telecommuting feasibility. This implies that between 2019 and 2021, the distances to these metropolitan areas have decreased for individuals with greater opportunity to work remotely, both in terms of residences and workplaces.

Taken together, the findings suggest heterogeneous responses to the ability to work from home among different types of individuals, and this also varies 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, as well as 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 wider regional hinterland scale across the south of Sweden which encourages work and home relocations towards the very largest cities. This latter effect has not before been observed.

5 Conclusions and policy implications

This study represents an important step towards deepening our understanding of the potential social and economic impacts of the increasing 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 potential economic geography implications of increasing work-from-home. Using uniquely-detailed and comprehensive population-scale dataset, we describe shifts in commuting distances during the pre- and post-pandemic periods. Second, we examine these changed distances and their relationship with individuals' ability to work from home, based on their occupations (teleworkability).

Focusing on distances related to the municipality of residence, we find that the results vary depending on the type of distance and geography. Surprisingly, teleworkability alone does not significantly affect the change in distance between the home and work municipalities when comparing 2021 to 2019. However, by dissecting our data—specifically, a sample that includes only southern Sweden—we uncover heterogeneity in the results. This segmentation is highly justified by the skewed geographical distribution of the population and the distinct commuting patterns observed in the southern parts compared to the northern areas.

For individuals residing in the more densely populated southern part of Sweden, it appears that the distance between home and work has increased for those with greater opportunities to work from home. This effect is pronounced in areas with relatively high commuting rates but shows negligible effects in areas farther from the three major metropolitan hubs. Delving further into this, within the metropolitan areas of Stockholm, Gothenburg, and Malmö, the observed effect is insignificant.

Notably, individuals with the flexibility to work remotely tend to reside farther from city centres in regions when they live outside the three major areas Stockholm, Gothenburg, and Malmö. It is important to note that these shifts in the distance between home municipality and work municipality may be threefold: the individual has moved; the workplace is in another municipality (due to a job change or the workplace relocating); or both. We further elucidate this by examining individuals who move to a different labour market region, not solely focusing on distances. In doing so, the results support the hypothesis that residents living outside these major metropolitan areas but in close proximity tend to relocate closer to them if they have the work opportunities to do so. This type of economic 'shadow effect' exerted by larger cities on peripheral regions points to significant socio-economic and policy implications for urbanization and regional dynamics. Contrary to the widespread predictions suggesting that remote work would reduce geographical disparities by removing much of the friction of distance and peripherality, it actually intensifies urbanization trends towards the largest cities even more.

Another aspect to consider is the workplace location, which appears to be shifting closer to the largest city within the labour market region for individuals with greater flexibility to work from home. For those in jobs offering remote work flexibility, the proximity of employment to the central business district has unexpectedly decreased, contrary to our initial predictions. However, this phenomenon is multifaceted; individuals might change jobs to a firm with a workplace closer to the city centre, or their 2019 workplace may have physically relocated. Additionally, when examining those who have changed their work region, we find their workplaces have moved closer to either Stockholm, Gothenburg, or Malmö. 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. However, a closer examination suggests an even more complex narrative. In the three largest regions of Sweden, located in the southern part of the country, we observe homes moving away from regional centres, while workplaces move closer to these hubs. Individuals and workplaces seem to move in opposite directions, a pattern that is particularly evident in Stockholm, Gothenburg, and Malmö. Conversely, when examining how people in southern Sweden change their locations in relation to these three regions, they actually move closer over our three-year analysis period.

Our results break new ground concerning the economic geography of the work-from-home revolution. Using a uniquely-detailed and comprehensive population-wide individual-level dataset, we can demonstrate not only the well-known local centrifugal ‘donut’ effect, but also a wider centripetal regional hinterland shadow effect which encourages relocation towards the major urban centres. This latter hinterland shadow effect has not before been observed, although 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 variables associated with work-from-home options.

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

During the preparation of this work, the authors used Grammarly in order to improve grammar and readability. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Appendix 1

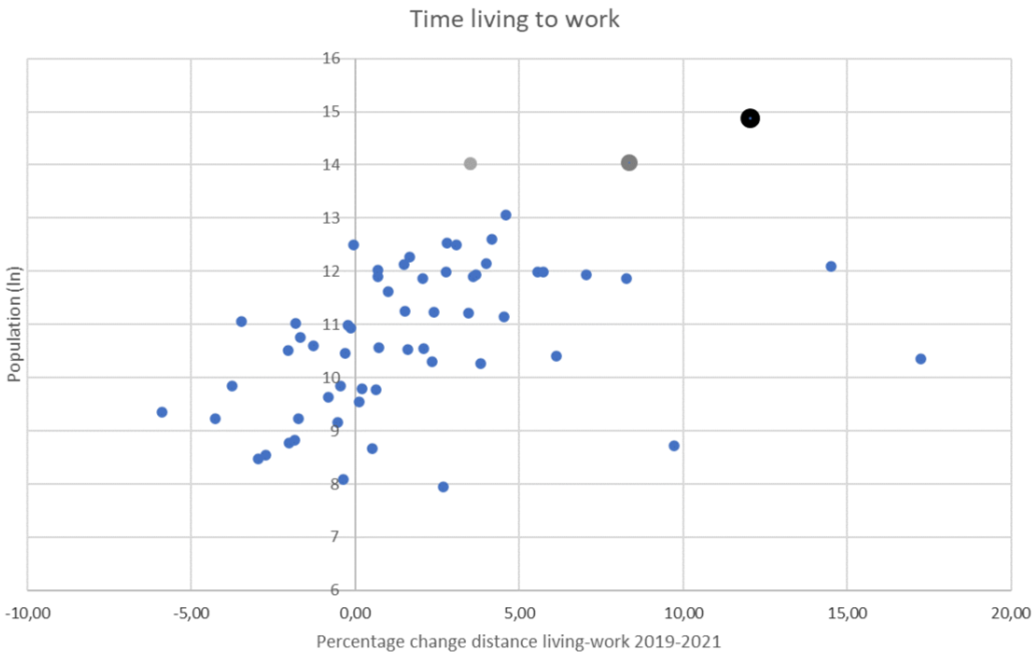

Figure 3 Scatterplot between population (ln) and percentage change in distance between living and work 2019-2021. Stockholm is the largest black dot, Gothenburg is the second largest dot, followed by Malmö.

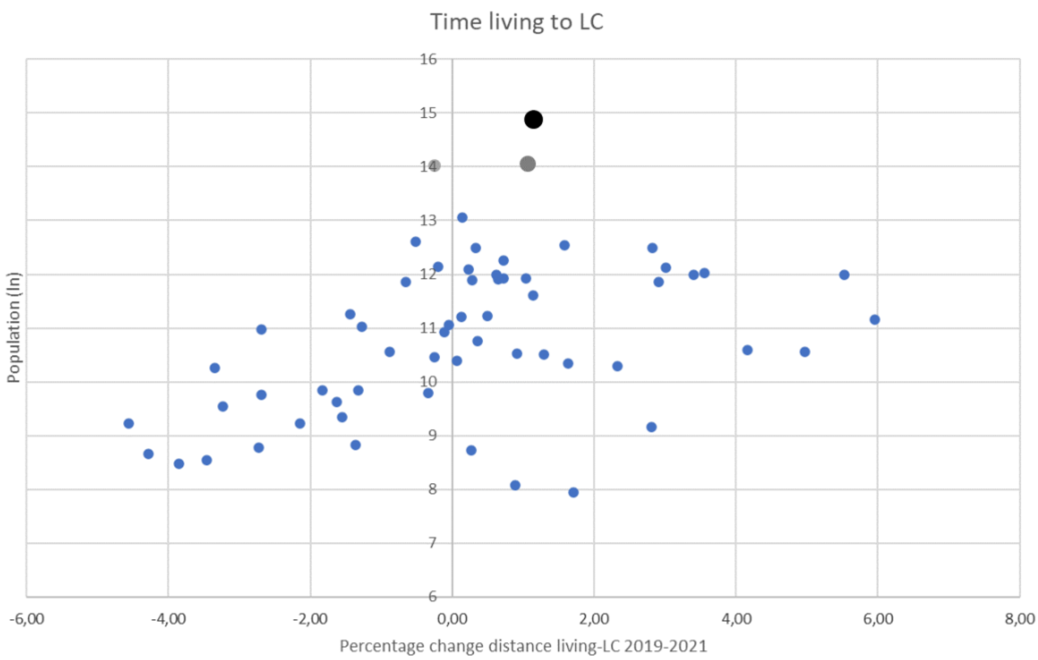

Figure 4 Scatterplot between population (ln) and percentage change in distance between living and largest city in municipality (LC) 2019-2021. Stockholm is the largest black dot, Gothenburg is the second largest dot, followed by Malmö.

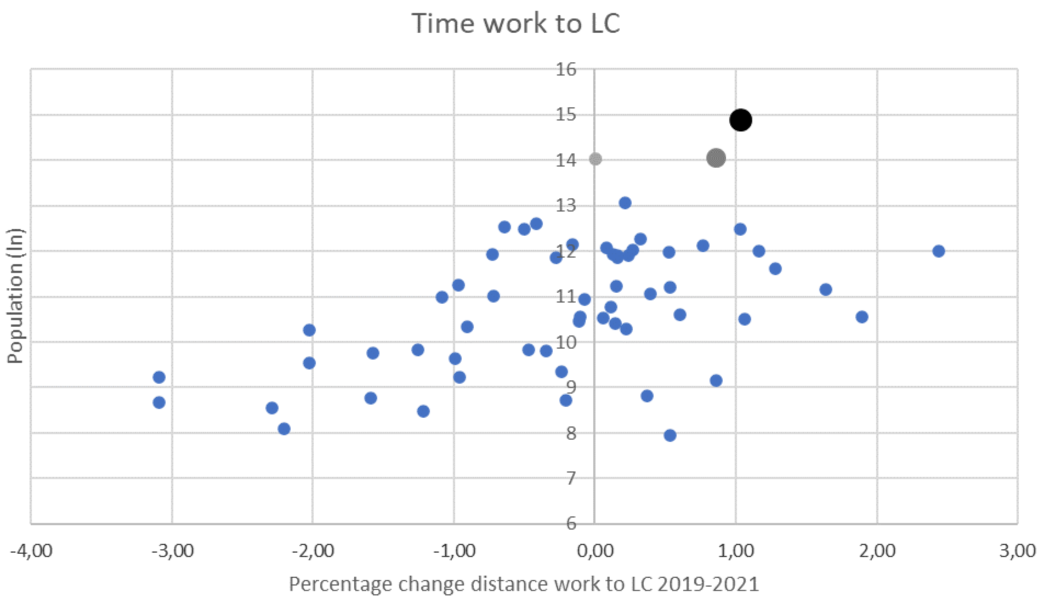

Figure 5 Scatterplot between population (ln) and percentage change in distance between work and largest city in municipality (LC) 2019-2021. Stockholm is the largest black dot, Gothenburg is the second largest dot, followed by Malmö.

Appendix 2

Table 9 Change of commute duration, expressed in percentage change in average minutes for all individuals in Sweden, aged 20-64

	Change %	**Change %**
All	**2017-2018**	**2018-2019**
Place of Residence - Workplace	-1.582	0.127
Place of Residence – Central Municipality	0.086	0.128
Workplace - Central Municipality	-0.047	-0.055
Place of Residence – Stockholm/Gothenburg or Malmö	-0.081	0.025
Workplace – Stockholm/Gothenburg or Malmö	-0.004	-0.056

Appendix 3

Table 10 Original numbers for commuting distances, not adjusted to minutes- all regions

	All		
	2019	**2021**	**Change**
Place of Residence - Workplace	23.30	24.65	5.79%
Place of Residence – Central Municipality	21.48	21.61	0.61%
Workplace - Central Municipality	20.01	20.07	0.30%
Place of Residence – Stockholm/Gothenburg or Malmö	93.21	93.47	0.28%
Workplace – Stockholm/Gothenburg or Malmö	91.01	91.19	0.20%

Table 11 Original numbers for commuting distances, not adjusted to minutes- all regions but Stockholm, Gothenburg and Malmö

	All regions but Stockholm, Gothenburg and Malmö		
	2019	**2021**	**Change**
Place of Residence - Workplace	26.61	27.45	3.16%
Place of Residence – Central Municipality	25.72	25.6	-0.47%
Workplace - Central Municipality	24.28	24.22	-0.25%
Place of Residence – Stockholm/Gothenburg or Malmö	173.5	171.4	-1.22%
Workplace – Stockholm/Gothenburg or Malmö	168.9	167.6	-0.78%

Table 12 Original numbers for commuting distances, not adjusted to minutes- all southern regions but Stockholm, Gothenburg and Malmö

	All southern regions but Stockholm, Gothenburg and Malmö		
	2019	**2021**	**Change**
Place of Residence - Workplace	23.59	24.20	2.59%
Place of Residence – Central Municipality	25.13	25	-0.52%
Workplace - Central Municipality	23.58	23.52	-0.25%
Place of Residence – Stockholm/Gothenburg or Malmö	114.2	113.5	-0.62%
Workplace – Stockholm/Gothenburg or Malmö	110.6	110.4	-0.24%

Table 13 Original numbers for commuting distances, not adjusted to minutes- Stockholm

	Stockholm		
	2019	**2021**	**Change**
Place of Residence - Workplace	18.95	21.23	12.04%
Place of Residence – Central Municipality	19.79	20.02	1.14%
Workplace - Central Municipality	16.88	17.06	1.04%

Table 14 Original numbers for commuting distances, not adjusted to minutes- Gothenburg

	Gothenburg		
	2019	**2021**	**Change**
Place of Residence - Workplace	21.32	23.11	8.37%
Place of Residence – Central Municipality	19.08	19.29	1.07%
Workplace - Central Municipality	17.00	17.15	0.86%

Table 15 Original numbers for commuting distances, not adjusted to minutes- Malmö

	Malmö		
	2019	**2021**	**Change**
Place of Residence - Workplace	25.14	26.02	3.53%
Place of Residence – Central Municipality	27.06	27.00	-0.24%
Workplace - Central Municipality	24.94	24.94	0.01%

Appendix 4

Multinomial logit estimations and marginal effects of teleworkability

The individual's potential change of distance relation between work and home between the years 2019 and 2021 is modelled as a multinomial choice where the individual i has the same distance (in time) between home and work (d_{same}) or it has increased ($d_{increase}$) or decreased ($d_{decrease}$). The probability of any of the three possible outcomes is expressed in the equation below with a vector of individual characteristics.

$$Y_d^i = \alpha_d + [Individual\ Characteristics_i]'\beta_d$$

with i=1,2………,N and d= Same, Increase, Decrease

, where the estimated probabilities are presented in relation to the base outcome. Everything in a multinomial logistic regression model (MNL) is stated relative to the base category. *Same* is expressed as the base outcome in the analysis. Consequently, one can formulate the estimated probability of a changed distance of an individual $P_{d=increase}^i$ as in the equation below.

$$P_{d=increase}^i = exp\left(Y_{d=increase}^i\right)/exp\left(Y_{d=same}^i\right)$$

The individual characteristics are the same as the explanatory variables used in the model in the paper (Table 5). The coefficients and standard errors of the multinomial estimations are available upon request. Due to space constraints, in this section, we focus solely on presenting the marginal effects of teleworkability. These effects are analyzed across all types of distances and for the entire population, as well as for the two distinct data subsets.[8]

Table 16 Marginal effects: Home- Work

	All	Southern Sweden	Southern Sweden except SGM	SGM
Teleworkability	dy/dx	dy/dx	dy/dx	dy/dx
Predict: same	-0.008^{***} *(0.002)*	-0.008^{***} *(0.003)*	-0.008^{***} *(0.003)*	-0.03^{***} *(0.006)*
Predict: increase	0.006^{***} *(0.002)*	0.006^{***} *(0.002)*	0.006^{***} *(0.002)*	0.02^{***} *(0.004)*
Predict: decrease	0.002^{***} *(0.002)*	0.003^{***} *(0.002)*	0.003 *(0.002)*	0.01 *(0.004)*

Table 17 Marginal effects: Home- LC

	All	Southern Sweden	Southern Sweden except SGM	SGM
Teleworkability	dy/dx	dy/dx	dy/dx	dy/dx
Predict: same	-0.009^{***} *(0.002)*	-0.008^{***} *(0.002)*	-0.008^{***} *(0.002)*	-0.01^{***} *(0.004)*
Predict: increase	0.003^{***} *(0.001)*	0.002^{**} *(0.001)*	0.002^{**} *(0.001)*	0.0004 *(0.003)*
Predict: decrease	0.005^{***} *(0.001)*	0.006^{***} *(0.001)*	0.006^{***} *(0.001)*	0.01^{***} *(0.0023)*

[8] Results are robust compared to OLS which is presented in the paper.

Table 18 Marginal effects: Work- LC

	All	Southern Sweden	Southern Sweden except SGM	SGM
Teleworkability	dy/dx	dy/dx	dy/dx	dy/dx
Predict: same	-0.005*** *(0.002)*	-0.005*** *(0.002)*	-0.005*** *(0.002)*	-0.01*** *(0.005)*
Predict: increase	0.004*** *(0.001)*	0.003* *(0.002)*	0.003* *(0.002)*	0.01*** *(0.004)*
Predict: decrease	0.001 *(0.001)*	0.002 *(0.002)*	0.002 *(0.002)*	0.01*** *(0.004)*