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DISCUSSION PAPER SERIES

IZA DP No. 18103

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ABSTRACT

Who Gains from Agglomeration? The Wage, Productivity, and Cost Effects of Transport Improvements on Firms and Workers*

We study the impact of transport-induced agglomeration on workers' earnings, as well as the productivity and costs of establishments, in the capital region of Finland using comprehensive individual- and establishment-level registry data. To our knowledge, we are the first to jointly examine firm- and worker-level effects of agglomeration. We find that improved workplace-to-workplace accessibility increases employees' annual earnings, particularly among workers in smaller firms. However, we find no statistically significant effects on value added or labour costs per worker at the establishment level. We propose two potential explanations for this discrepancy: (1) differences in the composition of workers between the worker- and establishment-level analyses due to, for example, new hires, and (2) rising costs associated with increased agglomeration. Further analysis reveals that enhanced accessibility leads to higher establishment employment and increased operating expenses, such as rents. Taken together, these findings suggest that the benefits of agglomeration are primarily shared between workers and property owners.

JEL Classification: R41, R42, R12
Keywords: agglomeration, productivity, transport project, accessibility

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1 Introduction

The stated goal of many transportation system improvements is to increase the productivity of workers and firms. Transportation raises productivity by increasing economic density, whose benefits are well documented in urban economics (for example, Melo et al., 2009; Donovan et al., 2022). Transportation improvements reduce travel costs between areas, increasing the number of accessible locations and effectively raising regional density, which in turn can raise productivity.

Duranton and Puga (2004) identify three mechanisms through which agglomeration generates benefits: sharing, matching, and learning. Sharing refers to firms' ability to pool infrastructure and intermediate inputs; matching describes better connections between firms and employees in larger markets; and learning captures knowledge spillovers and adoption of best practices across firms and workers. While these benefits are well studied (see, for example, Melo et al. (2009) and Donovan et al. (2022) for reviews), agglomeration also entails costs. Duranton and Puga (2020) highlight that denser areas face higher land and housing prices, as well as slower travel speeds from congestion. Similarly, Arzaghi and Henderson (2008) find that increased accessibility raises rents and operating costs, implying a trade-off between higher productivity and higher costs. How these benefits and costs are shared among workers, firms and other actors has not been extensively studied.

In this paper, we study how transportation-induced agglomeration affects worker productivity as well as establishment-level productivity and costs in Finland. To be able to quantify transportation's effect on agglomeration, we measure agglomeration using a Hansen-type accessibility metric (Hansen, 1959). This metric combines travel time and monetary cost of travel with the number of accessible destinations, improving upon traditional measures of agglomeration such as workplace density. We first investigate how changes in workplace accessibility affect annual earnings, then examine how accessibility impacts establishment-level outcomes including value added per worker, labor costs, and other expenses per worker.

Our analysis focuses on the Helsinki region using extensive micro-level register data from Statistics Finland. This unique data covers all individuals and the majority of establishments in our study years 2013 and 2019. We combine the individual- and establishment-level data with multimodal travel times and costs from a state-of-the-art transportation demand model that simulates car, public transit, cycling, and walking while accounting for congestion. This enables construction of a single accessibility measure aggregating travel costs across modes. We exploit changes in workplace-to-workplace accessibility resulting from various types of small and large transport system improvements to study both worker and establishment outcomes. Prior research on agglomeration has either studied establishments (Gibbons et al., 2019; Lee, 2021) or individuals (Börjesson et al., 2019; Knudsen et al., 2022). To our knowledge, no prior research has jointly examined worker-level and firm-level effects of agglomeration within a unified framework. Thus, an open question is whether gains in worker productivity translate into higher firm value added. Joint examination also enables us to assess how agglomeration benefits are shared between different actors. Similarly, research that studies agglomeration's effect on establishment outcomes in multimodal settings is scarce. Gibbons et al. (2019) study how new roads affect establishments, concentrating on car travel. While Lee (2021) studies establishment outcomes in Seoul, they only account for travel by car and public transport. Also, unlike our measure for agglomeration, the simple mode choice model used by Lee (2021) cannot account for people using a range of travel modes between same origin-destination pairs. Börjesson et al. (2019) use similar measure for agglomeration as us, but concentrate only on individual wages.

Recent research in agglomeration's effect on worker productivity has concentrated on workplace-to-workplace accessibility (Börjesson et al., 2019; Knudsen et al., 2022). Thus we omit the effect of matching our agglomeration elasticities for workers (Eliasson and Fosgerau, 2019). This makes our results useful for transportation project assessment, as omitting matching alleviates problems with double counting benefits from travel time savings. Our preferred estimate indicates that doubling accessibility raises worker annual earnings by approximately 3.5%, with larger effects for employees in smaller establishments.

Establishment-level effects on productivity are less conclusive: accessibility has statistically insignificant effects on value added and labor costs per worker. Two factors may explain this. First, compositional effects: worker-level analysis follows the same individuals across years, whereas establishment samples may include different workers due to, for example, new hires. Indeed, we observe that establishments expand employment in response to higher accessibility contrary to Gibbons et al. (2019) who found no effect of accessibility on employment in establishments. Second, cost effects: we find that doubling accessibility raises establishments' other expenses, including rents and operating costs, by 6.8% per worker, potentially offsetting productivity gains.

Our identification strategy compares workers or establishments experiencing larger accessibility gains with those experiencing smaller or even negative changes. Focusing on a single travel-to-work area mitigates confounding from local endowments. Non-random placement of transport improvements is addressed by measuring accessibility at fine spatial scales, exploiting incidental variation in network improvements. For worker-level estimates, we additionally leverage changes in accessibility due to workplace relocations to obtain plausibly exogenous variation in accessibility. Our measured travel times account for congestion, and instrumental variables isolate accessibility changes driven solely by transportation system improvements, holding workplace numbers and their spatial distribution fixed. Similar strategies have been applied by Börjesson et al. (2019), Gibbons et al. (2019), and Knudsen et al. (2022).

Our contribution is fourfold. First, we add to the limited literature on firm-level effects of transport-induced agglomeration. Prior studies link accessibility to firm outcomes (e.g., Gibbons et al., 2019; Graham, 2007; Holl, 2012; Lee, 2021; Yang, 2018); for instance, Gibbons et al. (2019) find that increases in car accessibility increase output, labor costs and use of intermediate outputs per worker in establishments in Britain. They study how road projects in more rural areas affected firm outcomes. We add on this literature by studying firm outcomes in an urban area with diverse modes of transport. Agglomeration can also raise costs, such as land rents (Arzaghi and Henderson, 2008). We provide establishment-level estimates of accessibility's effects on value added, labor costs, employment, and other expenses within a multimodal transport network, and, to our knowledge, are the first to jointly examine establishment- and worker-level effects. Second, we add to research on transportation-induced agglomeration, providing elasticity estimates for workplace-based accessibility that accounts for multimodal networks in a single travel-to-work area, extending prior studies in Sweden and Denmark (Börjesson et al., 2019; Knudsen et al., 2022).[1] Third, we provide estimates relevant for transport cost–benefit analyses, capturing wider economic effects of infrastructure beyond travel-time savings (Venables, 2007). Because our accessibility measure is defined between workplaces, our estimates omit matching effects and thus reduce concerns about double-counting agglomeration benefits in CBAs (Eliasson and Fosgerau, 2019), though some overlap may remain between goods transport benefits and agglomeration effects. Fourth, we contribute to two research gaps highlighted in Duranton and Puga (2004). We contribute to literature that separates different mechanisms of agglomeration by using inter-workplace variation in agglomeration to omit the effect of matching on individual productivity and to the literature that studies the effects of agglomeration in small geographic scales.

[1] Much of the agglomeration–productivity literature uses measures such as population density or total population (see, for reviews, Donovan et al., 2024; Melo et al., 2009; Proost and Thisse, 2019), which provide limited insight into the ability of transportation infrastructure to foster productivity through increased agglomeration. Recent studies from Sweden (Börjesson et al., 2019) and Denmark (Knudsen et al., 2022) use accessibility measures to estimate the impact of transport infrastructure on workers' annual earnings, finding elasticities in the range 0.025–0.029.

2 Data and empirical strategy

2.1 Data

We examine workers and establishments in the Helsinki region, Finland, in 2013 and 2019. The region comprises Helsinki—the capital and largest city of Finland—and 14 surrounding municipalities, functioning as a single travel-to-work area with Helsinki as the primary employment center. Key surrounding municipalities include Espoo to the west and Vantaa to the north, the second- and fourth-largest cities in Finland. Between 2013 and 2019, the region's population grew by 7.7%, from 1.41 million to 1.52 million.

Our worker- and establishment-level data are drawn from micro-level administrative registers maintained by Statistics Finland. We include all workers and establishments located in the region during both study years. Worker home locations and establishment addresses are recorded on a 250×250 m grid. The individual-level data include rich socio-economic and labor market information, such as gender, age, education, occupation, industry, family composition, and annual earnings, irrespective of employment status. Establishment coverage spans most industries, although publicly owned establishments are largely excluded. For each establishment, we observe value added, employment, intermediate inputs, and investments. Some establishment-level variables are imputed, though imputation flags are unavailable; we therefore conduct robustness checks using one-establishment firms with financial statements free of imputation. Additional variables describe the workforce composition by gender, education, age, and firm-specific experience, as well as public/private ownership status.

Transport-related data are obtained from a state-of-the-art transportation demand model developed by the Helsinki region's public transport authority. The model consists of a series of multinomial logit demand models integrated with a network assignment model that outputs travel times and costs for observed trip patterns. The transport supply model incorporates car, public transport, and bicycle networks, including public transport schedules, waiting times, and volume–delay functions for car and bus travel. The demand models are estimated and calibrated using Helsinki-region travel survey data and model outputs are validated against observed traffic volumes. The model is widely used in cost–benefit analyses (CBAs) and other transport impact assessments.

To construct accessibility measures, we use model outputs on travel times, monetary travel costs, mode choice probabilities, values of travel time savings, and the spatial distribution of workplaces. Accessibility is calculated at the zonal level, as defined by the transport model. The transport model divides the region into 1,977 zones of varying size—smaller in dense urban areas and larger in rural areas. The median zone area is 0.975 km^2, with the smallest zone measuring 200 m^2. We match each worker and establishment in our sample to a transport zone to measure their accessibility.

2.2 Accessibility

2.2.1 Measuring accessibility

Our main independent variable is workplace accessibility, defined as the effective density of workplaces considering both travel time and monetary costs—together referred to as the generalized travel cost—between origin and destination workplaces. We measure accessibility to workplaces following Börjesson et al. (2019) and Knudsen et al. (2022). The metric takes the form:

$$A_{t,z} = \sum_{z' \in Z} N_{t,z'} * exp(-\delta \tau_{t,z,z'}) \tag{1}$$

where $A_{t,z}$ is the accessibility of zone z at time t, Z is the set of all zones in our study area, $N_{t,z'}$ is the number of workers that are employed in zone z' at time t, and $\tau_{t,z,z'}$ is the generalised travel cost between zones z and z' at time t. The decay parameter, δ, governs the rate at which the influence of more distant workplaces declines as generalized travel costs increase. We estimate δ using a gravity model, with travel matrices from the transport model serving as the data source. The resulting point estimate is 0.268. The estimation procedure for δ is described in more detail in Appendix B.

The generalised travel cost $\tau_{z,z'}$ is defined as:

$$\tau_{z,z'} = \sum_{m \in M} P(m)_{z,z'}(v(m) * t(m)_{z,z'} + c(m)_{z,z'}) \tag{2}$$

where $P(m)_{z,z'}$ is the mode share of mode m in trips between z and z', M is the set of travel modes available, $v(m)$ is the value of travel time savings with mode m, $t(m)_{z,z'}$ is the travel time between z and z' with mode m and $c(m)_{z,z'}$

is the pecuniary travel cost between z and z' with mode m. The values of travel time savings (VTTS) for car and public transport are obtained from the transportation demand model, the VTTS for bicycle is from the national CBA guidelines and the VTTS for walking is inferred from the relative difference between VTTS of cycling and walking in Börjesson et al. (2019).[2]

2.2.2 The spatial reach of agglomeration benefits

To illustrate the implications of our estimated decay parameter for the accessibility measure, we examine how the weight of distant places declines as car travel time increases. We fit exponential[3] and inverse[4] curves to the dataset that includes our simulated car travel times and calculate accessibility weights[5]. The OLS estimates are $\kappa = 0.09$ and $\lambda = 0.964$. From these fits, the weight of workplaces in the accessibility measure declines to half within roughly 4–8 minutes of car travel. At 40–50 minutes, weights approach zero, with only 1.1% (inverse fit) or 2.3% (exponential fit) of workplaces in a destination zone contributing to an origin zone's accessibility. This indicates that if accessibility increases productivity, the effects of agglomeration are highly localized, mostly dissipating beyond 50 minutes of car travel. These findings are consistent with prior literature. For example, Graham and Gibbons (2019) suggest that typical inverse-distance weighting for urban accessibility is 1, while Ahlfeldt and Wendland (2016) estimate exponential decay parameters

[2]The value of travel time for car trips is 7.92 €/h, public transport trips 6 €/h, bicycle trips 12.06 €/h and walking trips 4.2 €/h.

[3]$e^{-\kappa * tt_{car}}$

[4]$\frac{1}{-\lambda * tt_{car}}$

[5]$e^{\delta \tau_{z,z'}}$

between 0.074 and 0.137.

Appendix Figure A1 plots the accessibility weight, ($e^{\delta\tau_{z,z'}}$), for 10,000 randomly selected zone pairs as a function of car travel time and the fitted exponential and inverse curves. The figure demonstrates how the transport network, in addition to car travel, affects accessibility weights. For instance, weights for zones approximately 10 minutes apart by car range from 0.25 to 0.45, depending on travel costs and modal shares of other transport modes.

2.2.3 Changes in accessibility

Between 2013 and 2019, the Helsinki region underwent several major transportation infrastructure and network changes, driven by investments in rail infrastructure, upgrades to the road network, revisions to bus routes, and changes in speed limits. Figure 1 illustrates the transport network and highlights several of the larger improvements.

In 2015, the Ring Rail Line to the airport opened, connecting downtown Helsinki to the airport and adding five new local train stations in Vantaa. The Vantaa bus network was restructured the same year to integrate with the new rail service. In late 2017, the Helsinki metro expanded westward into Espoo, adding eight new stations; southern Espoo's bus network was simultaneously redesigned to serve as feeder routes to the metro. Several bypasses around Helsinki were also upgraded through lane additions and conversions of intersections to grade-separated junctions. Additional smaller-scale improvements occurred throughout the region.

These changes produced both increases and decreases in travel times across the Helsinki region. For example, the new metro stations in Espoo improved accessibility for areas near the stations but reduced it for some areas farther away: former direct bus routes to downtown Helsinki were replaced by feeder services to the metro, increasing public transport travel times for those areas.

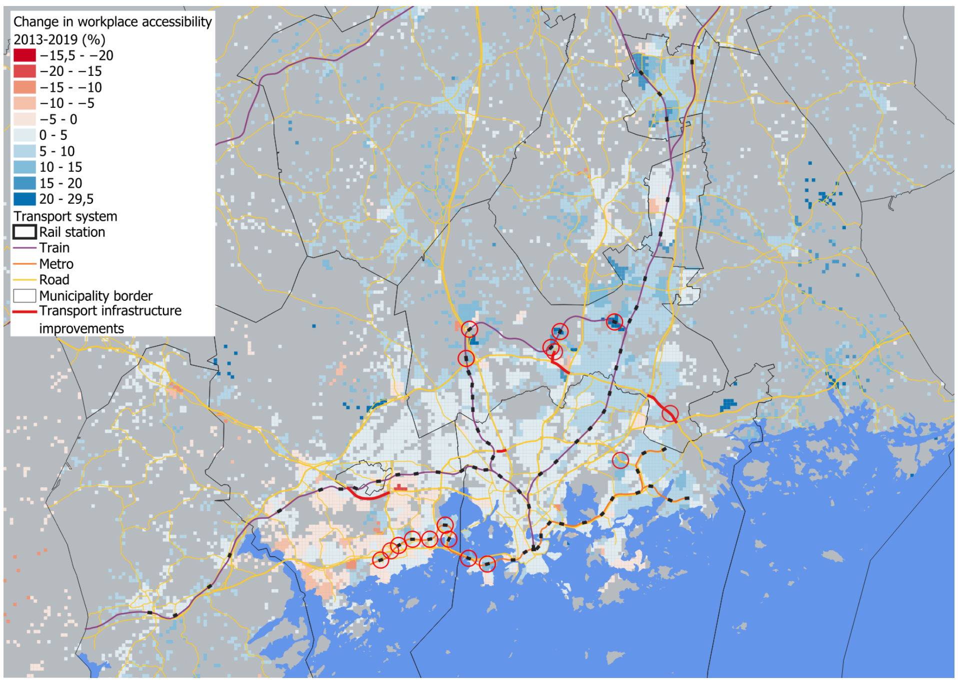

Figure 1: Transport system, major transport infrastructure improvements and change in workplace accessibility in the Helsinki region between 2013 and 2019

Notes: The figure shows the relative changes in accessibility for the Helsinki region between 2013 and 2019 for each 250x250m grid cell that has at least one worker in 2019. Black lines show the borders of municipalities. Areas marked in red are places of some large transport infrastructure improvements that happened between our study years. Largest relative accessibility changes happened along railway lines and in western parts of the region.

Figure 1 presents the relative change in accessibility across 250×250 m grid cells between 2013 and 2019. Changes reflect both transportation infrastructure developments and shifts in the number and spatial distribution of workplaces. Only grid cells containing at least one workplace in 2019 are shown; black lines indicate approximate municipal boundaries. The largest relative gains in accessibility occurred along railway corridors and in the eastern part of the region. Improvements along the rail lines are primarily attributable to the Ring Rail Line, while gains in the east may reflect upgrades to the bypass around Helsinki. Overall, the most pronounced improvements are concentrated near new public transport connections. Some changes, however, stem from general growth and redistribution of workplaces over the study period. Notably, accessibility declined in parts of western Espoo, largely due to bus network restructuring associated with the opening of the new metro extension.

2.3 Empirical Strategy

We use the following fixed-effects model to estimate the effects of agglomeration on productivity:

$$\ln(y_{izkt}) = \gamma \ln(A_{zt}) + \beta X_{izt} + \mu_i + \theta_{kt} + \varepsilon_{izkt} \tag{3}$$

where y_{izt} is the outcome of interest of a worker or establishment i in zone z where the establishment or the worker's workplace is located, in municipality k, during time t. A_{zt} is the accessibility of zone z during time t. X_{izt} includes controls for the worker or establishment such as industry, average age of the workforce and level of education. The term μ_i is worker or establishment specific fixed effect that controls for time-invariant unobservable characteristics and the term θ_{kt} is a municipality-year fixed effect that controls for common and municipality specific productivity enhancing time trends. ε_{izkt} is the error term. Our interest lies in the parameter γ that describes the accessibility elasticity of productivity. We cluster standard errors at the 250×250 m grid level for both study years.

At the worker level, we measure productivity using annual earnings. The underlying assumption is that in market equilibrium, wages reflect productivity.[6] For establishments, we consider two productivity measures: value added per worker and labor costs per worker. Later in the paper, we also examine how improved accessibility affects establishment costs and employment.

2.3.1 Endogeneity issues and solutions

Even though our panel data allow us to control for many observable and unobservable characteristics of workers and establishments, endogeneity concerns remain. The main concern relates to factors driving changes in accessibility for an individual worker or establishment. Such changes may occur for four reasons: (i) the transport network around the establishment or worker's workplace changes, (ii) the number of workplaces in the area changes, (iii) a worker switches to a workplace in a location with different accessibility or an establishment relocates, or (iv) the establishment where the worker is employed changes location.

Incidental places strategy Endogeneity related to (i) commonly arises from the potentially endogenous placement of transportation infrastructure.

[6]Empirical evidence shows a clear connection between productivity and wages, although the relationship may not be direct 1-to-1. For specific studies see, for example, Hellerstein et al. (1999); Lazear et al. (2022)

Infrastructure is not randomly assigned and might be targeted to areas that are economically worse off to stimulate growth or to areas that are already productive to improve access further. Our identification relies on variation in the continuous accessibility measure. Even if transport planners target infrastructure based on expected productivity growth, the resulting accessibility improvements depend on the pre-existing network. This creates small, incidental differences in accessibility that are not planned by policymakers. By using spatially refined measures of accessibility, we can exploit this incidental variation to identify the causal effect of transportation improvements. Similar strategies are used in Gibbons et al. (2019), Börjesson et al. (2019), and Knudsen et al. (2022).

Instrumental variable Endogeneity related to (ii) arises when non-transport-related productivity shocks affect the number of jobs in an area, creating reverse causality between productivity and accessibility. To address this, we construct an instrumental variable that isolates accessibility changes due solely to transportation infrastructure, as introduced by Börjesson et al. (2019):

$$\ln(\bar{A}_{z,t+1}) - \ln(A_{z,t}) = \ln\Big[\sum_{z' \in Z} N_{t,z'} \exp(\delta \tau_{t+1,z,z'})\Big] - \ln\Big[\sum_{z' \in Z} N_{t,z'} \exp(\delta \tau_{t,z,z'})\Big]. \tag{4}$$

Here, the first term measures accessibility at zone z using the transport network at $t+1$ but the workplace distribution at t, while the second term measures accessibility at t. Their difference captures the change in accessibility solely due to transport network changes, holding workplace distribution constant.

For the instrument to be valid, it must satisfy the exogeneity condition. While correlation with unobserved productivity shocks is possible if infrastructure is targeted to areas with expected growth, the long planning horizon of Finnish transport projects—typically 8–16 years from planning to completion—makes such correlation unlikely. To further isolate the effect of the network from the effect of workplace distribution, we fix the number of workplaces at 2004 levels while comparing the 2013 and 2019 networks.

One limitation of using variation from (i) and (ii) for workers whose workplace remains fixed, is that accessibility changes are often small. This limits the variation available for identification which can be seen from the descriptive statistics in Table 1.

Unobserved heterogeneity in productivity Endogeneity from (iii) arises because job changes may affect pay through factors unrelated to accessibility, such as promotions or new responsibilities. While we can control for some observable job characteristics, unobserved changes remain. For workers, changes in accessibility due to workplace relocation are plausibly exogenous, as individual workers cannot influence relocation decisions and are only informed near the relocation date. Thus, we focus on workers whose establishment relocated during our study years and drop those whose establishment remained in the same area and those who switched firms. Similar identification strategies using relocations have been employed in Knudsen et al. (2022) and Xiao et al. (2021). For establishments, relocations may be endogenous to productivity, hence we include all establishments in the regressions.

2.4 Descriptive statistics

Appendix Table A1 presents descriptive statistics for the workers in our sample. During the study period, the mean log accessibility for workers increased by 0.04, from 11.77 to 11.81, corresponding to an approximate 4% rise. Over the same period, mean annual earnings increased from €44,000 to €52,000, roughly an 18% increase. Appendix Table A2 presents descriptive statistics for establishments in 2013 and 2019. Mean log accessibility for establishments grew by 0.03, from 11.58 to 11.61, while mean turnover increased from €2.95 million to €3.34 million, and value added per worker rose from €69,000 to €82,000, representing relative increases of 13% and 19%, respectively.

Table 1 reports selected percentiles of log accessibility and log annual earnings for different subsets of workers. Panel A shows percentiles for all workers, Panel B for those whose workplace remained in the same 250x250m grid cell between 2013 and 2019 (stayers), and Panel C for those whose establishment relocated during the study period (movers). In Panel A, variation in accessibility and annual earnings is substantial, with most changes in accessibility ranging from -49% to 56%. In contrast, Panel B shows that for stayers, 90% of accessibility changes fall approximately between -1% and 10%, indicating that almost all variation in accessibility comes from movers. Panel C confirms this, with 90% of changes in accessibility for movers ranging from -66% to 72%.

Table 1: Change in log accessibility and log annual earnings for workers in the Helsinki region

	Panel A. All						
	p5	p10	p25	p50	p75	p90	p95
Change in log(accessibility)	-0.49	-0.26	-0.02	0.04	0.13	0.35	0.56
Change in log(annual earnings)	-0.63	-0.27	-0.01	0.12	0.36	0.88	1.39
Observations	243,153						
	Panel B. Stayers						
Change in log(accessibility)	-0.01	-0.00	0.02	0.03	0.05	0.08	0.10
Change in log(annual earnings)	-0.48	-0.18	-0.01	0.09	0.25	0.55	0.93
Observations	79,397						
	Panel C. Movers						
Change in log(accessibility)	-0.66	-0.40	-0.12	0.05	0.21	0.46	0.72
Change in log(annual earnings)	-0.70	-0.31	-0.02	0.14	0.43	1.04	1.56
Observations	163,756						

Notes: The table shows selected percentiles for the change in accessibility and annual earnings for workers in establishments that resided in the Helsinki region both in 2013 and 2019. Different panels show different subsets of the establishments. Stayers are defined as establishments that resided in the same 250x250m grid cell in 2013 and 2019, and movers are defined as establishments that changed their grid cell during that time. The percentiles of accessibility and annual earnings are independent of each other.

Variation in annual earnings follows a similar, though less extreme, pattern. annual earnings for stayers vary less than for movers, but the difference is smaller than that observed for accessibility. In Panel A, 90% of changes in annual earnings for all workers fall between -63% and 139%. For stayers (Panel B), this range is -48% to 93%, while for movers (Panel C), 90% of changes in annual earnings range from -70% to 156%.

3 Results

3.1 Worker-level analysis

Productivity We begin with worker-level results using annual earnings as a measure of productivity following previous literature. Table 2 presents estimates from different specifications. Columns (1) and (2) present the OLS estimates of γ without worker fixed effects. In column (1), we find a positive and statistically significant association between accessibility and productivity. The coefficient decreases in column (2) when we add controls for education level and field, industry, gender, age, and household size. Adding worker fixed effects in column (3) further reduces the coefficient relative to the OLS estimates. In column (4), we focus on workers whose accessibility changed due to their establishment relocating; the coefficient declines to 0.037. Using our instrumental variable for accessibility keeps the estimate virtually unchanged at 0.035. All coefficients remain statistically significant.

The results indicate that annual earnings are strongly correlated with accessibility. Adding worker controls reduces the elasticity by about one third, suggesting that more productive workers tend to locate in more accessible locations. Notably, adding worker fixed effects leaves the estimate largely unchanged, implying that unobserved time-invariant factors play a limited role in wage variation after controlling for observable characteristics. The stability of the estimate under the IV approach suggests reverse causality is not a major source of bias once we focus on accessibility changes due to workplace relocation.

Table 2: Worker-level results

	(1) OLS	(2) OLS	(3) FE	(4) FE, establishment relocation	(5) FE, IV	(6) FE, IV, establishment relocation
Log(accessibility)	0.158***	0.099***	0.091***	0.037**	0.088***	0.035**
	(0.020)	(0.013)	(0.012)	(0.018)	(0.018)	(0.018)
Individual fixed effects	NO	NO	YES	YES	YES	YES
Controls	NO	YES	YES	YES	YES	YES
Observations	817704	817704	817704	106386	817704	106386

Notes: Those working in the study area in the years 2013 and 2019 are included. The estimations use the following worker-level background characteristics as controls: level of education (four categories), gender, field of education (single-digit level), household size (1, 2, 3, 4+), age and age squared, industry, and ln(distance of the workplace to the centroid). In addition, year fixed effects have been added. Standard errors are clustered at the regional levels of the years 2013 and 2019 (250x250m grid-level). FE regressions include worker-level fixed effects and municipality*year fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The average change in accessibility for workers is 4.1%. This implies an average increase in annual earnings of 0.14%, corresponding to €61 per worker, given the 2013 average wage of €44,059. With 408,852 workers in our sample, transportation-induced agglomeration accounts for just under €25 million in total increases in annual earnings between 2013 and 2019.

Our elasticity of 0.035 is slightly higher but comparable to previous estimates of 0.025 (Börjesson et al., 2019) and 0.028 (Knudsen et al., 2022). Differences may reflect the study area's urban concentration; previous studies covering larger, more rural regions likely capture lower agglomeration effects. Agglomeration benefits have been shown to be nonlinear in density (Eliasson and Westerlund, 2023), which can explain higher estimates in more urbanized areas.

Establishment size In our main specifications, we do not control for establishment size, which may itself be influenced by accessibility and serve as a channel through which productivity changes occur. To examine whether establishment size drives our results, we re-estimate equation 3 for different establishment size categories, using the EU SME definitions: micro (under 10 employees), small (under 50), and medium (under 250). We sequentially add workers from larger establishments to the subset to assess how accessibility estimates vary across establishment sizes, pooling workers to maintain precision.

Table 3 reports results for our preferred specification (FE + IV, establishment relocation). Column (1) shows the estimate for workers in micro establishments, 0.059, which is higher than the main estimate but less precise due to fewer observations. Adding workers from small establishments (column 2) reduces the estimate to 0.040 while increasing precision. Including medium-sized establishments (column 3) lowers the estimate to 0.036, and using all workers with establishment size data (column 4) further reduces it to 0.029.

Table 3: Accessibility's effect on annual earnings for establishments of different sizes

	(1) FE + IV, establishment relocation, micro	(2) FE + IV, establishment relocation, up to small	(3) FE + IV, establishment relocation, up to medium	(4) FE + IV, establishment relocation, all
Log(accessibility)	0.059*	0.040*	0.036**	0.029*
	(0.032)	(0.020)	(0.018)	(0.017)
Individual fixed effects	YES	YES	YES	YES
Establishment size as control	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Observations	20840	43656	62670	91184

Notes: Those working in the study area in the years 2013 and 2019 are included. The estimations use the following worker-level background characteristics as controls: size of the employing establishment, level of education (four categories), gender, field of education (single-digit level), household size (1, 2, 3, 4+), age and age squared, industry, and ln(distance of the workplace to the centroid). Additionally the size of the establishment is controlled for. Fixed effects include worker-level and municipality*year fixed effects. Standard errors are clustered at the regional levels of the years 2013 and 2019 (250x250m grid-level). * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Although the differences in point estimates are not statistically significant, they suggest that workers in smaller establishments may gain more from improved accessibility. The results are in line with Knudsen et al. (2022), who find that the agglomeration benefits are largest for workers in establishments that employ less than 10 workers. Including establishment size as a control reduces the effect but does not qualitatively change the results, also consistent with Knudsen et al. (2022).

3.2 Establishment-level analysis

Having established that accessibility increases annual earnings, we examine whether this translates into higher establishment productivity, measured by value added per worker and labour costs per worker. We use total labour costs rather than annual earnings to reduce bias that may rise from entrepreneurs who may pay themselves differently compared to their employees.

Value added and labour costs Table 4 presents the establishment-level estimates. Panel A shows value added per worker. OLS estimates (columns 1–2) indicate a positive association with accessibility, which diminishes after adding controls, suggesting that more productive establishments locate in accessible areas. Fixed effects and IV estimates (columns 3–4) are small and statistically insignificant, with large standard errors, implying heterogeneous effects due to differences in cost structures. Panel B shows similar patterns for labour costs per worker: OLS estimates are positive, but fixed effects and IV estimates are imprecise, though the point estimates resemble worker-level results.

Table 4: Establishment-level results on value added and labour costs

	(1)	(2)	(3)	(4)
Panel A. Value added per worker				
	OLS	OLS	FE	FE IV
Log(accessibility)	0.040***	0.031***	-0.001	-0.005
	(0.010)	(0.008)	(0.032)	(0.032)
Observations	55,502	55,502	55,502	55,502
Panel B. Labour costs per worker				
Log(accessibility)	0.171***	0.124***	0.025	0.022
	(0.018)	(0.012)	(0.030)	(0.030)
Establishment fixed effects	NO	NO	YES	YES
Controls	NO	YES	YES	YES
Observations	53,414	53,414	53,414	53,414

Notes: Those establishments located in the study area in the years 2013 and 2019 are included. The estimations use the following establishment-level background characteristics as controls: the proportion of women, the proportion of different educational backgrounds (10 categories), the proportions of different age groups (5 categories), average age of staff, company-specific experience, educational level (in years), the industry of the workplace (only in OLS), and ln(distance to centroid). In addition, year fixed effects have been added. Standard errors are clustered at the regional levels of the years 2013 and 2019 (250x250m grid-level). FE regressions include establishment-level fixed effects and and municipality*year fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The lack of significant effects on establishment-level productivity contrasts with worker-level wage gains. This may reflect turnover: establishments continuously hire new workers who have not yet benefited from improved accessibility. On the other hand, the lack of effect in value added could also be due to increased costs.

Table 5: Effect of accessibility on establishment' employment and other operating expenses

Panel A. Employment				
	(1)	(2)	(3)	(4)
	OLS	OLS	FE	FE, IV
Log(accessibility)	0.358***	0.304***	0.118***	0.113***
	(0.031)	(0.021)	(0.034)	(0.034)
Panel B. Other operating expenses				
Log(accessibility)	0.121***	0.074***	0.086**	0.067*
	(0.014)	(0.011)	(0.037)	(0.038)
Establishment fixed effects	NO	NO	YES	YES
Controls	NO	YES	YES	YES
Observations	55,502	55,502	55,502	55,502

Notes: Those establishments located in the study area in the years 2013 and 2019 are included. The estimations use the following establishment-level background characteristics as controls: the proportion of women, the proportion of different educational backgrounds (10 categories), the proportions of different age groups (5 categories), average age of staff, company-specific experience, educational level (in years), the industry of the workplace (only in OLS), and ln(distance to centroid). In addition, year fixed effects have been added. Standard errors are clustered at the regional levels of the years 2013 and 2019 (250x250m grid-level). FE regressions include establishment-level fixed effects and and municipality*year fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Other operating expenses and employment Next we examine whether agglomeration increases employment and costs in establishments. Panel A of Table 5 confirms that accessibility strongly increases employment, with estimates that remain significant after controls and IV adjustments. Increased employment can attenuate observable productivity gains at the establishment level. This result contrasts one in Gibbons et al. (2019) who find no effect of accessibility on employment in establishments.

Agglomeration may also raise costs. We proxy rents via other operating expenses per workers[7]. (Table 5, Panel B). OLS estimates show a positive

[7] Other operating expenses include expenses such as marketing expenses or leasing costs in addition to rents.

association with accessibility, reduced but still significant after controls, fixed effects, and IV. Using the IV elasticity, the mean increase in costs per worker from 2013 to 2019 is €90. With an average of 10.97 workers per establishment across 28,008 establishments, this implies a total increase in costs of roughly €27.7 million per year, comparable to estimated worker-level wage gains. These results suggest that accessibility benefits are largely shared between workers and property owners, partly explaining the lack of observable productivity gains at the establishment level. These findings align with Gibbons et al. (2019), who show that improved accessibility attracts more establishments, potentially raising local land rents. Like our study, they also report inconclusive effects of accessibility on value added per worker.

4 Robustness and heterogeneity checks

4.1 Changes in the decay parameter

We test the robustness of the worker-level results to different values of the decay parameters. The decay parameter governs how quickly the importance of a workplace fades with the generalised travel cost. We test two different decay parameters: $\delta_1 = 0.2$ and $\delta_2 = 0.336$. The lower value, $\delta_1 = 0.2$, is used in the robustness checks of Gibbons et al. (2019), while $\delta_2 = 0.336$ represents an equivalent increase upwards from our preferred decay parameter $\delta = 0.268$. Higher values of the parameter imply a faster decay in the importance of more distant workplaces, and lower values imply slower decay.

The results for these robustness checks are shown in Appendix Table A3.

Columns correspond to alternative specifications, as in the previous tables. All of the specifications show similar tendencies where adding controls and fixed effects reduces the estimate. Looking at our preferred estimates for the sample where the establishment relocated in column (6), we find that decreasing the decay parameter increases the elasticity estimate and vice versa. None of the estimates are statistically different from our main estimate. Additionally, when the accessibility elasticity is multiplied with the standard deviation of the relative change in corresponding accessibility, this standardised effect on annual earnings is very stable when using different decay parameters. For example, with a decay parameter of $\delta_1 = 0.2$, the standard deviation in the relative change in accessibility is 0.032. Multiplying this by the corresponding elasticity estimate of 0.044 yields an estimated wage increase of $0.032 \times 0.044 = 0.0014$. For $\delta_2 = 0.336$, the standard deviation is 0.050 and the elasticity estimate is 0.030, implying a standardized effect of $0.050 \times 0.030 = 0.0015$ on annual earnings. Thus, the variation in the elasticity estimates seems to capture different size of variation in the accessibility measure.

4.2 Single establishment firms

Some values are imputed in the establishment data. We test the robustness of our results by focusing on data for single-establishment firms, for which no imputation is required since all business activity is concentrated in one location, thereby improving data quality. We report the estimates only for our preferred specification involving establishment controls, fixed effects and our IV for establishment outcomes. The results for single establishment firms are shown in Appendix Table A4. Restricting our sample to single establishment firms does not alter our results. We find no significant effect on value added per worker nor labour cost per worker, and positive and significant effects on both employment and other costs per worker. The point estimates are also similar to the ones with full sample of establishments. The point estimate for accessibility's effect on employment is 0.143 (compared to 0.113 for all establishments) and for costs per worker the point estimate is 0.075 (compared to 0.067 for all establishments).

4.3 Workers employed in establishments in the data

Since we lack data for all regional establishments, our worker-level sample includes individuals not covered in the establishment-level analysis. Notably, data on the establishments of public sector establishments is missing. To see whether the results are affected by the exclusion of this part of the workforce, we test the robustness of our results by restricting our sample to only those workers, who are working in establishments included in our establishment-level analysis. The results of these estimations are shown in Appendix Table A5. The estimates are similar to our main results. However, in this sample, including fixed effects for workers decreases the estimate considerably. Our preferred estimate with fixed effects, IV and sample of workers whose establishment relocated is 0.033. The estimate is statistically significant in 10 % level and does not differ statistically from our main estimate of 0.035.

5 Conclusions

We study the effect of transport induced agglomeration on productivity of both workers and establishments as well as costs of establishments in Helsinki region, Finland in years 2013 and 2019. We specifically consider the effect of accessibility between workplaces to concentrate on the learning and sharing channels of agglomeration benefits for employees. We find that accessibility between workplaces has a positive effect on annual earnings of workers. We also find that workers in smaller establishments benefit more from increased accessibility than workers in larger establishments.

However, our estimates for the effect of accessibility on value added per worker and labour costs per worker on the establishment level are statistically insignificant. These seemingly contradictory effects between establishments and workers can be explained by the fact that the composition of workers in our worker level analyses differs from establishment level analyses. We find that establishments increase employment when accessibility increases. Additionally, we find that establishments' other operating expenses (which include, e.g., rents) rise with accessibility. Combining these findings suggests that the benefits of agglomeration are mostly shared between workers and property owners.

By our preferred estimate, doubling accessibility increases workers' annual earnings by 3.5 %. With the average change in accessibility between our study years this translates to an average increase in yearly annual earnings of around 60 euros. Even if the effect for a single worker is small, transportation investments concern are large number of workers. Back of the envelope calculations suggest that for our whole sample of workers, the increase in annual earnings due to accessibility changes between 2013 and 2019 is almost 25 million euros per year. Our establishment-level results suggest that the rise in other costs from improved accessibility is of a similar magnitude, potentially offsetting effects on value added.

Our estimated accessibility measure suggests that agglomeration benefits extend up to 50 minutes of car travel, with most gains occurring near clusters of establishments. This suggests that transport projects reducing travel times between distant areas yield limited agglomeration effects, whereas productivity gains mainly arise from improving connections between nearby areas.

Our results can inform cost-benefit analyses by estimating the annual wage increase resulting from transportation infrastructure investments. When combined with marginal tax rate estimates, the additional tax revenue generated by these wage gains can be incorporated into transport project evaluations. However, caution is warranted, as some benefits related to goods transportation may be double-counted.

Future research could provide further insight into how agglomeration benefits are distributed among different actors. Additionally, our productivity estimates indicate heterogeneity in establishments' ability to capture gains from agglomeration, which warrants further investigation in subsequent studies.

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Appendices

A Additional Figures and Tables

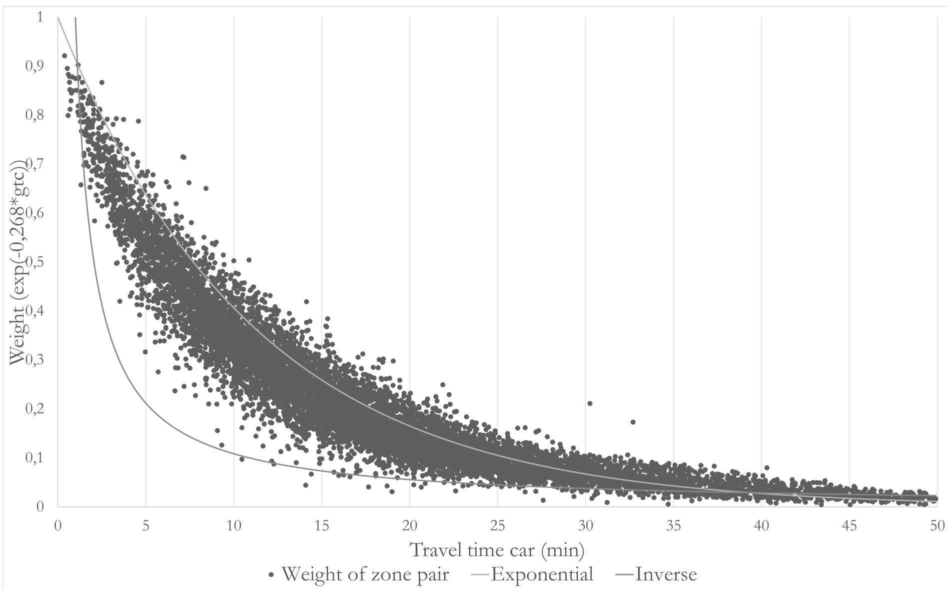

Figure A1: Accessibility weight as a function of car travel time

Notes: The figure shows the accessibility weight of 10,000 randomly selected zone pairs as a function of car travel time. Exponential and inverse curves were fitted to the dataset using OLS. The inverse curve generally lies below the exponential curve, underestimating accessibility weights.

Table A1: Descriptive statistics for workers in the Helsinki region

Year	**2013**		**2019**	
Variable	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Log(accessibility)	11.77	0.47	11.81	0.47
Annual earnings (deflated to 2015 level)	44 059	36 977	51 525	45 000
Log(Annual earnings)	10.45	0.80	10.65	0.72
Female	0.48	0.50	0.48	0.50
Age	39.60	10.54	45.60	10.54
Primary education	0.11	0.32	0.09	0.28
Secondary education	0.35	0.48	0.32	0.46
Tertiary education	0.51	0.50	0.57	0.50
Doctoral degree	0.02	0.15	0.03	0.16
Single	0.42	0.49	0.34	0.47
Household size	2.63	1.11	2.55	1.10
Publicly owned	0.29	0.45	0.30	0.46
Small establishment (<10 workers)	0.24	0.42	0.22	0.41
Industry shares				
A Agriculture, forestry and fishing	0.00	0.04	0.00	0.04
B Mining and quarrying	0.00	0.02	0.00	0.02
C Manufacturing	0.09	0.29	0.09	0.29
D Electricity, gas, steam and air conditioning supply	0.01	0.08	0.01	0.09
E Water supply: sewerage, waste management and remediation activities	0.00	0.05	0.00	0.06
F Construction	0.06	0.24	0.07	0.25
G Wholesale and retail trade; repair of motor vehicles and motorcycles	0.16	0.37	0.14	0.34
H Transportation and storage	0.07	0.25	0.07	0.25
I Accommodation and food service activities	0.04	0.19	0.03	0.17
J Information and communication	0.08	0.28	0.09	0.29
K Financial and insurance activities	0.04	0.20	0.05	0.21
L Real estate activities	0.01	0.11	0.01	0.12
M Professional, scientific and technical activities	0.09	0.29	0.10	0.30
N Administrative and support service activities	0.04	0.20	0.04	0.20
O Public administration and defence; compulsory social security	0.06	0.25	0.07	0.26
P Education	0.08	0.27	0.08	0.27
Q Human health and social work activities	0.10	0.29	0.10	0.30
R Arts, entertainment and recreation	0.02	0.16	0.02	0.15
S Other service activities	0.03	0.17	0.03	0.17
T Activities of households as employers	0.00	0.00	0.00	0.00
U Activities of extraterritorial organisations and bodies	0.00	0.02	0.00	0.01
Number of observations	408 852		408 852	

Notes: Those working in the study area in the years 2013 and 2019 are included.

Table A2: Descriptive statistics for establishments in the Helsinki region

Year	**2013**		**2019**	
Variable	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Log(accessibility)	11.58	0.57	11.62	0.57
Turnover	2,968,922.56	26,394,888.73	3,261,647.17	2,532,7148.77
Value added per worker	69,403.42	190,748.33	81,644.45	347,501.40
Log (value added per worker)	11.81	1.64	11.90	1.68
Other expenses per worker	36,278.91	157,013.20	40,350.27	131,597.61
Log(other expenses per worker)	10.01	0.88	10.15	0.86
Number of employees	9.24	38.94	10.04	41.71
Share of women	0.39	0.40	0.40	0.40
Share of primary educated (general)	0.19	0.31	0.17	0.29
Share of secondary educated (general)	0.12	0.24	0.10	0.23
Share of secondary educated (non-technical)	0.17	0.30	0.20	0.32
Share of secondary educated (technical)	0.15	0.29	0.15	0.29
Share of lowest tertiary educated (non-technical)	0.09	0.22	0.08	0.22
Share of lowest tertiary educated (technical)	0.02	0.11	0.02	0.11
Share of lower tertiary educated (non-technical)	0.08	0.20	0.09	0.21
Share of lower tertiary educated (technical)	0.04	0.14	0.04	0.15
Share of higher tertiary educated (non-technical)	0.10	0.26	0.10	0.26
Share of higher tertiary educated (technical)	0.04	0.15	0.04	0.16
Share of 16-24 year-olds	0.09	0.18	0.06	0.14
Share of 25-34 year-olds	0.21	0.29	0.15	0.23
Share of 35-44 year-olds	0.26	0.34	0.23	0.32
Share of 45-55 year-olds	0.31	0.37	0.29	0.36
Share of 55-70 year-olds	0.14	0.26	0.28	0.37
Average age	41.59	8.61	45.58	9.31
Firm-level experience (in months)	75.09	62.12	78.35	85.06
Average education (in years)	12.95	2.48	13.13	2.50
Publicly owned	0.01	0.09	0.01	0.09
Observations	27,751		27,751	

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Year	**2013**		**2019**	
Industry shares	**Mean**	**Standard deviation**	**Mean**	**Standard deviation**
Agriculture, forestry and fishing (A)	0.01	0.07	0.01	0.08
Mining and quarrying (B)	0.00	0.02	0.00	0.02
Manufacturing (C)	0.05	0.22	0.05	0.22
Electricity, gas, steam and air conditioning supply (D)	0.00	0.04	0.00	0.04
Water supply; sewerage, waste management and remediation (E)	0.00	0.04	0.00	0.05
Construction (F)	0.13	0.34	0.13	0.34
Wholesale and retail trade; repair of motor vehicles (G)	0.20	0.40	0.20	0.40
Transportation and storage (H)	0.08	0.27	0.08	0.27
Accommodation and food service activities (I)	0.05	0.22	0.05	0.22
Information and communication (J)	0.06	0.24	0.06	0.24
Financial and insurance activities (K)	0.01	0.10	0.01	0.10
Real estate activities (L)	0.02	0.13	0.02	0.13
Professional, scientific and technical activities (M)	0.15	0.36	0.15	0.36
Administrative and support service activities (N)	0.05	0.22	0.05	0.22
Education (P)	0.01	0.12	0.01	0.12
Human health and social work activities (Q)	0.07	0.25	0.07	0.26
Arts, entertainment and recreation (R)	0.02	0.15	0.02	0.15
Other service activities (S)	0.07	0.26	0.07	0.26
Observations	27,751		27,751	

Notes: Those establishments located in the study area in 2013 and 2019 are included.

Table A3: Changes in the decay parameter: Worker-level results

	(1) OLS, all	(2) OLS, all	(3) FE, all	(4) FE, establishment relocation	(5) FE, IV, all	(6) FE, IV, establishment relocation
			Panel A. Decay parameter $\delta_1 = 0.20$			
Log(accessibility)	0.203***	0.178***	0.113***	0.046**	0.111***	0.044*
	(0.027)	(0.045)	(0.016)	(0.023)	(0.016)	(0.023)
			Panel B. Decay parameter $\delta_2 = 0.336$			
Log(accessibility)	0.135***	0.132***	0.078***	0.032**	0.076***	0.030**
	(0.016)	(0.026)	(0.010)	(0.015)	(0.010)	(0.015)
Individual fixed effects	NO	NO	YES	YES	YES	YES
Controls	NO	YES	YES	YES	YES	YES
Observations	817704	817704	817704	106386	817704	106386

Notes: Those working in the study area in the years 2013 and 2019 are included. The estimations use the following worker-level background characteristics as controls: level of education (four categories), gender, field of education (single-digit level), household size (1, 2, 3, 4+), age and age squared, industry, and ln(distance of the workplace to the centroid). In addition, year fixed effects have been added. Standard errors are clustered at the regional levels of the years 2013 and 2019 (250x250m grid-level). FE regressions include worker-level fixed effects and municipality*year fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A4: Establishment-level results: Single establishment firms

	(1) Value added per worker	(2) Labour cost per worker	(3) Employment	(4) Other costs per worker
Log(accessibility)	0.016	-0.002	0.143***	0.075*
	(0.041)	(0.032)	(0.045)	(0.042)
Establishment fixed effects	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Observations	28412	28228	28412	28412

Notes: Results from specification including establishment fixed effects and our IV are reported. Those establishments and workers located in the study area in the years 2013 and 2019 are included.The estimations use the following establishment-level background characteristics as controls: the proportion of women, the proportion of different educational backgrounds (10 categories), the proportions of different age groups (5 categories), average age of staff, company-specific experience, educational level (in years), and ln(distance to centroid).

Table A5: Worker-level results: Workers in establishment-level data

	(1) OLS, all	(2) OLS, all	(3) FE, all	(4) FE, establishment relocation	(5) FE, IV, all	(6) FE, IV, establishment relocation
Log(accessibility)	0.153***	0.109***	0.026	0.032*	0.027*	0.033*
	(0.024)	(0.012)	(0.016)	(0.019)	(0.016)	(0.019)
Individual fixed effects	NO	NO	YES	YES	YES	YES
Controls	NO	YES	YES	YES	YES	YES
Observations	287532	287532	287532	76356	287532	76356

Notes: Those working in the study area in the years 2013 and 2019 are included. The estimations use the following worker-level background characteristics as controls: level of education (four categories), gender, field of education (single-digit level), household size (1, 2, 3, 4+), age and age squared, industry, and ln(distance from the workplace to the centroid). In addition, year fixed effects have been added. Standard errors are clustered at the regional levels of the years 2013 and 2019 (250x250m grid-level). FE regressions include worker-level fixed effects and municipality*year fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

B Estimating the Decay Parameter

An important parameter governing the spatial extent to which agglomeration benefits reach is the decay parameter δ from equation (1). The parameter governs how quickly the importance of a workplace to the accessibility of an area fades as the generalized cost to reach the workplace increases. More negative values of the parameter indicate that far away places are less important for accessibility. We estimate the decay parameter with a gravity model similarly to Lee (2021), as our accessibility metric can be seen as a scaled version of the sum of trips, $\sum_{z' \in Z} T_{z,z'}$, generated from a zone z to all other zones $z' \in Z$ in a gravity model. In its simplest form, the gravity model of travel explains the number of trips leaving from zone z to z' with features of the zones, and the distance between them. A simple gravity model is defined as (Graham and Melo, 2011):

$$T_{z,z'} = C A_z^{\alpha} B_{z'}^{\beta} exp(-\delta \tau_{z,z'}) \tag{5}$$

where α is a constant, $T_{z,z'}$ is the number of trips from zone z to z', C is a constant, A_z and B_z' are features of the zones that generate and attract trips and α and β are parameters that govern how the trip generating and attracting features affect the number of trips between two zones, $\tau_{z,z'}$ is the generalised travel cost between areas z and z' and δ is the decay parameter to be estimated.

The equation can be estimated with OLS by taking logs of both sides and adding an error term:

$$ln(T_{z,z'}) = c + \alpha a_z + \beta b_{z'} - \delta \tau_{z,z'} + \varepsilon_{z,z'} \quad (6)$$

where $c = ln(C)$ is a constant, $a_i = ln(A_i)$ and $b_i = ln(B_i)$ are origin and destination features and $\epsilon_{z,z'}$ is the error term. We use the demand matrix for home-work trips from our transportation demand model to estimate the parameter δ as a proper demand matrix for trips between workplaces is not available. As trip-generating characteristics, A_z, we use the population of each zone and as trip-attracting characteristics, $B_{z'}$, we use the number of workers employed in each zone.

The point estimate for δ is 0.268, which is close to the ones used in Börjesson et al. (2019) and Knudsen et al. (2022), who also measured agglomeration with a similar metric of accessibility between workplaces. Börjesson et al. (2019) use the parameter value of 0.28 and Knudsen et al. (2022) use the value of 0.27.[8]

[8]The original parameter from Knudsen et al.'s (2022) study is 0.037. However, they use 2010 DKK as their unit of generalised cost. With inflation and exchange rate corrections, the parameter they use translates to 0.27. Exchange rate in 2018 was 1 DKK = 0.13 EUR and the inflation in Denmark between 2010 and 2018 was 9.5 %. $\delta_k = \frac{0.037}{0.13} * 1.095 = 0.27$