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The relationship between individual employment probabilities and accessibility to matching jobs: A study of the Netherlands

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ABSTRACT

The role of transport in providing people with access to employment opportunities has received considerable attention. Existing studies have primarily applied aggregate public transport or car job accessibility measures to examine the impact on employment probabilities of (sampled) disadvantaged groups in mainly metropolitan areas. We improve on these existing studies by combining national administrative employment micro datasets of the full working-age population of the Netherlands, segmented by educational level, with a novel composite public transport-and-bicycle accessibility measure to matching job opportunities and national vehicle registration data for the first time. This allows us to examine differential employment effects of job accessibility by public transport in combination with the bicycle for different educational groups at the national level. In our employment models, we control for endogeneity of both job accessibility and vehicle ownership in relation to employment status through an instrumental variable approach. The study finds that jobs for higher educated tend to be concentrated in and around the city centres, while jobs for the lower educated are more often located outside these prime accessibility areas, thereby reducing job accessibility among low-educated groups. The study further identifies that employment, in particular of low-educated individuals, is sensitive to higher levels of public transport-and-bicycle job accessibility, but in contrast with prior studies we also find that middle- and higher educated groups could benefit from improved job accessibility. The usage of detailed job accessibility measures and employment micro datasets of the full population thus seem essential to accurately assess the relationship between job accessibility and individual employment probabilities. These findings are important for policymakers in that they imply that more tailored transport strategies may increase the participation of especially lower educated groups in society and therewith the full utilization of the potential labour force.

1. Introduction

The importance of employment as a pathway to socioeconomic inclusion has long been recognised. Generally, the inability to access and partake in paid employment is considered to have severe consequences on a person's full participation in society (SEU, 2003). Over the past decades, many countries have witnessed a process of decentralisation of firms and services that have

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systematically moved outwards into peripheral locations, often alongside an increasing concentration of traditional public transport services on the main corridors of urban centres, making it more difficult for people to access jobs, in particular for those without private transportation (Gobillon et al., 2007; Houston, 2005). While inner-cities have often maintained their role as major employment areas, mainly service sector jobs have expanded selectively in cities and along major transport corridors. As these jobs typically place a greater premium on higher-level skills, skills mismatches may prevent low-skilled job seekers from taking advantage of these employment opportunities (Kasarda, 1988; McQuaid et al., 2001). Concomitantly, many low-skilled jobs in sectors such as manufacturing have gradually declined and dispersed to business and industrial parks in the urban periphery and near highways, thereby reducing job access among the already more disadvantaged groups (Dujardin et al., 2008; Houston, 2005; Korsu & Wenglenski, 2010).

As with many other countries, the Netherlands also witnessed a strong decentralisation of employment, which continues in recent decades: since 2000, nearly 60 % of employment growth in the Netherlands has taken place in peripheral business parks near motorways, while urban locations with good public transport access have experienced little or no job growth (PBL, 2014). Recent studies by (De Koning et al., 2017) and (Martens & Bastiaanssen, 2019) in the Rotterdam-The Hague Metropolitan Area found large disparities in job accessibility between people with and without access to a car, despite having an extensive public transport and bicycle system: average public transport job accessibility levels in peak hours are just 40 % of those by car and this drops to only 20 % in off-peak hours. As a result, job seekers who rely on public transport services have been found to experience greater difficulties in getting access to jobs, which constrained their job uptake (Bastiaanssen & Martens, 2013). The Dutch Council for the Environment and Infrastructure (Rli) recently concluded that these disparities in transport access may reduce the economic and social participation of in particular (car-less) lower educated groups in Dutch society and could therefore prevent the full utilization of the potential labour force (Rli, 2020). To date, however, the association between transport job accessibility and individual employment prospects as measured by probabilities in discrete outcome models has not been scientifically proven in the Netherlands, and so it remains uncertain whether improved job accessibility would have a substantial effect on the employment outcomes of the low-educated. This is the first micro-based study at the national level of the Netherlands to examine differential employment effects of job accessibility by public transport in combination with the bicycle for different educational groups.

The relationship between transport job accessibility and individual employment probabilities has been extensively studied, typically within the context of the increasing spatial mismatch between jobs and disadvantaged workers in US metropolitan areas and in some EU cities (see (Bastiaanssen et al., 2020) for a recent review of the literature). Most studies have shown that car access improves individuals' employment probabilities, particularly among low-skilled groups and in car-dependent areas, while public transport job accessibility often yielded more mixed results (e.g. (Bastiaanssen et al., 2021; Batista Duarte et al., 2023; Blumenberg & Pierce, 2017; Cervero & Tsai, 2003; Gobillon et al., 2011; Kawabata, 2003; Korsu & Wenglenski, 2010; Shen & Sanchez, 2005). Yet, existing empirical studies have often applied aggregate job accessibility measures, which fail to capture job opportunities that match the skills of different groups (Fransen et al., 2019). Many studies have also not controlled for endogeneity in the relationship between job accessibility and employment status, therefore establishing an association rather than causality in this relationship (see e.g. (Blumenberg et al., 2019). All of these empirical studies have further relied on (small) population samples to examine the relationship between job accessibility and employment probabilities of specific disadvantaged groups in mainly metropolitan areas, and so it remains unclear to what extent similar patterns would hold for the *population at large*. It is uncertain that similar patterns would hold within a national context such as the Netherlands, with relatively compact cities and towns, an extensive public transport network, and an important role of the bicycle in daily commuting (Geurs & Ritsema van Eck, 2003).

In this current study, we have developed a novel composite public transport-and-bicycle accessibility measure that could be applied nation-wide to calculate people's access to matching jobs opportunities, using detailed transport and employment micro datasets. The accessibility measure incorporates cycling to the train stations, as the bicycle is often used in combination with train commutes (KiM, 2016), and uses cycling travel times when these are shorter than public transport travel times. In a departure from the existing empirical evidence, we next combined our job accessibility measure with a national employment micro dataset of the *full population* of the Netherlands, segmented by educational level, and national vehicle registration data so that each individual in the dataset could be allocated a matching job accessibility level from their area of residence. The size of our dataset reduces the risk of sampling errors and therefore reinforces the robustness of our employment estimates. We then estimated the impact of job accessibility on employment probabilities in national employment models for low-, middle- and high educated individuals in the Netherlands, while we controlled for endogeneity of both job accessibility and vehicle ownership in relation to employment probabilities through an instrumental variable approach.

2. Related literature

At least since the 1960 s, the association between transport job accessibility and individual employment outcomes has received considerable attention among scholars in urban economics, transport geography and sociology (e.g. (Kain, 1968; Wachs & Kumagai, 1973). Much of the early research is linked to the seminal work of (Kain, 1968) on the Spatial Mismatch Hypothesis, who argued that a major source accounting for unemployment in US metropolitan areas was to be found in poor access to job opportunities. In the following decades, a large body of empirical studies in mainly US metropolitan areas and in some EU cities has emerged (see (Bastiaanssen et al., 2020) for a review). Many of these studies apply an aggregate, potential-based job accessibility measure that calculates the number of jobs reachable within a certain travel time from an origin area, typically a Census area or Traffic Analyses Zone, and combine this with a (small) population sample to examine the relationship between job accessibility and individual employment probabilities of mainly disadvantaged groups (e.g. Kawabata, 2003; Blumenberg and Pierce, 2014; Smart and Klein, 2015; Bastiaanssen et al., 2021). Although the number of accessible jobs provides an indication of job opportunities, it fails to capture job opportunities that match the skills of different groups. Research in US metropolitan areas but also in some European cities has shown that especially higher skilled jobs in for example the service sector are concentrated in city centres and along major transport corridors, while low-skilled jobs have gradually declined and dispersed to peripheral locations, thereby reducing job opportunities among the typically more disadvantaged groups (Stoll, 2005; Houston, 2005). We therefore focus our literature review more specifically on those studies that accounted for matching job opportunities in their accessibility measures when assessing individual employment outcomes.

Various studies have examined the relationship between job accessibility and individual employment probabilities within US metropolitan areas. A cross-sectional study by Hu (2016) in the Los Angeles metropolitan area examined the effects of job accessibility on the employment status of different income groups. The study sampled long-term residents (>10 years) in order to control for residential endogeneity, finding that higher levels of job accessibility only positively affected employment probabilities of middle income groups, while job accessibility had no statistically significant effects on the employment status of low- or high-income groups. Several other US studies used longitudinal data on welfare recipients, as their residential location is more plausibly exogenous. Cervero et al. (2002) and Sandoval et al. (2011) found that higher levels of public transport accessibility to low-skilled jobs only slightly increased employment probabilities of welfare recipients in Alameda County, California, but not in the car-dominated Los Angeles metropolitan area and in rural San Joaquin, while gaining car access did increase employment prospects in all areas. Another study by Cervero and Tsai (2003) in San Bernardino, California, found no statistically significant effect of public transport accessibility to low-skilled jobs on employment probabilities of welfare recipients, and later studies by Sanchez et al. (2004) and Shen and Sanchez (2005) in various US metropolitan areas also found virtually no association between public transport accessibility to entry-level jobs and employment outcomes of welfare recipients, however car access did strongly increase employment probabilities in all three studies. The findings in these US studies thus seem to suggest that without access to a car it is often difficult for (disadvantaged) job seekers to access employment opportunities, while public transport job accessibility levels may simply be too low to yield differential employment effects.

More recent studies have turned their attention to the less car-dependent European context. A cross-sectional study by Fransen et al. (2019) in Flanders, Belgium, found that higher levels of accessibility to skills-matching job openings within 90 min by car and public transport was associated with decreased long-term unemployment probabilities among job seekers. However, their study did not control for endogeneity in the relationship between job accessibility, car ownership and employment probabilities, and so it remains unclear whether people may have moved to high-accessibility neighbourhoods in order to improve their job chances. Three other cross-sectional studies in metropolitan areas sampled long-term residents (>10 years) to reduce endogeneity. In the Paris metropolitan area, Korsu and Wenglenski (2010) found increased long-term unemployment probabilities among job seekers who could access less than 20 percent of all skills-matching jobs within 60 min by public transport, but found no employment effects for residing in neighbourhoods with higher accessibility levels. Two studies in the Barcelona and Madrid metropolitan areas found that more low-educated jobs reachable per minute by public transport and especially a higher number of households cars could increase employment probabilities of (low-educated) women (Di Paolo et al., 2014; Matas et al., 2010), while men only appeared sensitive to car access (Di Paolo et al., 2014). Two other longitudinal studies in the Paris metropolitan area, however, found that better public transport accessibility to blue-collar jobs within 45 min only yielded a small association with shorter unemployment durations (Gobillon et al., 2011), while job accessibility by public transport or by car had no association with unemployment to-work transitions of public housing tenants (Gobillon and Selod, 2007), yet, both studies did not control for individual car ownership.

The existing empirical evidence on the relationship between transport job access and individual employment probabilities thus clearly indicates that car ownership generally increases individual employment probabilities, while positive employment effects of public transport job accessibility mainly pertains to some disadvantaged groups in some European metropolitan studies. In this study, and in a departure from the existing empirical evidence, we use a unique national employment micro dataset of the *full population* of the Netherlands, segmented by educational level, and combine this with a novel composite public transport-and-bicycle accessibility measure to matching jobs and individual-level vehicle registration data. This allows us to examine differential employment effects of job accessibility by public transport in combination with the bicycle, while controlling for vehicle ownership, for lower and higher educated at the national level.

3. Study area and data

The study area encompasses the Netherlands, a densely-populated country of 18 million people (approx. 520 people/km2) located in Northwestern Europe. The country is characterised by a polycentric spatial structure consisting of a network of compact cities and towns with extensive public transport and bicycle networks. The Randstad area, entailing the four main cities of Amsterdam, Rotterdam, Utrecht and Den Haag, constitutes the most densely populated area in the western part of the country, with approximately half of the population and jobs in just 20 % of the country's area.

To examine the spatial pattern of job opportunities by educational level, we use the National Employment Database for 2020 (Landelijk Informatiesysteem Arbeidsplaatsen, LISA), which entails a yearly census of all registered enterprises in the Netherlands including their location at six-digit postcode area (approx. 387,000 areas at street-level) and the number and industrial classification of jobs (SBI 2008, based on 20 industry sectors). We matched this national employment database with microdata from Statistics Netherlands on the share of workers by educational level (low-, middle- and high-educated workers) in each industry sector by workplace region (40 regions in the Netherlands), in order to categorize all jobs by educational level: jobs held by middle- and high-educated make up 43 % to 44 % of all jobs in the Netherlands, respectively, with 13 % being held by low-educated (see Table 1 in the

Appendix). As shown in the below Fig. 1, job locations for all three educational levels are mainly concentrated in the larger urban areas in the Randstad, but with clear geographical differences.[1] While ‘high-educated’ jobs in sectors such as business services, finance and education are mainly concentrated in and around the cities, in particular ‘low-educated’ jobs in for example construction, manufacturing and transportation sectors are more often located outside the cities. This pattern is reconfirmed by the urbanization levels[2] of job locations: on average, ‘higher educated’ jobs are located in neighbourhoods with a significantly higher urbanization level (on average 2,130 addresses per km2) as compared to ‘low-educated’ jobs (on average 1,650 addresses per km2).

For an initial indication of the extent to which ‘low-educated’ jobs are less accessible than ‘high educated’ jobs, we matched the job locations at the six-digit postcode area with official Dutch national public transport service area statistics,[3] provided by the Netherlands Environmental Assessment Agency (Ontsluitingskwaliteit, PBL). Of all jobs in the Netherlands, on average 35.6 % are located within the service area of public transport, but with clear differences between jobs held by the high- and low educated. While 40.7 % of all ‘high-educated’ jobs fall within the service area of public transport, this only applies to 32.6 % of ‘middle-educated’ jobs and just 30 % of ‘low-educated’ jobs. Even in the Randstad area where on average 44.2 % of all jobs are located within public transport service areas, substantial differences remain between ‘high-educated’ jobs (48.4 % within service areas) compared to 40.9 % and 37.7 % for middle- and low-educated jobs respectively. We therefore conclude (in line with prior studies (e.g. Houston, 2005; Gobillon et al., 2009), that ‘low-educated’ jobs in particular are substantially more often located outside prime accessibility areas which, in turn, may affect job chances of (car-less) low-educated job seekers. In what follows, we examine the precise relationship between job accessibility and individual employment probabilities of different educational groups using (secure-access) national administrative micro datasets for the Netherlands.

4. Methodology

In this section of the paper, we first describe the calculation of our public transport-and-bicycle job accessibility measure. We then combine our accessibility measure with individual-level employment probability models for low-, middle- and high educated workers in the Netherlands, followed by controls for endogeneity in the model.

4.1. Public transport-and-bicycle job accessibility measure

This study applies a novel composite public transport-and-bicycle job accessibility measure that could be consistently applied nationwide, providing the number of accessible jobs by educational level using public transport in combination with the bicycle from each Dutch neighbourhood (there were 13,903 neighbourhoods in the Netherlands in 2020, of about 580 households in each (CBS, 2015)), whilst discounting the attractiveness of jobs with increasing travel times based on the widely used gravity model (Hansen, 1959). The standard gravity-based accessibility formula is implemented, which can be expressed in Eq. (1) as follows:

$$A_{ik} = \sum_j E_{jk} f(T_{ij}) \tag{1}$$

where A_{ik} is the level of public transport-and-bicycle accessibility to employment opportunities by educational level k in neighbourhood i for the morning peak hours (7:00–9:00 am); E_{jk} reflects the number of employment opportunities by educational level k available in destination area j, and $f(T_{ij})$ represents a decay function based on travel times between neighbourhood i and destination area j.

Public transport travel times were calculated using national general transit feed specification (GTFS) data for October 2020 in the GeoDMS© software package, which we used to compute optimal routing algorithms (shortest path) for journeys from each neighbourhood to all PC6 locations (approx. 387,000 employment locations), including access and waiting time to and at a public transport stop/ station, in-vehicle travel time, transfer time and egress times to the destination. To account for variations in public transport frequencies, we calculated the average travel time over 5-minute intervals for the period 7:00 to 9:00 am (morning peak hour), when most people travel to work. OpenStreetMap (OSM) provided a comprehensive topological representation (polygons) of the road, cycling and walking network, including speed limits per road segment. Different from existing studies, our job accessibility measure incorporates cycling as a potential access mode to train stations if this is faster than walking in combination with public transport, as the bicycle is used as an access mode to train stations for 40 % of all train journeys within the Netherlands, and it uses cycling as an alternative for public transport when destinations up to 30 min away (approx. 7,5km) can be reached in less time, which corresponds to the maximum bicycle commute distance in the Netherlands. Bicycle travel times were calculated using nationwide bike app data from National Cycling Weeks matched to the polygons of the OSM cycling network, which allowed us to account for actual bike speeds.

[1] Note that for low-educated jobs we use an adjusted job key to visualise the spatial pattern of job opportunities.

[2] Statistics Netherlands defines urbanization levels based on a neighbourhoods’ residential address density/km2.

[3] PBL classifies all six-digit postcode areas in the Netherlands by public transport service area: within 500 m from bus, tram or metro, and/or within 1,000 m of a local train station and/or within 1,500 m of an intercity train station.

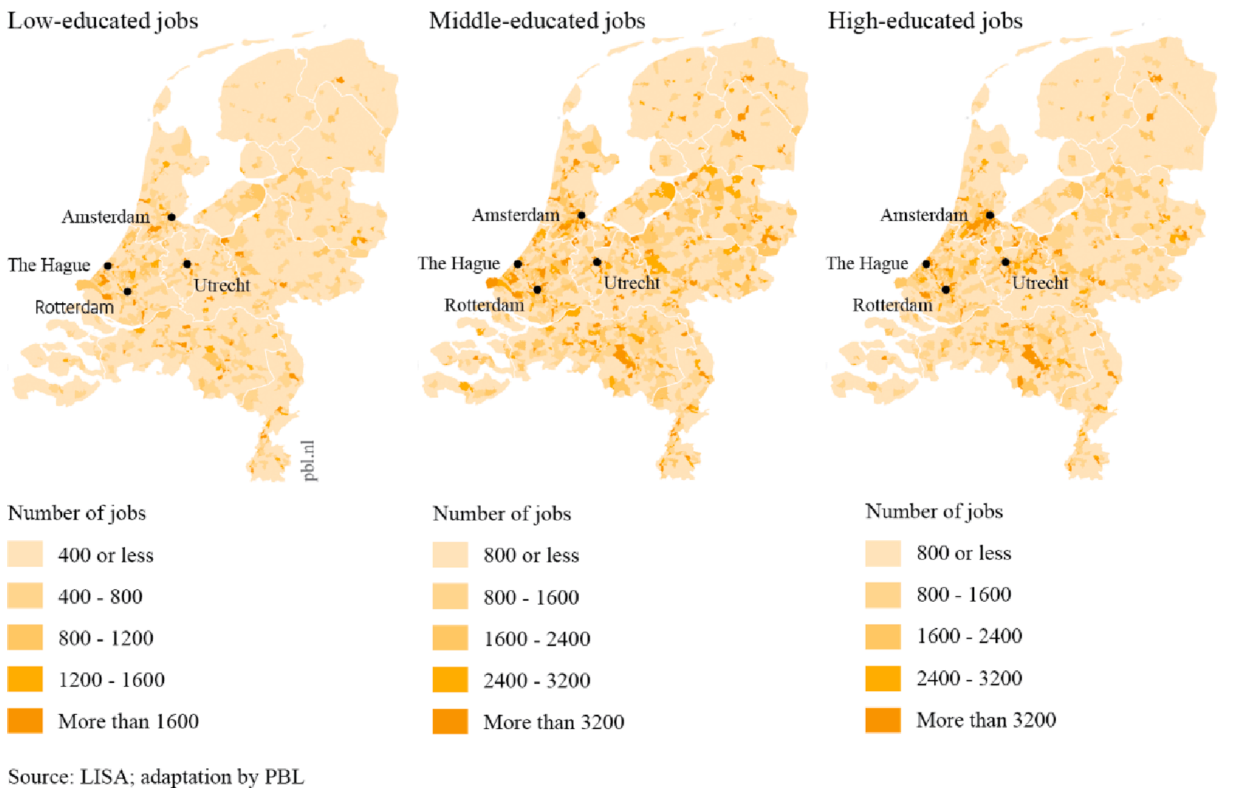

Fig. 1. Jobs by educational level per neighbourhood, 2020.

We combined the travel time datasets with our reworked National Employment Database for 2020 (as discussed in section 3), which provides all jobs in the Netherlands by educational level (low-, middle- and high-educated) at the PC6 location.[4] We calculated our public transport-and-bicycle job accessibility measure using a gravity model (Hansen, 1959), in which jobs are discounted through an impedance function based on travel time. The impedance function was estimated based on a (best fit) log-logistic formulation (see also Geurs & van Eck, 2001) using empirically observed trip travel times of public transport commuters in the Dutch National Travel Survey 2018–2019. A single impedance function was estimated in order to impose comparability between the educational groups (see also Pritchard et al. 2019 for discussion), as follows:

$$f(T_{ij}) = 1/(1 + \exp(a + b^* ln(T_{ij}) + c^* T_{ij})) \quad (2)$$

where T_{ij} is the travel time between neighbourhood i and PC6 employment location j, and a, b and c are estimated parameters at −12,979, 2,984 and 0,018, respectively (Appendix Graph 1 provides a plot of the estimated impedance function).

4.2. Employment probability models

We next combine our job accessibility measure with individual-level employment probability models for low-, middle- and high educated workers in the Netherlands. In an important departure from existing empirical studies, which all relied on small sample-based datasets, we use a cross-sectional administrative employment micro dataset of the *full population* of the Netherlands and combine this with our job accessibility measure and a national individual-level vehicle registration dataset. The size of our dataset reduces the risk of sampling errors and therefore reinforces the robustness of our employment estimates.

Following previous studies (e.g. (Bastiaanssen et al., 2021; Matas et al., 2010), we employed binomial probit models to explain this relationship, which can be conceptually expressed as follows:

$$EP_{lk} = f(A_{i(l)k}, V_l, I_l, N_{i(l)}) \quad (3)$$

where EP_{lk} represents the employment probability for individual l (1 = employed, 0 = not-employed) by educational level k as a

[4] Note that our accessibility measure does not include jobs in neighbouring countries as the share of the Dutch labour force working in Belgium or Germany is minimal (CBS/PBL. (2015). Arbeidsmarkt zonder grenzen. [Labour market without boundaries] *Statistics Netherlands/ Netherlands Environmental Assessment Agency, The Hague.*

function of: $A_{i(l)k}$ representing public transport-and-bicycle accessibility to jobs by educational level k in neighbourhood i for individual l; V_l is household vehicle ownership by individual l; I_l are individual and household characteristics for individual l; and $N_{i(l)}$ are characteristics of neighbourhood i for individual l.

All variables were constructed from national administrative micro datasets, derived from the Dutch Social Statistical Datasets for 31 December 2020 (Sociaal Statistische Bestanden, SSB), which was accessed by special permission from Statistics Netherlands (CBS). Our micro dataset covers all working-age individuals (18–67 years old) in the Netherlands and includes detailed individual and household characteristics, such as educational level, employment status, and residential neighbourhood. Since unemployment status is not registered in the administrative datasets, we identified those in the labour force but not in work by excluding students and those receiving pensions or benefits due to work-impeding illnesses or incapacity to work.

Table 1 shows the variables that are included as dummy or continuous variables in our employment models. Low-educated individuals are considerably less often employed as compared to middle- and in particular high-educated individuals, and so we hypothesise that they will be more sensitive to higher levels of public transport-and-bicycle accessibility to matching job opportunities.

Age is expected to decrease individual employment probabilities as employment levels in the Netherlands gradually decrease with increasing age. This age effect is assumed to diminish with each additional year beyond a certain age as reflected by the age squared variable, which we divided by 100 to normalise coefficients. Employment prospects of women are likely to be lower than men, in particular among lowed educated groups, which follows from their relatively higher unemployment rates.

Being a non-Western migrant, which is considerably more prevalent among the lower educated, is expected to decrease employment prospects as it is attached to higher overall job competition, while discrimination may also affect their employment outcomes. We also included a dummy variable for unemployment history (having received unemployed benefits in the past 5 years), which is likely to decrease employment prospects as it may make individuals less attractive for employers.

The number of dependent children (aged <12) in the household is further expected to reduce employment prospects due to increased caring responsibilities. We further assess the differential effects of being a single household or single parent household, which are likely to increase financial constraints and decrease the size of the social networks that can be used for job search.

As a measure of residential segregation, we constructed a neighbourhood variable based on the percent unemployed (excluding those in education) in each neighbourhood, as increased job competition and adverse social effects are expected to decrease employment prospects.

We subsequently matched our public transport-and-bicycle job accessibility measure under Secure Lab conditions to each individuals' residential neighbourhood and divided these by 1,000,000 to normalise coefficients. We further included information from a national vehicle registration dataset of 2020 from the Netherlands Vehicle Authority (RDW, 2020) to identify individuals with household access to a car, van or motorcycle. As this dataset only registers legal ownership of a vehicle, regardless of which household member uses the vehicle, we assigned each individual a dummy variable based on their access to a household vehicle.

4.3. Controlling for endogeneity

As discussed in the literature review, we needed to control in our models for endogeneity in the relationship between public transport-and-bicycle job accessibility, vehicle ownership and individual employment probabilities. Some studies have been able to utilise panel data or other longitudinal datasets to tease out endogeneity (see e.g. (Blumenberg, 2008; Gurley & Bruce, 2005). Due to the cross-sectional nature of our national dataset we apply an instrumental variable (IV) approach, which uses third variables (i.e. instruments) that are correlated with our endogenous explanatory variables (i.e. our job accessibility and car ownership variables), but not with our outcome variable (individual employment probabilities).

Following previous studies (see e.g. (Bastiaanssen et al., 2021; Hu & Giuliano, 2014), we created an instrumental variable based on the population density in each neighbourhood (people/km2) as an instrument for public transport-and-bicycle job accessibility. While public transport job accessibility levels are generally highest in (urban) areas with high population densities, within the context of the Netherlands these areas also tend to have the lowest employment levels due to the historic concentration of low-income and social housing: on average, employment rates by urbanization level vary from 89 % in very high urban areas up to 97 % in rural areas. The Pearson correlation coefficient between population density and our public transport-and-bicycle job accessibility was statistically significant and strong at 0.7 in our employment models, while the correlation coefficient between population density and individual employment status was very weak (−0.09) and insignificant. Further, following a study by Hu (2016), we created an instrumental variable for household vehicle ownership based on the share of households with one or more vehicles in each neighbourhood. The Pearson correlation coefficient between household vehicle ownership and the share of households with vehicle access in each neighbourhood is moderate at 0.4 and statistically significant, while the correlation coefficient between the share of households with vehicle access and individuals' employment status is insignificant. We also experimented with instruments based on car insurance premiums as applied by (Raphael & Rice, 2002) and with road infrastructure density, but these instruments proved insignificant.

To assess the impact of job accessibility and vehicle ownership on individual employment probabilities, each employment model estimated with the IV-approach was estimated in two stages. In the first stage model accessibility $A_{i(l)k}$ and household vehicle access V_l were estimated as a function of all individual and household variables I_l and the neighbourhood variable $N_{i(l)}$, plus our instrumental variables. In the second stage model, employment is estimated as a function of all I_l and $N_{i(l)}$ variables plus the predicted job accessibility and vehicle ownership values, $A_{i(l)k}$ and V_l, from the first stage regressions. The Wald Chi-Squared statistics of exogeneity for each employment model indicates whether we can reject the null hypothesis of exogeneity (P value <0.05) and report the estimates from the two-stage model, which uses the estimated public transport-and-bicycle job accessibility measure and household vehicle ownership from the first stage model.

Table 1
Descriptive statistics and expected effects of employment models.

Variables	Continuous or dummy measure	Mean (SD)			Expected effects
		Low educated	**Middle educated**	**High educated**	
Dependent variable					
Employed (1); not-employed (0)		0.827 (0.379)	0.951 (0.216)	0.970 (0.170)	
Individual & Household variables					
Age	*(continuous)*	45.220 (13.798)	40.784 (13.865)	41.657 (12.008)	−
Age squared/100	*(continuous)*	22.352 (11.700)	18.556 (11.408)	18.795 (10.354)	−
Female	*(dummy)*	0.457 (0.498)	0.470 (0.499)	0.502 (0.500)	−
Non-Western migrant	*(dummy)*	0.248 (0.432)	0.126 (0.334)	0.109 (0.312)	−
Unemployment history	*(dummy)*	0.129 (0.335)	0.084 (0.276)	0.059 (0.236)	−
Young children < age 12	*(continuous)*	0.551 (7.164)	0.449 (3.871)	0.514 (1.786)	−
Single household	*(dummy)*	0.203 (0.402)	0.163 (0.369)	0.183 (0.386)	−
Single parent household	*(dummy)*	0.112 (0.316)	0.092 (0.289)	0.054 (0.227)	−
Neighbourhood & accessibility variables					
Percent neighbourhood unemployment	*(continuous)*	0.086 (0.073)	0.068 (0.058)	0.065 (0.057)	−
PT-and-bicycle job accessibility/1,000,000	*(continuous)*	0.042 (0.035)	0.133 (0.111)	0.243 (0.197)	+
Household vehicle ownership	*(dummy)*	0.760 (0.427)	0.858 (0.349)	0.798 (0.401)	+
N		1,036,757	2,881,186	2,745,830	

5. Results

Fig. 2 shows the spatial patterns of public transport-and-bicycle accessibility levels to jobs by educational level.[5] The darker neighbourhoods represent higher levels of job accessibility, implying that people residing in these areas have greater access to jobs and, hence, will be more likely to gain employment than those living in low-accessibility neighbourhoods. The accessibility patterns reflect the large concentration of employment in the Randstad area and in the cities, which gradually decreases outwards to the periphery. While middle- and high-educated jobs constitute an equal share of all jobs in the Netherlands, accessibility to high-educated jobs is on average almost 1,5 times higher (see also Table 1), which follows from the larger concentration of these jobs near the city centres where the public transport and bicycle network is more extensive. Accessibility to low-educated jobs, on the other hand, is considerably lower due to much fewer job opportunities, but also because these are more often located outside the prime accessibility areas as we have shown in section 3. Due to these substantial disparities in job accessibility, we hypothesize that higher levels of job accessibility will yield larger positive differential effects on employment probabilities of low-educated individuals. We next examine this relationship, by combining our job accessibility measure with individual-level employment probability models, segmented by educational level, for the Netherlands.

Table 2 presents our employment probability models for low-, middle- and high-educated individuals in the Netherlands. From the resulting Wald Chi-Squared statistics of exogeneity, we reject the null hypothesis (i.e. we treat job accessibility and vehicle ownership as endogenous with employment) and use the estimates from the two-stage models which use the predicted values of job accessibility and vehicle ownership from the first stage models (Appendix Table 2 provides results of the first-stage regression). The reported Gragg-Donald Wald F statistics are all greater than the Stock-Yogo weak ID critical value of 7.03 and therefore we can infer weak instrument robustness. From the underidentification test Chi-squared statistics we can further reject the null-hypothesis that the instruments have insufficient explanatory power to predict our endogenous variables, i.e. there is no problem with underidentification of our instruments. The employment models without IV-approach are provided in the Appendix (Table 3). These single-stage probit models provide a similar pattern, but show that the job accessibility coefficients slightly increased in absolute value when applying the IV-approach to the models for low- and middle educated, i.e. they are biased downwards in the single-stage probit models. The opposite effect holds for the model for high educated, indicating that the single-stage probit model is slightly biased upwards.[6]

The results indicate that among the individual level variables, a higher age slightly improves individual employment probabilities among low- and high educated individuals, which may be explained by the larger share of young people that are unemployed. This effect diminishes with each additional year of age, as indicated by the negative coefficient for age squared/100. Being a female but especially being a non-western migrant also decreases employment probabilities, in particular among the low educated. While unemployment history also strongly decreases employment prospects, the negative effect increases with a higher level of education.

Of the household variables, having more dependent children only slightly decreases employment prospects, as caring responsibilities may constrain access to employment, while being single or a single parent household is clearly associated with lower individual employment probabilities among all groups.

The percentage unemployed in each neighbourhood significantly decreases employment prospects among all groups, which may

[5] Note that for low-educated jobs we use an adjusted job key to visualise the spatial pattern of job accessibility.

[6] This bias can work in either direction. Our finding on the low and middle educated reflects *meta*-analysis work undertaken by Melo et al. (2013) on the relationship between output and transport infrastructure investment, where they find studies using IV-techniques yield higher elasticities (i.e. downward bias). Johnson et al. (2017) in an aggregate estimation of the link between employment and public transport accessibility also found some evidence of a downward bias when comparing IV-models to single equation models.

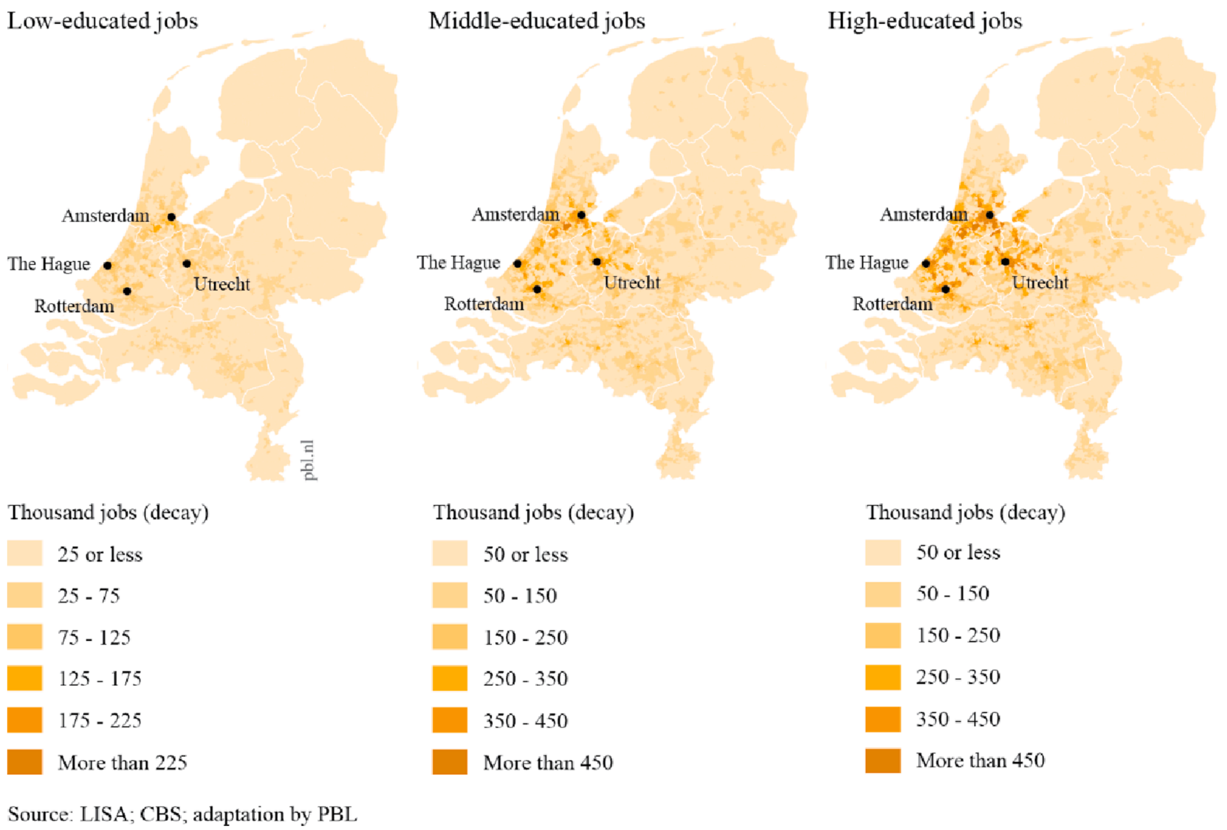

Fig. 2. Public transport-and- bicycle accessbility to jobs by educational level, 2020.

relate to higher competition for fewer job opportunities and adverse social effects related to deprived neighbourhoods (see e.g. (Gobillon & Selod, 2007).

Our public transport-and-bicycle job accessibility measure yields a significant and positive coefficient in all employment models. We derived employment elasticities to show changes in individual employment probabilities based on a 10 % increase in job accessibility levels.[7] In line with other Spatial Mismatch studies, we find the highest employment elasticity among low educated individuals, where a 10 % increase in public transport-and-bicycle job accessibility yields an employment elasticity of 0.003, which relates to a 0.03 % increase in the employment rate. We further find that middle- and high educated individuals could also benefit from higher job accessibility levels, albeit at an increasingly smaller rate, yielding employment elasticities of 0.002 and 0.001, respectively. Their substantially higher vehicle ownership and employment rates are likely to make them less sensitive to job accessibility changes.

Our household vehicle ownership variable shows a similar pattern, for which we derived marginal effects of vehicle ownership on employment probability.[8] The uplift on employment probability from household vehicle ownership is highest among low educated individuals, yielding a marginal effect size of 0.021, which clearly indicates that they could benefit from vehicle access. Again, for middle- and high educated individuals we also find that the uplift on employment probability from vehicle ownership is significant, but yielding increasingly lower marginal effect sizes of 0.007 and 0.004 with higher education levels.

6. Conclusions and policy implications

The aim of this paper has been to assess patterns of accessibility to jobs by educational level and to examine the relationship with employment probabilities of low-, middle- and high educated individuals within the context of the Netherlands. The usage of a *national* administrative employment micro dataset of the full population in combination with a novel composite public transport-and-bicycle accessibility measure to matching jobs and individual-level vehicle registration data is unique to this study. In our employment models, we control for endogeneity of both job accessibility and vehicle ownership in relation to employment status by applying an

[7] Employment elasticities were calculated in STATA 15 using the model coefficients for the average individual in the models, in which we increased the estimated public transport-and-bicycle job accessibility levels by 10% while keeping all other variables constant.

[8] Marginal effects of vehicle ownership on employment were calculated in STATA 15 using the model coefficients for the average individual in the models, in which we increased vehicle ownership from 0 to 1, i.e. the percentage uplift on employment expected from vehicle ownership.

Table 2
IV-Probit models of individual employment probabilities by educational level.

Variables	Coefficients (SE)			Elasticities: +10 % accessibility / Margin. effect vehicle
	Low educated	Middle educated	High educated	
Dependent variable				
Emp. (1); not-emp. (0)				
Individual & Household variables				
Age	−0.007*** (0.001)	−0.026*** (0.001)	−0.012*** (0.001)	
Age squared/100	−0.010*** (0.001)	−0.011*** (0.001)	−0.007*** (0.001)	
Female	−0.315*** (0.005)	−0.062*** (0.003)	0.001 (0.003)	
Non-Western migrant	−0.597*** (0.006)	−0.423*** (0.003)	−0.522*** (0.004)	
Unemployment history	−0.861*** (0.009)	−1.199*** (0.006)	−1.281*** (0.004)	
Young children (< age 12)	−0.006*** (0.000)	−0.015*** (0.000)	−0.021*** (0.001)	
Single household	−0.238*** (0.020)	−0.255*** (0.012)	−0.345*** (0.015)	
Single parent household	−0.370*** (0.022)	−0.380*** (0.006)	−0.284*** (0.007)	
Neighbourhood & accessibility variables				
Percent unemployed	−2.317*** (0.012)	−2.340*** (0.024)	−2.125*** (0.027)	
Estimated PT-and-bicycle job accessibility/ 1,000,000	1.579*** (0.136)	0.714*** (0.040)	0.245** (0.049)	**0.003 | 0.002 | 0.001**
Estimated Household vehicle ownership	1.228*** (0.049)	1.042*** (0.038)	0.238*** (0.058)	**0.021 | 0.007 | 0.004**
Constant	0.473*** (0.055)	2.318*** (0.043)	2.895*** (0.039)	
Wald Chi-Squared statistic	337,182.62***	369,802.47***	180,313.10***	
Wald Chi-Squared statistic of exogeneity	107.67***	177.12***	6.52*	
Under-id Chi-squared test	7,304.47***	37,284.03***	19,076.64***	
Gragg-Donald Wald F stat	3,669.06	18,818.38	9,593.076	
N	1,036,757	2,881,186	2,745,830	
Mean PT-and-bicycle job accessibility	42,302	132,695	242,771	
25th percentile	13,639	44,454	71,163	
75th percentile	63,814	196,424	382,064	

Significance levels: *: 0.05 % **: 0.01 % ***: 0.001 %.

instrumental variable approach, which showed that job accessibility and vehicle ownership were a significant but endogenous determinant of employment. The accessibility coefficients were also consistently lower in the (single-stage) probit models for low- and middle educated as compared to our IV-probit models, while being higher in the probit model for higher educated, which indicates that not adequately controlling for endogeneity underestimates the effect of job accessibility on employment probabilities for low- and middle educated while overestimating these effects for higher educated.

While the association between job accessibility and employment outcomes has mainly been studied in relation to the Spatial Mismatch Hypothesis (Kain, 1968) in US metropolitan areas and, more recently, in some European cities, The Netherlands, as many other western countries, has also experienced a strong decentralisation of employment and amenities to peripheral locations near motorways, which are often poorly served by traditional public transport services and difficult to reach by bicycle. Our empirical analyses have clearly shown that in particular low-educated jobs are often located outside prime accessibility areas, thereby limiting accessibility to job opportunities for low-educated individuals: only 30 % of all low-educated jobs fall within the catchment area of public transport, as compared to nearly 41 % of all high-educated jobs.

The empirical findings of our employment models further demonstrate that higher levels of public transport-and-bicycle job accessibility levels could increase individual employment probabilities, in particular among low-educated individuals: a 10 % increase in public transport-and-bicycle job accessibility, keeping all other variables constant, yielded an employment elasticity of 0.003. We further found an uplift on employment probability from household vehicle ownership of 0.021, which indicates that low educated groups could also substantially benefit from access to vehicles. In contrast with previous Spatial Mismatch studies (Bastiaanssen et al., 2021), however, we also found that middle- and high educated individuals could benefit from higher public transport-and-bicycle accessibility to matching jobs and vehicle ownership, but yielding increasingly smaller effect sizes with higher educational levels. The substantially higher job accessibility levels and employment rates are likely to make middle- and higher educated less sensitive to job accessibility changes.

The usage of detailed job accessibility measures and micro datasets of the entire population thus seem essential to accurately assess the relationship between job accessibility and individual employment probabilities, which may not be fully captured by the small population samples used in prior studies.

The empirical results of our study imply that employment probabilities of Dutch job seekers could be improved by providing higher levels of job accessibility and vehicle access, but targeted policy interventions in particular among lower educated groups without access to private vehicles would be needed to achieve this outcome. In turn, this could increase both the participation in society and the full utilization of the potential labour force, as previously referred to by the Dutch Council for the Environment and Infrastructure (Rli, 2020).

As our public transport-and-bicycle job accessibility measure reflects the quality of both the transport and land use system, an increase in job accessibility levels could potentially be achieved through improvements in availability, reliability, routing, speeds and frequencies of transport services, especially to low-skilled job locations outside the prime accessibility areas. The affordability of public transport fares and vehicle-related costs also affect accessibility, especially among lower income groups, which could therefore also be explicitly taken into account when implementing price policies. The combined use of the bicycle and train network in the Dutch context substantially increases the geographical range by bicycle and door-to-door accessibility by train (Kager et al., 2016), yet, the bicycle is mainly used as an access mode to train stations. Further improvements of the bicycle network and better connections to smaller train stations, metro-, tram- and bus stops could enhance public transport-and-bicycle accessibility (see also (Geurs et al., 2016; Martens, 2004)). In addition, the e-bike also offers opportunities for improving accessibility, but bicycle facilities adapted to the higher speeds of the e-bike and secure parking facilities near employment and residential locations are crucial to give the e-bike a full-fledged role in facilitating accessibility.

While vehicle access can also clearly improve employment probabilities of disadvantaged job seekers, their limited financial resources may not allow them to purchase or maintain vehicles. However, vehicle donation programs in the US (Lucas & Nicholson, 2003) and transport hiring schemes through the ‘Wheels to Work’ programs in the UK (Lucas et al., 2009) have shown to improve people’s access to, and probability of, employment.

As the decentralisation of employment over the past decades to locations in the urban periphery and near highways has often made it more difficult for people without private vehicles to access job opportunities, making better use of locations near urban centres and around public transport hubs for employment developments could also help over the longer term to improve people’s accessibility to, and probability of, employment. Housing development at such locations can also contribute to accessibility by connecting to the existing bicycle and public transport infrastructure. We have shown that this is particularly important for low-educated groups, also given that matching job opportunities are often located outside prime accessibility areas. It would require further case study research to establish which specific transport and land use interventions would derive the greatest benefit.

CRediT authorship contribution statement

Jeroen Bastiaanssen: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. **Daniel Johnson:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Karen Lucas:** Conceptualization, Supervision, Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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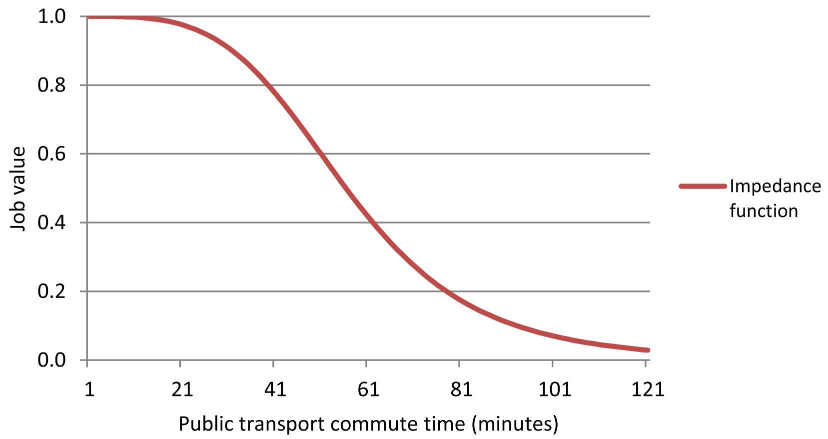
Appendix

Table 1
Jobs by educational level per industry sector.

	Low educated	Middle educated	High educated
A Agri., forestry & fishing	21 %	54 %	25 %
B Mining	8 %	37 %	55 %
C Manufacturing	22 %	46 %	32 %
D Electricity, gas	4 %	36 %	60 %
E Water supply	20 %	50 %	30 %
F Construction	22 %	59 %	19 %
G Wholesale and retail	18 %	54 %	28 %
H Transportation	23 %	54 %	23 %
I Accommodation and food	24 %	57 %	19 %
J Information & commun.	4 %	27 %	69 %
K Financial institutions	3 %	24 %	73 %
L Real estate	7 %	37 %	56 %
M Business services	4 %	24 %	72 %
N Business support	24 %	48 %	28 %
O Public administration	6 %	34 %	61 %
P Education	3 %	16 %	81 %
Q Health	8 %	46 %	47 %
R Culture, sports and recr.	9 %	36 %	55 %
S Other services	14 %	50 %	37 %
Average all sectors	**13 %**	**43 %**	**44 %**



Graph 1. Log-logistic impedance function

Table 2
IV-probit models by educational level with first stage and second stage regression.

Variables	Coefficients (SE)									Elasticities: +10 % accessibility / Margin. effect vehicle
	Low educated			Middle educated			High educated			
	1st stage *(access.)*	1st stage *(vehicle.)*	2nd stage *(emp.)*	1st stage *(access.)*	1st stage *(vehicle.)*	2nd stage *(emp.)*	1st stage *(access.)*	1st stage *(vehicle.)*	2nd stage *(emp.)*	
Individual & Household variables										
Age	0.000***	0.004***	−0.007***	0.000***	0.004***	−0.026***	0.003***	0.013***	−0.012***	
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	
Age squared/100	−0.000***	−0.003***	−0.010***	−0.000***	−0.003***	−0.011***	−0.004***	−0.011***	−0.007***	
	0.000	(0.000)	(0.001)	0.000	(0.000)	(0.001)	0.000	(0.000)	(0.001)	
Female	0.000	−0.053***	−0.315***	0.001***	−0.013***	−0.062***	0.000	0.020***	0.001 (0.003)	
	(0.000)	(0.001)	(0.005)	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)		
Non-Western migrant	0.008***	−0.092***	−0.597***	0.036***	−0.032***	−0.423***	0.044***	−0.039***	−0.522***	
	(0.000)	(0.001)	(0.006)	(0.000)	(0.001)	(0.003)	(0.000)	(0.001)	(0.004)	
Unemployment history	−0.001***	−0.095***	−0.861***	−0.004***	−0.074***	−1.199***	−0.007***	−0.015***	−1.281***	
	(0.000)	(0.001)	(0.009)	(0.000)	(0.001)	(0.006)	(0.000)	(0.001)	(0.004)	
Young children (< age 12)	0.000***	0.002***	−0.006***	0.000***	0.001***	−0.015***	0.002***	0.003***	−0.021***	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	
Single household	−0.001***	−0.382***	−0.238***	−0.000***	−0.280***	−0.255***	−0.004***	−0.255***	−0.345***	
	(0.000)	(0.001)	(0.020)	(0.000)	(0.000)	(0.012)	(0.000)	(0.001)	(0.015)	
Single parent household	0.001***	−0.203***	−0.370***	0.005***	−0.113***	−0.380***	−0.002***	−0.081***	−0.284***	
	(0.000)	(0.001)	(0.022)	(0.000)	(0.001)	(0.006)	(0.000)	(0.001)	(0.007)	
Neighbourhood & accessibility variables										
Percent unemployed	−0.688***	−0.099***	−2.317***	−0.263***	0.298***	−2.340***	−0.560***	0.501***	−2.125***	
	(0.000)	(0.006)	(0.012)	(0.001)	(0.004)	(0.024)	(0.000)	(0.004)	(0.027)	
Population density (people/km2)	0.037***	−0.033***		0.135***	−0.061***		0.165***	−0.080***		
	(0.000)	(0.001)		(0.000)	(0.001)		(0.000)	(0.000)		
Estimated PT-and-bicycle job accessibility/ 1,000,000			1.579***			0.714***			0.245** (0.049)	**0.003 | 0.002 | 0.001**
			(0.136)			(0.040)				
Share of households without vehicles per neighbourhood	−0.092***	0.524***		−0.278***	0.629***		−0.509***	0.680***		
	(0.000)	(0.004)		(0.000)	(0.002)		(0.001)	(0.002)		
Estimated Household vehicle ownership			1.228***			1.042***			0.238***	**0.021 | 0.007 | 0.004**
			(0.049)			(0.038)			(0.058)	
Constant	0.080***	0.495***	0.473***	0.260***	0.425***	2.318***	0.410***	0.093***	2.895***	
	(0.000)	(0.004)	(0.055)	(0.001)	(0.002)	(0.043)	(0.001)	(0.003)	(0.039)	
Wald Chi-Squared statistic			337,182.62***			369,802.47***			180,313.10***	
Wald Chi-Squared statistic of exogeneity			107.67***			177.12***			6.52*	
Under-id Chi-squared test	9,041.14***	7,339.02***	7,304.47***	45,344.44***	37,658.20***	37,284.03***	20,182.62***	19,193.67***	19,076.64***	
Gragg-Donald Wald F stat	9,041.08	7,338.96	3,669.06	45,344.31	37,658.09	18,818.38	20,182.54	19,193.60	9,593.076	
N	1,036,757			2,881,186			2,745,830			
Mean PT-and-bicycle job accessibility	42,302			132,695			242,771			
25th percentile	13,639			44,454			71,163			
75th percentile	63,814			196,424			382,064			
Mean employment rate %	*82.7 %*			*95.1 %*			*97.0 %*			
Mean hh vehicle ownership %	*76.0 %*			*85.8 %*			*79.8 %*			

Significance levels: *: 0.05 %, **: 0.01 %, ***: 0.001 %.

Table 3
Probit models individual employment probabilities by educational level.

Variables	Coefficients (SE)			Elasticities: +10 % accessibility / Margin. effect vehicle
	Low educated	Middle educated	High educated	
Dependent variable				
Emp. (1); unemp. (0)				
Individual & Household variables				
Age	−0.005*** (0.001)	−0.025*** (0.001)	−0.014*** (0.001)	
Age squared/100	−0.012*** (0.001)	0.010*** (0.001)	−0.005*** (0.001)	
Female	−0.343*** (0.003)	−0.067*** (0.003)	−0.002 (0.004)	
Non-Western migrant	−0.642*** (0.003)	−0.417*** (0.003)	−0.522*** (0.004)	
Unemployment history	−0.916*** (0.003)	−1.241*** (0.003)	−1.280*** (0.004)	
Young children (< age 12)	−0.005*** (0.000)	−0.014*** (0.000)	−0.024*** (0.001)	
Single household	−0.415*** (0.004)	−0.372*** (0.003)	−0.313*** (0.004)	
Single parent household	−0.465*** (0.004)	−0.425*** (0.004)	−0.274*** (0.006)	
Neighbourhood & accessibility variables				
Percent unemployed	−2.960*** (0.020)	−2.416*** (0.020)	−2.103*** (0.026)	
PT-and-bicycle job accessibility/ 1,000,000	0.790*** (0.042)	0.230*** (0.012)	0.338*** (0.009)	**0.002 | 0.001 | 0.002**
Household vehicle ownership	0.801*** (0.003)	0.645*** (0.003)	0.363*** (0.004)	**0.021 | 0.007 | 0.005**
Constant	1.893*** (0.014)	2.731*** (0.014)	2.822*** (0.023)	
Wald Chi-Squared statistic	441,087.40***	451,428.72***	201,740.13***	
Pseudo R2	0.3008***	0.2905***	0.2244***	
N	1,036,757	2,881,186	2,745,830	

Significance levels: *: 0.05 % **: 0.01 % ***: 0.001 %.

Data availability

The data that has been used is confidential.

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