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ABSTRACT

Investment in railways, and transport infrastructure in general, are often motivated because they are believed to improve peoples' accessibility to jobs. By linking together and increasing the size of labour markets, the matching between individuals and jobs is improved, and the productivity increases. Communities and municipalities lobby for investments that lead to higher accessibility and those that are successful often see inflows of people as a consequence. This paper looks at the entire Swedish railway network, at the level of service of each station and at the connectivity among stations during the morning peak hour, considering different time bands. Causal inferences between job accessibility levels and socio-demographic features are explored and disclosed, looking at the longitudinal impacts of railway investments over 4 years (from 2011 to 2014) on annual wages. Estimating a fixed effects model, very small effects on wages have been found with the increase in the number of jobs around accessible rail stations. These preliminary results indicate that additional jobs along the rail network seem to have a marginal effect. The findings of this analysis, if communicated to planners, may assist them in assessing and predicting the effects of future railway measures to implement over the Swedish territory.

1. Introduction

One of the reasons that motivates transport infrastructure and service improvements is that they are supposed to promote the overall economic development, essentially by reducing transport associated costs (time and/or distances) and increasing accessibility levels (Deng, 2013). In turn, this can enable redistribution of employment, as access is opened to opportunities located in other places (Knowles and Ferbrache, 2016). It can also entail the creation of new jobs, and the decision of some workers to cover longer distances while maintaining similar commuting times, indirectly improving labour market productivity and expansion (Pooley et al., 2005).

The concept of accessibility can be expressed as a measure of potential opportunities (Hansen, 1959). Which are these opportunities, and how they can be reached, is a peculiarity of each studied context; accordingly, several ways to compute accessibility are possible, and a variety measures can be used (Bhat et al., 2002). However, the parameters included in the final indicators mainly refer to travel times, travel costs, travel distances, contour measures, accessible regions, and/or potential accessibility (Gutiérrez et al., 1996; Gutiérrez, 2001; Geurs and van Wee, 2004; Coto-Millán et al., 2007; Cheng et al., 2014).

In this study, the opportunities we are looking at are jobs that can be potentially reached in different travel time bands. As mentioned above, job accessibility is a proxy for economic mobility and a crucial component that can allow understanding underlying social dynamics that may explain (or support) previous (or future) transport infrastructure investments. Previous research has deeply dealt with these issues. In particular, look at the studies of Cheng and Bertolini (2013), Le Vine et al. (2013), Chen et al. (2014), Lin et al. (2014), Karou and Hull (2014), Wang and Chen (2015), where different job accessibility concepts have been comprehensively reviewed, together with their calculations. These are examples in which potential jobs located within a certain travel time/distance, in addition to the connected transportation impedance, are the two main factors that have been taken into account to assess job accessibility.

When it comes to the specific transport mode used to reach jobs opportunities on the network, this paper deals with the Swedish railways. Findings from previous studies indicate that the accessibility of a railway station can be a factor in determining if the train is chosen or not as transport alternative (Hine and Scott, 2000; Wardman and Tyler, 2000). In other words, if a worker resides near a railway station and potential jobs are located close to other railway stations that are connected through the network, chances are that rail will be a useful transport mode. The purpose of this study is twofold:

- To investigate the railway job accessibility in Sweden in relation to annual wage, while controlling for socio-economic factors.
- To assess the longitudinal economic impacts (from 2011 and 2014) of railway investments and railway network design on the Swedish population living close to train stations.

The method developed in this paper builds on workshop 6 at Thredbo 15, which identified a need for more longitudinal studies in this context. We hope that this preliminary study could be the first of a series of more extended and detailed investigations, relevant to transport planners in order assist them in assessing and predicting effects of future railway measures to be developed on the Swedish territory.

The remainder of the paper is organised as follows: Section 2 describes material and methods, introducing the Swedish railway network, the databases that have been used, and an outline of the followed approach. Section 3 presents theory, calculations and data description, leading to Section 4 where the actual results are provided, followed by a discussion. Section 5 includes some conclusive remarks and possible future research directions to expand the impact of the proposed approach.

2. Material and methods

2.1 The Swedish context

Since this study focuses on the jobs accessible through the railway network in Sweden, this subsection provides a short description of the Swedish context. The Swedish railway network consists of over 1,200 stations covering mostly the southern part of the country as can be seen in Figure 1. Of these, about 550 stations have frequent passenger services that can be used for commuting. This network currently consists of about 16,500 km of tracks, mostly (about 80%) electrified single-track lines.

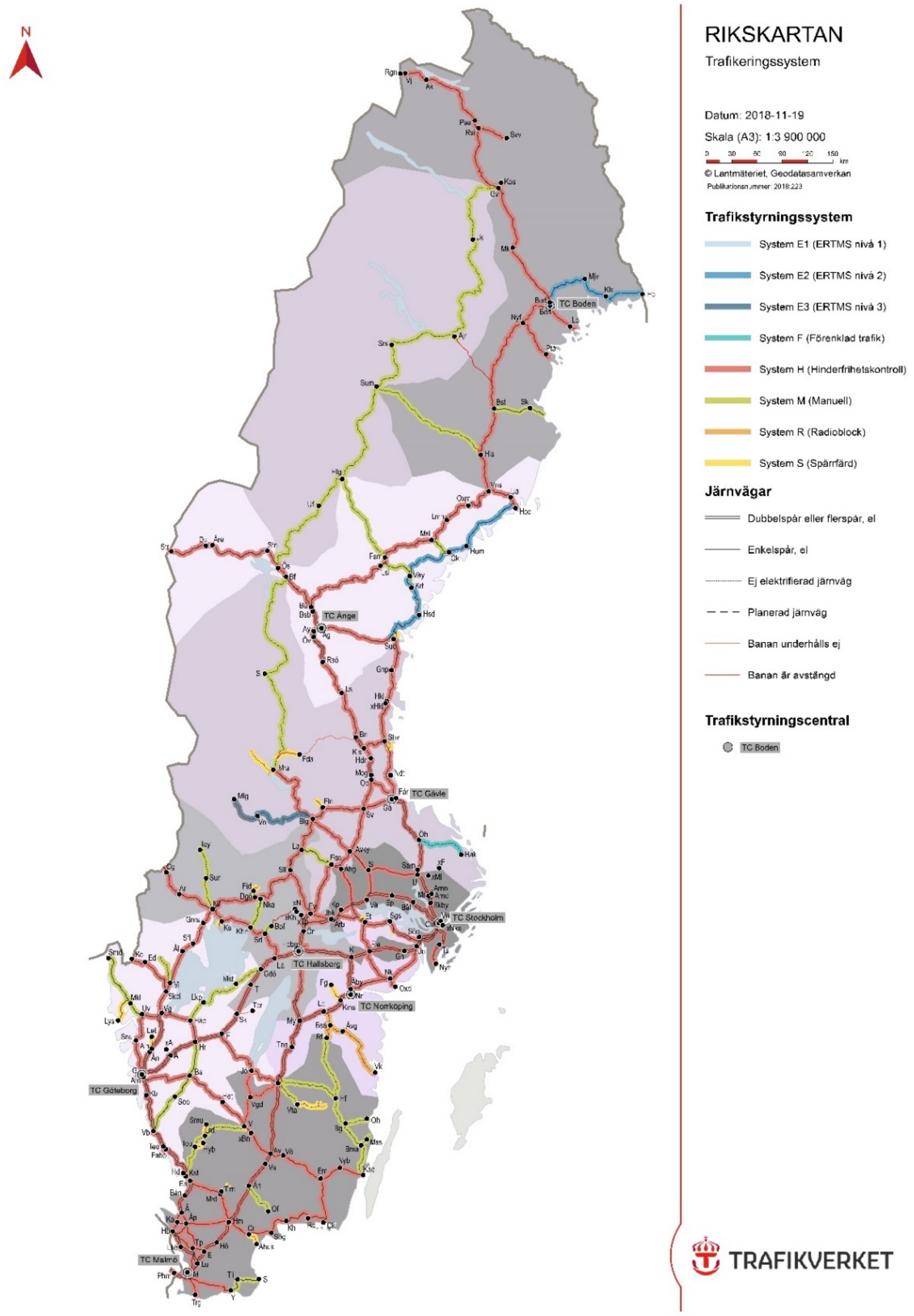

Figure 1. The Swedish railway network. Source: Trafikverket (2018). *The different colours signify different signalling systems, with red representing ATC (automatic train control), the light green and yellow corresponding to manual operation on lines with little traffic, and the darker blue indicating the*

more modern ERTMS level 2, which is required on all new construction, and is to be gradually rolled out over the remaining network. The eight regional Traffic Control centres are highlighted with grey.

The number of trains and passengers has risen steadily by about 3% per year since a major deregulation of the Swedish railway sector began in 1988, mostly spurred by an increase in investments and supply by the local and regional public transport authorities. This growth has mostly been on the existing network, such using newer signalling systems, coloured blue in Figure 1 and focused on the northern parts of the country. Another significant addition, not shown on the map, is the Öresund bridge, which opened in the year 2000 and connected Malmö in the South to Copenhagen, Denmark and the continent. This has led to a significant increase in regional traffic in Southern Sweden.

According to the national travel survey, RVU Sverige (Sweden) 2011-2014, which contains data on the everyday movements and longer journeys, Sweden's population travelled 4.4 times farther by car than by public transport. On an average day, 50.4% travelled by car, 14.8% by public transport and 4.8% by both car and public transport. Trips made by railways are included in the public transport category.

The Swedish census data used in this study is geographically available in a grid format with two different cell sizes. The data on built up areas are provided in a cell size of 250 x 250 meters, while the information for rural areas are recorded in larger cells of 1000 x 1000 meters. The grids are given by the National Land Survey Office using the official coordinate system in Sweden. While these cell sizes correspond to the urban density, they also ensure the anonymity of the data.

2.2 Data sources

One of the novel aspects of this paper is that it combines two large Swedish datasets in order to quantify, as stated above, accessibility and connectivity via the railway network throughout Sweden, and their longitudinal effects with regard to local and regional labour markets.

- *Lupp from the Swedish Transport Administration*, which covers all train movements in Sweden, approximately 30 million per year, in detail.
- *Longitudinal integration database for health insurance and labour market studies (LISA),* a longitudinal integration database for health insurance and labour market studies available from Statistics Sweden. LISA has contained micro-data (annual registers) since 1990 and includes all individuals 16 years of age and older registered in Sweden on 31 December each year. The uniqueness of this database is that it integrates existing data from registers on the labour market, education and social sectors using background information from population registers. The primary units in LISA are individuals, with connections to family, employers and the location of workplaces and housing, available through special retrieval tables and descriptive data.

The rail data from Lupp are needed to identify all trips that are possible to make within a selected time interval using the Swedish railway network. This allows to create a matrix of all feasible origin and destination pairs for train commuters and provides a measure of the accessibility from each station (more details provided in Section 3). From one year to another, an alteration in the railway network design (e.g. opening of new stations and timetable changes) may have impacts on the accessibility. For instance, between 2011 and 2012, the towns Oxie and Svedala, near Malmö, saw their levels of service more than doubled, with passengers from these stations being able to reach many more destinations within a reasonable commute. Such improvements increase the number of jobs accessible by rail and have the potential to make these towns more attractive to live in.

The administrative data from LISA are used for two main purposes. The first is to estimate the number of jobs close to different stations. As some stations are surrounded by more job opportunities than others, being able to access those stations is relatively more important than reaching other stations. In other words, it is not the number of stations that one can reach, per se, that is important, but what is on offer near those stations. The second purpose is to control for socio-economic features (such as education levels and employment status) connected to the individuals residing in the catchment areas of the rail stations, i.e. those potentially more affected by the outcomes of railway related policies/investments.

Together, these data sources allow assessing some of the impacts of railway projects and network design over the selected time frame, with a focus on the economic effects on the working age population.

2.3 Methods

In previous studies, two streams of research on the spatial relationships between job accessibility and built-environment/socioeconomic factors can be found: graphical comparisons and the metropolitan structure (Chen et al., 2014; Cheng and Bertolini, 2013; Karou and Hull, 2014; Le Vine et al., 2013; Lin et al., 2014), and statistical regression modelling (McCann, 2001; Park and von Rabenau, 2011; Sung et al., 2014).

In this study, we suggest using an accessibility measure in order to be able to 'predict' the average annual wage of a certain area. From a policy perspective, this may imply, for instance, some modifications in the rail transport supply to make an impact on the demographic profile of those residing in the station catchment area.

Since our accessibility targets are job places, a subsection of residents have been considered, i.e. those between 20 and 64 years old supposed to be in working age. We are aware that the meaning of working age is changing and that a growing share of people aged 65 or more is often still employed. Still, we have chosen to limit the study to this specific age group.

Therefore, since our approach suggests calculating the job accessibility at a cell size level (Subsection 2.1) using the railway network, only cells served by railways within a certain distance/catchment area (more details are provided in Section 3.2) have been considered.

We propose a fixed effects regression approach to modelling the relationship between a scalar response (in this case, related to an economic variable: annual wage) and a set of explanatory (independent) variables. The list of explanatory variables has been narrowed to two main dimensions:

- *Built-environment features,* connected to the number of opportunities/job places spread over the Swedish territory. In this category, a specific variable refers to the opportunities that are located around the origin, while a second one (job accessibility score), on the other side, refers to the opportunities at the destinations. They can be attributed to each railway station in the network. Additionally, the level of service of the station itself can be assessed based on its level of connectivity with the surrounding railway network.
- *Socio-economic features*: we have selected residents belonging to the working age population, and measured their annual wage, level of education and employment status.

The spatial patterns of these variables (built-environment and socio-economic features) are compared to the average wage of people in working age living in the catchment area around the origin station, to assess possible spatial matches.

3. Theory and calculations

3.1 Cumulative job accessibility

A measure of place accessibility normally consists of two elements: a transportation (or resistance, or impedance) element, and an activity (or motivation, or attraction, or utility) element (Handy and Niemeier, 1997; Geurs and van Wee, 2004). If the first one comprises travel distance, time or cost for the selected mode(s) of transport, the activity element considers amount and location of various activities/opportunities (Makri and Folkesson, 1999).

Cumulative-opportunity measures evaluate accessibility with respect to the number of opportunities accessible within certain travel distance or time from a given location (Oberg, 1976; Wachs and Kumagai, 1973). The cumulative measure of accessibility provides an idea of the range of choices available to residents within a certain area. All potential destinations within the cut-off area are usually weighted in the same way: this means that, as further opportunities are equally weighted with closer ones, any upward movement of the travel time threshold increases the value of the final index.

In this paper, this measure has been selected to calculate the job accessibility using the Swedish railway network, accounting for the number of jobs (or more specifically, the number of employed) that can be reached within a certain travel time threshold. The following formulation (Equation 1 and 2) has been used to assess the cumulative job accessibility A_i of each railway station i in the network:

$$A_i = \sum_{j=1}^{n} O_j f(C_{ij}) \quad (1)$$

where

$$f(C_{ij}) = 1 \text{ if } C_{ij} \leq t_{ij} \text{ ; } f(C_{ij}) = 0 \text{ if } C_{ij} > t_{ij} \quad (2)$$

In Equations 1 and 2, A_i is the accessibility from the station *i* to all the other stations *j;* O_j is the number of employed in the catchment area of station *j* (that is, the sum of all the individuals working in the catchment area of that station); $f_{ij}(C_{ij})$ is the weighting function with C_{ij} being the travel time from *i* to *j*, and t_{ij} is the travel time threshold. More specifically, being a formulation of cumulative accessibility, if the travel time is greater than the specified threshold t_{ij}, jobs reachable beyond that threshold are not considered (Equation 2). This allows to potentially consider different thresholds/time band, to explore and compare how the accessibility levels change over different bands.

The cumulative-opportunity approach has its own limitations: above all, this type of measure evaluates all destinations equally; and it does not acknowledge the gradually, rather than abruptly diminishing attractiveness of opportunities located further away but still below the threshold. Nevertheless, it has been widely used in accessibility studies because of calculation and interpretation convenience (Fan et al., 2012; Wang and Chen, 2015), and it appears to be in line with our research question, focused on larger areas rather than on analysing effects on individual travel behaviour.

3.2 Calculations

A key factor in the calibration of cumulative accessibility measures is the cut-off travel distance or time t_{ij} (Equation 2), to which accessibility levels can be strongly affected.
In this study, we have allowed three possible values (that is: 30, 45 and 60 minutes) as potential travel time thresholds. Different thresholds correspond to the different approximate average time of journey to work in the selected study areas all over Sweden.

A maximum of two interchanges is allowed for each journey within the selected threshold. Each travel time threshold includes *rail riding time* and *transfer time* (the last one is dependent upon the frequency of the specific route at a specific time of the day). The *walking time* (that is, from the origin cell centroid to the starting station and from the ending station to the destination cell centroid) has not been considered.

We have performed our calculations in the morning peak hours of an average weekday. More specifically, all the trips that have been analysed involve a train leaving the origin station after 7 am and arriving at the destination before 10 am. The transfer time (when interchange(s) is (are) expected within the trip) has been set equal to 5 minutes. A different transfer time threshold may affect the final outcomes: a shorter one can enable more connection opportunities, vice versa fewer trains may be available for a longer one.

The level of service of each origin railway station has been defined as the number of destination stations that can be reached within the selected time frame. This means that the level of service itself is not strictly related to the actual number of job opportunities available in that time band.

Knowing the level of service of each station, a matrix with all the possible connections within the three selected time travel thresholds has been built. Therefore, each origin has been paired with a list of destinations, for each time-band. Note that the same destination may be reached from a given origin in multiple ways.

In order to calculate how many job places can be reached from any origin station *i*, and to estimate the pool of residents whose socio-economic features are relevant for the analysis, a catchment area needs to be properly identified. We have established a catchment area having a radius of 800 meters (that is, a maximum Euclidean distance from any train station). These 800 meters represent the maximum walking distance that an individual is willing to cover to reach a railway station (both origin and destination of his/her job trip) (Guerra et al., 2012). The stations that intercept fewer than 30 people in working age have been not considered in this analysis.

Knowing the job place locations in the network, it is possible to know how many of them fall within the station catchment areas and calculate how many individuals are working in each of the catchment areas. The sum of these individuals is the estimated work place capacity, corresponding to O_j in Equation 1. In parallel, we can calculate how many people between 20-64 years old that are living in the respective catchment area, and assess their socio-economic features to be used in the regression model.

3.3 Accessibility score calculation

This subsection provides an explanatory example that better clarifies the process of accessibility calculation within different time travel bands.

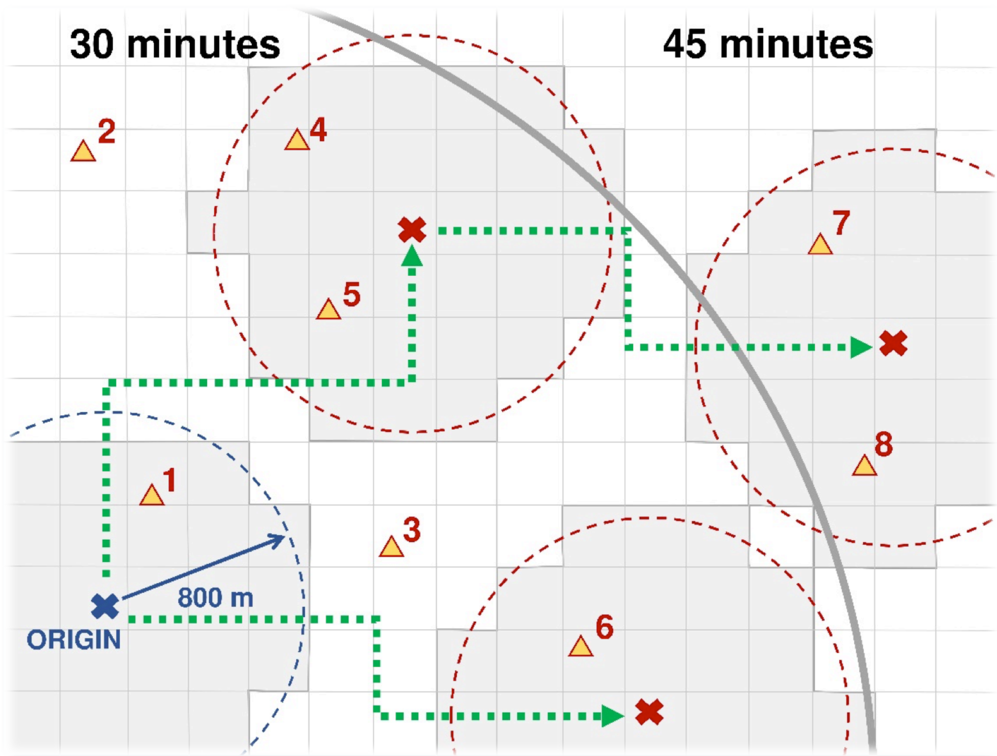

Figure 2. A schematization for the calculation of the cumulative job accessibility

Figure 2 summarizes all the most important elements involved in the calculation of cumulative job accessibility and station level of service:

- The grid in the background represents the way in which data are provided. In this example, we are supposing to be in an urban area, where cell sizes are equal to 250 x 250 meters.
- The railway stations have been identified with a cross symbol: blue for the origin one (bottom-left corner), red for the potential destinations that can be reached from the origin by traveling on the railway network (dashed green line).
- Each destination can be reached within a certain travel time. In Figure 2, less than 30 minutes are needed to reach two potential destinations, while a third one falls in the travel time band of 45 minutes.
- Job places are spread on the territory and denoted with yellow triangles. It is known the cell to whom they belong, although their exact coordinates are not available. It is also known how many individuals are working in each of them (estimated workplace capacity).
- Around each station, a circumference having a radius of 800 meters has been drawn; note that it intersects different cells. Each cell can either belong or not to the catchment area of a station. This means that the light grey areas have to be considered as actual catchment areas of the railway stations. In this way, it is immediate to define if a job place falls within or beyond each catchment area.

According to their location in the network, job places are included or not in the calculation of the cumulative job accessibility:

- The one denoted with number 1 is within the origin station buffer. Although this is a variable in the regression model described in Section 4.1, it is not included in the job accessibility calculation.
- Job places number 2 and 3 do not belong to any catchment areas, hence they have not been considered.
- Job places having number 4, 5 and 6 fall within the catchment areas of two potential destination stations accessible within 30 minutes. This implies that the level of service for the origin station in the 30 minutes band is equal to 2, while its cumulative accessibility is equal to the sum of the estimated workplace capacities of job places 4, 5 and 6.
- Job places having number 7 and 8 fall within the catchment area of a potential destination reachable within 45 minutes. The level of service for the origin station in the 45 minutes band is equal to 3 (three destination stations in total are accessible within 45 minutes), while its cumulative accessibility for this travel time band is equal to the sum of the estimated workplace capacities of job places 4, 5, 6, 7 and 8.

3.4 Data description

On individual level, we have collected data on annual wage, education level and employment status. On the station area level, we have calculated the number of jobs and working age population (*Pop*) residing at the origin, and the number of jobs accessible by rail.

The annual wage is measured in hundreds of Swedish kronor (SEK) and in 2014 prices. The variable *Edu* is defined as the proportion of the population that has studied three years or more at university. Similarly, *Emp* is the proportion of the population with employment. Table 1 reports some key statistics for the first (2011) and last (2014) year in the dataset. Unsurprisingly, the maximum value for origin jobs is in Stockholm Central, with approximately 102,000 jobs in 2014 within 800 meters from the station.

Table 1. Descriptive statistics

Year	Variable	N	Mean	Std. Dev	Min	Max
2011	Annual wage (hundreds of SEK)	420	2558	334	1713	4019
	Origin jobs (thousands)	420	2	6	0.01	97
	Dest. jobs (thousands)	420	37	62	0	261
	Edu	420	0.19	0.1	0.01	0.62
	Emp	420	0.76	0.08	0.43	0.92
	Pop	420	716	1363.5	34	17598
2014	Annual wage (hundreds of SEK)	439	2944	362	1889	4770
	Origin jobs (thousands)	439	2	6	0.01	102
	Dest. jobs (thousands)	439	42	68	0	290
	Edu	439	0.22	0.11	0.02	0.65
	Emp	439	0.76	0.08	0.46	0.94
	Pop	439	661	1303.7	32	17246

The variable of interest in this study is the number of jobs accessible by rail summarized in Figure 3. Expectedly, the number of accessible jobs increases each year, and as the travel time threshold increases (from 30 to 60 minutes). Changes in the rail network are also contributing to this job accessibility, as highlighted by the brown portions of the histogram bars.

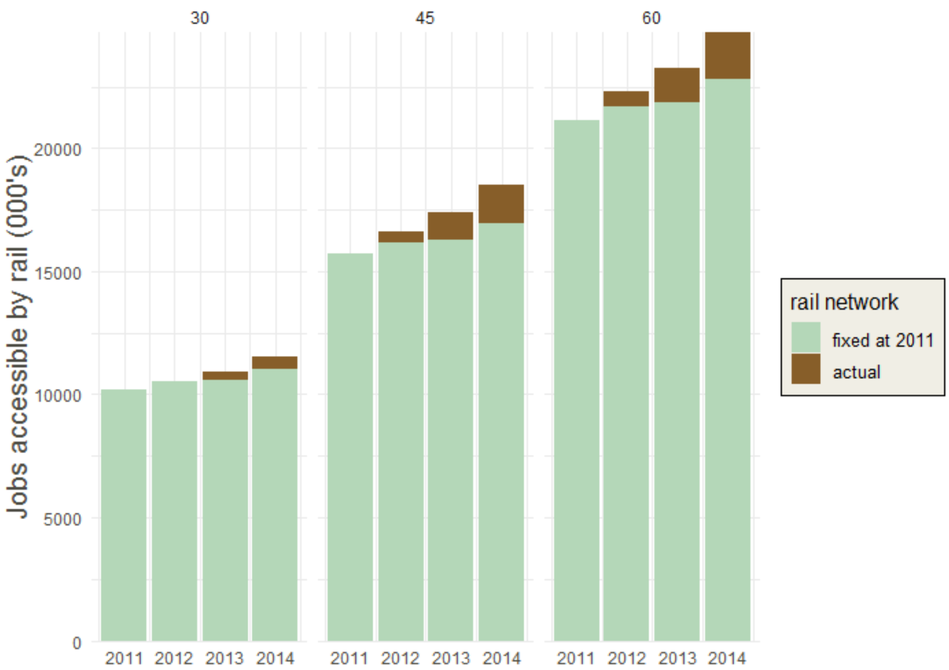

Figure 3. Aggregate number of accessible jobs (thousands). *There is one bar per year and travel time threshold. The pistachio colour indicates the accessible jobs supposing no changes in the railway network, while the brown colour emphasises the additional accessibility provided by rail network improvements.*

Earlier in this paper, we used the town Oxie as an example of increased rail transport supply. According to our calculations, the accessibility to jobs (by rail) increased from about 12,000 in 2011 to over 85,000 in 2012 in Oxie (similar for Svedala, which is nearby). If we fix the rail network for 2011 and calculate the accessible jobs, we see an increase from 12,000 in 2011 to 13,000 in 2012. Hence, in this case, the job accessibility by rail have significantly improved. Still, the change in annual wages is more modest: the average wage increased by approximately 10 percent between 2011 and 2014 in Oxie.

4. Results and discussion

The results presentation is structured in two subsections. In the first one, a fixed effect regression model has been applied to investigate the relationship between railway job accessibility and residents' average wage in the surrounding areas of the stations, over 4 years (2011-2014); a sensitivity analysis has been performed for three different time travel bands. In the second one, railway network design potential impacts on the job accessibility have been cross-sectionally assessed to see if there is an association between more accessible jobs and annual wage.

4.1 Fixed effect panel data models

To fit the panel data, we have used a fixed effects specification with annual wages in logarithms as response variable. Table 2 displays estimates based on the actual network and the counterfactual network fixed on its status in 2011; the estimates are shown for the three travel time bands: 30, 45, and 60 minutes.

The estimate *Dest. jobs* indicate no effect of better accessibility to workplaces through the rail network and the wage level. Additionally, the effect of jobs at the origin has resulted modest. For every 1000 job increase at the origin, wages are 0.5 % higher on average.

Regarding the socioeconomic control variables, there is an expected (positive) sign of the estimate for education rate, but a rather unexpected sign for the working age population *Pop* residing at the origin (that is, the larger the population, the lower the wages). It is reasonable to believe that people with high incomes want to live in larger dwellings, all else equal. Hence, stations with surrounding areas consisting of single-family homes or large apartments have higher average wages, but lower population density, and vice versa.

Table 2. Panel data models

Response: Log(Wage)	Changed network	Unchanged network	Interpretation of estimates in terms of wage levels
Time threshold: 30 min, N = 468, T = 4			
Origin jobs	0.005**	0.005**	0.5 % per 1000 jobs
Dest. jobs	0.000	0.000	
Edu	0.287***	0.287***	33 % of a one unit increase
Emp	-0.061	-0.061	
Pop	-0.097***	-0.097***	-9.7 % per 1000 inhabitants
Year Dummies	Yes	Yes	
Time threshold: 45 min, N = 469, T = 4			
Origin jobs	0.005**	0.005**	0.5 % per 1000 jobs
Dest. jobs	-0.000	-0.000	
Edu	0.290***	0.290***	33.6 % of a one unit increase
Emp	-0.064	-0.064	
Pop	-0.095***	-0.095***	-9.5 % per 1000 inhabitants
Year Dummies	Yes	Yes	
Time threshold: 60 min, N = 471, T = 4			
Origin jobs	0.005**	0.005**	0.5 % per 1000 jobs
Dest. jobs	-0.000	-0.000	
Edu	0.284***	0.284***	32.8 % of a one unit increase
Emp	-0.060	-0.060	
Pop	-0.096***	-0.096***	-9.6 % per 1000 inhabitants
Year Dummies	Yes	Yes	

*Signif. Codes: 0.000 *** 0.001 ** 0.01 * 0.05*

4.2 Cross-sectional models

Cross-sectional models have been estimated for each year using OLS with robust standard errors. Again, the response variable is annual wage levels in logarithms. Like table 2, table 3 includes estimates for both the actual rail network for each year and the network supposed 'fixed' from 2011 onwards. The different models have produced identical estimates with respect to both rail network and year. The estimate of interest is *Dest. jobs,* since it explains how wages are associated with the total number of jobs you accessible by rail. An increase in 1000 jobs is associated with 0.1 % higher wages.

Table 3. Cross-sectional models

Response: Log(Wage)	Changed network	Unchanged network	Interpretation of estimates in terms of wage levels
		2011, N = 420	
Origin jobs	0.002***	0.002***	0.2 % per 1000 jobs
Dest. jobs	0.001***	0.001***	0.1 % per 1000 jobs
Edu	0.397***	0.397***	≈ 50 % of a one unit increase
Emp	0.795***	0.795***	> 100 % of a one unit increase
Pop	-0.003	-0.000	
		2012, N = 411	
Origin jobs	0.002***	0.002***	0.2 % per 1000 jobs
Dest. jobs	0.001***	0.001***	0.1 % per 1000 jobs
Edu	0.4***	0.4***	≈ 50 % of a one unit increase
Emp	0.8***	0.75***	> 100 % of a one unit increase
Pop	-0.004	-0.004	
		2013, N = 428	
Origin jobs	0.002***	0.002***	0.2 % per 1000 jobs
Dest. jobs	0.001***	0.001***	0.1 % per 1000 jobs
Edu	0.479***	0.47***	≈ 60 % of a one unit increase
Emp	0.45***	0.445***	≈ 50 % of a one unit increase
Pop	-0.003	-0.003	
		2014, N = 439	
Origin jobs	0.002***	0.002***	0.2 % per 1000 jobs
Dest. jobs	0.001***	0.001***	0.1 % per 1000 jobs
Edu	0.479***	0.45***	≈ 60 % of a one unit increase
Emp	0.4***	0.424***	≈ 50 % of a one unit increase
Pop	-0.002	-0.002	

*Signif. Codes: 0.000 *** 0.001 ** 0.01 * 0.05*

Similarly, an increase of 1000 jobs at the origin is associated with 0.2 % higher wages. The other two significant variables in these models are the proportion of individuals who have studied three years or more at university (*Edu*) and the employment rate (*Emp*). The magnitudes for these are harder to interpret in a marginal sense, but the estimates have the expected sign. Areas with higher education and employment rates also tend to have higher average wages.

In all, the results indicate that the changes in the rail network over these years have not had a significant impact on wages. The relationship between accessibility to jobs through the railway network and wages is weak to begin with if we look at the cross-sectional models in table 3, and improvements of the rail network have an no effect when we look at the panel data models in table 2.

There are different possible explanations for this. One explanation could be that railways are only one of the several modes of transport that provide job accessibility. The car is still the preferred mode on the countryside, while within urban areas buses and other forms of urban transport provide good levels of accessibility.

A second explanation could be that more accessible jobs of any kind do not necessarily imply that people work more productively, or switch to a job with a higher wage. An area that gets better rail connections to a labour market with mostly highly skilled jobs may be more attractive for high-educated people and therefore experience higher wages. However, if the jobs that have become accessible through improved rail connections are in other sectors, the area is unlikely to experience higher wages on average.

5. Conclusions

There is no best approach to measuring accessibility: different situations and purposes may demand a different approach. However, what is important is an awareness of the assumptions upon which each method is based. Although its intrinsic limitations, in this study a cumulative opportunity measure has been selected to assess job accessibility via railways throughout Sweden.

The number of people travelling by rail in Sweden has increased steadily since the late 1980s and investments in rail have been proposed as a mean to widen labour markets. Our results indicate that the impact of 1000 more accessible jobs through the railway network have no relevant effect on annual wages, when looking at the panel data models. The cross-sectional models indicate a positive relationship of a small magnitude between accessible jobs and wages. Still, this estimate does not differ when we compare a counterfactual fixed network on the starting year to the actual changes in the network. This gives an indication that the railway network has provided only marginal accessibility over these years, in terms of jobs.

There are some limitations to this preliminary study; however, we hope that this could be the first of a series of more extended and detailed investigations and that the following remarks could be opportunely addressed during our next studies. More realistic walking distances, calculated by means of network distances over centre lines, could replace the Euclidean one that has been used to define the accessible areas around each railway station.

It would be also interesting to extend the methodology with more sophisticated railway-based job accessibility measures other than the cumulative one, with opportunely calibrated decay functions. Additionally, it may be relevant to disaggregate different job categories (e.g. manufacturing, services, etc.), or consider different wage level, and/or focus on different segments of the population. In particular, this can allow assessing the distributional effects among individuals, raising potential equity implications that could be further discussed to better assist in future policies' development.

Declarations of interest

None.

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