Commuting time changes following residential relocations and job relocations

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Abstract

This paper focuses on empirical analysis of commuting time changes for workers who relocate residence, relocate job, or combine both residence and job relocation. A large register data set of individuals on the Swedish labor market, including travel times, is studied. Workers are not necessarily seeking to decrease their commuting time when they relocate job and/or residence. In fact, the average commuting time is longer after a relocation than before, thus suggesting that workers trade between a better job, a better residence and commuting time. The paper also presents results from a set of econometric models suggesting that commuting time changes differ substantially with respect to socio-economic characteristics as well as with respect to the part of the distribution of commuting time change that is analyzed.

Keywords: Commuting time; Commuting time changes; Relocations; Register data; Longitudinal; Quantile regression

1 Introduction

In this paper, commuting time changes in Sweden are analyzed. Changes in commuting distances and commuting times result from individual or household decisions on where to live and work. Therefore, the focus in this study is particularly on analyzing commuting time changes that follow three different types of relocation: relocation of where to work, relocation of where to live and a combination of these two. Throughout this paper, these types of relocation will be denoted residential relocation, job relocation and combined residential and job relocation.

In the modern industrialized society, a long commuting time is becoming more and more common. In a number of studies around the world, the average commuting distance or average commuting time, has been analyzed over time to entail policy recommendations in the transport sector. Without considering any potential trade-offs, commuting distance or time above a certain minimum level can be seen as wasteful and workers would therefore be expected to seek to minimize commuting. At least over time the commuting would converge towards the minimum level, i.e. over time the excess commuting would move towards zero.

In other words, since commuting time entails disutility, to be accepted by the worker excess commuting has to be compensated by other utility-increasing factors. Compensations in this sense are better housing characteristics, for example a larger house, and/or better job characteristics, for example a higher wage. However, full compensation is not always the case since there are search imperfections in the labor and housing markets (Deding et al., 2009) and also since two-earner households have a more complex choice of commuting. Furthermore, workers may be indifferent when comparing a very short commuting time and an extremely short commuting time. For example, workers may not care if they commute two minutes per trip or five minutes per trip although in the former case they save more than 20 hours compared to the latter, during a year of working. Thus, small time changes in the commuting trip duration may, in the long run add up to considerable changes in total commuting time.

The results of several empirical studies show that the change in commuting time is negatively influenced by the commuting time prior to the change (Clark et al., 2003; Krizek, 2003; Prillwitz et al., 2007). An interpretation of this result has been that workers seek to reduce commuting time (Clark et al., 2003). However, Rouwendal (2004) shows that such an empirical result can be found from a sequence of non-correlated commuting times resulting from a job search model. Since the expected commuting time in a job search model is the same in every search, longer commutes are likely to be followed by shorter commutes, while shorter commutes are likely to be followed by longer commutes. Thus the negative relation between commuting time changes and the commuting time prior to the change is an example of regression towards the mean and cannot be interpreted as workers acting rationally by reducing their commuting time when it is initially large (Rouwendal, 2004).

Zax and Kain (1991) suggest that for metropolitan areas workers who relocate jobs are more likely to decrease their commuting, whereas workers who relocate residence are more likely to increase their commuting. This prediction, based on urban economics theory, assumes negative wage and house pricing gradients, which means that these variables decrease with the spatial distance to the metropolitan center. The rational locator hypothesis, on the other hand, posits that individuals will maintain approximately steady commuting times over time since they will choose to adjust their residences and workplaces (Levinson and Wu, 2005). This hypothesis was inspired by the empirical finding that the commuting time was remarkably stable between 1957 and 1988 in the metropolitan area of Washington DC despite an increase in commuting distance and congestion (Levinson and Wu, 2005). The rational locator hypothesis is also empirically supported by studies such as Wachs et al. (1993) and Kim (2008).

Nevertheless, the most common empirical result in the literature when commuting is analyzed over time, is an increase in the averages of both commuting time and commuting distance (Zax and Kain, 1991; Rouwendal and Rietveld, 1994; Vandersmissen et al., 2003; Prillwitz et al., 2007; Sandow, 2008; Yang, 2008). Workers who are willing to accept a longer commuting time/distance can more easily get good job matching and an attractive residence location since the search area is extended. It is often claimed that larger local labor markets enhance regional growth and the opportunity to sustain living in non-urban areas (see e.g. Sandow, 2008). Many local politicians realize the importance of connecting their region to a larger labor market area to decrease the vulnerability in case of a structural labor market decline (SKL, 2008).[1] There may also be negative effects of regional expansion such as the increase of road congestion and pollution, increased stress due to tighter time schedules and deterioration of gender equality since it is the husband of a two-earner household who most often has the longer commute (Boverket, 2005). Longer average commuting times may also be caused by suburbanization, which means that individuals move from urban city centers to live in outer suburbs within the same metropolitan area. Thus, the workers still belong to the same local labor market and most have a longer commute since most jobs are located in the city center.

Many of the contributions of the commuting behavior literature during the last decades are based on access to good data. Most earlier empirical exercises used aggregate data that could not be used to model individual behavior. More recently, studies that use disaggregate data have been more common. Also, the use of register data provides a new approach to this field (Sandow, 2008; Deding et al., 2009; Isacsson and Swärdh, 2009).

Another important issue in the commuting time literature is changes over time, which may have important policy implications for the transport sector regarding such issues as demand, congestion and environmental effects. Some studies, such as Vandersmissen et al. (2003) and Levinson and Wu (2005), have compared different survey samples of the same area in different years to see how the commuting behavior changes over time. Longitudinal data, where the same individuals are observed over time provides additional information on this. A limitation of longitudinal data however is the difficulty in following the same individual over a long time period and therefore in stating how the commuting behavior changes in the long run. Among the longitudinal studies in this field, some focus only on a single metropolitan area (e.g. Zax and Kain, 1991; Wachs et al., 1993; Clark et al., 2003; Krizek, 2003; Kim, 2008) whereas others focus on the determinants of the level of commuting time (e.g. Sandow, 2008).

In this study the commuting time changes that follow from relocations, are analyzed. Three different types of relocation that result in a change of commuting time[2] are defined: residential relocation, job relocation or combined residential and job relocation. Previous studies that analyze commuting time changes following different types of relocation are Clark et al. (2003), Krizek (2003), Prillwitz et al. (2007), Kim (2008) and, in this case on aggregated data, Yang (2008).

This previous research is extended here by a study of a whole country instead of a single metropolitan area as in Clark et al. (2003), Krizek (2003) and Kim (2008), of whom used data from the greater Seattle area. A large set of register data on the Swedish labor market, combined with travel time data between small administrative areas in Sweden, is used. The commuting time of the worker is given as the travel time between the worker's residential area and the worker's workplace area. In total, 183 641

[1] This particular reference refers to Swedish politics.

[2] Strictly speaking a change in commuting distance. This follows since a change in commuting distance theoretically might be counterbalanced by a travel speed change, such that the result will be an unchanged commuting time.

observations where the individuals relocate either job, residence or both, are used in the estimated models.

To my knowledge, this is the first time register data is used to analyze commuting time changes following relocations. Register data provides a lot of important socio-economic characteristics and does not suffer from the problem of non-response bias that is common for survey data. In addition, there is no risk that the respondents give incorrect information regarding their socio-economic characteristics or their commuting time, since these variables are taken from registers. However, measurement errors of other types may exist in register data, for example imputation errors or coding errors.

Furthermore, the large number of observations gives an opportunity to split the sample into subsamples each of which will still have a substantial number of observations. One relevant division of the data is to analyze the commuting time changes separately for different regions, since most previous studies focus on metropolitan areas. An exception is Prillwitz et al. (2007), who use data from all areas in Germany, however, Germany is much more densely populated than Sweden, therefore this study on Swedish data is more relevant for non-metropolitan areas. Also, the number of daily commuters used for final estimation is only 3188 in that study, i.e. less than two percent of the number in this study.

Another contribution to the literature is made by estimating quantile regression models on the change of commuting time. These models, unlike OLS, are not based on the conditional mean function and therefore provide a more complete picture of the relationship between the covariates and the commuting time change at different points of the conditional distribution of the commuting time changes (Cameron and Trivedi, 2009). Here, the intuition is that socio-economic characteristics might influence the commuting time change differently in different parts of the distribution of commuting time changes. One reason is that commuting time changes are distributed around zero, which implies that the commuting time changes are negative at the lower tail while the commuting time changes are positive at the upper tail. For example, this is important if a certain characteristic implies a small commuting time change regardless of whether the change is negative or positive. Then, the effect of this characteristic on commuting time changes will be negative at the upper tail and positive at the lower tail.

The rest of the paper is outlined as follows. In the next section, the data, including variable definitions and sample restrictions, and econometric models are described. Then follows the empirical results with interpretations. A concluding discussion is presented at the end of the paper.

2 Method

In this section, the data, including variable definitions and sample restrictions, is briefly described. This section is concluded with a subsection describing the econometric models.

2.1 Data

The data consists of Swedish longitudinal matched employee-establishment register data. The individuals were randomly stock sampled in 1998 including also observations from 1993, 1990 and 1986. The establishment-level data identifies different establishments, i.e. workplaces, and their characteristics. Also, from this matched data a small geographical area (SAMS [3]) is observed for both the residence and the establishment. From this information, all workers' commuting times are imputed in the data by the use of travel-time matrices for the road network of all possible combinations of SAMS areas. These travel times correspond to the fastest car route between the central points of each SAMS area in accordance with the speed limit. The matched employee-establishment data is provided by Statistics Sweden while the travel time matrices are provided by the Swedish Road Administration. See Isacsson and Swärdh (2009) for a more detailed description of the data used in this study.

The four different years of observation can be combined into three different intervals of time; 1986-1990, 1990-1993 and 1993-1998. In the following, within each pair, the earlier observation will be denoted $t-1$ and the later observation will be denoted t. This means, for example, that for the interval 1986-1990, 1986 is denoted $t-1$ and 1990 is denoted t.

Note that the potential bias from sample selection will not be considered in this paper. As noted by Deding et al. (2009), workers with long commutes are probably more likely to leave the labor market. Workers who leave the labor market between $t-1$ and t will not be observed in period t. However, as Deding et al. (2009) conclude for Denmark, the labor force participation rates of Sweden are high for both men and women in an international perspective, which probably leads to a negligible problem with sample selection bias.

2.1.1 Variable definitions

The definition of a residential relocation is when someone is living in another SAMS area in period t than in period $t-1$. This definition means that individuals who have moved within a SAMS area are not considered to have relocated their residence. However, since these areas are relatively small, moving within a SAMS area is most likely not motivated by a desire to adjust the commuting time. Similarly, a job relocation is when an individual is coded to a different workplace in period t than in period $t-1$.

The commuting time variable is the travel time of the car route between the central points of each SAMS area in accordance with the speed limit, plus one additional minute. This extra minute is included for two reasons. First, according to the definition of travel times, those workers who work and live in the same SAMS area have a

[3] SAMS is short for Small Area Market Statistics. Sweden has 9230 SAMS areas. Although the population is not equally distributed among the SAMS areas, the Swedish population of approximately 9 000 000 citizens means that each SAMS area has on average about 1000 citizens.

commuting time of zero.[4] This is not completely realistic since the time to transport oneself from the residence to the workplace is always positive unless you work at home but such cases are likely to be rare.[5] Therefore, this extra minute can be seen as a start-up time for the commuting. The other reason for the extra minute is practical. A positive commuting time for all workers offers the attractive opportunity to calculate the logarithm of the commuting time, which, following Deding et al. (2009), will be used in the empirical models. Note also that the commuting time difference will be the same regardless of this added minute.

The income variable used is the sum of employment income, self-employment income and payments from labor-related insurances. To be comparable with the income in t, with respect to general wage increases, the income variable in $t-1$ is inflated by a within-sample inflator, which is specific for each of the three time intervals 1986-1990, 1990-1993 and 1993-1998. Also, this inflated wage is calculated after excluding observations where the individual is assumed to be working part-time.[6] Finally, since there are three distinct time intervals in the sample, the income variable is adjusted to the income value of 1998 by using the average wage increase between the observation years in the total sample.

Accessibility to other jobs might be an important explanatory factor for the commuting time change. The accessibility measure in this study is SAMS-specific and is for SAMS area j in period t defined as

$$\text{Accessibility}_{jt} = \sum_{k=1}^{K} e^{-c_{jkt}}(X_{kt}), \tag{1}$$

where c_{jkt} is the commuting time between SAMS area j and k in period t and X_{kt} is the number of jobs in area k in period t.

2.1.2 Sample restrictions

In the empirical analysis only full-time workers who commute on all working days will be included. Since these cannot be observed directly in the data some kind of proxy has to be constructed, using the income and commuting time variables.

For income, a lower limit of the annual income is set to exclude most part-time workers. The lower limits of the non-inflated annual incomes are set to 75 700 Swedish Crowns (SEK[7]) in 1986, 120 300 SEK in 1990, 134 700 SEK in 1993, and 157 100 SEK in 1998.

[4] This holds for approximately 9 percent of the total sample.

[5] Notice that these workers with a commuting time of zero are not teleworkers, since such workers are coded to a workplace but actually works at home and, therefore, their commuting time will be based on their coded workplace. The problem of dealing with potential teleworkers is further described in subsection 2.1.2. However, in a Swedish study, the number of teleworkers in a sample of 8211 workers collected in 1999-2001 was only 391, i.e. about 4.8 percent (Haraldsson, 2007).

[6] The sample restrictions are explained in more detail in subsection 2.1.2.

[7] 1 Euro is approximately equal to 10 SEK.

These shares are calculated by within-sample truncation based on knowledge of the share of part-time workers. [8] By the use of a within-sample truncation and these shares of part-time workers, the lower limits of the non-inflated annual incomes as given above, are calculated. Note, however, that the restricted sample still includes some part-time workers who have a sufficiently high hourly wage rate to exceed the lower limits of income despite part-time working.

The commuting time variable takes values that are in some cases, totally unrealistic for daily commuters. This is so because some workers commute weekly, have double residences, are teleworking, or may be registered to a workplace that is not their actual place of work. Thus an upper limit of commuting time is used to reduce the probability that the workers do not commute this distance every working day. This limit is set to 90 minutes per one-way trip between the residence and the workplace. Also, in Marion and Horner (2007) one-way commuting times above 90 minutes is denoted as extreme commuting.

2.2 Econometric models

The model specification uses a dependent variable that measures a change in commuting time between time periods $t-1$ and t. The explanatory variables can be divided into two types: level variables and change variables. [9] The level variables are measured in $t-1$, whereas the change variables denote a change between $t-1$ and t, that is the value in t, minus the value in $t-1$. Level variables are included since the effect of a change may depend on the starting levels of the variables (Krizek, 2003).

Level variables included are commuting time; income; age; marital status; number of children aged 0-6; number of cars in the household coded as 2 if the number of cars is 2 or more; gender; interaction between number of children aged 0-6 and gender; high school education completed; university education completed; time periods; accessibility to other jobs, and county of residence. Change variables included are income change; getting married; getting divorced or becoming a widow(er); more children aged 0-6; less children aged 0-6; more cars in the household; less cars in the household; change of education level; change of accessibility to other jobs, and change of county of residence.

The models are estimated in two ways. First, OLS models are estimated separately for residential relocations, job relocations and combined residential and job relocations.

In addition, quantile regression models are estimated (see e.g. Koenker, 2005). Such models are not based on the conditional mean function as OLS is. Instead, quantile regression can be used to estimate models based on conditional quantile functions at any quantile. For a continuous random variable y, the qth quantile is the value μ_q such

[8] According to data from Statistics Sweden, the share of all employed individuals who normally worked less than 35 hours per week was 22.5 percent in 1998, 24.9 percent in 1993 and 23.3 percent in 1990. For 1986, there is no value obtainable so instead the average value of the shares in 1985 and 1987, which is calculated to 24.7 percent, is used. These shares of the workers in each year are assumed to be working part-time.

[9] This follows the approach of both Krizek (2003) and Prillwitz et al. (2007).

that y is less or equal to μ_q with probability q. Where OLS uses squared error losses for the estimation, quantile regression uses asymmetric absolute losses with median regression that uses absolute error losses as a special case. The advantages of quantile regression are, among others, that it provides a more complete picture of the relationship between the covariates and the dependent variable and that it is more robust to outliers. (Cameron and Trivedi, 2005)

All models are estimated in Stata. For the OLS models, the estimated standard errors are robust and adjusted for clusters, which are more than one observation belonging to the same individual. For the quantile regression models, the standard errors are computed by 400 bootstrap replications.

3 Results

In this section, the empirical results are presented and interpreted. First, the distribution of commuting time for the complete sample in the different observation years, is analyzed. Then follows the analysis of commuting time changes that follow residential relocations and job relocations. Finally, the results from the econometric models are presented.

3.1 Commuting time over time

In Table 1, some information on the distribution of the commuting time for all workers in the sample of each respective year is presented. As can be seen, the average commuting time has increased monotonically during the observation period of 1986 to 1998, from 11.43 minutes in 1986 to 12.92 minutes in 1998. This is in contrast to the findings by Levinson and Wu (2005) of a constant average commuting time in Washington DC 1957-1988.

Table 1
Distribution of one-way commuting time in minutes over the years

	1986	**1990**	**1993**	**1998**
Mean	11.43	11.76	12.26	12.92
Lower quartile	4.31	4.43	4.60	4.75
Median	8.39	8.71	9.16	9.83
Higher quartile	15.31	15.80	16.37	17.34
No. of observations	114 975	131 671	140 401	139 519

Furthermore, the whole distribution of commuting time seems to have shifted towards longer commuting times over these twelve years. The median as well as the lower and higher quartiles also increased monotonically from 1986 to 1998. Note also that the mean commuting time is much higher than the median commuting time, suggesting a distribution of commuting time that is heavily skewed with a lot of observations fairly close to zero and some observations with very long commutes.

3.2 Commuting time changes following relocations

The average commuting time for all workers was found to be trending upwards. But what happens if the workers are split into the three different types of relocation? In Table 2, the average commuting time before the relocation and after the relocation are compared. For all types of relocation, the average commuting time increases and these changes are all strongly significant with p-values less than 0.001. When all time periods are considered, the size of the increase of the average commuting time is largest for combined residential and job relocations and smallest for job relocations, although there is only a small difference between job relocations and residential relocations. These results falsify the rational locator hypothesis that predicts stable commuting times over time. Also, the prediction of Zax and Kain (1991) that states an average decrease in commuting time when workers relocate jobs, is falsified. Nevertheless, for residence relocations, the increase in average commuting time supports this prediction of Zax and Kain (1991). This may be a result of suburbanization where workers move out from the cities to live in the outer suburbs but still commute to the same jobs. Also, when the sample is split into the different time periods, the commuting time is significantly longer after the relocation than before the relocation, regardless of the type of relocation. In addition, job relocators and combined job and residential relocators tend to have longer commuting times before the relocation as compared to residential relocators.

Also in Table 2, a test of the change of commuting *distance* between $t-1$ and t is presented. This result is presented since most previous research focuses on distance instead of time. However, the pattern for distance is more or less the same as for time, including a significant increase of commuting distance after all types of relocation.

Finally in Table 2, the commuting time change is analyzed for the subsample where workers with imputed SAMS areas for their workplace and/or residence are excluded. [10] Despite substantial decreases of about 30 percent in the number of observations, the results are remarkably stable. The average commuting times are lower in this subsample whereas the increase of average commuting time after the relocations is fairly similar to the complete sample. Therefore, the complete sample will be used for all analyses throughout the paper.

In Tables 3 to 6, the commuting time changes following relocations are analyzed for different subsamples with respect to socio-economic characteristics.

First, in Table 3, these socio-economic characteristics are gender, marital status, children aged 0-6 in the household and car accessibility in the household. For all these subsamples the earlier result is confirmed, that is all types of relocation result in a significant increase of the average commuting time. Furthermore, men, married workers and workers with young children have longer average commuting times than their counterparts. This result holds both before and after the relocations as well as for all

[10] For some observations, the SAMS area of residence or workplace is not observable. However, the municipality is observable so the SAMS area is imputed to be the SAMS area in which the population midpoint of the municipality is located.

Table 2
Change in average one-way commuting time in minutes or one-way commuting distance in kilometers by type of relocation

Period	**Residential relocations**		**Job relocations**		**Residential and job relocations**	
	Before	**After**	**Before**	**After**	**Before**	**After**
All periods - time	11.22	12.15	13.21	14.05	12.54	13.86
p-value	<0.001		<0.001		<0.001	
No. of observations	52 557		87 691		43 393	
1986-1990 - time	10.50	11.55	12.62	12.91	11.87	12.85
p-value	<0.001		<0.001		<0.001	
No. of observations	14 271		30 235		16 976	
1990-1993 - time	11.58	12.35	12.81	13.76	12.59	13.75
p-value	<0.001		<0.001		<0.001	
No. of observations	18 330		25 124		9146	
1993-1998 - time	11.39	12.39	14.07	15.35	13.17	14.90
p-value	<0.001		<0.001		<0.001	
No. of observations	19 956		32 332		17 271	
All periods - distance	13.38	14.65	16.12	17.44	15.32	17.16
p-value	<0.001		<0.001		<0.001	
No. of observations	52 557		87 691		43 393	
Excl. imputed SAMS - time	10.84	11.77	12.70	13.50	12.17	13.41
p-value	<0.001		<0.001		<0.001	
No. of observations	36 927		55 286		26 918	

Note: The p-values correspond to two-tailed t-tests of the hypothesis that the average commuting time/distance is the same after the relocations as before the relocations.

types of relocation. Also presented in this table is the result for the workers who have at least one car in the household. As the commuting time is based on car trips, the reason for this exercise is to check the sensitiveness of assuming travel time based on car trips for all workers. The result for this group is the same as for all individuals regarding the significant increase in commuting time following all types of relocation. The average commuting time before relocation is slightly higher for the group of car owners compared to the complete sample, although the difference is relatively small.

In Table 4, the sample is split into subsamples with respect to income. Five different subsamples are defined by the different quintiles of the income distribution. The results show that for all types of relocation and for all income quintiles the commuting time increases significantly. Furthermore, there is a clear relationship between income group and average commuting time. For all types of relocation, the higher the income quintile, the higher the average commuting time. Despite this clear pattern, all income quintiles indicate an increased average commuting time following all types of relocation.

In Table 5, the sample is split into seven groups with respect to age. The previous result of significant increases in commuting time after relocation also holds for all these groups.

Table 3
Change in average one-way commuting time in minutes by type of relocation with respect to different socio-demographic characteristics

Group	Residential relocations		Job relocations		Residential and job relocations	
	Before	**After**	**Before**	**After**	**Before**	**After**
Women	10.80	11.69	11.74	12.52	11.63	12.94
p-value	<0.001		<0.001		<0.001	
No. of observations	18 834		33 985		16 430	
Men	11.45	12.41	14.14	15.02	13.10	14.42
p-value	<0.001		<0.001		<0.001	
No. of observations	33 723		53 706		26 963	
Married	11.72	12.42	13.59	14.50	13.22	14.44
p-value	<0.001		<0.001		<0.001	
No. of observations	18 487		52 499		14 543	
Not married	10.94	12.00	12.63	13.38	12.20	13.56
p-value	<0.001		<0.001		<0.001	
No. of observations	34 070		35 192		28 850	
Children aged 0-6	11.57	12.78	14.19	14.69	13.26	14.87
p-value	<0.001		<0.001		<0.001	
No. of observations	9993		21 706		8452	
No children aged 0-6	11.13	12.00	12.89	13.84	12.37	13.61
p-value	<0.001		<0.001		<0.001	
No. of observations	42 564		65 985		34 941	
Car in household	11.41	12.53	13.69	14.55	13.02	14.40
p-value	<0.001		<0.001		<0.001	
No. of observations	34 454		65 742		25 849	

Note: The p-values correspond to two-tailed t-tests of the hypothesis that the average commuting time is the same after the relocations as before the relocations.

Here, on the other hand, there is no clear pattern regarding the average commuting time across the age groups.

In the tests presented in Table 6, the sample is restricted to include only workers who had no children of age 0 to 6 in period $t-1$ but at least one child of age 0 to 6 in period t. Also, this sample is split with respect to gender. When there are only residential relocations or combined residential and job relocations, the result shows a relatively large and significant increase of the average commuting time for both men and women. However, when there are only job relocations, there is no significant commuting time change between $t-1$ and t. For residential relocators, a child birth may cause a demand for a larger residence and/or a residence located further away from the city center. Therefore, a residential relocation that implies a longer commuting time is acceptable since it also offers other attractive characteristics. Regarding job relocations, workers who have young children may be more sensitive to longer commuting times and

Table 4
Change in average one-way commuting time in minutes by type of relocation with respect to different incomes

Income quintile	**Residential relocations**		**Job relocations**		**Residential and job relocations**	
	Before	**After**	**Before**	**After**	**Before**	**After**
Lower quintile	10.38	10.91	11.55	12.23	11.60	12.52
p-value	<0.001		<0.001		<0.001	
No. of observations	11 971		16 912		10 796	
Second quintile	10.68	11.57	12.24	12.97	11.91	13.20
p-value	<0.001		<0.001		<0.001	
No. of observations	11 781		16 089		8913	
Third quintile	11.06	12.16	12.94	13.75	12.34	13.83
p-value	<0.001		<0.001		<0.001	
No. of observations	10 874		17 088		8256	
Fourth quintile	11.60	12.80	13.63	14.63	13.10	14.69
p-value	<0.001		<0.001		<0.001	
No. of observations	9969		17 382		7633	
Upper quintile	13.01	14.04	15.23	16.21	14.23	15.66
p-value	<0.001		<0.001		<0.001	
No. of observations	7962		20 220		7795	

Note: The p-values correspond to two-tailed t-tests of the hypothesis that the average commuting time is the same after the relocations as before the relocations.

require more compensation for an increase in commuting time compared to workers without young children. This result may therefore reflect the fact that the value of commuting time becomes higher for workers after a child birth due to more restrictions in their daily schedule. Also, note that the average commuting time level before the relocations is much higher for job relocations than for residential relocations, which may be conducive to this result.

The large sample used in this paper offers the opportunity of splitting the sample into many subsamples without having too small a number of observations in each subsample. Also, since most previous research is based on metropolitan areas it is interesting to analyze the commuting time changes in different regions. Here the 21 counties of Sweden are used to this end.[11] In this exercise, there are no longer only significant increases in the commuting time following relocations. Therefore, in Tables 7, 8 and 9, the counties are listed with respect to their results of the commuting time change after relocations, i.e. if the average commuting time significantly increases, if the average commuting time significantly decreases, or if the average commuting time change is non-significant. The significance level is set to five percent.

In Table 7, the counties are listed for the commuting time changes following residential relocations. Here, the counties of Uppsala and Södermanland both indicate a significant

[11] In Figure 1, a map showing the counties of Sweden is found.

Table 5
Change in average one-way commuting time in minutes by type of relocation with respect to different age groups

Age group	**Residential relocations**		**Job relocations**		**Residential and job relocations**	
	Before	**After**	**Before**	**After**	**Before**	**After**
Age 20-24	11.24	12.23	13.36	14.03	12.40	13.58
p-value	<0.001		<0.001		<0.001	
No. of observations	10 692		8054		10 708	
Age 25-29	11.14	12.65	13.58	14.30	12.46	14.15
p-value	<0.001		<0.001		<0.001	
No. of observations	9081		11 999		8726	
Age 30-34	10.97	12.02	13.30	14.03	12.54	13.95
p-value	<0.001		<0.001		<0.001	
No. of observations	7616		15 307		6386	
Age 35-39	11.49	12.01	13.20	14.19	13.06	14.31
p-value	<0.001		<0.001		<0.001	
No. of observations	7341		18 141		5479	
Age 40-44	11.75	12.48	13.33	14.25	12.89	14.12
p-value	<0.001		<0.001		<0.001	
No. of observations	6732		18 017		4359	
Age 45-49	10.88	11.97	12.71	13.65	12.08	13.10
p-value	<0.001		<0.001		0.004	
No. of observations	3662		10 062		2136	
Age 50-64	10.90	12.21	11.92	12.77	11.30	12.78
p-value	0.001		<0.001		0.029	
No. of observations	1109		3247		543	

Note: The *p*-values correspond to two-tailed *t*-tests of the hypothesis that the average commuting time is the same after the relocations as before the relocations.

decrease in commuting time. These two counties have in common the fact that they are the only counties in Sweden that have a land border to the county of Stockholm, which is the largest metropolitan area in Sweden. In these counties, a substantial number of workers commute to Stockholm so this result can possibly be explained by some workers moving to Stockholm to live closer to their jobs. Furthermore, most counties have a significant increase in commuting time but there are also six counties where this average commuting time change is non-significant.

Table 8 presents the corresponding results pertaining to job relocations. There is no county that exhibits a significant decrease in the average commuting time as a result of job relocations. As for residential relocations, most of the counties show a significant increase but there are eight counties that show no significant commuting time change. Note that in Uppsala and Södermanland, where residential relocators signifi-

Table 6
Change in average one-way commuting time in minutes for workers with young children in t but without young children in $t-1$ by type of relocation with respect to gender

Gender	**Residential relocations**		**Job relocations**		**Residential and job relocations**	
	Before	**After**	**Before**	**After**	**Before**	**After**
Men	10.73	12.77	14.32	14.61	12.70	14.68
p-value	<0.001		<0.178		<0.001	
No. of observations	6248		4315		6089	
Women	10.42	12.95	13.42	12.93	12.42	14.27
p-value	<0.001		<0.197		<0.001	
No. of observations	2365		1174		2168	

Note: The p-values correspond to two-tailed t-tests of the hypothesis that the average commuting time is the same after the relocations as before the relocations. The definition of young children is children aged 0-6.

Table 7
Significant and non-significant changes in average one-way commuting time following residential relocation with respect to different counties of residence

Significant increase	**Significant decrease**	**Non-significant**
Stockholm	Uppsala	Kronoberg
Östergötland	Södermanland	Kalmar
Jönköping		Gotland
Blekinge		Halland
Skåne		Jämtland
Västra Götaland		Norrbotten
Värmland		
Örebro		
Västmanland		
Dalarna		
Gävleborg		
Västernorrland		
Västerbotten		

Note: The significance is determined by two-tailed t-tests of the hypothesis that the average commuting time is the same after the residential relocations as before the residential relocation. The significance level is five percent.

cantly decreased their average commuting times, job relocators significantly increased their commuting times on average.

In Table 9, commuting time changes following both residence and job relocation are studied. Most counties have a significant increase in average commuting times. Once again, and in this case as the only county, Uppsala has a significant decrease in average commuting times. For five of the counties, including Södermanland, there is no significant change.

To summarize the results of splitting the sample into regions, the three counties that contain the three largest metropolitan areas of Sweden, that is Stockholm, Västra Götaland and Skåne all show a significant increase in commuting time for all types

Fig. 1. The 21 counties of Sweden. Source: National Atlas of Sweden, www.sna.se

of relocation.[12] The non-significant counties are mainly counties that are relatively sparsely populated and without large cities. The largest city in the counties that are non-significant, is Umeå which is the twelfth largest city in Sweden.[13]

3.3 Linear regression models of commuting time changes

Presented in Table 10 are the results of the linear regression models where change in commuting time is the dependent variable. As described in subsection 2.2, the covariates

[12] Stockholm, the largest city in Sweden, is the main city in the county of Stockholm. Göteborg, the second largest city in Sweden, is the main city in the county of Västra Götaland. Malmö, the third largest city in Sweden, is the main city in the county of Skåne. These cities are also the ones marked in their respective counties on the map found in Figure 1.
[13] On 31st of December 2005 according to Statistics Sweden.

Table 8
Significant and non-significant changes in average one-way commuting time following workplace changes with respect to different counties of residence

Significant increase	**Significant decrease**	**Non-significant**
Stockholm		Kalmar
Uppsala		Gotland
Södermanland		Blekinge
Östergötland		Gävleborg
Jönköping		Västernorrland
Kronoberg		Jämtland
Skåne		Västerbotten
Halland		Norrbotten
Västra Götaland		
Värmland		
Örebro		
Västmanland		
Dalarna		

Note: The significance is determined by two-tailed t-tests of the hypothesis that the average commuting time is the same after the workplace relocations as before the workplace relocations. The significance level is five percent.

Table 9
Significant and non-significant changes in average one-way commuting time following both residential relocation and workplace change with respect to different counties of residence

Significant increase	**Significant decrease**	**Non-significant**
Stockholm	Uppsala	Södermanland
Östergötland		Kalmar
Jönköping		Gotland
Kronoberg		Halland
Blekinge		Jämtland
Skåne		
Västra Götaland		
Värmland		
Örebro		
Västmanland		
Dalarna		
Gävleborg		
Västernorrland		
Västerbotten		
Norrbotten		

Note: The significance is determined by two-tailed t-tests of the hypothesis that the average commuting time is the same after the residential and workplace relocations as before the residential and workplace relocations. The significance level is five percent.

of the linear models are either level or change variables. The level variables are all defined in period $t-1$, while the change variables denote a change between $t-1$ and t.[14]

[14] Note, however, that Krizek (2003) focuses on distance and number of trips and not on travel time. Also, the analysis in Krizek (2003) covers all travel purposes and not just commuting.

The commuting time level in period t shows a strongly negative effect on the change in commuting time regardless of the type of relocation. This result is similar to the results of Krizek (2003) and Prillwitz et al. (2007). As noted in the literature review of Prillwitz et al. (2007, p. 66-68), this result is expected. Nevertheless, this result cannot be interpreted as in Krizek (2003) and in Clark et al. (2003), that workers tend to decrease long commutes over time. For such an interpretation, as explained by Rouwendal (2004), average commuting time/distance has to decrease significantly over time. Empirical support for such a phenomenon, however, is difficult to find in the literature. Also in this study, as can be seen from the results in Table 1, the average commuting time for all workers is found to increase over time.

Also in all types of relocation models, the effect of the income variable is found to be positive and significant. This means that income not only influences the commuting time but also commuting time changes. An interpretation is that workers with higher incomes have specific occupations and to increase their wage considerably, they have to search for jobs in a larger region. This could also explain why the effect of income is much larger for workplace relocators than for residential relocators.

The results of the rest of the level variables are mixed for the different relocation models. Age, for example, is positive for residential relocation and negative for job relocation. Women tend to increase the commuting time less than men when they relocate job. For the other types of relocation, the negative effect for women appears only when there are young children in the household. Also, a higher education level entails a larger commuting time increase when there are job relocations. Finally, the commuting time changes are increasing over time for all types of relocation. This means that, controlling for other effects, the commuting time change during periods 1990-1993 and 1993-1998 is significantly larger than the commuting time change during period 1986-1990. The commuting time change during period 1993-1998 is also larger than the commuting time change during 1990-1993.

Turning to the change variables, the effect of income change is positive for job relocations. It seems that workers accept longer commuting time since they are, to some extent, compensated by a higher wage. For residential relocations, the effect of the income change is negative but only weakly significant. The negative sign may reflect that workers with a wage increase that is larger than the average, use their increased relative purchase power on a more expensive residence located closer to their workplace. [15] Thus, the negative coefficient for the income change may reflect a positive income effect for housing. A variable that measures the change in some housing characteristics would be attractive in this case, unfortunately, no such variable is accessible in the data. In addition, education change shows a substantial positive effect when there are job relocations. Higher educated workers are probably more specialized and therefore they might have to search for a job further away from home.

[15] Recall that the income variable is inflated with regards to the average income increase between the observation years. Thus, the higher the income change, the higher the income increase relative to other workers.

Table 10
OLS regressions of commuting time changes following relocations

Variable	**Residential relocations**		**Job relocations**		**Residential and job relocations**	
	Coeff.	**(S. err.)**	**Coeff.**	**(S. err.)**	**Coeff.**	**(S. err.)**
Level						
Commuting time	-6.91**	(0.095)	-7.79**	(0.081)	-11.3**	(0.119)
Income	0.951**	(0.217)	2.88**	(0.181)	3.39**	(0.271)
Age	0.020**	(0.006)	-0.018**	(0.006)	-0.011	(0.009)
Married	-0.348**	(0.113)	-0.201*	(0.097)	0.133	(0.184)
No. of children	0.225*	(0.105)	-0.090	(0.106)	0.214	(0.189)
No. of cars	0.611**	(0.092)	0.109	(0.078)	-0.489**	(0.138)
Women	0.063	(0.105)	-0.405**	(0.097)	0.072	(0.149)
Children×women	-0.279*	(0.142)	-0.186	(0.121)	-0.454*	(0.216)
High school	0.079	(0.104)	0.655**	(0.105)	0.498**	(0.184)
University	0.218†	(0.131)	1.18**	(0.125)	0.438*	(0.207)
1990-1993	0.270*	(0.113)	0.605**	(0.107)	0.904**	(0.183)
1993-1998	0.465**	(0.112)	1.48**	(0.102)	1.92**	(0.157)
Accessibility	-1.49**	(0.042)	-1.15**	(0.028)	-1.89**	(0.056)
Change						
Income/100 000	-0.184†	(0.102)	0.707**	(0.096)	0.378**	(0.073)
Getting married	0.275†	(0.142)	-0.063	(0.206)	0.415*	(0.206)
Divorced	-0.101	(0.190)	0.522†	(0.272)	-0.172	(0.303)
More children	-0.061	(0.115)	-0.584**	(0.162)	-0.197	(0.177)
Less children	-0.321†	(0.191)	0.049	(0.177)	-0.058	(0.332)
More cars	1.29**	(0.118)	0.580**	(0.119)	0.979**	(0.172)
Less cars	-0.754**	(0.148)	-0.389**	(0.150)	0.363†	(0.218)
Education	0.307†	(0.187)	0.714**	(0.165)	0.780**	(0.226)
Accessibility	-2.05**	(0.034)	-0.635**	(0.082)	-1.86**	(0.041)
County of residence	5.45**	(0.655)			-0.486*	(0.196)
R-square	0.327		0.195		0.345	
No. of observations	52 557		87 691		43 393	

Note: For the coefficients, **, * and † denote difference from zero at the one, five and ten percent significance level respectively. The model for residential relocation also includes level dummy variables for the county of residence. For simplicity, these coefficients are not shown in the table. All models also includes an intercept, which is more or less non-interpretable. The standard errors are robust and also adjusted for clusters, i.e. that some observations belong to the same individual. The level variables of commuting time and income are given in the natural logarithm. No. of cars is the number of cars in the household but defined as 2 if the actual number is 2 or more. No. of children is the number of children aged 0-6.

Regarding a comparison with the results of Krizek (2003), he did not have access to as many different variables as in this study, so a relevant comparison can only be made for commuting time, income and number of children. For the level of commuting time the similarity across these studies has already been mentioned. Furthermore, the income variables of both the level and the change are positive and significant in Krizek (2003) so in this case there seems to be a robustness across the different data and the different commuting variables. Finally, the number of children in level, is non-significant in this study as well as in that of Krizek (2003).

3.4 Quantile regression models of commuting time changes

In Tables 11 through 13, the results of quantile regression models of the commuting time changes are presented. For all three types of relocation, models are estimated for the 0.1, 0.5 (median) and 0.9 quantile. Thus, the effect of the covariates at points relatively far out in each of the tails, as well as the middle point of the distributions of commuting time changes, is analyzed. At the 0.1 quantile, the commuting time change is negative while at the 0.9 quantile, the commuting time change is positive. The covariates will be the same as for the OLS models presented in the former subsection. The attention, however, will mainly be at the variables where the effect is different at different points of the distribution of the commuting time changes.

In Table 11, the quantile regression results for residential relocations are presented. Among the level variables, income has a much higher positive influence at the 0.9 quantile compared to at the other quantiles. Income seems to be an even more important factor for the commuting time change when the change is an increase compared to when the change is a decrease. Furthermore, the effect of age and the effect of the number of cars in the household are positive only at the upper tail of the distribution of the commuting time changes. The effect of number of young children is positive and significant at the 0.1 and 0.5 quantiles.

Regarding the change variables, the effect of a residential change across a county border on the commuting time change, has reversed signs at the lower and upper tail of the distribution of the commuting time changes. A move to another county without a job change suggests a substantial absolute change in commuting time. Therefore, moves to another county plausibly imply commuting time changes further out in the tails of the distribution, ceteris paribus.

Similar quantile regressions for job relocations are presented in Table 12. Here, the effect of the income level is strongly positive at both tails of the distribution. The effect for women has a negative sign at the upper tail of the distribution of the commuting time changes and a positive sign at the lower tail of the distribution of the commuting time changes. These reversed signs mean that women increase their commuting time less at the upper tail of the distribution and decrease their commuting time less at the lower tail of the distribution, as compared to men. In other words, men tend to have larger commuting time changes in absolute terms than women, and thus the distribution of commuting time changes has a larger variance for men than for women. One reason could be that men also have a larger variance in commuting times, which may lead to larger commuting time changes in absolute terms. This finding may be a reflection of a larger commuting time tolerance among men than among women. At the upper tail, the gender effect is even larger if there are young children in the household. Also, the results show a significant positive time trend of the commuting time changes at all quantiles but the effect is largest at the upper tail. Increases of commuting time later on during this observation period seem to be larger on average.

The change variables that show the most interesting results here are more children and education. More children is strongly negative only at the upper tail of the distribution

Table 11
Quantile regressions of commuting time changes following residential relocations

Variable	**0.1 quantile**		**0.5 quantile**		**0.9 quantile**	
	Coeff.	**(S. err.)**	**Coeff.**	**(S. err.)**	**Coeff.**	**(S. err.)**
Level						
Commuting time	-7.24**	(0.093)	-3.21**	(0.066)	-3.90**	(0.115)
Income	0.692**	(0.225)	0.442**	(0.102)	1.72**	(0.416)
Age	-0.009	(0.006)	0.001	(0.003)	0.036**	(0.011)
Married	0.069	(0.111)	-0.078	(0.052)	-0.830**	(0.210)
No. of children	0.322**	(0.115)	0.159**	(0.048)	-0.281	(0.205)
No. of cars	-0.295**	(0.096)	0.076†	(0.041)	1.41**	(0.184)
Women	0.194†	(0.104)	-0.017	(0.051)	0.007	(0.196)
Children×women	0.031	(0.156)	-0.089	(0.071)	-0.698*	(0.274)
High school	-0.042	(0.101)	0.049	(0.051)	0.135	(0.224)
University	0.032	(0.125)	0.158*	(0.064)	0.581*	(0.266)
1990-1993	0.044	(0.115)	-0.118*	(0.049)	0.278	(0.212)
1993-1998	-0.066	(0.111)	0.216**	(0.051)	0.530**	(0.205)
Accessibility	-0.645**	(0.053)	-0.817**	(0.023)	-2.21**	(0.071)
Change						
Income/100 000	0.044	(0.093)	0.031	(0.036)	-0.371**	(0.141)
Getting married	0.366*	(0.152)	0.227**	(0.078)	0.076	(0.315)
Divorced	-0.002	(0.208)	-0.064	(0.083)	-0.201	(0.306)
More children	0.289*	(0.123)	0.040	(0.056)	-0.236	(0.239)
Less children	-0.059	(0.214)	-0.187*	(0.081)	-0.520	(0.362)
More cars	0.234*	(0.111)	0.545**	(0.056)	2.30**	(0.255)
Less cars	-0.620**	(0.166)	-0.263**	(0.061)	-0.666*	(0.278)
Education	-0.013	(0.193)	0.140†	(0.078)	0.753*	(0.335)
Accessibility	-1.18**	(0.032)	-1.78**	(0.017)	-2.83**	(0.053)
County of residence	-20.0**	(1.48)	6.10**	(0.739)	30.7**	(2.01)
R-square	0.352		0.189		0.206	
No. of observations			52 557			

Note: For the coefficients, **, * and † denote difference from zero at the one, five and ten percent significance level respectively. The models also includes level dummy variables for the county of residence. For simplicity, these coefficients are not shown in the table. All models also includes an intercept, which is more or less non-interpretable. The standard errors are obtained by bootstrapping with 400 repetitions. The level variables of commuting time and income are given in the natural logarithm. No. of cars is the number of cars in the household but defined as 2 if the actual number is 2 or more. No. of children is the number of children aged 0-6.

of commuting time changes. This means that a new child between $t-1$ and t influences the commuting time change negatively if the commuting time change is an increase. This can be seen as a confirmation of the result in Table 6 and may depend on a reduction of the commuting time tolerance after a child birth. Education change is positive and significant at all these three quantiles. However, the effect is strongest at the upper tail of the distribution of the commuting time changes.

In Table 13, the results of the quantile regression models for combined residential and job relocations are presented. The results of these models are fairly similar to the results of the models on job relocation. This holds in particular for income, number of

Table 12
Quantile regressions of commuting time changes following job relocations

Variable	**0.1 quantile**		**0.5 quantile**		**0.9 quantile**	
	Coeff.	**(S. err.)**	**Coeff.**	**(S. err.)**	**Coeff.**	**(S. err.)**
Level						
Commuting time	-8.30**	(0.098)	-1.85**	(0.042)	-7.31**	(0.124)
Income	2.84**	(0.234)	0.948**	(0.059)	3.175**	(0.441)
Age	0.015†	(0.008)	-0.002	(0.002)	-0.067**	(0.014)
Married	-0.360**	(0.136)	-0.066*	(0.031)	-0.619**	(0.241)
No. of children	0.033	(0.153)	-0.039	(0.032)	0.052	(0.290)
No. of cars	-1.26**	(0.117)	-0.110**	(0.027)	1.68**	(0.176)
Women	1.21**	(0.141)	0.085**	(0.033)	-1.70**	(0.249)
Children×women	-0.091	(0.173)	-0.027	(0.047)	-0.632*	(0.269)
High school	1.20**	(0.159)	0.191**	(0.034)	0.865**	(0.239)
University	1.41**	(0.168)	0.244**	(0.039)	3.06**	(0.288)
1990-1993	0.183	(0.139)	0.026	(0.031)	1.05**	(0.233)
1993-1998	0.472**	(0.141)	0.650**	(0.035)	2.79**	(0.251)
Accessibility	-1.11**	(0.049)	-0.343**	(0.010)	-1.12**	(0.063)
Change						
Income/100 000	0.730**	(0.087)	0.279**	(0.028)	0.709**	(0.018)
Getting married	-0.507*	(0.257)	-0.065	(0.057)	-0.173	(0.458)
Divorced	0.571	(0.359)	0.054	(0.096)	0.709	(0.497)
More children	-0.355†	(0.210)	-0.061	(0.050)	-1.03**	(0.376)
Less children	0.440†	(0.240)	0.031	(0.054)	-0.527	(0.400)
More cars	-0.668**	(0.153)	0.111**	(0.036)	2.34**	(0.270)
Less cars	-0.132	(0.199)	-0.010	(0.047)	-0.737*	(0.336)
Education	0.610**	(0.194)	0.285**	(0.062)	1.79**	(0.365)
Accessibility	-0.504**	(0.139)	-0.342**	(0.024)	-0.778**	(0.207)
R-square	0.239		0.017		0.075	
No. of observations			87 691			

Note: For the coefficients, **, * and † denote difference from zero at the one, five and ten percent significance level respectively. The models also includes level dummy variables for the county of residence. For simplicity, these coefficients are not shown in the table. All models also includes an intercept, which is more or less non-interpretable. The standard errors are obtained by bootstrapping with 400 repetitions. The level variables of commuting time and income are given in the natural logarithm. No. of cars is the number of cars in the household but defined as 2 if the actual number is 2 or more. No. of children is the number of children aged 0-6.

cars, gender, the interaction variable between gender and the number of young children and the time intervals. These similarities suggest that the results following combined residential and job relocations are mostly driven by the job relocation. A further interpretation is that the residential relocation here is adjusted in such a way that the commuting time change is similar, compared to a situation where the job is changed without a change of residence. Remember, however, that combined relocations of jobs and residences might be interregional and therefore impaired by more restrictions compared to job relocations only, which most likely are intraregional.

Table 13
Quantile regressions of commuting time changes following combined residential and job relocations

Variable	0.1 quantile		0.5 quantile		0.9 quantile	
	Coeff.	(S. err.)	Coeff.	(S. err.)	Coeff.	(S. err.)
Level						
Commuting time	-11.8**	(0.142)	-7.63**	(0.113)	-8.91**	(0.233)
Income	3.05**	(0.300)	2.81**	(0.193)	3.66**	(0.634)
Age	-0.054**	(0.011)	-0.029**	(0.006)	0.046*	(0.021)
Married	0.487*	(0.243)	0.035	(0.131)	-0.810†	(0.492)
No. of children	0.246	(0.227)	-0.023	(0.141)	0.430	(0.465)
No. of cars	-1.53**	(0.183)	-0.915**	(0.099)	1.59**	(0.330)
Women	0.686**	(0.197)	0.378**	(0.103)	-0.972*	(0.399)
Children×women	-0.141	(0.253)	-0.200	(0.157)	-1.83**	(0.562)
High school	0.301	(0.234)	0.158	(0.122)	1.28**	(0.411)
University	0.048	(0.270)	0.252†	(0.141)	2.20**	(0.470)
1990-1993	0.046	(0.220)	0.479**	(0.118)	1.97**	(0.435)
1993-1998	0.830**	(0.192)	1.34**	(0.104)	3.26**	(0.367)
Accessibility	-1.29**	(0.078)	-1.39**	(0.037)	-2.36**	(0.129)
Change						
Income/100 000	0.294**	(0.066)	0.364**	(0.082)	0.388**	(0.119)
Getting married	0.692**	(0.238)	0.434**	(0.136)	-0.247	(0.540)
Divorced	-0.247	(0.387)	-0.317†	(0.186)	0.425	(0.785)
More children	-0.089	(0.210)	-0.039	(0.119)	-0.586	(0.366)
Less children	0.059	(0.407)	0.078	(0.228)	0.062	(0.852)
More cars	-0.358†	(0.197)	0.390**	(0.120)	3.50**	(0.442)
Less cars	0.528*	(0.263)	0.684**	(0.137)	-0.892†	(0.486)
Education	0.781*	(0.318)	0.465**	(0.164)	0.880†	(0.509)
Accessibility	-1.02**	(0.057)	-1.86**	(0.029)	-2.54**	(0.091)
County of residence	-2.85**	(0.246)	-1.22**	(0.138)	4.41**	(0.536)
R-square	0.369		0.179		0.113	
No. of observations			43 393			

Note: For the coefficients, **, * and † denote difference from zero at the one, five and ten percent significance level respectively. The models also includes level dummy variables for the county of residence. For simplicity, these coefficients are not shown in the table. All models also includes an intercept, which is more or less non-interpretable. The standard errors are obtained by bootstrapping with 400 repetitions. The level variables of commuting time and income are given in the natural logarithm. No. of cars is the number of cars in the household but defined as 2 if the actual number is 2 or more. No. of children is the number of children aged 0-6.

4 Concluding discussion

In this study, the objective was to analyze commuting time changes that follow residential relocation, job relocation and combined residential and job relocation. A large set of register data on the Swedish labor market combined with car route travel times between small homogeneous areas, are used to this end.

First, the empirical results show that the average commuting time of all workers has steadily increased in Sweden between 1986 and 1998. This result falsifies the rational locator hypothesis (Levinson and Wu, 2005), which posits that workers adjust their workplace and/or residence in such a way that the average commuting times over time are stable.

Further results that also falsify the rational locator hypothesis are found when the average commuting time change following relocation is analyzed. Here, in more or less all subsamples and for all types of relocation, the commuting time increases significantly after relocations. After a job relocation and a child birth, however, the average commuting time change is non-significant, which may reflect a higher value of commuting time for this group compared to others. When the sample is split with respect to counties, a significant decrease in average commuting time is found in three cases out of 63. In 19 cases, no significant commuting time change is found. In the latter cases, a small sample size may be the reason for at least some of the counties.

This result partly supports and partly contradicts the theory stating that workers who relocate job will be more likely to decrease their commuting, whereas workers who relocate residence will be more likely to increase their commuting. One objection here might be that this theory is claimed to hold for metropolitan areas only and that most previous empirical studies are based on metropolitan areas. The results of this study, however, hold for the Stockholm region as well as for the regions with the second and third largest cities in Sweden.

The results of the econometric regressions for changes in commuting time show that socio-economic characteristics have a large influence on the commuting time changes following workers' relocations. Furthermore, quantile regressions show that several covariates influence the commuting time differently at the upper tail of the distribution of commuting time changes compared to the lower tail of the same distribution. The commuting time level has a strong negative impact on the commuting time change, which should not be interpreted as workers seeking to decrease commuting time when they relocate (see Rouwendal, 2004). Also, the commuting time change following relocations tends to become larger over time during this observation period. For job relocations, the commuting time changes that are already positive tend to become even larger over time. These last findings may, if the trends continue in the future, have large policy implications. For example, gender equality may worsen given that regional expansion entails a longer commuting time only for the husband of two-earner households. Also, environmental effects such as increased road congestion, traffic noise and increased emissions of greenhouse gases may be the result.

This study is the first attempt to analyze commuting time changes following relocations by the use of register data. Therefore, the analysis is kept relatively simple and descriptive. This implies a number of opportunities for refining this type of analysis in future research. First, it would be interesting to analyze commuting time changes with a household dimension. The choice to relocate residence is clearly a household choice, and the choice to change jobs that influences the commuting time is most likely a decision based on discussion within the household. Nevertheless, the analysis of commuting time changes split into married and non-married individuals presented in Table 3, shows no clear difference between these two groups. Second, it would be attractive to incorporate the characteristics of the direction of the relocations in the analysis. For example, no consideration is taken of the length of a relocation. Including such characteristics may also help to explain whether suburbanization is the correct explanation for the increase in average commuting time after residential relocations. Finally, it would be interesting to analyze other classifications of the region. Here, the definitions of the local labor markets is a possible suggestion, since these classifications are actually based on commuting flows.

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References

Boverket: 2005, 'Är regionförstoring hållbar?'. Report, The National Board of Housing Building and Planning (Boverket), Karlskrona, Sweden.

Cameron, A. C. and P. K. Trivedi: 2005, *Microeconometrics: Methods and Applications*. New York: Cambridge University Press.

Cameron, A. C. and P. K. Trivedi: 2009, *Microeconometrics Using Stata*. College Station, Texas: Stata Press.

Clark, W. A., Y. Huang, and S. Withers: 2003, 'Does commuting distance matter? Commuting tolerance and residential change'. *Regional Science and Urban Economics* **33**(2), 199–221.

Deding, M., T. Filges, and J. Van Ommeren: 2009, 'Spatial mobility and commuting: The case of two-earner households'. *Journal of Regional Science* **49**(1), 113–147.

Haraldsson, M.: 2007, 'Essays on Transport Economics'. Ph.D. thesis, Department of Economics, Uppsala University, Uppsala, Sweden.

Isacsson, G. and J.-E. Swärdh: 2009, 'The value of commuting time in an empirical on-the-job search model - Swedish evidence based on linked employee-establishment data'. Working Paper, Swedish National Road and Transport Research Institute (VTI).

Kim, C.: 2008, 'Commuting time stability: A test of a co-location hypothesis'. *Transportation Research Part A: Policy and Practice* **42**(3), 524–544.

Koenker, R.: 2005, *Quantile Regression*. Cambridge: Cambridge University Press.

Krizek, K. J.: 2003, 'Residential relocation and changes in urban travel: Does neighborhood-scale urban form matter?'. *Journal of the American Planning Association* **69**(3), 265–281.

Levinson, D. and Y. Wu: 2005, 'The rational locator reexamined: Are travel times still stable?'. *Transportation* **32**(2), 187–202.

Marion, B. and M. W. Horner: 2007, 'Comparison of socioeconomic and demographic profiles of extreme commuters in several U.S. metropolitan statistical areas'. *Transportation Research Record* **2013**, 38–45.

Prillwitz, J., S. Harms, and M. Lanzendorf: 2007, 'Interactions between residential relocations, life course events, and daily commute distances'. *Transportation Research Record* **2021**, 64–69.

Rouwendal, J.: 2004, 'Search theory and commuting behavior'. *Growth and Change* **35**(3), 391–418.

Rouwendal, J. and P. Rietveld: 1994, 'Changes in commuting distances of Dutch households'. *Urban Studies* **31**(9), 1545–1557.

Sandow, E.: 2008, 'Commuting behaviour in sparsely populated areas: evidence from northern Sweden'. *Journal of Transport Geography* **16**(1), 14–27.

SKL: 2008, 'Pendlare utan gränser? En studie om pendling och regionförstoring'. Report, Swedish Association of Local Authorities and Regions (SKL), Stockholm, Sweden.

Vandersmissen, M. ., P. Villeneuve, and M. Thriault: 2003, 'Analyzing changes in urban form and commuting time'. *Professional Geographer* **55**(4), 446–463.

Wachs, M., B. D. Taylor, N. Levine, and P. Ong: 1993, 'The changing commute: a case-study of the jobs-housing relationship over time'. *Urban Studies* **30**(10), 1711–1729.

Yang, J.: 2008, 'Policy implications of excess commuting: Examining the impacts of changes in US metropolitan spatial structure'. *Urban Studies* **45**(2), 391–405.

Zax, J. S. and J. F. Kain: 1991, 'Commutes, quits, and moves'. *Journal of Urban Economics* **29**(2), 153–165.