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"On the Non-Linearity of the Willingness to Commute"

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ABSTRACT

Established analyses of labour market commuting are based on random-choice models and gravity type models. In these models generalised transport costs are formulated as exponential or log linear distance-dependent functions. This paper presents empirical observations which imply that time-distances influence the commuting behaviour in a non-linear way, such that the time sensitivity is much lower for very short and long distances, whereas intermediate distance display a high time sensitivity. This is explained in a model which is parameterised and estimated. The results are important for understanding and predicting commuter behaviour. It also helps to delineate space, as in classical traditions, into local, intra-regional and extra-regional space.

1. INTRODUCTION

This paper adheres to the tradition of discrete-choice analysis. This tradition comprises models of travel demand behaviour (e.g. Domenchich and McFadden, 1975; Ben-Akiva and Lerman), labour market commuting (e.g. White, 1977 and 1986) and location behaviour of firms and households (e.g. Mattsson, 1984; Turner and Niemeir, 1997). Many models in this tradition have the ambition to explain but also more explicitly predict behaviour on the basis of utility-maximising agents. Another issue in this context is time budgets and the value of time (e.g. Eliasson, 2000 and Gonzales, 1997).

1.1 Context and hypotheses

The focus in this paper is on labour market commuters and their behaviour. The study has been triggered by observation indicating that although the willingness of an individual to commute depends on the time distance between origin and destination, this time dependency is strikingly different for short, medium and longer distances. In view of these observations the paper introduces a preference function for an individual commuter, where the preferences includes variables such as wage level and commuting time. In this function there is an explicit separation of short time distances (intra-municipality), medium time distances (intra-regional commuting), and long time distances (extra-regional commuting). This separation has the form of three different time-sensitivity parameters. In addition, each commuter has an explicit preference for having a job in the "home municipality" and the "home region".

The preference function is assumed to have a random-choice form of the logit type. The parameters of this function are estimated by means of a multiple-constraint optimisation model. The estimated parameters are assessed against a set of hypotheses. These include the following properties. First, the time sensitivity is distinctly highest for intra-regional commuting and lowest for intra-municipal commuting. Second, the preference for where to work is highest for the "home municipality" and lowest for jobs outside the own region.

The empirical analysis separates male and female commuters. Moreover, for each of these categories separate estimations are made separately for three different education levels. In this context the paper formulates three hypotheses based on observations in Johansson, Klaesson and Olsson (2002). First, the time sensitivity decreases with the level of education . Second, for each education class the time sensitivity is lower for male than for female commuters. Third, female commuters are more sensitive than male commuters to the size of both the own municipality's and the own region's labour market.

1.2 Outline of the Paper

Section 2 presents the characteristics of Sweden's structure of municipalities and labour markets and introduces the concept of LA-region (local labour-market region), referred to as region. Section 3 introduces the random-choice preference function of an individual and formulates the optimisation model that is used to estimate parameters of the the preference function. Section 4 presents and evaluates the empirical results. The paper ends with section 5, which presents a set of conclusions.

2. SPATIAL STRUCTURE OF THE LABOUR MARKETS

2.1 Time Distances

Interaction between economic agents can have many forms. In this paper the focus is on contacts that involve the displacement of persons. This excludes mediated contacts such that persons or organisations interact by sending messages. Typical examples of displacement contacts are face-to face meetings, a consumer's commuting to a shopping area and an individual's commuting to work. In the empirical analysis data about labour market commuting are used, but the intention is to reflect all forms of displacement interaction.

The study assumes that time has a strongly non-linear influence of the behaviour of interacting individuals (interactors). The intuition behind the assumption is that an interactor has different time sensitivity for local, regional and interregional interaction. In this context local interaction refers to contacts for which the displacement consumes small amounts of time, which implies that such contacts require very little planning and hence can take place on short notice. As an everyday reference we may think of 10-15 minutes as an upper boundary for such local or short time distances. The second time interval would then have this as a lower boundary, with 50-60 minutes as an upper boundary. This upper boundary corresponds to the conventional idea that 60 minutes travel time defines a daily commuting region. Time distances beyond an hour are classified as long.

2.2 LA-regions and Municipalities

In the subsequent analysis space is arranged in three categories: (i) municipality, (ii) functional region called LA-region, and (iii) extra-regional space, which consists of locations outside the LA-region. The available data make it possible to decompose each municipality into a set of zones. The local labour market region (LA region) is composed of a set of municipalities between which the commuting intensity is high. The concept of an LA region can be associated with the concept of a functional urban region (FUR), as defined by Cheshire and Gordon (1995, 1998). The current paper identifies a functional labour market from the perspective of each individual municipality. The method to do this is straightforward. For each individual municipality one can specify the accessibility to jobs and the accessibility to labour supply. Such accessibility measures depict the size of a municipality-centred local labour market, as revealed by the behaviour of households and firms in the municipality. These and related accessibility measures do not only explain existing patterns of commuting, they can also be used in predicting changes in municipality growth with regard to population size and number of jobs. The latter statement really means that when time distances change, the accessibility pattern will change and these changes affect the extension of each region. In this way, changed time distances will affect growth and relocation of households and jobs.

How do municipalities and regions compare with regard to time distances? First, we measure the commuting time distance by travel time by car, without adding any time for the initiation and termination of a trip. In other words, "feeder time is excluded". For a large share of municipalities the commuting distance between zones inside each municipality amounts to an average around 10 minutes. The corresponding average for commuting between municipalities in the same region can be approximated by 25-30 minutes. The average commuting time from a municipality to destinations outside the pertinent region is more than 45 minutes. An overwhelmingly large share of the commuting takes place inside each LA-region, which justifies that they are classified as labour-market regions.

The empirical analyses are based on observations from the two years 1990 and 1998. In the first of these years there were 284 municipalities and in the second 289 ones. For both years these municipalities are arranged into 81 LA-regions.

2.3 Willingness to Commute

Each commuter in our analysis has a place of residence in a zone of a municipality. The labour market opportunities of this individual consists of jobs (i) inside the municipality, (ii) in other municipalities in the region to which the municipality belongs, and (iii) jobs in municipalities outside the region. Everything else equal, the attraction of the labour market in a specific municipality can be thought of as the size (number of jobs) of that market.

To make our arguments precise, let A_s denote the number of jobs in municipality *s*, and let m_{ks} denote the commuter flow from municipality *k* to municipality *s*. With these two variables the willingness to commute is defined as

$$b_{ks} = m_{ks} / A_s \tag{2.1}$$

This means that the flow of commuters is related to the size of the labour market in the destination municipality. By first calculating the different b_{ks}-values for municipality *k* and then matching each such value with the corresponding time distance, t_{ks}, we can plot a willingness to commute curve as illustrated in Figure 2.1. This means that b_{ks} is described as a function $b(t_{ks})$.

The commuting inside municipality *k* takes place on another geographical scale. Let there be *n* zones in *k* and let m_{kk} be the total commuting inside *k*. Then the willingness to commute inside the municipality can be approximated by the following formula:

$$b_{kk} = [m_{kk} / n(n-1)]/[A_k / n] = m_{kk} / A_k(n-1) \tag{2.2}$$

where *n* denotes the number of zones in the municipality, which implies that the number of links (and flows) is *n*(*n*-1). Moreover, A_k / n describes the average size of a commuting destination inside the municipality. Formula (2.2) describes the average willingness to commute inside the municipality.

Outside the municipality

Figure 3.1: Willingness to commute to other municipalities as observed for a medium-sized Swedish LA-region

The *b*-curve is described in Figure 2.1. The curve start with and almost flat part fort short time distances, then it starts to fall rapidly with an inflexion point around 45 minutes. Further to the right the curve flattens out again. The authors have observed this pattern for a large number of Swedish municipalities (Johansson, Klaesson and Olsson, 2002). These observations have generated the following hypothesis:

H1: The time sensitivity is lower for intra-municipality than for intra-regional commuting. Moreover, the time sensitivity is lower for extra-regional than for intra-regional commuting.

When examining H1 and the subsequent hypotheses we assume that intra-municipality commuting corresponds to short time-distances, intra-regional commuting to medium time-distances and extra-regional commuting to long time-distances. There are more than 70 000 potential commuter links in the data set and for a small number of links these time distance conditions are violated, but these deviations disappear in the large-number mass.

Let l_0, l_1 and l_2 denote the time sensitivity of intra-municipality, intra-regional and extra-regional commuting, respectively. With these notations we also want to examine the following more distinct hypothesis:

H2: The following pattern is assumed to hold: $l_1 > l_2 > l_0$.

Let d_0, d_1 and d_2 denote the specific preference of individuals for job opportunities in the own municipality, the own region, and other regions, respectively. With these notations we want to examine the following hypothesis:

H3: The following pattern is assumed to hold: $d_0 > d_1 > d_2$, which implies a hierarchical preference ordering of jobs inside the municipality and inside the region, respectively.

Hypotheses H1-H3 relate to perceptions that short time distances allow an individual to make contacts in a less planned and less restrictive way than do long time distances. With short time distances an individual can have many contacts and can adjust his/her behaviour at low costs. The knowledge about opportunities in the local (home) territory is also in general better than in other parts of the geographical space.

In addition to hypotheses H1 – H3, observations in Johansson, Klaesson and Olsson (2002) have also generated the following hypotheses:

H4: The time sensitivity decreases with the level education and this applies to both male and female commuters.

H5: The time sensitivity is lower for male than for female commuters.

H6: Female commuters are more sensitive than male commuters to the size of each potential labour market (the number of jobs in each destination).

The three hypotheses above may be interpreted as follows. An individual with higher education has in general a more specialised labour-market matching problem to solve. Matching jobs are more dispersed across space than they are for an individual with lower education. This remark relates to H4. With regard to the difference between male and female commuters, the latter may be assumed to have a stronger commitment to carry out family related activities, and these tend to be local in nature. This makes female time budgets more strict and binding. Hence, female commuters should be expected to have a higher time sensitivity than male commuters. Moreover, female commuters have a stronger preference for jobs located close to the place of residence.

Hypotheses H1 – H3 are compatible with the willingness-to-commute curve that is illustrated in Figure 2.1. Moreover, hypotheses H4 – H6 imply that different labour categories have different willingness-to-commute patterns. Before making these hypotheses more precise we need to formulate a theoretical model of commuting and then formulate models for testing the hypotheses.

3. A SPATIAL INTERACTION MODEL

3.1 Discrete Choice and Time Sensitivity

Discrete choice is a decision process in which the individual can select from a set of mutually exclusive alternatives. In this analysis we assume that the individual has a preference function that assigns a value to each of the alternatives. The context is an individual with residence in municipality k who has to select a job in municipalities s = 1,..., k, ..., K including k itself. In this setting R_k denotes the set of municipalities in the same region as k, and E_k denotes the set of municipalities outside this region. The preference value of living in k and working in s is denoted by U_{ks}. As a first step we assume that individuals are characterised by random-choice preferences, which means that $U_{ks} = V_{ks} + \mathbf{e}_{ks}$, where the last term is a random term with a given distribution. As a reference the following preference function is specified:

$$V_{kl} = h_l + D_{kl} - \mathbf{l}_{kl} t_{kl}$$
$$D_{kl} = \mathbf{d}_0 \text{ if } l = k;\ D_{kl} = \mathbf{d}_1 \text{ if } l \neq k \text{ and } l \in R_k;\text{ and } D_{kl} = 0 \text{ if } l \in E_k$$
$$\mathbf{l}_{kl} = \mathbf{l}_0 \text{ if } l = k;\ \mathbf{l}_{kl} = \mathbf{l}_1 \text{ if } l \neq k \text{ and } l \in R_k\text{, and } \mathbf{l}_{kl} = \mathbf{l}_2 \text{ if } l \in E_k \qquad (3.1)$$

where h_l is an attractiveness factor associated with the labour market in l, and where $\mathbf{d}_0$ and $\mathbf{d}_1$ refer to preferences for the intra-municipality and intra-regional labour market respectively. Moreover, $\mathbf{l}_0$, $\mathbf{l}_1$ and $\mathbf{l}_2$ represent the time sensitivity for intra-municipality, intra-regional and extra-regional commuting, respectively. We may also observe that $D_{kl} = 0$ if $l \in E_k$ means that $\mathbf{d}_0$ and $\mathbf{d}_1$ are defined with extra-region locations as a reference.

The attractiveness factor h_l is assumed to depend on the wage level in municipality l such that $h_l = a_l + b(w_l - w)$, where w_l is the wage level in l and w is the average wage level in the system of municipalities. We may also observe that (3.1) implicitly assumes that other commuting costs than time costs are proportional to time and hence included in the $\mathbf{l}$-values.

We assume that each individual decides where to work by selecting the alternative that has the largest U_{ks}-value. Moreover, the $\mathbf{e}_{ks}$-terms are assumed to be extreme-value distributed, which yields a multinomial logit model (Train, 19xx). This has the followoing consequence. For a resident in k, the probability of selecting a job in municipality in l can be calculated as

$$P_{kl} = \exp\{V_{kl}\} / \Sigma_l \exp\{V_{kl}\} \qquad (3.2)$$

Now, let M_k denote the number of persons with a job inside and outside municipality k. Then (3.2) implies that the expected number of commuters, $\hat{m}_{ks}$, can be calculated as $\hat{m}_{ks} = M_k P_{ks}$ for all s.

3.2 Time Sensitivity and Willingness to Commute

In Section 2 we introduce and discuss a measure of the willingness to commute. The context is a person living in municipality k and contemplating to select a job in a set of municipalities 1, ..., l, ..., K The number of jobs in municipality l is denoted by A_l, and the willingness to commute is calculated as $b_{kl} = m_{kl} / A_l$.

The willingness to commute can now be derived from the choice model introduced in the preceding sub section. First we specify the realised number of commuters from k as

$M_k = \sum_l m_{kl}$. As a second step we observe that $M_k P_{kl}$ represents the expected value of m_{kl} . In view of this we can write

$$\hat{b}_{kl} = M_k \exp\{V_{kl}\} / A_l \sum_l \exp\{V_{kl}\} \qquad (3.3)$$

where $\hat{b}_{kl}$ denotes the expected willingness to commute. Formula (3.3) implies that $\hat{b}_{kk} / \hat{b}_{kl}$ = $P_{kk} A_l / P_{kl} A_k$ = $A_l \exp\{V_{kk}\} / A_k \exp\{V_{kl}\}$. From (3.2) we can state that for $l \neq k$

$$P_{kk} > P_{kl} \text{ when } \exp\{h_k + \boldsymbol{d}_0 - \boldsymbol{l}_0 t_{kk}\} > \exp\{h_l + D_{kl} - \boldsymbol{l}_0 t_{kl}\} \qquad (3.4)$$

Observe that in (3.4) we compare only the nominators in the expressions for P_{kk} and P_{kl}, because they have the same denominator. According to our hypotheses H2 and H3 above we have that ((i) $\boldsymbol{l}_1 > \boldsymbol{l}_0$, (ii) $\boldsymbol{l}_2 > \boldsymbol{l}_0$, and (iii) $\boldsymbol{d}_0 > \boldsymbol{d}_1$. It is also evident that $t_{kl} > t_{kk}$. We can then see that $\hat{b}_{kk} > \hat{b}_{kl}$ as long as $h_l / \ln A_l$ is not too much smaller than $h_k / \ln A_k$. In Johansson, Klaesson and Olsson (2002) a model is presented for which $h_l / \ln A_l$ = $h_k / \ln A_k$. In that case it always true that $\hat{b}_{kk} > \hat{b}_{kl}$, given our hypotheses.

We can also provide similar conditions, though more complex, to show that $\hat{b}_{kl} > \hat{b}_{ks}$ for $l \in R_k$ and $s \in E_k$. In that way we have established that our hypotheses are compatible with the curve in Figure 2.1.

> *Remark*: The model structure developed in sub section 3.2 can be applied for total commuter flows (average commuter), and for male and female commuters subdivided with regard to different education levels (all, low, medium and high).

3.3 A Multiple-Constraints Commuting Model

Consider the random choice model (of logit type) introduced in the previous sub section and summarised in (3.1)-(3.2). Our task in this subsection is to formulate an applied model that can be used to estimate the parameters for the model introduced. Following Leonardi (1981) and Mattsson (1984) we can estimate the model by means of a spatial-interaction model with an objective of entropy type. Such a model is equivalent to the logit model formulation.

Our first task is to distinguish flows inside a municipality, between municipalities in the same LA-region, and between municipalities in different regions. The total number of person with a job in municipality k is denoted by M_k . These commuters are subdivided into intra-municipality commuters, M_{k0}, intra-region commuters, M_{k1}, and extra-region commuters, M_{k2}, such that $M_k = (M_{k0} + M_{k1} + M_{k2})$.

Our next step is to introduce three dummy variables c_{ks}, d_{ks} and e_{ks} such that

$$c_{ks} = 1 \text{ if } s = k, \text{ and } 0 \text{ otherwise}$$

$d_{ks} = 1$ if $s \in R_k$ and $s \neq k$, and 0 otherwise
$e_{ks} = 1$ if $s \in E_k$, and 0 otherwise

With the help of this new notation the following optimisation model can be introduced:

$$Max - \sum_{ks} m_{ks}(\ln m_{ks} - 1), \text{ subject to constraints (i) – (vii):}$$
$$\text{(i) } \sum_s m_{ks} = M_k, \text{ (ii) } \sum_k m_{ks} = A_k, \text{ (iii) } T_0 = \sum_{ks} c_{ks} m_{ks} t_{ks}, \text{ (iv) } T_1 = \sum_{ks} d_{ks} m_{ks} t_{ks},$$
$$\text{(v) } T_2 = \sum_{ks} e_{ks} m_{ks} t_{ks}, \text{ (vi) } \sum_{ks} c_{ks} m_{ks} = M_{k0}, \text{ (vii) } \sum_{ks} d_{ks} m_{ks} = M_{k1} \quad (3.5)$$

Constraints (i) and (ii) ascertain that supply of and demand for commuters equilibrate, constraints (iii)-(v) ascertain that the model solution reproduces the correct time consumption for intra-municipality, intra-region and extra-region flows. Constraints (vi) and (vii) require that the model solution reproduces the flows M_{k0} and M_{k1}. We can observe that including a constraint $M_{k2} = \sum_{ks} e_{ks} m_{ks}$ would be redundant.

The optimisation model in (3.5) corresponds to the following Lagrange function:

$$\Lambda = -\sum_{k,s} m_{ks}(\ln m_{ks} - 1) + \sum_k \boldsymbol{a}_k (\sum_s m_{ks} - M_k) + \sum \boldsymbol{b}_s (\sum_s m_{ks} - A_s) +$$
$$\boldsymbol{l}_0[T_0 - \sum_{ks} c_{ks} m_{ks} t_{ks}] + \boldsymbol{l}_1[T_1 - \sum_{ks} d_{ks} m_{ks} t_{ks}] + \boldsymbol{l}_2[T_2 - \sum_{ks} e_{ks} m_{ks} t_{ks}] + \quad (3.6)$$
$$\boldsymbol{d}_0[\sum_{ks} c_{ks} m_{ks} - M_{k0}] + \boldsymbol{d}_1[\sum_{ks} d_{ks} m_{ks} - M_{k1}]$$

The solution to 3.6 can be derived for the three types of flows in the following form:

$$\text{(i) } P_{kk} = m_{kk} / \sum_s m_{ks} = \exp\{\boldsymbol{b}_k + \boldsymbol{d}_0 - \boldsymbol{l}_0 t_{kk}\} / \sum_s \exp\{\boldsymbol{b}_s + D_{ks} - \boldsymbol{l}_{ks} t_{ks}\}$$
$$\text{(ii) } P_{kl} = m_{kl} / \sum_s m_{ks} = \exp\{\boldsymbol{b}_l + \boldsymbol{d}_0 - \boldsymbol{l}_{1kl}\} / \sum_s \exp\{\boldsymbol{b}_s + D_{ks} - \boldsymbol{l}_{ks} t_{ks}\},$$
$$\text{for } l \in R_k \text{ and } l \neq k$$
$$\text{(iii) } P_{kl} = m_{kl} / \sum_s m_{ks} = \exp\{\boldsymbol{b}_l + \boldsymbol{d}_0 - \boldsymbol{l}_0 t_{kk}\} / \sum_s \exp\{\boldsymbol{b}_s + D_{ks} - \boldsymbol{l}_{ks} t_{ks}\}$$
$$\text{for } l \in E_k \quad (3.7)$$

By direct observation we can see that (3.7) describes the same solution as the one in (3.1) and (3.2) for $\boldsymbol{b}_l = a_l + b(w_l - w)$.

The model described in (3.6) is used in Section 4 to estimate parameters for the following 9 types of flows: (i) average commuter, average (ii) male and (iii) female commuter, (iv)-(vi) male commuters with three different education levels, and (vii-ix) female commuters with three different education levels. Going back to (3.6) we can also see that $\boldsymbol{d}_0$ reflects the value of increasing the size of the labour market in the "home" municipality, and that $\boldsymbol{d}_1$ reflects the value of increasing the size of the labour market in the "home" region.

From formula (3.6) we can see that only $\boldsymbol{d}_0$ and $\boldsymbol{d}_1$ are estimated explicitly, whereas $\boldsymbol{d}_2$ is defined implicitly. Since we have formulated a hypothesis about these three parameters, we have also selected a variant of the model (3.5)-(3.6). This latter model excludes the constraints

(i) and (ii) in (3.5) and adds the constraint $\sum_{ks} e_{ks} m_{ks} = M_{k2}$, which yields the Lagrange function

$$\Lambda = \sum_{k,s} m_{ks}(\ln m_{ks} - 1) + \lambda_0[T_0 - \sum_{ks} c_{ks} m_{ks} t_{ks}] + \lambda_1[T_1 - \sum_{ks} d_{ks} m_{ks} t_{ks}] + \\ \lambda_2[T_2 - \sum_{ks} e_{ks} m_{ks} t_{ks}] + \theta_0[\sum_{ks} c_{ks} m_{ks} - M_{k0}] + \theta_1[\sum_{ks} d_{ks} m_{ks} - M_{k1}] + \\ \theta_2[\sum_{ks} e_{ks} m_{ks} - M_{k2}] \qquad (3.8)$$

The solution to (3.8) implies that

$$P_{kl} = \exp\{D_{kl} - \lambda_{kl} t_{kl}\} / \sum_l \exp\{D_{kl} - \lambda_{kl} t_{kl}\}$$

Suppose that we want this result to be compatible with (3.1)-(3.2). Then we have to require that $D_{kk} = \theta_0 = a_k + b(w_k - w) + \delta_0$, where the left-hand side consists of a parameter which is the same for intra-municipality flows in all municipalities. The equality sign then implies that $a_k + b(w_k - w) = 0$. From this we can understand that the model in (3.8) is a simplified version of the one in (3.1)-(3.2). Similar conclusions can be drawn with regard to D_{kl} for $l \neq k$.

4. RESULTS FROM MODEL ESTIMATIONS

Sub section 4.1 and 4.2 are used to assess hypotheses H1- H4. Subsection 4.3 is focused on hypotheses H5 and H6. As a way of evaluating the quality and reliability of the estimated parameters, section 4.4 examines the robustness of estimations.

4.1 Total Commuter Flows

For total commuter flows we have formulated hypotheses H1 – H3, which are being empirically assessed in this sub section. H2 implies H1 and states that $\lambda_1 > \lambda_2 > \lambda_0$. The results in Table 4.1 shows that this pattern is reproduced for total commuting in all three model solutions.

Hypothesis H3 states that $\delta_0 > \delta_1 > \delta_3$. The hypothesis implies that a large labour market in the home municipality is valued higher than a large market in the home region, which in turn is valued higher than a large external market. Table 4.1 tells us that all three model-estimations reproduce the required parameter order.

There is also another information in Table 4.1. Our base model, (3.6), is estimated for both 1990 and 1998. The results indicate that the time-sensitivity parameters are approximately invariant over this ten years period. This may indicate that the parameters reflect robust preference patterns of the labour market participants.

Table 4.1: Parameters estimated for total commuting

Time sensitivity	Model (3.6), 1990	Model (3.6), 1998	Model (3.7), 1998

l_0 (inside muncipality)	0.023	0.025	0.029
l_1 (inside region)	0.096	0.096	0.103
l_2 (outside region)	0.053	0.052	0.049
Proximity preference			
d_0 (inside muncipality)	3.22	2.98	9.63
d_1 (inside region)	1.97	1.94	8.53
d_2 (outside region)	0	0	6.18

Remark: Estimations based on commuting between a set of more than 280 municipalities

4.2 Flows for Different Categories of Commuters

For different flows have been estimated for male as well as female commuters. Estimations have been for 1990 and 1998. The former can be found in the Appendix but will be used as comparisons when the 1998 estimations are presented here. All estimations follow the same conditions as in the preceding section.

The education categories used in the subsequent analysis is made with the following criteria. Low education means the pre-university college is missing, and corresponds to 9 years of study. Medium education includes 12 years of study and usually qualifies the student for university entrance. The criterion for high education is at least 3 years of completed university education.

Table 4.2 contains the four estimations of male commuter flows. They are all in accordance with hypotheses H1-H2. Table 4.2 also shows results in accordance with hypothesis H3, which requires that $d_0 > d_1 > d_2$, where we recall that in model (3.6) $d_2 = 0$ by construction. In addition we can see that the preference for municipal and regional commuting becomes smaller the longer the education is. Turning to hypothesis H4, it is clear that the estimated time-sensitivity parameters satisfy the condition that their values are falling as the education level is shifted from low to medium and to high.

Table 4.2: Parameters estimated for male commuters based on model (3.6) 1998

	l_0	l_1	l_2	d_0	d_1
Average male	0.023	0.090	0.050	2.844	1.850
Low education, male	0.032	0.092	0.056	3.090	1.728
Medium education, male	0.030	0.092	0.052	2.951	1.896
High education, male	0.014	0.083	0.045	2.334	1.673
Average, all commuters	0.025	0.096	0.052	2.985	1.936

Table 4.3 contains the four estimations of male commuter flows. Hypotheses H1-H2 predict the results correctly. The same is true for hypothesis H3. However, H4 makes incorrect predictions with regard to intra-municipal commuting. Results are not in accordance with the hypothesis, because the table shows higher time sensitivity for females with medium and high education than with low education. However, the hypothesis is not contradicted with regard to intra-regional and extra-regional commuting. Just like men, women reveal stronger preference

for intra-municipality and intra-regional commuting the lower the education level is. N other words, $d_0 > d_1 > d_2$ also for women.

Table 4.3: Parameters estimated for female commuters based on model (3.6) 1998

	l_0	l_1	l_2	d_0	d_2
Average female	0.026	0.105	0.057	3.07	2.010
Low education, female	0.028	0.110	0.060	3.638	2.175
Medium education, female	0.028	0.109	0.060	3.232	2.081
High education, female	0.031	0.100	0.056	2.632	1.774
Average, all commuters	0.025	0.096	0.052	2.985	1.936

4.3 Comparing Male and Female Commuters

In the preceding sub section estimations for male and female are presented. In this sub section the estimated parameters for male commuters are compared with the corresponding parameters for female commuters. In this way we can assess hypotheses H5 and H6.

The first hypothesis states that the time sensitivity is lower for male than for female commuters. Table 4.4 shows that this condition is not violated for the 12 parameter-values referring to 1990. With regard to intra-municipality commuting 1 it is violated twice in 1998 . In this year male commuters with low and medium education had a higher l_0 -value than the corresponding female commuters. The major reason is a clear increase in these parameter values for male commuters between 1990 and 1998.

What are the conclusions? H5 is not rejected by the 1990 observations. For 1998 H5 is not rejected as an overall characterisation of total male and female flows. For the disaggregate flows it also remains valid, except for intra-municipality flows.

Table 4.4: The ratio between parameters estimated for male and female commuters, %

	l_0	l_1	l_2	d_0	d_1
Total commuting	87.6 (67.0)	85.6 (89.5)	86.6 (89.3)	92.5 (85.9)	92.9 (87.1)
Low education	113.1 (97.8)	83.7 (83.5)	94.8 (95.0)	84.9 (82.5)	79.4 (78.6)
Medium education	101.6 (78.0)	84.3 (83.9)	86.7 (86.2)	91.3 (87.0)	91.1 (89.6)
High education	46.1 (34.6)	82.9 (82.5)	79.9 (84.3)	88.7 (83.2)	94.3 (90.6)

Remark: Parameters for 1998 without and for 1990 within parenthesis.

The next task is to examine the two d -parameters in table 4.4. According to the hypothesis we should observe that male commuters have a weaker preference for intra-municipality commuting than females. This is not violated by the observations. In addition we should observe that male commuters have weaker preference also for intra-regional commuting. Again there is no violation of the statement. According to our a random-utility model these are preference values. In the multiple-constraint model they appear as shadow prices, showing how valuable it would be to expand the number of jobs in the municipality and the region, respectively. It is of course possible to interpret these parameters as reflections of not observed micro-level constraints.

4.4 Robustness of Parameter Values over Time

Why should we examine the robustness of the time-sensitivity parameters and the d-parameters? One reason is to find out how reliable estimated parameters are for predicting future behaviour. Another is to find out if there is an systematic change over time and how fast such changes are.

Table 4.5: The ratio between time parameters 1998 and 1990, %

	$l_0(98)/l_0(90)$	$l_1(98)/l_1(90)$	$l_2(98)/l_2(90)$	Average deviation, %
Total commuting	108.0	99.6	98.5	3.3
Total male commuting	122.6	99.7	97.7	8.4
Total female commuting	93.8	99.2	100.0	2.3
Male, low education	120.7	97.9	98.7	8.0
Male, medium education	112.8	100.2	100.7	4.6
Male, high education	131.8	100.6	96.7	11.9
Female, low educ.	104.4	97.7	98.9	2.6
Female, medium educ.	86.6	99.7	100.1	1.3
Female, high educ.	99.0	100.0	102.0	1.0

Table 4.5 indicates that there is a moderate change for total commuting, where the only significant change is for intra-municipal flows. A second observation is that all categories of female flows remain close to invariant, whereas male flows change in a clear way for intra-municipality flows. The intra-municipality male flows increase systematically, and the most remarkable growth is observed for male commuters with high education. As regards intra-regional and extra-regional flows change very little across all flows.

Table 4.6: The ratio between d-values 1998 and 1990, %

	$d_0(98)/d_0(98)$	$d_1(98)/d_1(90)$	Average deviation, %
Total commuting	92.8	98.5	4.4
Total male commuting	95.3	99.7	2.5
Total female commuting	88.4	93.9	8.9
Male, low education	96.2	99.2	2.3
Male, medium education	96.2	98.9	2.5
Male, high education	95.3	97.7	3.5
Female, low educ.	93.6	98.1	4.4
Female, medium educ.	91.6	97.3	5.6
Female, high educ.	89.5	93.9	8.8
Average deviation for 9 observations, %	6.8	2.5	

Table 4.5 informs us that d-values are consistently falling between 1990 and 1998. This should be interpreted as a geographical extension of labour markets during the covered period. There is especially a marked decline in the preference for intra-municipal commuting. The stronger decline for these trips may reflect that the difference between intra-municipal and

intra-regional commuting is declining. It may also, in an indirect way, indicate that the intra-municipal time distances do not fully reflect time delays due to congestion phenomena. We may get some information about this by inspecting table 4.7, which shows the ratio between l_0 and l_1 in 1990 and 1998. Unfortunately the information in the table is somewhat ambiguous. The ratio tends to fall for female commuters and rise for male ones. At the same time, the changes during the period of eight years, with clear changes in the commuting flows, are small rather than large. The main impression is that the difference between intra-municipal and intra-regional commuting remains strong and systematic.

Table 4.7: The ratio between l_0 and l_1 in 1998 and 1990, %

	1990	1998	Average deviation, %
Total commuting	0.242	0.263	+8.6
Total male commuting	0.206	0.253	+22.6
Total female commuting	0.255	0.247	-3.1
Male, low education	0.283	0.348	+23.0
Male, medium education	0.281	0.316	+12.5
Male, high education	0.132	0.174	+31.8
Female, low education	0.242	0.258	+6.6
Female, medium education	0.302	0.262	-13.2
Female, high education	0.315	0.312	-1.0

5. CONCLUSIONS

The issues raised in this paper can be summarised by two statements. First, there is clear distinction between local (intra-municipal), regional (intra-regional) and distant (extra-regional commuting. This is emphasised by the fact that on the average for 1998 one can observe that 74 percent of all flows are local, 18 percent are regional and less than 5 percent are extra-regional. Second, the difference between these three categories of cannot be described accurately by one single exponential function showing how the willingness to commute decays as the time-distance increases. There is a need for a separate representation of time sensitivity for each of the three geographical scales. The observations we have made indicate that the willingness to commute is non-linear. This observation has implication both for models of commuting, but also for the formulation of accessibility indices that are applied in location models and the like.

In the empirical analysis we have maid one systematic observation of changes. Between 1990 and 1998 we can observe falling d-values for intra-municipal commuting. This observation signals a stronger integration of labour markets over extended geographic areas.

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APPENDIX

Table A1: Parameters estimated for male commuters based on model (3.6) 1990

	λ_0	λ_1	λ_2	δ_0	δ_2
Average male	0.019	0.090	0.051	2.985	1.856
Low educ. male	0.027	0.094	0.057	3.210	1.742
Medium educ. male	0.026	0.091	0.051	3.069	1.917
High educ. male	0.011	0.082	0.046	2.449	1.712
Averge, all commuters	0.023	0.096	0.053	3.217	1.966

Table A2: Parameters estimated for female commuters based on model (3.6) 1990

	λ_0	λ_1	λ_2	δ_0	δ_2
Average female	0.028	0.106	0.057	3.476	2.132
Low educ. female	0.027	0.113	0.060	3.889	2.217
Medium educ. female	0.033	0.109	0.060	3.527	2.139
High educ. female	0.031	0.100	0.055	2.942	1.889
Averge, all commuters	0.023	0.096	0.053	3.217	1.966