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The impact of telecommuting on residential relocation and residential preferences

A latent class modeling approach

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Abstract: The advance of information and communication technologies (ICTs) has changed travellers' appreciation of travel distance in various ways. In the context of telecommuting, ICT increasingly allows us to work from home one or more days per week. One hypothesis that has been put forward is that because ICTs reduce the frequency of commuting, it allows workers to accept longer commute distances, implying that telecommuters have a different valuation of travel distance than regular commuters and would also favour more peripheral residential locations. The question can be raised, however, whether telecommuters can be regarded as a homogeneous group with respect to their valuation of commute distance and residential preferences. To investigate the heterogeneity of commuters' and telecommuters' preferences, latent class discrete choice models of workers' intended relocation probability and preferred residential environment were estimated. The results suggest that telecommuting is not a factor that can be used to identify segments with different residential preferences. However, within the group of telecommuters, two different classes can be identified, which can be characterised as being sensitive and insensitive to commute distance.

Keywords: Transport; Land Use; Telecommuting

1 Introduction

Studying and modelling spatial patterns of settlement is an important activity in urban and transportation planning. If we understand which particular household types reside in particular locations, we are better able to predict how they will use the spatial system and how demand for facilities is distributed across space. For instance, in order to predict the use of the road network in future scenarios (e.g. in strategic policy assessment), it is important to account for changes in residential patterns due to changes in accessibility or to external factors. This principle underlies land use transport interaction (LUTI) models, which have been applied for various decades (see Timmermans (2006) for an overview).

Households' residential location decisions have also been studied for several decades. In these studies, a distinction is usually made between two phases in the relocation process (Brown and Moore 1970). The first phase concerns the decision to start looking for another dwelling. This decision can be driven by the perception of a discrepancy between the desired and the

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actual residential situation. For instance, due to accepting a new job, commute distance can become too large; this may prompt the second phase of the relocation process, which is searching for a new dwelling. This process involves an inventory of available dwellings and the actual choice of a new dwelling. Over the years, remarkable stability is observed with respect to the factors that influence both decisions.

With respect to the decision to relocate, Clark and Onaka (1983) provide a useful framework that distinguishes between induced moves and adjustment moves. Adjustment moves are caused by a discrepancy between housing preferences and current housing situation, caused by changes in the housing market or institutional structure or gradual changes in household income or lifestyle. According to the meta-study by Clark and Onaka, accessibility plays a very limited role in such adjustment moves.

Induced moves are moves that are triggered by specific events, such as a change in household composition, household formation or dissolution, a drop in income, a change of work location, etc. that lead to a sudden change in the needs of a household. For instance, the birth of a child may lead to a need for an extra bedroom, which triggers the move to a larger dwelling. Although life cycle events are the most frequent source of induced moves, accessibility is also found to be a reason for induced moves in the context of job changes (for example, see Bina and Kockelman 2006). Dökmeci and Berköz (2000) find that accessibility to relatives may also be a reason for an induced move. It is noted that when accessibility plays a role in relocation decisions, it is expressed in terms of distance or travel time. Changes in travel costs, e.g. due to the introduction of road pricing, have been found to have a limited effect on households' relocation probability (Arentze and Timmermans 2007; Tillema *et al.* 2010b).

Also with respect to residential preferences, factors influencing residential location choice are remarkably stable (Bhat and Guo 2004; Guo and Bhat 2007; Molin and Timmermans 2003; Walker and Li 2007). These factors include housing attributes (rent or price, type of dwelling, size of the dwelling and lot, number of rooms, tenure), neighbourhood attributes (percentage of homeowners, density, presence of schools and facilities, age of neighbourhood, ethnic composition), and attributes related to accessibility (accessibility of stores and schools, commute time). Some of these characteristics usually interact with household characteristics. For instance, the effect of price/rent depends on household income, and the effect of the availability of a garden is related to the presence of children. The effect of accessibility strongly depends on the definition used. General accessibility measures—such as the number of stores that can be reached or the distance to public transport facilities—have a minor effect on residential location decisions (Molin and Timmermans 2003). The commute distance, however, invariably has a significant effect on the residential location decision (Tillema *et al.* 2010a). Mok (2007) shows that as the proportion of couples in which both members are wage earners has increased, residential location has been increasingly chosen based on proximity to both workplaces. The acceptability of a particular commute distance in this respect depends on the income of each partner.

Having noted the relative stability of factors determining residential patterns, it should also be noted that the relative importance of these factors is not necessarily constant across contexts. With respect to the importance of accessibility for the decision to move and the residential location decision, the development of information and communication technologies (ICTs) may change the valuation of the commute distance and thereby its importance as a factor for relocation and residential location choice. The objective of this paper is to explore how and to what extent ICTs influence locational preferences, with a focus on telecommuting. To this end, latent class models will be estimated of both commuters' and telecommuters' relocation propensity and locational preferences.

This paper is organised as follows. Section 2 discusses theoretical notions regarding the relationship between ICTs, travel, and locational preferences. Section 3 outlines the study design and methodology. Section 4 describes that data that was used to empirically verify the hypotheses. Section 5 discusses the estimation results, followed by conclusions and avenues for further research in Section 6.

2 ICTs, travel, and locational preferences

Given that travel implications are an important factor in residential location decisions, the impact of ICTs on residential preferences is likely to be via travel. In this respect, the following notions are important.

First, various ICTs may increase individuals' options to use travel time more pleasantly or more productively (Kenyon and Lyons 2007). In this respect, one may think of mobile phones making it possible to use travel time for communication, laptop computers allowing one to work while travelling in public transport, and portable DVD and audio players allowing one to enjoy entertainment while travelling. Empirical evidence (Ettema and Verschuren 2007) suggests that such ICT options may indeed affect individuals' travel time valuation. In particular, it may be hypothesized that if travel time can be used more productively or pleasantly, individuals are willing to accept longer commute times and to accept dwellings that are farther away from the work location. This would extend the choice set of potential residential areas with areas that would otherwise not be feasible—for instance, rural areas with lower accessibility but with an attractive environment.

A second effect of ICTs is that they have fundamentally changed the relationship between locations and activities (Couclelis 2003). Whereas in the pre-ICT age many activities (working, shopping) were tied to particular locations, today the relationship between locations and activities has become much more loosely defined. ICTs allow access to many services and to information on virtually every location at any time, giving users options to work and shop outside of the traditional locations and time slots. In the domain of work, ICTs have contributed to the increase of telecommuting, meaning that individuals work from home one or more days per week during which time they communicate with colleagues by telephone and Internet. Over the past years, the share of telecommuters has increased considerably. For instance, the share of professionals in Dutch firms working occasionally from home is now 51% (Ernst & Young). Given that commute time is a relevant factor in residential location decisions, it is likely that telecommuting will affect the importance of commute distance in residential location decisions. In particular, assuming that workers have a given multi-day (say weekly) time budget available for commuting, lowering the commute frequency through telecommuting will make longer commute distances acceptable, leading to new areas becoming feasible residential locations.

To date, however, the effect of telecommuting on residential location decisions has hardly been investigated (Mokhtarian *et al.* 2004). However, the few empirical studies in this area (Mokhtarian *et al.* 2004; Muhammad *et al.* 2007; van Reisen 1997) indicate that telecommuters have longer commute distances than non-telecommuters, suggesting a different treatment of travel time. At the same time, it is noted that telecommuting exists in various forms, and that not all forms of telecommuting necessarily reduce travel distance (e.g. working at home in the morning to avoid congestion and working in the office in the afternoon; see Lyons and Jones 2006). This study defines telecommuting as working from home during the whole day, one or more days per week, so that one avoids travelling on these days. It is noted that while ICTs may facilitate telecommuting, they are not a prerequisite, implying that also working from home without the support from telephone and Internet is regarded as telecommuting. In the remainder of this paper, we will term workers who work from home one or more days per week, either using ICTs or not, telecommuters, as opposed to workers who only work in the workplace, who are termed commuters.

Recalling that commute distance can play a role in both the decision to move and the residential location decision, it is noted that telecommuting as defined above can affect the residential (re)location process in different ways. In this respect, different hypotheses can be formulated (see Muhammad *et al.* 2007).

The first assumption would be that the telecommuting decision is independent of the residential location decision. This would imply that individuals decide to telecommute for reasons of work or household organisation or to postpone departure until congestion has disappeared, and not in order to reduce the negative effects of a long commute time by lowering the frequency of commuting.

A second hypothesis would be that telecommuting is used as a tool to reduce the negative effects of a long commute time resulting from a job or residential relocation, in anticipation of finding a residence closer to the work location (or a job closer to the residence). According to this reasoning, telecommuting is a temporary solution, suggesting that telecommuters are more likely to relocate. However, since telecommuting is only adopted to overcome a long commute, this hypothesis implies that telecommuters by and large have the same residential preferences as non-telecommuters.

A third hypothesis would be that the telecommuting decision is an integral part of households' work and mobility organisation. In this view, telecommuting is regarded as a way to deal with a longer commute time, allowing one to live in a more rural environment or closer to friends or relatives. Thus telecommuters prefer a situation with a longer commute (made tolerable through telecommuting) and an attractive residential environment over a situation with a shorter commute distance but in a less attractive residential setting. Telecommuting, then, is a more permanent state, suggesting that telecommuters are not more likely to relocate—but also suggesting that they have different residential preferences than commuters. For instance, telecommuters may be more likely to prefer living in peripheral areas, with (on average) a longer travel distance to employment but with a more attractive natural environment.

Underlying these three hypotheses is an assumption that households' decisions about relocation are not constrained, i.e. that a desire to decrease the commute distance can be realised via relocation. In reality, however, financial or personal constraints may prevent households from relocating in the short-term, even if they would prefer a shorter commute distance. This constrained group can be expected to have similar residential preferences as non-telecommuters, while not having the intention to relocate. The implication of such constraints would be that a desire to decrease commute distance, as in the second hypothesis, cannot be overt in the form of a decision to move. The above hypotheses can be tested by investigating commuters' and telecommuters' intentions to relocate as well as their residential preferences. A previous paper by Muhammad *et al.* (2007) explored the above hypotheses by carrying out multivariate analyses of relocation probability and residential location type in which telecommuting status was used as an explanatory factor. These analyses suggested that telecommuters are not more likely to relocate than non-telecommuters, and that their locational preferences might differ slightly from the preferences of non-telecommuters. This would support the third hypothesis. It should be noted, however, that that Muhammad *et al.* treated telecommuting as a single factor, assuming that the effect of telecommuting and motivations to telecommute were uniform for everyone. In reality, however, it is likely that considerable heterogeneity exists between telecommuters with respect to their motivations and residential preferences, as indicated by the example of Lyons and Jones (2006).

Several studies have been carried out indicating that heterogeneity in residential preferences exists and that it cannot be explained by socio-demographic and spatial characteristics. Tillema *et al.* (2010a) used a mixed logit model to demonstrate the existence of unobserved heterogeneity with respect to commute time valuations in residential location choice. Walker and Li (2007) used a latent class model to demonstrate the existence of different classes of households, each holding different preferences toward the residential situation. These classes were defined in terms of household characteristics, such as income, occupation and life cycle. An alternative approach was taken by Bagley *et al.* (2002), who used an attitudinal survey to characterise households' lifestyles, which was used to explain residential preferences.

Given that households' residential preferences in general are found to be heterogeneous, this paper further explores heterogeneity with respect to the effect of telecommuting on residential location preferences. In particular, it is assumed that the motivations for telecommuting may differ between households, according to the above hypotheses, resulting in different valuations of commute distance, different relocation probabilities, and different residential preferences. A related issue is whether heterogeneity that exists with respect to residential preferences in general—and the valuation of commute distance in particular—differs between commuters and telecommuters. That is to say: are classes with particular preferences related to telecommuting status or not?

Answering these questions is important in order to properly assess the effect of telecommuting on residential location patterns and commute distances. To this end, using the Dutch WBO database, latent class models are estimated in order to investigate:

- whether different classes of commuters exist, which differ with respect to their likelihood of relocation and residential preferences;
- whether these classes correlate with telecommuting status;
- whether these classes can be characterised by specific socio-demographic or spatial characteristics.

3 Study design and methodology

The purpose of this study is to investigate heterogeneity in the residential preferences of commuters and telecommuters. We hypothesise that this heterogeneity may be observed both in the decision whether or not to relocate (the relocation probability) and the preference for a particular residential area type. Building on the three hypotheses formulated in the introduction, we can formulate specific hypotheses with respect to the relocation probability and residential preference.

H1: Telecommuting is adopted for organisational reasons (e.g. combining work and household tasks) and not to avoid travelling. This would imply that telecommuters and non-telecommuters are equally likely to relocate, and that the two groups have similar preferences for particular areas.

H2: Telecommuting is used as a tool to reduce the negative effects of a long commute time resulting from a job or residential relocation, in anticipation of finding a residence closer to the work location (or a job closer to the residence). This would imply that telecommuters are more likely to relocate, but that they would have (by and large) the same residential preferences as non-telecommuters.

H3: The telecommuting decision is an integral part of a household's work and mobility organisation. In this view, telecommuting may be regarded as a way to deal with a longer commute time, allowing one to live in a more rural environment or closer to friends or relatives. Telecommuting, then, is a more permanent state, suggesting that telecommuters are not more likely to relocate but have different residential preferences.

We will investigate these hypotheses by estimating latent class discrete choice models of intended relocation and intended residential area type choice. We focus on intended behaviours because the hypotheses we want to test are formulated in terms of intentions and preferences. For instance, focusing on observed relocation behaviour would make it very difficult to distinguish between telecommuters who see their commuting status as a temporary state (with intention to relocate) and those who see it as a permanent state (without intention to relocate). Also, focusing on the currently preferred residential area type (instead of the actual residential area type) will yield a better insight into current preferences, as discrepancies may exist between the preferred and the actual residential setting (Clark and Onaka 1983).

In these models, telecommuting status serves as an explanatory variable together with sociodemographic and spatial variables. Latent class models are useful because they can distinguish different classes with specific preferences. By estimating models for all commuters and for telecommuters only, it is possible to determine whether classes having particular preferences differ with respect to telecommuting status, and which classes of telecommuters can be identified.

Latent class discrete choice models consist of two components (Walker and Li 2007): a class membership model describing the probability of falling into a particular latent class of decision makers, and a class-specific choice model describing the choice behaviour of each class. The class membership model describes the probability of falling into class s, given a vector of characteristics of the decision maker (X). In this study, we assume that the class membership model is a multinomial logit (MNL) model, such that:

$$P(s\bar{X}) = \frac{\exp(U_s)}{\sum_{t=1}^{T} \exp(U_t)} \tag{1}$$

where

$$U_s = \sum_m \beta_{sm} X_m \tag{2}$$

where X_m is the m-th characteristic of the decision maker, and β_{sm} is a parameter that expresses the impact of characteristic X_m on the probability of falling into class s. The utility of one of the classes is defined as $U_s = 0$ so that it serves as a reference category. The class-specific choice model expresses the probability of choosing alternative i given that one falls into class s and is defined as:

$$P(i|Y_i, s) = \frac{\exp(U_i)}{\sum_{j=1}^{J} \exp(U_j)} \tag{3}$$

where Y_i is a vector of characteristics of choice alternative i (e.g. a residential area type) and

$$U_i = \sum_k Y_{ik} \gamma_{iks} \tag{4}$$

Since class s is a latent concept that cannot be observed in reality, the class membership model and the class-specific choice models are estimated simultaneously, maximising the goodness-of-fit according to the latent class choice model:

$$P(i|X_n Y_i) = \sum_{s=1}^{S} P(i|Y_i, s) P(s|X_n) \tag{5}$$

An important issue when specifying a latent class choice model is the specification of the variables in the latent class membership model. Since our objective is to investigate heterogeneity in the effects of telecommuting, we decided to use work-organisation variables as explanatory variables of the class-specific models of relocation probability and location type choice. These variables include employment status (full-time or part-time worker), commute distance, and telecommuting status. The explanatory variables of the class membership models are socio-demographic characteristics, such that the resulting classes can be interpreted in terms of socio-demographic classes.

To investigate heterogeneity in the effects of telecommuting, two approaches were followed. First, models were estimated for a sample of both telecommuters and non-telecommuters. By including telecommuting as an explanatory variable in the class membership model, it is possible to investigate whether the relocation probability and residential preferences of telecommuters differ from those of non-telecommuters and whether this coincides with different classes. Second, models were estimated for a subsample consisting only of telecommuters. In this case, the resulting classes can be interpreted directly as classes in which relocation probability and residential preferences differ, representing heterogeneity in the effect of telecommuting. The estimated models and their explanatory variables are summarised in Table 1. It is noted that the explanatory variables also include characteristics of the working partner (commute status and commute distance) although a portion the respondents do not have working partners. This implies that the variable should be interpreted as an interaction variable (i.e. interacting with a dummy that takes 1 if the respondent has a working partner and 0 otherwise). Thus, the estimated coefficient expresses the effect of partners' commute status and commute distance, given that a working partner is present. It is also noted that the estimations are based on a data set of housing preferences, implying that certain potentially interesting variables—such as commute mode and vehicle availability—were not available. Further, we have regarded the relocation and area type choice as household decisions, implying that characteristics of the individual respondent (such as gender) are of less importance. Nevertheless, we have included characteristics that give information about the socio-economic status of the household (age, education) and relevant household characteristics such as household composition.

Table 1: Explanatory variables in latent class models.

	Variables in choice model	Variables in class membership model
Relocation probability model:		
All commuters	Commute distance respondent Commute distance partner Working status partner	Area type Homeowner Income Age class Education Working status (full-/part-time) Telecommuting status
Telecommuters	Commute distance respondent Commute distance partner Working status partner	Area type Homeowner Income Age class Presence of children in household Relocation history
Residential area type model:		
All commuters	Commute distance respondent Commute distance partner Working status partner Presence of children in household	Area type Age class Working status (full-/part-time) Telecommuting status
Telecommuters	Commute distance respondent Commute distance partner Working status partner Presence of children in household	Income class Area type Age class

4 Data and sample

Data in the WBO database is collected in the Netherlands every four years. The database exhaustively covers variables that relate to households' residential preferences. Apart from a variety of socio-demographic data such as income, education, ethnicity, age, household composition etc., it includes detailed questions about the current residential situation (such as type of dwelling, costs, and satisfaction with the dwelling and the environment), the residential history (timing and motivation of the previous relocation), and questions about relocation plans (likelihood of a relocation within two years, reasons for a planned relocation, and the preferred type of dwelling and neighbourhood). In addition, respondents are asked whether or not they work one or more days per week from home, which is used to classify workers into commuters and telecommuters as discussed previously.

The 2002 WBO data set, which was used in this study, covers about 90,000 households throughout the Netherlands. The WBO records data on both the head of the household and the partner. With respect to analysing the effect of telecommuting, we have focused on the head of the household as being a telecommuter or not. Since we are interested in comparing telecommuters and commuters, our analysis only includes households in which the head of the household is working. This selection results in 39,969 households, of which 2,930 (7.3%) have a telecommuting head. In the case of double-income households, the partner of the head may either commute or telecommute. Table 2 gives the distribution of commuting/telecommuting across spouses. It appears that if the head telecommutes, the partner is more likely to telecommute. However, most telecommuters in this data set have a non-telecommuting partner.

Table 2: Composition of households: Commuters and telecommuters (percentages).

Main respondent	Single	Partner		
		Telecommuter	Commuter	Do not work
Telecommuter	22.5	16.2	43.3	18.0
Commuter	26.7	4.2	44.3	24.8
Overall	26.4	5.1	44.2	24.3

With respect to the presence of children, the differences are small, although telecommuters tend to have children younger than 12. This may point toward telecommuting as a means to combine work with childcare tasks. No difference is seen with respect to the presence of children between 12 and 18 in the household. With respect to residential environment, only very small differences are observed. Telecommuters live slightly less frequently in the outer city and slightly more frequently in rural areas. With respect to working full-time or part-time, the difference between the groups is very small, with 70% working full-time.

5 Estimation results

5.1 General

Latent class (LC) discrete choice models are estimated for the decisions: a) whether or not to relocate, and b) which residential area type is preferred. The first decision was measured in the WBO by respondents' stated intention to move within the next two years. The second decision (only recorded for those planning to relocate) was measured as the preferred residential area type (inner city, outer city, urban green, town, or rural). For each model, two versions are estimated. First, a model is estimated across commuters and telecommuters, to identify classes of decision makers with similar preferences. Explanatory variables of the choice models (whether to move and where to move) are work-related variables, such as work hours, commute distance, and telecommuting status, since we are interested in the effect of these variables on locational decisions and aim to identify classes with different weights attached to these factors. Which variables are included in the models is the outcome of a trial and error process, aiming at including significant effects and obtaining robust estimations. As a result, not all models have the same set of explanatory variables. Class membership is modelled as a function of socio-demographics in order to link certain preference classes to socio-demographic characteristics. Second, a similar model is estimated for telecommuters only, to more clearly identify classes within the population of telecommuters and to investigate to what extent these classes coincide with more general classes in the population. When estimating a LC model, it is important

Table 3: Sample characteristics.

Variable	Categories	Commuters (%)	Telecommuters (%)
Age	< 25 years	21.40	6.60
	26-25 years	28.40	29.20
	36-45 years	24.70	32.20
	46-55 years	19.30	24.90
	> 55 years	6.20	7.20
Income	Low	18.50	6.80
	Medium	37.10	18.40
	High	44.40	74.80
Education	Low	18.60	6.60
	Medium	53.50	37.40
	High	27.90	56.00
Children < 12?	no	73.10	61.80
	yes	26.90	38.20
Children 13-18?	no	82.90	82.20
	yes	17.10	17.80
Residential environment	urban	7.00	8.10
	outer city	38.40	35.40
	green suburban	13.20	13.80
	town	30.50	29.60
	rural	10.90	13.00
Working full time?	no	28.70	30.90
	yes	71.30	71.10

to decide how many classes are to be distinguished. In practice, decisions about the number of classes must strike a balance between the interpretability of the results, the improvement in goodness-of-fit (GOF) (in terms of log-likelihood) relative to the additional degrees of freedom, and possible identification problems in estimating the model. In this study, we used two classes in each case, since this resulted in the most meaningful models. Finally, it is noted that all models were, for computational reasons, estimated on a random subsample of the WBO, consisting of 2,800 observations for the relocation decision model and 1,080 observations for the location choice model.

5.2 Relocation decision model

All commuters

Estimation results of the relocation decision model (commuters and telecommuters) are displayed in Table 4. An MNL model is estimated for comparison. Looking at the MNL model, it is seen that of the work-related variables, only the working status of the partner has a significant (positive) impact. If the partner has a job, the household is more likely to have relocation plans. This may be due to a need to move closer to the work place of the partner. Alternatively, it can be argued that if the partner has a job, the household income will be larger and there are more opportunities for relocation. According to this model, neither commute distance (of the head or the partner) nor telecommuting status has an impact on the relocation probability.

The LC model results in a GOF improvement of 26.87. The choice models of the two resulting classes, although displaying a similar trend, differ in the weight of different factors. First, commuters in the first class are more likely to relocate, as indicated by the constants and by the signs and sizes of the coefficients. In addition, respondents in the first class are even more likely to relocate if their partner has a job. In the second model, this effect is much smaller and only marginally significant. Hence, it appears that two classes of households exist, with different relocation probabilities.

The class membership model suggests that the probability of belonging to Class 1 (more likely to relocate) increases if one lives in a town or rural area or is a homeowner, and decreases if one is younger than 25. Combining the class membership and choice models, it appears that there is a small class of commuters who are less inclined to move, who belong to the younger age category. A possible explanation is that these commuters are young workers with limited options to relocate. Based on the class membership model, 63% of the respondents are predicted to fall into Class 1, and thus belong to the more relocation-prone segment.

An important conclusion from the LC model is that telecommuting status does not have a significant effect on class membership. This suggests that the different classes of commuters, which differ with respect to relocation probability and the effect of the partner's working status, are not related to telecommuting status. Another important finding is that commute distance is not found to be a reason for relocation for any class.

Telecommuters

A similar model was estimated for telecommuters only. The MNL version of the model is very similar to the model of all commuters. As with all commuters, relocation probability is higher if the partner has a job. The size of the parameters is also comparable.

The LC model results in a GOF improvement of 47.01. However, the relocation choice models show a different segmentation as for all commuters. The choice model for Class 1 indicates a higher relocation probability if the partner has a job or if commute distance is longer, suggesting a higher sensitivity for commute distance. The second choice model suggests that relocation probability decreases with increasing commute distance. A potential explanation is that telecommuters in this class prefer attractive residential environments that are further away from their work locations. A longer commute would then be related to a more attractive environment and a lower relocation probability. In fact, this would support the third hypothesis. Looking at the expected commute distance in each class (i.e. the average commute distance weighted by class membership probability), we note that these are almost identical (36.76 km for Class 1, 36.78 km for Class 2), suggesting that it is not so much a difference in commute distance but rather a difference in its appreciation that causes the difference in sign. Also, with average vales of the explanatory variables, the Class 1 model implies a larger probability to relocate. Thus Class 1 represents telecommuters who are more sensitive to distance, whereas Class

Table 4: Estimation results for relocation probability models.

	All commuters		Telecommuters	
	MNL Model			
	β	t-stat	β	t-stat
Constant	1.31	17.12	1.41	13.73
Commute distance	0.01	0.51	0	−0.22
Commute distance partner	−0.01	−0.36	0	0.15
Partner works	0.72	5.86	0.61	4.92
GOF	*-1224.91*		*-1117.79*	
Adj. R^2	*0.36*		*0.42*	
n	*2800*		*2800*	
	Latent Class Model			
Choice model, class 1:	β	t-stat	β	t-stat
Constant	1.77	13.49	1.51	10.47
Commute distance	0	0.77	0.01	2.08
Commute distance partner	0	0.21	0	−1.17
Partner works	1.3	4.69	1.37	6.07
Choice model, class 2:	β	t-stat	β	t-stat
Constant	0.84	9.58	1.08	8.32
Commute distance	0	−0.51	−0.01	−4.03
Commute distance partner	0	−0.69	0	1.8
Partner works	0.22	1.68	−0.25	−1.6
Class membership, class 1:	γ	t-stat	γ	t-stat
Constant	−0.32	−0.66	−0.54	−1.07
Lives in town or rural	1.36	2.97	0.83	1.95
Children in household	−0.39	−0.92	0.47	1.29
Homeowner	1.57	3.4	2	4.2
Low Income	−0.79	−1.19	1.84	1.46
Age < 25	−1.69	−2.65	−1.64	−4.09
High education	−0.65	−1.58		
Works part-time	0.7	1.4		
Telecommuter	0.07	0.13		
Relocated < 2 years			1.51	2.95
GOF	*−1198.04*		*−1070.78*	
Adj. R^2	*0.38*		*0.45*	
n	*2800*		*2800*	

2 represents telecommuters accepting a long commute distance. In addition, having a working partner increases the relocation probability in the first choice model.

The class membership model suggests that telecommuters who live in a town or rural setting, are homeowners, and have recently moved are more likely to fall into the distance-sensitive Class 1. Young telecommuters are less likely to fall into the distance-sensitive class. Hence, an important observation is that taste heterogeneity exists among telecommuters with respect to their distance sensitivity, suggesting that the hypotheses raised earlier cannot be accepted or rejected uniformly for all telecommuters. Based on the class membership model, 74% of the telecommuters are predicted to fall into the more distance-sensitive and more relocation-prone group. The minority will thus be likely to accept longer commute distances.

5.3 Residential area type choice

All commuters

The MNL model of residential location choice (Table 5) indicates that current commute distance does not affect the preferred residential type, and neither does the partner's working status. The presence of children in the household, however, increases the preference for all residential types relative to the inner city. The preference for the outer city and urban green environment increases most strongly with the presence of children, which can be understood in terms of parents' desire for a safe environment in which children can play and of the supply of family houses with gardens.

The LC model (Table 6) results in a GOF improvement of 130.91. The LC model distinguishes two classes, representing different types of commuters. The first class has, if there are no children in the household and assuming normal commute distances, a stronger preference for the outer city and a very low preference for town and rural settings. If respondents have children, they have a relatively stronger preference for outer city, urban green, town, and rural settings. A longer current commute time leads to a preference for a town environment, probably reflecting the current residential type.

The second class has a relatively strong preference for town over the other settings. In this class, the presence of children leads to a higher preference for a rural setting. To summarise, the first class seems to represent a suburban orientation, whereas the second class represents a more town/rural orientation.

The class-membership model indicates that respondents currently living in the inner or outer city are more likely to belong to Class 1, which coincides with the preference for outer city and urban green. Thus, commuters who currently live in an urban setting prefer suburban over rural settings. The effect of telecommuting is not statistically significant. Hence, the classes do not clearly coincide with telecommuting status. Based on the class-membership model, 55% of the respondents are predicted to fall into Class 1.

Telecommuters

The MNL model of location choice (Table 5) estimated for telecommuters suggests that, discarding the effects of partners' working status and having children, telecommuters would have a preference toward the outer city and strongly dislike a rural setting. With children and a working partner, which affect residential preferences in similar ways, the town and rural envi-

Table 5: Estimation results for residential area type choice models.

	All commuters		Telecommuters	
MNL-model	β	t-stat	β	t-stat
Outer city:				
Constant	0.44	4.02	0.47	3.49
Commute distance partner			0	−0.68
Partner works			0.37	1.38
Commute distance	0	0.14	0	−1.5
Children in household	0.84	3.85	0.66	2.38
Urban green:				
Constant	−0.37	−2.84	−0.03	−0.17
Commute distance partner			−0.01	−1.83
Partner works			0.54	1.94
Commute distance	0.02	0.78	0	0.46
Children in household	1.16	4.93	0.85	2.97
Town:				
Constant	−0.32	−2.51	0.12	0.87
Commute distance partner			−0.01	−1.14
Partner works			0.5	1.8
Commute distance	0.03	1.12	0	−0.21
Children in household	0.66	2.66	0.48	1.65
Rural:				
Constant	−1.86	−8.37	−0.99	−5.16
Commute distance partner			0	−0.39
Partner works			0.86	2.59
Commute distance	0.02	0.36	0	−0.1
Children in household	1.24	3.57	0.45	1.25
GOF	*-1733.06*		*-1659.11*	
Adj. R2	*0.1*		*0.04*	
n	*1080*		*1080*	

ronment become more popular, although urban green and outer city remain the most preferred residential types.

The LC model (Table 6) results in a significant GOF increase of 94.46. According to the choice model of the first class, a strong preference exists for the outer city, and a low preference for the town and rural areas, reflecting an urban preference. This order in preference is observed for every combination of partner working status and presence of children. The presence of children leads to a stronger preference for all residential types relative to the inner city, but most strongly for urban green and rural environments. A long current commute distance is associated with a higher preference for a rural environment, probably reflecting the current residential type.

Table 6: Estimation results for residential area type choice models

	Choice Model: Class 1				Choice Model: Class 2			
	All commuters		Telecommuters		All commuters		Telecommuters	
	β	t-stat	β	t-stat	β	t-stat	β	t-stat
Outer city:								
Constant	0.47	4.31	0.46	3.18	0.16	0.6	0.5	2.48
Commute distance partner			0	−0.99			0.01	0.51
Partner works			0.32	1.22			0.64	1.31
Commute distance	0	0.1	−0.01	−1.71	0.02	0.41	0	−0.36
Children in household	0.82	3.79	0.92	3.05	0.67	0.07	−0.01	−0.04
Urban green:								
Constant	−0.3	−2.28	−0.04	−0.24	−0.93	−2.75	0.1	0.45
Commute distance partner			−0.01	−1.64			−0.01	−0.53
Partner works			0.24	0.83			1.4	2.87
Commute distance	0.02	0.6	0	1.02	0.05	0.94	0	−0.81
Children in household	1.07	4.49	1.24	4.12	2.23	2.58	−0.01	−0.01
Town:								
Constant	−1.43	−7.9	−1.06	−5.12	1.53	7.06	1.42	7.82
Commute distance partner			−0.02	−1.47			0	0.21
Partner works			0.35	0.87			1.21	2.72
Commute distance	0.06	1.96	0	0.96	−0.03	−0.75	−0.01	−2.11
Children in household	0.89	2.91	0.86	2.12	1.93	2.45	−0.39	−1.12
Rural:								
Constant	−2.34	−8.38	−2.37	−7.43	−0.37	−1.24	0.45	2.07
Commute distance partner			0	0.51			0	0.09
Partner works			0.24	0.5			1.85	4
Commute distance	0.02	0.27	0.01	2.31	−0.05	−0.88	−0.01	−3.17
Children in household	0.58	1.2	1.71	3.65	2.96	3.57	−1.03	−2.34

	Class Membership: Class 1			
	γ	t-stat	γ	t-stat
Constant	−1.22	−2.15	1.01	1.39
Rural			−6.24	−4.62
Urban	4.88	5.74		
Age < 25	0.44	0.74	0.68	0.82
Works part-time	0.45	0.76		
Telecommutes	0.8	0.73		
Low Income			2.28	1.8
Age > 45			2.21	1.29

	All commuters	Telecommuters
GOF	*−1602.15*	*−1564.65*
Adj. R^2	*0.17*	*0.09*
n	*1080*	*1080*

The second class choice model indicates a strong preference for the town environment and less for the outer city and rural environment for different combinations of partners' working status and presence of children. In this model, the effect of the partner having a job is significant in three cases, suggesting a stronger preference for urban green, town, and rural settings. A longer current commute distance in this class leads to a lower preference for town and rural settings, indicating an intention to reduce the commute distance by living in more centrally located areas. The presence of children in this model leads to a lower preference for rural settings. To summarise, the first class represents decision makers with a preference for an (sub)urban setting, who divert to town and rural settings in the presence of children and when accustomed to longer commute distances. The second class is more town-oriented, provided that commute distances are not too long.

The class-membership model indicates that telecommuters' class membership strongly depends on their characteristics. Low-income telecommuters are more likely to fall into the first (urban-oriented) class, whereas telecommuters from rural settings are logically more likely to fall into the second class. The class-membership model predicts that 58% of the telecommuters fall into the first urban-oriented class.

6 Conclusions and discussion

This paper has explored residential preferences of telecommuters and compared them to commuters' residential preferences in general. The specific aim has been to find out if telecommuters are more or less uniform in their residential preferences or if, alternatively, specific classes of telecommuters exist that differ in their relocation probability and residential preferences. In particular, it is hypothesised that telecommuting can either be a permanent state, in which telecommuting allows one to combine a longer commute distance with a more attractive residential setting, or a state to temporarily overcome a long commute, in anticipation of a job or residential change.

To test both hypotheses, latent class discrete choice models of residential relocation probability and residential area type choice were estimated. These models allow for the identification of latent classes characterised by particular preferences. With respect to relocation probability, the MNL models estimated for all commuters and for telecommuters only are remarkably similar, and telecommuting is not found to be a significant factor for relocation. This suggests that telecommuters are not more likely to relocate than regular commuters. The LC model estimated for telecommuters, however, suggests that two classes of telecommuters exist. One class includes relatively more rural telecommuters and homeowners and is distance-sensitive, whereas the other class includes relatively more young telecommuters and is less distance-sensitive.

With respect to residential preferences, the estimated model for all commuters suggests the existence of a more (sub)urban-oriented class and a more town/rural-oriented class, where telecommuting tends to be positively associated with a (sub)urban preference. A separate model for telecommuters suggests that this group can be divided into two classes: one more suburban-oriented and one more rural-oriented.

In terms of the hypotheses that were put forward, the models suggest that telecommuters cannot be treated as one uniform group, but instead show considerable heterogeneity. Differences in relocation probability and residential preference could possibly be attributed to differences in the motivation for telecommuting, as hypothesised. Thus, the results make clear that in order to understand the impact of telecommuting on residential patterns, it is important to distinguish different types of telecommuters. To properly assess such effects, however, additional analyses will be necessary.

First, in this analysis, we could only use relocation as a dependent variable and regarded telecommuting status as given. In reality, however, it is possible (see H2) that workers decide about residential location and telecommuting status as a joint decision. This implies that also commuters who currently do not telecommute may base their residential decision on a future telecommuting state. In addition, we have treated commute distance as given. In reality, workers may not only change residence, but also change jobs in return to a long commute, and may include the opportunity to telecommute in their job choice. Consequently, future analyses should treat decisions to change residence, change job, and change telecommuting status in mutual coherence, preferably using retrospective data on all these aspects.

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