Places and people: multilevel modelling in geographical research

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1 INTRODUCTION

Gert Westert and René Verhoeff

This volume of the Netherlands Geographical Studies concentrates on multi-level analysis. It is the outcome of an intensive NETHUR seminar, held in April 1996, which was attended by PhD students, members of the NETHUR research staff, and two guests from the Geographical Department of the University of Portsmouth: Professor Kelvyn Jones and Craig Duncan. Jones and Duncan, both specialists in the field of multi-level analysis, were willing to give the 25 participants a master class in Zeist.
The seminar, titled "Places and People: Interactions Between Macro and Micro Level", was a sequel to one held four years earlier. The 1992 seminar dealt with the complex manner in which micro-processes (human behaviour) and macro-phenomena (social and spatial patterns) are interconnected in theory construction. One of the conclusions drawn from the first multilevel seminar was that scholars in sciences like human geography and sociology can elucidate macro-phenomena by studying micro-processes. Because one of the central themes in these disciplines is modelling human behaviour and predicting collective outcomes, the problem of switching between various levels of analysis is critical. The seminar held in 1992 tackled problems that arise in the first stage of research, which is devoted to *theory construction.* The contributions to that seminar were published as NGS study No. 151, edited by Groenewegen and Huigen (1992). Especially Chapter 2, by Peter Groenewegen, and Chapter 3, by Pieter Hooimeijer, give the reader a firm grasp on the micro-macro issue in sociology and human geography. The aim of the 1996 seminar was to get a better understanding of multilevel modelling from the *perspective of data analysis*, which comprises the second phase of research.
Multilevel modelling is a relatively new analytical tool. One might wonder why we need new statistical methods for analysing social data. Why can't we stick to the usual tools, like ordinary multiple regression? The answer is implicit in the following quotation (Paterson and Goldstein 1991): "Almost all data collected in the social sciences have some form of inherent hierarchical structure, and this structure should be reflected in the statistical models that are used to analyse them." Nowadays, multilevel techniques have reached maturity and, again following Paterson and Goldstein, they should be applied routinely in the analysis of social data. Failure to do so can result in potentially serious misinterpretations. Bosker and Snijders (1990) discuss this caveat with reference to educational research, and Westert (1992) does the same regarding research on health services. For a thorough discussion of what is lost by not using multilevel models, see Blalock (1984) and DiPrete and Forristal (1994).

What is gained by using multilevel techniques? First, multilevel models are much better suited to the explanatory scheme taken by more and more scholars in the social sciences, namely explaining macro-phenomena in terms of micro-processes. Second, as DiPrete and Forristal (1994) put it, multilevel models also fit better, because they provide a better framework for the central task of sociologists, which is "to specify the effect of social context on individual-level outcomes." The notion of 'context' is quite general. It may include spatial contexts, temporal contexts, and organizational or institutional contexts. Third, in operational terms, multilevel models provide answers to problems that occur when we aggregate or disaggregate our data, e.g. aggregation bias and (mis)estimation precision. As Paterson and Goldstein (1991) wrote, "Multilevel modelling offers both a statistical and

2.2 The relation between micro and macro level

This section looks at micro-macro problems from three perspectives. It begins with a discussion of the general approach to the problem, as developed by Coleman (1986; 1990). Then, the analysis of social change is discussed, according to the heuristics of Boudon (1981). Finally, a special topic is considered, namely the unintended consequences of behaviour.

The general approach
Coleman's thesis is that the analysis of relations between macro-level phenomena is central to the social sciences. The explanation of macro-level relations requires the specification of a behavioural mechanism at the micro level and the transformation of micro level outcomes back to the macro level. Figure 2.1 shows the basic scheme.

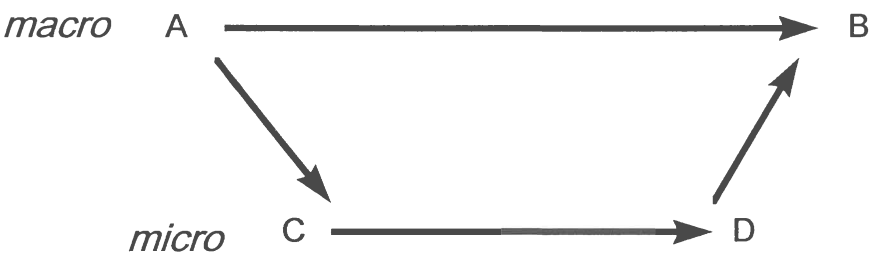

Figure 2.1 Coleman's scheme of the relations between micro and macro level

This scheme depicts the relation between two macro-level phenomena, A and B. An example from the field of health services research is the issue of the spatial distribution of health care facilities. Consider the following research question: Why is the provision of health care more evenly spread in centrally governed and funded health care systems? (Smith 1979). This research question makes a connection between two phenomena: the organization of health care systems, and the distribution of health care provision. The micro-level mechanism to explain a relation like this one is locational decision-making by health care providers. The institutional structure of health care systems (A) influences the range of options open to health care providers and facilities (C) upon which locational decisions (D) are made. Individual locational decisions aggregate to patterns of distribution (B). In sum, the explanation of a macro-level relationship between A and B requires the steps from A to C, from C to D, and from D to B.
This heuristic integrates macro- and micro-level analysis. These two levels sometimes appear to be unrelated fields of research:

> "There appear to be two mutually exclusive approaches to investigation, one *ecological*, the other *behavioural*. The ecological approach poses questions such as: 'what sorts of characteristics are associated with a favourable ratio of physicians relative to population?' The behavioural approach, by contrast, seeks to establish the nature and relative importance of factors relevant to the locational decision making of individual physicians." (Joseph and Phillips 1984).

Analysing social change
Coleman's heuristic shows the basic structure of the explanation of macro-level relations. It is, however, more easily applied to comparatively static problems than to problems involving social change. Boudon intentionally designed a heuristic to analyse processes of

social change. He distinguishes between *environment,* which includes the social and institutional structure, the *interaction system,* which includes the relevant actors, and the *outcomes,* which is a distribution, e.g. of scarce resources. These elements correspond to Coleman's A, C and D, and B respectively: the environment influences the interaction system which produces certain outcomes. However, Boudon's next step, which makes the system a dynamic one, is that outcomes might feed back to the processes in the interaction system or to the environment. Boudon distinguishes three processes of social change. In the first, called reproduction, there are no feedbacks, and outcomes stay the same. In the second, there is feedback from outcomes to the interaction system, causing a process of cumulation or the gradual change of a distribution. Finally, if there is also feedback to the environment, a process of transformation is occurring.

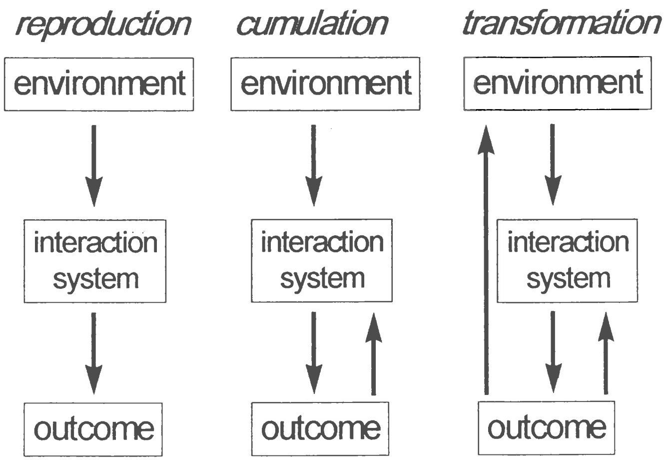

Figure 2.2 Boudon's scheme for analysing processes of social change

As an example of these processes of social change, one could look at the system of care surrounding childbirth (Schuller 1995). As outcomes, we are interested in the changing distribution of the place where women bear their children. By the end of the last century and the beginning of this century in Western countries, most children were born at home with assistance of a midwife. With the single exception of the Netherlands, where approximately 30 percent of the children are still born at home, childbirth has become a hospital affair in Western countries. How did this change come about? The interaction system consists of child-bearing women and their direct social environment, midwives, and physicians. The environment consists of the broader health care and hospital system. That system should be understood both in the structural sense of accessibility and supply and in the institutional sense of the regulation of professions involved. Furthermore, the environment also consists of developments in medicine and medical technology. Until the early 20th century, the system was in equilibrium and could characterized as a reproduction process. There was not much choice; nearly all women had their babies at home, attended by a midwife. However, with the development of the modern hospital, improved hygiene, and new medical technology, the outcome of hospital deliveries in terms of the health of child and mother became as good as the outcome of home deliveries and under some conditions even better.

From that time on, there was a choice. Generally speaking physicians developed an interest in doing hospital obstetrics; their safety arguments appealed to women, and midwives were not in a position to counteract. These good and sometimes better results of hospital births feed back to the interaction system and influence the decision-making process on the place of birth, especially in the case of a first child. The declining of family size during the 20th century resulted in relatively more first children per family. Combined with the changing decision-making on place of birth, the share of hospital births started to increase rapidly: a process of cumulation. In most European countries, sometime in the 1960s the number of home births was so low that having one's baby at home virtually disappeared as an alternative. Market shares became too low for self-employed community midwives. Physicians doing home deliveries would be scandalized within their profession. So in the end, even the environment is affected. Again, there is no choice whatsoever: hospital birth has become the rule. Among Western industrialized countries, the Netherlands is the only exception, probably due in part to the stronger legal position of midwives, their professional education, and the reimbursement rules of public insurance.
Generally, in this heuristic, the interaction system is the micro-level process. The environment is the macro-level, determining the range of options of the actors within the interaction system. And the outcome is the macro-level result of (inter-)action.

Unintended consequences of behaviour
Unintended consequences are part and parcel of social change. Decreasing family size, for instance, the unintended consequence of speeding up the cumulation process of the share of hospital deliveries.
Unintended consequences of behaviour are at the centre of interest among social scientists (Popper 1963; Wippler 1981; Boudon 1982). If, as a first approximation, human behaviour is seen as goal-oriented, the question arises why people do not always reach their goals. Part of the answer lies in the transformation from the micro to the macro level. Two important sources of unintended consequences are interdependencies of individual behaviour and incorrect anticipation of the reactions of others. An example of interdepencies leading to unintended consequences can be found in what has been called fee inflation. This occurs when there is a macro budget for, say, specialist care, and individual specialists are paid on a fee-for-service basis. If they bill too many services, they overrun the budget and have to adjust their fees downward. If individual physicians want to maintain their income level, they have to increase the number of services they provide. While all the others do the same, the unintended consequence arises that they all have to work harder to earn the same income (Delnoij 1994).
Health policy struggles with unintended consequences due to the incorrect anticipation of the reactions of policy subjects. Take, for example, the response to the announcement of the basic ideas for health system reform in the Netherlands in the second half of the 1980s. The aim of the intended reforms was to improve the performance of the system by introducing market elements and competition in health care. Health insurance organizations preempted this policy by a series of mergers. This, in turn, made it very difficult to attain the original aims of the policy when competition was actually introduced because of the low number of competitors (Groenewegen 1994).

In sum
This section has briefly discussed three heuristics to connect the micro and the macro levels. Macro-level structures and institutions influence individual behaviour and the interaction between individuals. At the same time, individual behaviour is transformed into macro-level

outcomes, both intended and unintended. The following sections will deal with some aspects of the behavioural theory at micro level. Subsequently, the relation between macro and micro level, and the other way around, will be discussed.

2.3 Micro level: the behaviour of patients and providers

An important element in analysing macro-level phenomena is the behavioural theory at micro level. The point of departure is that people's acts are goal-oriented and rational in a restricted sense, i.e. against the background of their knowledge and ideas about goals and means to reach them (Boudon 1981). The extent to which people achieve their goals will be determined by the constraints imposed on them as well as by the resources at their disposal. In as far as constraints and resources are structurally or institutionally determined, they are the way to bridge the gap between macro and micro level (Wippler and Lindenberg 1987).

If we apply a theory of goal-oriented behaviour as an element of an explanation, we need to know the background against which people weigh up their alternatives - in other words, what their goals are. A systematic approach to this is given in social production function theory (Lindenberg 1996). The assumption here is that people have a limited number of ultimate goals, namely physical well-being and social approval. In which way, or via which intermediate or instrumental goals, people try to achieve these ultimate goals depends on social structural and institutional conditions.

The behaviour of health care providers

Health workers may be assumed to strive to achieve the same general goals of physical and social well-being as everyone else. An important instrumental goal specific to health workers is to promote their patients' or clients' health. The importance of this goal has been inculcated through a long period of socialization in medical school and internships and during post-graduate specialization. The patient's health is usually the first and foremost frame of reference that determines a physician's definition of a decision situation. This also underlines the mutual dependence of health workers' and patients' goals.

The fact that health workers also have other instrumental goals makes it understandable that they are not necessarily perfect agents for their patients (Mooney and Ryan 1993; Domenighetti et al., 1993). The actions they take to improve their patients' health have consequences for other goals: they take time, generate income, or lead to approving or disapproving reactions by colleagues. Structural conditions at the system level might influence the possibilities to achieve an optimal mix of income and leisure time. Fee-for-service payment makes it attractive to perform more services, because that increases income, as was hypothesized by Westert (1992). Physicians who work in a single-handed practice depend on their patients for social approval, while those in a group practice depend on their colleagues to achieve the same goal (Freidson 1970).

The behaviour of patients

Models of patients' behaviour have been elaborated mainly from a social-psychological point of view. A common model is the Health Belief Model (Janz and Becker 1984), which is based on attitude theory. A more sociologically oriented model is the so-called Andersen-Newman model (Andersen and Newman 1973). It is used to predict health care utilization on the grounds of three types of influence: predisposing variables, such age and gender; enabling variables (or constraints), such as insurance status or availability of health services;

and need variables, such as the experience of symptoms of ill health. These models miss a theory of preference, such as social production function theory. They either take the goals of patients for granted (as in the Anderson-Newman model) or just ask people for their preferences (as in the Health Belief Model). In the area of health economics, the Grossman model (Grossman 1972; Van Doorslaer 1987) assumes that health care utilization is an instrumental goal, among other instrumental goals, to produce health. The basic idea is that people invest in maintaining their 'stock of health capital' by their life style, preventive actions, and use of health care. We assume that, apart from maintaining or regaining health, people also have other instrumental goals, such as reducing anxiety or uncertainty (Ben Sira 1986) or finding quick or slow solutions to their problems (e.g. depending on sickness benefits). However, a systematic elaboration of patients' instrumental goals, relating them to structural and institutional circumstances, is not available yet.

Patient-provider interaction
Utilization of health services, the meeting point of supply and demand, is constituted in the interaction between health care providers and patients, usually during the consultation. A typical feature of this interaction is its asymmetry. First of all, asymmetry exists in the importance of the consultation. For a particular patient, there is only one problem and that is his or hers, while for the health worker there are many patients with many problems (Gillon 1988). Secondly, there is asymmetry in information. Providers have information that patients do not have, and the former use that information to come to a diagnosis or to advise therapy. Finally, health care providers sometimes govern access to scarce resources, such as drugs that are only available on prescription or sickness certificates that entitle the patient to certain benefits (Stone 1979).
Given these asymmetries, one would hypothesize that the expectations of health workers and patients often diverge (Persoon 1975). Of course, both also have other instrumental goals in addition to regaining or maintaining health. In situations of diverging expectations, patients may choose among three modes of action:
- negotiate or confront the health worker: the alternative of the knowledgeable patient;
- find another health care provider: the option of 'doctor shopping' on turning of alternative medicine;
- act as if they accept the situation but neglect the advice: the option of non-compliance.

Both the diverging expectations and the options that will be chosen in such situations depend on constraints and resources.

2.4 From macro to micro level: constraints at different levels

The gap between macro and micro level is bridged by assumptions about structural and institutional constraints that influence the way people can realize their goals. These constraints operate at different levels. Basically, the organization of the phenomenon one studies determines what the relevant levels are and where they are located. In the case of health services research, three levels might be relevant: the level of the health care system; the level of the practice or organization providers work in and, on the patient side, his or her social context; and the level of the actual consultation between provider and patient. The upper half of figure 2.3 shows these levels.

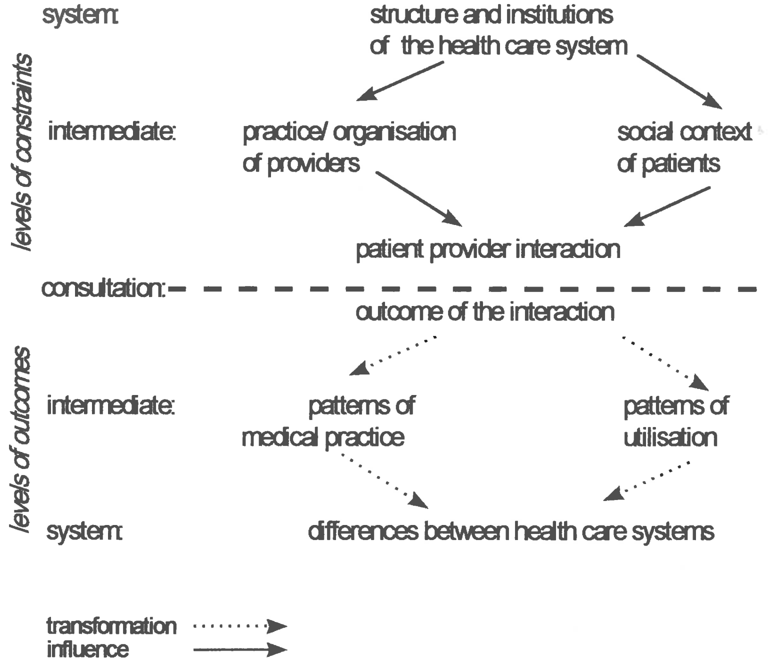

Figure 2.3 Levels of constraints and levels of outcomes

At the system level, both health care providers and patients are influenced by the structure and institutions of the health care system. The result of the interaction between patient and provider, in terms of the alternative modes of action distinguished above, is influenced at the system level by the extent to which consultations are embedded in an existing patient-provider relationship. This is particularly evident when patients are on the list of a specific health care provider. This casts a shadow on the quality of future interactions. Moreover, in some systems, the restrictions on changing one's doctor are more stringent than in others (Thomas et al., 1995). If providers are paid on a fee-for-service basis, patients and health workers are usually not tied to each other institutionally; if so, they are bound for a limited time only. In this case, one would expect patients to negotiate when expectations diverge. If providers are paid on a capitation basis, patients and providers are tied to each other. Usually, there are then administrative barriers to making a change in one's doctor. It is hypothesized that the reaction to diverging expectations in this situation will often be non-compliance. If providers are in salaried service, patients are usually tied to a group of providers, but not to an individual doctor. In this case, we would expect to find a higher incidence of doctor shopping.

The second, intermediate level at which constraints operate is at the level of the practice or organization of the provider and the social context of the patient. Doctors in single-handed practice are more dependent on their patients to gain social approval, while doctors who work in larger groups depend more on each other to gain this good (Freidson 1970). As a consequence, the former might be more willing to negotiate with their patients. On the patient side, the tendency to negotiate might be influenced by a person's ability to communicate one's goals to the health care provider which is probably related to their

educational level. In addition, negotiation may be motivated by the need to communicate one's goals, probably related to the patient's economic position (the costs of proposed treatment in terms of time or money) (Westert et al., 1991).
Finally, constraints emerge at the level of the consultation. The more urgent a health care problem is, the less important the patient's other goals will be and the more patients will be inclined to follow professional advice. If the health problem is less urgent, the goals will coincide to a lesser extent. If, in such a case, the doctor's freedom of decision-making is reduced by professional guidelines or protocols, the patients might be more inclined to try doctor shopping to get a second opinion.

2.5 From micro level to macro level

Health services research does not usually try to explain the choices made by individual health care providers or patients. On the side of providers, the interest is mainly in patterns of medical practice; there is less interest in the choice of a therapy in an individual case. In the same way, on the patient side, interest is mainly in patterns of health care utilization. The behaviour of individual providers and patients, therefore, has to be transformed to higher levels (see the lower half of figure 2.3). Just as the above discussion distinguished different levels at which constraints operate, it also distinguishes different levels of results: from the results of the interaction of provider and patient in particular consultations, to intermediate-level results in terms of practice patterns and utilization patterns, to differences between health systems at the system level.
The transformation of micro level to macro level can take diverse forms. We distinguish five:

- aggregation; in this case, individual behaviour is transformed to a distribution through the application of a mathematical transformation. An example is the rate of Caesarian sections in a region. This is the sum of the individual decisions by gynacologists to perform a section, divided by the total number of births in certain time period.
- partial definition (or definition by convention); when the incidence of an individual effect reaches a certain level, a collective effect is supposed to exist by definition. An example is the existence of an epidemic. One might use the partial definition that if a certain percentage of the population at risk is infected, an epidemic is supposed to exist.
- the application of institutional rules; in this case the transformation is not made through a more or less arbitrary definition but is based on an institutional rule. An example is the process of creating consensus statements or protocols for medical treatment. In a process like this, implicitly or explicitly, a majority rule is used as a necessary step in transforming individual expert opinion into a consensus document.
- game theory and simulation; the analogy of a game can be used to predict the collective outcomes of joint individual actions. Game theory can be applied in analysing fee inflation, for instance. When formal mathematical solutions cannot be found, simulation can be used to transform individual effects to collective outcomes.

2.6 Conclusions

This chapter has discussed the relations between micro and macro levels by using examples from health services research. These examples provide the grounds for a heuristic approach. The approach used here is based on Coleman's general scheme of explaining macro-level relations through micro-level mechanisms, Boudon's analytical scheme of processes of social change, and the analysis of unintended consequences of behaviour. One important element in this heuristic is a behavioural theory at micro level. The approach used here is based on goal-oriented behaviour and the idea of social production functions. That basis makes it possible to relate macro-level structures and institutions to behaviour.

This approach has proven to be fruitful in a number of theory-guided empirical studies of the spatial distribution of physicians (Groenewegen and Van der Zee 1983; Groenewegen 1985), health care providers' allocation of time (Calnan et al., 1992; Cancrinus-Matthijsse 1995), and practice patterns (Flierman 1991; Westert 1992; Uunk et al., 1992; Delnoij 1994; Delnoij and Spreeuwenberg, forthcoming).

The heuristic approach is being used in a number of current studies on patterns of medical practice and differences between health care systems. The aim of these studies is to gain insight in the spatial and dynamic relations of health care supply and hospital production in European countries.

Health services research is both applied and policy-oriented. The approach described in this chapter appears to be easily transferable to other applied fields, such as housing.

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3 MULTILEVEL APPROACHES TO MODELLING CONTEXTUALITY: FROM NUISANCE TO SUBSTANCE IN THE ANALYSIS OF VOTING BEHAVIOUR[1]

Kelvyn Jones

3.1 Introduction

Multilevel models allow the quantitative modelling of contextuality and heterogeneity. This paper discusses how the approach can be used to analyse voting data obtained from multistage sampling designs. It develops the arguments through three graphical typologies and by a range of empirical analyses of voting behaviour in recent British General Elections. Research on voting behaviour has long been concerned to assess the importance of context (Ennis 1962; Wright 1977). A major question is whether observed differences between places are genuine or merely an artifact of within-place characteristics, that is the social and demographic composition of a place. To help place ideas, consider voting behaviour in the South Wales Valleys. It is well-known that people there have a strong and long-term tendency to vote Labour. This may be interpreted as a contextual effect so that there is something about the social and economic milieux of this area that produces a distinctive political culture. It could also be argued, however, that this is nothing more than the result of the class composition of the area. Individuals of low social class have a strong tendency to vote Labour *wherever* they live.[2] People in the Valleys are predominantly drawn from the lower social classes, and the high-level of Labour support in the area merely reflects this. Some are convinced that any apparent contextuality is merely the result of composition:

> 'contextual variables have little or nothing to add to explanations of individual political behaviour based on individual variables' Tate (1974, p. 1662);

while others have their doubts:

> 'election surveys have to face up to the challenge posed by ecological accounts of voting patterns .. . survey researchers cannot afford to treat the ecological evidence as an aside in explaining electoral behaviour' Scarbrough (1987, p. 241).

It is important to realize that these differences are in part a result of research design and technique, with those dismissing the importance of contextual effects basing much of their empirical support on large-scale, cross-sectional surveys of individual voters.[3]

3.2 From nuisance to substance

For reasons of cost and efficiency, most if not all large-scale probabilistic surveys adopt a multistage or clustered design. Typically this involves a three-stage design, so that constituencies are first selected, then wards, and only then individuals. Such a design generates a 3-level hierarchical structure with individuals at level 1 nested in wards at level 2, which are in turn nested in constituencies at level 3. Individuals living in the same ward can be expected to be more alike than a random sample, that is they are autocorrelated, and consequently such clustered samples do not contain as much information as simple random samples of similar size. It is well known (Skinner *et al.*, 1989) that ignoring this autocorrelation results in incorrect estimates of precision, standard errors, confidence limits and tests. There is an increased risk of finding differences and relationships where none exist, and of building unnecessarily complicated models. From this perspective the convenience of a hierarchical design becomes a nuisance in the analysis, and much effort has been spent in both measuring this 'design effect' and correcting for it.

The multilevel perspective, to be developed here, is radically different (Goldstein 1987, 1991b, 1995; Jones 1993a, Hox and Kreft 1994). The hierarchical structure is seen not as a result of multistage sampling, but rather the *population* itself is conceptualised to have a complex (often hierarchical) structure. Individuals, wards, and constituencies are seen as distinct structures in the population which may be measured and modelled. As a result of supra-individual contextual processes operating at a ward or constituency level, individuals within a unit will tend to be more alike than those in different units. The differing levels are then seen as an integral part of the population structure that needs to be properly modelled. In the terminology of survey research, multilevel models automatically adjust the standard errors for the design effect and associated autocorrelation or intra-class correlation that results from the hierarchical structure. But there is more to it than just technical improvements as a multilevel analysis is able to get some purchase on modelling *contextuality*. Thus, such models are not only able to model between-individual variation (at level 1) but also between-place variation (between-ward and between-constituency variation at levels 2 and 3 respectively). Consequently, this higher-level variation is not a nuisance but of key substantive importance.

Previously, researchers have been on the horns of a dilemma. They have had to work at *either* the level of the aggregate (as adopted by many geographers) *or* the individual (the preferred choice of many political scientists). Choosing to work at the aggregate level lays one open to the charge of the ecological fallacy (Robinson 1950) and aggregation bias (Roberts and Burstein 1980), while choosing to work at the individual level risks being found guilty of the atomistic fallacy (Alker 1969). The latter approach misses the context in which individual behaviour occurs, while the former fails to recognize that it is individuals who act, not aggregates. Working at the individual level misses the context of local cultures, while working at the aggregate level fails to capture fully individual variation. The standard statistical approaches to aggregate analysis (such as the calculation of rates and averages and regression modelling) and to disaggregate analysis (such as cross-tabulation, logistic and loglinear modelling) cannot deal with these problems because they operate at a *single* level. Clearly if we ignore any level in an analysis we can say nothing substantive about it, but this is what researchers have been forced to do.

Multilevel models were explicitly developed to resolve this dilemma by working at more than one level simultaneously, so that an overall model can handle the micro-scale of people and the macro-scale of places. Most importantly by distinguishing different levels, multilevel procedures allow relationships to vary according to context. Indeed, there are now a growing number of examples where multilevel models have revealed contextuality and complexity which would have been hidden by standard procedures. This paper aims to outline and develop this multilevel approach by outlining three graphical typologies which are illustrated by analyses of voting behaviour in recent British general elections. An Appendix provides more, yet brief, technical details on the specification and estimation of multilevel models.

3.3 Three graphical typologies

I Graphs of varying relationships

To introduce the basic concepts, I will begin with a two-level model, individuals at level-1 and constituencies at level-2, and consider just two variables. The response variable is underlying propensity of voting for the Conservatives and the individual predictor variable is income (centred around the survey average).[4] Figure 3.1 gives a range of possible models. In 3.1(a) the general voting/age relation is shown as a straight line with a positive slope; 'rich' people vote for the 'right'. In this graph there is no context; place does not matter for voting is conceived only in terms of individual characteristics. This is remedied in 3.1(b) with each of the different places (six in this example) having its own relation represented by a separate line at a varying 'distance' from the general underlying relationship shown by the thicker line. The parallel lines imply that, while the voting/income relation in each constituency is the same, some places have uniformly higher rates of support for the right than others.

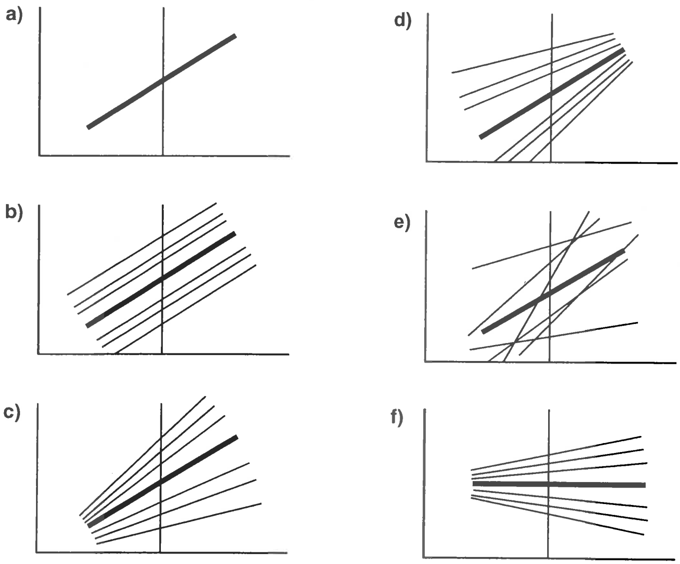


Figure 3.1 Varying relationships between voting and income

The situation becomes more complicated in 3.1(c) to 3.1(f) as the steepness of the lines varies from place to place. In 3.1(c) the pattern is such that place makes very little difference for the 'poor', but places have very different Tory support from the 'rich'. In contrast, 3.1(d) shows relatively large place-specific differentials in voting by the 'poor'. The next graph, 3.1(e), with its criss-crossing, represents a complex interaction between income and place. In some places there is support for the Tories by the 'poor' while in others the well-off support Labour. The final plot, 3.1(f), shows that the poor are similar in all constituencies in terms of voting Conservative, but the intentions of the 'rich' vary from place to place. This is similar to 3.1(c), but this time this difference is achieved by some constituencies having a high rate of Tory support from the 'rich', while in others it is the well-off who vote for the left.

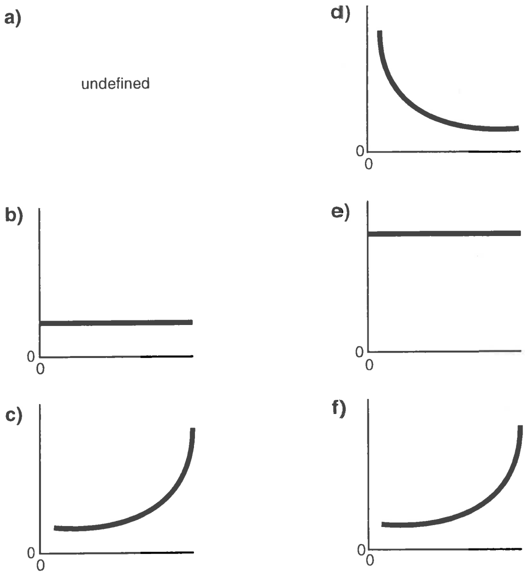


Figure 3.2 Between-place heterogeneity

Another way of portraying these varying relationships is to plot, in figure 3.2, the between-place heterogeneity, that is the variation at level 2. In (a) all places have the same relationship so that there is no variation between places; in (b) there are differences between places but this is unchanging with income. In (c), the differences between places increases rapidly with income, as they do in (f), while in (d) they decrease with income. The complexity of (e) is characterised by a between-place difference that is relatively large at all levels of income. The differing patterns of figures 3.1 and 3.2 are achieved by varying the slopes and intercepts of the lines. The slope measures the increase in right-wing voting associated with a unit increase in income; since the vertical axis in these graphs is centred at the mean of income, the intercept is the probability of voting Tory for a person of average income. The *key* feature of multilevel models is that they specify the potentially different intercepts and slopes for each place as coming from a *distribution at a higher level*. Figures 3.3 and 3.4 show the higher-level distributions for the slope and intercept that correspond to the different graphs of figure 3.1. Figure 3.3 shows a 'dotplot' for the distributions of the slopes and intercepts separately, while figure 3.4 plots the 'scatter' of the joint distribution. These distributions concern places, not individuals, and result from treating constituencies as a sample drawn from a population.
It can then be seen that:

- 3.1(a) is the result of a single, or *fixed*, non-zero intercept and slope;
  3.1(b) has a single fixed slope, but intercepts are allowed to vary or treated as *random* terms;
- 3.1(c) to (f) have sets of intercepts and slopes, that is both the slopes and intercepts are allowed to vary or treated as *random* terms.

The different forms of 3.1(c) to (f) are a result of how the intercepts and slopes are associated. In (c) the voting/income relation is strongest in places where there is strong right-wing support by people of average income; a steep slope is associated with a high intercept. Put another way, there is positive association between the intercepts and slopes as shown in figure 3.4(c). In contrast, in figure 3.1(d), places where there is strong Tory support by people with average incomes, have a weak voting/income relationship. A high intercept is associated with a shallow slope. Consequently, figure 3.4(d) shows negative association between the slopes and intercepts. The complex criss-crossing of 3.1(e) is the result of the lack of pattern between the intercepts and slopes shown in 3.4(e). The degree of Tory support from people of average income in a particular constituency tells us nothing about the marginal increase in right-wing voting with income in that community. The distinctive feature of the final plot, 3.1(f), results from the slopes varying about zero so that in the 'typical' constituency there is no relation between voting and income; in some the slope is positive, in others it is negative. In this latter case, a single-level model would reveal no relationship whatsoever between income and right-wing voting; this average relationship, however, would occur nowhere.

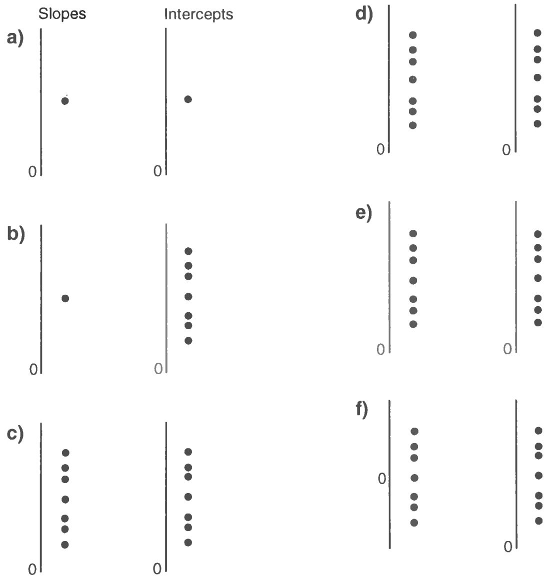


Figure 3.3 Dotplots of the higher-level distributions underlying figure 3.1

These graphs provide a valuable 'technical apparatus' for discussing geographical variations. In particular, the plots of the intercepts and slopes demonstrate that we can achieve quite different and complex variations by straightforward changes of the underlying structure. The plots of figures 3.3 and 3.4 which characterise the higher-level distribution refer specifically to places and not people. While it is possible to directly measure which way people vote, place differences have to be estimated in a modelling framework for they are not directly observable. A particular strength of the multilevel approach is that higher-level units such as wards and constituencies remain in the analysis as identifiable entities that are not lost in the statistical soup of aggregate analysis, or assumed away as in an individual-level analysis. If the multilevel analysis reveals distinctive contextual influences in particular places, it would be possible to adopt qualitative, intensive approaches to try and uncover the social processes that are operating there. Thus in terms of figure 3.4(f), the analysis would reveal the constituency with the strongest positive relationship between income and right-wing vote, and also the place where the relation is the inverse.

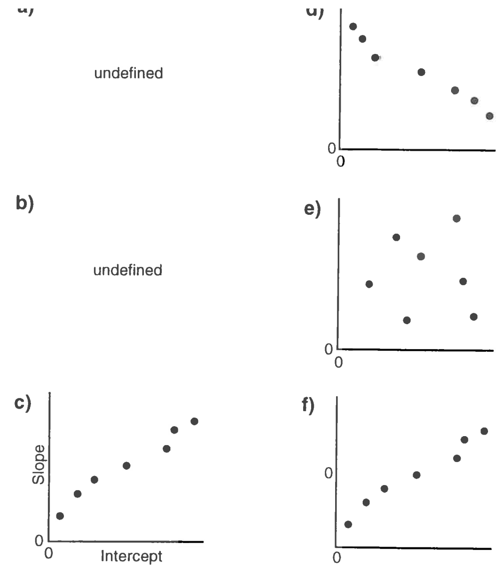


Figure 3.4 Scatterplots of the higher-level distributions underlying figure 3.1

The basic concept underlying multilevel modelling is the specification of models at each level and then their combination into an overall model (Jones 1991a). More specifically, there is an individual-level, micro-model which represents the within-place equation, and a ecological, macro-model in which the parameters of the within-place model are the responses in the between-places models. This simultaneous specification allows for the separation, in a quantitative sense, of the compositional from contextual (Mason *et al.*, 1984). The central empirical question concerning contextual variation becomes does the level-2 variation remain significant when a range of appropriate and relevant individual variables (such as income, class, employment status) are included in an overall model?[5] At the same time it must be stressed that it is always possible to argue that apparent contextual effects are a result of the mis-specification of individual effects (Hauser 1970). However, if higher-level variation remains substantial after taking into account 'many' individual factors, then it is not unreasonable to conclude (albeit and always provisionally) that there are genuine contextual differences.

It is important to realise that these substantive advantages are made within a robust technical framework. From the graphs in figure 3.1 it appears as though a separate line is fitted in each constituency. This would be equivalent to procedures based on traditional single level OLS regression in which the fixed part of the model is expanded to include a slope and intercept term for each individual constituency (that is 'Analysis of Covariance'). If there were 200 constituencies, however, this approach would involve fitting a model with 400 parameters and a very large sample size would be needed to obtain reliable estimates.[6] Traditional quantitative approaches to contextual analysis are, therefore, highly inefficient. In contrast, multilevel techniques involve estimating the statistical characteristics of the higher-level intercept and slope distributions for the population using the constituencies as a sample. Consequently, it is the random part of the model that is expanded and, in the example above, a multilevel analysis would involve estimating only two fixed part terms giving the average intercept and slope across all 400 places and three random terms summarising the variability between specific places. It should be noted, however, that *predictions* of place-specific intercepts and slopes can be obtained once the overall between-place variance has been estimated. Since these predictions are made using the entire sample of places they are more efficient than those from a traditional approach in which each place is estimated separately.[7] Since the multilevel approach involves estimating more than one random term, traditional OLS estimation strategies cannot be used and special multilevel modelling software is required (such as *Mln*, Rasbash and Woodhouse 1995).

II Cross-level interactions

The distinctive feature of the second graphical typology is that an additional predictor variable is included in the model that refers not to individual characteristics, but to the nature of the constituencies. Again there is a two-level model (individuals in constituencies) but this time the response is voting Labour, while the individual predictor variable identifies the working- as opposed to the middle-class, and the constituency variable is the ecological characteristic, the percent of the voters who are working-class.

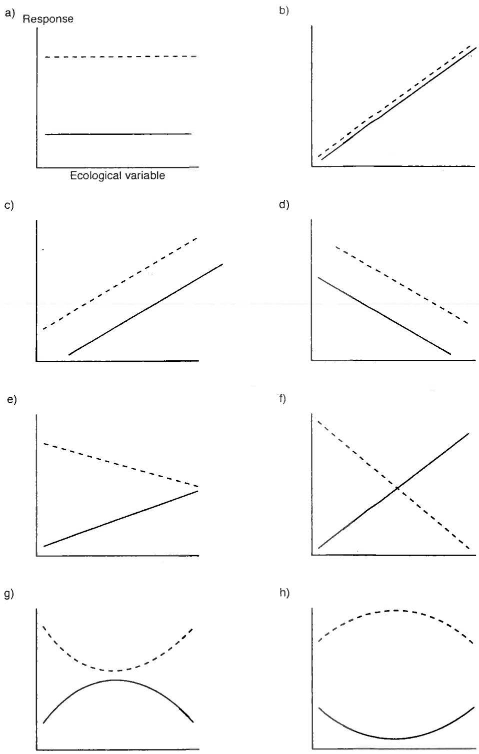


Figure 3.5 Individual and ecological cross-level relationships: a range of people and place interactions (see text for explanation)

A very wide range of differing results involving these three variables are possible of which a selection are shown in figure 3.5. The vertical axis represents the response, the horizontal axis the ecological variable, while the lines on the graph represent different types of individual (the dotted line and continuous lines represents low-status and high-status individuals respectively). Thus, figure 3.5(a) shows that there are marked differences between individuals but no ecological effect, while (b) represents the converse: little difference between types of people but a substantial ecological effect. The parallel lines of figure 3.5(c) and 3.5(d) represent the cases when both the individual and ecological effects are marked: the former represents what Miller (1978, p. 266) calls a 'consensual environmental effect', while the latter shows a 'reactive effect'. In the consensual case, both the ecological and individual effect of class are operating in the same 'direction'so as to reinforce each other. The strongest Labour support coming from lower-class individuals in 'lower-class'areas. But in the reactive case, while it is generally lower-class individuals who vote for the left, they are less likely to do so when resident in areas with a high percentage of lower-class. Examples of both types of effects are provided by Huckfeldt (1984, p. 400). Figure 3.5(e) represents what is known in the political science literature as the Przeworski environmental effect. The graph shows a model in which the environmental effect is reactive for the lower-class but consensual for the middle class (Przeworski and Soares 1971). Figure 3.5(f) represents the case where the cross-level interactions are strong enough to invert the individual-level effects; while in (g) and (h), non-linear interaction terms are of importance so that either the smallest or largest ecological effects are found at 'middling'levels of the ecological variable. While such concepts of environmental influences have long been of interest to empirical researchers (Van den Eeden and Huettner 1982) and are the subject of much conceptual interest (Jones 1993b), it is only with the development of the multilevel model with its micro and macro equations that the full complexities of such relationships can be effectively analysed.

III A multitude of multilevel models

The third and final graphical typology (figure 3.6) depicts a wide range of multilevel structures (Jones and Duncan 1996). The two-level structure of 3.6(a) can be readily extended to the three-level structure of 3.6(b) with individuals at level 1 nested within households at level 2 and places at level 3. Variables can be included at each level so that the relations between an individual's voting and age, for example, can be examined in the context of household income. The extension of the framework to many levels (individuals, polling districts, wards, constituencies, regions . . .) is important for, as pointed out by McAllister (1987b, p. 47):

> 'The level at which contextual effects are supposed to operate has never been satisfactorily resolved. The bulk of the British literature assumes that the effect is confined to a parliamentary constituency (containing on average some 80,000) people, but at least part of this choice reflects the spatial level at which disaggregation is possible in a sample survey, and the availability of census statistics'.

Until very recently the number of levels in available software has been restricted to only 2 or 3. However, with the release of *Mln*, the number of levels can be set dynamically. Consequently, the richness and size of available surveys is likely to be a greater restriction than software. For example, in the British Electoral Studies only one ward has been sampled in each constituency, so that the variation of these two distinct levels is confounded in the survey design.

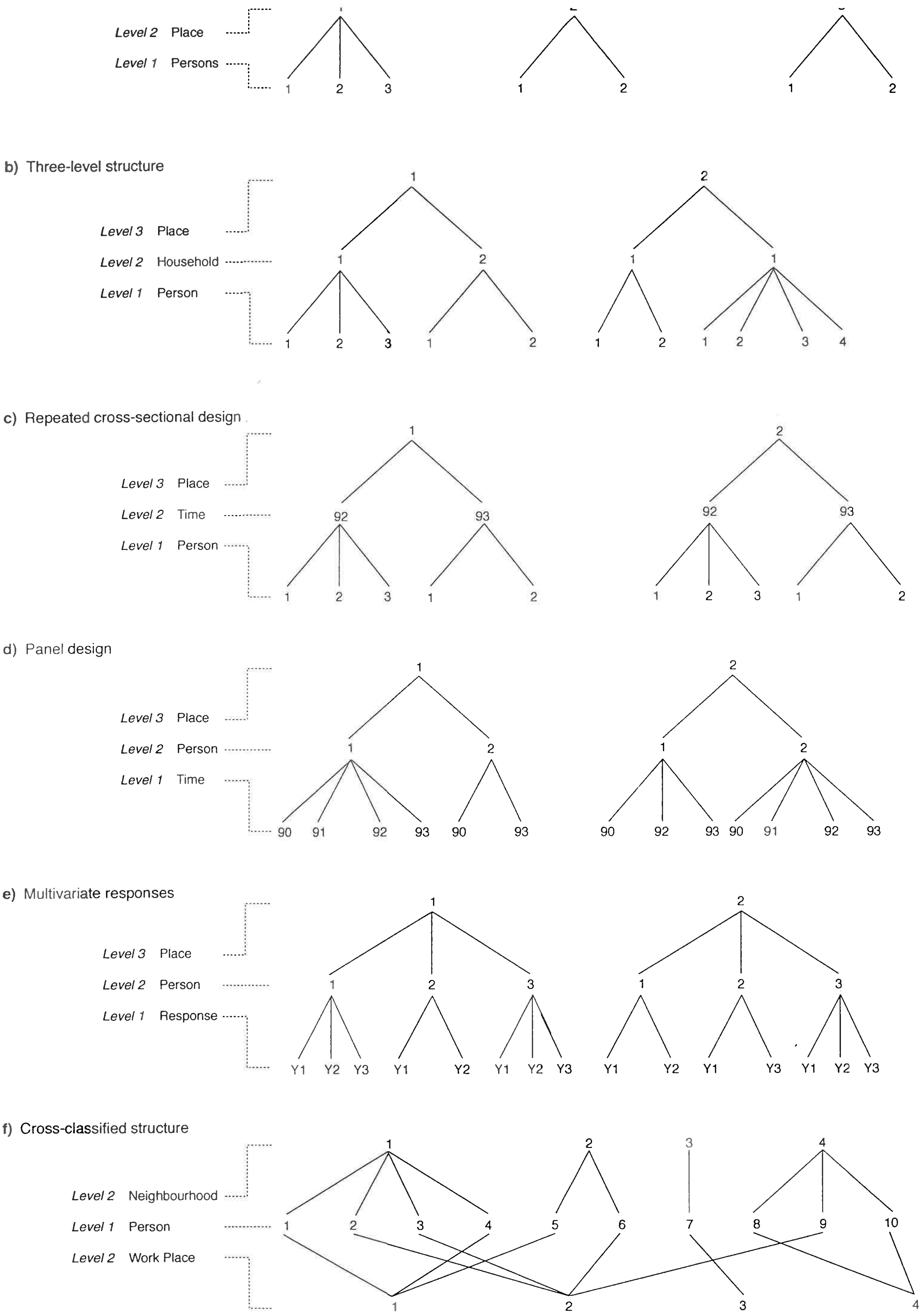


Figure 3.6 A range of multilevel data structures

Changing contexts and changing behaviour are important too, and the framework handles temporal setting as well as place as context. Two possibilities arise depending on the level of unit that is repeatedly measured. If repeated cross-sectional surveys are undertaken then constituencies could be monitored every year, producing a structure with individuals at level 1, years within constituencies at level 2, and constituencies at level 3. This is shown in figure 3.6(c).

When individuals are repeatedly measured in a panel design, the behavioral measurement taken at different times is level 1. These are nested within individuals at level 2, which in turn nest within a further higher level unit such as the constituency. This structure is shown in figure 3.6(d). The first case permits the examination of trends within settings having allowed for their compositional make-up. The second case allows the assessment of individual change within contextual settings. Substantively, the multilevel approach allows the flexible specification of variance and covariance structures through which it becomes possible to assess both which sort of individuals and which sort of constituencies 'change' their behaviour. Technically, multilevel analysis is not affected by the restrictive data requirements that have hampered conventional repeated measures analyses (Ware 1985). Within a multilevel structure both the number of observations per unit *and* the spacing among observations may vary. This flexibility enables efficient use to be made of all the data available. Such models could be used to explore what Warde (1986) has termed the '*electoral mystery*'of increasing individual class de-alignment and simultaneous constituency class polarization (McMahon and Heath 1992), and to develop arguments regarding the geographical variations in class de-alignment (Johnston and Pattie 1992).

Standard approaches are not well-suited to modelling several response variables simultaneously. Yet, it would be reasonable to examine simultaneously several measures of voting intention (such as intended vote in local and general elections). By extending the multilevel framework to a multivariate model it becomes possible to assess the degree to which different behaviours are connected (Duncan *et al.*, 1993a). If we collect information for individuals on each behaviour then we can produce a multivariate, multilevel structure in which level 1 is a set of response variables, one for each behaviour, which nest within individuals at level 2, who nest within constituencies at level 3. This form of multilevel structure is given in figure 3.6(e). In substantive terms, two main benefits arise from a multilevel, multivariate approach. First, the behaviours are directly comparable in terms of how each is related to individual-level characteristics. Answers to complex questions can be given: for example, is voting in local elections related to income and socio-economic status in the same way as in general elections? Second, the residual covariance matrix between the set of responses can be estimated at any level, so that it is possible to assess the 'correlation'of voting behaviours both between individuals and between constituencies, and to do so conditional on other variables. For example, if this correlation at the higher level is negative, there will be places which support Labour in the local elections but not in the general, and *vice versa*.

All multilevel models can use both continuous and categorical data. Importantly, therefore, this multivariate multilevel framework can be applied to continuous response variables, categorical response variables, and also a combination of the two. For example, the multivariate response could be the choice set of voting intentions (Labour, Conservative, Liberal-democrats, Other). This produces what is termed a multinominal, multivariate model and provides a way of modelling multiple response categories (Multilevel Models Project 1993). Alternatively, when the response is more than one choice set, there could be two sets of binary outcomes: supporting Labour in comparison to other parties; and actually voting for Labour in comparison to other parties. There may be a different set of relationships for one choice set to another. Finally, the responses can be a mixture of both categorical and continuous variables (Duncan *et al.*, 1996). Technical benefits flow in terms of efficiency if the responses are correlated and there are many missing responses as in matrix sample designs.

All these examples have so far been strictly hierarchical so that each lower unit nests exactly into one, and only one, higher-level unit. But it is likely that there will not be a single context but many. The possible existence of multiple contexts can be examined through the cross-classified multilevel model. The appropriate structure is given in figure 3.6(f) with individuals at level 1 nested in residential neighbourhoods at level 2, and in workplaces also at level 2. This approach is extremely valuable as it can identify contextual settings which are having a confounding influence. In the example above it may be discovered that what appears as between-workplace variation is in fact really between-neighbourhood variation (Goldstein 1994). Such models could be used to examine debates in the literature about regional effects (Warde 1986) and whether these differences reflect 'geography', that is continuous 'blocks of territory'or 'functional regions' that is groups of constituencies with similar characteristics, irrespective of location such as that used by Johnston *et al.* (1988).

3.4 Implications for survey design

Given this power and flexibility of the multilevel approach, there are now obvious questions about what sort of survey design should be used, how large the number of higher-level units, and how modest the sample size within a higher unit (Jones 1994). In terms of sample design, Goldstein (1984) has argued that the multistage design is the most efficient one for studying contextual effects. To take an example, and using census wards as the higher-level unit, if a national study was conducted on 10,000 respondents chosen according to simple random sampling, we would anticipate that only one voter would be found on average in each of the wards. The within-ward variation would then be totally confounded with the between-ward variation and no separate estimates of these distinct components would be possible. To obtain reliable estimates of both the within- and between-group variation, we need a compromise between the number of lower- and higher-level units. This is, of course, what is achieved by a multistage design. For a given total sample size, if we allow the number of higher-level units to increase each unit will contain fewer individuals, and we approach the situation of a single-level model, where we are unable to model contextual effects.

To get reliable estimates of place differences we need lots of places. Having many individual respondents provides information on the voting/income relation within a place, but many places are needed to assess the differences between places. While it is difficult to be specific about the required sample size (much depends on the magnitude of the higher-level random effects) there is some guidance from educational research, the area in which multilevel modelling has been most applied. Bryk and Raudenbush (1992, p. 203) find that with 60 students per school and 160 schools it is possible to have a total of four coefficients random at the school level. Paterson and Goldstein (1992) suggest a minimum of 25 individuals in each of 25 groups to do useful work; in preference 100 groups are needed. What is not appropriate, and yet this has often been the case in researching locality effects, is hundreds of respondents in five or ten higher-level units. Of course, in some situations it is impossible to follow this 'rule of 25'such as when dealing with households and repeated measures of voting behaviour. In such cases while it is vital that multilevel approaches are applied (because of high levels of anticipated autocorrelation), it would not be sensible nor useful to make inferences about particular households or individuals.[8] Finally, if there is a need to derive sample-based aggregate variables, then a higher degree of sample clustering than is normal may be employed. For example, if a researcher is interested in cross-level interactions between voting and individual and neighbourhood income, then a sample based estimate of the latter would require a sizeable number of respondents in each neighbourhood.

3.5 Exemplification: the geography of voting behaviour

'*Class is the basis of British politics; all else is mere embellishment and detail*'; so wrote Pulzer in 1967. If this is correct and still valid, there is no space for geography. This argument has been made in its most sophisticated form by McAllister (1987a,b), and Rose and McAllister (1990) who have maintained that the apparent differences between places in their voting behaviour is simply the result of differential social and demographic make-up, the composition versus context argument outlined earlier. Much of the work in this area has been undertaken using single-level analyses, but this debate can only be adequately addressed by recognising that individuals, constituencies and regions form different levels in a hierarchical structure.

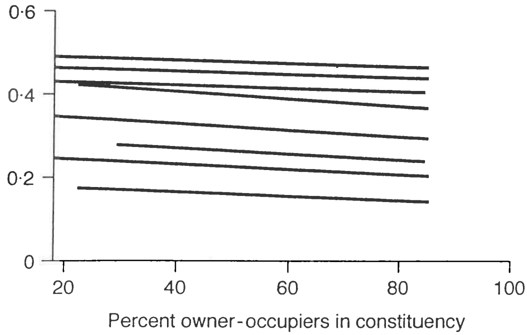
At the same time as the 1987 General Election, a social survey (Heath *et al.*, 1991) was conducted on voting and voters'characteristics; this allowed Jones *et al.* (1992) to explore how voting varies from place to place in a multilevel model. The structure of the data is given in table 3.1. The basic finding from this work is that there are substantial differences in voting behaviour between the regions and constituencies even after the differing compositions of the areas are taken into account. Thus, the South Wales region is strongly pro-Labour even when allowance is made for the class, tenure, employment and demographic characteristics of the voters who live there. To put it another way, people of similar characteristics vote differently in different places.

Table 3.1 Data structure used by Jones, Johnston and Pattie (1992)

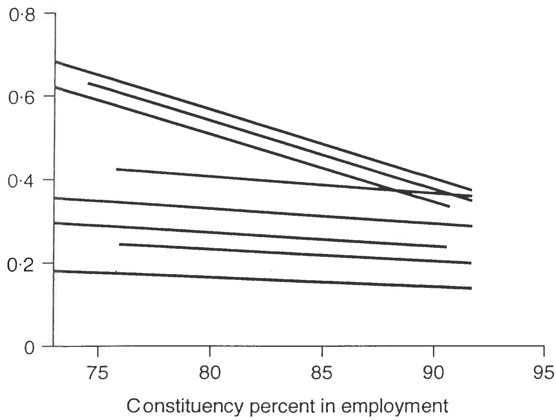
Level 1:	2.281 individual voters response: choice of Labour as opposed to Conservative predictors: age, occupational-class, housing tenure, employment status
Level 2:	250 constituencies predictors: unemployment, employment change, workers in the mining industry
Level 3:	22 economic regions as defined by *The Economist* in their presentation of election results

The variations are not, however, adequately described by a simple model in which only the intercepts are allowed to vary, that is a model in which certain places are uniformly pro-Labour for all types of voter (as in figure 3.1a). Some of the complexity of the results is conveyed in figure 3.7. In the model that lies behind this figure, the constituency-level relationship between mining and voting Labour is allowed to be random at the regional level; the parameter for a level-2 variable is allowed to have a distribution at level 3. Consequently each line on the graph represents the predicted regional relationship between the percentage of miners in each constituency and constituency support for Labour (after allowing for constituencies' composition in terms of age, class and tenure, and its economic prosperity). Traditionally, mining constituencies have been seen as Labour's heartland, and while this is generally true as shown by the majority of slopes being positive, there are some

a) Class and housing interactions



b) Class and employment interactions



c) Class and percent employers and managers interactions

Figure 3.8 Cross-level interactions estimated for the 1992 General Election: individual and constituency interactions

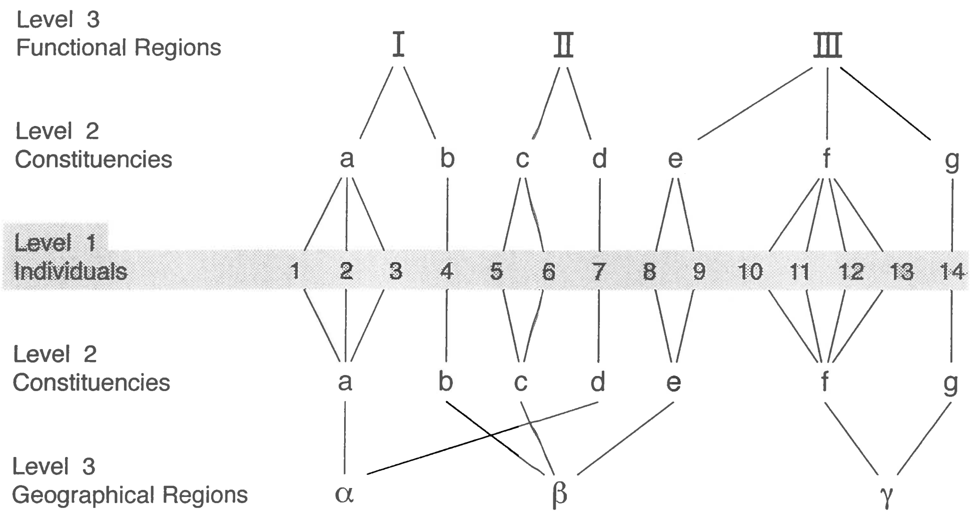


Figure 3.9 A multilevel cross-classified structure for analysing 'regional' variation

This ecology most strongly relates to the class character of a constituency defined in terms of employers and managers. Where this group forms a sizeable proportion of the population, more or less everyone, irrespective of their individual class, votes Conservative. Constituencies are more polarised politically than people. These results support the findings of aggregate analyses (Miller 1978,1979; Waller 1983).

The final illustration concerns another debate in the literature about the importance of contextual effects. It focuses on the relative importance of social and geographical contexts in accounting for voting outcomes, and particularly, on whether the differences are more marked for a 'geographical' regionalisation, than for a 'functional'one. According to Johnston *et al.* (1988), the former refers to:

> 'contiguous blocks of territory'.

while the latter represents:

> 'groups of constituencies with similar characteristics, irrespective of location'.

They argue that both types of grouping are:

> 'relevant contextual variables for voting behaviour: the first linked to Britain's growing North-South divide . . . and the latter to a growing urban: rural divide with the urban sector divided into different functional types'.

Savage, in contrast, argues that (1987, p. 66) functional differences are becoming of increasing importance in comparison to geographical differences:

> 'whereas in the past constituencies of a similar type often had different political alignments because of the salience of their local political cultures, this is becoming much less apparent and constituencies of a similar type are behaving in similar ways whatever part of the country they are in'.

In order to assess these different regionalisations, Jones *et al.* (1996a,b) used a cross-classified multilevel model with the structure given in figure 3.9 and the variables given in table 3.3. Individual voters (at level 1) are nested within constituencies (at level 2) which are nested within geographical regions (at level 3) and functional regions (also at level 3). There are 31 types of constituency based on a large-scale cluster analysis of census variables, and 24 regional groupings of constituencies based essentially on the non- and metropolitan division of Standard Regions.

Table 3.3 Data structure used for multilevel cross-classified analysis of 1992 General election

Level 1:	2275 individual voters response: choice of Labour as opposed to Conservative predictors: age, gender, occupational-class, housing tenure, employment status, income, educational qualifications
Level 2:	218 constituencies
Level 3:	31 functional regions and 24 geographical regions

The results from a random intercept three-level model show that the largest higher-level variance is the between-functional regional variance and the smallest is the between-geographical regional variance. To give some appreciation of the size of these effects consider the estimated probability of voting Labour for the type of person whose characteristics are the most commonly occurring in the sample. This is a 46-year old woman without educational qualifications who lives in owner-occupied household whose head is in employment, receives a 'middle' annual income (£12-20,000) and who is classified as unskilled working class. Nationally this type of person has a 0.49 probability of voting Labour. For the geographical regions, the predicted probability at the extremes ranges from 0.36 in the 'South Coast' to 0.63 in the 'Industrial North East'. For the functional regions this range is from 0.25 ('Scottish rural areas') to 0.75 ('Areas with poorest domestic conditions'). The differences between functional regions remain substantial despite taking account of a wide range of predictor variables. For comparison the greatest fixed effects for individual class are the difference between unskilled manual (0.49) and petty bourgeoisie (0.15) when all the other predictor variables are held at their 'stereotypical' value.
A further model allows the size of the higher-level effects to be differentiated by class. It is found that geographical regions are not differentiated by class, but for the functional regions the results suggest that where the working class vote for Labour is high, there is a tendency for the upper class differential to be negative. In terms of probabilities, the range of Labour support amongst the working class goes from 0.28 in '*Scottish rural*' areas to 0.75 in '*areas with poorest domestic conditions*'. For the private salariat, the range is from 0.13 in '*very high status*' areas to 0.42 in the '*Scottish industrial*' constituencies. The biggest difference between the classes is found in '*Textile*' areas where the probabilities for the working class and private-sector salariat are 0.62 and 0.25 respectively. The smallest difference is in '*Agricultural areas*' where the probabilities are 0.31 and 0.17. At the constituency level, a similar pattern is found. This suggests a complex geography of constituency preference even after allowing for demographic and social characteristics of individuals, with a tendency for places that are pro-Labour for the working class to be relatively even more anti-Labour for the upper class. In summary, there is evidence that contextuality is complex and differentiated. While differences between geographical regions are not great, the differences between functional regions and constituencies are substantial and the size of effect is differentiated by class.

3.6 Three caveats

As with all technical developments, there are always real dangers of 'overuse' and 'oversell'. While there are a range of technical problems that remain in the use of multilevel models (Jones 1991b), I want to point out three important substantive problems that beset current practice.

The first problem relates to defining the higher-level units. Multilevel models were first extensively developed for pupils in schools, so that the institution was the readily-identifiable higher-level to which individuals belonged. Applying the approach to places (Duncan *et al.,* 1993b) is, of course, fraught with difficulties, for as Massey (1991) points out:

> 'localities are not simply spatial areas you can easily draw a line around';

as they must be must be seen as:

> 'the intersection of sets of locales'.

While it may be possible to use Openshaw's (1977) automatic zoning procedure in tandem with cross-classified multilevel models in an overall GIS framework, this is not a problem that can be overcome by a technical fix. While the levels of constituency (and individuals) seem entirely reasonable ones for voting behaviour, it is a much more open question how to define neighbourhoods and regions.

The second problem relates to the fact that the overwhelming majority of electoral studies have adopted a static rather than a dynamic approach. Consequently, such work has been unable to distinguish the 'breeder' hypothesis (that social milieux breeds social attitudes) from that of the 'drifter' hypothesis, whereby differentials in geographical mobility create spatial patterns of voting behaviour. While the type of structure discussed earlier (figure 3.6d) allows the examination of repeated measures of voting, this is not enough to tackle changing contexts. Voters may be socialized in their youth in a particular context and subsequently move to another context to have these views challenged or reinforced. This necessitates a non-hierarchical structure. As yet there are no examples of such research. This is due to a lack of suitable datasets and because, until recently, the calibration of cross-classified models has been somewhat intractable. Recent developments in multilevel computational estimation strategies (Jones *et al.,* 1996b; Rasbash and Goldstein 1994) and the collection of long-term multistage panel studies such as the British Household Panel Survey will allow such problems to be tackled in the future.

The third and final problem to be considered here is to recognize that apparent 'place' heterogeneity may really be 'people' heterogeneity. The models discussed above (and indeed the published literature) have focused on the elaborations of the higher-level random terms so as to capture between-place heterogeneity. In contrast, the micro-models have, in the main, been simple with a single random part attempting to summarize between-people differences. This formulation presumes that people differ by a 'fixed' amount, but have the same variability; an unlikely presumption but more or less universally made in single-level regression modelling. To take a specific example, it may be that working-class voters are not only more likely to vote for Labour, but are also more variable in their voting behaviour than the non-working class.[9] Crucially, the heterogeneity between levels may be confounded so that when simple level 1 models are used, there may be an overestimate of the higher-level variation. Multilevel estimation procedures and software can deal with such complexity (Bullen *et al.*, 1996), and such developments must now routinely be put into practice.

3.7 Conclusions

Multilevel procedures have a number of features that make them attractive. Technically, by taking into account the complexity of the data, they overcome difficulties associated with autocorrelation. Consequently, significance tests and confidence intervals will more properly reflect the data structure, and there is reduced risk of mis-estimated precision and inferential error. Moreover, by pooling data they ameliorate the small number problem by making use of precision-weighted estimation.[10] In substantive terms, multilevel modelling allows us to explore some of the complexity that we know exists in reality (Rose 1974), and in so doing, provides for improved empirical description that is sensitive to context. As Skinner *et al.* (1989, p. 289) put it:

> "the issues raised are not mere technical issues which have only a marginal esoteric interest . . .. On the contrary our experience suggests that the use of analytical procedures which take account of the population structure and the sample selection mechanism can change the objectives of the analysis and can have a substantial impact on the subsequent interpretation of the results".

while Eagles' (1995) book on '*Spatial and contextual models in political research*' concludes (p. 282):

> "capturing the effects of context is likely to involve influences from a variety of spatial scales . . . developments in multilevel modelling . . . will enormously facilitate this important research agenda in political science".

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Notes

1. Various versions of this paper were delivered at an ESRC seminar on the Role of locality and spatial effects held at the University of Manchester; the Political Geography Speciality Group meeting - 'A critical examination of methodology and theory in electoral geography' held at the Association of American Geographers Annual Meeting, Charlotte, April 1996; and a NETHUR conference held in Utrecht in April 1996. I thank the participants for their comments.
2. It may also be argued that these political differences are created not through some sort of social miasma but through differential mobility; a longitudinal design would be needed to assess the claims of such an explanation.
3. Another major reason for the differing findings is the common practice by those who use survey data to include attitudinal variables at the individual level as an explanation of actual voting. To claim that contextual effects then disappear is, to say the least, problematic. It is like saying there is no geography of death when we take account of those who are gravelly ill.
4. The underlying propensity to vote Conservative is usually modelled through a non-linear multilevel model (Goldstein 1991a).
5. It is also possible (Jones and Bullen 1993) for genuine contextual effects to be hidden or masked by not allowing for social and demographic composition. Such a result can occur, for example, when a place with a genuinely low Tory support rate has relatively high numbers of high-status individuals who nationally have a high probability of voting Conservative.
6. It would also require for effective estimation that within each constituency, there was a 'reasonable' range of values on the predictor variable; a constituency specific OLS slope parameter would be impossible to

estimate if all individuals in a constituency had the same income.

7. It must be stressed that this formulation of place differences as random effects implies that each place is not assumed to be a 'separate entity' but rather is seen as coming from a distribution. If it was believed that a particular place (or set of places) were not part of a single 'national' distribution but was in some way untypical, this could accommodated by including appropriate differentiating factors as fixed terms in the model. There would be no 'pooling' of information across the typical and untypical sets of places. In practice, this approach can also be adopted when a particular place is an outlier thereby unduly inflating the size of the between-place variance.
8. That is the higher-level variances can and should be estimated, but the *predictions* for specific individuals or households will have large confidence intervals.
9. In non-linear models of the propensity to vote Labour, this heterogeneity between individuals is called 'extra-binomial' variation (Goldstein 1991a).
10. These technical issues have been at best dealt with here sketchily; for further discussion see Goldstein (1991b, 1995); Jones and Bullen (1994).

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Appendix: specifying multilevel models

The general structure for all statistical models can be written as:

Response = systematic component + fluctuations (1)

or equivalently

Response = fixed terms + random terms (2)

This becomes in the single-level simple regression model:

Response		*Systematic part*				*Random part*	
right-wing support for individual i	=	right-wing support for person of average income	+	support for unit increase in income	+	change in residual variation for individual i	(3)
		Intercept		*Slope*		*Residual*	

This can be developed into a *micro* model for individual voters by having an intercept and slope for each place:

Response		*Systematic part*				*Random part*	
right-wing support for individual i	=	right-wing support for person of average income in place j	+	change in support for unit increase in income in place j	+	residual variation for each individual i	(4)
		Intercepts		*Slopes*			

Two *macro* statistical models can also be specified at the higher level to model the between place variations in the intercepts and slopes:

Response		*Systematic part*		*Random Part*	
right-wing support for person of average income in place j	=	national support for person of average income	+	place-specific differential support for person of average income	(5)

Response		*Systematic part*		*Random Part*	
change in support for unit increase in place j	=	national change in support for a unit change in income	+	place-specific differential change for unit change in income	(6)

That is we have a micro-model that represents the within-place equation, and two macro, between-place models in which the parameters of the within-place model are the responses.

Equations 4, 5 and 6 can be written in (fairly) standard notation as

Micro model: $y_{ij} = \beta_{0j} + \beta_{1j}x_{ij} + \epsilon_{ij}$ (4)

Macro models: $\beta_{0j} = \beta_0 + \mu_{0j}$ (5)

$\beta_{1j} = \beta_1 + \mu_{1j}$ (6)

and combined into an overall multilevel model

$$y_{ij} = \beta_0 + \beta_1 x_{ij} + (\mu_{1j} x_{ij} + \mu_{0j} + \epsilon_{ij}) \tag{7}$$

where y_{ij} the response, is a measure of right-wing support for individual i in place j;
x_{ij} the predictor, is the income of person i in place j centred about the national mean for income;
β_0 is the overall intercept, representing the national right- wing support for a person of average income;
β_1 is the overall slope, representing the national relationship between income and right-wing support; this overall slope and intercept are used to draw the thick 'general' line in figure 3.1;
( ) represents the random part which in this model consists of three elements:
μ_{1j} the differential slope for place j, a residual at level 2;
μ_{0j} the differential intercept for place j, another residual at level 2;
ϵ_{ij} the remaining individual differential after taking into account income and place; the residua l at level 1.

The level 2 residuals estimate the 'differences'between places, the level-1 residuals estimate the 'differences' between individuals within places.

The novel feature of the ML model is the random terms ($\mu_{1j,}$ μ_{0j}) at level 2, and it estimates of these terms that are plotted in figures 3.3 and 3.4. In fact it is not their specific values that are estimated but their variances and covariances ($\sigma^2_{\mu 0}$, $\sigma^2_{\mu 1}$, $\sigma_{\mu 0 \mu 1}$) as well as the level-1 residual variance, σ^2_{ϵ}. The total variance at level-2 is the sum of two level-2 random variables:

$$\text{Var}\ (\mu_{0j}, \mu_{1j} x_{ij}) = \sigma^2_{\mu 0} + 2\sigma_{\mu 0 \mu 1} x_{1ij} + \sigma^2_{\mu 1} x_{1ij}{}^2 \tag{8}$$

It is the graph of this quadratic function that is shown in figure 3.2. If the covariance is substantial and positive, we get the greater between-place differences for high income shown in 3.2(c); if negative, we get the narrower between-place differences at high income of 3.2(d). If the covariance is zero but the slope and intercept variances are large, we get the complexity of 3.2(e). If the covariance and slope variances are close to zero we get the parallel lines of 3.2(b), the 'random-intercepts'model. If all the higher-level variances are zero, the model reduces to the single-level of 3.2(a).

The basic model can be extended in a number of ways; here I will briefly consider complex heterogeniety at level 1, and the inclusion of macro variables at level 2. Level-1 heterogeneity can be modelled by specifying a micro-equation:

$$y_{ij} = \beta_0 + \beta_1 x_{ij} + (\epsilon_{0ij} + \epsilon_{1ij} x_{1ij}) \tag{9}$$

in which there are now two level-1 random terms. The total variation at level 1 is then a quadratic function of income:

$$\text{Var}\ (\epsilon_{0ij}, \epsilon_{1ij} x_{ij}) = \sigma_{\epsilon 0}{}^2 + 2\sigma_{\epsilon 0 \epsilon 1} x_{ij} + \sigma_{\epsilon 1}{}^2 x_{ij}{}^2 \tag{10}$$

A substantial positive estimate for $\sigma_{\epsilon 0 \epsilon 1}$ represents 'fanning out' in which higher income individuals are not only more likely to vote for the right on average (a positive value for the fixed effect, β_1) but are also more variable. A sizeable negative estimate for $\sigma_{\epsilon 0 \epsilon 1}$ suggests 'fanning in' so that at the individual level, the highest income groups are the least variable in their support for the right.

A higher-level variable, w_j , relating to the constituency not to the voter, could also be included in the model through specification in the macro models

$$\beta_{0j} = \beta_0 + w_j + \mu_{0j} \tag{11}$$
$$\beta_{1j} = \beta_1 + w_j + \mu_{1j} \tag{12}$$

which results in the overall multilevel:

$$y_{ij} = \beta_0 + \beta_1 x_{ij} + \alpha_0 w_j + \alpha_1 w_j x_{ij} + (\mu_{1j} x_{ij} + \mu_{0j} + \epsilon_{ij}) \tag{13}$$

It is equations of this type which are used to develop models according to the second graphical typology of figure 3.5.

The presence of more than one random term in the model means that we cannot use standard Ordinary Least Squares procedures to derive estimates. There are a number of different estimation strategies that have been developed for multilevel models and these have been implemented in a number of different software products (Goldstein 1995). Two programs, BUGS and MLn are able to estimate all the models discussed in this paper. For details of currently available software point your Web browser to http://www.ioe.ac.uk/multilevel/-index.html which provides links to a number of producers offering multilevel products.

4 GIS FUNCTIONALITY FOR MULTI-LEVEL RESEARCH

Tom de Jong and Henk Ottens

4.1 Introduction

Geographical Information Systems (GIS) are widely recognized and accepted as useful data-handling tools in geographical research. They provide the user with capabilities to capture, structure, integrate, manage, manipulate, and visualize spatial data (Maguire 1991, pp. 10-12). In principle, a GIS includes a regular database which contains data with one special characteristic: each case in the database has a reference to a location. Through this reference, each case is spatially positioned relative to all other cases in the database. Information about these relative locations is also stored and maintained in the database. Location may be specified in the form of a single coordinate point (representing for instance, the location of a house), a string of coordinate points forming a line (representing, for instance, a road), or a string of coordinate points forming a polygon boundary (representing, for instance, a municipality). Apart from the everyday functionality of a database management system (data entry, data edit, data query, etc.), a GIS also contains special analytical and visualization functions based on the spatial 'intelligence' in the database. Because of these data management, manipulation, and viewing functions, a GIS is able to contribute to data-handling in multi-level spatial research.
Multi-level research approaches in geography have been devised to broaden the perspective and improve the statistical explanation methodology by explicitly taking into account (relations between) different levels of spatial aggregation (Jones 1993). In this respect, a regular analytical GIS can perform a number of tasks:

1. provide objects with a geocode for further spatial processing;
2. create higher-level spatial objects (composite or aggregate objects) based on locational, thematic, and functional characteristics of lower-level objects;
3. determine the spatial relationships between lower-level spatial objects and higher-level spatial objects;
4. generate values for attributes of higher-level objects, with the possibility to add them to the lower-level objects as well;
5. generate or add 'contextual' information about objects by neighbourhood analysis or by integrating and processing data files from different sources;
6. display cartographical views on the created and manipulated multi-level database.

This article reviews various aspects of the functionality of a standard GIS with respect to multi-level data handling and then illustrates these aspects with examples. The first one is the use of GIS for studying spatial relationships. After introducing geocoding principles, the regular way of determining spatial relationships in a GIS is discussed. Special attention is given to the database tables that are created in the process. The next part of the article deals with spatial relationships. In particular, it covers the creation of higher-level objects based on network approaches and functional distances. The last section is a discussion of the possibilities, limitations, and prospects of using GIS for multi-level research.

4.2 GIS and spatial relationships

When conducting any kind of multi-level analysis, for each case it is imperative to know to which object it belongs at each of the various levels involved. If there are various spatial levels in the analyses, this information can usually be obtained in a fairly straightforward way. Most of the time, the researcher or a respondent in a survey can accurately identify the various levels, such as the borough or municipality where the respondent lives. Registrations that are often used as a data source for multi-level research are generally enhanced by adding a number of regional classifications to which a case belongs. Those classifications are normally added as variable values for each record (e.g., in cadastral files, population, housing, and business registers, etc.). With regard to standard regions, a reference can be obtained by a simple aggregation procedure from a lower level to the 'standard' higher level. For instance, municipalities in the Netherlands can be directly aggregated into ten different statistical spatial divisions or thirteen different political spatial divisions. Those divisions are based on a file with cross-references between municipalities and standard regional divisions composed of municipal units. When aggregation is done in this manner, spatial relationships can easily be recorded as variables in a relational database management system and directly handled by statistical, modelling, and mapping software. A GIS can be used for data management and thematic mapping, but analytical capabilities will not be needed.

However, it could also happen that the researcher or respondent is not well acquainted with the spatial divisions, such as census wards or police regions. In designing a survey, it is not always possible to connect an observation directly to a standard spatial unit (address, road segment, etc.). Furthermore, spatial divisions simply are not always clearly defined in terms amenable to human reference, such as a possible radiation zone around a nuclear power plant. Spatial divisions can also vary depending on certain assumptions. For instance, an area may be defined as being within a 10- or 15-minute drive from an ambulance post. In all these situations, GIS functionality can be used to establish the spatial relationships between the different levels and to create a level with relevant higher-order objects. However, before this functionality can be applied, all the data must have a digitally available locational reference or geocode.

4.3 Geocoding lower-level data

Most of the higher-level spatial divisions are directly available in digital format (as 'boundary files') or can easily be obtained. They can be derived by digitizing an analog map or can be created through the various GIS functionalities for regionalisation. However, getting a geocode for data at the lowest level is usually more cumbersome. There are several ways to go about it. The choice depends on the desired accuracy and the available equipment.

With only a few cases, the easiest way is to mark the position on an analog map and digitize it afterwards. Alternatively, direct field measurements can be made using a Global Positioning System (GPS), which produces geographical coordinates. Under optimal conditions, the deviation may be as low as about one metre. This accuracy can be further improved, but at considerable cost some innovations in this market are positioning systems based on radio beacons.

Human geography often deals with data about many cases that can be linked to addresses. In that event, the best way to proceed is through address conversion based on the postal

code (Raper, Rhind and Shepherd 1992). In the Netherlands, several data sets are commercially available to convert addresses to points or polygons in geographical space. Postal codes can be converted into about 4,000 different centroids based on the first four digits of the postal code, about 27,000 centroids based on five digits, or about 400,000 centroids based on six digits. The average error is very small when all addresses in one six-digit postal code area are located closely together, as they are in urban areas. But in rural areas, one six-digit postal code area may stretch along a road of considerable length. In a study in the province of Limburg, a road segment of over eight kilometres long was found to have the same six-digit postal code, which results in an average error of about two kilometres.
Alternatively, it also possible to convert an address (full six-digit postal code plus house number) to the centroids of the national 500-by-500-metre grid. The average error using this latter method is about 200 metres all over the country. Based on this same national grid, it also possible to obtain a data set with one weighted grid centroid for each six- digit postal code area. This method diminishes the amount of data required but combines the inaccuracy of the two previous methods.
Finally, addresses can be linked to street sections using a line segment file, representing streets and including address ranges for street sections. The software distributes the addresses as points along the street segments in some regular way. This 'address matching' procedure yields coordinates for each address with a relatively high accuracy (Castle 1993, p. 101).

4.4 Determination of spatial relationships

At the lowest level of analysis, there are many individual cases. As mentioned above, they usually are or can be represented in GIS as data points. At higher levels, there may be all sorts of spatial units. If the higher-level units are polygons (or 'regions'), a simple 'point in polygon' analysis can establish spatial relationships between levels. The software selects all objects whose coordinate pairs fall within the boundaries of the polygon. If the higher-level components are points or lines, they have to be converted into polygons. Then the same procedure as described above can be applied. This conversion can take place by two different methods. In the first method, Voronoi or Thiessen polygons can be calculated. These divide the entire space into exclusive areas that are closest to one original spatial object. Figure 4.1 shows Thiessen polygons calculated around a set of random points. In the second method, buffers can be calculated. These define a sphere of influence around each of the original objects; the spheres may overlap. Instead of using the buffer method combined with 'point in polygon', some GIS packages use the 'proximity' method. That method performs a direct selection from the database based on airline distance to a set of spatial objects. Figure 4.2 shows buffers calculated around the same points that were used for the Thiessen example.

Case study: ambulance stations
The two methods can be used in combination. A few years ago, a study was done to evaluate the proposed closure of two ambulance stations in the Noord Veluwe region in the Netherlands (Ritsema van Eck 1993, pp. 102-111). Population data were available at the settlement level. As part of this study it had to be determined which settlements were currently served (within nine minutes) by particular ambulance stations. Originally, airline distances were used in this study. Figure 4.3 shows the study area in lighter grey; it shows the location of settlements (bars reflect the population size); and it depicts the ambulance stations as circles (dark circles indicate proposed closure). Furthermore, figure 4.3 shows the Thiessen polygons around the ambulance stations delimited by eight-kilometre buffers around the same ambulance stations. Any settlement that falls within a cross-hatched zone will suffer direct consequences of the proposed closure.

The example of the ambulance stations demonstrates the GIS capabilities for determining spatial relations between objects at different levels. It also showed that, under special conditions, GIS can be used to create a spatial division and spatial units at higher levels before the spatial relations are determined. Table 4.1 gives an overview of the widely available GIS methods to determine the membership relationships between spatial objects at different levels.

Table 4.1 GIS tools for determining spatial relations

Lower level	Higher level	Method
Points	Polygons	Point in Polygon (PIP)
Points	Points	Thiessen/Buffer -> PIP or Proximity
Points	Lines	Buffer -> PIP Proximity
Polygons	Polygons	Overlay

After a 'point in polygon' analysis GIS produces a so-called 'one on one' relation table. The purpose of such a table is to define the membership of one higher-level spatial object for each case. That table can be added to the original data set to perform multi-level analysis. Sometimes, the lower-level data is not in point format but consists of polygons as units. In that event, GIS provides the polygon overlay method. That method determines how polygons of the different levels overlap. When polygon boundaries at the two levels do not coincide exactly, a 'one on one' table cannot be calculated directly. Instead, another table can be produced that contains the amount of coverage of each lower-level polygon by higher-level polygons. From that table, a 'one on one' table can be generated. For instance, this may be done by defining a lower-level polygon as a member of the higher-level spatial object that has the largest amount of coverage. With aggregate and overlay operations, the software can deal in various ways with the attribute information involved. For newly created objects, attribute values can be calculated as sums, averages, weighted averages, etc. of the values for the original objects out of which the new, composite object is formed.
When the spatial objects at the higher level overlap, it is not only possible to use GIS to find out to which objects a case belongs but also to find out how many objects it belongs to. In addition, when the objects at both levels are points, it is possible to create a full distance table. That table can be used to find out for each case how many higher-level objects are within a set distance range. Furthermore, for each case, that table can be used to determine the distance to first, second, or third (and so on) nearest higher-level object.

4.5 Spatial relationships based on transport networks

All GIS tools for creating higher-level spatial objects discussed so far are based on airline distances. Using these distances to determine a sphere of influence may be sufficient when studying natural phenomena like radiation or noise pollution. However, in most instances involving people or goods that travel, it is better to use the use of distances (or travel time estimates) derived from an actual or proposed transportation network (De Jong and Ritsema van Eck 1992). To use this approach a street and road network file must be available. Preferably, it will give average travel speeds or travel times for each of the street segments in the network.

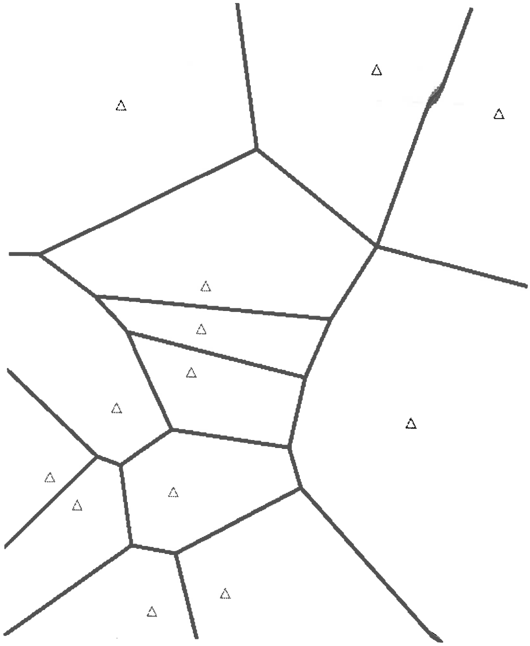

Figure 4.1 Thiessen polygons around random points

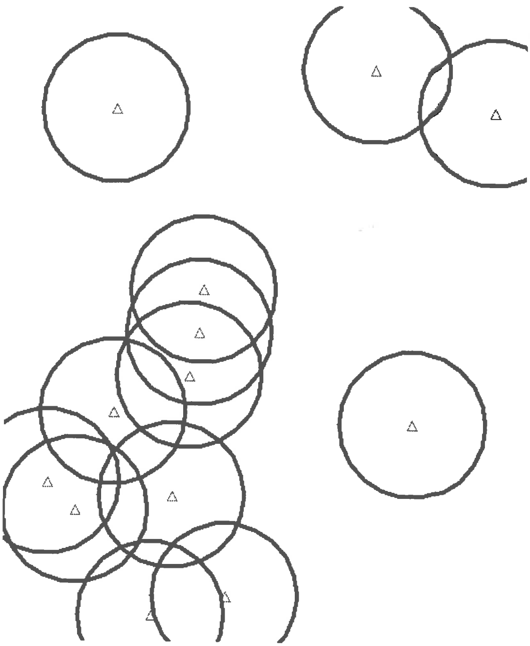

Figure 4.2 Buffers around random points

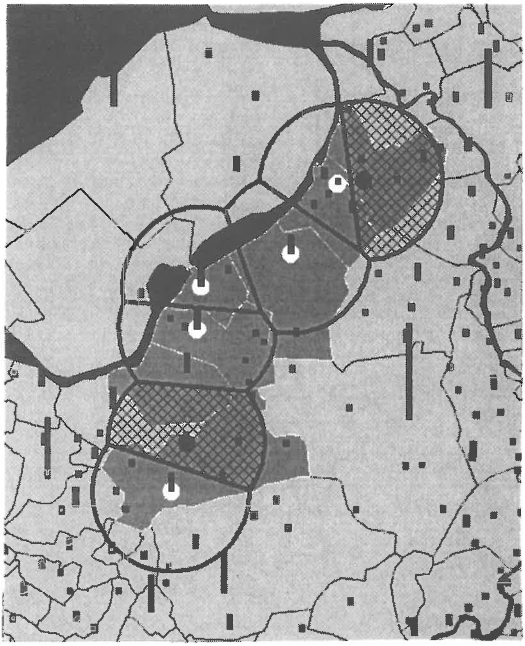

Figure 4.3 Thiessen polygons in combination with buffers

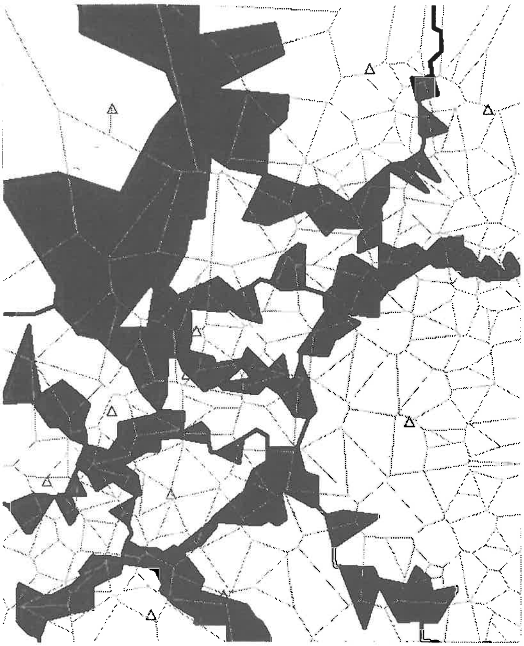

Figure 4.4 Transport network based zones

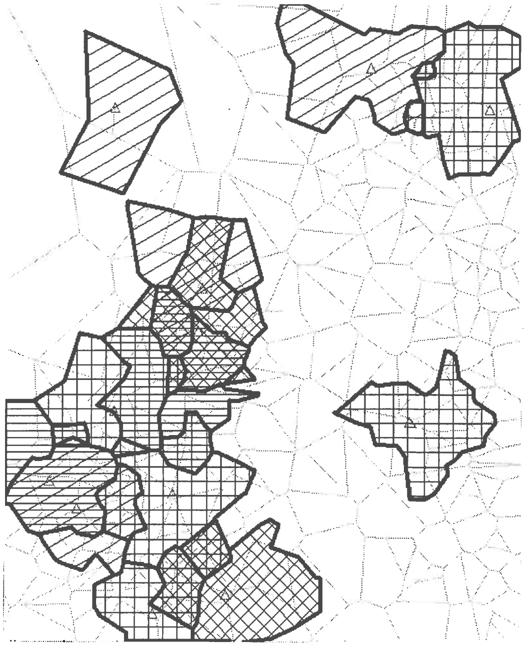

Figure 4.5 Transport network based districts

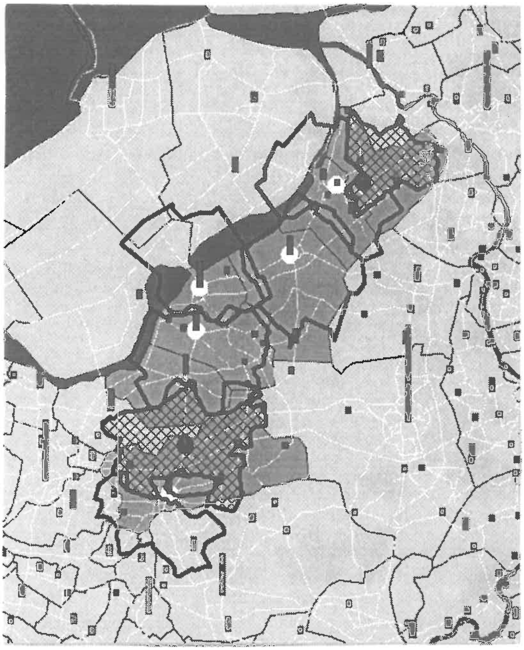

Figure 4.6 Combination of transport network zoning and districting

Instead of the Thiessen method, a network-based districting method can be applied (figure 4.4). And instead of the buffer method, a network-based zoning method (figure 4.5) can be used. To create figures 4.4 and 4.5, a random network (displayed in light grey) was used. In figure 4.4, the white areas could be allocated to one of the original points, whereas the dark grey areas are undecided. In figure 4.5, all network buffers are shaded with different crosshatching to illustrate the amount of overlap. As in the airline distance method, it is also possible to combine the two methods. Moreover, network-based catchment area analysis makes it possible to take the capacity of the provided service into account when determining the size of the sphere of influence. When multiple-mode networks are used (e.g., streets, bus lines, and railways) and multi-mode trips are included, analysis becomes more complicated.

Case study: ambulance stations revisited
The original airline-based buffer method used by the province was criticized for not taking the actual accessibility of settlements into account. This criticism is countered by using methods based on transportation networks. The base map of figure 4.6 is similar to that of one difference is that figure 4.3. Figure 4.6 but also shows the location of settlements and ambulance stations in relation to the transport network. Furthermore, figure 4.6 shows the network districts around the ambulance stations in combination with nine-minute zones around the ambulance stations. As network-based analysis does not generate clear polygons, the boundaries between the districts thus produced had to be accentuated artificially. This was done by inserting G&Ps between districts. Note that the result, in terms of settlements that fall inside the crosshatched zones, differs from the airline-based approach.

4.6 Spatial relationships based on functional distance

So far, this review has looked at GIS tools dealing with distances based on both airline routes and transportation networks. There is also a third kind of 'distance', namely functional distance. Only a limited number of GIS packages provide tools for measuring functional distance. Interaction among people or goods between different locations in space may be taken as a measure of functional distance. The more interaction, the shorter the 'distance'. The traditional way of representing interaction in maps is by the drawing so-called 'desire lines'. Figure 4.7 shows the desire lines representing the daily flows of commuters. The direction of flows can be indicated by placing arrows or wedge-shaped desire lines. Line thickness can also be used to indicate the intensity of interaction.
Clustering spatial objects that are close in terms of functional distance leads to the creation of functional regions. There are several methods for arriving at functional regions. Slater (1976) developed a grouping procedure but the Intramax procedure developed by Masser and Brown is probably better known. 'The objective of the Intramax procedure is to maximise the proportion of the within group interaction at each stage of the grouping process while taking account of the variations in the row and column totals of the matrix' (Masser and Brown 1975). This implies that the two areas are grouped together, for which the following objective function is maximized:

$$T_{ij}/(O_i*D_j) + T_{ji}/(D_j*O_i)$$

where: T_{ij} = interaction between origin location i and destination location j;

$$O_i = \Sigma_j T_{ij}$$

and $D_j = \Sigma_i T_{ij}$.

The objective function can only be calculated for all $D_j > 0$ and for all $O_i > 0$.

Figure 4.7 Desire line representation of selected commuting

The Intramax procedure is a stepwise analysis. In each step, two areas are grouped together. The interaction between the two areas becomes the internal (or intrazonal) interaction for the resulting area. This new area then takes the place of the two parent areas in the next step of the analysis. So with N areas, after N-1 steps, all areas are grouped together into one area and all interaction is intrazonal. One of the outcomes of an Intramax procedure is a functional spatial division. That functional division can be used for further multi-level analysis.

4.7 Generation of contextual information

As Jones and Moon (1993) point out, places or regions should not (only) be viewed as 'spatial containers'. Their specificity should be taken into account as well. A consequence of this approach is that, with reference to regional aggregates, not only composition attributes but also ecological attributes should be considered. Compositional attributes are the characteristics of a region that can be derived from the (attributes of) units of which it is composed. Ecological attributes are of a 'contextual' nature and relate to the position and function of a spatial object in a larger system. An integrated analysis of individual, compositional, and contextual information is an important aspect of multi-level research. The GIS methods described so far will produce a set of compositional attributes for the newly created higher-level objects. However, a GIS is perfectly capable of adding attributes related to 'background' and 'context' to this set. The most obvious approach would be to extract relevant data from other data sources and spatially integrate them with the existing data set. In this way, environmental data could, for instance, be combined with socio-economic data for further processing. Another possibility is to perform a 'neighbourhood' analysis in GIS. That would generate attributes for a spatial unit, of which the values are based on values for corresponding attributes of adjacent objects or objects at some specified 'distance'. In this way, characteristics of the geographical context can be incorporated into multi-level analysis.

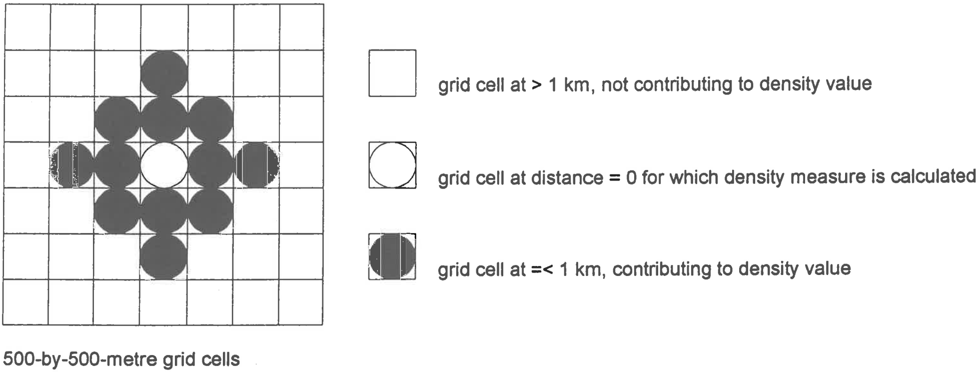

Figure 4.8 Calculation of 'neighbourhood address density'

Example of 'neighbourhood density' calculations
The Netherlands Central Bureau of Statistics (CBS) has produced a new indicator of urban density (Den Dulk, Van de Stadt and Vliegen 1992; Ottens 1994). It is based on the density of addresses of private individuals, businesses, and institutions. For each 500-by-500-metre grid cell, the number of addresses is calculated from the Geographical Base Register (GBR). The GBR contains a grid reference for each address in the country. The register is maintained by the PTT Post, CBS, and the National Physical Planning Service. Although the address density for each grid cell can be easily calculated, this measure is not used as the indicator of urban density. Instead, a neighbourhood analysis is performed to generate a density measure which takes the density in the immediate vicinity of the grid cell into consideration as well. This contextual measure seems to better represent the way density is perceived in reality. All grid cells with a centre point within one kilometre of the centre point of the grid cell for which the density is calculated contribute equally to the value of the 'neighbourhood density' measure. With 500-by-500- metre cells, there are 13 contributing values of cell density (figure 4.8). In this way, a 'context' variable could be created by locational data processing.

4.8 Discussion

A geographical information system can be a useful tool in multi-level research, although its role will be limited. The main advantage of a GIS is its ability to work with data layers that are specified at different levels of spatial aggregation or geographical scale. Both within and between the data layers, spatial relationships are or can be established. These relationships can be used to generate higher-level objects, to establish locational linkages between the higher- and lower-level objects, and to generate locational aggregated and contextual variables. The linkages can be recorded in data tables. The GIS operations will create a multi-level 'spatially intelligent' database to be used in further micro-macro research. Moreover, the GIS makes it relatively easy to produce various cartographical visualizations of this database.
This means that the role of GIS will primarily be one of 'data preprocessor' and of 'data viewer'. The multi-level analysis will have to be done with statistical (modelling) software. Generally, it will be possible for both types of software to share the databases.

burden. Others questioned the capacity of home help services. The provision of adequate home help is the responsibility of the Department of Public Health. Their objective is to support households in need by providing care and domestic aid. At present, home help organizations are already confronted with long waiting lists.

This bottleneck in providing home help is caused by a restricted budget, the difficulty of providing care in urban areas, a high rate of absenteeism among home helpers, and a shortage of personnel. By the end of 1992, people had to wait for 12 days on average until the needs assessment visit could take place. More seriously, they had to wait again before they actually received home help. The waiting time for clients after needs assessment was on average six weeks. The waiting time differs greatly between the regional working areas of home help (Groenewegen *et al.*, 1993).

The question is which behavioural responses of older people in need are triggered by this shortage in home help provision. First, the home help organization applied a stricter assessment of needs (Groenewegen *et al.*, 1993). As a result, at the individual level, getting access will probably be more difficult for those with minor impairments. Also, a substitution of formal help by other resources is supposed to take place. A shift to informal care, self-paid help and adapted housing may be expected (Huijsman *et al.*, 1994). A 'last resort' behavioural response which could occur as a reaction to stricter rules for access to home help is a reduction or termination of utilization (De Bakker *et al.*, 1994).

A further retrenchment in home help would intensify these behavioural responses. The question is, which behavioural responses to a further restriction of access will predominate among which elderly persons. One way of predicting these responses is to study the effects of differential access to home help services in areas that differ in the level of provision as indicated by the length of the waiting list. The research question is therefore *what behavioural responses of older people living in the community are triggered by regionally restricted access to public home help given its institutional rules on needs assessment and co-payment*? These behavioural responses include access opportunities for the most impaired elderly only, substitution of home help by other resources, and under-consumption, among others.

In Section 2, the relation between need, resources and provision of home help is elaborated. Then, in Section 3, hypotheses are formulated. These hypotheses will be tested in a secondary analysis of a large representative sample of people aged 55 and over who were questioned about their care, housing and health situation. This data set and the variables used are described in Section 4. In Section 5 and 6, the results of the analyses are presented. Section 7 draws some conclusions answering the central research question.

5.2 Opportunities, resources and responses

The research question as described in Section 1 can be viewed as a two-level problem. It refers to the micro level of individual responses of older people as well as to the macro level of the characteristics of the structure of home help provision. In analysing the relations between micro and macro levels (Coleman 1990; and Groenewegen, Chapter 2 in this book), our point of departure is the relation of two phenomena at the macro, societal level. These phenomena are schematically shown in the upper half of figure 5.1. It depicts the interaction between the phenomena, whereby regional differences in supply, eligibility criteria, and co-payment charges result in an unequal distribution of

supply in relation to the needs of residents in those areas.
The second step is to analyse this macro level phenomenon with the help of processes at the micro level (left part of figure 5.1). At the micro level, older people have different options when confronted with increasing impairments. These options consist of 1) use of one's own social, economic and housing resources, and 2) access to public home help services. When people receive the necessary help in one way or another, one could speak of a 'match' between need and resources at the micro level; when this is not the case, a 'mismatch' is present.

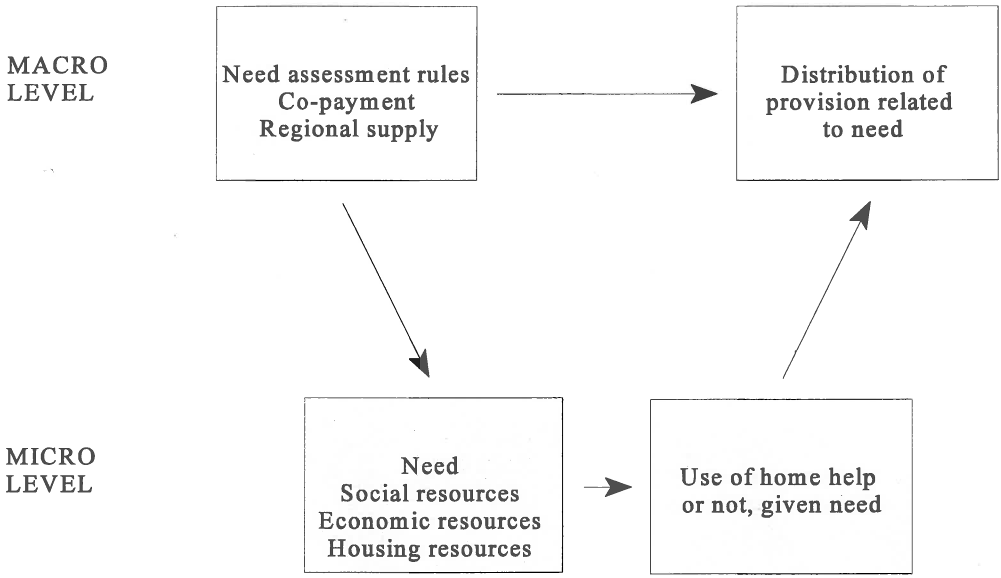

Figure 5.1 Relation between need and home help provision

The final step in the analysis focuses on the way the behaviour of older people at the micro level relates to the distribution of care provision in accordance with need at the macro level (right part of figure 5.1). This step reveals how differences in resources and opportunities, given a specific need situation, at the micro level lead to differences in utilization of home help at the macro level. In this article we are primarily interested in the analysis of the influence of macro level supply characteristics on micro level opportunities and resources. We do not take the step from micro to macro level. An appropriate way to study the micro-macro relation is the use of simulation models (see for example Filius 1993).
Before formulating hypotheses on the use of home help by older people in different situations and/or living in different areas, we have to describe in more depth *how* older people with a given need are influenced by *which* supply characteristics. We first describe the relevant aspects of provision (needs assessment, charges involved and regional variation). This is followed by a description of (mis)matches between need and provision at the individual level and a theoretical explanation of the presence of these (mis) matches. That description is elaborated into different behavioural responses of older people in the next section.

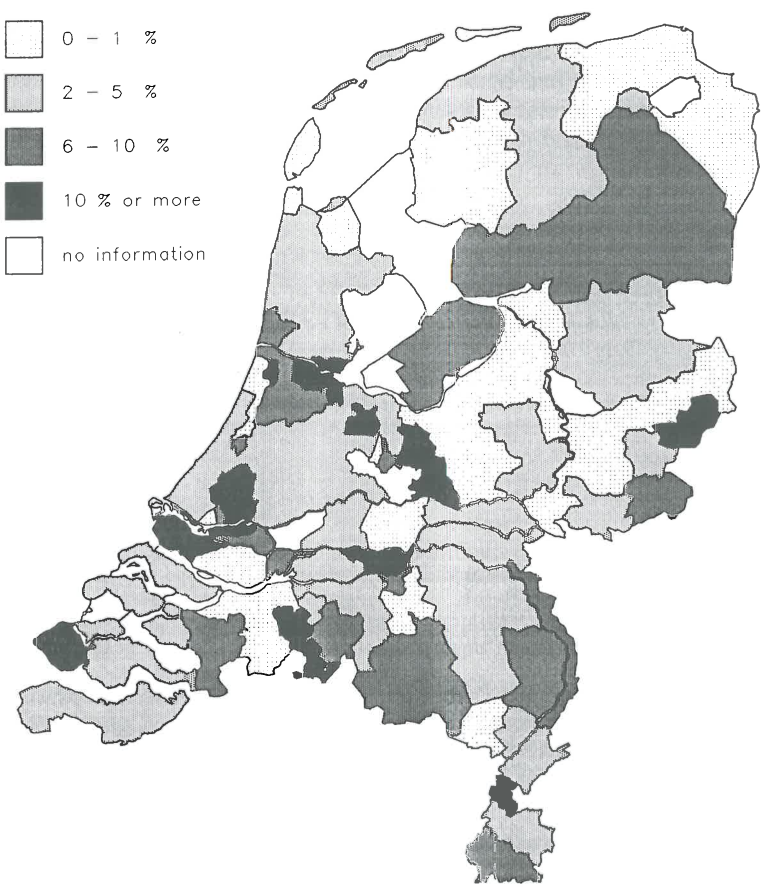

Figure 5.2 Spatial distribution of the length of waiting lists of households eligible for home help (as a percentage of the number of households who receive care), December 1992

The eligibility criteria for home help form an important filter in gaining access to services. At the time our data were collected, the home help organizations used a standardized assessment form, the LIER system (*Landelijke Indicatie en Registratie Systeem* or National Intake and Documentary System). With the help of this system an inventory of the problems of the potential client is made (Kerkstra 1996). This form makes it possible to assess in an objective way the amount and quality of home help that is needed. Currently, following mergers of home help organizations and community nursing organizations, new assessment forms are being developed. These new forms will be suitable for assessing needs for both home help and home nursing (De Bruin *et al.*, 1996).

Home help is supplied at regular working hours on weekdays, up to 40 hours per week. This maximum is only reached in acute need situations. In that case, home help is also

provided during the night and in the weekend. For the terminally ill, it is possible to receive home help more frequently during a three-month period. Reassessment is carried out at least twice a year.
The idea behind co-payment in the publicly financed health sector is to discourage unnecessary utilization of care, to create more freedom of choice, and to appeal to people's own responsibility in order to contain health care expenditure (VVW 1992). Users of home help contribute an income-dependent co-payment according to a uniform nationwide system. The co-payment per hour in 1992 was Dfl. 8.25. The maximum amount of money one has to pay per week is dependent on the net household income of the client. It also depends on whether or not the client belongs to a household with children or lives alone (De Bakker *et al.*, 1994). The co-payment for a two-person household without children is Dfl. 3 per week for those with a net monthly income under Dfl. 1,775. The co-payment increases to Dfl. 225 per week for those receiving a net monthly income above Dfl. 4,600.
Home help is organized regionally. Together, the home help organizations cover the whole country. Regional variation in the supply of home help is large. Figure 5.2 shows the distribution of the waiting time as an indicator of 'shortage' in home help in 1992 over the country. Waiting time is measured for each home help organization as the number of eligible households on the waiting list for every hundred households that receive home help. The map shows large differences in provision. In the northern and eastern part of the country, there are areas where waiting lists are absent. In the urban areas in the centre of the country (*Randstad*), there are areas with long waiting lists.
The structure of provision as described above and the availability of private resources as an alternative for home help are supposed to influence the extent to which a match between need for and provision of home help is present. Table 5.1 shows that the link between need measured by 'objective' indicators and the use of home help is direct but far from perfect. The percentage of users of home help among those with no handicaps is close to zero (0.6%). Among those with minor handicaps, the percentage is very small (1.9%). However, among those with a multitude of functional impairments, the use of home help is limited. Even among those who have difficulty with their personal care, who are impaired in their mobility, and who have problems in performing domestic work, only 35% use home help. People obviously use other resources to obtain informal or paid care or else they refrain from using home help, even if they need it.

Table 5.1 Match between need and home help provision at the micro level

Disability status of the most disabled	% Non-use of home help	% Use of home help	Prevalence of impairments
No handicaps	99.4	0.6	35
1-2 problems with keeping house	98.1	1.9	15.9
>=3 problems with keeping house	86.2	13.8	7.2
Personal care (+housekeeping) problems	94	6	3.5
Mobility problems	98.8	1.2	3.4
Mobility + 1-2 housekeeping problems	94.8	5.2	4.3
Mobility + >=3 housekeeping problems	75.4	24.6	6.8
Personal care + mobility problems	95.5	4.5	3.6
Personal care + mobility + 1-2 housekeeping problems	93.6	6.4	4.7
Personal care + mobility + >=3 housekeeping problems	64.7	35.3	15.7
N (weighted numbers households)	1884813	201912	2086725

It is supposed that older people respond in different ways to a certain disability status, depending on the options they have. Underlying these responses is one basic assumption, originating from social production function theory (Lindenberg 1991). This theory states that people are goal-oriented. They try to reach or maintain an optimal level of well-being within the confines of the available means. Steverink (1996) has elaborated this idea in an empirical study on frail older people and their attitude towards entering an old-people's home. She specified the starting point and the mechanism by which maintaining well-being is realized.

The starting point is the perspective (or 'frame') for action. A perspective highlights the opportunities that people notice in a given situation. Three perspectives are distinguished by Steverink (1996): the 'growth', 'loss', and 'maintenance' perspective. As long as resources are growing and people improve their conditions, the 'growth' perspective is present. Contrasting with this perspective is the 'loss' perspective, whereby people try to avoid further loss of resources. A medium position is present when people are conservative with regard to their available resources. This is the 'maintenance' perspective.

The underlying mechanism is called substitution of resources. It is assumed that resource substitution is possible, but that resources are not completely convertible. An example of substitution of resources is the replacement of the informal help from e.g. a daughter by the paid help of a domestic servant. Resources can be used directly to relieve certain physical problems, such as help with shopping by informal others or professionals. Other resources, such as financial means, can only be used indirectly to relieve physical problems. These resources, if available, can be made active in order to improve the status of another resource, e.g. hired domestic help.

5.3 Hypotheses

Our point of departure is that older people respond differently to rationing of supply of home help in order to maintain a certain level of well-being (maintenance perspective). A consequence of rationing is that it becomes more difficult to gain access to publicly financed care; eligibility criteria will be more stringent.

If access is restricted, a search for alternatives which can serve as substitutes for publicly financed help will be triggered. These are the following:

- Substitution by the private sector (domestic servant) takes place, if income permits. The difference between paying a co-payment to get professional home help and paying for private domestic help is negligible for the well-off; higher-income groups are therefore supposed to hire private help.
- Substitution by help from family, friends or neighbours, takes place. Informal care takers are called in, if available, instead of presenting the need to publicly financed helpers.
- The need for care is decreased by changing the housing situation. This may mean adapting the dwelling or moving into a suitable dwelling.

When older people run out of possibilities to substitute within their private living arrangements and access to publicly financed help is blocked, they are forced to exchange their 'maintenance' perspective for a 'loss' perspective, resulting in a 'last resort' response. This is the following:

- Reducing or terminating the use of publicly financed home help.

In areas with limited regional supply, rationing will be stronger and these four responses will be more pronounced.
In this section, more specific hypotheses with respect to regional shortages are elaborated. First, the hypotheses on the relation between macro opportunities (need assessment and co-payment rules in relation to economic resources and the use of private help) and the use of home help are formulated (Hypotheses 1 and 2). Second, the influence of micro level resources (informal and housing resources) on the use of home help are described (Hypotheses 3 and 4). In the last hypothesis, the interaction of macro level opportunities and the use of micro level resources is made explicit (Hypothesis 5).

Macro-level opportunities

Meeting the eligibility criteria hypothesis (1)
In the Dutch LIER system of needs assessment, three types of problems are taken into account:
- problems related to keeping house: preparing meals, washing clothes, shopping;
- problems related to personal care: washing, dressing, taking medicines; and
- problems related to supervising the household: running the household, organizing the household finances.

Urgency of needs, and especially difficulty performing tasks in personal care, are very important in the needs assessment (Huijsman 1990). If specific tasks can be performed by the partner or other members of the household, potential clients are not assigned home help (Kerkstra 1996). A stringent application of these impairment and household criteria is one of the most frequently used measures to restrict the entry of new clients and to reduce the number of hours of help for those who are 'in care' already (Groenewegen *et al.*, 1993).
However, it is important to extend the eligibility criteria with proxy measurements of other impairments for two reasons. First of all, the aforementioned Welschen Committee bases its conclusion exclusively on problems related to housekeeping and personal care (ADL and IADL). Additionally, there are problems related to supervising the household that probably increase with age, as memory and cognitive organization gradually decrease. Secondly, ADL and IADL measurements are imperfect and thus do not measure all relevant differences in need. Age and gender could cover these unmeasured differences to some extent. We expect, therefore, that *older people who meet functional impairment criteria for home help supplemented with by for other unmeasured impairments (which together represent the formal need assessment criteria for home help) are more likely to receive home help.*

Co-payment hypothesis (2)
Older people with a higher income from an old-age pension, private pension scheme, or private assets more often substitute home help by other resources such as private help in the household (Huijsman *et al.*, 1994). The difference between paying a co-payment to get professional home help from a home help organization and paying for private domestic help may be so small that other advantages of hiring private help may prevail. For instance, these private servants are not restricted to specific tasks related to their function. One could argue therefore that *older people with more financial means are less likely to use home help; they substitute these resources by privately paid help.*

Micro-level resources

Substitution by informal care hypothesis (3)
For frail people, professional home care and informal resources (including privately paid help with household tasks) are substitutes (Timmermans and Schoemakers-Salkinoja 1996). This means that the use of these two resources for household help at the same time will be rare. When people need help with personal care, home help and informal care occur together more often. Home help then serves as a complement to help with the housekeeping.
This decision-making process regarding complementary resources and substitution of resources is in line with the preferences expressed by older people themselves (Groeneboom and Wielink 1995). Only in case of the need for help in performing household tasks during a short period of time do older people want help from their children. When it comes to (long-term) personal care, they prefer help from professionals. We expect, therefore, that *older people who use informal care resources for performing household tasks are less likely to use home help*. Complementary effects of help with personal care cannot be tested.

Substitution in the field of housing hypothesis (4)
One of the assumptions of Dutch policy on home care is that adaptations within the home can prevent or postpone the move to a home for the elderly (WVC 1991). This assumption is based on the idea that living in a suitable residence can relieve some of the problems encountered by older people. There is some empirical evidence to support this statement. For example, De Klerk and Huijsman (1993) claim that the use of technical aids for bathing and in the kitchen is essential in keeping older people from moving into a home for the elderly. In their study population, these researchers found that one-third of the group of older people eligible to enter a home for the elderly are able to remain independent for a longer period of time with the help of such aids. They conclude that home care technology can reduce annual admissions into homes for the elderly by anywhere between two and 15 per cent. We therefore expect that *older people living in suitable dwellings are less likely to use home help*.

Macro opportunities and micro resources

The behavioural responses formulated in Hypotheses 1, 2, 3 and 4 are supposed to occur more often in limited supply areas. Moreover, in line with the fourth response of older people -- the reduction or termination of home help utilization as a last-resort reaction to restricted access -- we suppose that the use of home help is lower in areas with long waiting lists. Integrating these responses, we expect therefore that for *older people living in areas with long waiting lists, need assessment is much stricter, substitution by people's own resources (by privately paid domestic help via income resources, informal care and suitable housing), and reduction of utilization occur more frequently, compared to older people living in areas where supply is less restricted (Hypothesis 5).*

5.4 Design, method and operationalisation

The hypotheses formulated in Section 3 are tested in two ways. First, multivariate analyses are performed to test the hypotheses that do not take the effect of regional

restrictions in supply into account (Hypotheses 1, 2, 3 and 4). In a second multivariate analysis, this regional effect on utilization is tested (Hypothesis 5). The reason to take a two-step approach is that supply characteristics, in contrast to older people's resources, are positioned at a higher level. That level is the place where people live.
As our dependent variable is dichotomous, we use logistic regression models. These models describe the odds of being a client of the home help organization rather than being a non-client, given the influence of other independent factors. This influence is expressed by the ß, the parameter estimate, which shows the extent and direction of the relation between the selected independent variables and the use of home help. All independent variables are categorical, and the constant (intercept) of the model indicates the use of home help by the reference group.

Table 5.2 Concepts, operationalization, descriptives (%), number of categories (NC), number of hypothesis and expected sign of parameters for each analysis

Concepts	Operationalization	Hypothesis No.	Descriptives	NC	Use of home help	Regional supply *(very restricted)*
Macro opportunities						
Meeting eligibility criteria	Disability status of the most disabled in the household *(ADL, MOB and IADL problems)*	1	16	10	positive	stronger positive
	Partner status *(no partner)*		46	3	positive	stronger positive
	Age of the most disabled in the household *(75 or older)*		26	3	positive	stronger positive
	Gender of the most disabled in the household *(man)*		61	2	positive	stronger positive
Co-payment	Net household income *(Dfl. 34, 201 or more)*	2	27	3	negative	stronger negative
	Owner-occupation status *(owner)*		43	2	negative	stronger negative
	Use of package of care in the household *(domestic servant only)*		11	4	negative	stronger negative
Micro resources						
Informal care resources	Use of package of care in the household *(informal care only)*	3	20	4	negative	stronger negative
Housing resources	Suitability of the dwelling *(yes)*	4	33	2	negative	stronger negative
	Technical aids *(four or more)*		30	2	negative	stronger negative
	Daily services in the neighbourhood *(four or more)*		82	2	negative	stronger negative
	Urbanization *(not urbanized)*		19	5	negative	stronger negative
Relation between macro opportunities and micro resources		5	-	-	-	lower intercept

Two data sets are used. These are linked at the municipality level. The first set of data is derived from the Living Situation Survey conducted by the Central Bureau of Statistics from 1990 to 1993. The second set is the 1992 Waiting List in Home Care Project, which was conducted by the Netherlands Institute of Primary Health Care. The resulting data set provides information on the use of home help as well as on functional impairments the availability of resources of care for nearly 8000 older peoples who were living independently at the time of study. That information is supplemented by home help supply characteristics in the area where these respondents were living.

Table 5.2 presents the hypotheses, with their concepts, operationalizations, descriptives, and number of categories. In the column 'Use of home help', the expected directions of the parameters are given for the analysis of the whole data set. In the last column, 'Regional supply (very restricted)', the expected directions of the parameters are given for separate analysis of the data in four areas with divergent supply situations.

The operationalisation of meeting the requirements of the need assessment requires further explication. We have selected the disability status of the most impaired member of the household and the disability status of the partner as operationalisation of the extent to which older households meet formal access criteria for home help.

The impairment status of the most impaired member of the household is measured with the help of the items available in the data set: personal care, mobility, and household management. Personal care activities (ADL) refer to the ability to eat, go to the toilet, to dress and bathe. Mobility refers to the capacity to walk up and downstairs, enter the house, move in the house on the same floor, move outside the home (MOB). Household management abilities (IADL) consist of preparing one's own meals, keeping house and shopping. For those living together with someone it is established whether or not that other person has difficulty with personal care activities (ADL). This aspect is included in the variable 'disability status of the partner'.

A final remark on packages of care should be made at this point. Different packages are distinguished in order to test Hypotheses 2 and 3 on informal care and co-payment:

- the older household receives no help from others;
- the older household receives informal help from others only (family, friends or neighbours);
- the older household receives help from private domestic servants only;
- the older household receives help from informal caretakers as well as from domestic helpers.

5.5 Differentiation in the use of home help

Table 5.3 shows the results of five logistic regression models, based on information on the whole data set of older people (N=7,613). The results are presented in a stepwise design.

Model 1 shows the influence of meeting assessment criteria only (Hypothesis 1). In Model 2, Model 1 is supplemented by indicators for co-payment (Hypothesis 2). The additional effect of co-payment rules, apart from being eligible or not, can be estimated here. In the third model, the other need indicators, namely age and gender, are included in order to 'picture' need more completely (Hypothesis 1). In this way, the first hypothesis is tested in two steps. There are two reasons for a stepwise procedure: estimating the effect of the macro opportunities (that is meeting eligibility criteria and co-payment rules first) should be followed by estimating the effect of other indicators of need and resources; and estimating the effect of the baseline disability measure should occur separately from estimating the effect of the other need measures.

Table 5.3 Logistic regression of the use of home help by older people

N=7613 Parameter	Model 1 ß	 s.e.	Model 2 ß	 s.e.	Model 3 ß	 s.e.	Model 4 ß	 s.e.	Model 5 ß	 s.e.
Needs assessment criteria										
Disability status of the most disabled		*0.35*		*0.33*		*0.29*		*0.29*		*0.27*
no handicaps	-2.03	0.23*	-1.87	0.23*	-1.67	0.23*	-1.75	0.23*	-1.71	0.23*
1-2 housekeeping problems	-1.26	0.20*	-1.25	0.20*	-1.19	0.20*	-1.28	0.20*	-1.24	0.21*
>=3 housekeeping problems	0.62	0.14*	0.61	0.14*	0.53	0.15*	0.58	0.15*	0.63	0.15*
personal care (+hh)	0.12	0.25	0.12	0.25	0.17	0.25	0.19	0.25	0.19	0.25
mobility problems	-1.06	0.46*	-1.04	0.46*	0.99	0.46*	-1.04	0.46*	-1.04	0.46*
mobility + 1-2 hh	-0.15	0.23	-0.21	0.23	-0.24	0.23	-0.27	0.24	-0.27	0.24
mobility + >=3 hh	1.49	0.12*	1.44	0.12*	1.3	0.13*	1.37	0.13*	1.35	0.13*
personal care + mobility	0	0.28	0.04	0.28	0.13	0.28	0.12	0.28	0.11	0.28
persc+mob+1-2 hk	0.25	0.21	0.2	0.21	0.16	0.21	0.17	0.21	0.14	0.21
persc+mob+>=3 hk	2.02	0.09*	1.94	0.10*	1.8	0.10*	1.9	0.11	1.82	0.11*
Partner status		*0.12*		*0.07*		*0.05*		*0.08*		*0.08*
no partner	0.52	0.07*	0.3	0.07*	0.24	0.08*	0.42	0.08*	0.41	0.08*
disabled partner	-0.04	0.09	0.04	0.09	0.04	0.10	0.07	0.10	-0.06	0.1
partner not disabled	-0.48	0.09*	-0.35	0.09*	-0.28	0.09*	-0.35	0.09	-0.36	0.09*
Co-payment										
Household income				*0.09*		*0.08*		*0.03*		*0.04*
f 25080			0.53	0.08*	0.51	0.08*	0.27	0.09*	0.3	0.09*
f 25081-*f* 34200			-0.11	0.09	-0.11	0.10	-0.05	0.10	-0.06	0.10
f 34201 or more			-0.42	0.12*	-0.39	0.12*	-0.22	0.12	-0.23	0.12*
Owner-occupation status				*0.03*		*-0.03*		*0*		*0*
owner			-0.14	0.05*	-0.14	0.05*	-0.07	0.05	-0.04	0.06
renter			0.14	0.05*	0.14	0.05*	0.07	0.05	0.04	0.06
Proxies for unmeasured impairments										
Age of the most disabled in the household						*0.09*		*0.12*		*0.11*
-64 years					-0.4	0.09*	-0.51	0.09*	-0.47	0.09*
65-74 years					-0.06	0.07	-0.07	0.07	-0.07	0.07
75+					0.46	0.07*	0.58	0.07*	0.54	0.07*
Gender the most disabled in the household						*0*		*0*		*0*
man					0.03	0.05	0	0.05	0.02	0.05
woman					-0.03	0.05	0	0.05	-0.02	0.05
Informal care resources										
Use of care package								*0.19*		*0.19*
to help							0.84	0.09*	0.91	0.09*
informal help							1.05	0.09*	1.09	0.09*
domestic help							-1.02	0.16*	-1.06	0.16*
informal and domestic help							-0.87	0.14*	-0.93	0.14*

(Continued)

N=7613	Model 1		Model 2		Model 3		Model 4		Model 5	
Parameter	ß	s.e.	ß	s.e.	ß	s.e.	ß	s.e.	ß	s.e.
Housing resources										
Stability of the dwelling										*0*
no									-0.06	0.05
yes									0.29	0.05*
Technical aids in the dwelling										*0.08*
0,1,2 or 3 technical aids									-0.29	0.05*
four or more technical aids									0.29	0.05*
Daily services in the neighbourhood										*0*
1-2 nearby									0.04	0.05
3 or more nearby									-0.04	0.06
Urbanization rate										*0*
very strongly urbanized									0.07	0.09
strongly urbanized									0	0.09
moderately urbanized									-0.05	0.09
little urbanized									0.14	0.09
not urbanized									-0.17	0.09
Constant	-2.9		-3.1		-3.1		-3.7		-3.7	
-2 LL	3539		3479		3430		3194		3147	
Model of Chi-square	11		14		17		20		27	
R is printed in Italics										

In the fourth model, the influence of the use of various care resources is the central issue (Hypothesis 3). The effects of indicators related to need assessment criteria and co-payment rules are controlled for in this analysis. The last model includes all independent variables influencing the use of home help: fulfilling the eligibility criteria, co-payment rules, and care and housing resources of people aged 55 and over (Hypothesis 4). The extra contribution of 'housing', can be derived in this analysis when other variables are held constant.
The odds of the reference group in the last model may be expressed as exp(-3.65) or 0.026. This means there are only 2.6 clients for each 100 non-users of home help.

Meeting the eligibility criteria hypothesis
Being eligible for home help has a significant positive impact on the use of home help, as expected. Fulfilling the criteria of the LIER system -- for instance, having trouble running the household (also in combination with mobility or personal care problems) -- increases the chance of access to home help services. For this group of older households, the 'odds' of being a user are estimated to be exp(1.82) or 6.17 times higher than the average for all categories of this variable. Impairment status of the household is by far the strongest predictor of the use of home help (R=0.27, 0.29, 0.33 and 0.35).
The 'partner status' is an important determinant of access, too. Living alone does have a positive relation to home help utilization; living together with a healthy partner decreases the chances of utilization.
Age and gender are viewed as proxies for other need characteristics that are not part of the baseline disability measures included in Model 1. According to the stable parameter estimates of 'disability status of the most disabled in the household' (compare Model 4

and 5), 'age' is indeed necessary to measure demand for help more completely. For the oldest age group, the odds are estimated at exp(0.46) or 1.58 times the average for all ages. The age effect might also express a preference on the part of home help organizations to help the eldest people living in their territory. The effect of gender is not significant.

Co-payment hypothesis
The more wealthy households are less often home help users compared to people with less economic resources. When the use of care packages is included in the model (compare 'household income' and 'care-package' estimates in Model 3 and 4), it is apparent that the influence of income rapidly decreases. This provides a clear indicator of the substitution of resources by using privately financed domestic help. However, the parameters of the income variable remain significant, indicating that co-payment also triggers an overall reduction in the use of public and private services.

Substitution by informal care hypothesis
The variable 'care package' is the second strongest predictor of home help utilization among older people (see Model 4 and 5: R=0.19). The parameter estimate on 'use of informal care only' is 1.05; this means that the odds for this group are estimated at exp(1.05) or 2.86 times the average for all care packages. Based on this outcome, it can be stated that publicly financed help is supplementary to household help from informal caretakers. The relation between use of home help and the use of privately paid helping resources is negative. As expected, substitution by the private household help sector takes place. As stated before, this is only true for the higher income categories.

Substitution in the field of housing hypothesis
Different operationalisations of 'suitability of the housing situation' do not point in the same negative direction. The influence of the suitability of the dwelling (no stairs to enter the house and no stairs inside the house), the availability of services (such as a supermarket and medical facilities), and urbanization on the use of home help is not significant.
However, the presence of technical aids in the dwelling does have a significant effect on the use of help. Technical aids do not decrease but increase the chance to receive home help. This kind of home care technology is mobile; in most cases, it is not standard in the dwelling. It is possible that home helpers and local providers of technical aids refer to each other, thereby increasing the chance of having both. An alternative explanation is that unmeasured functional impairments show up here.

5.6 Use of home help under conditions of restricted regional supply

In this section, we test Hypothesis 5 regarding the interaction of macro-level opportunities and the use of micro-level resources.
Table 5.4 shows four different regression models. These are based on subsets of the whole elderly population in the data set. The first model only refers to older people who live in areas where there are no waiting lists for home help or very short ones (0-1%; N=1.415). The second model refers to older people who live in 2-5% waiting list-areas (N=3.179). The third and the fourth model include older people who live in areas with long waiting lists, respectively 6-10% and 10% or more (N=1.670; N=1.349).

Macro opportunities and micro resources hypothesis
The analysis confirms parts of Hypothesis 5. That hypothesis supposes that the impact of meeting need assessment and co-payment rules, using alternative resources, and reducing consumption is higher in areas where waiting lists for home help are longer.

Table 5.4 Logistic regression of the use of home help in different regions

Length of waiting list	0-1%	2-5%	6-10%	10% or more
Needs assessment criteria				
Disability status of the most disabled				
no handicaps	-2.4*	-1.4*	-1.35	-1.54
1-2 household problems	-1.04*	-1.47*	-0.76	-0.52
>=3 household problems	0.79*	0.62*	1.06	1.12
personal care (+hh)	0.58	0.32	0.74	-4.54
mobility problems	-0.46	-1.13	-4.77	-0.36
mobility + 1-2 hh	-0.31	-0.59	0.85	-0.5
mobility +>=3 hh	0.77*	1.53*	1.89*	1.85*
personal care + mobility	-0.15	0.24	-0.12	1.23
personal care+mobility+1-2 hh	0.68	-0.11	0.26	0.78
personal care+mobility+>=3 hh	1.53*	1.98*	2.2	2.47*
Partner status				
no partner	0.76*	0.47*	0.05	0.48*
disabled partner	-0.41	0.03	0.02	-0.06
partner not disabled	-0.35	-0.49*	-0.07	-0.42
Co-payment				
Household income				
- *f* 25080	-0.02	0.32*	0.67*	0.23
f 25081 - *f* 34200	-0.18	0.1	-0.39	0.15
f 34201 and more	0.19	-0.43*	-0.28	-0.38
Owner occupation				
owner	-0.11	-0.09	0.09	0.13
renter	0.11	0.09	-0.09	-0.13
Proxies for unmeasured impairments				
Age of the most disabled in the household				
- 64 years	-0.66*	-0.26	-0.63*	-0.58*
65 - 74 years	0.09	-0.19	-0.02	-0.02
75+	0.57*	0.45*	0.66*	0.6*
Sex of the most disabled in the household				
man	0.23	0.03	-0.04	-0.16
women	-0.23	-0.03	0.04	0.16
Informal care resources				
Use of care package				
no help	0.95*	0.96*	0.97*	0.73*
help from informal others	1.15*	1*	1.11*	1.36*
domestic help	-1.05*	-0.97*	-1.33*	-0.94*
informal and domestic help	-1.06*	-0.99*	-0.74*	-1.15*

(Continued)

Length of waiting list	0-1%	2-5%	6-10%	10% or more
Housing resources				
Suitability of the dwelling				
no	-0.08	0	-0.24*	0.05
yes	0.08	0	0.24*	0.05
Technical aids in the dwelling				
0,1,2 or 3 technical aids	-0.44*	-0.31*	-0.23*	-0.35*
four or more technical aids	0.44*	0.31*	0.23*	0.35*
Daily services in the neighbourhood				
1-2 nearby	0	0.08	-0.04	0.13
3 or more nearby	0	-0.08	0.04	-0.13
Urbanisation rate				
very strong urbanized	-0.43	-0.09	-0.61	0.74*
strong urbanized	-0.06	0.02	0.2	0.27
moderate urbanized	0.21	-0.04	0.14	0
little urbanized	0.48*	0.06	0.4	0.16
not urbanized	-0.2	0.04	-0.13	-1.17
Constant	-3.8	-3.8	-4.3	-4.6
N	1415	3179	1670	1349
-2LL	540	1297	683	542
Model Chi-square	281	743	419	407

According to the constants of the four models (at the bottom of table 4.4), the use of home help is different for each waiting list area. The odds of being a user are estimated at exp(-3.8), exp(-3.8), exp(-4.3) and exp(-4.6) respectively. With increasing waiting time for home help, the number of clients is cut in half. Starting at 2.2 per 100 non-users in the less restricted area, the number of clients drops via 2.2 and 1.3 to 1.1 for every 100 non-users of home help in the areas with the longest waiting time. Hypothesis 5 is thus confirmed. The longer the waiting list in home help in a specific area, the more the utilization of home help is restricted.

Furthermore, the influence of variables related to needs assessment increases with larger shortages. On the one hand, older people with three types of health problems are prioritized to a greater extent by the home help organization in areas where there is short supply areas. Priority is given to those who have problems performing more than three household tasks; those who have both housekeeping and mobility problems; and the most impaired, being those with household, personal care, and mobility problems. On the other hand, for older people with minor housekeeping problems, the utilization probabilities largely depend on where they live. People with these disabilities who are living in areas where there is no wait for home help have much higher access chances than those living in the 10% (or more) area; compare exp(-1.04) or 2.8 and exp(-0.52) or 0.59 with the average impaired household.

No extra priority is given to specific groups in restricted areas, such as lower-income groups, older people living alone, etc. The parameter estimates for these groups do not change in a specific direction with increasing restrictions on home help.

5.7 Conclusions and discussion

This article concerns the joint influence of macro opportunities for publicly financed help (such as regional variation in supply, needs assessment norms, and co-payment rules) and the availability of own resources at the micro level on the differentiation of utilization by older people. Here, three issues are brought to the forefront for closer examination. These are:

1. five important outcomes;
2. micro-macro issues in home help utilization among older people; and
3. the consequences for policy that pursues maximum substitution.

Five important outcomes

The data for the analysis were derived from a random representative sample of nearly 8000 older people in the Netherlands who were living independently. In order to obtain a set this large, data from 1990 up to 1993 had to be pooled. This set was enriched with 1992 figures on length of waiting lists from home help provision. Hence, the interpretation of outcomes of the analysis is restricted to one point in time and to elderly persons living independently.

Meeting the eligibility criteria hypothesis: Access to home help is largely determined by meeting the formal needs assessment criteria of the LIER system. That is, an applicant has to belong to a household with an impaired member and/or be living together with a disabled partner. For example, the use of home help among those experiencing housekeeping mobility, and personal care problems is more than six times the use made by the average impaired household. Furthermore, the variable age showed to be an important extra indicator to assess need for care.

Co-payment hypothesis: Substitution by private help takes place among those who can afford it. The difference between paying a co-payment to get home help and paying for private domestic help in the household narrows the higher the income is. However, the overall use of public and private services decreases among people with a higher income. This indicates that the substitution of resources is not complete. Indeed, there is underconsumption of help by some of the more wealthy elderly, especially with regard to personal care. There are two reasons for this:

1. the private paid helper in the household will generally not offer personal help and not be trained to provide this kind of help; and
2. unlike collectively financed home help, the private market does not have a system of quality control for help.

Substitution by informal care hypothesis: Home help is complementary to the help from informal caretakers. These resources appeared to be used at the same time. Older people who receive informal help from others (apart from their household members) use home help three times as much as older households with an average care package.

Substitution in the field of housing hypothesis: There is no relation between housing and publicly financed help, except for the presence of technical aids. Their presence in the dwelling is positively related to home help utilization. This effect is probably due to referral practices between home helpers and local providers of home care technology. At the same time, it might also reflect unmeasured health problems.

Macro opportunities and micro resources hypothesis: For older people experiencing minor health problems, such as difficulty doing light household tasks only, the use of home help is strongly influenced by where they live. Those living in areas without waiting lists for home help have three times more chance of receiving home help compared to the average impaired household in that area. In the areas with very long waiting lists, this probability decreases to 0.60.
Furthermore, spatial differences in waiting lists for home help appear to be of major importance for the use of home help. In areas without waiting lists, it is estimated that there are 2.2 clients per 100 non-users. In severely restricted areas, this figure is cut in half, being 1.1 clients per 100 non-users.
It was also assumed that the presence of informal caretakers, high-income resources (followed by substitution by the private sector), and living in a suitable dwelling would reduce home help in restricted supply situations. However, this could not be confirmed.

Micro-macro issues

There are two major advantages to incorporating macro opportunities and micro responses in one and the same analysis. It gives an indication of the match between demand and provision, both at the macro and the micro level. At the macro level, we saw that the match between demand of older people and provision is deficient in areas with long waiting lists for home help compared to other areas. Contrary to expectations, older people's own resources appeared not to be used more intensively in restricted areas. It is most likely that they have already used all available resources. A reduction in the use of services is their common response.
At the micro level there are also indications of a potential mismatch between need and provision in the middle and higher income categories. The application of co-payment rules does reduce home help consumption, but the demand for help is only partly compensated in the private market. The lower income categories are protected to a certain extent from under-consumption by a maximum weekly co-payment based on net household income. However, the strategy of reducing or terminating utilization (especially for those with medium and higher income resources) might occur more often when access is more difficult.
A second advantage of combining micro and macro factors is that the consequences of governmental measures written down in policy documents can be foreseen by analysing behavioural reactions to restricted supply situations. Restricted capacity of home help services already provokes behavioural shifts among older people. Apparently, the responses that are envisaged by the Welschen Committee are not evaluated before implementing policy changes. The proposals are based on untested assumptions about over-consumption of institutional services in the past and current inappropriate use of home help and institutional care by elderly persons with minor impairments. Our results indicate that a further restriction of access to home help does not lead to substitution by informal or private care. Instead, it leads to an overall reduction in the utilization of services.

Implications for policy aiming at maximum substitution

The possibilities for a maximum substitution policy as suggested by the Welschen Committee are over-estimated. The main reason lies in the incorrect assumptions about shifts in behaviour among older people. Three points of departure used by the Committee will discussed here.

First, the Welschen Committee assumes that one-third of the clients of publicly financed help can be taken over by informal caretakers. This assumption is untrue. The analysis has clearly shown that publicly financed help is usually only a complement to informal help with household tasks. It is found that substitution by the private market will take place among the well-off. However, the market will only partly fulfil their needs.

Furthermore, the Committee has used indicators of functional impairment to determine the extent to which people meet the eligibility criteria. However, in addition to this, it is important to include age a a proxy for need in estimating who is or is not eligible for home help. It should be taken into account because the current indicators of functional impairments do not completely cover older people's ability to run their household. Especially in older age, people might gradually develop memory problems that hamper their independence.

Third, the group of elderly who do not use home help even though they have of health problems is ignored by the Welschen Committee. On the one hand, only about three per cent of those who do not experience any functional problems at all are clients of home help organizations as we have shown. In the Welschen report, this group is estimated to be much larger, 31 per cent. The literature suggests that 31 per cent might be the upper limit and three per cent the lower limit (Huijsman *et al.*, 1994). The reliability of the percentage of non-impaired users among the elderly should be studied more thoroughly. Differences in the operationalisation of impairment and the level of analysis, individual versus household, might influence the outcomes. On the other hand, the results indicate that only one out three households that have multiple impairments actually use home help. People obviously either use other resources of informal or paid care or else refrain from using home help, even if they need it.

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benefits outweigh the costs, the answer is yes; if not, the answer is no. Two factors may influence the effect of place characteristics on the outcome of this decision: the seriousness of the health problem, and ability to overcome distance.
The more serious the problem, the more treatment is a necessity, the more the individual will be inclined to accept the costs. In the case of less serious problems, the individual has more freedom of choice. Therefore, it is hypothesized that the individual will be more influenced by place characteristics if the need is not so great.
Similarly, we can hypothesize that the effect of place characteristics like availability is smaller for individuals who encounter fewer obstacles in overcoming distance. This clearly applies to higher socio-economic groups. Not only do they have fewer financial barriers for bridging distances, but they have larger daily systems (in which it is more likely that a physiotherapist can be found). It is hypothesized that there are fewer place differences among higher socio-economic groups.
To test these conditional hypotheses, the following research questions are addressed:

- Are place differences larger for the seriously ill than for the not-so-seriously ill?
- Are place differences larger for lower socio-economic groups than for higher socio-economic groups?
- What is the role of availability and urbanicity in the differential effect of place?

6.2 Data and operationalizations

Data were obtained from the Dutch National Survey, conducted by the Netherlands Institute of Primary Health Care (NIVEL) in 1987/88. These data contain utilization figures, health indicators, and background characteristics for 13,000 patients of 100 general practices in the Netherlands, living in 427 different settlements (Foets and Van der Velden 1990).
Indicators of availability were obtained by taking patient places of residence and physiotherapist practice sites and subsequently computing road distances between the two. This was done with the NEARSERV software developed at Utrecht University (Van Dam 1995; Huigen and De Vocht 1993).
The dependent variable is utilization of physiotherapy in the past two months. The predisposing factors (individual level) are age and gender. Need factors are measured with four dichotomous variables. The first indicates whether or not the patient perceived more than two subjective health complaints. The second indicates the presence of one or more chronic conditions. The perception of one's general state of health as 'less than good' is the third indicator. A fourth health indicator was constructed by counting the number of musculoskeletal complaints. That indicator was dichotomized into 1-2 items and ≥ 3 items. The enabling factors consist of insurance coverage (private/public) and education (high/middle/low).
Higher-level independent variables consisted of a dichotomy indicating whether or not the patient lived in one of the three major cities. This operationalization was chosen because it provides the largest contrast in utilization rates (figure 6.1). It is recognized that availability is a more complex concept, in which characteristics of the supply source may also be relevant (quality, size) (Joseph and Phillips 1984). Nevertheless, the distance to the nearest physiotherapist farther than two kilometres away was used as an indicator of availability. In the Dutch context, a distance of more than two kilometres is considered far. The maximum distance shown in the data is 13 kilometres.

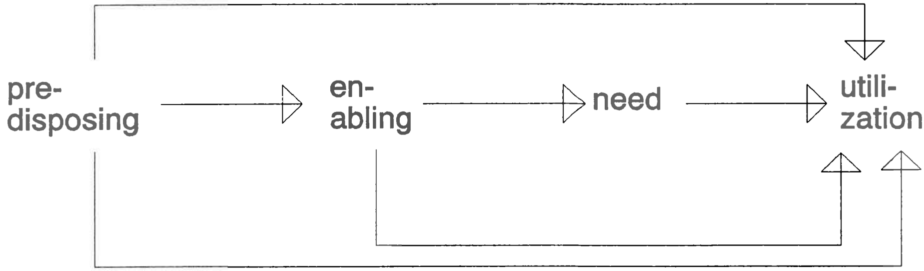

Figure 6.2 Andersen and Newman model

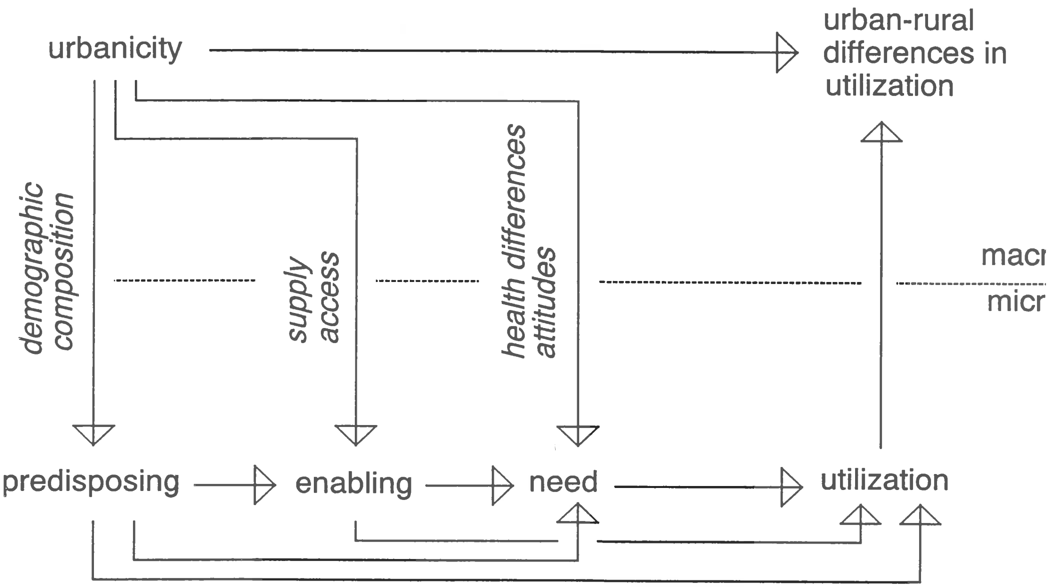

Figure 6.3 Coleman's heuristic and Andersen and Newman model

6.3 Methods

The dependent variable is a dichotomy and the data are nested in two levels. Level 1 represents the individual, whereas level 2 represents the individual's place of residence. These qualities of the data warrant a logistic multi-level design. The analyses were carried out with MLn (see Paterson 1995).
The alternative would be a 'normal' logistic multiple regression. However, to use such an approach, either the data would have to be aggregated to the level of places of residence, or the settlement characteristics (urbanicity, availability) would have to be distributed over individuals. The former would represent a loss of information and the introduction of aggregation bias. The latter would lead to an overestimation of the significance of the estimates at the place of residence level (atomistic fallacy).

Table 6.1 Models 1-5: one random term. Estimates (log-odds) and t-values

	Model 1		Model 2		Model 3		Model 4		Model 5	
Parameter	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
Fixed effects										
Constant	-1.779	50.2	-2578	43.13	-2.523	40.83	-2.597	43.83	-2.546	41.16
Age			-0.005732	3	-0.00571	3	0.005894	3.08	-0.00586	3.07
Health 'less than good'			0.332	4.59	0.323	4.51	0.3305	4.57	0.3249	4.49
Lower education			-0.221	2.35	-0.214	2.27	-0.2202	2.34	-0.213	2.27
Chronic condition			0.305	4.42	0.3015	4.38	0.3068	4.45	0.3035	4.4
Musculoskeletal complaints			1.434	21.7	1.436	21.74	1.434	21.67	1.436	21.71
Distance to therapist >2 km					-0.2851	2.99			-0.2668	2.84
Living in 3 large cities							0.3989	2.69	0.3645	2.49
Random effects										
Level 2 constant	0.066	3.02	0.066	2.88	0.6052	2.74	0.05248	2.48	0.04716	2.36
Level 1 constant	0.975	71.94	0.974	71.9	0.9724	71.82	0.9781	71.81	0.9761	71.98

With the multi-level approach, it is possible to specify and estimate models at different scales simultaneously. Indeed, the purpose of our analysis is to explore the relevance of place characteristics, *controlling for individual-level effects*. The results of this analysis are similar to those of normal logistic regression. The major difference, however, is that the error terms in the models are split between the two levels, indicating the variation at each level, controlling for the variables in the model. Furthermore, a multi-level model enables us to split place-specific variation between groups of individuals, such as those with public and private insurance. This is necessary to test the conditional hypotheses presented above.

6.4 Place differences in general

Are there place variations?
To answer the first question, a model tested in which only the general mean propensity to visit a physiotherapist was included in the fixed part and only constants in the random parts.
The figures under model 1 in table 6.1[2] indicate that there is indeed place-specific variance. The magnitude and relevance of the between-place differences can be judged by calculating the level 2 variance as a percentage of the total variance. This amounts to about six per cent. Also, the estimates can be compared with their standard error. The estimate is more than twice its standard error (t-value >2). It is therefore decided that it is significant and that there are indeed place differences.
Figure 6.5 depicts the between-place variation in model 1. Each line represents one place of residence. Its location on the Y-axis depicts the probability of physiotherapy utilization in that place.

To what extent can place variations be explained by composition effects?
In the second step, individual-level variables are brought into the model to find out whether the observed place-specific variance is simply a matter of composition. The probability of physiotherapy utilization is, for example, influenced by one's age. Therefore, we would want to control for the fact that one place may have a large number of elderly people, whereas another may have a relatively young population.
If no place-specific variance would remain, it makes no sense to investigate the role of either distance or urban/rural place of residence. Place differences are simply a consequence of individual characteristics.
Model 2 shows that between-place variance remains about the same after including age, perceived health, lower education, chronic conditions, and musculoskeletal problems in the model. Gender and type of insurance did not contribute significantly to the model and were therefore excluded from it. Although each variable in the model has a significant effect, place differences cannot be explained by these aspects of the composition of the area populations.
In figure 6.4 (model 2), the lines represent the probability of physiotherapy utilization in each place for respondents of average age, in relatively good health, and with higher education. Comparison of the graphs of model 1 and model 2 shows that, while place variances remained the same, the intercept has decreased.

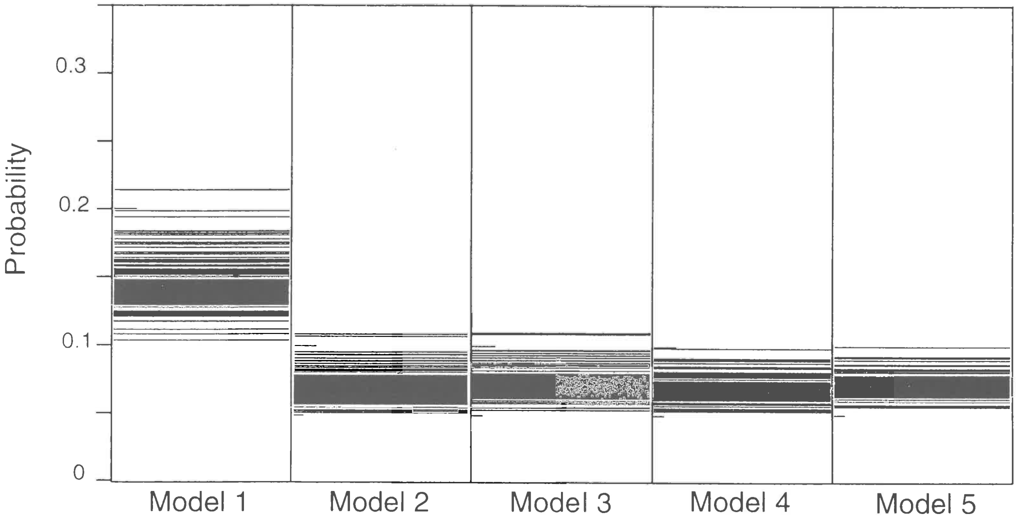

Figure 6.4 Graphical representation of models 1-5. The remaining between-place variation in probability of physiotherapy utilization

To what extent is the remaining place-specific variance a matter of availability, and does the effect of urbanicity persist while controlling for availability?
It is now clear that, controlling for compositional differences, there remains some unexplained between-place variance. Place still matters. The next step is to find out whether this between-place variance is a matter of availability.
Model 3 is extended with the variable indicating availability (physiotherapist available at a distance of more than two kilometres). Place-specific variance is clearly reduced (nine per cent compared with model 2, table 6.1). It can be concluded that the availability of physiotherapy has a positive effect on utilization. In model 4 (table 6.1), availability is exchanged for living in large city. Here too, between-place variance is reduced (by 22 per cent compared with model 2), indicating that place variations are also a matter of urbanicity. This is confirmed in model 5 in which both higher-level variables are taken into account simultaneously, reducing between-place variance by 29 per cent.
The estimates suggest that living in a large city, as well as availability, increase utilization. The conclusion must be that variance between places is a matter of availability as well as urbanicity. But there is a significant amount of between-place variance left unexplained. The remaining between-place variation for the models is graphically represented in figure 6.4.

6.5 Between-place variation and seriousness of problems

In order to test the conditional hypothesis that place matters more in cases where the need is not so great, the 'distance' and 'urban/rural residence' variables were removed from the model. Furthermore, the number of musculoskeletal health problems is made random (i.e., allowed to vary at the higher level).

Table 6.2 Model 6-9: two random terms: 1-2 versus >2 musculoskeletal complaints. Estimates (log-odds) and t-values

	Model 6 (base model)		Model 7 base model + availability		Model 8 base model + urbanicity		Model 9 base model + urbanicity + availability	
Parameter	Estimate	t	Estimate	t	Estimate	t	Estimate	t
Fixed effects								
Constant	-2587	42.16	-2.532	40.68	-2.605	42.66	-2.5533	41.14
Age	-0.005831	3.07	-0.005818	3.06	-0.006015	3.16	-0.005985	3.14
Health 'less than good'	0.3336	4.64	0.3274	4.55	0.332	4.61	0.3262	4.52
Lower education	-0.2321	2.48	-0.2225	2.37	-0.2286	2.44	-0.22	2.34
Chronic condition	0.3066	4.47	0.3033	4.42	0.3089	4.5	0.3055	4.44
Musculoskeletal complaints	1.463	16.33	1.464	19.38	1.458	19.63	1.459	19.67
Distance to therapist >2 km			-0.2921	3.16			-0.274	2.98
Living in 3 large cities					0.4083	2.95	0.3763	2.73
Random effects								
Level 2 0-2 complaints	0.08692	2.19	0.0722	1.96	0.06761	1.85	0.05521	1.62
Level 2 >2 complaints	0.08094	2.22	0.08675	2.32	0.06834	1.98	0.07415	2.11
Level 1 constant	0.9626	71.36	0.962	71.36	0.9678	71.37	0.9677	71.68
RTEST-statistic (1 df)	0.01		0.08		0.00		0.15	

Table 6.3 Models 10-13: two random terms: lower versus non-lower educated. Estimates (log-odds) and t-values

Parameter	Model 10 (base model)		Model 11 base model + availability		Model 12 base model + urbanicity		Model 13 base model + urbanicity + availability	
	Estimate	t	Estimate	t	Estimate	t	Estimate	t
Fixed effects								
Constant	-2.579	43.26	-2.525	41.16	-2.599	43.51	-2.549	41.53
Age	-0.005663	2.98	-0.005617	2.96	-0.005846	3.07	-0.00579	3.05
Health 'less than good'	0.3324	4.62	0.3261	4.53	0.3311	4,59	0.3251	4.51
Lower education	-0.2144	2.01	-0.2099	1.95	-0.2137	2.02	-0.2083	1.95
Chronic condition	0/3042	4.44	0.3013	4.4	0.3068	4.47	0.3038	4.43
Musculoskeletal complaints	1.432	21.8	1.434	24.82	1.432	21.74	1.434	21.78
Distance to therapist >2 km			-0.284	3.03			-0.2666	2.88
Living in 3 large cities					0.4122	2.87	0.3786	2.67
Random effects								
Level 2 lower educated	0.2221	1.81	0.2406	1.92	0.2106	1.74	0.2289	1.85
Level 2 middle and high educated	0.06621	2.65	0.05869	2.49	0.05185	2.29	0.04524	2.11
Level 1 constant	0.9635	71.32	0.9626	71.57	0.9684	71.63	0.9664	71.59
RTEST-statistic (1 df)	1.55		2.04		1.66		2.14	

In other words, the between-place variance, controlling for individual-level characteristics, is split between people with and without more than two musculoskeletal complaints. Thus, it can be seen whether place differences are larger for individuals in relatively poor health than for individuals in relatively good health.
Controlling for other variables in the model (need characteristics and age), between-place variance hardly differs among people with many and with few complaints. It is significant for both groups (model 6, table 6.2). The procedure RTEST in MLn provides the possibility for testing the significance of differences between level-2 variance. The test produces a non-significant Chi^2 statistic (0.01, df=1).
Although there seems to be no differential place effect, it is still possible that availability or urbanicity have differential effects for both groups. Again, availability and urbanicity were introduced into the model separately as well as simultaneously. Adding distance to nearest physiotherapist (model 7, table 6.2) results in an increase in place variance in the group with >2 complaints and a decrease in the group with 1-2 complaints. The RTEST statistic is still not significant (0.08, df=1).
Substituting the distance term for urbanicity (model 8, table 6.2) closes the gap in place variation between the two groups. Not surprisingly, if both terms are included in the fixed part of the model, there is also no significant place variance left (model 9, table 6.2).

6.6 Between-place variation and socio-economic status

In order to test the conditional hypothesis that lower socio-economic groups show larger place differences, a similar procedure was followed. Between-place variance was split between people with lower education and people with intermediate and higher education. Model 10 (table 6.3) shows that there is a difference between the two groups. As was expected, higher socio-economic groups are less prone to place variance. Although it is clear that place differences are highly significant for the higher educated groups and not for the lower educated, the RTEST statistic is not significant. Model 11 (table 6.3) shows the results with inclusion of availability. Place differences are still somewhat larger for the lower educated than for the higher educated. The difference has become smaller and the RTEST statistic is still not significant. The same can be concluded from model 12 (table 6.3), in which availability is substituted for urbanicity (RTEST 1.66, df=1).
In model 13 (table 6.3), both level-2 variables are included in the model, and the difference between the two groups has decreased again. The RTEST statistic is still not significant (2.14, df=1).

6.7 Conclusions and discussion

In this paper, we have tried to ascertain what is behind urban-rural differences in physiotherapy utilization. It was hypothesized that these differences are a consequence of concurrent variations in supply.
It can be concluded that place differences in physiotherapy utilization exist, even if compositional differences in age, need, and education are controlled for. These differences can partly be explained by place variations in availability and partly by urbanicity of the place of residence. This indicates that urban-rural variations are not (solely) a matter of urbanicity of residence, but also of availability of services. However, urbanicity still has

a significant effect, independent of the supply variations and composition of the population. Also, some significant unexplained between-place variation remains.
Conditional hypotheses were formulated with respect to the seriousness of the problem. It was supposed that the more serious a person's health problem, the more compelling the physiotherapeutic treatment, the less effect there is to be expected from environmental characteristics. This hypothesis was rejected. Place differences for people with few physical problems are similar to those for people with many physical problems.
A similar conditional hypothesis was formulated concerning the differential effect of place characteristics according to socio-economic status. However, place differences are somewhat larger for lower socio-economic groups than for higher socio-economic groups. With respect to the latter finding, it should be noted that extending the base model with availability and urbanicity increased the place differences for both groups. Beforehand, and on the basis of the analyses with only one random term, it was expected that these differences would decrease.

Where should we go from here?

We have seen that distance to the nearest service forms only a partial explanation for place differences in utilization. Another part is 'explained' by residence in one of the three major cities. But even if both these area-level variables are included in the model, there is some between-place variance that goes unexplained. Two questions still have to be answered: What causes these remaining place-differences? And what is behind the persisting urban-rural differences?
The answer to the first question probably lies in the health care system, and more specifically, the referral system. The referral system may act as a modifier of distance decay effects (Joseph 1979). This means that we have to carry on to a three-level model, in which the highest level represents the GP, place of residence is located at an intermediate level, and the individual is found at the bottom.
A closer look at the data structure shows that places of residence largely coincide with GP practice areas. There is a large overlap between where one lives and which GP one is registered with. The data structure is not hierarchical. We have to take recourse to so-called cross-classified models (Jones 1993).
The answer to the second question (what is behind the remaining effect of urbanicity?) is probably hidden in some other aspects of urbanicity. Perhaps cultural differences play a role, such as suggested in a study on hospital utilization and outpatient clinic attendance (Perenboom *et al.,* 1988). Clear and meaningful hypotheses on these cultural differences as well as adequate operationalizations are needed to investigate their relevance. There may be regional variations in health locus of control or religion that influence health services utilization.
However, before including more levels and more variables in the model, and before trying different operationalizations, another question needs to be answered. Do the modest area variations that were found justify such an extension of the model and the effort that would entail?

Notes

1. Standardized residuals are calculated by dividing the difference between actual and expected cell counts by the square root of the expected cell count. This standardization gives the measure a distribution that is roughly unrelated to the size of the expected cell count (Wickes 1989, p. 134).
2. All analyses were carried out with the following linear options: logit model; first order approximation, pql prediction; unconstrained level 1 variance function.

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7 CHANGING COMMUTER DISTANCES IN THE NETHERLANDS: A MACRO-MICRO PERSPECTIVE

Linda Smit

7.1 Introduction

The collective increase of individual home-work distances is a major cause of the steep increase in commuter traffic over the past several decades. This connection gives ample reason to focus on the factors influencing individual home-work distances. The interactions and variations in time between these factors on the *micro level* (professional, residential, demographic, household, socio-economic career, etc.) as well as on the *macro level* (welfare state, labour market, housing market, infrastructure, etc.) indicate the process to be very dynamic. To obtain more insight in the changing process conditions in home work relations, an exploratory analysis has been made of workplace and residential relocations in the course of the professional career. Commuter distances seem to increase with each relocation. This article deals with the different levels of analysis involved in the study of home-work relations.

Total growth of traffic and mobility in recent decades has caused major congestion in the Netherlands. Most of the congestion is due to commuter traffic. More and more employees could cover longer home-work distances as car ownership increased and roads were improved. Near the urban centers in the western part of the Netherlands (the Randstad), the largest number of commuters spend a disproportionate amount of time travelling, either by private or public transport. This is also the case in the less densely populated parts of the Netherlands. There, although the number of commuters is proportionally smaller, the commuters cover longer home-work distances (Van der Laan 1996). For example, during the 1980s, the total sum of commuter distances increased by 45 percent in the Randstad (the highly urbanized western part of the Netherlands) and the mean distance by 6.5 percent (Dingemanse 1993). Among the above-mentioned developments, it is mainly the growing number of workers and the increased distances between home and work locations that have been adding to the growth of traffic, especially during the peak hours and in the Randstad. Another important factor is the increase in travel for diverse reasons (shopping, transporting children, recreation) (VidaKovi'c 1983; BGC 1991; BGC/AVV 1995); often combined with home-work travel.

Which relations exist between changes in home and work locations and changes in commuter distances? Many micro studies have been carried out on professional, residential, and social careers and the interactions between them. These studies point out the dependency between these different careers (e.g. Verster and Mulder 1983; Konter and Van den Booren 1986; Kipnis and Mansfeld 1986; Doorn 1989; Rouwendaal and Rietveld 1993). Most of these studies treat changing home-work distances as a secondary issue, as it was supposedly of minor importance to individual decisions. However, the collective increase in commuter traffic in relationship to these careers gives sufficient reason to focus on individual home-work distances. Several studies conclude that this type of analysis has to be done over a long period and at the individual level (Dingemanse 1993; Van Ommeren et al., 1994; Van Wee 1994). The analysis of an individual biography is often called the *life cycle approach*. In this paper, the analyses are based on retrospective questionnaire responses used as longitudinal data. Other studies have used the life cycle approach in combination with duration data for all stages in life relations between different careers

(Ginsberg 1979; Sandefur and Scott 1981; Runyan 1982; Pickles et al., 1982; Courgeau 1985; Bonnerman et al., 1991; Mulder 1993; Van Wee 1994; Van Ommeren et al., 1994; Camstra 1996). Models on this *micro level* can explain individual behaviour as a function of a person's life-course characteristics (professional, residential, household, etc.), which are derived from event- history survey data. However, characteristics (labour market, housing market) on the *macro level* (aggregate level) should not be ignored. The inter-relations of the main macro characteristics (of a group) can be found with a model, simplifying reality. This model is often based on hypothetical individual behaviour types. One problem is that the outcomes cannot be verified, as the data are of an aggregate nature (Courgeau 1995). Because the characteristics are measured on different levels, the task of integrating them will be difficult. Another problem is that the macro approach works on a *cross-sectional* basis, whereas the micro approach works *longitudinally* (Courgeau 1995). Little is known about an individual's changes in home-work distances over time and their links to the person's life cycle. Are residential changes responsible for increasing home-work distances, or do job changes lead to longer commutes? And to what extent are these changes related to household type, age, income, or residential environment? The aim of this paper is to present some results of a study of home-work relations. First, the background of the study is briefly described. Then the multilevel problems connected to the analysis of interactions between micro and macro phenomena in home-work relations are specified. Then the main interactions are described -- for instance, between changes in housing, working and household careers and the implications of those changes for home-work distances measured at different levels. The data used in this paper were obtained from the Telepanel survey[1]. The data comprise a number of longitudinal files with retrospective information on roughly 2000 to 3000 respondents.

7.2 Background to home-work relations

The process of suburbanisation accelerated mainly in the Western part of the Netherlands. The increased suburbanisation of households led to a considerable population decline in the biggest cities of the Randstad. This has had a major impact of commuter traffic. Suburbanisation is not only a spatial phenomenon. It is strongly related with some important demographic changes as well. More households needed more houses and therefore started looking for residential locations further from the major urban centers. The suburbanisation wave in the Netherlands can be divided into three periods (Vijgen and Van Engelsdorp Gastelaars 1991). From 1950 to 1965, there was mainly suburbanisation and/or counter-urbanization of upper-class people. From 1965 to 1980, also the less prosperous middle-income families could suburbanize; they moved to one-family houses in the suburbs and new towns.

Although the number of births decreased by 35 percent, the number of inhabitants grew from 12.4 million in 1965 to about 15.5 million in 1996. The spectacular increase in the number of households (100 percent) combined with a decrease in the number of household members generated a larger consumption of space for housing. This, in turn, led to longer commuter distances. Smaller households are a result of the fact that more people started to live alone in the age categories of 18-25 years and 30-45 years. Couples postponed having children or remained childless. More couples got divorced. These influences, along with better education, caused more women to participate on the labour market. Since 1960, the participation of working women on the labour market has doubled. Nevertheless, women commute less and have shorter commuting distances than men. Also, fewer women than

men continue to work when a residential mobility event occurs. However, Camstra (1996) found that women who stayed on the job despite a long-distance move tended to have an increased commuter distance more often than men. This means the continued-work woman group is not as sensitive to commuting distance as was thought, which is remarkable.
The higher number of potential professional workers could apparently not be absorbed by the labour market. As a result, the number of registered unemployed workers who are dependent on social support or unemployment benefits rose from 35,200 in 1963 to 305,000 in 1992. With regard to unemployment, the problem of commuter distances may be an important factor. An increasing discrepancy seems to develop between the place of residence of unemployed potential workers and job locations.
Along with the growing diversity in households, residential patterns of individuals, and living conditions in society (Vijgen and Van Engelsdorp Gastelaars 1991), changes in the housing and labour market have contributed to the increase in commuter distances. Besides adapting specific theories on home-work behaviour, also theories on urban structure should be revised as a result of these changes. However, the use of urban models in combination with individuals requires some caution. Structural changes of cities are difficult to verify (Jobse and Musterd 1994).
Running counter to government aims, employers hardly suburbanized to the new towns. The inhabitants of the new towns had to commute on a large scale (Musterd and Ostendorf 1996). Since 1980, suburbanisation has slowed down because the government no longer built houses on a large scale in the growth centers. The main reasons to reverse this policy were the deteriorating cities, the growing number of commuters and their distances, growing car mobility and environmental problems.
As a reaction, the Dutch government sought to revitalize the big cities and introduced the concept of the *compact cities*. This policy entails locating more new houses and jobs in or near old cities and towns and adjacent to public transport hubs. At the same time, the government wants to see more private investment in the old towns, but the private sector is more interested in the suburban areas. In that light, Musterd and Ostendorf (1996) do not expect the compact cities policy to succeed.

7.3 Spatial asymmetry and the macro-micro approach

A study on home-work relations in the western part of the Netherlands between 1975 en 1979 (NEI 1984) referred to the uneven division of home and work locations as spatial *asymmetry*. That asymmetry was associated with a theoretical minimal required home-work journey, called the forced commuter distance (FC). The voluntary commuter distance (VC) can be defined as the real commuter distance (RC) minus the forced commuter distance (FC). The diagonal in figure 7.1 shows the real discrepancy between home and work locations.
The proportion of voluntary commuting to total commuting was 11 percent in 1979. This percentage has since increased for the Randstad to 59 percent in 1981 and to about 65 percent in 1989 (figure 7.2).
This discrepancy between forced and voluntarily covered home-work distances, going beyond the city limits, is self-evident. Its rapid increase is obvious too. But the question is whether or not the choice for longer home-work distance travelling is really a voluntary one.

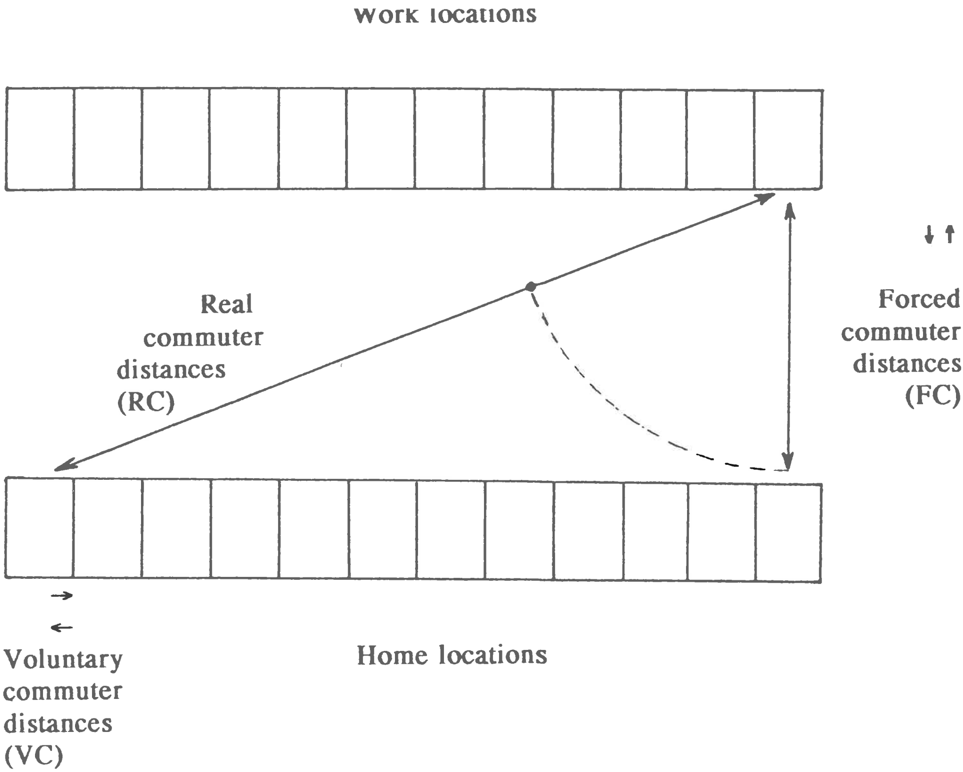

Figure 7.1 Dynamic commuter distances

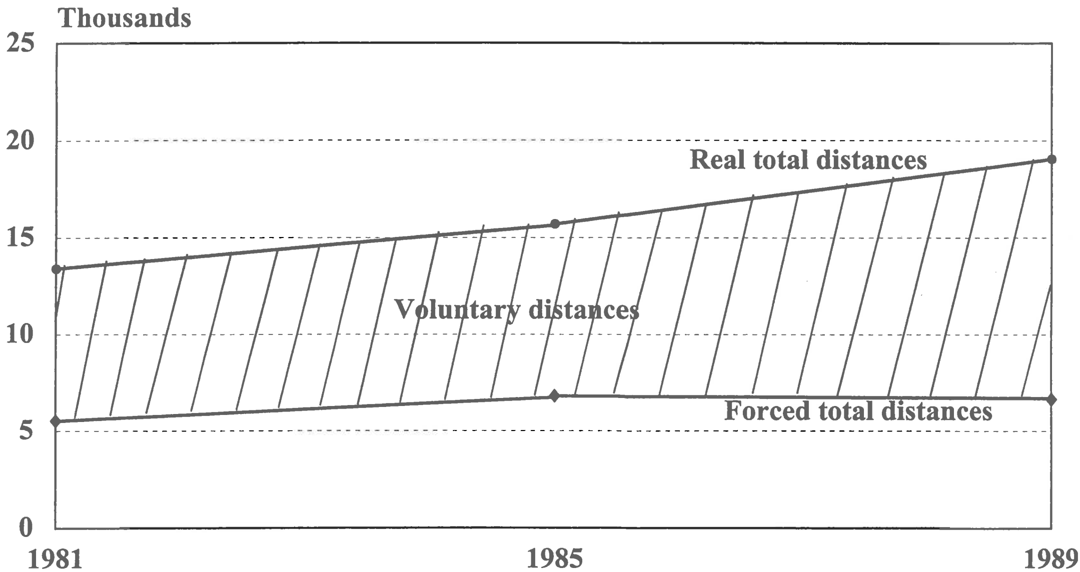

Figure 7.2 Total commuter distances in the western part of the Netherlands (Randstad)

It seems unlikely that people will choose to spend more and more time and money getting to and from work if they have no compelling reason to prefer travelling to changing either their place of residence or their place of work. Therefore, it seems useful to express the effect of their motives, which may be based on a complex of conditions on the micro as well as the macro level, as the commuting necessity factor (c). This factor can be related to real commuting and forced commuting as:

$$RC = c * FC$$

To find factor c, a thorough inventory of all conditions that influence the motivation to change home-work distances is necessary. These conditions must then be subjected to extensive analysis and evaluation.

Spatial patterns and social phenomena in human geography and sociology are often explained by the following patterns of human behaviour. Actors at the micro level, generally individuals, have a certain limited space in which to act. That action space offers them the possibilities and limitations that determine their actual behaviour. This behaviour, in turn, leads to phenomena on the macro level (Hooimeijer 1992).

Microsimulation models are used increasingly to get more detailed information about households, regional populations, etc. Existing theories on geographical and social mobility processes can be used to determine the probabilities (or rates, when using a continuous time approach) that an individual with given characteristics has experienced certain events (change in place of work or residence). The probabilities or rates can be used to simulate the behaviour of each individual from an initial population whose characteristics, past experience, and spatial information are known at the beginning of the observation (Courgeau 1995). It should be kept in mind when using these models that estimation of future behaviour must be interpreted with great caution. These models cannot incorporate the whole set of characteristics and interacting phenomena.

In recent years, geographers have generally viewed relations between actors and society as unique, place-specific interpretations of general processes. As Jones (1993, p. 2) states:

> The juxtaposition of disparate forces in a place creates a qualitatively different setting which of itself can influence and modify the general processes. People and places exist in a recursive dialectic relationship. People create structures in the context of places; those structures then condition the making of people.

This statement does not reveal how these relations between macro processes and micro phenomena exactly operate. Do we have to approach the processes from the actor's position? Or are these actors merely subject to the processes initiated by them, processes that may follow unforeseen patterns.

For the relation between the macro and the micro level, the technique of multilevel analysis has been developed (see Duncan et al., 1994). The geographical method of analysis requires an emphasis on context, which stresses differences in people and places. However, in statistical modelling, the geographer meets with difficulties: if he chooses to work at the aggregate level, he risks the *ecological fallacy;* if he chooses to work at the individual level, he risks the *atomistic fallacy* (Jones 1993; Courgeau 1995). The ecological fallacy appears in connection with individuals when dealing with aggregates. The atomistic fallacy occurs when there is no context in which individuals are acting. The use of aggregate and individual characteristics simultaneously can give complementary results (Duncan et al., 1994; Courgeau 1995). Yet it is impossible to connect them by attributing results found at

the aggregate level to individuals (ecological fallacy) or vice versa (atomistic fallacy). Behind the home-work distance variation, there are many characteristics at the *micro level* (occupational, demographic, household, socio-economic, residential career, etc.) as well at the *macro level* (labour market, housing market, etc.). There are interactions between residential, professional, and household careers, and these interactions vary in time. These different careers are influenced by social, economic, and technical changes in society, which also change over time. Interpretations of the variation in home-work relations should therefore be dynamic. Many people obviously try to (re)adjust the home-work discrepancy. This process is counteracted by conditions and circumstances at the macro level that are more or less beyond the influence of individuals.
In the next section, we explain why changing commuter distances must be analysed at the individual level. Also the residential moves and job changes of individuals in relation to commuter distances are analysed to discern the relative contribution of these changes on the increase in commuting.

7.4 Framework for analysis

Figure 7.3 shows how changes in home-work relations are linked and which relations are stressed. First, there is a direct relation between residential or job relocations and the home-work distance. Within these relations, there is also an interaction between residential and job relocations. According to most of the (economic) theories about individual choice of workplace and residence, the place of residence is a consequence of a certain workplace. The explanatory variables are wage, commuting costs, and residential costs (Van Wee 1994). Commuting costs can be divided into monetary outlays and commuting time. It has been demonstrated that commuting time is more important. Other studies have stressed residence as the most important factor in the decision-making of individuals. In this study, there is no a priori choice for workplace or residence. Their mutual dependence is explained in terms of changes in the residential environment and events in the household career and the professional career. The residential environment is treated as an individual context variable which represents the residential career.

Dependent variable at the micro level
The home-work distances belonging to the different stages in the professional career are unfortunately not available as travel times. The distances are determined with the aid of a matrix of distances *between* the centers of gravity of the addresses within the municipalities (corrected by road curve).

Independent variables at the micro level: household and professional careers
The changes that occur in households can be divided into a number of stages (Kingkade 1983; Cortie and Dekker 1992). Most people in the Netherlands go through a household sequence that starts with children living in the parental home. That stage is followed by young singles or (married) couples, followed by bringing up children, whereafter the growing-up children leave the parental home. Each of these stages is associated with demand for a particular type of housing and with a given financial position (see Vijgen and Van Engelsdorp Gastelaars 1991).

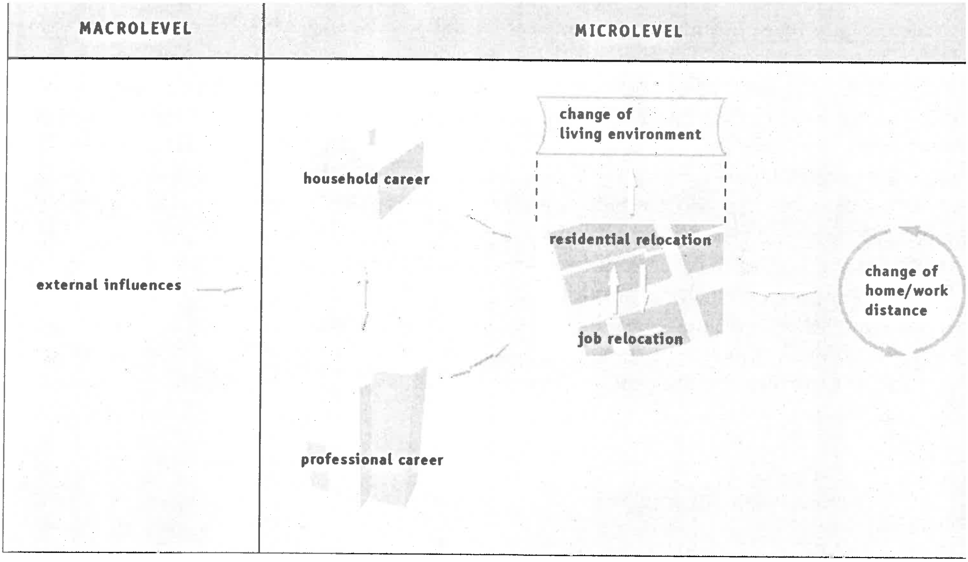

Figure 7.3 Changes in home-work relations at the macro and micro level

Professional career indicators such as promotion, (possibility of) a permanent job, additional studies, and the like are potential influences on home-work distances. The frequency of changes in commuter distance depends on job characteristics such as branch, career sensitivity, and part-time/full-time work (see Tuma and Hannan 1984).

Independent variables at the macro level
Various social economic developments will have an influence on commuter distances. For example, fluctuations in job availability will be reflected in the increase/decrease of distances. Besides these macro-economic factors, the effect of government spending is very important. Subsidization of public transport and housing, social benefits, and the like are closely related with decisions about location and thus will have an effect on home-work distances. The influence of the welfare state on the different careers in retrospect is very extensive. The only way to consider that effect is to take the welfare state as an interpretive framework, which will be connected to relations at the micro level in a qualitative way.

7.5 Preliminary results

The respondents' first six steps in their residential and employment career are taken into account for all respondents with at least a first job. In six steps, 91 percent of all their residential changes are reached, as are the 61 percent of all the job changes. These percentages are based on the total number of residences and jobs respondents reported at the end of the questionnaire. After the sixth career step, the number of respondents becomes too small for analysis. Because changing home-work distances are closely related to professional careers and the household cycle, the variables of age, sex, income and type of household are important indicators of this relationship.
The relations between the different careers, the work and residence changes, and commuter distances are complicated to a degree that requires a step-by-step approach. For each

residential location and for each work location, it has been determined when and how long each respondent lived or worked there. The duration of living or working is measured in months. Job moves do not necessarily imply a relocation of workplace; it is possible to take another job within the same company or be out of work (temporarily). The starting point for our observations is the first job and the place of residence at that time. The home-work distance and duration were measured for each change in residence or job. Figure 7.4 shows the average home-work distances, *for each home-work trip,* after the first six career steps (first job and job or residential relocations). All steps except the second one have increased distances. Thus, at the time of the first job, the home-work distance is longer than after the second career step. There may be a bias because after each career step there are fewer respondents left.

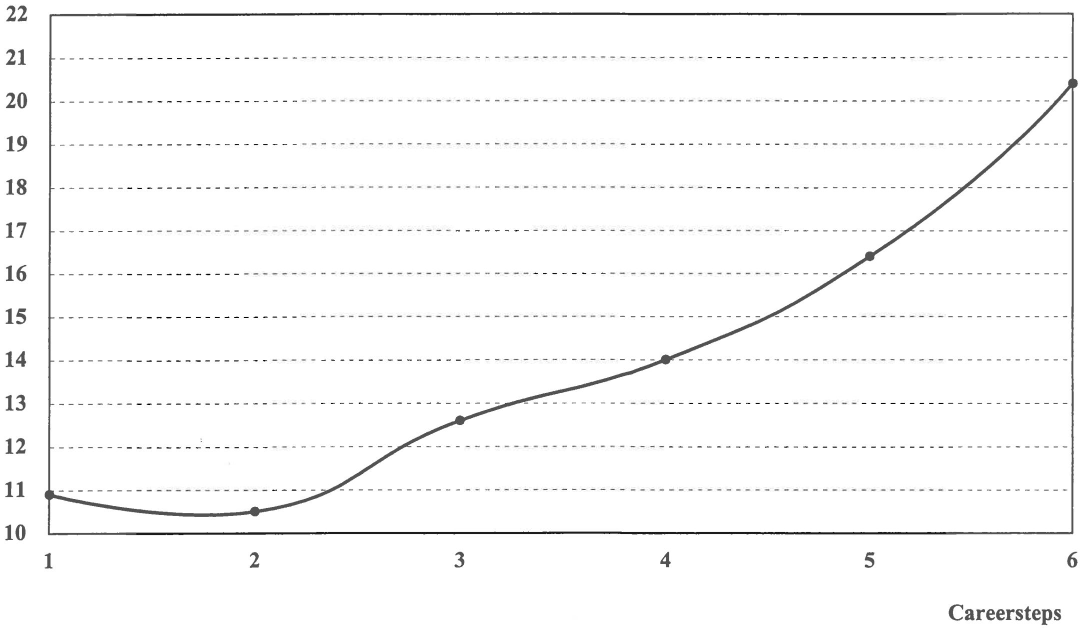

Figure 7.4 Average commuter distance (≤ 100 km) for each trip by career step

Subsequently, the development of variation in home-work distances through time has to be traced to ascertain the extent to which this development was structural. Time has two dimensions. The duration of each step in the career is crucial to an explanation of relations between events in these careers. The second dimension, time in the longitudinal perspective, is an important aspect of this study. Figure 7.5 shows the increased commuter distances. The average distance between 1980 and 1985 is somewhat above the average of the CBS and the distance after 1986 is somewhat below the average of the CBS (see Smit 1995).
Career steps as defined here can be expressed as the sum of job mobility and residential mobility. Appropriate statistical data about job mobility are scarce; when available, these are aggregate data. In an analysis of job mobility from 1959 to 1990, Mekkelholt (1993) found the same relative changes. Figure 7.6 shows the average job mobility for each period as a percentage by calendar year. For example, in figure 7.6, job mobility in the period 1945-1950 was 20.7 percent. Thus, in this period, the average interval between two jobs (or

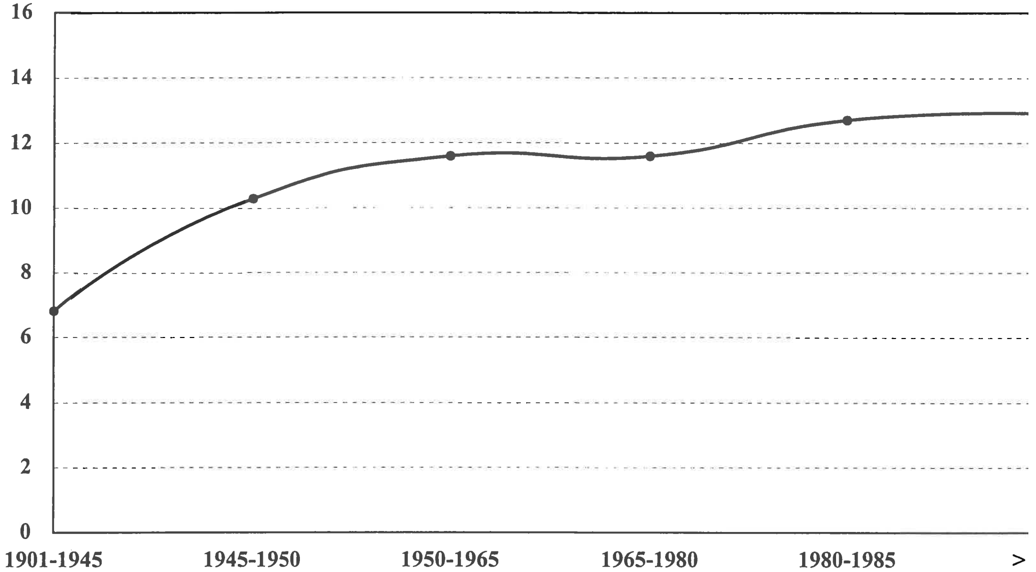

Figure 7.5 Average of commuter distance (≤ 100 km) for each trip by period

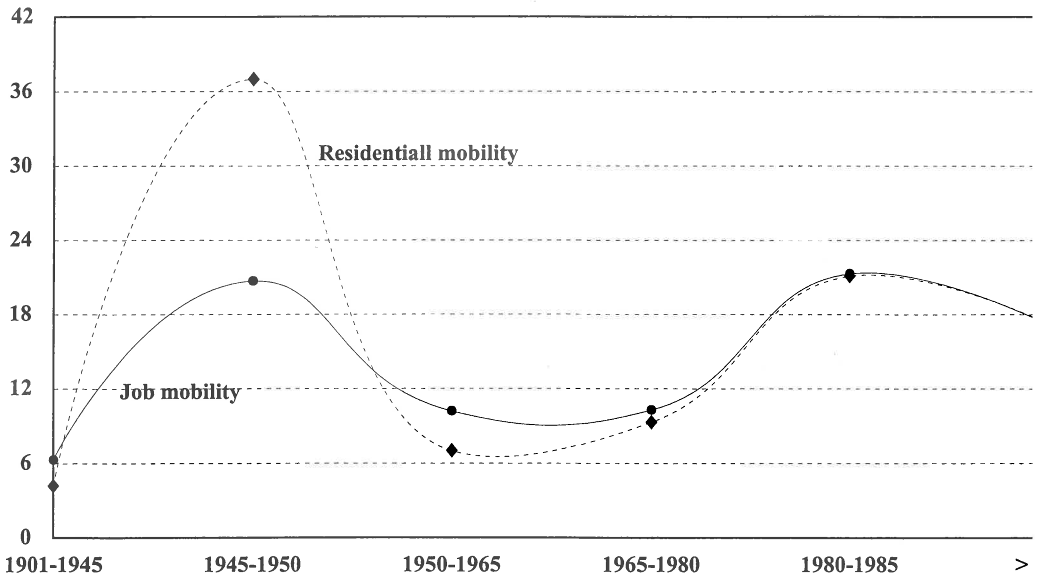

Figure 7.6 Average job mobility and residential mobility (%) by period (weighted by age)

different positions) was 4.8 years. Residential mobility increased steeply between 1945 and 1950. Influences of the economic cycle resulted in strong fluctuations in job mobility (Mekkelholt 1993). Also, residential mobility fluctuated greatly throughout the post-war period. An explanation for these fluctuations can be found in the phenomenon of post-war industrialization, which entailed the decentralisation of industry and the suburbanisation of residence (Deurloo et al., 1981).
Not only the sequence and duration of events are important but also the relation between the events in different careers. Table 7.1 shows the changes in home-work distances after each career step (job or residential shift). After a job shift, distances increase more often than after home relocations. This confirms the hypothesis that people are inclined not to take a longer home-work distance into serious consideration when accepting a new job.

Table 7.1 Percentage of decrease(-)/no change (0)/increase(+) in home-work distance after each career step (home or job shift)

		Home	Job
Home-work	*Step 1* n=1066		
Distance	-	12	22
↑	0	79	61
	+	9	17
	Step 2 n=528		
	-	9	18
	0	82	53
	+	9	29
	Step 3 n=277		
	-	15	27
	0	69	45
	+	16	28
	Step 4 n=212		
	-	12	24
	0	65	46
	+	23	30

Further elaborations will be aimed at the background variables of the relationship between commuter distances and professional and household careers. To know the effects of relocations on commuter distances in the long term, it would be interesting to link this micro level with macro variables in one model. In the next section, we discuss the advantages of multilevel analysis and point out some drawbacks of this approach.

7.6 Multilevel analysis of home-work relations

Relatively few researchers have attempted to specify models that characterize or explain processes at the macro level by using micro-level data (DiPrete and Forristal 1994).
One of the approaches applying different aggregation levels simultaneously is the *multilevel model*. Multilevel models operate at more than one scale or level. When using a multilevel model, it is possible to consider the micro level of individuals and the macro level of places simultaneously in a single model. The model can use bivariate or multivariate variables. A *multivariate multilevel model* has several measures of behaviour that are related to the individual *and* contextual characteristics. For example, when explaining long home-work

distances, it is possible to assess whether variables like education, income, and age have the same effect at the individual level and the macro level. The residual covariances measure correlation of behaviour both between individuals and between groups (aggregates). Multilevel models can use either continuous or categorical data for the dependent variables or a mixture of both categorical and continuous variables (Jones 1993).

A *repeated measures design* can be made to use panel or retrospective data. Unlike conventional repeated measures methods, which require a fixed set of repeated observations for *all* persons, both the number of observations per person and the spacing among the observations may vary. Multilevel estimation is based on a combined estimation of the 'fixed' and the 'random' part. The fixed estimates represents the overall, general relationship and are a weighted average of all the group-specific ones (Duncan et al., 1994). Whereas the older models can be characterized as fixed effects regression models, the new models specify the regression coefficients as random effects. In the random effects model, the micro-level coefficient is not expressed as an exact function of macro-level variables but contains error terms in the macro equations.

For example, the *basic model* (single level) for the relationship between commuter distances and career steps could be the length of the *home-work distance* related to *duration of workplace*. In this model, the estimate is given of the expected home-work distance of an individual whose duration is at the mean. Furthermore, an estimate is given of the effect of duration on the length of the home-work distance. This single-level regression model specifies the length of the home-work distance of all individuals with mean duration to have the same expected lengths of home-work distances. It also specifies the effect of duration to be the same for all individuals. The effects in this model are equal for all individuals, which makes it a fixed model. In a random effects model, each individual is supposed to have his own specific response to a certain length of home-work distance related to duration of a workplace.

Traditionally, longitudinal data analysis and the assessment of change over time have caused many methodological problems. But the extension of the random-effects multilevel regression model to the case of repeated measures can be represented by multilevel structures (Duncan et al., 1994). In analysing commuter distances in a retrospective manner, the basic model can be extended by at least one extra aggregate level. In our scheme, a distinction is made between level 1: events or career steps and level 2: individuals. The repeated measures are the events; in this case, the events can be only job or residential relocations. Because the data are retrospective, there are many events. These differ in number for each individual. Each career step is tied to a commuter distance. Level 1 is nested within individuals at level 2. Level 2 can also nest within a higher level. This could be households, though methodologically that is not possible because there are not enough cases in these constituencies. The two-level model has an additional term in the random part. That term is associated with individuals and represents a differential effect of the events on different persons. The person-specific random term represents a person's differences after allowing for age and duration and event variation. The level 1 random term represents event differences after allowing for age, duration, and between-person differences. The average probability of having a certain commuter distance for each individual depends on an overall general average plus an allowed-to-vary random difference for each person with specific characteristics. The advantage of using a multilevel model here, even only with an aggregate non-geographical level, is that the use of a large set of 1 or 0 dummy variables (2022 persons as dummies) can be avoided (Jones et al., 1996). Then separate regressions would be fitted to each individual. At each level only a single parameter, the variance of the differentials, is being estimated. This can result in a marked improvement in the precision of the estimates when the sample is small (<25 events) in relation to the number of higher-level units (individuals).

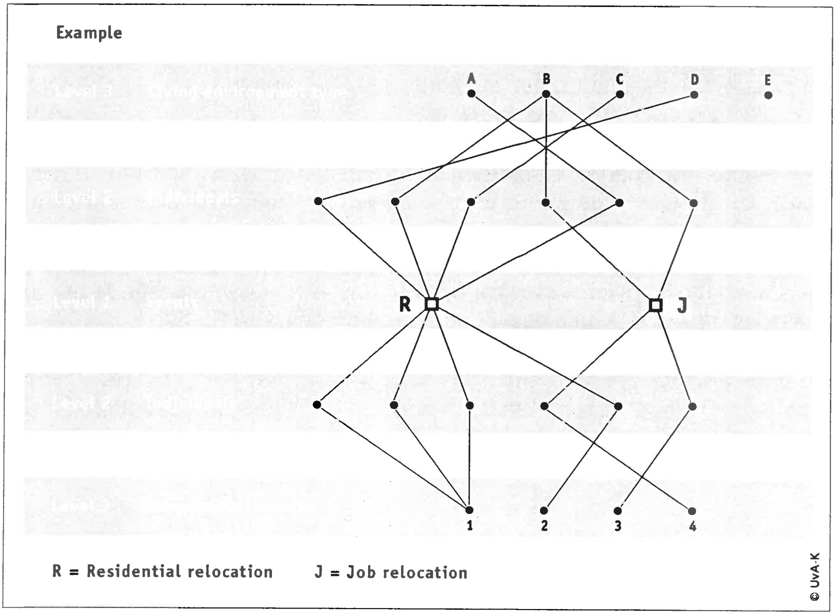

Figure 7.7 Tree structure

The multilevel structure has a panel design and can also have a *cross-classified structure*: persons nest within both geographical regions and residential environment types at level 3 if the residential environment is considered as a contextual level (macro). These two contextual higher-level units are not nested with each other but are overlapping contexts (figure 7.7). According to the scheme, the multilevel approach that was used in this longitudinal survey is quite complex because of:

a. The large number of levels: The number of parameters increases with the number of higher-level units and reliability problems could arise.
b. The large number of variables: Variables like income, type of household, education etc. are important indicators to study the dynamics of home-work relations. Problems can arise because the subgroups are getting too small.
c. A repeated measures structure: Commuter distances may vary strongly and frequently during the different periods of an individual's lifetime by different type of events (residential moves and job changes). This is an important advantage of the model because it makes it possible to relate more and different events for the same individual. But it also implies that the model has many parameters, which makes it less reliable.
d. In the simplest case, the multilevel data structures are purely hierarchical; each lower-level unit is nested within only one unit at the next higher level. It may often be the case that such hierarchical nesting does not occur. Then a number of different contexts may exist at the same level. This situation requires a cross-classified structure. In the case of home-work relations, individuals nest, for example, within both geographical regions and residential environment types at level 3.

7.7 Conclusions

When analysing home-work relations, we are inevitably confronted with the question of how to integrate multilevel information and characteristics. Using the multilevel technique, relations can be made between variables on different levels of analysis. Another important advantage of multilevel analysis is that more and different events can be analysed than would be possible with many other methods. This advantage is due to the fact that the multilevel structure does not need to be strictly hierarchical. Thus, it is possible to use different contextual variables at the same level (e.g. functional and geographical regions). In fact, the macro information is difficult to link to retrospective individual data. Macro (contextual) variables can sometimes be considered on the micro level. For example, the variable of residential environment is a macro variable but it is linked to the individual; it becomes a contextual variable at the individual level. Even without having the macro level directly in the analysis, macro-level influences play an intervening role at the individual level. A serious problem, which occurs with either method, is the large number of empty cells. This problem arises in all retrospective or panel data sets in the Netherlands. Extensive collection of data which are more precisely suited to the purpose of analysing this subject would be an improvement. It is necessary to find new and better adapted analysis techniques that, perhaps combined with multilevel analysis, could improve the analysis of retrospective data.

Note

[1] The survey was conducted by the Foundation Telepanel. It was commissioned by the Dutch National Science Foundation (NWO). In the first round (1992), the study was focused on social and labour mobility.

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8 APPLYING MIXED MULTIVARIATE MULTILEVEL MODELS IN GEOGRAPHICAL RESEARCH

Craig Duncan

8.1 Introduction

Multilevel models have been shown to have considerable value for studies focusing on the interactions between people and places (Jones and Duncan 1996) and are beginning to be widely applied by researchers, especially in the field of health geography (recent examples include Congdon 1995; Duncan *et al.*, 1995a; Ecob 1996; Gould and Jones 1996; Langford and Bentham 1996). So far, the majority of published examples utilise relatively straight-forward hierarchical data structures in which individuals nest within higher level geographical contexts, or smaller spatial units nest within larger spatial units. As Goldstein's (1995) recent volume emphasises, however, the basic multilevel hierarchical structure can be extended to reflect a number of other more complex, yet frequently occurring and substantively interesting, data structures. The present paper focuses on one such extension, and, more specifically, the way in which it can be applied to response data that is a mixture of both categorical and continuous variables. While the discussion will concentrate on how such an extension can be employed in health-related behaviour research, the approach taken can be applied in many other areas of geographical enquiry.

8.2 Multivariate multilevel data structures

One important extension available within the general multilevel framework is the multivariate, multilevel model. Such models are based on data structures in which the lowest level consists of a number of different, though related, response variables (Cresswell 1991; Duncan *et al.,* 1995b; Goldstein 1995). These level-1 units then nest within the subjects being measured and the structure can continue upwards by recognising the higher-level contextual settings in which these subjects are located.

The general form of this structure is shown (in simplified fashion) in figure 8.1. As can be seen, the structure consists of four response variables at level-1, nested within individuals at level-2, who nest within places at level-3. It is important to note that the structure does not have to be balanced, i.e.: not every individual has to have every response variable.

In the case of health-related behaviour research, such a structure can be used to represent a series of measurements recording different aspects of people's health-related behaviour (for example, smoking, drinking, eating) which would facilitate an examination of behavioral clustering (the degree to which different behaviours are inter-related or coincide) at both the level of people and places (Duncan *et al.*, 1996). Since multilevel models can use both continuous and categorical data, the measurements could take the form of continuous values (e.g., the number of cigarettes per day; the units of alcohol consumed per week) or they could represent systems of classification (e.g.: low-smoker/high smoker; low drinker/high drinker).

Moreover, multivariate multilevel models can accommodate sets of responses which are a mixture of *both* categorical and continuous variables. This variant of the multivariate multilevel model -- known as the mixed, multivariate multilevel model -- has great potential as researchers are often interested in two different, though related, dimensions of behaviour.

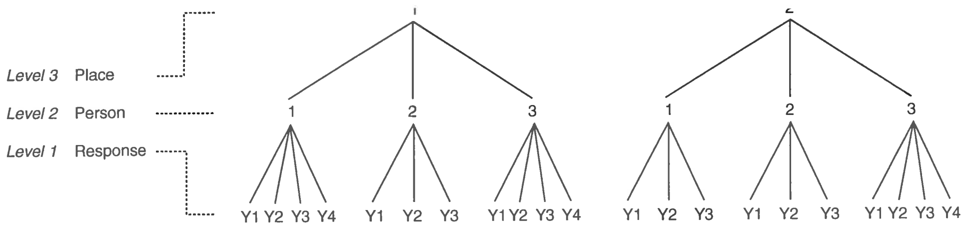

Figure 8.1 A multivariate multilevel data structure

First, whether it actually occurs or not (occurrence), and second, if it does occur, to what degree (quantity). For example, in terms of health-related behaviour, researchers are interested in knowing both who smokes and who does not, and the number of cigarettes consumed by those who are smokers.[1]

The rest of this paper will outline how a mixed, multivariate multilevel model can be developed in relation to this example. There are three main sections. The first considers the conceptual background in more detail and shows how serious technical problems can arise if researchers use simple quantitative measures of behaviour without distinguishing between occurrence and quantity. This section also provides a non-technical outline of mixed, multivariate multilevel models and considers how they can be applied and the advantages associated with their use. In the second section, a technical outline of such models is presented showing how they can be developed and specified. The third section reports their use in an analysis of the data recording smoking behaviour in the first Health and Lifestyle Survey (HALS1) conducted in Britain in 1984/5 (Cox *et al.*, 1987). The paper concludes with a short section summarising the main methodological advantages of the approach outlined together with details of how it may be extended.

8.3 Behavioural dimensions

The two dimensions of behaviour just referred to -- occurrence and quantity -- are immediately apparent when one considers the distributive form of simple quantitative measures summarising individual health-related behavioral practice, for example the number of cigarettes smoked in a day or the number of units of alcohol consumed in a week. An example of this is given in figure 8.2 which shows the data recording smoking quantity in HALS1. As can be seen there is a 'spiked' distribution - a large number of values at zero followed by a positively skewed distribution of non-zero values. The 'spike' of zero values distinguishes those people who are smokers from those who are not, thus reflecting the occurrence of smoking behaviour. At the same time, the distribution of non-zero values reveals the quantity of smoking by those who are smokers. Thus, besides providing a direct behavioral quantification in terms of consumption, quantitative measures, when applied to everybody, also record the prevalence or occurrence of a particular behaviour. As Colby *et al.* (1994) recognise, these two dimensions are quite different and should not, therefore, be conflated. The occurrence of behaviour can be regarded as a cultural or normative measure of acceptability, whilst the number of times a behaviour is performed is a quantitative measure of consumption and repetitive practice.

Due to the existence of these different dimensions, the analysis of data consisting of simple behavioral quantitative measures needs to be considered carefully. If such data are treated as a single continuous response variable and a simple linear model is fitted, the estimates obtained provide poor descriptors since the distribution of the response variable is so heavily skewed by the considerable number of zero values. In this instance, for example, if the simple model:

$$y_i = \beta_0 + \beta_1 x_1 + e_i \quad (1)$$

is fitted, where β_0 represents the average cigarette consumption for females and β_1 the contrast in average cigarette consumption for males, women are estimated as smoking 4.7 cigarettes per day with males smoking an additional 1.4 cigarettes per day. However, as figure 8.2 reveals, very few people actually smoke these amounts.

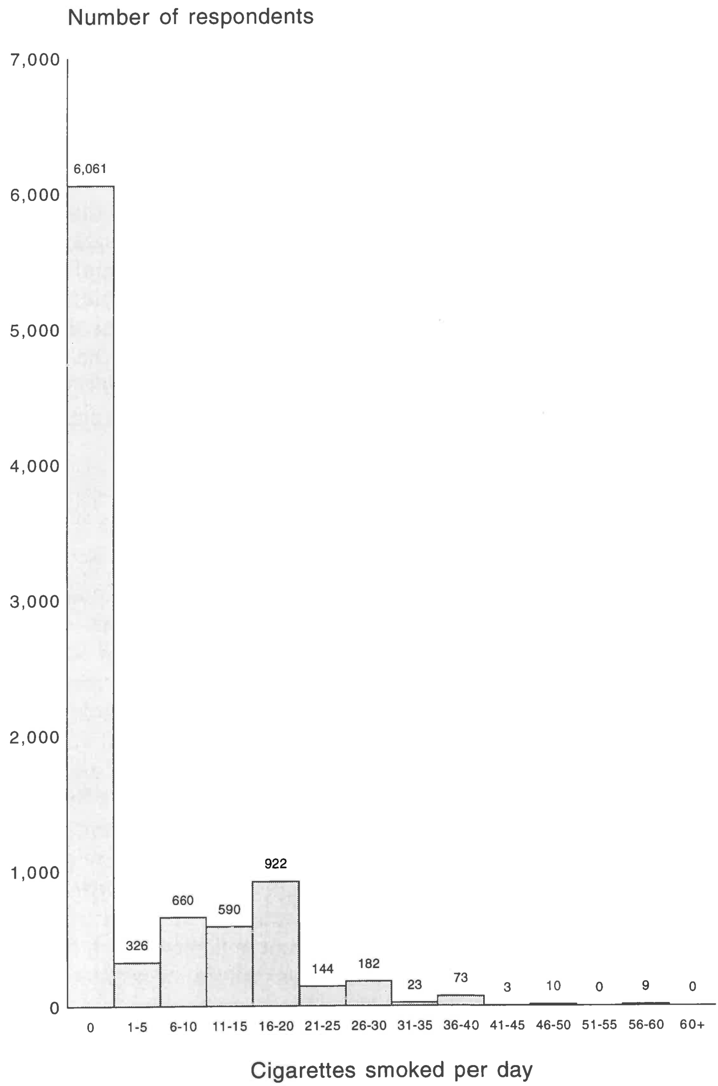

Figure 8.2 Distribution of cigarette smoking quantity in the 1984/5 Health and Lifestyle Survey

This situation can be avoided by explicitly distinguishing between the two different dimensions of behaviour. One way to do this would be by carrying out two separate analyses: the first, based upon a (0,1) categorical response variable indicating those who smoke, in which all people are included; the second, based upon a continuous variable relating to quantity, in which only those people who are smokers are included. Typically, a logistic model with binomial error structure would be applied in the first instance, and a linear model with a Gaussian error structure in the second. However, as noted earlier, the multivariate extension of the multilevel framework can handle sets of response variables which are a mixture of both categorical and continuous data, making it possible for the two smoking responses to be handled simultaneously within one single, overall model. Figure 8.3 shows a simplified representation of the multilevel data structure that would be used.

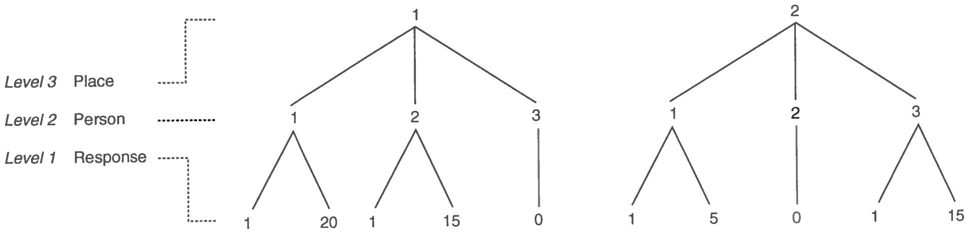

Figure 8.3 A mixed, multivariate multilevel data structure representing smoking behaviour

As can be seen the structure consists of the general multivariate form whereby a number of different, though related, responses at level-1 nest within units at level-2. In this particular instance, one of the responses is categorical whilst the other is continuous. Those people who smoke have both a categorical response variable set to '1' indicating that they are a smoker and a continuous response variable showing the number of cigarettes consumed daily. As noted earlier, the multilevel approach does not require balanced data so the non-smokers have only the categorical response variable set to '0' indicating that they do not smoke. The result of this is that the occurrence of smoking can be separated from, yet considered simultaneously with, the quantity smoked.

Adopting this form of multilevel approach brings a number of substantive advantages. First, there are the general benefits obtained by distinguishing the two dimensions: researchers can ensure they do not remain conflated; they are not forced to study one to the exclusion of the other; they can avoid having to reduce consumption measures to simplistic dichotomies. Second, and most importantly, specific benefits arise from the multilevel, multivariate formulation. By using such an approach it is possible for each response variable to have its own set of individual-level explanatory variables. Thus, we can compare and contrast the relationship between each dimension of a particular behaviour and a number of different personal characteristics. As each dimension can be conceived as representing a distinct process, there are likely to be substantively interesting differences between them in terms of these relationships. For example, it may be that while age is strongly implicated in the probability of an individual being a smoker, there is little difference in the number of cigarettes consumed by smokers of different ages once they do smoke. In terms of gender-related differences, while there may be no substantial differences between men and women in the probability of being a smoker, there may be a tendency for male smokers to consume much greater quantities of tobacco than female smokers.

The multilevel formulation also makes it possible to develop the examination of people-place relationships in relation to each of the two dimensions of behavioral practice. If higher, contextual levels are recognised, as has been done in figure 8.3 where individuals are grouped according to the places in which they live, then it becomes possible to assess, allowing for each context's composition in terms of the socio-demographic characteristics of the individuals within it, whether both the proportion of people performing a particular behaviour and the number of times that behaviour is performed by those people varies across contexts. Again, there may be substantively interesting differences between the two dimensions - for example, we may find that whilst the proportion of smokers does not vary substantially from place to place, there may be significant between-place variation in the quantity of cigarettes consumed by those who are smoking in particular places.

The major advantage from treating the two mixed response variables together in a multivariate model in terms of developing a contextual analysis is, however, that higher-level *covariance* terms can be estimated. When we allow two variables to be random at a higher level not only can we estimate separate variance terms to summarise the degree to which each varies across contexts, but we can also estimate a joint covariance to assess the degree and the manner in which they co-vary across contexts. In this instance, the covariance will show whether there are any systematic relationships across different contexts between the occurrence of behaviour and the quantity of behaviour. Importantly, this feature allows empirical research to represent contextual influences in terms of the co-presence of similarly-behaving people as a factor affecting the number of times people practice particular behaviours. For example, in relation to smoking behaviour, such higher-level covariance terms allow the assessment of whether places with high proportions of smokers are also characterised by high quantities of cigarette consumption. Or, put another way, it is possible to investigate whether smokers smoke more cigarettes when they have more people around them who are also smokers.

8.4 Developing a mixed multivariate multilevel model

To show how a mixed, multivariate multilevel model can be developed we will start by considering the data matrix that can be formed from the smoking data represented in figure 8.2 recognising both individuals and their place of residence. An accompanying appendix shows how to prepare this matrix and specify a mixed response multilevel model using the software package MLn (Rasbash and Woodhouse 1995).

To begin we have two response variables for each respondent, one, called *Smoker*, is categorical and records occurrence, the other, called *Amount*, is continuous and records quantity, and this is shown in table 8.1 below:

Table 8.1 Original smoking data

Person	Place	Smoker	Amount	Age
1	1	1	25	-14
2	1	0	0	1
3	2	1	15	20

Thus, the first and third individuals are smokers and consume 25 and 15 cigarettes a day respectively, whilst the second individual is a non-smoker. If we make a single column vector containing both of the response variables, *Smoker* and *Amount*, rather than having each of them on one record, then we create a multivariate structure. When we do this it is also necessary to duplicate the values of any individual level variables which we wish to use as predictors. In this instance we have included just one, *Age*, which has been centred around its mean. This produces the matrix of interleaved responses shown in table 8.2 below:

Table 8.2 Interleaved responses

Person	Place	Response	Age
1	1	1	-14
1	1	25	-14
2	1	0	1
2	1	0	1
3	2	1	20
3	2	15	20

It is necessary to perform three additional steps before we have a suitable data matrix for modelling. First, we need to recognise the type of response variable that each record contains and this is done by creating indicator variables which will also represent the constants. Second, further explanatory variables are defined by multiplying the indicator variables by individual level explanatory variables. Finally, as stated earlier, the multilevel approach does not require balanced data and so we can, indeed we must, delete the continuous response record for those people who are not smokers, to distinguish the two dimensions of behaviour. When these three steps are performed we produce the final data matrix shown in table 8.3 below:

Table 8.3 The final data matrix

Person	Place	Response F_{ijk}	Categorical Z_{1jk}	Continuous Z_{2jk}	Age-Cat $Z_{1jk}X_{1jk}$	Age-Con $Z_{2jk}X_{1jk}$
1	1	1	1	0	-14	0
1	1	25	0	1	0	-14
2	1	0	1	0	1	0
3	2	1	1	0	20	0
3	2	15	0	1	0	20

This table reveals that we wish to model a response vector, F_{ijk}, consisting of i responses which are a mixture of both categorical and continuous variables for j individuals in k places, with the structure of the vector being given by the two indicator variables, Z_{1jk} and Z_{2jk}. If we use a three-level model with level 1 defining the multivariate structure using the indicator variables, level 2 describing between-individual variation and level 3 describing between-place variation we can specify the following relationship between the mixed response variables and the explanatory variables for *Age* in table 8.3:

$$F_{ijk} = F^{(1)}{}_{jk} + F^{(2)}{}_{jk} \qquad (2)$$

where $F^{(1)}$ expresses the model for the categorical response and $F^{(2)}$ expresses the model for the continuous response. We can now write a series of models for each, beginning with fixed-effects micro-models specified at the individual level followed by macro-models for any of the micro-model parameters that we wish to allow to vary between places (Jones 1993).

First, we will write a fixed effects micro-model for the categorical response which, for a number of technical reasons (Healy 1988), has a binomial random term at level-1 and takes a non-linear form. Hence:

$$F^{(1)}_{jk} = \pi^{(1)}_{jk}$$

where:

$$\pi^{(1)}_{jk} = \frac{\exp(\beta_0^{(1)} z_{1jk} + \beta_1^{(1)} z_{1jk} x_{1jk})}{1 + \exp(\beta_0^{(1)} z_{1jk} + \beta_1^{(1)} z_{1jk} x_{1jk})} \quad (3)$$

where:

$\pi^{(1)}_{jk}$ is the 'true' underlying probability of person *j* in place *k* being a smoker.

This model can be linearised for estimation by taking a logit transformation. Hence:

$$E(L^{(1)}_{jk}) = E[\log(\pi^{(1)}_{jk}/(1-\pi^{(1)}_{jk}))] = \beta_0^{(1)} z_{1jk} + \beta_1^{(1)} z_{1jk} x_{1jk} \quad (4)$$

where:

$L^{(1)}_{jk}$ is the log-odds of being a smoker;

$\beta_0^{(1)}$ is the fixed intercept term representing the log-odds that a person of average age is a smoker;

$\beta_1^{(1)}$ is the fixed slope term between the log-odds that a person is a smoker and age.

Any of the parameters from this micro-model can be allowed to vary from place to place at the higher level. Here, we shall only allow the intercept to do so. This is done by indexing the intercept in the micro-model ($\beta_0^{(1)}$) with the subscript *k* to distinguish places:

$$E(L^{(1)}_{jk}) = E[\log(\pi^{(1)}_{jk}/(1-\pi^{(1)}_{jk}))] = \beta_{0k}^{(1)} z_{1jk} + \beta_1^{(1)} z_{1jk} x_{1jk} \quad (5)$$

and then specifying the macro-model (the between-place model):

$$\beta_{0k}^{(1)} = \beta_0^{(1)} + \mu_{0k}^{(1)} \quad (6)$$

In this higher level model, the terms are:

$\beta_{0k}^{(1)}$ the differential log-odds in place *k* that a person of average age is a smoker;

$\beta_0^{(1)}$ the national average log-odds that a person of average age is a smoker;

$\mu_{0k}^{(1)}$ place differences in the log-odds that an individual is a smoker allowing for age composition.

The level 3 between-place random term, $\mu_{0k}^{(1)}$, represents the place-specific differences in the log-odds that a person of average age is a smoker and the intercept term varies according to a higher level distribution which is summarised by its overall mean, $\beta_0^{(1)}$ and its variance, $\sigma^2_{\mu 0}{}^{(1)}$.

This procedure is then repeated for the second response variable. This time, however, since the response variable is continuous we write a standard linear model with a Gaussian random part:

$$F^{(2)}_{jk} = \beta_0^{(2)} z_{2jk} + \beta_1^{(2)} z_{2jk} x_{1jk} + (\epsilon_{jk}) \quad (7)$$

where:

$F^{(2)}_{jk}$ is the number of cigarettes smoked daily by person *j* in place *k*, that is the continuous response variable;

$\beta_0^{(2)}$ is the fixed intercept term representing the average number of cigarettes smoked daily by a person of average age;

$\beta_1^{(2)}$ is the fixed slope term between daily cigarette consumption and age;

(ϵ_{jk}) summarises random variation between individuals.

Any of the parameters of this micro-model can also be allowed to vary and we follow the same procedure as before. Again, we shall only allow the intercept term to vary and so we index this term and write just one macro-model:

$$\beta_{0k}^{(2)} = \beta_0^{(2)} + \mu_{0k}^{(2)} \tag{8}$$

In this higher level model, the terms are as follows:

- $\beta_{0k}^{(2)}$ the differential daily cigarette consumption in place *k* by a smoker of average age;
- $\beta_0^{(2)}$ the national average daily cigarette consumption for a smoker of average age;
- $\mu_{0k}^{(2)}$ place differences after 'controlling' for age composition.

The level 3 between-place random term, $\mu_{0k}^{(2)}$, represents the place-specific differences in the daily cigarette consumption by a person of average age and so the continuous intercept term also varies according to a higher level distribution which is summarised by its overall mean, $\beta_0^{(2)}$ and its variance, $\sigma^2_{\mu 0}{}^{(2)}$.
Considering the model overall we can see that there are two variables ($\beta_0^{(1)}$ and $\beta_0^{(2)}$) with higher-level distributions. Consequently, besides estimating the mean and variance of each of these we can also summarise their joint distribution by the covariance term, $\sigma_{\mu 0}{}^{(1)}{}_{\mu 0}{}^{(2)}$ and it is this term that allows us to assess the relationship between the proportion of smokers in a place and the quantity of cigarettes consumed by those who are smokers in a place allowing for compositional make-up. This contextual relationship is potentially of major significance and can only be estimated when the two mixed responses are modelled simultaneously as occurs in a mixed, multivariate multilevel model.
In summary, the fixed part of such models can include a range of individual-level explanatory variables -- for example, age, gender, and socio-economic status -- and due to the multivariate formulation each of the response variables can have its own set of these making it possible to compare and contrast the relationship between each dimension of behaviour and a number of different personal characteristics. Any of the coefficients from both of these sets can be allowed to vary *and* co-vary at the higher, contextual levels. In the outline given above, only the two intercepts have been allowed to vary. This model could be extended by including a variable recording the gender of respondents and setting it random at the higher level. Besides seeing how the gender gap on each dimension varies from place to place attention could also focus on whether, for example, places where there is an increased probability of men being smokers are also places where men smoke heavily. It can be seen, therefore, that the mixed, multivariate formulation allows the notion of contextual influences to be developed according to a sophisticated interpretation of the co-presence of similarly behaving people.

8.5 A mixed multivariate multilevel analysis of smoking behaviour

To illustrate this procedure for distinguishing, yet handling simultaneously, the occurrence and the quantity of behavioral practices, the results of an analysis of smoking behaviour as recorded in HALS1 will now be reported. In this work, respondents were classified as being regular smokers if they identified themselves as being regular smokers and responded to a question concerning their daily consumption by declaring a rate of one cigarette or more. For these individuals, there was a second, continuous response variable which was the self-declared daily consumption rate.

Table 8.4 Fixed part estimates from a mixed, multivariate multilevel model of smoking behaviour as recorded by the 1984/5 Health & Lifestyle Survey

	(A) Categorical	(B) Continuous
Intercept	-0.58	15.86
Age (Centred around the mean of 46 years)		
Linear	0.07 (5.71)	0.41 (4.76)
Quadratic	-0.001 (-7.52)	-0.005 (-5.43)
Sex (Female)		
Male	0.07 (1.05)^{ns}	4.07 (8.99)
Age-Sex		
Linear	-0.02 (-1.41)^{ns}	0.33 (3.01)
Quadratic	0.0003 (1.62)^{ns}	-0.003 (-2.75)
Social Class (III manual)		
I/II	-0.38 (-5.52)	0.96 (2.06)
III non-man	-0.29 (-3.64)	-0.98 (-1.87)^{ns}
IV/V	0.05 (0.73)^{ns}	-0.29 (-0.75)^{ns}
Missing/Other	-0.22 (-1.22)^{ns}	-0.53 (-0.45)^{ns}
Employment Status (Employed)		
Unemployed	0.49 (4.49)	-0.38 (-0.63)^{ns}
Housing Status (Owner Occupier)		
LA renter	0.69 (11.49)	1.27 (3.47)
Other renter	0.53 (5.91)	1.75 (3.09)
Missing	0.94 (2.32)	-1.99 (-0.82)^{ns}
Marital Status (Married)		
Single	0.07 (0.93)^{ns}	-0.46 (-0.89)^{ns}
Widowed	0.06 (0.57)^{ns}	0.72 (0.98)^{ns}
Div/Sep	0.44 (4.43)	1.44 (2.53)
Ethnicity (White)		
Nonwhite	-0.37 (-2.58)	-5.04 (-5.21)
Missing	-0.60 (-1.74)^{ns}	0.27 (0.11)^{ns}
Household Income (£416-£995 per month)		
Low (£415 per month)	0.11 (1.68)^{ns}	-0.28 (-0.67)^{ns}
High (£996 per month)	0.01 (0.15)^{ns}	-0.27 (-0.46)^{ns}
Missing	-0.05 (-0.76)^{ns}	-0.14 (-0.29)^{ns}
Age Leaving School (Pre-16)		
16	-0.26 (-3.87)	-0.66 (-1.51)*ns*
Post-16	-0.46 (-5.82)	-1.23 (-2.30)
Missing	-1.29 (-2.02)	2.51 (0.52)^{ns}

Note: base (reference) categories given in brackets after each variable description; estimates in column A represent logit values; estimates in column B represent number of cigarettes smoked per day; figures in parentheses represent ratio of estimates to standard error; those terms that are non-significant at the 0.05 level are marked^{ns}.

As discussed, the mixed, multivariate model is based on a response which is a vector consisting of binomial and continuous variables and in the present analysis this vector was formed in exactly the same way as outlined in the previous section. A four level model was formulated with the two mixed response variables at level-1, nested within individuals at level-2, who were classified according to their electoral ward of residence at level-3, and their region of residence, based on *The Economist's* classification (Johnston *et al.*, 1988),[2] at level-4. As there were 6061 non-smokers and 2942 smokers, the actual final data structure consisted of 11,945 responses at level-1, nested within 9,003 individuals at level-2, who nested within 396 electoral wards at level-3, and 22 regions at level-4.

To allow for population composition a set of individual level explanatory variables were used, i.e.: age, gender, social class, employment status, housing status, marital status, ethnicity, household income and age on leaving school. Apart from age, which was represented in the models by a continuous variable centred around its mean, the other characteristics were represented by a set of dummy, indicator variables which were contrasted with the base category of a 46-year old employed woman who left school before the age of 16, is married, does not belong to an ethnic minority, and lives in an owner occupied household which receives a middle income of £416 - £995 per month, the head of which is in social class III-manual. This base category represents the set of individual characteristics that occur most frequently amongst the 9,003 respondents to the survey - that is, the stereotypical individual.

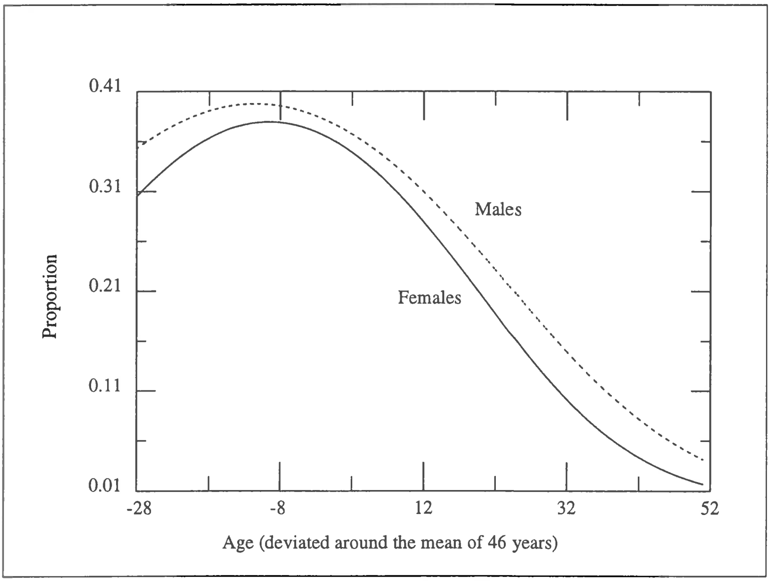

Figure 8.4 The relationship between age and the occurrence of smoking for men and women

To take advantage of the possibility afforded by the multivariate formulation to compare the relationship between different response variables and a set of predictor variables, a number of extra terms were included in the fixed part to examine non-linear relationships with age and age-gender interactions for each dimension of smoking behaviour. The model was estimated using the software package *MLn* (Rasbash and Woodhouse 1995) and the fixed part results obtained are presented in table 8.4 and the random part results in table 8.5.[3] First, let us consider the fixed effects beginning with the intercepts. The estimate for the intercept for the categorical response is given in logit form at the top of column A in table 8.4 and gives a nation-wide average estimate of the stereotypical individual, taking account of gender-specific, non-linear relationships with age, being a smoker. When transformed from its logit value, it represents a probability of 36%. The intercept for the continuous response is given at the top of column B in table 8.4. This represents the average daily cigarette consumption by the stereotypical individual, a female with the characteristics listed earlier, who smokes - here it is 15.86 cigarettes per day. Comparing the other estimates in the two columns in table 8.4, using a pseudo-z test of significance (if the ratio of the estimate to its standard error is more than ± 2, the estimate can be judged to be significantly different from zero at the 0.05 level), we can see a number of interesting differences between the way in which the occurrence of smoking and the quantity actually smoked by those who are smokers are related to personal characteristics. Age and gender-related differences will be considered first.

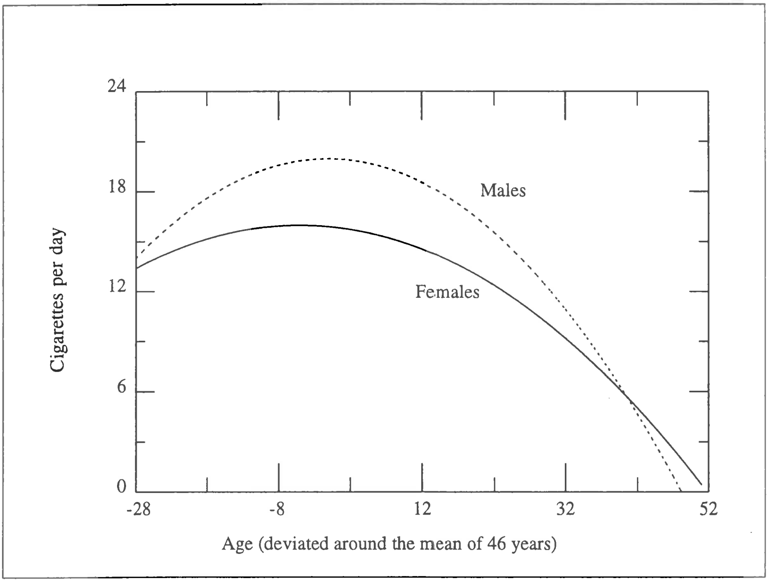

Figure 8.5 The relationship between age and the quantity of smoking for male and female smokers

In terms of gender, whilst we see that there are not strong differences between men and women of average age in the probability of being a regular smoker, there does appear to be a marked tendency for average-aged men who are smokers to smoke more heavily - such men are estimated as smoking slightly more than an extra 4 cigarettes per day compared to female smokers of the same age.[4] In terms of age-related differences, we see a strong non-linear relationship which is identical for men and women in terms of the probability of being a regular smoker. In terms of the quantity of cigarettes consumed, however, there is a suggestion that each gender has a different non-linear relationship with age - the *Age* terms (which represent the relationship between age and quantity for women) and the *Age-Sex* terms (which represent the contrast from women for the relationship between age and quantity for men) are both significant. To ease interpretation graphs have been produced using the estimated fixed-effect terms. The relationships for the occurrence of smoking are given in figure 8.4 and for the quantity of cigarettes consumed in figure 8.5. As can be seen, whilst the relationship between both dimensions of smoking behaviour and age share the same general non-linear form for both men and women (the curves start at a moderately high value, they then peak in middle age before declining to the lowest values in old age), in the case of cigarette consumption, there is a significant gap between men and women which is most extreme in the middle years. It appears, therefore, that in terms of the patterning of smoking behaviour according to age-gender differences the most marked features are the increased likelihood of young, and especially middle-aged, men and women being smokers and the marked tendency for males aged between 35 and 60 who are smokers to smoke heavily.

There are also a number of interesting contrasts between the two dimensions of behaviour on the basis of the other personal characteristics. For the occurrence of smoking there is a marked social class gradient whereby those in higher-status social groups are less predisposed to being regular smokers. In terms of the quantity of cigarettes consumed by those who are smokers, however, apart from some suggestion that those in the highest social status group smoke slightly more per day (though the estimate only has marginal significance), there are no real differences between the different social class categories. The probability of being a smoker is also much higher if an individual is out of work though again this has little significance in terms of consumption.

Important differences on the basis of housing tenure, meanwhile, are evident for both dimensions with those living in rented accommodation being more likely to be smokers and to be smoking more heavily. These effects are, in fact, some of the largest which offers support to recent suggestions that housing tenure cleavages are more sensitive predictors of health-associated socio-economic variations than traditional occupational social class measures (Pugh *et al.*, 1991). Ethnicity is also significant for both dimensions, with ethnic minority groups being less likely to be smokers and less likely to be smoking heavily. These results are in accord with previous research which has led to smoking being labelled a 'white health behaviour' (Graham 1990, p. 202).

Table 8.5 Random part estimates from a mixed, multivariate multilevel model of smoking behaviour as recorded by the 1984/5 Health & Lifestyle Survey

	(A) Categorical		(B) Continuous
		Level 4 (Regions)	
Intercept Variance	0.01 (1.40)		0.28 (1.16)
Covariance		0.08 (2.21)	
		Level 3 (Wards)	
Intercept Variance	0.05 (2.59)		0.23 (0.35)
Covariance		0.09 (1.05)	
		Level 2 (Individuals)	
Intercept Variance	0.99		69.07

Note: estimates in column A represent logit values; estimates in column B represent cigarettes smoked per day; figures in parentheses represent ratio of estimates to standard error; non-binomial variation as described in Chapter 3, section 3.4.3, has been allowed for the level-2 (individual-level) categorical intercept.

Marital status is not associated with either dimension. Interestingly, household income is also not significantly associated with either dimension suggesting that the punitive tax policy approach to tobacco products currently favoured by many governments in the developed world may not represent the most effective means of reducing cigarette smoking.

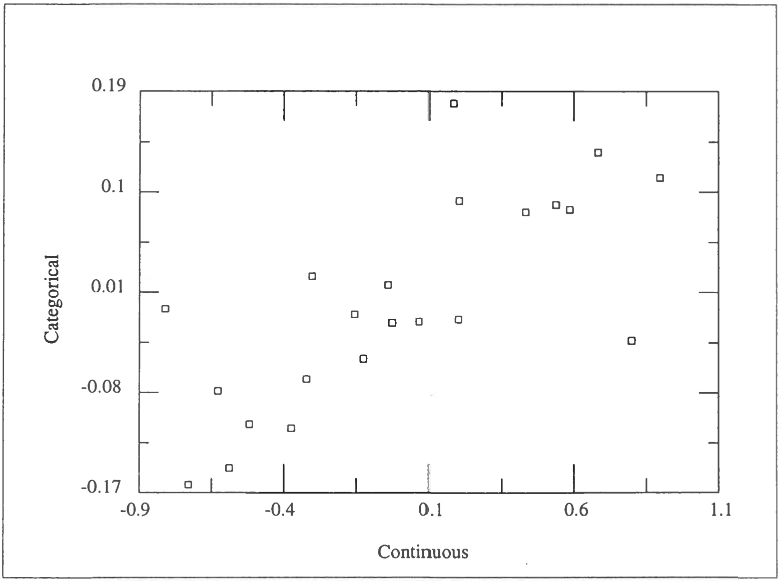

Figure 8.6 Scatterplot of the region-specific residuals for the two response variables (note: the residuals for the categorical (occurrence) response represent logit values; the residuals for the continuous (quantity) response represent the number of cigarettes smoked per day)

Given the high cost of smoking generated by this approach, it raises the interesting matter of why those in less advantaged social class and employment positions are more likely to be regular smokers. Finally, in terms of the individual level variables used in the present analysis, the likelihood of being a smoker seems to also be associated with educational disadvantage and there is some suggestion that people who leave school early are also likely to smoke slightly more.

By way of summary to this discussion of the results for the fixed part of the model, there does, in general terms, appear to be one major difference between the two dimensions of behaviour. Inspecting all the fixed part estimates and their significance ratios reveals that the patterning of cigarette consumption, in contrast to the patterning of who actually smokes, relates more closely to age and gender rather than the other personal characteristics used here. Thus, it seems that once the smoking 'switch' is on, few other factors besides age and gender are significant.

As can be seen in table 8.5 the random part of the model is comparatively simple and only overall, rather than person-type specific, place-differences are examined as this analysis was intended as an initial exploration of the different dimensions of behaviour and an introductory illustration of the mixed, multivariate multilevel approach. Beginning at level-4, the region level, it can be seen that the intercept term for each response variable is random. Inspecting the estimates we see that there is little between-region variation in the probability that an individual is a regular smoker. In this model we also see that there is a lack of

between-region variation in the amount of cigarettes consumed by those who are smokers: the variance of the intercept for the continuous variable at level-4 is estimated at only 0.28 which is not significant according to a χ^2 test ($\chi^2 = 1.34$, df = 1, p = 0.25).[5]
At level-3, the ward level, both of the intercept terms are also random and whilst a small, but significant ($\chi^2 = 6.71$, df = 1, p = 0.01), degree of contextual variation in the probability that an individual is a regular smoker is evident there is virtually no variation in the quantity of cigarettes consumed by those who are smokers: the variance of the intercept for the continuous variable at level-3 is estimated at only 0.23 which is not significant according to a χ^2 test ($\chi^2 = 0.12$, df = 1, p = 0.73). It appears, therefore, that the cigarette consumption of smokers relates almost completely to individual characteristics and independent higher level contextual or area effects, in terms of overall place-differences at the ward or region level, have virtually no influence. This is confirmed by examining the level-2 random part of the model. Here, the continuous intercept term represents the degree of variation between smokers in terms of the number of cigarettes consumed. As can be seen this value is very large and considerably bigger than estimates for the variation in the continuous intercept at any of the higher levels confirming that most variation in the number of cigarettes smoked is at the individual level.[6]

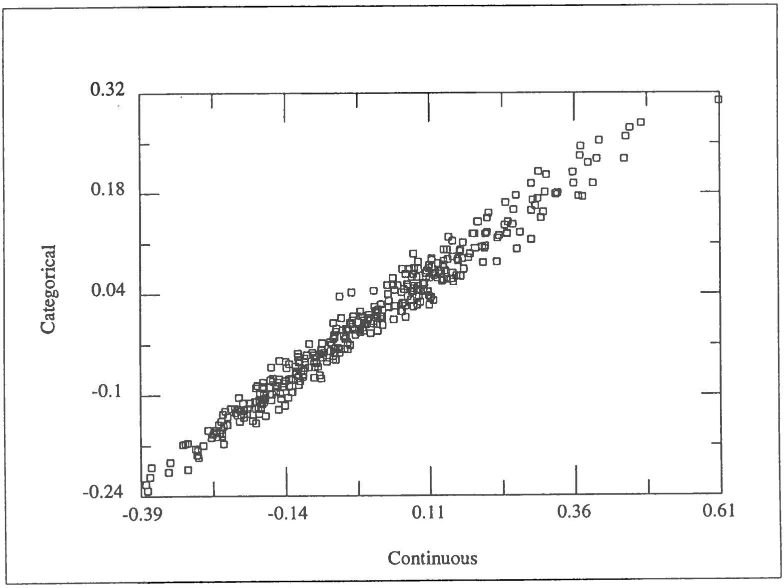

Figure 8.7 Scatterplot of the ward-specific residuals for the two response variables (note: the residuals for the categorical (occurrence) response represent logit values; the residuals for the continuous (quantity) response represent the number of cigarettes smoked per day)

As there is hardly any higher-level variability in the amount of cigarettes consumed by smokers and only a marginal amount in the probability that an individual is a smoker we need to be careful when considering the existence of any systematic relationship across contextual settings between the two. As stated earlier, it is the covariance term that assesses the degree to which the two dimensions are related across contexts. This term, however, cannot be considered in isolation for if there is to be a meaningful relationship then both dimensions should display a significant degree of contextual variation. Thus, we need to examine the covariance *and* the variances term at each higher level.

Doing this at level-4, the region level, we see that whilst the covariance term is positive and significant ($\chi^2 = 4.88$, df = 1, p = 0.03), suggesting that in those regions where there are many smokers many cigarettes are smoked, neither intercept term, as already noted, displays a significant degree of contextual variability. This suggestion is supported by the reasonably neat positive linear relationship shown in figure 8.6 which is a scatterplot of the region-specific residuals for each intercept.[7] It is important, however, to realise that these residuals are only estimates and, as indicated by the non-significance of the region-level variance terms, would have large standard errors. Consequently, the significant covariance term and the scatterplot cannot really be interpreted as evidence that those regions with many smokers are heavy smoking regions.

At level-3, the ward level, as already noted, whilst the categorical intercept displays a marginally significant degree of contextual variability, the continuous intercept displays virtually none and the covariance term is also non-significant ($\chi^2 = 1.11$, df = 1, p = 0.29). A scatter-plot of the ward-level residuals, figure 8.7, where each point represents one of the 396 wards sampled in HALS1, again portrays a positive linear relationship due to the positive covariance but as before this cannot really be interpreted as a sign that wards with many smokers are high smoking wards.

In summary, the lack of variability in the intercepts together with the lack of significance in the covariance terms suggest that in the present analysis there is no strong evidence of a place-based effect, in terms of overall place-differences, either for regions or wards whereby the prevalence of smokers in a place reinforces the actual amount of smoking that is practised in that place. In terms of contextuality, the most striking finding of this analysis is that cigarette consumption displays very little variation between places once population composition is controlled for. Thus, this analysis suggests that smoking behaviour does not display a considerable degree of contextual variation for the specific 'geographies' used here and that there is much greater variation in smoking between different types of people than between different places.

8.6 Conclusions

This paper has shown how one type of model that can be developed within a multilevel framework -- the mixed, multivariate multilevel model -- affords the opportunity to distinguish different dimensions of behaviour whilst considering them simultaneously. This ability brings a number of technical and substantive advantages for quantitative research. By distinguishing the different dimensions of behaviour, representative and meaningful estimates of individual-level relationships and contextual variabilities can be obtained for each. Since the different dimensions of behaviour are handled simultaneously, these estimates can be readily compared and contrasted thus allowing research to focus on the similarities and differences between particular aspects of behaviour. Of particular importance is the way in which the multilevel approach allows researchers to investigate notions of contextuality in terms of place-specific cultures whereby the co-presence of similarly behaving people reinforces the number of times people practice particular behaviours.

In terms of the empirical analysis presented here, places, be they wards or regions, did not seem to have any role in structuring co-presence effects in smoking behaviour as neither dimension of behaviour displayed any significant degree of between-place variation after including a range of appropriate and relevant individual variables to take account of the population composition of particular places. Thus, it seems that it is the characteristics of people rather than places that is important for both dimensions of smoking behaviour. As was noted, however, the model reported was comparatively simple with place-effects being considered only in terms of overall differences and no attempt being made to identify complex, person-specific forms of contextuality. Further, more complex, models need to be estimated to assess whether the social patterning of smoking takes different forms in different places.

Finally, it is important to note that these types of models can also be applied more generally as they can handle polychotomous response variables together with several continuous response variables. For example, this would be useful in the situation where we wanted to model a 2x2 classification of individuals on the basis of their smoking (yes/no) *and* drinking behaviour (yes/no), both of which would be measured by continuous response variables.

Acknowledgements

The author would like to thank the ESRC Data Archive at the University of Essex for supplying the Health and Lifestyle Survey Data (ESRC Data Archive, 1988).

Notes

1. This distinction has a broad application. For example, in educational research, interest focuses on both whether children pass exams and, if they do, by how much. In health services research, attention focuses on whether doctors prescribe medication to certain patients or not, and, if they do, how many prescriptions they make. Both these examples are ideally suited to a mixed, multivariate multilevel approach.
2. Essentially, this grouping represents a sub-division of the standard administrative regional classification into twenty-two metropolitan and non-metropolitan areas. Consequently, it is considered to be more finely attuned to the regional, 'macro' geography of the country than the ten Standard Regions commonly used for administrative purposes.
3. Since *MLn* was used, rather than its predecessor *ML3*, the terms relating to the categorical response were calibrated using new improved estimation procedures based on the second-order Taylor expansion and Partial Quasi-Likelihood approximations (Goldstein 1994). Non-binomial variation was allowed for the categorical level 2 (individual-level) random term.
4. The estimates of average female and male daily cigarette consumption in the mixed multivariate multilevel model (15.86 and 19.93 respectively) are very different, therefore, compared to those obtained from the simple model given in equation (1) (4.7 and 6.1 respectively). Obviously, the two are not directly comparable as the full range of predictor variables were not included in the simple model. However, this is not the reason for the differences. Instead, they result because the occurrence of smoking has been separated from the quantity of smoking in the mixed, multivariate, multilevel model whereas in the model based on equation (1) they remain confounded. This was confirmed by estimating a mixed multivariate multilevel model with only two intercept terms and a single predictor variable relating to gender and quantity smoked. On the basis of this model, average female and male cigarette consumption was estimated to be 13.12 and 15.84 cigarettes per day respectively.
5. Since the exact distribution theory of random terms is poorly understood, their significance should be assessed using the contrast testing procedure based on a χ^2 statistic available within the *MLn* software package rather than on a pseudo-z test.

6. A null model was also estimated which gave the degree of between-individual variation in cigarette consumption before the inclusion of any fixed-part individual level variables. This was estimated at 77.3 and therefore we can see that the inclusion of the individual level explanatory variables does not produce a substantial reduction in the variation between individuals. It seems the variables included in this analysis only have marginal 'explanatory' significance for cigarette consumption and this raises the interesting issue of what does account for the 'unexplained' individual variation in the quantity of cigarettes smoked. One possibility is access to social support networks. The individual-level variables used in this analysis relate either to demographic characteristics or access to material resources and there are no measures of social isolation or integration which have been identified as having significance for smoking behaviour (Graham 1993). There is also the possibility that this 'unexplained' individual variation relates to contextual effects but that 'inappropriate' geographies have been applied in this analysis.
7. In figure 8.6 there are two potential outliers which will have inflated the estimate of the degree of between-region variation. If, for some reason, it was believed that these regions were not part of the single 'national' distribution but were in some way untypical, they should not be regarded as being 'exchangeable' with the remaining random sample of regions and they would need to be treated as fixed effects. Whilst such decisions can be made empirically after fitting a model there are dangers to this approach as the models are based on shrinkage estimation procedures (Jones 1993). Consequently, such decisions should either be made on theoretical grounds or, best of all, at the design stage by ensuring the data comes from a representative sample taken from a clearly-defined population (Draper 1995).

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Appendix: Specifying mixed, multivariate multilevel models with *MLn* software

This appendix shows how to prepare the interleaved data structure outlined in the chapter and set up a random intercepts mixed response multilevel model using *MLn*. For full details of specifying such models see Rasbash and Woodhouse, 1995, Appendix E, pp. 79-90.

MLn Commands	Comments
DINPut C1-C5	Input from disc, 5 variables sorted in the order people within places with 'Age' centred and put into columns 1 to 5
NAME C1 'Person' C2 'Place' C3 'Smoker' C4 'Amount' C5 'Age'	Name the columns
CHANge 0's in 'Amount' to -9999 and put back into 'Amount'	Change the zero values in 'Amount' indicating non-smokers to -9999 for later LISTwise deletion (smokers have non-zero values in 'Amount')
VECT 2 variates in C3 C4 output to C10 identifier to C11	The VECTorise command places two response variables from one data record into two consecutive records and allows an identifier to be specified
REPEat 2 times the data in C1 C2 C5 output to C8 C9 C12	The variables in C1, C2 and C5 are carried into the new columns C8, C9 and C12 for each of the two new records
ERASE C1-C5	Erase the original data columns
NAME C8 'Person' C9 'Place' C10 'Response' C11 'Iden' C12 'Age'	Name the new columns
DUMMies C11 C13 C14	Create two dummy variables to show which record relates to which response: a 1 in C11 ('Smoker' as response) is coded 1 in C13 and 0 in C14, and a "2" in C11 ('Amount' as response) is coded 0 in C13 and 1 in C14
NAME C13 'Smoker' C14 'Amount'	Name the dummy variables
CALC C15 = 'Smoker' * 'Age'	Create the explanatory variable showing the relationship between age and the probability of being a smoker
CALC C16 = 'Amount' * 'Age'	Create the explanatory variable showing the relationship between age and the number of cigarettes smoked
NAME C15 'Smoke Age' C16 'Amnt Age'	Name the two new variables
LISTwise delete -9999 values in C8-C16 output to C8-C16	Delete any records which contain -9999 (the second response variable for non-smokers)
CALC C17 = 'Smoker'	Create variable to model the between-person level-2 binomial variation
NAME C17 'Bvar_s'	Name this variable
AVERage 'Smoker' B1	Obtain the average so as to store the number of cases in B1
PUT B1 copies of the value 1 into C18	Create a string of 1's the appropriate number of cases long to act as the level-1 identifier column
NAME C18 'Cons'	Name this variable
CALC C19 = 'Cons'	Create another string of 1's to represent the denominator which is needed by MLn
NAME C19 'Denom'	This variable must have the exact name 'Denom'

MLn Commands	Comments
IDENtifying codes for level 1 in 'Cons' 2 in 'Person' 3 in 'Place'	The IDENTIFY command specifies the data structure of the mixed responses at level 1, people at level 2 and places at level 3
EXPLanatory 'Smoker' 'Amount' 'Bvar_s'	Put the explanatory variables into the fixed part of the model (specify a null random intercepts model first)
FPAR 'Bvar_s'	'Bvar_s' will appear only in the level 2 random part
SETVariance at level 3 based on 'Smoker' 'Amount'	Specify the level 3 (places) random part (random intercepts)
SETVariance at level 2 based on 'Bvar_s' 'Amount'	Specify the level 2 (people) random part
LRElement at level 2 'Bvar_s' 'Amount'	Remove the covariance between the two responses at level-2 (between-people) - it is best not to estimate this term
RESPonse 'Response'	Specify the response variable
SUMMary	Check the data structure
NOTE nonlinear specification	Set up the information required to estimate nonlinear models in MLn
FPATH C:\MLN\NONLIN	Specify where the nonlinear macros are
PREFile PRE	Specify pre-processing macro file
POSTfile POST	Specify post-processing macro file
SET B10 0	Set binomial link function and error distribution
SET B11 1	Set first order approximation
SET B12 0	Set MQL linearising procedure
SET B14 0	Set variance at level 1 to be constrained to binomial distribution
SET B15 2	Set multivariate structure
SET B16 1	Set mixed continuous/categorical response model
LINK 'Bvar_s' G9	Tell the macros which variable is modelling the binomial variation
LINK 'Amount' G11	Tell the macros which explanatory variables are modelling the continuous response and should not be linearised
BATCh	Turn batch mode on
START	Start estimating the model
FIXEd part results	Display the fixed part estimates
RANDom part results	Display the random part estimates
EXPLanatory 'SmokeAge' 'AmntAge'	Include the variables relating to 'Age' in the fixed part of the model
LINK 'Amount' 'AmntAge' G11	Recreate G11 to show which variables are not to be linearised in this newly specified model
NEXT	Estimate the newly specified model starting from the current estimates

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