CHOICE AND DEMAND IN A SOCIAL HOUSING SYSTEM: POLICY SIMULATIONS FOR GLASGOW[1]

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Abstract
This paper develops a model for simulating an urban housing system dominated by non-market social housing, primarily to forecast demand for social housing under different scenarios. The urban system concerned is the city of Glasgow and its suburbs, a post-industrial city in West Central Scotland.

There is an established literature concerned with the development of metropolitan housing market models in both the USA and the UK. The present model draws from both traditions but is heavily influenced by the work of Meen (1999). The Glasgow model is largely demand-determined, only a limited supply-side with market-adjustment occurring through supply adjustment. Data for the model comes from the Scottish House Condition Survey 1996 and from extraneous housing, multiple deprivation, population and household estimates.

The focus of the paper is on the demand-side. Demand in the model is composed of three elements: new household formation, net migration and the tenure and locational choices of existing households. It is this third element that poses the most difficulties and is modelled separately using a nested multinomial logit (NMNL) formulation. The results from the NMNL model attempt to explain the locational, tenure and mobility decisions of existing households. The results are then adopted as conditional probabilities in the simulation model. The paper then sets out the structure of the basic model and reports on the model's performance across a range of possible scenarios. The paper concludes by examining the academic and policy implications of the model and suggests future avenues for refinement and further work.

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1. INTRODUCTION

This paper reports research to model and forecast the Glasgow housing system. The motivation for the work arose out of two research requirements. First, Glasgow City Council wished to estimate the future demand for social housing across the City under a range of plausible economic and policy intervention scenarios. Second, Scottish Homes, the national housing agency, wished to commission research aimed at the construction of metropolitan housing models that could be used for housing planning purposes. The research team viewed this coincidence of wants as a rare opportunity to construct a computer model of a UK city's housing system, building on work by Meen and Andrew (1999) which examined housing and labour markets in London and the South East, as well as the North American tradition of simulation models of metropolitan housing systems (Anas and Arnott, 1991, 1993a, 1993b, 1993c, 1997, McFadden, 1978, Quigley, 1985, Wheaton, 1979). A distinctive feature of the present model is its focus on non-market social housing within a tenure choice framework (normally, the tenure choice focuses on owning versus private renting).

In this paper, we begin by setting out the housing and economic context for the model. Second, the paper examines the issues involved in the construction of such a model: its structure, its data and modelling requirements, its strengths and weaknesses. In particular, the paper focuses on a separate modelling exercise required for the model, namely, the need to construct a discrete choice model that explains the location, tenure and mobility decisions of existing households. The results of such a nested multinomial logit model are reported and appraised. Finally, the full computer model is implemented and results are reported, including scenario simulations, along with consequent policy implications. The concluding section considers refinements and future possibilities and applications of the model.

2. THE GLASGOW HOUSING SYSTEM

Glasgow is Scotland's largest city, located to the west of the country's Central belt, forty miles from Edinburgh. Glasgow is situated on the River Clyde and that fact plus strong canal links with the east of Scotland allowed the City to grow in the 18th and 19th

Centuries through manufacturing trade west to North America and East to Northern Europe. The City experienced rapid urbanisation in order to fuel the development of key industrialisation industries: coal and steel, shipbuilding, engineering, chemicals and related industries. Urban population grew rapidly with large-scale in-migration from both the Scottish Highlands and from rural Ireland. The City quickly became the hub of a much larger industrial conurbation across west-central Scotland. Population peaked in the inter-war period at just over one million before falling back steadily to its present levels of around 600,000. Between 1951 and 1991, the annual average population loss was 12,000 – primarily suburbanisation through public policy slum clearance and new town developments and more recently through the private choices of moving households.

A major reason for contraction has, of course, been the economic decline of the City that has been well-documented elsewhere (e.g. Maclennan and Gibb, 1988; Bailey, et al, 1999). The primary reason for decline was deindustrialisation – Glasgow had a relatively high share of manufacturing jobs and lost 70% of them between 1971 and 1997. Construction, Transport and communications jobs were also disproportionately lost in Glasgow. At the same time, services growth has, until recently, been relatively modest in Glasgow (Bailey et al, 1999, p.13). These broad trends have also been associated with shifts in employment location with patterns of decentralisation of jobs away from Glasgow in the 1950s and again in the 1980s.

From around 1980, there has been a concerted effort to improve both the image and the economic base of the City, pursuing many of the policies and initiatives that will be familiar from North America. The main elements were: image-building, attracting inward investment and massive reinvestment in the existing tenemental housing stock (typically transferring stock locally to the voluntary sector) and through the regeneration of neighbourhoods (central, inner city and peripheral). At the same time, the City succeeded in promoting Glasgow and some of its more attractive neighbourhoods as successful, dynamic and cosmopolitan places to live and work (Maclennan and Gibb, 1988).

Despite these initiatives, Glasgow retains profound problems of economic non-activity, concentrated levels of social or multiple deprivation and relative economic decline

compared with its suburbs. More than half of the multiple deprived small areas in Scotland are found within Glasgow. Unemployment is stubbornly high (as is economic inactivity, reliance on incapacity benefit and benefit-dependence) and Glaswegians suffer from a range of health problems associated with poverty, bad housing and disadvantage. There is considerable public policy debate about the future economic strategy for the city. However, at the heart of all of the discussions about Glasgow's possible futures is the key problem of tackling several, related housing concerns.

Glasgow has many of the housing problems shared by other parts of urban Britain: polarisation of housing outcomes between owners and tenants; poor quality and badly maintained public housing saddled with large debt repayments; pockets of very high value housing; a combination of both market failure and state failure in certain aspects of the organisation of housing in the City, and, an increasing problem of low demand for social housing characterised by surpluses of social housing and declining demand crudely measured by waiting lists. What makes Glasgow unique is the scale of the problem: the City council owned and managed more than 117,000 units (1997).

The tenure structure in 1997 broke down as 44% owner-occupied, 4% privately rented, 10% rented by non-profit housing associations and co-operatives and the remaining 42%, rented by the City council. In relation to Scotland, this implies a relatively small owner-occupied sector and a relatively large social rented sector. Glasgow house prices are lower than the Scottish average (but there are some local hot spots). The recent national house condition survey (1996) suggests that Glasgow exhibits particular housing problems: bad housing conditions, particularly problems of dampness and condensation, the low income dependency of tenants, high vacancy rates in certain areas, major backlogs of disrepair, growing homelessness (the highest levels in Scotland) and associated management problems in letting property. Evidence suggests that demand for social rented housing is declining in aggregate terms and in specific neighbourhoods (Gibb, et al, 2000).

Presently, there are two key housing policies underway in Glasgow. The first is to create new private neighbourhoods for families in an attempt to reverse the out-migration of couples and families. Second, there is the on-going investigation of transferring *all* of the existing council stock to a new social landlord vehicle, the Glasgow Housing

Association, as a forerunner to community ownership locally of the ex-council stock, thereby unlocking private finance to fund the massive backlog of repairs and improvements required to be carried out to the stock. Public spending rules mean that local authority housing investment, even though it is repaid by rental income, counts as public spending in the year of borrowing and is thus controlled (and prevented) by Government. Changing ownership and effectively shifting to the voluntary sector opens up the opportunity to borrow from the private sector and to plan repairs properly. A critical concern for those lenders who might fund the estimated £1.6 billion syndicated loan thought to be involved is a defensible estimate of future demand for social housing in the City.

The policy-level or practical case for a computer simulation model of the wider Glasgow housing system rests on a number of reasons:

1. A wider understanding of the housing choices and preferences of households in the Greater Glasgow area is required to feed into the economic and physical planning strategy of the City and its suburbs.
2. A need by the Council to forecast demand for social rented housing under a range of plausible economic and policy environment scenarios (for instance, the Council has been pursuing a policy of large-scale demolition of its own stock for several years).
3. A wider requirement to understand the private market processes governing the housing market of the city and its suburbs. This would facilitate housing planning both in terms of social provision but also land release for private house building (seen to be critical to re-attract commuters back to the City).
4. An interest by Scotland's housing agency in the feasibility of a replicable model of urban housing systems.

These prerogatives coincided with a long-standing desire to develop a comprehensive model of the wider Glasgow housing system. Consequently, a feasibility study was commissioned in 1999, followed by the full simulation model, completed the following year (Gibb, Meen and Mackay, 2000).

3. AN ECONOMIC MODEL OF THE HOUSING GLASGOW SYSTEM

Our purpose is to construct, on economic principles, a coherent simulation model of the Greater Glasgow housing system, such that forecasts and scenarios can be developed for future levels of housing demand. There is a long tradition of urban housing market

models in the United States (Anas and Arnott, 1993) and more recently, similar techniques have been deployed in the UK (Meen and Andrew, 1999).

A key feature of these models is that they are able to incorporate in a consistent manner both the demand and supply sides of the market and can show how the system responds to changes in economic and demographic conditions, including appropriate feedback effects. Simulation models allow us to trace through these impacts. This allows the economist to understand better market dynamics and provide policymakers with information about the possible consequences of policy interventions and environmental changes.

Of course, it is not possible to model all of the elements thought to explain these dynamic relationships and interactions. Economists are constrained in their modelling strategy by the lack of suitable data (particularly across space) and by the conceptual complexity of many of the relationships themselves. The model develops by focusing on a number of key relationships or equations and by combining new econometric modelling with imposed values for other relationships taken from the literature and/or based on the modeller's judgement. The simplest way to explain these issues further is to describe the elements of the Glasgow model itself.

The Greater Glasgow model

The Glasgow model has three main elements: a demand-side, a supply-side and a market-clearing relationship. Of these, the demand-side is the most complex and consists of three main parts: new household formation, net migration and the housing choices (i.e. mobility, tenure, location) of existing households within greater Glasgow. Again, it is the existing households who pose the most problems for the model's development (and this is the main subject of the next section of the paper). However, at the relatively small spatial scale with which we are concerned, these flows by existing households are crucial. Unfortunately, few studies in Britain exist in the literature from which we can draw experience.

Figure 1 illustrates the model structure. The geography of Greater Glasgow is reduced to three elements for simplicity: North Glasgow (i.e. North of the River Clyde within the City boundaries), South Glasgow (i.e. South of the River Clyde within the City

boundaries) and the suburbs (consisting of contiguous local authorities). As an example, the first diagram examines the situation for owner-occupiers in the north of Glasgow (there exists five other corresponding diagrams for renters in the North and both owners and renters in each of the South and Outwith Glasgow). Total housing demand in the north for owner-occupiers will depend on the sum of nine inflows:

?? New household formation within the North of owner-occupying households
?? Net in-migration from the rest of the UK to Greater Glasgow
?? Non-movers in owner-occupation from within the North
?? Within the north movers switching from renting to owning
?? Within the North moving within the owner-occupied sector
?? Moving from the South to the North switching from renting to owning
?? Moving from Outwith to the North switching from renting to owning
?? Moving from the South to the North within the owner-occupied sector
?? Moving from Outwith to the North within the owner-occupied sector.

Owner-occupied housing demand in the North will also depend on five outflows:

?? Movers within the North switching from owning to renting
?? Movers going from North to South switching from owning to renting
?? Movers going from North to Outwith switching from owning to renting
?? Movers going from North to South within the owner-occupied sector
?? Movers going from North to Outwith within the owner-occupied sector.

The diagram also indicates that the supply-side is much simpler. Owner-occupied supply in the North is a function of the existing stock, new construction, demolitions and transfers from the rented stock (normally the Right to Buy). Demand and supply for owner-occupation in the North are then 'cleared' by gradual supply adjustment (rather than through price adjustment) to bring the system (households and stock) into balance.

The second diagram (Figure 2) 'blows up' one of the boxes from the demand inflows in the first diagram and describes how it is aggregated up from the seven individual household types identified in the model. If the focus was only on renters previously living in the South who move to owner-occupation in the North, then one would require to track those households (in each of the seven household types) living in rented

housing in the South in the previous period and then in the current period calculate their respective probabilities of moving (which is a function of income and demographic factors), choice of location i.e. moving to the North from the South and also tenure (which depends on neighbourhood quality, previous location and costs). This is done separately for each of the seven household types in order to calculate the total number of movers within Greater Glasgow who make this particular switch. The same process is then repeated for all of the boxes described in Figure 1.

New household formation is based on Planning data that provide zero migration population forecasts and headship rates. From this and an assumption about the future age distribution of the propensity to form households, new household projections in each of the three sectors of our Glasgow model (North, South and Outwith the City) can be obtained. Net migration from the rest of Scotland calculates net migration as a function of relative employment growth, relative house prices (both with respect to Scotland) and previous net migration. This provides information on population flows that have to be converted into households again based on assumptions about the propensity to form certain household types.

The existing households component (that determines internal tenure and dwelling mobility choices) is the largest part of the model and makes extensive use of the conditional probabilities derived from the econometric model discussed in the next section of the paper. Essentially, the equations in this part of the model determine the proportion of existing households who move in each period across the three areas within Greater Glasgow, how many change tenure and how many do not move or otherwise alter their housing requirements.

The three elements of the demand-side are constructed in a series of equations that allocate seven household types to three different areas and two (owning and renting) tenures. Efforts to add house type as a fourth dimension of choice failed to work statistically. Data was collected for the 1996 values for all of the households that go into each type/area/tenure box and these are calibrated to change through time as a result of the cumulative effect of the probabilities derived from the various modelled and imposed relationships (and their interaction with supply).

Housing supply is constructed by adding owner-occupied supply (net of demolitions) and rented supply (net of demolitions). A new housing price elasticity of supply is imposed on the owner supply-side and account is taken of the impact of council house sale transfers from renting to owning. The market is 'cleared' by quantity adjustment as supply expands to close any gaps between demand and supply. In essence, the model clears by assuming constant real house prices. Once again, starting values data are collected for 1996 for all of these variables.

This project is about the demand for social housing in Glasgow. It is therefore important to clarify the role of *private renting* in this model. The two tenures used in this model are 'owning' and 'renting'. Renting encompasses both social and private renting. This means that an estimate of the private rented component has to be deducted from our renting projections in order to arrive at the level of social rented housing demand.

Why has the model been constructed in this way? The private rented sector (PRS) is small in Glasgow and it is thus not possible to derive meaningful sample scores for private renting households in the econometric model. Second, there are grounds for treating the PRS in Scotland as a residual part of the social rented sector – evidence of this can be found from analysis of the composition of private tenants in the 1996 Scottish House Condition Survey. In our results, we use the 1996 and 2005 estimates of tenure share provided by the extraneous planning data to calculate the residual share of social renting that needs to be deducted to account for the PRS.

Data for the Model

The model requires (1996) starting values for the number and composition of households (disaggregated by tenure, location, household type, age band of household head) as well as the housing stock (disaggregated by tenure and location). There are also starting values required for house prices and rents (again, disaggregated by tenure, location and property type). Most of this data was collected from official Planning sources but with missing data grossed up from survey data.

Extensive use within the model (see below), was made of the Greater Glasgow component of the 1996 Scottish House Condition Survey (SHCS). The SHCS is an extensive household and physical survey of 18,000 households and homes. Data is

collected on households, their economic position, their housing histories, intentions and experiences, as well as property characteristics and finances. The sample basis is mixed, including a random component, a longitudinal component (the earlier wave was also random) and two boosts, one to increase particular property types and one bought by various local authorities to increase the statistical strength of samples within their boundaries. The sample size for the SCHS as a whole was 18,158. The sample data used for the Greater Glasgow modelling involved more than 5,391 households.

A further source of data was wholly extraneous: where no information was readily available or no model existed or could be constructed at the relevant spatial scale, values or models were imposed. This was the case for the price elasticity of supply and a model of long distance migration – both of which were based on earlier research. A third such data source used was the recently developed area deprivation index for Scotland (Gibb, et al, 1998). This small area (post code sector) index of multiple deprivation (based on six domains of disadvantage) was used as a proxy for neighbourhood quality and conditions.

The Greater Glasgow area which is the subject of the model is defined in three parts: within the present City boundaries and North of the River Clyde; within the present City boundaries south of the River Clyde; and, all of the remaining six contiguous Glasgow local authorities (West Dunbarton, East Dunbarton, North Lanarkshire, South Lanarkshire, East Renfrew and Renfrew). Both Glasgow and South Lanarkshire had boosts to their sample within the SHCS. In terms of relative sizes, the planning data reported in Table 1 indicates that the relative sizes of the three areas are very different. In 1996, there were 170,686 households in the North but only 99,247 in South Glasgow. In 1996, there were 438,501 outwith Glasgow. The respective percentage shares were 14:24:62. The tenure pattern across the three areas is also distinctive with 60% home ownership outwith the city but between 39-49% within the City boundaries.

Table 1 Households in 1996

Tenure	**South**	**North**	**Outer**	**Total**
Owners				
1996	47642 (48)	67284 (39)	262230 (60)	377156 (53)
Private rent				
1996	5046 (5)	7839 (5)	7776 (2)	20661 (3)
Social rent				

1996	46559 (47)	95563 (56)	168495 (38)	310617 (44)
All households				
1996	99247 (100)	170686 (100)	438501 (100)	708434 (100)

Source: Glasgow and Clyde Valley Joint Structure Plan Team (GCVJSPT)
Note: percentage figures (in brackets) are rounded.

4. THE NMNL CHOICE MODEL

The approach adopted is analogous to that in the field of transport economics where one often wants to model the mode of transport chosen by different individuals and identify those factors that determine specific choice of travel (rail, air, car or bus). It is straightforward to see how this is relevant to the area of housing choice since the options faced by the household are just as complex: for instance, the choices to own v rent, choose location A or B, decide to move or to stay, or to pick a house or a flat.

Imagine that households only concerned themselves with their tenure choice: owning v renting. If this were the case then modelling the household's decision would be fairly straightforward. However, to do so would be to oversimplify the choice and would miss out some important information relevant to the typical housing choice decision. Most importantly, it ignores the role of *location* in the decision. It is likely that if the household cannot move to the location that they prefer then they may not move at all. Thus the problem is that the decision to move may be 'joint' or *conditional* on finding the 'right' location. In effect, the two decisions are simultaneous and cannot be disentangled. Figure 3 illustrates the complexity of the housing choice problem. In the figure, called a decision tree, the choice of private housing versus public housing is clearly conditional on location and the decision to move or not. There are many permutations of such trees. The main point to take, however, is that the housing choice decision is a complex one *conditional on other factors* as well as the ultimate choice of owning versus renting.

This conclusion has consequences for the modelling of residential choice. Instead of modelling tenure choice using a discrete choice procedure such as a logit regression, one must now explicitly take into account the other decision levels. In effect, the 'ultimate' choice of owner occupation versus renting is now *nested* within these other decision levels. As a result, modellers use a procedure called nested multinomial logit (NMNL) to model the likelihood of individuals choosing to move to a specific location

and tenure. In other words, each level of the decision tree is modelled. There is also a technical reason to support this approach – in seeking to overcome the problem of the Irrelevance of Independent Alternatives (IIA). The non-nested model assumes that providing an extra alternative, for instance, a new location, will not affect the choice made. This is implausible in the context of housing choice – a new development creating effectively a new location alternative will impact on wider housing choices - and the nested model allows explicit account to be taken of alternatives (McFadden, 1978; Quigley, 1985). However, the statistical and computational requirements to make the NMNL model work are onerous and can lead to the researcher having artificially to force the model to work.

The model operates by stacking data – one row for each possible choice. This means that if a household has seven choices (three locations, two tenures and one non-moving option), then each observation involves seven rows – factoring up the statistical and computational complexities of the model. We saw above that the data is drawn primarily from the SHCS and that this also constrains the flexibility of the model. This is particularly a problem because the moving decisions that we are interested in are typically *push* factors that involves housing change at the margin for instance, the new housing requirements that emerge from a household splitting. The SHCS data set only allows estimation of household type and size, not *recent change* to the household. At the same time, one can plausibly argue that location choices are driven by wider non-housing factors. Following this argument, extensive use is made of of multiple deprivation indicators as a measure of neighbourhood quality.

There are a number of ways in which one could construct the household choice decision tree. Initially, the research team wanted to distinguish between flats and houses but it quickly became apparent that the data would not support a fourth level in the tree with too few observations being observed in this lowest level of the tree to make estimation feasible. Consequently, the research team opted to try a three level tree as illustrated in Figure 3. The decision to try a 3 level tree did resolve the problem of too few observations in the choice categories but resulted in some counter-intuitive and unstable results. These counter intuitive results occurred as a result of a lack of variation in the data used to model the *locational* choice level of the tree. Basically, the values of the deprivation index and housing costs terms, the factors we were using to model the

locational choice level, were more or less identical for the North and South of Glasgow. Consequently the study team decided to adopt a two level tree structure, as shown in Figure 4.

As can be seen from Figure 4, the location level is now modelled together with the tenure choice level. This is readily achieved by interacting the location choice variables/factors (such as the deprivation index and the housing cost term) with constants for North, South and Outwith Glasgow. Using this specification, robust results were obtained compatible with what was expected from our understanding of the housing choice literature. The results for the two-level model used to construct conditional probabilities are illustrated in Table 2 below and are presented in two parts. The first part consists of the results for tenure choice and location i.e. owning (Private) versus renting (Public) and the second part consists of the results for the move decision. The results have been deliberately simplified to ease interpretation (standard results and diagnostics are presented in Appendix 1). The full variable description is given as well as the sign on its coefficient and an indicator of its significance or importance, represented by a *. The number of stars indicates the level of statistical significance (one star implies a ten per cent level of significance, two stars, a five per cent level of signficance and three stars a one per cent level of significance).

Looking at part A of Table 2, the results suggest that housing costs play a statistically insignificant role in the tenure/location choice decision of households. Instead, the greater the availability of social housing then the more likely is the household to move into rented (public sector) housing in the north of Glasgow. This is also true for SOUTH and OUTWITH. The *** indicate that these variables are highly significant. Household permanent income is also a highly significant factor in housing choice. The results also say that low income households tend to choose rented (public sector) housing, in all locations. (NORTH, SOUTH and OUTWITH). As expected, the level of deprivation in an area impacts strongly on location choice. Households who choose low deprivation areas tend to be in owner occupied housing - again this holds true across all locations. The final significant factor in tenure choice is previous location with those households who moved from the North and those households who moved from the South more likely to remain in those areas.

Table 2 Econometric Model Results

A. Tenure Choice Decision (Bottom level of decision tree)

Variable	Sign	Significance
Housing cost	_	ins
Public sector rationing (interacted with NORTH and PUBLIC)	+	***
Public sector rationing (interacted with SOUTH and PUBLIC)	+	***
Public sector rationing (interacted with OUTWITH and PUBLIC)	+	***
Household permanent income (interacted with NORTH and PUBLIC)	_	***
Household permanent income (interacted with SOUTH and PUBLIC)	_	***
Household permanent income (interacted with OUTWITH and PUBLIC)	_	***
Deprivation score (interacted with NORTH and PRIVATE)	_	***
Deprivation score (interacted with SOUTH and PRIVATE)	_	***
Deprivation score (interacted with OUTWITH and PRIVATE)	_	***
Household's previous location is NORTH	+	***
Household's previous location is SOUTH	+	***

B. Move-stay Decision (Top level of decision tree)

Variable	Sign	Significance
Household permanent income	_	*
Head of household is married or co-habiting	_	***
Number of children aged below 16	+	ins
Head of household is aged 16-24	_	***
Head of household is aged 25-29	_	***
Head of household is aged 30-34	_	***
Head of household is aged 35-44	_	***
Head of household is aged 45-54	_	***
Head of household is aged 55-59	_	***

Part B of table 2 illustrates the factors that influence the move-stay decision of households. The lower a household's income then the significantly more likely they are to stay. This is also the case if the head of the household is married or co-habiting. The number of children under 16 would appear to have no significant effect. The most significant factor in the move-stay decision is the head of household's age. Compared with heads of households over 60 years of age, every younger head of household is significantly less likely to stay.

The results are largely plausible but may not be wholly conclusive. Income and demographics seem to determine moving decisions while neighbourhood quality, locational attachment and income seem to shape tenure/location decisions. Other particular concerns remain with the sign on the housing cost term, which we would have expected to be negative (this can, perhaps be explained, by the fact that most tenants

receive substantial housing benefits which completely insulate them from the cost of housing and marginal changes thereof). It may be that housing costs only affect the private sector –further evidence (not reported here in detail) suggests that the housing cost term does become significant if it is interacted with the private sector (i.e. we ignore the housing cost term for the renters). The other main issues concern the absence of an explicit role for previous tenure within the model and the continuing need to force the overall model to work by imposing inclusive values of around 1.0.

5. APPLICATIONS OF THE FULL MODEL

The Base Position

The estimates discussed above were then applied to the Glasgow housing system (i.e. by allowing the construction of probabilities of movement, location switch and tenure choice for different *existing* households within the Greater Glasgow area). The model has a base of 1996 and uses data primarily from the 1996 Scottish House Condition Survey for the Greater Glasgow area and demographic numbers for households and population provided by GCVJSPT[2] for 1996 and projections they provided for 2005 based on their assumptions about migration. Table 3 sets out the basic household and stock position in 1996 along with the 'official' City projections for 2005 (including an assumption for migration). This table should be interpreted carefully. The first figure shows the number of households for the given year, followed by the column percentage for that year i.e. the tenure share for that year. The figure in italics indicates the percentage change in households in that tenure between 1996 and 2005. The main messages from Table 3 are:

?? The sizes of the three areas are very different. In 1996, there were 170,686 households in the North but only 99,247 in South Glasgow. In 1996, there were 438,501 outwith Glasgow.

?? Tenure will change considerably – increasing owner-occupied households by 22% and reducing social renting households by 14%.

?? The private renting shares are static although the numbers increase in all three areas, with the biggest increase in households (3.9%) in North Glasgow.

Table 3 Households 1996 and 2005 – 'Official' City Estimates

Tenure	South	North	Outer	Total

[2] Glasgow and Clyde Valley Joint Structure Plan Team

Owners				
1996	47,642 (48)	67,284 (39)	262,230 (60)	377,156 (53)
2005	56,647 (56)	83,164 (47)	321,568 (68)	461,379 (61)
% Change in households	*18.9*	*23.6*	*22.6*	*22.3*
Private rent				
1996	5,046 (5)	7,839 (5)	7,776 (2)	20,661 (3)
2005	5,085 (5)	8,146 (5)	7,884 (2)	21,115 (3)
% Change in households	*.08*	*3.9*	*1.4*	*2.2*
Social rent				
1996	46,559 (47)	95,563 (56)	168,495 (38)	310,617 (44)
2005	39,941(39)	83,508 (48)	143,621 (30)	267,070 (36)
% Change in households	*-14.2*	*-12.6*	*-14.8*	*-14.0*
All households				
1996	99,247 (100)	170,686 (100)	438,501 (100)	708,434 (100)
2005	101,673 (100)	174,818 (100)	473,073 (100)	749,564 (100)
% Change in households	*2.4*	*2.4*	*7.9*	*5.8*

Source: as Table 1.
Note: percentage figures (in brackets) are rounded.

Central Model Estimates

After testing the senstivity of the calibrated model by shocking certain parameters, and content with its performance, the following central estimates were generated. Starting from a base of 1996, results are reported for 2005 (to compare with the official projection) and for 2009. Comparing the model-generated estimates for 2005 with the 'official' projections, it is clear that they are close together (Table 4). In fact, all of the figures are within one per cent apart from the figures for South Owners that are 2.6% apart.

Table 4 Base position

Location and Tenure	**1996 Base**	**2005 Official**	**2005 Model**	**2009 Model**
Glasgow Own	114,926	139,811	139,259	149,607
Glasgow Rent	155,007	136,680	135,584	130,322
Outwith Own	262,230	321,568	322,036	346,334
Outwith Renter	176,271	151,505	152,645	144,317

Table 4 completes the story by adding in the numbers generated by the computer model. It starts with the same 1996 figures, it then compares the figures 2005 between the

GCVJSPT's estimates and the model's own numbers before setting out the base position estimates, *in the absence of intervention*[3], for 2009. The Glasgow numbers combine North and South. In the rest of the discussion, the focus is aggregate – Core City versus Suburbs (Outwith). Table 4 suggests that between 1996 and 2009, owning households in Glasgow will increase from 115,000 to just below 150,000. In the same period renting households (social and private) will fall from 155,000 to just over 130,000. In the suburbs, owning households will grow from more than 262,000 in 1996 to more than 346,000 in 2009. Suburban renters will decline from slightly more than 176,000 to a little more than 144,000.

Table 5 summarises the proportionate changes in demand between 1996 and 2009, provides a combined total for the City of Glasgow and makes a correction for private rented housing, in order to calculate social rented demand. In Glasgow it is assumed that private renting will be approximately 10.6% of the total in 2009 (note that the increase in this ratio is primarily due to the decline in social rented households and that private renting households are fairly constant in terms of households).[4] This suggests that the demand for social rented housing will be 89.4% of the total renting households' figure in 2009 (and 91.7% in 1996). For the area outwith Glasgow, the equivalent proportions for social renting as a share of all renting are 95.6% in 1996 and 94.5% in 2009 (the PRS outwith Glasgow grew from 4.4 to 5.2% to 2005 - extrapolating this to 2009 gives a PRS share of all renting at 5.5%). Using these figures, this implies that social renting in Glasgow will fall from 142,175 in 1996 to 116,508 in 2009. For the suburbs, social renting is estimated to fall from 168,515 to 136,380 between 1996 and 2009.

Table 5 Base Housing Demand Change 1996-2009

Tenure & location	Absolute change (number of households)	Percentage change in households
Glasgow owning	+34,681	+30.2
Glasgow social renting	-25,667	-18.1
Outwith owning	+81,104	+30.9
Outwith social renting	-32,135	-19.1

[3] In other words, in the absence of any response by planners in terms of land release as a result of demand levels or change thereof.

[4] However, one should remember that initially, many newly forming households and migrants will reside in the private rented sector. In other words, the marginal effects will be different from the average. We could argue that the private rented sector share should in fact be larger.

Table 5 suggests that social housing demand will fall in Glasgow by 25,667 households between 1996 and 2009, which is 18.1% of the 1996 level. At the same time, owner-occupation in the City would increase by 34,681 or 30.2%. This reflects an overall increase in households in Glasgow of 9,959 (a 3.7% increase from 1996 to 2009). For the area outwith Glasgow, social housing demand would fall by 32,135, a reduction of 19.1%. Owner-occupied demand in the Outwith area would rise by 81,104, an increase of 30.9%. Overall, households in the area outwith the City would increase by 49,150, a percentage increase of 11.2%.

Scenario Simulations

There are many scenario simulations that could be conducted with the Glasgow Citywide Model. Essentially, a scenario simulation alters the parameter value of one of the drivers or policy intervention variables in the system and then one traces the longer-term impact of the change by contrasting the outcome with the non-intervention base estimate. However, the proportionate change that one makes to the variable in question is a matter of judgement, policy interest, and feasibility within the constraints of the model. For present purposes, a number of scenarios concerned with changes to economic drivers have been developed. The main focus of these simulations concern:

?? A relative improvement and worsening in neighbourhood quality in Glasgow relative to its suburbs.

?? An increase and decrease in incomes within the wider Glasgow housing system.

Changing Neighbourhood Quality

One can think of the deprivation index as a crude measure of neighbourhood quality. One of the policy aims of Glasgow economic and social regeneration agencies is to improve Glasgow's neighbourhoods through a range of policy interventions. Using the model, it is possible to change the deprivation scores of Glasgow relative to its suburbs and thus mimic a change in the quality of the City's neighbourhoods. By examining the deviation from the base estimate benchmark it is possible to indicate how tenure and location choices would shift as a consequence.

Table 6 Simulation Impact of 5% Improvement in Glasgow's Deprivation Scores in terms of overall households by tenure

Location & tenure	2009 base (2)	5% improvement in score (3)	Deviation (3-2)

Glasgow social renters	116,508	108,805	-7,703
Glasgow owners	149,607	175,325	25,718
Outwith social renters	136,380	132,599	-3,781
Outwith owners	346,334	333,390	-12,944

Table 6 contrasts the City with the Outwith area by comparing the 2009 estimates of the benchmark with those of the model assuming a 5% improvement in the deprivation scores of the City. The percentage change is a large one but the message is clear. Improving neighbourhood quality in this way should lead to a significant increase in owner-occupation, primarily from tenure shift within Glasgow and from owners moving into the City from the suburbs. There is also, however, an element of suburban renters seeking to move into owner-occupation within Glasgow as well. The additional supply requirements for owner-occupation over and above normal net supply change would require an additional annual level of 3,215 new homes. At the same time, however, the City would require an annual reduction of 963 socially rented units.

Table 7 shows the opposite scenario, a five per cent worsening of the deprivation scores for areas within the City, proxying for further neighbourhood decline. This has a largely symmetrical effect in that ownership would decline within Glasgow (but by less than the corresponding increase in the previous table) and social renting would actually increase substantially in the City (and to a lesser extent outside in the suburbs. Approximately the same growth would occur for suburban owner demand as for City renters. The implication seems to be that neighbourhood change primarily affects the housing system through the owner-occupied sector, with the impacts of declining quality split between moving out of the City or simply remaining as a renter and not opting for ownership in dilapidated neighbourhoods.

Table 7 Simulation Impact of 5% Worsening in Glasgow's Deprivation Scores in terms of overall households by tenure

Location & tenure	2009 base (2)	5% worsening in score (3)	Deviation (3-2)
Glasgow social renters	116,508	121,643	5,135
Glasgow owners	149,607	132,524	-17,083
Outwith social renters	136,380	138,881	2,501

Outwith owners	346,334	354,952	8,618

Income Change

A second important drive in the choice model was the role of income, which was found to be important in explaining the decision to move, where to locate and which tenure to choose. In this simulation, the income change affects all of Greater Glasgow. This is more plausible than assuming that the administrative jurisdiction of the City only rather than the functional urban area as a whole would benefit more from income changes. In the case below, we increase average incomes after 2002 by 10% and compare the base estimate for 2009 with the new housing demand configuration that occurs when relative incomes rise.

Table 8 indicates that increased incomes would increase demand for owning in Glasgow and more so, increase demand for owning in the suburbs (although the relative increase is much less in the Outwith area). Renting demand falls substantially in both Glasgow and its suburbs. Income effects would appear to be having their usual effect of increasing owner-occupation but, in addition to reducing rental demand, Glasgow households are using their higher incomes to purchase wider afield, reflecting supply constraints in Glasgow. The change in tenure patterns means that 1,003 fewer social rented housing units would be required annually in Glasgow. At the same time, there would be an additional requirement for 464 owner-occupied units per annum within the City.

Table 8 Simulation Impact of 10% Increase in Incomes after 2002

Location & tenure	2009 base (2)	10% increase in incomes (3)	Deviation (3-2)
Glasgow social renters	116,508	108,480	-8,028
Glasgow owners	149,607	153,320	3,713
Outwith social renters	136.380	126,355	-10,025
Outwith owners	346,334	362,790	16,456

6. CONCLUSIONS

This paper reports the construction and results of a new simulation model of the Greater Glasgow housing system. The development of the model involved the application of

work conducted by Meen and Andrew in the South East of England to the different context of West Central Scotland. The model is particularly elaborate on the demand-side involving new household formation, migration and the internal housing choices of existing households. This latter sub-group requires separate econometric modelling in order to measure their conditional probabilities. The model essentially allocates owning and renting households into tenure, location and moving decision boxes, split by household type and age. The market is then cleared by supply adjusting toward demand. Supply is more mechanistic but the overall framework provides for a rich diversity of possible scenarios to test and simulate.

The main results of the model can be divided into two: the determinants of the housing choices of existing residents and the overall model central estimates and scenario simulations for housing demand. The NMNL choice model suggested that incomes and demographics determine mobility and mobility, neighbourhood quality, previous location and incomes shape tenure and location decisions. The full model suggests that social housing demand will fall by 18.1% between 1996 and 2009 within a broader context of urban decentralisation. The simulations suggested that increasing metropolitan incomes would increase both home ownership and suburbanisation; increasing neighbourhood quality would significantly increase home ownership in Glasgow. Job increases within Glasgow will have differential housing impacts depending on who gets the jobs. Apart from suggesting changes in social demand, the simulation model has important implications for housing and local economic planning.

Continuing work with the model(s) will take two basic routes. First, we will continue to refine and develop the NMNL model of housing choice. Second, extensions of the computer model and its supply-side will be investigated. Computer models continually develop. The model reported in this paper is only the first iteration and we hope to push it much further. The key characteristic of the model – analysing tenure and city-suburb location choices simultaneously – has considerable practical and academic scope for further work.

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FIGURE 1: MODEL OVERVIEW

This demonstrates the model for owner-occupiers in North Glasgow. Similar diagrams exist for the other 2 areas and for renters.

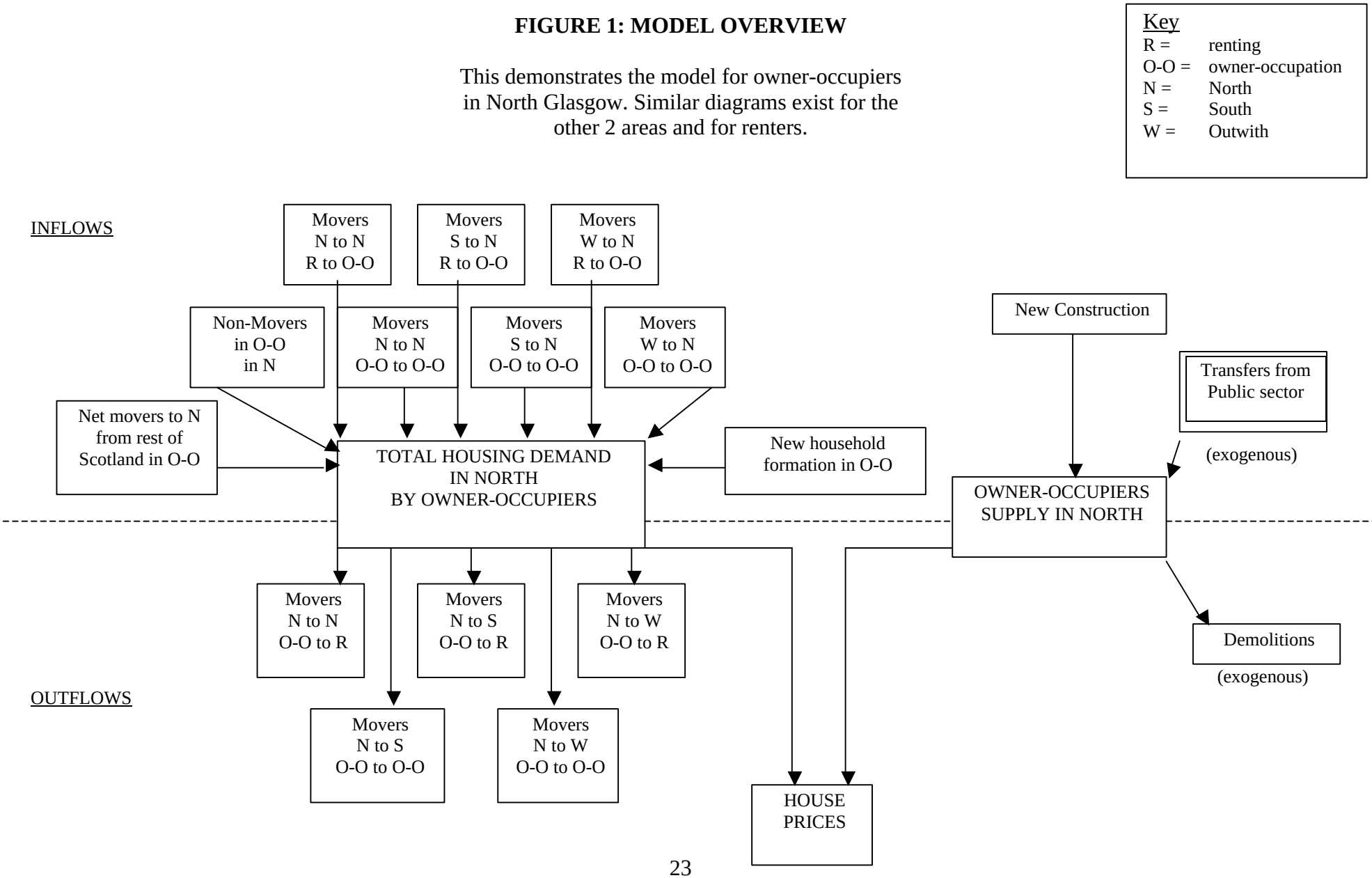


FIGURE 2: THE NUMBER OF MOVERS

e.g.1 renters previously living in South moving to owner-occupation in the North.

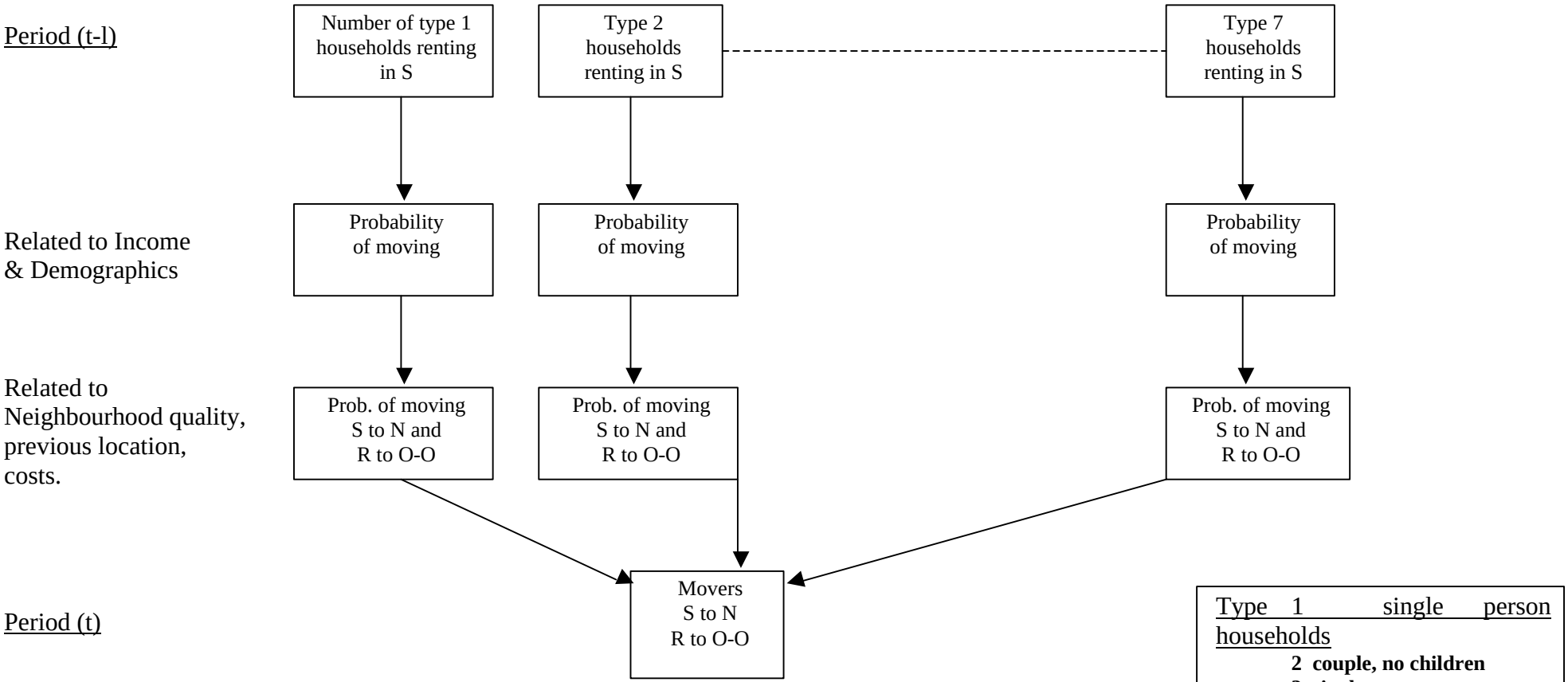


FIGURE 3

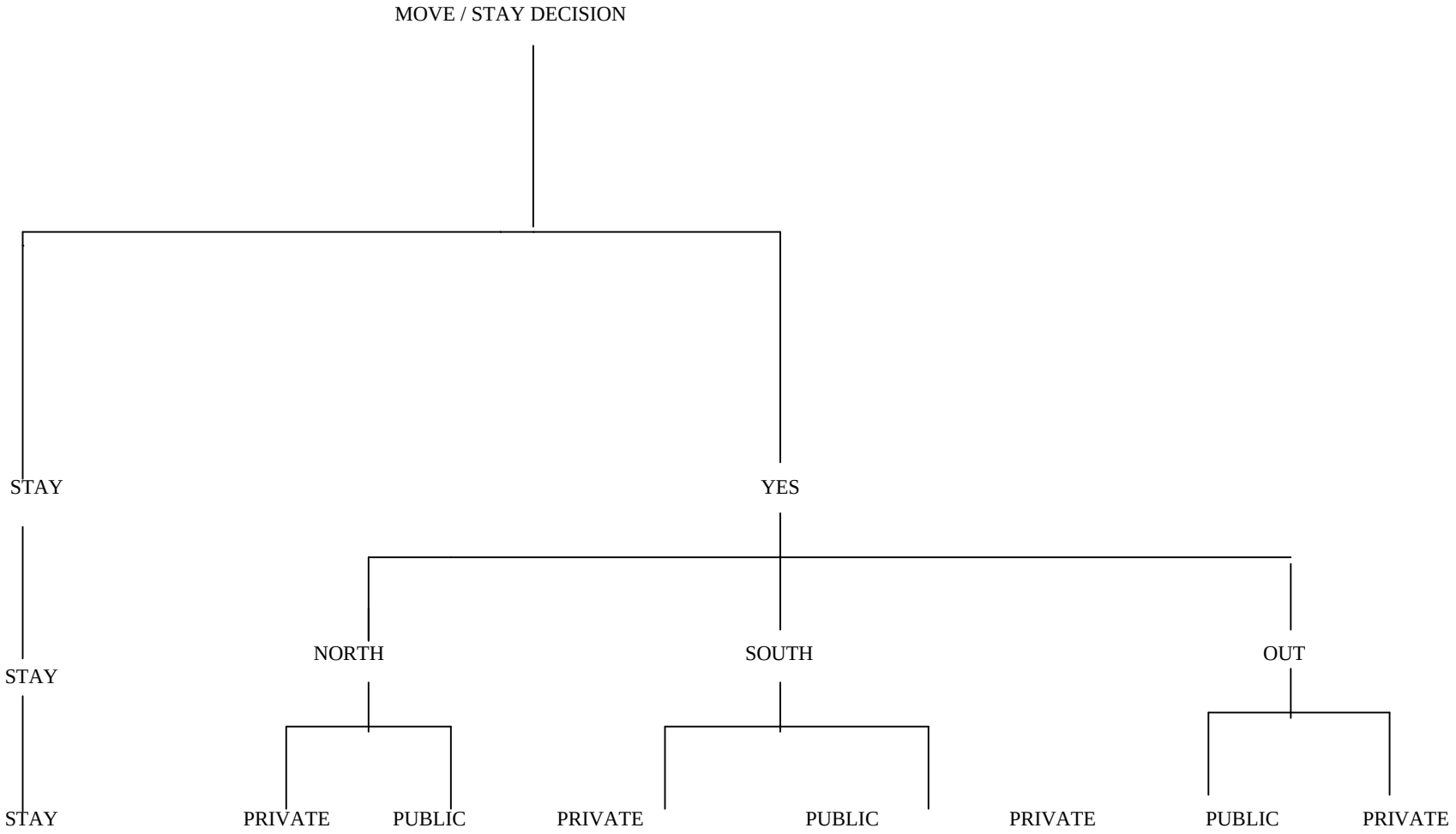
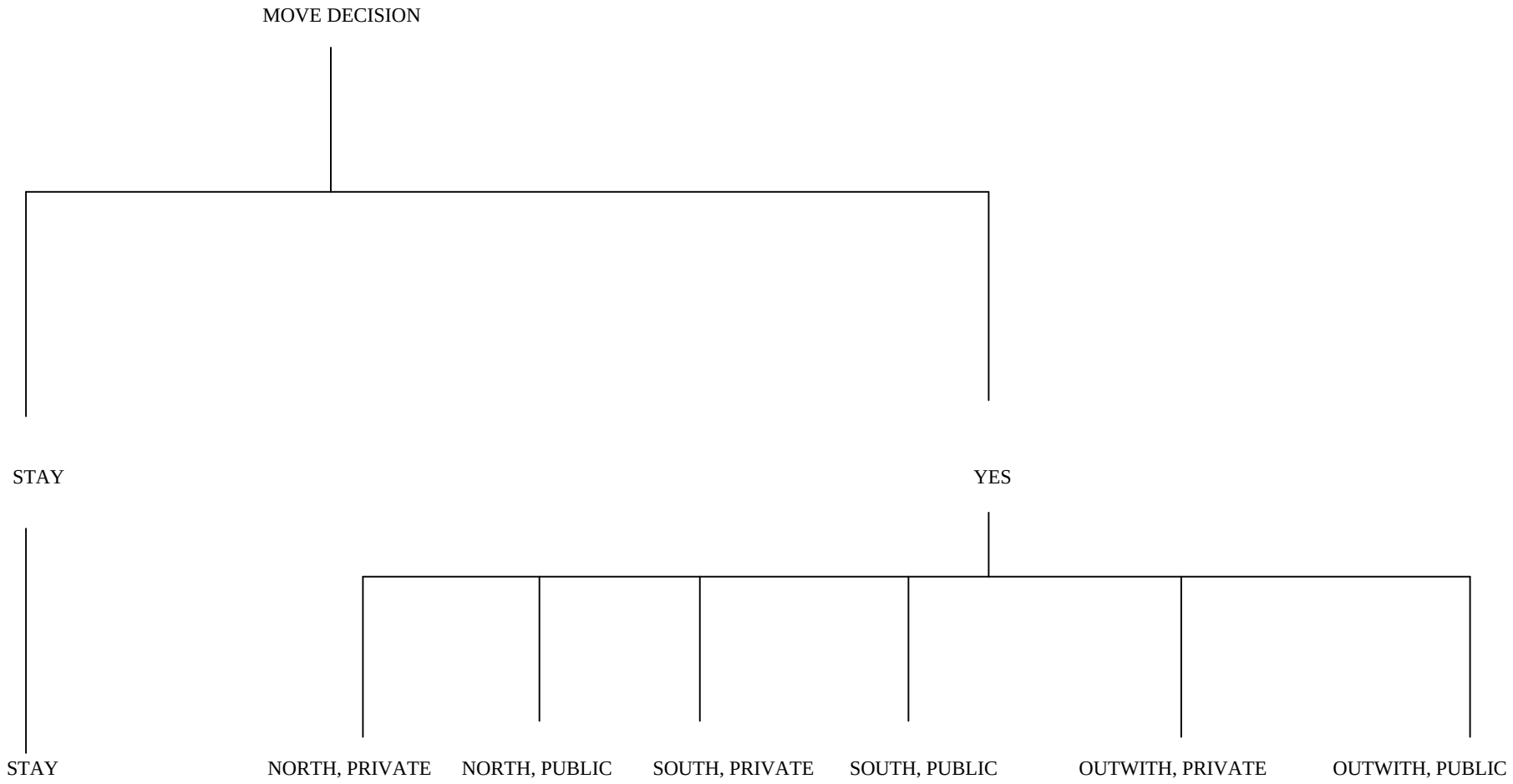

MOVE / STAY DECISION
STAY
YES
STAY
NORTH
SOUTH
OUT
STAY
PRIVATE
PUBLIC
PRIVATE
PUBLIC
PRIVATE
PUBLIC
PRIVATE

FIGURE 4


MOVE DECISION
STAY
YES
STAY
NORTH, PRIVATE
NORTH, PUBLIC
SOUTH, PRIVATE
SOUTH, PUBLIC
OUTWITH, PRIVATE
OUTWITH, PUBLIC

APPENDIX 1
Econometric Results: Two Level decision Model

```
+--------------------------------------------+
| FIML: Nested Multinomial Logit Model       |
| Maximum Likelihood Estimates               |
| Dependent variable              ACHOICE    |
| Weighting variable                  ONE    |
| Number of observations            26719    |
| Iterations completed                 30    |
| Log likelihood function       -1366.029    |
| Restricted log likelihood     -3265.692    |
| Chi-squared                    3799.326    |
| Degrees of freedom                   21    |
| Significance level             .0000000    |
| R2=1-LogL/LogL*  Log-L fncn  R-sqrd  RsqAdj |
| No coefficients  -3265.6916  .58170  .58132 |
| Constants only   -1712.3937  .20227  .20154 |
| At start values  -6911.1491  .80234  .80216 |
| Response data are given as ind. choice.    |
+--------------------------------------------+
```

NMNL MODEL FOR THE CITYWIDE SURVEY DATA SHCS

```
+--------------------------------------------+
| FIML: Nested Multinomial Logit Model       |
| The model has 2 levels.                    |
| Coefs. for branch level begin with I1      |
| Number of obs.=  3817, skipped   0 bad obs. |
+--------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Attributes in the Utility Functions (TENURE CHOICE EQUATION)					
A25	.1134627624E-02	.90414509E-03	1.255	.2095	
C1	12.92586561	4.3566197	2.967	.0030	
C2	19.22213134	7.0945842	2.709	.0067	
C3	24.30001594	5.4143598	4.488	.0000	
C4	-2.470813494	.39398810	-6.271	.0000	
C5	-2.799819984	.54676066	-5.121	.0000	
C6	-2.436946264	.32134790	-7.584	.0000	
C9	-.8315789055	.63808887E-01	-13.032	.0000	
C10	-.8873725672	.70122205E-01	-12.655	.0000	
C11	-.9447035888	.96286889E-01	-9.811	.0000	
C12	2.894515739	.30588976	9.463	.0000	
C13	2.698320668	.32840588	8.216	.0000	
Attributes of Branch Choice Equations (MOVE-STAY EQUATION)					
I1	-3.201553573	.23604809	-13.563	.0000	
I2	-2.262798433	.22818272	-9.917	.0000	
I3	-1.878722562	.23186567	-8.103	.0000	
I4	-.9331817255	.23254940	-4.013	.0001	
I5	-.6905933462	.22814375	-3.027	.0025	
I6	-.8732926894	.25968495	-3.363	.0008	
I12	.9952857431E-01	.74982760E-01	1.327	.1844	
I28	-.6341078189	.18228246	-3.479	.0005	
I49	-.1844564118	.10175273	-1.813	.0699	
Inclusive Value Parameters					
NOMOVE	1.000000000	.....(Fixed Parameter).....			
MOVEYES	.9000000000	.....(Fixed Parameter).....			

Variable List

Variables appearing in the tenure choice equation (lowest level)

A25 housing cost by tenure and location (per month)

C1 rationing variable interacted with alternative specific constant for PUBLIC and NORTH
C2 rationing variable interacted with alternative specific constant for PUBLIC and SOUTH
C3 rationing variable interacted with alternative specific constant for PUBLIC and OUTWITH

C4 permanent income interacted with alternative specific constant for PUBLIC and NORTH
C5 permanent income interacted with alternative specific constant for PUBLIC and SOUTH
C6 permanent income interacted with alternative specific constant for PUBLIC and OUTWITH

C9 deprivation index score interacted with alternative specific constant for PRIVATE and NORTH
C10 deprivation index score interacted with alternative specific constant for PRIVATE and SOUTH
C11 deprivation index score interacted with alternative specific constant for PRIVATE and OUTWITH

C12 dummy variable for previous location is NORTH
C13 dummy variable for previous location is SOUTH

Variables appearing in the mobility equation (top level)

I1 dummy variable for head of household is aged between 16 and 24 years
I2 dummy variable for head of household is aged between 25 and 29 years
I3 dummy variable for head of household is aged between 30 and 34 years
I4 dummy variable for head of household is aged between 35 and 44 years
I5 dummy variable for head of household is aged between 45 and 54 years
I6 dummy variable for head of household is aged between 55 and 59 years

I12 number of children under 16 years of age
I28 dummy variable for head of household is married/living together

I49 permanent income of household (monthly)